

# **LITTLE SWATARA CREEK TRIBUTARIES TMDL**

**Lebanon and Berks Counties**

Prepared for:

Pennsylvania Department of Environmental Protection



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## TMDL SUMMARIES

1. The impaired stream segments addressed by this Total Maximum Daily Load (TMDL) are located in Swatara, Bethel, North Lebanon, Jackson, Marion, and Tulpehocken Townships in Lebanon and Berks Counties, Pennsylvania. The stream segments drain approximately 18.27 square miles as part of State Water Plan subbasin 7D. The aquatic life existing uses for Little Swatara Creek, including its tributaries, are cold water fisheries upstream of the Berks/Lebanon County line and warm water fisheries downstream of the Berks/Lebanon County line (25 Pa. Code Chapter 93).
  
2. Pennsylvania's 2008 303(d) list identified 30.35 miles within the Little Swatara Tributaries Subwatersheds as impaired by nutrients and sediment from agricultural and residential land use practices. The listings are based on data collected in 1997 through the Pennsylvania Department of Environmental Protection's (PADEP's) Surface Water Monitoring Program. In order to ensure attainment and maintenance of water quality standards in the Little Swatara Tributaries Subwatersheds, mean annual loading for sediment will need to be limited from 1,040.8528 to 2,821.2366 pounds per day (lbs/day) and for phosphorus from 0.6961 to 2.9957 lbs/day.

The major components of the Little Swatara Tributaries TMDL are summarized below.

<b>UNT 09936 Subwatershed Components</b>	<b>Total Phosphorus (lbs/day)</b>	<b>Sediment (lbs/day)</b>
TMDL (Total Maximum Daily Load)	1.2853	1,210.4576
WLA (Wasteload Allocation)	-	-
MOS (Margin of Safety)	0.1285	121.0458
LA (Load Allocation)	1.1568	1,089.4118

<b>UNT 09947 Subwatershed Components</b>	<b>Total Phosphorus (lbs/day)</b>	<b>Sediment (lbs/day)</b>
TMDL (Total Maximum Daily Load)	1.1120	1,047.2098
WLA (Wasteload Allocation)	-	-
MOS (Margin of Safety)	0.1112	104.7210
LA (Load Allocation)	1.0008	942.4888

<b>UNT 09938 Subwatershed Components</b>	<b>Total Phosphorus (lbs/day)</b>	<b>Sediment (lbs/day)</b>
TMDL (Total Maximum Daily Load)	2.9957	2,821.2366
WLA (Wasteload Allocation)	-	-
MOS (Margin of Safety)	0.2996	282.1237
LA (Load Allocation)	2.6961	2,539.1129

<b>UNT 09933 Subwatershed Components</b>	<b>Phosphorus (lbs/day)</b>
TMDL (Total Maximum Daily Load)	0.6961
WLA (Wasteload Allocation)	-
MOS (Margin of Safety)	0.0696
LA (Load Allocation)	0.6265

<b>UNT 09932 Subwatershed Components</b>	<b>Total Phosphorus (lbs/day)</b>	<b>Sediment (lbs/day)</b>
TMDL (Total Maximum Daily Load)	1.1052	1,040.8528
WLA (Wasteload Allocation)	-	-
MOS (Margin of Safety)	0.1105	104.0853
LA (Load Allocation)	0.9947	936.7675

<b>UNT 09944 Subwatershed Components</b>	<b>Total Phosphorus (lbs/day)</b>	<b>Sediment (lbs/day)</b>
TMDL (Total Maximum Daily Load)	2.0949	1,972.9585
WLA (Wasteload Allocation)	-	-
MOS (Margin of Safety)	0.2095	197.2959
LA (Load Allocation)	1.8854	1,775.6626

<b>UNT 09902 Subwatershed Components</b>	<b>Total Phosphorus (lbs/day)</b>
TMDL (Total Maximum Daily Load)	1.2032
WLA (Wasteload Allocation)	-
MOS (Margin of Safety)	0.1203
LA (Load Allocation)	1.0829

3. Mean daily sediment and phosphorus loadings are estimated to range from 1,724.4425 to 7,719.0262 lbs/day and 1.0024 to 9.8451 lbs/day, respectively. To meet the TMDL, the sediment and phosphorus loadings will require reductions of 21 to 67 percent and 37 to 73 percent, respectively.
4. There are no point sources addressed in these TMDL segments.
5. The adjusted load allocation (ALA) is the actual portion of the load allocation (LA) distributed among nonpoint sources receiving reductions, or sources that are considered controllable. Controllable sources receiving allocations are hay/pasture, cropland, developed lands, and streambanks. The sediment and phosphorus TMDL includes a nonpoint source ALA that ranges from 932.7127 to 2,533.2499 lbs/day and 0.3916 to 1.7380 lbs/day, respectively. Sediment and phosphorus loadings from all other sources, such as forested areas, were maintained at their existing levels. Allocations of sediment and phosphorus to controllable nonpoint sources, or the ALA, for the Little Swatara Tributaries TMDL are summarized below.

