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Total Maximum Daily Load (TMDL)

South Branch Codorus Creek Watershed
York County

Pennsylvania Department of Environmental Protection
Central Office
Office of Water Management

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Summary of the South Branch Codorus Creek TMDL

1. The impaired segment of the South Branch Codorus Creek addressed by this TMDL is located in York County. The watershed covers approximately 72 square miles. The creek flows from the Pennsylvania/Maryland border to its confluence with Codorus Creek just southwest of the City of York. The protected use of the watershed is aquatic life. The aquatic life designation for the main stem South Branch Codorus Creek is *warm water fishes*, with the tributaries also designated as *warm water fishes*. For the purposes of developing this TMDL, two subbasins were delineated within the South Branch Codorus Creek subwatershed.

2. The TMDL for the South Branch segment was developed to address use impairments caused by siltation and nutrients. The main stem of South Branch Codorus Creek was placed on Pennsylvania's 303(d) list in 1996. A total of 16 miles were listed as impaired due to agriculture. The cause code indicates excess amounts of nutrients and suspended solids to be a problem. In 1999, as part of Pa. DEP's Unassessed Waters Program, an additional 15 miles were added to the year 2000 305(b) report. In order to ensure attainment and maintenance of water quality standards in the South Branch Codorus Creek for the 1996 listed segment, mean annual loadings of total phosphorus and sediment for subbasin 1 will need to be limited to 16,367.00 lbs/yr and 13,773,460.00 lbs/yr respectively. Mean annual loadings of total phosphorus and sediment for subbasin 2 will need to be limited to 13,493.61 lbs/yr and 11,355,391.80 lbs/yr respectively.

   The major components of the South Branch Codorus Creek TMDL are summarized below:

Subbasin 1 Components	Total Phosphorus (lbs/yr)	Sediment (lbs/yr)
TMDL (Total Maximum Daily Load)	16,367.00	13,773,460.00
WLA (Wasteload Allocation)	3,650.00	0.00
MOS (Margin of Safety)	1,636.70	1,377,346.00
LA (Load Allocation)	11,080.30	12,396,114.00

Subbasin 2 Components	Total Phosphorus (lbs/yr)	Sediment (lbs/yr)
TMDL (Total Maximum Daily Load)	13,493.61	11,355,391.80
WLA (Wasteload Allocation)	4,562.50	0.00
MOS (Margin of Safety)	1,349.36	1,135,539.18
LA (Load Allocation)	7,581.75	10,219,852.62

3. Mean annual total phosphorus and sediment loading for subbasin 1 is estimated to be 33,852.94 lbs/yr and 29,141,794.00 lbs/yr respectively. Mean annual total phosphorus and sediment loading for subbasin 2 is estimated to be 24,269.89 lbs/yr and 17,753,092.40 lbs/yr respectively. To meet the TMDL, the phosphorus and sediment loading for subbasin 1 will require a 52 percent and 53 percent

reduction respectively. To meet the TMDL, the phosphorus and sediment loading for subbasin 2 will require a 44 percent and 36 percent reduction respectively.

4. There are two point sources of total phosphorus to address in this TMDL. Load Allocations (LA) for phosphorus and sediment were made to the following nonpoint sources: hay and pasture lands, croplands, coniferous forest, mixed forest, deciduous forest, developed areas, stream banks, groundwater and septic systems.

5. For subbasin 1, the phosphorus and sediment TMDL includes a nonpoint source LA of 11,080.30 lbs/yr and 12,308,514.00 respectively. For subbasin 2, the phosphorus and sediment TMDL includes a nonpoint source LA of 7,581.75 lbs/yr and 10,219,852.62 respectively. Sources receiving allocations are hay/pasture, cropland, developed lands, and stream banks. Phosphorus and sediment loadings from all other sources were maintained at their existing levels. Allocations of phosphorus and sediment to all nonpoint sources in the TMDL segment are summarized below:

Load Allocations for Sources of Phosphorus and Sediment

Pollutant	Current Loading (lbs/yr)	Load Allocation (lbs/yr)	% Reduction
Subbasin 1			
Phosphorus	33,852.94	11,080.30	67
Sediment	29,141,794.00	12,396,114.00	58
Subbasin 2			
Phosphorus	24,269.89	7,581.75	69
Sediment	17,753,092.40	10,219,852.62	42

6. Ten percent of the South Branch Codorus Creek phosphorus and sediment TMDL was set-aside as a margin of safety (MOS). The MOS is that portion of the pollutant loading that is reserved to account for any uncertainty in the data and computational methodology used for the analysis. For subbasin 1, the MOS for the phosphorus and sediment TMDL was set at 1,636.70 lbs/yr and 1,377,346.00 lbs/yr respectively. For subbasin 2, the MOS for the phosphorus and sediment TMDL was set at 1,349.36 lbs/yr and 1,135,539.18 lbs/yr respectively.

7. The continuous simulation model used for developing the South Branch Codorus Creek TMDL 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 accounts for seasonal variability.

I. Introduction

A. Watershed Description

The impaired segment of the South Branch Codorus Creek addressed by this TMDL is located in York County. The watershed covers approximately 72 square miles (Figure 1). The creek flows from the Pennsylvania/Maryland border to its confluence with Codorus Creek just southwest of the City of York. The protected use of the watershed is aquatic life. The aquatic life designation for the main stem South Branch Codorus Creek is *warm water fishes*, with the tributaries also designated as *warm water fishes*, under §93.9f in Title 25 of the Pa. Code (Commonwealth of Pennsylvania, 2001).

B. Topography & Geology

The South Branch Codorus Creek subwatershed is located in the Upland Section of the Piedmont Province in south-central Pennsylvania. The watershed area is typical of watersheds in the Piedmont Province. The elevations range from 520 to 780 feet. In general, the elevation decreases from the south to the north, and the drainage follows this pattern. This area receives approximately 38.5 inches of precipitation per year.

The surficial geology of the South Branch Codorus Creek Watershed is 94 percent igneous/metamorphic, 3 percent carbonate, and 3 percent sedimentary. The igneous/metamorphic strata are predominately composed of the Antietam, Harpers, and Wissahickon Formations. The carbonate and sedimentary strata are composed of the Conestoga and Chickies Formations, respectively.

The soils found in the subwatershed are comprised of the Chester-Glenelg-Linganore and Chester-Glenelg-Manor series. The Chester series are moderately deep and well drained with moderate to rapid permeability. The soils tend to highly fertile with a high available moisture capacity. To a large extent, the soil is used for pasture and cropland throughout the South Branch Codorus Creek subwatershed; the remaining areas are typically forested. The erodibility (k) factor is a measure of inherent soil erosion potential based on the soils texture and composition. The k factor for both soils is approximately 0.31, so soil erosion is a significant concern for the subwatershed.

C. Land Use

Based on GIS datasets, land use values were calculated for the South Branch Codorus Creek subwatershed. Agriculture was the dominant land use at 70 percent. Forested areas account for 29 percent of the watershed. Developed areas are 1 percent of the watershed, comprised predominantly of low intensity residential and some commercial land. Riparian buffer zones are nearly nonexistent in the agricultural and developed areas. Cropland lies directly adjacent to the stream bank in many areas. Livestock have unlimited access to streambanks throughout most of the watershed, resulting in streambank trampling and severe erosion. Impervious surfaces in developing areas are contributing to an increase in stream velocities and decrease in infiltration and recharge. This increase in flow can also cause stream bank erosion problems.

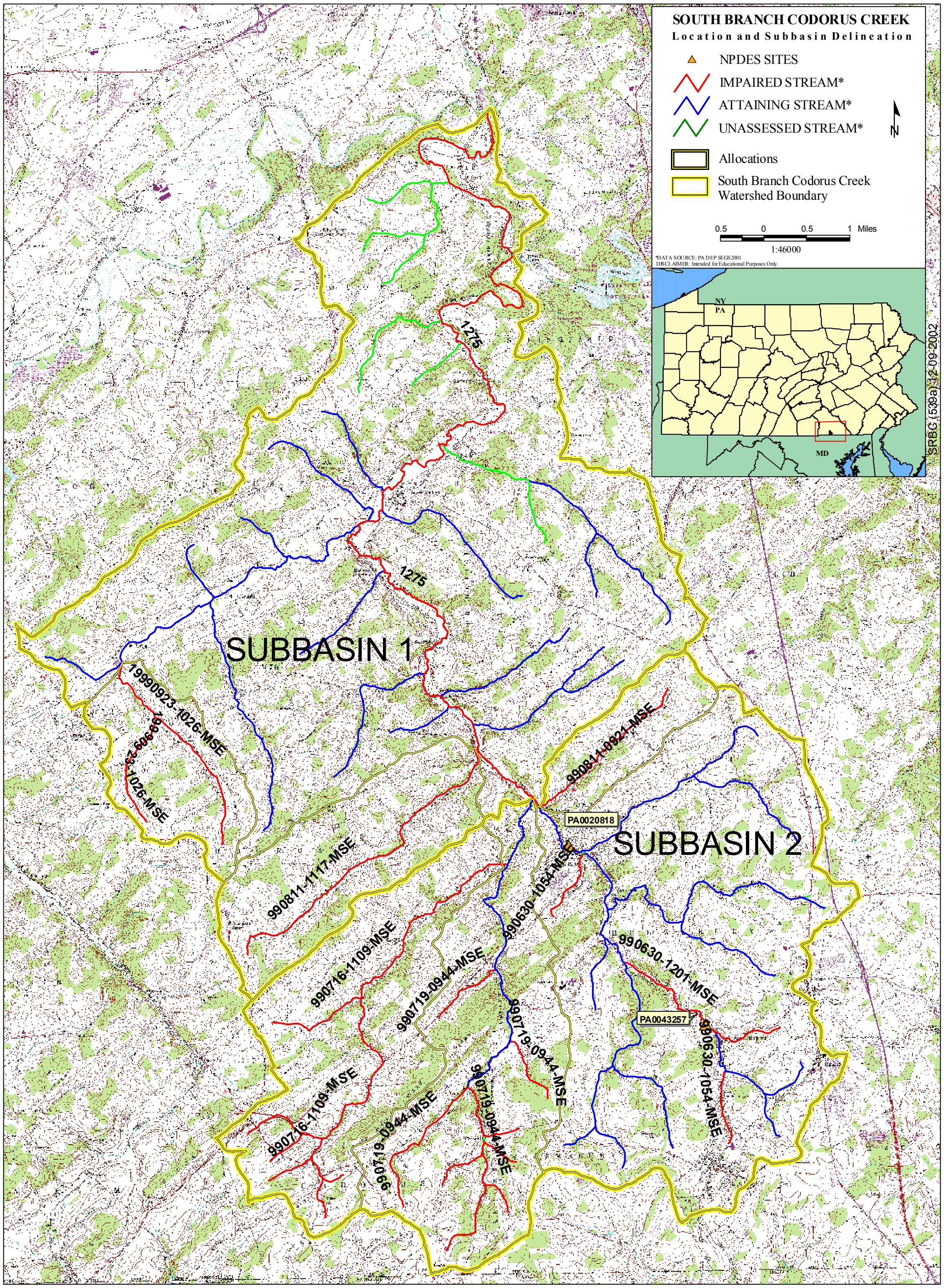

Figure 1. South Branch Codorus Creek Subwatershed, York County

D. Surface Water Quality

Pennsylvania's 1996 303(d) list identified five miles of a segment of South Branch Codorus Creek as impaired by nutrients and sediment emanating from agricultural activities in the basin (Table 1). The miles impaired were then increased to 17.69 on Pennsylvania's 1998 303(d) list. Figure 1 and Table 1 show the segments addressed by this TMDL. Upon visiting the stream segment, stream bank erosion was easily apparent and the substrate showed evidence of heavy siltation. There is a significant portion of the watershed area upstream of the listed segment dedicated to agricultural activities, both cropland and pasture.

As part of the Pa. DEP's ongoing Unassessed Waters (UW) program, assessments were conducted on selected segments of South Branch Codorus Creek in 1999. Information collected during these assessments identified designated use impairments for tributaries to South Branch Codorus Creek throughout the watershed. The cause of the impairments is predominantly related to siltation and emanating from agricultural activities. The additional listings from the 1999 surveys addressed in this TMDL are shown under the 2002 303(d) listings in Table 1. Although there are additional listings for designated use impairments on the 2002 303(d) list, this TMDL does not address those listings since the impairments are related to flow and habitat alterations. The TMDLs are not the appropriate mechanism to address this type of stream impairment. TMDLs are designed to address pollutant loadings that cause a violation of water quality standards. There is no pollutant loading to address for this type of impairment.