<b>UNT 09936 Subwatershed: Adjusted Load Allocations for Sources of Sediment and Phosphorus</b>			
<b>Pollutant</b>	<b>Allocated Loading (lbs/day)</b>	<b>Adjusted Load Allocation (lbs/day)</b>	<b>% Reduction</b>
<b>Sediment</b>	1,210.4576	1,086.1241	10
<b>Phosphorus</b>	1.2853	0.7236	44

<b>UNT 09947 Subwatershed: Adjusted Load Allocations for Sources of Sediment and Phosphorus</b>			
<b>Pollutant</b>	<b>Allocated Loading (lbs/day)</b>	<b>Adjusted Load Allocation (lbs/day)</b>	<b>% Reduction</b>
<b>Sediment</b>	1,047.2098	939.9682	10
<b>Phosphorus</b>	1.1120	0.6502	42

<b>UNT 09938 Subwatershed: Adjusted Load Allocations for Sources of Sediment and Phosphorus</b>			
<b>Pollutant</b>	<b>Allocated Loading (lbs/day)</b>	<b>Adjusted Load Allocation (lbs/day)</b>	<b>% Reduction</b>
<b>Sediment</b>	2,821.2366	2,533.2499	10
<b>Phosphorus</b>	2.9957	1.7380	42

<b>UNT 09933 Subwatershed: Adjusted Load Allocations for Sources of Phosphorus</b>			
<b>Pollutant</b>	<b>Allocated Loading (lbs/day)</b>	<b>Adjusted Load Allocation (lbs/day)</b>	<b>% Reduction</b>
<b>Phosphorus</b>	0.6961	0.3916	44

<b>UNT 09932 Subwatershed: Adjusted Load Allocations for Sources of Sediment and Phosphorus</b>			
<b>Pollutant</b>	<b>Allocated Loading (lbs/day)</b>	<b>Adjusted Load Allocation (lbs/day)</b>	<b>% Reduction</b>
<b>Sediment</b>	1,040.8528	932.7127	10
<b>Phosphorus</b>	1.1052	0.6342	43

<b>UNT 09944 Subwatershed: Adjusted Load Allocations for Sources of Sediment and Phosphorus</b>			
<b>Pollutant</b>	<b>Allocated Loading (lbs/day)</b>	<b>Adjusted Load Allocation (lbs/day)</b>	<b>% Reduction</b>
<b>Sediment</b>	1,972.9585	1,771.3887	10
<b>Phosphorus</b>	2.0949	1.2001	43

<b>UNT 09902 Subwatershed: Adjusted Load Allocations for Sources of Phosphorus</b>			
<b>Pollutant</b>	<b>Allocated Loading (lbs/day)</b>	<b>Adjusted Load Allocation (lbs/day)</b>	<b>% Reduction</b>
<b>Phosphorus</b>	1.2032	0.7308	39

- Ten percent of the Little Swatara Tributaries subwatersheds' sediment and phosphorus TMDLs were 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. The MOS for the sediment and phosphorus TMDL ranged from 104.0853 to 282.1237 lbs/day and 0.0696 to 0.2996 lbs/day, respectively.
- The continuous simulation model used for developing the Little Swatara Tributaries 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.

## **WATERSHED BACKGROUND**

The Little Swatara Creek Watershed is approximately 99.2 square miles in area. The headwaters of Little Swatara Creek are located inside the western border of Berks County, a few miles northwest of Strausstown, Pa. The watershed is located on the U.S. Geological Survey (USGS) 7.5 minute quadrangles of Strausstown, Pine Grove, Lebanon, Fredericksburg, Bethel, Swatara, and Friedensburg, Pa. The stream flows west from western Berks County into eastern Lebanon County, where it joins Swatara Creek. The major tributaries to Little Swatara Creek include Elizabeth Run, Earlakill Run, Crosskill Creek, Mill Creek, Stone Creek, Deep Run, and several unnamed tributaries (UNTs). Smaller towns include Jonestown, Fredericksburg, Bethel, Rehrersburg, Frystown, Mt. Zion, and Mt. Aetna. Interstate 78 and U.S. Highway 22 travel through the majority of the watershed. State Highways 183, 645, 501, 343, and 419 bisect other portions of the watershed. Numerous township roads provide access to the Little Swatara Creek Watershed and its tributaries.

The TMDL watershed is located within the Great Valley Section of the Ridge and Valley physiographic province. The highest elevations are located in the northern portion of the watershed area on Blue Mountain. The total change in elevation in the watershed is approximately 1,280 feet from the headwaters to the mouth.

The majority of the rock type in the upland portions of the watershed is interbedded sedimentary (55 percent), predominantly associated with the Hamburg Sequence (Figure 1). The remaining rock types found in the lowlands are shale and graywacke (40 percent), predominantly associated with other formations of the Hamburg Sequence. There is also a presence of carbonate rock type (5 percent) in the southern portion of the watershed that is associated with the Hershey Formation and Myerstown Formation Undivided and variations of the Hamburg Sequence.