Table 1. 1996, 1998, and 2002 303(d) Listings for the South Branch Codorus Creek Watershed (State Water Plan 07-H)

1996 303(d) LIST

STREAM NAME	STREAM CODE	SOURCE	CAUSE	MILES
South Branch Codorus Creek	8093	Agriculture	Suspended Solids Nutrients	5.0

1998 303(d) LIST

SEGMENT ID	WATERSHED	STREAM CODE	SOURCE	CAUSE	MILES
1275	South Branch Codorus Creek	8093	Agriculture	Suspended Solids Nutrients	17.69

2002 303(d) Report

SEGMENT ID	STREAM NAME	STREAM CODE	SOURCE	CAUSE	MILES
19990923-1026-MSE	Buffalo Valley Hollow	8156, 8157	Agriculture	Siltation	4.2
19990719-0944-MSE	Centerville Creek	8172 thru 8178	Agriculture	Siltation	8.1
19990811-0921-MSE	Foust Creek	8179	Agriculture	Siltation	2.2
19990811-1117-MSE	Krebs Valley Run	8164	Agriculture	Siltation	4.2
19990716-1109-MSE	Pierceville Run	8166 thru 8171	Agriculture	Siltation	9.8
1275	South Branch Codorus Creek	8093	Agriculture	Nutrients Suspended Solids	16.4
19990630-1054-MSE	South Branch Codorus Creek	8190, 8191	Urban Runoff	Siltation	2.7
19990630-1201-MSE	South Branch Codorus Creek	8093	Municipal Point Source	Nutrients	1.6

II. Approach to TMDL Development

A. Pollutants & Sources

Based on field observations, nutrients and siltation from agricultural runoff and streambank erosion have been identified as the pollutants causing designated use impairments in the South Branch Codorus Creek subwatershed. Pastures and croplands along and upstream of the impaired segment extend right up to the edge of the stream with little to no riparian buffer zone. In many places, cropland channels drain directly into the stream. Livestock also have unlimited access to streambanks throughout most of the watershed, resulting in accelerated streambank erosion. Best Management Practices (BMPs) are very limited in the watershed.

There are two point sources in the watershed that discharge nutrients into impaired reaches of the South Branch Codorus Creek. Both discharges are wastewater treatment plants associated with the towns of Glen Rock and New Freedom. New Freedom has been documented as causing the water quality impairment downstream of its discharge. The permit for the plant expired in September. The South-central Pa. DEP office renewed the permit with reduced nutrient limits for a period of time until a final effluent limit will be established. Details concerning the loads emanating from the discharges are covered in the waste load allocation section of the TMDL.

B. TMDL Endpoints

The TMDL developed for the South Branch Codorus Creek subwatershed addresses total phosphorus and sediment loads. The total phosphorus and sediment loads were developed to address impairments first noted on Pennsylvania's 1996 303(d) list. The decision to use phosphorus load reductions to address nutrient impairments was based on an understanding of the relationship between nitrogen, phosphorus and organic enrichment in stream systems. Elevated nutrient loads (nitrogen and phosphorus in particular) can lead to increased productivity of plants and other organisms (Novotny and Olem, 1994). In aquatic ecosystems the quantities of trace elements are typically plentiful; however, nitrogen and phosphorus may be in short supply. The nutrient that is in the shortest supply is called the limited nutrient because its relative quantity affects the rate of production (growth) of aquatic biomass. If the limiting nutrient load to a water body can be reduced, the available pool of nutrients that can be utilized by plants and other organisms will be reduced and, in general, the total biomass can subsequently be decreased as well (Novotny and Olem, 1994). In most efforts to control the eutrophication processes in water bodies, emphasis is placed on the limiting nutrient. This is not always the case. For example, is nitrogen is limiting nutrient, it still may be more efficient to control phosphorus loads if the nitrogen originates from difficult to control sources such as nitrates in groundwater.

In most freshwater systems, phosphorus is the limiting nutrient for aquatic growth. In some cases, however, the determination of which nutrient is the most limiting is difficult. For this reason, the ratio of the amount of N to the amount of P is often used to make this determination (Thomann and Mueller, 1987). If the N/P ratio is less than 10, nitrogen is limiting. If the N/P ratio is greater than 10, phosphorus is the limiting nutrient. For South Branch Codorus Creek, the N/P ratio is estimated to be 13, which indicates to phosphorus as the limiting nutrient. Controlling the phosphorus loading to the South Branch Codorus Creek will limit plant growth, thereby helping to eliminate use impairments currently being caused by excess nutrients.

C. Reference Watershed Approach

The TMDL developed for South Branch Codorus Creek watershed addresses phosphorus and sediment. Because neither Pennsylvania nor the U.S. Environmental Protection Agency (USEPA) has instream numerical water quality criteria for sediment, a method was developed to implement the applicable narrative criteria. The method for these types of TMDLs is termed the "Reference Watershed Approach". Meeting the water quality objectives specified for this TMDL will result in the impaired stream segment attaining its designated uses.

The Reference Watershed Approach compares two watersheds, one attaining its uses and one that is impaired based on biological assessments. Both watersheds ideally have similar land use/cover distributions. Other features such as base geologic formation should be matched to the extent possible; however, most variations can be adjusted for in the model. The objective of the process is to reduce the loading rate of pollutants in the impaired stream segment to a level equivalent to the loading rate in the nonimpaired, reference stream segment. This load reduction will result in conditions favorable to the return of a healthy biological community to the impaired stream segments.

D. Selection of the Reference Watershed

In general, three factors are considered when selecting a suitable reference watershed. The first factor is to use a watershed that the Pa. DEP has assessed and determined to be attaining water quality standards. The second factor is to find a watershed that closely resembles the impaired watershed in physical properties such as land cover/land use, physiographic province, and geology/soils. Finally, the size of the reference watershed should be within 20-30 percent of the impaired watershed area. The search for a reference watershed for the South Branch Codorus Creek subwatershed, 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 headwater area of North Branch Muddy Creek was selected as the reference watershed for developing the South Branch Codorus Creek subwatershed TMDL. Muddy Creek is located southeast of City of York, in York County, Pennsylvania (Figure 2). The watershed is located in State Water Plan subbasin 7I, and protected uses include aquatic life and recreation. The entire basin is currently designated as CWF under §93.9z in Title 25 of the Pa. Code (Commonwealth of Pennsylvania, 2001). Based on the Department's 305(b) report database, North Branch Muddy Creek is currently attaining its designated uses. The attainment of designated uses is based on sampling done by the Department in 1999, as part of its Unassessed Waters Protocol.

Drainage area, location, and other physical characteristics of the South Branch Codorus Creek subwatershed were compared to the reference portion of the North Branch Muddy Creek subwatershed (Table 2). Agriculture is the dominant land use category in both the North Branch Muddy Creek subwatershed (63 percent) and the South Branch Codorus Creek subwatershed (70 percent). The geology, soils and precipitation in both subwatersheds is similar (Table 2).

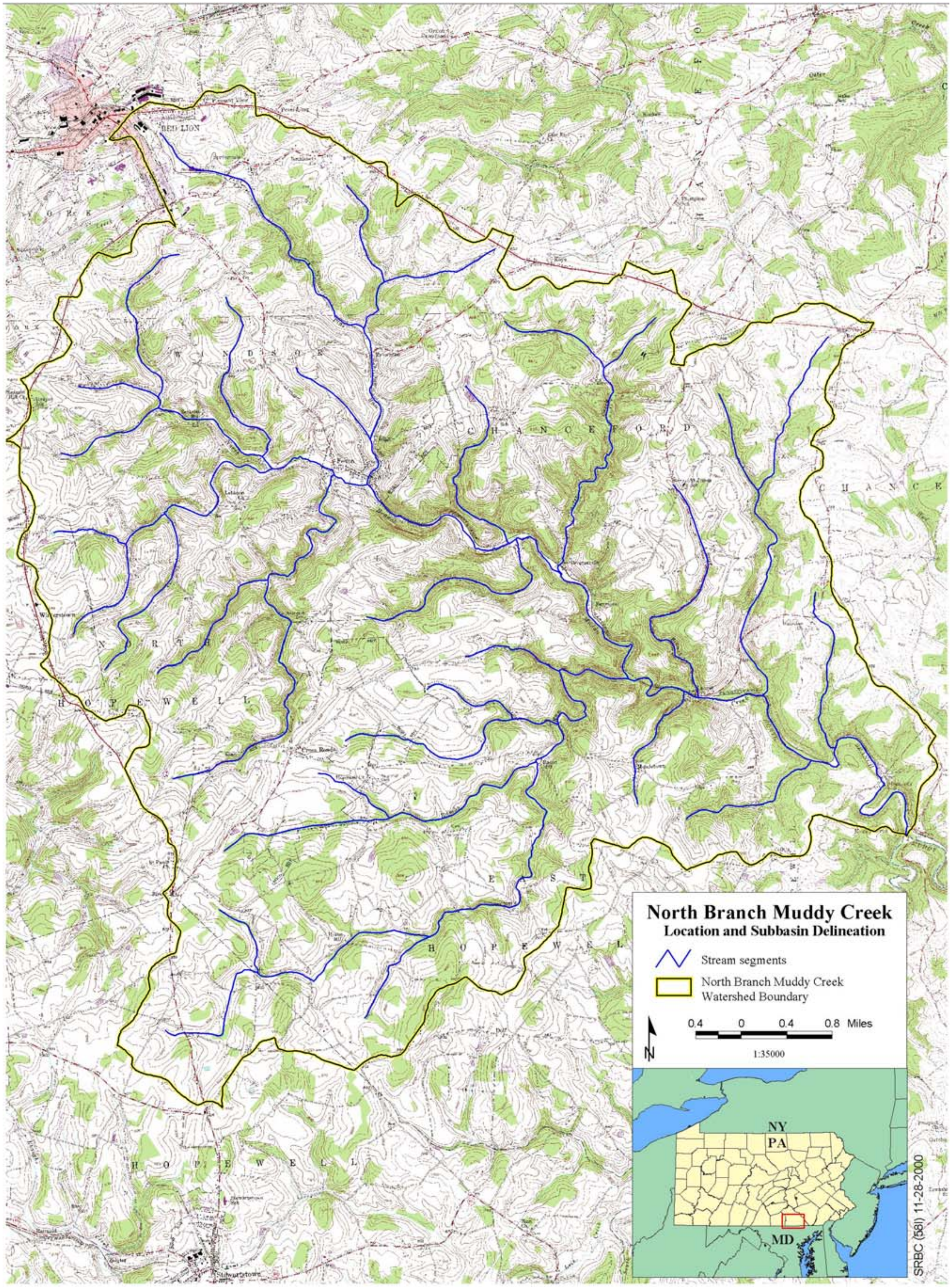

Figure 2. North Branch Muddy Creek Subwatershed, York County

Table 2. Comparison Between South Branch Muddy and North Branch Muddy Watersheds		
Attribute	Watershed	
	South Branch Codorus	North Branch Muddy
Physiographic Province	Piedmont (100%)	Piedmont (100%)
Area (mi^2)	39 (Subbasin 1) / 32 (Subbasin 2)	43
Land Use	Agriculture (70%)	Agriculture (63%)
Geology	Igneous/Metamorphic (94%)	Igneous/Metamorphic (100%)
Soils	Mt. Airy-Glenelg-Linganore Chester-Glenelg-Manor	Chester-Glenelg-Manor
Dominant HSG	Dominantly A/B	Dominantly B
K Factor	0.30 - 0.32	0.32
20-Yr. Ave. Rainfall (in)	39.5	38.5
20-Yr. Ave. Runoff (in)	0.54	1.2

III. Watershed Assessment and Modeling

The TMDL for the South Branch Codorus Creek subwatershed was developed using the Arcview Generalized Watershed Loading Function model (AVGWLF) as described in Appendix B. The AVGWLF model was used to establish existing loading conditions for the South Branch Codorus Creek subwatershed and the reference portion of the North Branch Muddy Creek subwatershed. All modeling inputs have been attached to this TMDL as Appendices C and D. Susquehanna River Basin Commission staff visited the South Branch Codorus and North Branch Muddy subwatersheds in the fall and winter of 2001. The field visits were conducted to get a better understanding of existing conditions that might influence the AVGWLF model. General observations of the individual watershed characteristics include:

South Branch Codorus Creek Subwatershed

- Local geology dominated by igneous/metamorphic rocks.
- Heavily grazed pastures with no streambank fencing.
- Severely limited riparian buffer zones, with pastures, cropland, and developed areas extending right up to streambanks.
- General lack of strip cropping and contour plowing.

North Branch Muddy Creek Subwatershed

- Local geology dominated by igneous/metamorphic rocks.
- Forest buffers along streams in many areas.
- Presence of cover crops and contour planting.
- Abundant silt-free gravel substrate throughout the entire subwatershed.

Minor adjustments were made to specific parameters used in the AVGWLF model based on observations made while touring the watersheds. The C and P factors for cropland were adjusted slightly. The model appeared to be underestimating the loadings emanating from cropland for both subwatersheds. The C and P factors were adjusted to 0.30 and 0.50 respectively. The default values for the C and P factors were 0.21 and 0.45 respectively. The default values were equal to those assigned to forested land uses, which did not appear to accurately represent the loads from cropland. The details concerning how parameter adjustments can affect model output are discussed in Appendix B.

Figure 3. Typical Riparian Zone in South Branch Codorus Creek

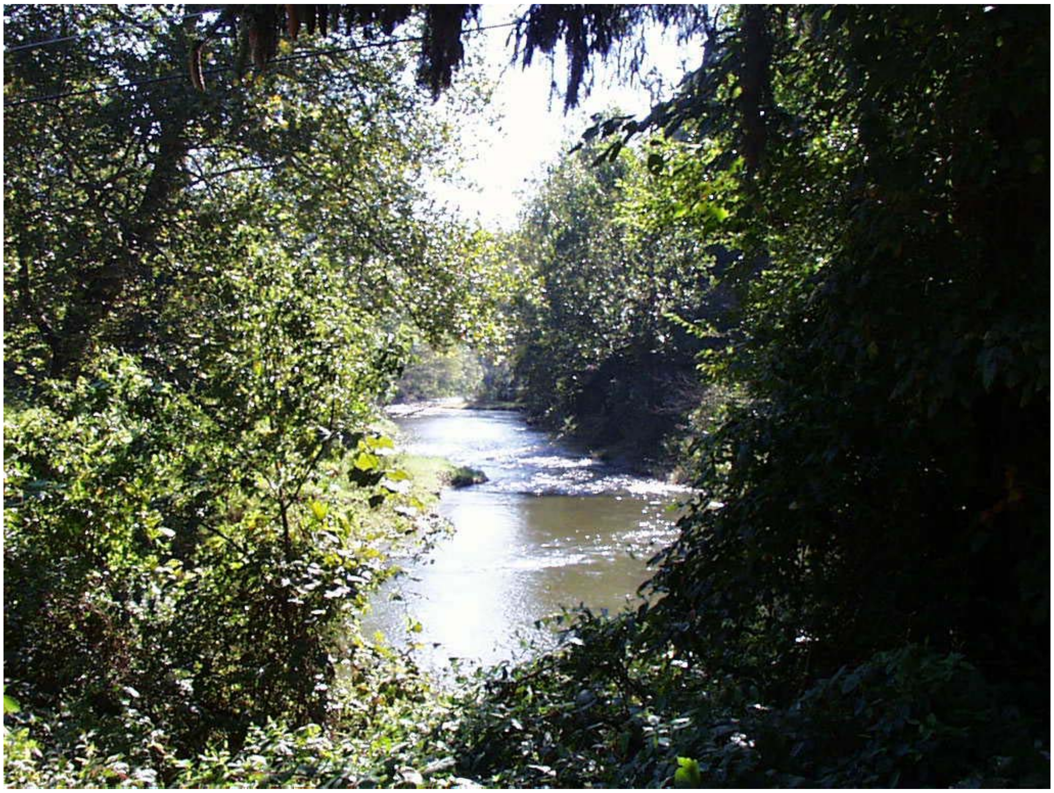

Figure 4. Typical Riparian Zone in the North Branch Muddy Creek Watershed

Figure 5. Example of Contour Planting in North Branch Muddy Creek Watershed

The AVGWLF model produced information on watershed size, land use, phosphorus, and sediment loading (Appendices C and D). The phosphorus and sediment loads represent an annual average over a 20-year period (1978 to 1998). This information was then used to calculate existing unit area loading rates for subbasin 1 and 2 of the South Branch Codorus Creek and the North Branch Muddy Creek subwatersheds (Tables 3, 4, and 5).

Table 3. Existing Phosphorus and Sediment Loads for Subbasin 1 of the South Branch Codorus Creek

Pollutant Source	Acreage	Phosphorus		Sediment	
		Mean Annual Loading (lbs/yr)	Unit Area Loading (lbs/ac/yr)	Mean Annual Loading (lbs/yr)	Unit Area Loading (lbs/ac/yr)
HAY/PAST	5,839.10	830.70	0.14	849,600.00	145.50
CROPLAND	12,286.10	26,185.00	2.13	27,868,000.00	2,268.25
CONIF_FOR	363.20	1.10	0.00	1,200.00	3.30
MIXED_FOR	486.80	1.70	0.00	1,800.00	3.70
DECID_FOR	6,064.00	77.30	0.01	84,600.00	13.95
UNPAVED_RD	49.40	39.00	0.79	38,000.00	769.23
LO_INT_DEV	84.00	0.00	0.00	1,600.00	19.05
HI_INT_DEV	7.40	0.00	0.00	0.00	0.00
Stream bank		134.84		296,994.00	
Groundwater		4,724.10			
Glen Rock WWTP PA0020818		1,754.00			
Septic Systems		105.20			
Total	25,180.00	33,852.94	1.34	29,141,794.00	1,157.34

Table 4. Existing Phosphorus and Sediment Loads for Subbasin 2 of the South Branch Codorus Creek					
		Phosphorus		Sediment	
Pollutant Source	Acreage	Mean Annual Loading (lbs/yr)	Unit Area Loading (lbs/ac/yr)	Mean Annual Loading (lbs/yr)	Unit Area Loading (lbs/ac/yr)
HAY/PAST	4,709.80	485.70	0.10	532,400.00	113.04
CROPLAND	9,296.10	15,299.80	1.65	16,936,800.00	1,821.93
CONIF_FOR	392.90	1.10	0.00	1,200.00	3.05
MIXED_FOR	479.40	1.50	0.00	1,600.00	3.34
DECID_FOR	5,307.80	57.10	0.01	65,200.00	12.28
UNPAVED_RD	12.40	6.60	0.53	6,400.00	516.13
LO_INT_DEV	454.70	1.20	0.00	12,200.00	26.83
HI_INT_DEV	106.30	0.30	0.00	1,200.00	11.29
Stream bank		85.79		196,092.40	
Groundwater		3,220.10			
New Freedom WWTPPA0043257		5,031.80			
Septic Systems		78.90			
Total	20,759.40	24,269.89	1.17	17,753,092.40	855.18

Table 5. Existing Phosphorus and Sediment Loads for North Branch Muddy Creek					
		Phosphorus		Sediment	
Pollutant Source	Acreage	Mean Annual Loading (lbs/yr)	Unit Area Loading (lbs/ac/yr)	Mean Annual Loading (lbs/yr)	Unit Area Loading (lbs/ac/yr)
HAY/PAST	4,900.10	490.20	0.10	327,800.00	66.90
CROPLAND	12,651.80	13,723.80	1.08	14,261,600.00	1,127.24
CONIF_FOR	303.90	0.70	0.00	600.00	1.97
MIXED_FOR	358.30	0.90	0.00	800.00	2.23
DECID_FOR	9,365.30	127.70	0.01	142,400.00	15.21
UNPAVED_RD	54.40	26.10	0.48	20,200.00	371.32
TRANSITION	4.90	6.20	1.27	6,400.00	1,306.12
LO_INT_DEV	160.60	0.10	0.00	2,400.00	14.94
HI_INT_DEV	54.40	0.10	0.00	800.00	14.71
Stream bank		202.10		474,405.20	
Groundwater		3,459.50			
Point Source		0.00			
Septic Systems		107.10			
Total	27,853.70	18,144.50	0.65	15,237,405.20	547.05

IV. TMDLs

Targeted TMDL values for the South Branch Codorus Creek subbasins were established based on current loading rates for phosphorus and sediment in the North Branch Muddy Creek reference subwatershed. Biological assessments have determined that the North Branch Muddy Creek subwatershed is currently attaining its designated uses. Reducing the loading rate of phosphorus and sediment in the South Branch Codorus subbasins to levels equivalent to those in the reference portion of the North Branch Muddy Creek subwatershed will provide conditions favorable for the reversal of current use impairments.

A. Background Pollutant Conditions

There are two separate considerations of background pollutants within the context of these TMDLs. First, there is the inherent assumption of the reference watershed approach that because of the similarities between the reference and impaired watershed, the background pollutant contributions will be similar. Therefore, the background pollutant contributions will be considered when determining the loads for the impaired watershed that are consistent with the loads from the reference watershed. Second, the AVGWLF model implicitly considers background pollutant contributions through the soil and the groundwater component of the model process.

B. Targeted TMDLs

The targeted TMDL values for phosphorus and sediment were determined by multiplying the total area of subbasins 1 and 2 (25,180.00 acres and 20,759.40 acres respectively) by the appropriate unit area loading rate for the North Branch Muddy Creek reference subwatershed (Table 6). The existing mean annual loading of phosphorus and sediment to subbasin 1 (33,852.94 lbs/yr and 29,141,794.00 lbs/yr respectively) will need to be reduced by 52 percent and 53 percent to meet the targeted TMDL of 16,367.00 lbs/yr of phosphorus and 13,773,460.00 lbs/yr of sediment respectively. The existing mean annual loading of phosphorus and sediment to subbasin 2 (24,269.89 lbs/yr and 17,753,092.40 lbs/yr respectively) will need to be reduced by 44 percent and 36 percent to meet the targeted TMDL of 13,493.61 lbs/yr of phosphorus and 11,355,391.80 lbs/yr of sediment respectively.

Table 6. Targeted TMDL for the South Branch Codorus Creek Subbasins

Pollutant	Area (ac)	Unit Area Loading Rate North Branch Muddy Creek Subwatershed (lbs/ac/yr)	Targeted TMDL (lbs/yr)
Subbasin 1			
Phosphorus	25,180.00	0.65	16,367.00
Sediment	25,180.00	547.00	13,773,460.00
Subbasin 2			
Phosphorus	20,759.40	0.65	13,493.61
Sediment	20,759.40	547.00	11,355,391.80

Targeted TMDL values were then used as the basis for load allocations and reductions in the South Branch Codorus Creek subbasins, using the following two equations:

1. TMDL = WLA + LA + MOS
2. LA = ALA + LNR

where:

TMDL = Total Maximum Daily Load
WLA = Waste Load Allocation (point sources)
LA = Load Allocation (nonpoint sources)
ALA = Adjusted Load Allocation
LNR = Loads not Reduced

C. Wasteload Allocation

There are two point sources in the watershed that discharge nutrients into the South Branch Codorus Creek. Both discharges are wastewater treatment plants associated with the towns of Glen Rock and New Freedom. Glen Rock has an average annual loading for phosphorus of 1,754.00 lbs/yr, with a permit limit of 3,650.00 lbs/yr. New Freedom has an average annual loading for phosphorus of 5,031.80 lbs/yr, with a permit limit of 4,562.50 lbs/yr to be implemented in September 2005. An interim permit limit for phosphorus of 6,752.50 lbs/yr currently exists at the New Freedom facility. This TMDL utilizes the final permit limits for both facilities in determining the loading limits. Table 7 shows the permit information associated with both wastewater treatment plants.

Table 7. Waste Load Allocations (WLA) for the South Branch Codorus Creek Subbasins

Permitted Discharges	Phosphorus Load (lbs/yr)	
	Existing (Calculated from December 1999 thru June 1999 DMRs) (Used in AVGWLF)	TMDL WLA (Used in EMPR Scenario)
Subbasin 1		
Glen Rock PA0020818	1,754.00	3,650.00
Subbasin 2		
New Freedom PA0043257	5,031.80	4,562.50

D. Margin of Safety

The MOS is that portion of the pollutant loading that is reserved to account for any uncertainty in the data and computational methodology used for the analysis. For this analysis, the MOS is explicit. Ten percent of the targeted TMDL for sediment was reserved as the MOS. Using 10 percent of the TMDL load is based on professional judgment and will provide an additional level of protection to the designated uses of the South Branch Codorus Creek subbasins. The MOS used for the phosphorus and sediment loads for subbasin 1 were 1,636.7 lbs/yr and 1,377,346.00 lbs/yr respectively. The MOS used for the phosphorus and sediment loads for subbasin 2 were 1,349.36 lbs/yr and 1,135,539.18 lbs/yr respectively.

Subbasin 1
Phosphorus - MOS = 16,367.00 lbs/yr (TMDL) x 0.1 = 1,636.70 lbs/yr
Sediment - MOS = 13,773,460.00 lbs/yr (TMDL) x 0.1 = 1,377,346.00 lbs/yr

Subbasin 2
Phosphorus - MOS = 13,493.61 lbs/yr (TMDL) x 0.1 = 1,349.36 lbs/yr
Sediment - MOS = 11,355,391.80 lbs/yr (TMDL) x 0.1 = 1,135,539.18 lbs/yr

E. Load Allocation

The LA is that portion of the TMDL that is assigned to nonpoint sources. The LA was computed by subtracting the WLA and MOS values from the targeted TMDL value. The LAs for subbasin 1 for phosphorus and sediment were 11,080.30 lbs/yr and 12,396,114.00 lbs/yr respectively. The LAs for subbasin 2 for phosphorus and sediment were 7,581.75 lbs/yr and 10,219,852.62 respectively.

Subbasin 1
Phosphorus - LA = 16,367.00 lbs/yr (TMDL) – 3,650.00 lbs/yr (WLA) – 1,636.7 lbs/yr (MOS)
= 11,080.30 lbs/yr
Sediment - LA = 13,773,460.00 lbs/yr (TMDL) – 0.0 lbs/yr (WLA) – 1,377,346.00 lbs/yr (MOS)
= 12,396,114.00 lbs/yr

Subbasin 2
Phosphorus - LA = 13,493.61 lbs/yr (TMDL) – 4,562.50 lbs/yr (WLA) – 1,349.36 lbs/yr (MOS)
= 7,581.75 lbs/yr
Sediment - LA = 11,355,391.80 lbs/yr (TMDL) – 0.0 lbs/yr (WLA) – 1,135,539.18 lbs/yr (MOS)
= 10,219,852.62 lbs/yr

F. Adjusted Load Allocation

The adjusted load allocation (ALA) is the actual portion of the LA distributed among those nonpoint sources receiving reductions. It is computed by subtracting those nonpoint source loads that are not being considered for reductions (loads not reduced or LNR) from the LA. Phosphorus and sediment reductions were made to the hay/pasture, cropland, developed areas, and streambanks. Those land uses/sources for which existing loads were not reduced (CONIF_FOR, MIXED_FOR, DECID_FOR, GROUNDWATER) were carried through at their existing loading values (Tables 8 and 9). The ALAs for phosphorus and sediment for subbasin 1 were 6,276.10 lbs/yr and 12,308,514.00 lbs/yr respectively. The ALAs for phosphorus and sediment for subbasin 2 were 4,301.95 lbs/yr and 10,151,852.62 lbs/yr respectively.

Table 8. Load Allocations, Loads Not Reduced, and Adjusted Load Allocations for Subbasin 1

	Phosphorus (lbs/yr)	Sediment (lbs/yr)
Load Allocation	11,080.30	12,396,114.00
Loads Not Reduced	4,804.20	87,600.00
CONIF_FOR	1.10	1,200.00
MIXED_FOR	1.70	1,800.00
DECID_FOR	77.30	84,600.00
Groundwater	4,724.10	--
Adjusted Load Allocation	6,276.10	12,308,514.00

Table 9. Load Allocations, Loads Not Reduced, and Adjusted Load Allocations for Subbasin 2

	Phosphorus (lbs/yr)	Sediment (lbs/yr)
Load Allocation	7,581.75	10,219,852.62
Loads Not Reduced	3,279.80	68,000.00
CONIF_FOR	1.10	1,200.00
MIXED_FOR	1.50	1,600.00
DECID_FOR	57.10	65,200.00
Groundwater	3,220.10	--
Adjusted Load Allocation	4,301.95	10,151,852.62

G. TMDLs

The phosphorus and sediment TMDLs established for the South Branch Codorus Creek subbbasins consists of a WLA, a LA and a MOS. No TMDL was established for nitrogen because the stream is phosphorus limited. The individual components of the TMDL are summarized in Tables 10 and 11.

Table 10. TMDL, WLA, MOS, LA, LNR, and ALA for Subbasin 1

Component	Phosphorus (lbs/yr)	Sediment (lbs/yr)
TMDL (Total Maximum Daily Load)	16,367.00	13,773,460.00
WLA (Wasteload Allocation) *Glen Rock PA0020818*	3,650.00	0.00
MOS (Margin of Safety)	1,636.70	1,377,346.00
LA (Load Allocation)	11,080.30	12,396,114.00
LNR (Loads Not Reduced)	4,804.20	87,600.00
ALA (Adjusted Load Allocation)	6,276.10	12,308,514.00

Table 11. TMDL, WLA, MOS, LA, LNR, and ALA for Subbasin 2

Component	Phosphorus (lbs/yr)	Sediment (lbs/yr)
TMDL (Total Maximum Daily Load)	13,493.61	11,355,391.80
WLA (Wasteload Allocation) *New Freedom PA0043257*	4,562.50	0.00
MOS (Margin of Safety)	1,349.36	1,135,539.18
LA (Load Allocation)	7,581.75	10,219,852.62
LNR (Loads Not Reduced)	3,279.80	68,000.00
ALA (Adjusted Load Allocation)	4,301.95	10,151,852.62

V. Calculation of Sediment Load Reductions

The ALAs established in the previous section represent the annual phosphorus and sediment loads that are available for allocation between contributing sources in the South Branch Codorus Creek subbasins. The ALAs for phosphorus and sediment were allocated between agricultural and developed land uses, and stream banks. Data needed for load reduction analyses, including land use distribution, were obtained by GIS analysis. The Equal Marginal Percent Reduction (EMPR) allocation method (Appendix E) was used to distribute the ALA between the appropriate contributing land uses.

The load allocation and EMPR procedures were performed using MS Excel and results are presented in Appendix F. Tables 12 and 13 contain the results of the EMPR for total phosphorus and sediment for the appropriate contributing land uses in the South Branch Codorus Creek subbasins. The load allocation for each land use is shown, along with the percent reduction of current loads necessary to reach the targeted LA. Each allocation unit corresponds with a TMDL listed segment shown in Figure 1 and Table 1.

Table 12. Phosphorus and Sediment Load Allocations & Reductions for Subbasin 1

Allocation 1 – South Branch Codorus, Segment ID 1275						
Pollutant Source	**Acres**	**Unit Area Loading Rate (lbs/ac/yr)**		**Pollutant Loading (lbs/yr)**		**% Reduction**
		Current	**Allowable**	**Current**	**Allowable (LA)**	
Phosphorus						
HAY/PASTURE	4,580.28	0.14	0.1	641.24	549.63	14
CROPLAND	10,132.81	2.13	0.4	21,582.89	4,357.11	80
Developed	145.17	1.02	0.9	148.07	126.30	15
Streambanks				110.92	94.10	15
Sediment						
HAY/PASTURE	4,580.28	145.50	132.71	666,430.74	607,848.96	9
CROPLAND	10,132.81	2,268.25	913.76	22,983,746.28	9,258,956.47	60
Developed	145.17	281.25	256.53	40,829.06	37,240.46	9
Streambanks				240,565.14	219,419.30	9

Allocation 2 – Buffalo Valley Hollow						
Pollutant Source	**Acres**	**Unit Area Loading Rate (lbs/ac/yr)**		**Pollutant Loading (lbs/yr)**		**% Reduction**
		Current	**Allowable**	**Current**	**Allowable (LA)**	
Phosphorus						
HAY/PASTURE	507.25	0.14	0.1	71.02	60.87	14
CROPLAND	1,040.24	2.13	0.4	2,215.71	447.30	80
Developed	9.44	1.02	0.9	9.63	8.21	15
Streambanks				9.79	8.17	17
Sediment						
HAY/PASTURE	507.25	145.50	132.71	73,804.88	67,317.15	9
CROPLAND	1,040.24	2,268.25	913.76	2,359,524.38	950,529.70	60
Developed	9.44	281.25	256.53	2,655.00	2,421.64	9
Streambanks				23,759.52	21,671.04	9

Allocation 3 – Krebs Valley Run						
Pollutant Source	Acres	Unit Area Loading Rate (lbs/ac/yr)		Pollutant Loading (lbs/yr)		% Reduction
		Current	Allowable	Current	Allowable (LA)	
Phosphorus						
HAY/PASTURE	792.95	0.14	0.1	111.01	95.15	14
CROPLAND	1,183.88	2.13	0.4	2,521.66	509.07	80
Developed	10.09	1.02	0.9	10.29	8.78	15
Streambanks				12.48	10.46	16
Sediment						
HAY/PASTURE	792.95	145.50	132.71	115,374.23	105,232.39	9
CROPLAND	1,183.88	2,268.25	913.76	2,685,335.81	1,081,782.19	60
Developed	10.09	281.25	256.53	2,837.81	2,588.39	9
Streambanks				3,2669.34	29,797.68	9

Table 13. Phosphorus and Sediment Load Allocations & Reductions for Subbasin 2

Allocation 1 – South Branch Codorus Creek, Segment ID 19990630-1054-MSE & 19990630-1201-MSE						
Pollutant Source	Acres	Unit Area Loading Rate (lbs/ac/yr)		Pollutant Loading (lbs/yr)		% Reduction
		Current	Allowable	Current	Allowable (LA)	
Phosphorus						
HAY/PASTURE	2,272.25	0.10	0.09	227.23	204.50	10
CROPLAND	4,886.30	1.65	0.40	8,062.40	1,954.52	76
Developed	502.72	0.15	0.13	75.41	65.35	13
Streambanks				45.25	39.14	13
Sediment						
HAY/PASTURE	2,272.25	113.04	105.28	256,855.14	239,222.48	7
CROPLAND	4,886.30	1,821.93	1,017.09	8,902,496.56	4,969,806.87	44
Developed	502.72	34.53	32.16	17,358.92	16,167.48	7
Streambanks				103,928.97	96,794.27	7

Allocation 2 – Foust Creek						
Pollutant Source	Acres	Unit Area Loading Rate (lbs/ac/yr)		Pollutant Loading (lbs/yr)		% Reduction
		Current	Allowable	Current	Allowable (LA)	
Phosphorus						
HAY/PASTURE	254.50	0.10	0.09	26.25	22.76	13
CROPLAND	631.37	1.65	0.40	1,039.13	253.39	76
Developed	12.02	0.15	0.13	1.82	1.58	13
Streambanks				5.30	4.59	13
Sediment						
HAY/PASTURE	254.50	113.04	105.28	28,768.68	26,793.76	7
CROPLAND	631.37	1,821.93	1,017.09	1,150,311.94	642,160.11	44
Developed	12.02	34.53	32.16	415.05	386.56	7
Streambanks				11,765.54	10,957.84	7

Table 13. Continued						
Allocation 3 – Centerville Creek						
Pollutant Source	**Acres**	**Unit Area Loading Rate (lbs/ac/yr)**		**Pollutant Loading (lbs/yr)**		**% Reduction**
		Current	**Allowable**	**Current**	**Allowable (LA)**	
Phosphorus						
HAY/PASTURE	997.26	0.10	0.09	99.73	89.75	10
CROPLAND	1,884.38	1.65	0.40	3,109.23	753.75	76
Developed	21.13	0.15	0.13	3.17	2.75	13
Streambanks				17.14	14.83	13
Sediment						
HAY/PASTURE	997.26	113.04	105.28	112,730.27	104,991.53	7
CROPLAND	1,884.38	1,821.93	1,017.09	3,433,208.45	1,916,584.05	44
Developed	21.13	34.53	32.16	729.62	679.54	7
Streambanks				39,218.48	36,526.14	7
Allocation 4 – Pierceville Run						
Pollutant Source	**Acres**	**Unit Area Loading Rate (lbs/ac/yr)**		**Pollutant Loading (lbs/yr)**		**% Reduction**
		Current	**Allowable**	**Current**	**Allowable (LA)**	
Phosphorus						
HAY/PASTURE	1,182.48	0.10	0.09	118.25	106.42	10
CROPLAND	1,898.42	1.65	0.40	3,132.39	759.37	76
Developed	19.04	0.15	0.13	2.86	2.48	13
Streambanks				18.31	15.84	13
Sediment						
HAY/PASTURE	1,182.48	113.04	105.28	133,667.54	124,491.49	7
CROPLAND	1,898.42	1,821.93	1,017.09	3,458,788.35	1,930,864.00	44
Developed	19.04	34.53	32.16	657.45	612.33	7
Streambanks				41,179.40	38,352.45	7

VI. 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 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 nutrients to a waterbody and the resulting impact on beneficial uses, establishing these TMDLs using average annual conditions is protective of the waterbody.

VII. 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.

VIII. Recommendations for Implementation

TMDLs represent an attempt to quantify the pollutant load that may be present in a waterbody and still ensure attainment and maintenance of water quality standards. The South Branch Codorus Creek TMDL identifies the necessary overall load reductions for those pollutants currently causing use impairments and distributes those reduction goals to the appropriate nonpoint sources. Reaching the reduction goals established by this TMDL will only occur through stream restoration efforts and the use of BMPs. BMPs that would be helpful in lowering the amount of total phosphorus and sediment reaching the South Branch Codorus Creek segment include stream bank fencing, riparian buffer strips, strip cropping, contour plowing, conservation crop rotation, and heavy use area protection, among many others.

Numerous restoration initiatives are currently underway in the South Branch Codorus Creek Watershed. The York County Conservation District has been assisting with the coordination of many of these initiatives. The projects completed to date have been funded both through Pennsylvania Growing Greener Grant Program and the USEPA Clean Water Act Section 319 Grant Program. Several thousand feet of stream banks have been restored since 2000. In addition, other specific BMPs include manure storage systems, treatment of runoff from animal confinement and barnyard areas, as well as stormwater management controls. The York Chapter of the Isaak Walton League has been an active contributor to many of the restoration efforts within the South Branch Codorus watershed. The projects have been aimed at reducing the nonpoint source pollution and sediment loads from eroded stream banks and overland flow. Some stream restoration projects have also attempted to mitigate increased stream velocities due to an increase in impervious surfaces, or urban runoff.

In addition, continuing studies are underway to assess future restoration priorities. The Codorus Creek Watershed Association and U.S. Army Corps of Engineers are developing plans to further protect and restore the watershed through Rivers Conservation Plan and Study 206 respectively.

All of the above mentioned efforts have been supported by numerous government, industry, and citizen partnerships. The umbrella organization for many of the efforts in York County is the Watershed Alliance of York (WAY).

For more information on the utility of BMPs, the Natural Resources Conservation Service maintains a National Handbook of Conservation Practices (NHCP). The NHCP is available online at http://www.ncg.nrcs.usda.gov/nhcp_2.html. Many of the practices described in the handbook could be used on agricultural lands and urban areas in the South Branch Codorus Creek to help limit nutrient and sediment impairments. Determining the most appropriate BMPs, where they should be installed, and actually putting them into practice, requires the development and implementation of a comprehensive watershed restoration plan. Development of any restoration plan involves the gathering of site-specific information regarding current land uses and existing conservation practices. For the South Branch Codorus Creek Watershed, most of the planning required has been completed, or is in the final stages of completion.

By developing TMDLs for the South Branch Codorus Creek Watershed, the Pa. DEP has set the stage for the design and implementation of restoration plans to correct current use impairments. The Pa. DEP welcomes local efforts to support these watershed restoration plans. For more information about this TMDL, interested parties should contact the appropriate Watershed Manager in the Pa. DEP's Southcentral Regional Office (717-705-4700).

IX. Public Participation

A notice of availability for comments on the draft South Branch Codorus watershed TMDL was published in the PA Bulletin on December 14, 2002. The document is on the Pa. DEP's web page, at http://www.dep.state.pa.us/watermanagement_apps/tmdl. In addition, a public meeting will be held on January 29th, 2003, at 7 p.m. in the Nature Center, Nixon County Park, 5922 Nixon Drive, York, to address any outstanding concerns regarding the draft TMDLs. A 60-day period (ending on February 14, 2003) is being provided for the submittal of comments. Comments and responses will be summarized in Appendix G after the close of the comment period.

Notice of final TMDL approvals will be posted on the Pa. DEP's website.

Literature Cited

Commonwealth of Pennsylvania. 2001. Pennsylvania Code. Title 25 Environmental Protection. Department of Environmental Protection. Chapter 93. Water Quality Standards. Harrisburg, PA.

Novotny, V. and H. Olem, 1994. Water Quality: Prevention, Identification, and Management of Diffuse Pollution. Van Nostrand Reinhold, New York.

Thomann, R.V. and J.A. Mueller, 1987. Principles of Surface Water Quality Modeling and Control. Harper & Row, New York.

Appendix A. Information Sheet for the South Branch Creek TMDL

What is being proposed?

Total Maximum Daily Load (TMDL) plans have been developed to improve water quality in a segment of South Branch Codorus Creek.

Who is proposing the plans? Why?

The Pennsylvania Department of Environmental Protection (Pa. DEP) is proposing to submit the plans to the U.S. Environmental Protection Agency (USEPA) for review and approval as required by federal regulation. In 1995, USEPA was sued for not developing TMDLs when Pennsylvania failed to do so. Pa. DEP has entered into an agreement with USEPA to develop TMDLs for certain specified waters over the next several years. This TMDL has been developed in compliance with the state/USEPA agreement.

What is a TMDL?

A TMDL sets a ceiling on the pollutant loads that can enter a waterbody so that it will meet water quality standards. The Clean Water Act requires states to list all waters that do not meet their water quality standards even after pollution controls required by law are in place. For these waters, the state must calculate how much of a substance can be put in the water without violating the standard, and then distribute that quantity to all the sources of the pollutant on that water body. A TMDL plan includes waste load allocations for point sources, load allocations for nonpoint sources, and a margin of safety. The Clean Water Act requires states to submit their TMDLs to USEPA for approval. Also, if a state does not develop the TMDL, the Clean Water Act states that USEPA must do so.

What is a water quality standard?

The Clean Water Act sets a national minimum goal that all waters be "fishable" and "swimmable." To support this goal, states must adopt water quality standards. Water quality standards are state regulations that have two components. The first component is a designated use, such as "warm water fishes" or "recreation." States must assign a use, or several uses to each of their waters. The second component relates to the instream conditions necessary to protect the designated use(s). These conditions or "criteria" are physical, chemical, or biological characteristics such as temperature and minimum levels of dissolved oxygen, and maximum concentrations of toxic pollutants. It is the combination of the "designated use" and the "criteria" to support that use that make up a water quality standard. If any criteria are being exceeded, then the use is not being met and the water is said to be in violation of water quality standards.

What is the purpose of the plans?

The South Branch Codorus Creek is impaired due to nutrients and sediment emanating from agricultural runoff. The plans include a calculation of the loading for phosphorus, the limiting nutrient, and sediment that will correct the problem and meet water quality objectives.

Why was the South Branch Codorus Creek selected for TMDL development?

In 1996, Pa. DEP listed a portion of the South Branch Codorus Creek under Section 303(d) of the federal Clean Water Act as impaired due to causes linked to nutrients and sediment.

What pollutants do these TMDLs address?

The proposed plans provide calculations of the stream's total capacity to accept phosphorus and sediment.

Where do the pollutants come from?

The nutrient and sediment related impairments in the South Branch Codorus Creek come from nonpoint sources of pollution, primarily overland runoff from agricultural and developed areas, as well as from streambank erosion.

How was the TMDL developed?

Pa. DEP used a reference watershed approach to estimate the necessary loading reduction of phosphorus and sediment that would be needed to restore a healthy aquatic community. The reference watershed approach is based on selecting a nonimpaired watershed that has similar land use characteristics and determining the current loading rates for the pollutants of interest. This is done by modeling the loads that enter the stream, using precipitation and land use characteristic data. For this analysis, Pa. DEP used the AVGWLF model (the Environmental Resources Research Institute of the Pennsylvania State University's Arcview based version of the Generalized Watershed Loading Function model developed by Cornell University). This modeling process uses loading rates in the nonimpaired watershed as a target for load reductions in the impaired watershed. The impaired watershed is modeled to determine the current loading rates and determine what reductions are necessary to meet the loading rates of the nonimpaired watershed. The reference stream approach was used to set allowable loading rates in the affected watershed because neither Pennsylvanian nor USEPA has instream numerical water quality criteria for nutrients or sediment.

How much pollution is too much?

The allowable amount of pollution in a water body varies depending on several conditions. TMDLs are set to meet water quality standards at the critical flow condition. For a free flowing stream impacted by nonpoint source pollution loading of nutrients or sediment, the TMDL is expressed as an annual loading. This accounts for pollution contributions over all stream flow conditions. Pa. DEP established the water quality objectives for nutrients and sediment by using the reference watershed approach. This approach assumes that the impairment is eliminated when the impaired watershed achieves loadings similar to the reference watershed. Reducing the current loading rates for nutrients and sediment in the impaired watershed to the current loading rates in the reference watershed will result in meeting the water quality objectives.

How will the loading limits be met?

Best Management Practices (BMPs) will be encouraged throughout the watershed to achieve the necessary load reductions.

How can I get more information on the TMDL?

To request a copy of the full report, contact Bill Brown at (717) 783-2300 between 8:00 a.m. and 3:00 p.m., Monday through Friday. Mr. Brown also can be reached by mail at the Office of Water Management, PADEP, Rachel Carson State Office Building, 400 Market Street, Harrisburg, PA 17105 or by e-mail at willbrown@state.pa.us.

How can I comment on the proposal?

You may provide e-mail or written comments postmarked no later than February 14th, 2003, to the above address.

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Appendix B. AVGWLF Model Overview & GIS-Based Derivation of Input Data

The TMDL for the South Branch Codorus Creek was developed using the Generalized Watershed Loading Function or GWLF model. The GWLF model provides the ability to simulate runoff, sediment, and nutrient (nitrogen and phosphorus) loadings from watershed given variable-size source areas (e.g., agricultural, forested, and developed land). It also has algorithms for calculating septic system loads, and allows for the inclusion of point source discharge data. It is a continuous simulation model, 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.

GWLF is a combined distributed/lumped parameter watershed model. For surface loading, it is distributed in the sense that it allows multiple land use/cover scenarios. Each area is assumed to be homogenous in regard to various attributes considered by the model. Additionally, the model does not spatially distribute the source areas, but aggregates the loads from each area into a watershed total. In other words, there is no spatial routing. For subsurface loading, the model acts as a lumped parameter model using a water balance approach. No distinctly separate areas are considered for subsurface flow contributions. Daily water balances are computed for an unsaturated zone as well as a saturated subsurface zone, where infiltration is computed as the difference between precipitation and snowmelt minus surface runoff plus evapotranspiration.

GWLF models surface runoff using the Soil Conservation Service Curve Number (SCS-CN) approach with daily weather (temperature and precipitation) inputs. Erosion and sediment yield are estimated using monthly erosion calculations based on the Universal Soil Loss Equation (USLE) algorithm (with monthly rainfall-runoff coefficients) and a monthly composite of KLSCP values for each source area (e.g., land cover/soil type combination). The KLSCP factors are variables used in the calculations to depict changes in soil loss erosion (K), the length slope factor (LS) the vegetation cover factor (C) and conservation practices factor (P). A sediment delivery ratio based on watershed size, transport capacity, and average daily runoff is applied to the calculated erosion for determining sediment yield for each source area. Surface nutrient losses are determined by applying dissolved nitrogen and phosphorus coefficients to surface runoff and a sediment coefficient to the yield portion for each agricultural source area. Point source discharges also can contribute to dissolved losses to the stream and are specified in terms of kilograms per month. Manured areas, as well as septic systems, can also be considered. Urban nutrient inputs are all assumed to be solid-phase, and the model uses an exponential accumulation and washoff function for these loadings. Subsurface losses are calculated using dissolved nitrogen and phosphorus coefficients for shallow groundwater contributions to stream nutrient loads, and the subsurface submodel only considers a single, lumped-parameter contributing area. Evapotranspiration is determined using daily weather data and a cover factor dependent upon land use/cover type. Finally, a water balance is performed daily using supplied or computed precipitation, snowmelt, initial unsaturated zone storage, maximum available zone storage, and evapotranspiration values. All of the equations used by the model can be viewed in GWLF Users Manuel.

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

(WEATHER.DAT) file contains daily average temperature and total precipitation values for each year simulated.

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

In using this interface, the user is prompted to identify required GIS files and to provide other information related to "non-spatial" model parameters (e.g., beginning and end of the growing season, the months during which manure is spread on agricultural land, and the names of nearby weather stations). This information is subsequently used to automatically derive values for required model input parameters, which are then written to the TRANSPRT.DAT, NUTRIENT.DAT and WEATHER.DAT input files needed to execute the GWLF model. For use in Pennsylvania, AVGWLF has been linked with statewide GIS data layers such as land use/cover, soils, topography, and physiography; and includes location-specific default information such as background nitrogen and phosphorus concentrations and cropping practices. Complete GWLF-formatted weather files also are included for 80 weather stations around the state.

The following table lists the statewide GIS data sets and provides an explanation of how they were used for development of the input files for the GWLF model.

GIS Data Sets	
DATASET	**DESCRIPTION**
Censustr	Coverage of Census data including information on individual homes septic systems. The attribute *usew_sept* includes data on conventional systems, and *sew_other* provides data on short-circuiting and other systems.
County	The County boundaries coverage lists data on conservation practices, which provides C and P values in the Universal Soil Loss Equation (USLE).
Gwnback	A grid of background concentrations of N in groundwater derived from water well sampling.
Landuse5	Grid of the MRLC that has been reclassified into five categories. This is used primarily as a background.
Majored	Coverage of major roads. Used for reconnaissance of a watershed.
MCD	Minor civil divisions (boroughs, townships and cities).
Npdespts	A coverage of permitted point discharges. Provides background information and cross check for the point source coverage.
Padem	100-meter digital elevation model. Used to calculate landslope and slope length.
Palumrlc	A satellite image derived land cover grid that is classified into 15 different landcover categories. This dataset provides land cover loading rate for the different categories in the model.
Pasingle	The 1:24,000 scale single line stream coverage of Pennsylvania. Provides a complete network of streams with coded stream segments.
Physprov	A shapefile of physiographic provinces. Attributes *rain_cool* and *rain_warm* are used to set recession coefficient
Pointsrc	Major point source discharges with permitted nitrogen and phosphorus loads.
Refwater	Shapefile of reference watersheds for which nutrient and sediment loads have been calculated.
Soilphos	A grid of soil phosphorous loads, which has been generated from soil sample data. Used to help set phosphorus and sediment values.
Smallsheds	A coverage of watersheds derived at 1:24,000 scale. This coverage is used with the stream network to delineate the desired level watershed.
Statsgo	A shapefile of generalized soil boundaries. The attribute *mu_k* sets the k factor in the USLE. The attribute *mu_awc* is the unsaturated available capacity, and the *muhsg_dom* is used with landuse cover to derive curve numbers.
Strm305	A coverage of stream water quality as reported in the Pennsylvania's 305(b) report. Current status of assessed streams.
Surfgeol	A shapefile of the surface geology used to compare watersheds of similar qualities.
T9sheds	Data derived from a Pa. DEP study conducted at PSU with N and P loads.
Zipcode	A coverage of animal densities. Attribute *aeu_acre* helps estimate N & P concentrations in runoff in agricultural lands and over manured areas.
Weather Files	Historical weather files for stations around Pennsylvania to simulate flow.

Appendix C. AVGWLF Model Outputs for Subbasins 1 and 2

Subbasin 1

Edit Transport File

Rural LU	Area (ha)	CN	K	LS	C	P
HAY/PAST	2363	43	0.30281	1.14858	0.03	0.45
CROPLAND	4972	64	0.30267	1.61226	0.3	0.5
CONIF_FOR	147	37	0.30217	0.37995	0.002	0.45
MIXED_FOR	197	37	0.30152	0.43638	0.002	0.45
DECID_FOR	2454	37	0.30176	1.65754	0.002	0.45
UNPAVED_RD	20	72	0.30245	0.10243	0.8	1

Urban LU	Area (ha)	CN	K	LS	C	P
LO_INT_DEV	34	75	0.30352	0.12314	0.08	0.2
HI_INT_DEV	3	85	0.30666	0.04549	0.08	0.2

Month	Ket	Day Hrs	Season	Eros Coef
APR	0.4898	13	0	0.300
MAY	0.8025	14	1	0.300
JUN	0.9839	15	1	0.300
JUL	1.0891	15	1	0.300
AUG	1.1501	14	1	0.300
SEP	1.1855	12	1	0.120
OCT	0.8999	11	0	0.120
NOV	0.7343	10	0	0.120
DEC	0.6383	9	0	0.120
JAN	0.4247	9	0	0.120
FEB	0.4587	10	0	0.120
MAR	0.4784	12	0	0.120

Antecedent Moisture Condition

Day -1	Day -2	Day -3	Day -4	Day -5
0	0	0	0	0

Init Unsat Stor (cm)	10	Initial Snow (cm)	0
Init Sat Stor (cm)	0	Sed Del Ratio	0.114
Recess Coef (l/day)	0.10024	Sed LE Rate	1.000E-05
Seepage Coef (l/day)	0	Unsat Avail Wat (cm)	11.948

c: [LOCAL DISK] | avgwlf_40 / Apr / sbrcod1 | transedit1.dat

Load Transport File | Save Changes | Close

Edit Nutrient File

Runoff	Dis N mg/L	Dis P mg/L
HAY/PAST	2.9	0.2
CROPLAND	2.9	0.2
CONIF_FOR	0.19	0.006
MIXED_FOR	0.19	0.006
DECID_FOR	0.19	0.006
UNPAVED_RD	2.9	0.2
Manure	2.44	0.38

Washoff	N kg/ha/d	P kg/ha/d
LO_INT_DEV	0.012	0.0016
HI_INT_DEV	0.101	0.0112

Point source and septic system nitrogen and phosphorus

Month	Pt Src N Kg	Pt Src P Kg	Norm Sys	Pond Sys	Short Circ Sys	Discharge Sys
APR	1200	66.3	2764	0	56	0
MAY	1200	66.3	2764	0	56	0
JUN	1200	66.3	2764	0	56	0
JUL	1200	66.3	2764	0	56	0
AUG	1200	66.3	2764	0	56	0
SEP	1200	66.3	2764	0	56	0
OCT	1200	66.3	2764	0	56	0
NOV	1200	66.3	2764	0	56	0
DEC	1200	66.3	2764	0	56	0
JAN	1200	66.3	2764	0	56	0
FEB	1200	66.3	2764	0	56	0
MAR	1200	66.3	2764	0	56	0

Per capita tank effluent (g/d) N	P	Growing season (g/d) N Uptake	P Uptake	Sediment (mg/kg) N	P	Groundwater (mg/l) N	P
12	2.5	1.6	0.4	3000	908	2.52462	0.0480335

c: [L...] | erri / avgwlf_40 / Apr / sbrcod1 | nutredit1.dat

Load Nutrient File | Save Changes | Close

Average Loads by Month

GWLF Nutrient Summary for sbrcod1-2

Period of analysis: 20 years, from Apr 1978 to Mar 1998

	MG (1000 Kg)		Nutrient Loads (Kg)			
Month	Erosion	Sediment	Dis. Nitr.	Tot. Nitr.	Dis. Phos.	Tot. Phos
APR	12024.0	185.2	20024.0	20608.6	408.1	585.0
MAY	18320.8	234.8	15971.9	16700.9	326.1	546.7
JUN	15802.1	603.2	7202.7	9027.8	216.1	768.5
JUL	19266.6	263.1	4128.3	4924.7	145.5	386.5
AUG	15243.9	63.2	1453.3	1644.7	74.6	132.6
SEP	7083.3	741.2	1854.8	4079.8	85.6	759.0
OCT	6088.9	350.7	4680.8	5737.6	136.8	456.7
NOV	7661.7	1454.7	7557.8	11931.0	204.8	1528.4
DEC	3462.5	2432.8	16173.2	23494.4	349.2	2565.1
JAN	2570.5	2024.3	18162.6	24261.0	462.6	2308.4
FEB	2742.8	2310.6	21605.8	28566.5	521.0	2627.8
MAR	4502.3	2405.0	23674.8	30921.8	484.6	2678.1
Total	114769.4	13068.9	142489.9	181898.9	3414.9	15342.6

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Export to Jpeg | Close

Average Hydrology by Month in Standard Units

GWLF Transport Summary for sbrcod1-2

Period of analysis: 20 years, from Apr 1978 to Mar 1998

	Units in Inches				
Month	Precip	Evapotrans	Gr. Wat. Flow	Runoff	Streamflow
APR	3.09	1.00	2.57	0.04	2.61
MAY	4.22	2.71	2.02	0.01	2.03
JUN	3.44	4.74	0.78	0.05	0.84
JUL	4.13	5.19	0.39	0.03	0.42
AUG	3.39	3.50	0.03	0.00	0.03
SEP	3.21	2.45	0.08	0.01	0.09
OCT	2.98	1.39	0.47	0.02	0.49
NOV	3.82	0.63	0.83	0.06	0.90
DEC	2.86	0.26	2.04	0.05	2.09
JAN	3.05	0.12	2.24	0.12	2.36
FEB	2.82	0.19	2.72	0.12	2.84
MAR	3.56	0.55	3.05	0.07	3.12
Total	40.60	22.70	17.24	0.58	17.81

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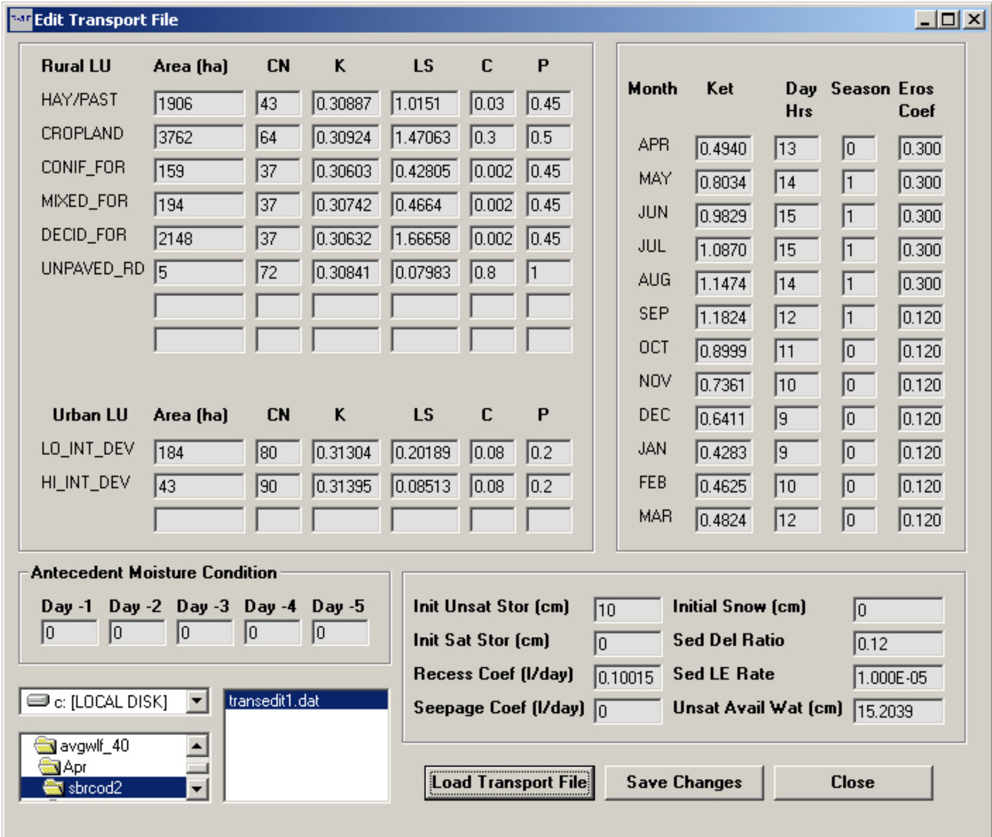
Average Loads by Source

GWLF Total Loads for sbrcod1-2

Period of analysis: 20 years, from Apr 1978 to Mar 1998

Source	(Ha) Area	(cm) Runoff	Mg (1000 Kg) Erosion	Mg (1000 Kg) Sediment	Total Loads (Kg) Dis. Nitr.	Total Loads (Kg) Tot. Nitr.	Total Loads (Kg) Dis. Phos.	Total Loads (Kg) Tot. Phos.
HAY/PAST	2363	0.34	3380.44	385.37	207.51	1363.62	26.9	376.82
CROPLAND	4972	2.7	110883.24	12640.69	3550.87	41472.94	399.58	11877.33
CONIF_FOR	147	0.14	4.63	0.53	0.39	1.97	0.01	0.49
MIXED_FOR	197	0.14	7.11	0.81	0.52	2.95	0.02	0.75
DECID_FOR	2454	0.14	336.58	38.37	6.45	121.56	0.2	35.04
UNPAVED_RD	20	5.11	151.04	17.22	29.65	81.3	2.04	17.68
LO_INT_DEV	34	6.48	6.2	0.71	0.0	0.07	0.0	0.01
HI_INT_DEV	3	14.7	0.2	0.02	0.0	0.0	0.0	0.0
Stream Bank				134.7		202.1		61.2
Groundwater					112624.82	112624.82	2142.8	2142.8
Point Sources					14400	14400	795.6	795.6
Septic Syst.					11669.72	11669.72	47.71	47.71
Totals	10190	1.5	114769.4	13218.4	142489.92	181941.03	3414.87	15355.4

Subbasin 2



Edit Transport File

Rural LU	Area (ha)	CN	K	LS	C	P
HAY/PAST	1906	43	0.30887	1.0151	0.03	0.45
CROPLAND	3762	64	0.30924	1.47063	0.3	0.5
CONIF_FOR	159	37	0.30603	0.42805	0.002	0.45
MIXED_FOR	194	37	0.30742	0.4664	0.002	0.45
DECID_FOR	2148	37	0.30632	1.66658	0.002	0.45
UNPAVED_RD	5	72	0.30841	0.07983	0.8	1

Urban LU	Area (ha)	CN	K	LS	C	P
LO_INT_DEV	184	80	0.31304	0.20189	0.08	0.2
HI_INT_DEV	43	90	0.31395	0.08513	0.08	0.2

Month	Ket	Day Hrs	Season	Eros Coef
APR	0.4940	13	0	0.300
MAY	0.8034	14	1	0.300
JUN	0.9829	15	1	0.300
JUL	1.0870	15	1	0.300
AUG	1.1474	14	1	0.300
SEP	1.1824	12	1	0.120
OCT	0.8999	11	0	0.120
NOV	0.7361	10	0	0.120
DEC	0.6411	9	0	0.120
JAN	0.4283	9	0	0.120
FEB	0.4625	10	0	0.120
MAR	0.4824	12	0	0.120

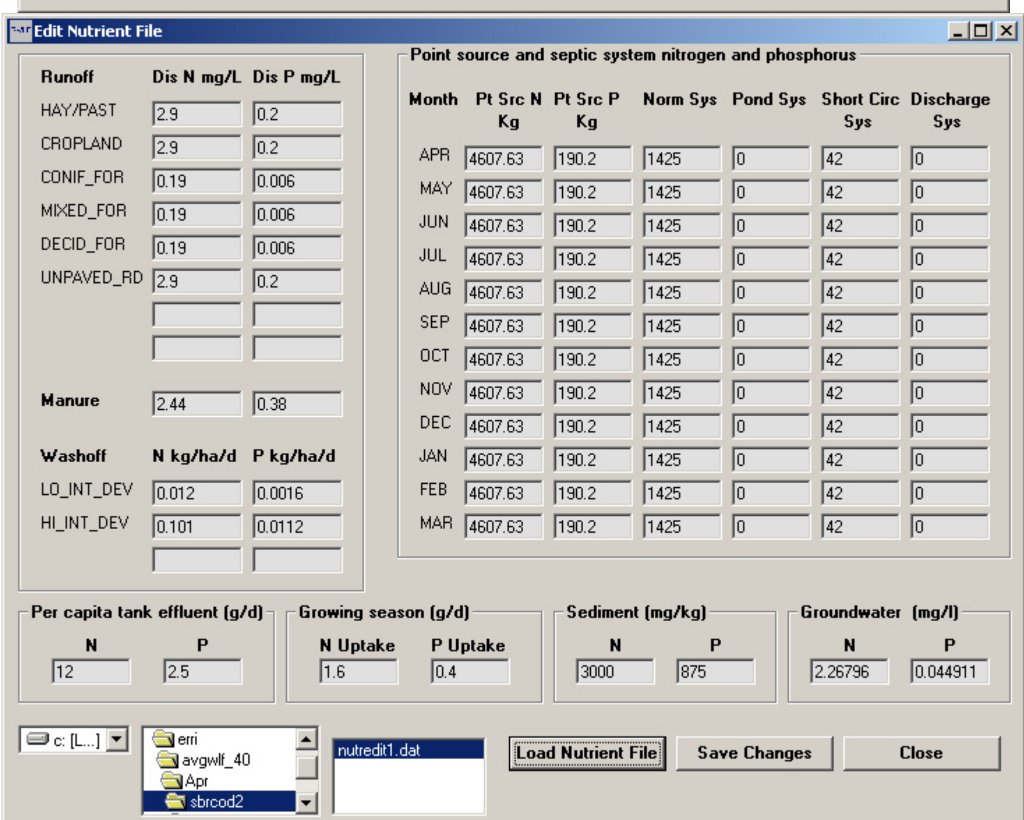
Antecedent Moisture Condition

Day -1	Day -2	Day -3	Day -4	Day -5
0	0	0	0	0

Init Unsat Stor (cm)	10	Initial Snow (cm)	0
Init Sat Stor (cm)	0	Sed Del Ratio	0.12
Recess Coef (l/day)	0.10015	Sed LE Rate	1.000E-05
Seepage Coef (l/day)	0	Unsat Avail Wat (cm)	15.2039

c: [LOCAL DISK] — avgwlf_40, Apr, sbrcod2 — transedit1.dat

Load Transport File | Save Changes | Close



Edit Nutrient File

Runoff	Dis N mg/L	Dis P mg/L
HAY/PAST	2.9	0.2
CROPLAND	2.9	0.2
CONIF_FOR	0.19	0.006
MIXED_FOR	0.19	0.006
DECID_FOR	0.19	0.006
UNPAVED_RD	2.9	0.2
Manure	2.44	0.38

Washoff	N kg/ha/d	P kg/ha/d
LO_INT_DEV	0.012	0.0016
HI_INT_DEV	0.101	0.0112

Point source and septic system nitrogen and phosphorus

Month	Pt Src N Kg	Pt Src P Kg	Norm Sys	Pond Sys	Short Circ Sys	Discharge Sys
APR	4607.63	190.2	1425	0	42	0
MAY	4607.63	190.2	1425	0	42	0
JUN	4607.63	190.2	1425	0	42	0
JUL	4607.63	190.2	1425	0	42	0
AUG	4607.63	190.2	1425	0	42	0
SEP	4607.63	190.2	1425	0	42	0
OCT	4607.63	190.2	1425	0	42	0
NOV	4607.63	190.2	1425	0	42	0
DEC	4607.63	190.2	1425	0	42	0
JAN	4607.63	190.2	1425	0	42	0
FEB	4607.63	190.2	1425	0	42	0
MAR	4607.63	190.2	1425	0	42	0

Per capita tank effluent (g/d)		Growing season (g/d)		Sediment (mg/kg)		Groundwater (mg/l)	
N	P	N Uptake	P Uptake	N	P	N	P
12	2.5	1.6	0.4	3000	875	2.26796	0.044911

c: [L...] — erri, avgwlf_40, Apr, sbrcod2 — nutredit1.dat

Load Nutrient File | Save Changes | Close

Average Loads by Month

GWLF Nutrient Summary for sbrcod2-2

Period of analysis: 20 years, from Apr 1978 to Mar 1998

	MG (1000 Kg)		Nutrient Loads (Kg)			
Month	Erosion	Sediment	Dis. Nitr.	Tot. Nitr.	Dis. Phos.	Tot. Phos
APR	8000.4	162.8	18164.1	18674.0	452.5	601.0
MAY	12122.6	498.8	15505.4	17021.4	396.3	838.4
JUN	8670.8	135.2	9590.5	10007.7	291.3	412.9
JUL	10231.0	615.1	6593.8	8445.5	242.2	782.1
AUG	8036.0	8.4	4733.8	4760.3	195.3	203.0
SEP	4702.2	583.9	5295.1	7049.2	208.0	719.5
OCT	3534.8	509.4	6882.4	8414.5	240.2	687.0
NOV	4403.7	670.2	7292.2	9307.5	253.0	840.7
DEC	2443.2	1052.7	13300.5	16472.6	366.1	1291.2
JAN	1069.3	1303.8	13513.2	17438.7	413.0	1557.9
FEB	1103.9	1317.0	16885.3	20854.1	465.2	1622.8
MAR	2047.2	1106.4	19499.1	22840.0	483.0	1457.4
Total	66365.0	7963.8	137255.3	161285.5	4006.1	11014.0

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Export to Jpeg | Close

Average Hydrology by Month in Standard Units

GWLF Transport Summary for sbrcod2-2

Period of analysis: 20 years, from Apr 1978 to Mar 1998

	Units in Inches				
Month	Precip	Evapotrans	Gr. Wat. Flow	Runoff	Streamflow
APR	3.10	0.93	2.56	0.04	2.60
MAY	4.11	2.52	2.05	0.02	2.08
JUN	3.20	4.56	0.92	0.02	0.94
JUL	3.60	5.33	0.36	0.02	0.38
AUG	3.14	3.66	0.02	0.00	0.02
SEP	3.23	2.29	0.12	0.02	0.14
OCT	2.85	1.26	0.42	0.02	0.44
NOV	3.61	0.59	0.48	0.04	0.53
DEC	2.81	0.24	1.64	0.05	1.69
JAN	3.00	0.09	1.62	0.10	1.72
FEB	2.60	0.14	2.27	0.09	2.36
MAR	3.28	0.46	2.79	0.07	2.85
Total	38.54	22.07	15.24	0.50	15.74

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Export to Jpeg | Close

Average Loads by Source

GWLF Total Loads for sbrcod2-2

Period of analysis: 20 years, from Apr 1978 to Mar 1998

			Mg (1000 Kg)		Total Loads (Kg)			
Source	(Ha) Area	(cm) Runoff	Erosion	Sediment	Dis. Nitr.	Tot. Nitr.	Dis. Phos.	Tot. Phos.
HAY/PAST	1906	0.15	2012.57	241.51	73.05	797.57	9.0	220.32
CROPLAND	3762	2.03	64019.77	7682.37	2051.82	25098.94	217.8	6939.87
CONIF_FOR	159	0.04	4.68	0.56	0.13	1.81	0.0	0.5
MIXED_FOR	194	0.04	6.25	0.75	0.15	2.4	0.0	0.66
DECID_FOR	2148	0.04	246.2	29.54	1.7	90.33	0.05	25.91
UNPAVED_RD	5	4.29	24.57	2.95	6.22	15.06	0.43	3.01
LO_INT_DEV	184	8.64	46.42	5.57	0.0	4.0	0.0	0.53
HI_INT_DEV	43	21.5	4.59	0.55	0.0	1.35	0.0	0.15
Stream Bank				88.9		133.4		38.9
Groundwater					73759.94	73759.94	1460.62	1460.62
Point Sources					55291.56	55291.56	2282.4	2282.4
Septic Syst.					6070.74	6070.74	35.78	35.78
Totals	8401	1.3	66365.0	8052.7	137255.31	161267.13	4006.09	11008.66

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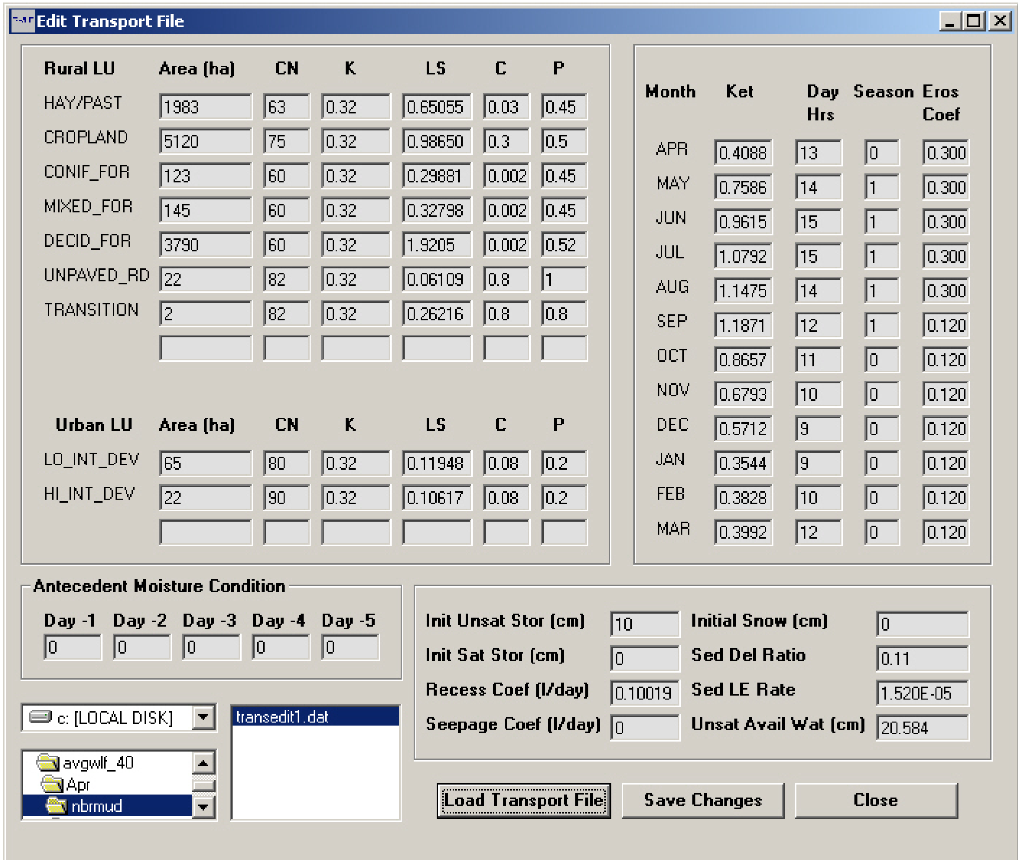
Appendix D. AVGWLF Model Outputs for the North Branch Muddy Creek Reference Subwatershed



Edit Transport File

Rural LU	Area (ha)	CN	K	LS	C	P
HAY/PAST	1983	63	0.32	0.65055	0.03	0.45
CROPLAND	5120	75	0.32	0.98650	0.3	0.5
CONIF_FOR	123	60	0.32	0.29881	0.002	0.45
MIXED_FOR	145	60	0.32	0.32798	0.002	0.45
DECID_FOR	3790	60	0.32	1.9205	0.002	0.52
UNPAVED_RD	22	82	0.32	0.06109	0.8	1
TRANSITION	2	82	0.32	0.26216	0.8	0.8

Urban LU	Area (ha)	CN	K	LS	C	P
LO_INT_DEV	65	80	0.32	0.11948	0.08	0.2
HI_INT_DEV	22	90	0.32	0.10617	0.08	0.2

Month	Ket	Day Hrs	Season	Eros Coef
APR	0.4088	13	0	0.300
MAY	0.7586	14	1	0.300
JUN	0.9615	15	1	0.300
JUL	1.0792	15	1	0.300
AUG	1.1475	14	1	0.300
SEP	1.1871	12	1	0.120
OCT	0.8657	11	0	0.120
NOV	0.6793	10	0	0.120
DEC	0.5712	9	0	0.120
JAN	0.3544	9	0	0.120
FEB	0.3828	10	0	0.120
MAR	0.3992	12	0	0.120

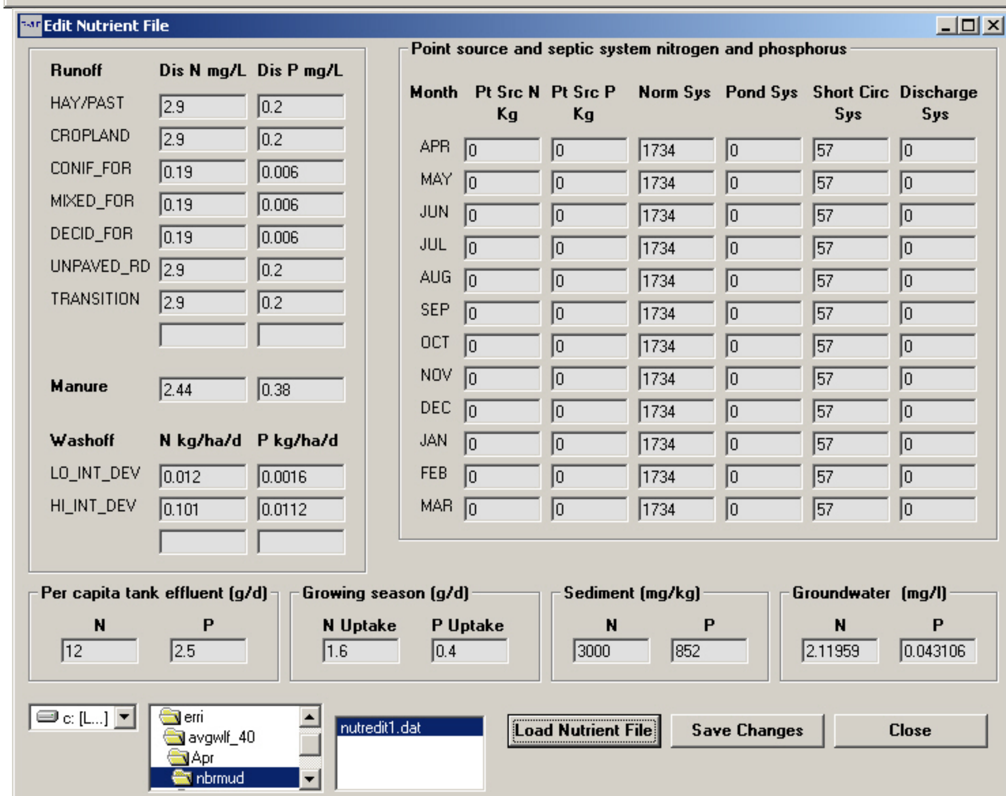
Antecedent Moisture Condition

Day -1	Day -2	Day -3	Day -4	Day -5
0	0	0	0	0

Init Unsat Stor (cm)	10	Initial Snow (cm)	0
Init Sat Stor (cm)	0	Sed Del Ratio	0.11
Recess Coef (l/day)	0.10019	Sed LE Rate	1.520E-05
Seepage Coef (l/day)	0	Unsat Avail Wat (cm)	20.584

c: [LOCAL DISK] | avgwlf_40 | Apr | nbrmud | transedit1.dat

Load Transport File | Save Changes | Close



Edit Nutrient File

Runoff	Dis N mg/L	Dis P mg/L
HAY/PAST	2.9	0.2
CROPLAND	2.9	0.2
CONIF_FOR	0.19	0.006
MIXED_FOR	0.19	0.006
DECID_FOR	0.19	0.006
UNPAVED_RD	2.9	0.2
TRANSITION	2.9	0.2
Manure	2.44	0.38

Washoff	N kg/ha/d	P kg/ha/d
LO_INT_DEV	0.012	0.0016
HI_INT_DEV	0.101	0.0112

Point source and septic system nitrogen and phosphorus

Month	Pt Src N Kg	Pt Src P Kg	Norm Sys	Pond Sys	Short Circ Sys	Discharge Sys
APR	0	0	1734	0	57	0
MAY	0	0	1734	0	57	0
JUN	0	0	1734	0	57	0
JUL	0	0	1734	0	57	0
AUG	0	0	1734	0	57	0
SEP	0	0	1734	0	57	0
OCT	0	0	1734	0	57	0
NOV	0	0	1734	0	57	0
DEC	0	0	1734	0	57	0
JAN	0	0	1734	0	57	0
FEB	0	0	1734	0	57	0
MAR	0	0	1734	0	57	0

Per capita tank effluent (g/d) N	Per capita tank effluent (g/d) P	Growing season (g/d) N Uptake	Growing season (g/d) P Uptake	Sediment (mg/kg) N	Sediment (mg/kg) P	Groundwater (mg/l) N	Groundwater (mg/l) P
12	2.5	1.6	0.4	3000	852	2.11959	0.043106

c: [L...] | erri | avgwlf_40 | Apr | nbrmud | nutredit1.dat

Load Nutrient File | Save Changes | Close

Average Loads by Month

GWLF Nutrient Summary for nbr2

Period of analysis: 20 years, from Apr 1978 to Mar 1998

	MG (1000 Kg)		Nutrient Loads (Kg)			
Month	Erosion	Sediment	Dis. Nitr.	Tot. Nitr.	Dis. Phos.	Tot. Phos
APR	6734.5	99.4	17398.6	17752.1	358.3	458.7
MAY	10534.9	183.2	13112.1	13709.2	261.7	431.2
JUN	6916.2	90.1	4523.6	4820.6	109.1	193.4
JUL	9766.8	182.7	1749.7	2309.2	72.1	230.9
AUG	8123.2	209.0	544.7	1177.2	29.0	208.6
SEP	4144.5	299.4	393.1	1294.1	28.5	284.4
OCT	3176.3	285.4	2595.4	3460.9	76.4	322.2
NOV	4093.6	934.2	2716.3	5530.4	103.6	902.8
DEC	2459.2	749.6	6587.6	8858.0	170.9	815.7
JAN	1224.2	1376.3	9322.3	13481.8	368.6	1549.9
FEB	1392.5	1101.0	14745.6	18092.8	454.2	1404.8
MAR	2309.9	1182.2	18886.5	22490.8	401.8	1425.5
Total	60875.9	6692.7	92575.5	112977.1	2434.3	8228.3

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Export to Jpeg | Close

Average Hydrology by Month in Standard Units

GWLF Transport Summary for nbr2

Period of analysis: 20 years, from Apr 1978 to Mar 1998

	Units in Inches				
Month	Precip	Evapotrans	Gr. Wat. Flow	Runoff	Streamflow
APR	3.08	0.81	2.52	0.09	2.61
MAY	4.02	2.54	1.91	0.05	1.95
JUN	3.04	4.74	0.65	0.03	0.68
JUL	3.88	6.22	0.22	0.04	0.27
AUG	3.26	4.49	0.03	0.04	0.08
SEP	3.15	2.67	0.00	0.05	0.05
OCT	2.97	1.35	0.33	0.06	0.39
NOV	3.56	0.58	0.27	0.14	0.41
DEC	2.77	0.23	0.89	0.12	1.01
JAN	2.97	0.09	1.19	0.25	1.44
FEB	2.54	0.14	2.02	0.22	2.24
MAR	3.29	0.44	2.69	0.14	2.83
Total	38.51	24.30	12.71	1.23	13.95

Go Back | Loads by Month | Print

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Average Loads by Source

GWLF Total Loads for nbr2

Period of analysis: 20 years, from Apr 1978 to Mar 1998

Source	(Ha) Area	(cm) Runoff	Mg (1000 Kg) Erosion	Mg (1000 Kg) Sediment	Total Loads (Kg) Dis. Nitr.	Total Loads (Kg) Tot. Nitr.	Total Loads (Kg) Dis. Phos.	Total Loads (Kg) Tot. Phos.
HAY/PAST	1983	1.7	1351.82	148.7	907.24	1353.34	95.65	222.34
CROPLAND	5120	5.02	58808.57	6468.94	6935.61	26342.44	713.46	6225.0
CONIF_FOR	123	1.25	2.57	0.28	2.92	3.77	0.09	0.33
MIXED_FOR	145	1.25	3.32	0.37	3.45	4.54	0.11	0.42
DECID_FOR	3790	1.25	587.58	64.63	90.1	284.01	2.85	57.91
UNPAVED_RD	22	9.16	83.46	9.18	58.44	85.98	4.03	11.85
TRANSITION	2	9.16	26.05	2.87	5.31	13.91	0.37	2.81
LO_INT_DEV	65	7.7	9.65	1.06	0.0	0.23	0.0	0.03
HI_INT_DEV	22	19.46	2.9	0.32	0.0	0.37	0.0	0.04
Stream Bank				215.2		322.8		91.7
Groundwater					77160.89	77160.89	1569.22	1569.22
Point Sources					0	0	0	0
Septic Syst.					7411.52	7411.52	48.56	48.56
Totals	11272	3.1	60875.9	6911.5	92575.49	112983.79	2434.32	8230.18

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Appendix E. Equal Marginal Percent Reduction Method

The Equal Marginal Percent Reduction (EMPR) allocation method was used to distribute Adjusted Load Allocations (ALAs) between the appropriate contributing nonpoint sources. The load allocation and EMPR procedures were performed using the MS Excel and results are presented in Appendix F. The five major steps identified in the spreadsheet are summarized below:

1. Calculation of the TMDL based on impaired watershed size and unit area loading rate of the reference watershed.

2. Calculation of Adjusted Load Allocation based on TMDL, Margin of Safety, and existing loads not reduced.

3. Actual EMPR Process.

   a. Each land use/source load is compared with the total ALA to determine if any contributor would exceed the ALA by itself. The evaluation is carried out as if each source is the only contributor to the pollutant load of the receiving water body. If the contributor exceeds the ALA, that contributor would be reduced to the ALA. If a contributor is less than the ALA, it is set at the existing load. This is the baseline portion of the EMPR.
   b. After any necessary reductions have been made in the baseline, the multiple analyses are run. The multiple analyses will sum all of the baseline loads and compare them to the ALA. If the ALA is exceeded, an equal percent reduction will be made to all contributors' baseline values. After any necessary reductions in the multiple analyses, the final reduction percentage for each contributor can be computed.

4. Calculation of total loading rate of all sources receiving reductions.

5. Summary of existing loads, final load allocations, and percent reduction for each pollutant source.

Appendix F. Equal Marginal Percent Reduction Calculations for the South Branch Codorus Creek Subbasins

SUBBASIN 1

Step 1:	TMDL Total Load				Step 2:	Adjusted LA = (TMDL total load - MOS) - uncontrollable						
	Load = loading rate in ref. * Acres in Impaired					4991.70	4991.70					
		16367										
	PHOSPHORUS LOADING											
Step 3:		Annual Average Load	Load Sum	Check	Initial Adjust	Recheck	% reduction allocation	Load Reduction	Initial LA	Acres	Allowable Loading Rate	% Reduction
	Hay/Past.	830.70	27294.74	good	831	ADJUST	0.14	151.09	679.61	5839.10	0.12	18%
	Cropland	26185.00		bad	4992	1110	0.82	907.90	4083.80	12286.10	0.33	84%
	Developed	144.20		good	144		0.02	26.23	117.97	140.80	0.84	18%
	Streambank	134.84		good	135		0.02	24.52	110.32	0.00		18%
	Total	27294.74			6101.44		1.00		4991.70			
Step 4:	All Ag. Loading Rate	0.26										
Step 5:		Acres	Allowable (Target) Loading Rate	Final LA	Current Loading Rates	Current Load	% Red.					
	Final Hay/Past. LA	5839.10	0.12	679.61	0.14	831	18%					
	Final Cropland LA	12286.10	0.33	4083.80	2.13	26185	84%					
	Developed	140.80	0.84	117.97	1.02	144	18%					
	Streambank	0.00		110.32		135	18%					
				4991.70								

Step 1:	TMDL Total Load				Step 2:	Adjusted LA = (TMDL total load - MOS) - uncontrollable						
	Load = loading rate in ref. * Acres in Impaired					12308514.00	12308514					
		13773460										
	SEDIMENT LOADING											
Step 3:		Annual Average Load	Load Sum	Check	Initial Adjust	Recheck	% reduction allocation	Load Reduction	Initial LA	Acres	Allowable Loading Rate	% Reduction
	Hay/Past.	849600.00	29054194	good	849600	ADJUST	0.06	74680.42	774919.58	5839.10	132.71	9%
	Cropland	27868000.00		bad	12308514	1186194	0.91	1081926.74	11226587.26	12286.10	913.76	60%
	Developed	39600.00		good	39600		0.00	3480.87	36119.13	140.80	256.53	9%
	Streambank	296994.00		good	296994		0.02	26105.97	270888.03	0.00		9%
	Total	29054194.00			13494708		1.00		12308514.00			
Step 4:	All Ag. Loading Rate	662.14										
Step 5:		Acres	Allowable (Target) Loading Rate	Final LA	Current Loading Rates	Current Load	% Red.					
	Final Hay/Past. LA	5839.10	132.71	774919.58	145.50	849600	9%					
	Final Cropland LA	12286.10	913.76	11226587.26	2268.25	27868000	60%					
	Developed	140.80	256.53	36119.13	281.25	39600	9%					
	Streambank	0.00		270888.03		296994	9%					
				12308514.00		29054194.00	58%					

SUBBASIN 2

Step 1:	TMDL Total Load				Step 2:	Adjusted LA = (TMDL total load - MOS) - uncontrollable						
	Load = TP loading rate in ref. * Acres in Impaired					2111.95	2111.95					
	13494											
	PHOSPHORUS LOADING											
Step 3:		Annual Average Load	Load Sum	Check	Initial Adjust	Recheck	% reduction allocation	Load Reduction	Initial LA	Acres	Allowable Loading Rate	% Reduction
	Hay/Past.	485.70	15958.29	good	486	ADJUST	0.18	115	370.26	4710	0.08	23.8%
	Cropland	15299.80		bad	2112	658	0.76	502	1609.97	9296	0.17	89.5%
	Developed	87.00		good	87		0.03	21	66.32	573	0.12	23.8%
	Streambank	85.79		good	86		0.03	20	65.40	0		23.8%
	Total	15958.29			2770.439		1		2111.95			
Step 4:	All Ag. Loading Rate	0.14										
Step 5:		Acres	Allowable (Target) Loading Rate	Final LA	Current Loading Rates	Current Load	% Red.					
	Final Hay/Past. LA	4709.80	0.08	370.26	0.10	485.70	24%					
	Final Cropland LA	9296.10	0.17	1609.97	1.65	15299.80	89%					
	Developed	573.40	0.12	66.32	0.15	87.00	24%					
	Streambank	0.00		65.40		85.79	24%					
				2111.95								

Step 1:	TMDL Total Load				Step 2:	Adjusted LA = (TMDL total load - MOS) - uncontrollable						
	Load = TP loading rate in ref. * Acres in Impaired					10151852.62	10151853					
	11355392											
	SEDIMENT LOADING											
Step 3:		Annual Average Load	Load Sum	Check	Initial Adjust	Recheck	% reduction allocation	Load Reduction	Initial LA	Acres	Allowable Loading Rate	% Reduction
	Hay/Past.	532400.00	17685092.4	good	532400	ADJUST	0.05	36549.14	495850.86	4709.80	105.28	7%
	Cropland	16936800.00		bad	10151853	748292	0.93	696922.30	9454930.32	9296.10	1017.09	44%
	Developed	19800.00		good	19800		0.00	1359.27	18440.73	573.40	32.16	7%
	Streambank	196092.40		good	196092		0.02	13461.70	182630.70	0.00		7%
	Total	17685092.40			10900145.02		1.00		10151852.62			
Step 4:	All Ag. Loading Rate	710.47										
Step 5:		Acres	Allowable (Target) Loading Rate	Final LA	Current Loading Rates	Current Load	% Red.					
	Final Hay/Past. LA	4709.80	105.28	495850.86	113.04	532400	7%					
	Final Cropland LA	9296.10	1017.09	9454930.32	1821.93	16936800	44%					
	Developed	573.40	32.16	18440.73	34.53	19800	7%					
	Streambank	0.00	#DIV/0!	182630.70	#DIV/0!	196092	7%					
				10151852.62								

Appendix G. Comment & Response Document for the South Branch Codorus Creek Subwatershed TMDL