The Berks-Weikert-Bedington series is the predominant soil type in the Little Swatara Creek Watershed. This soil is listed as being brown, shaly, silt, loam soil and is mostly associated in the uplands of the watershed (Figure 2). Other dominant soils in the watershed consist of Hazleton-Dekalb-Buchanan and Ryder-Clarksburg-Berks.

Based on GIS datasets created in 2001, land use values were calculated for the Little Swatara Creek Watershed. Agriculture was the dominant land use at approximately 70 percent (Figure 3). Forested land uses account for approximately 26 percent of the watershed. Developed areas are 3 percent of the watershed, covering low-intensity residential, high-intensity/commercial land, and areas currently being developed. Disturbed land uses consisted of approximately 1 percent of the total land use in the watershed. Riparian buffer zones are nearly nonexistent (Figure 4) in some of the agricultural lands. Livestock also have unlimited access to streambanks in certain parts of the watershed, resulting in streambank trampling and severe erosion. Little contiguous forested tracts remain in the watershed.

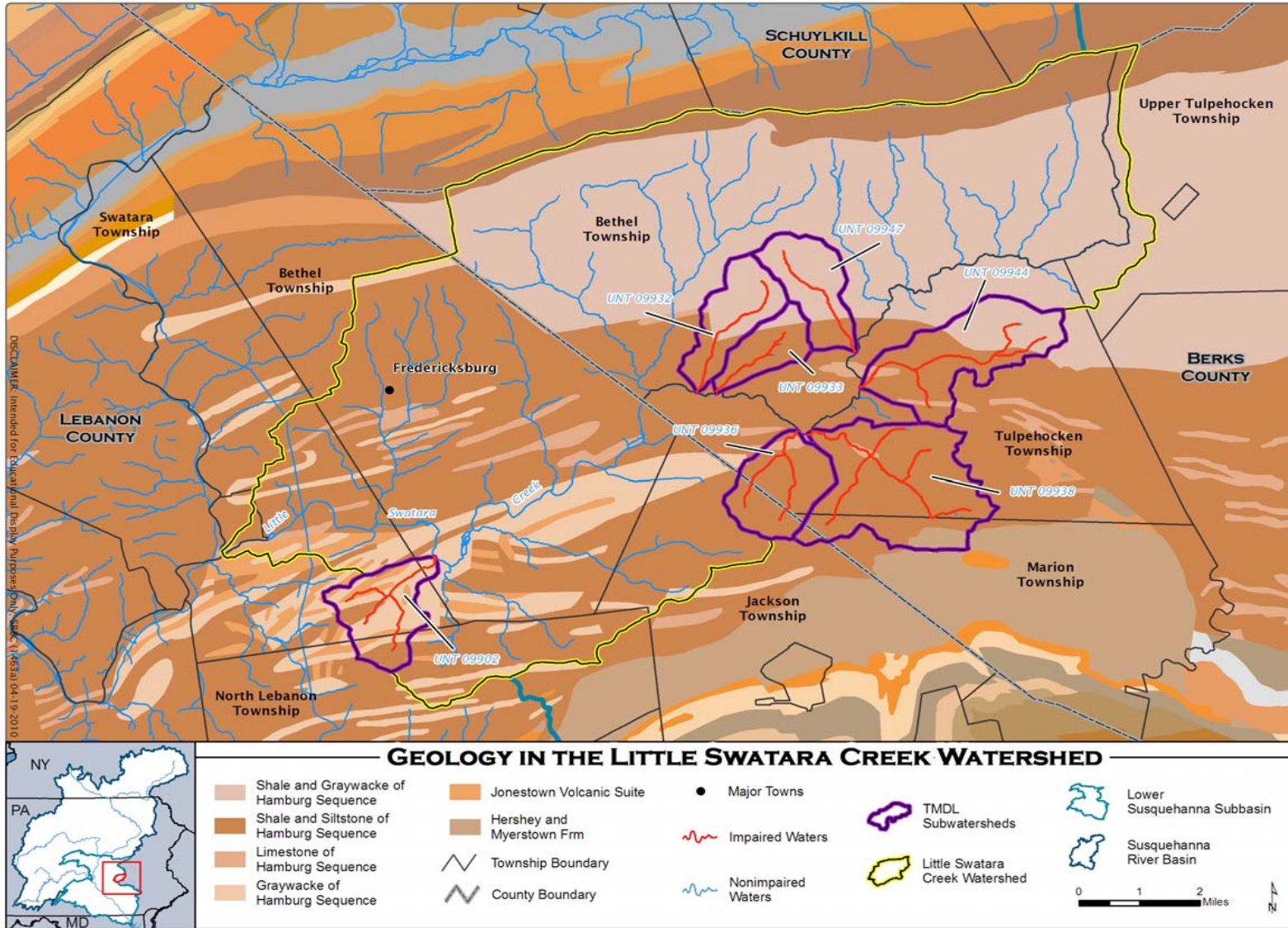


Figure 1. Geology Map of Little Swatara Creek Watershed

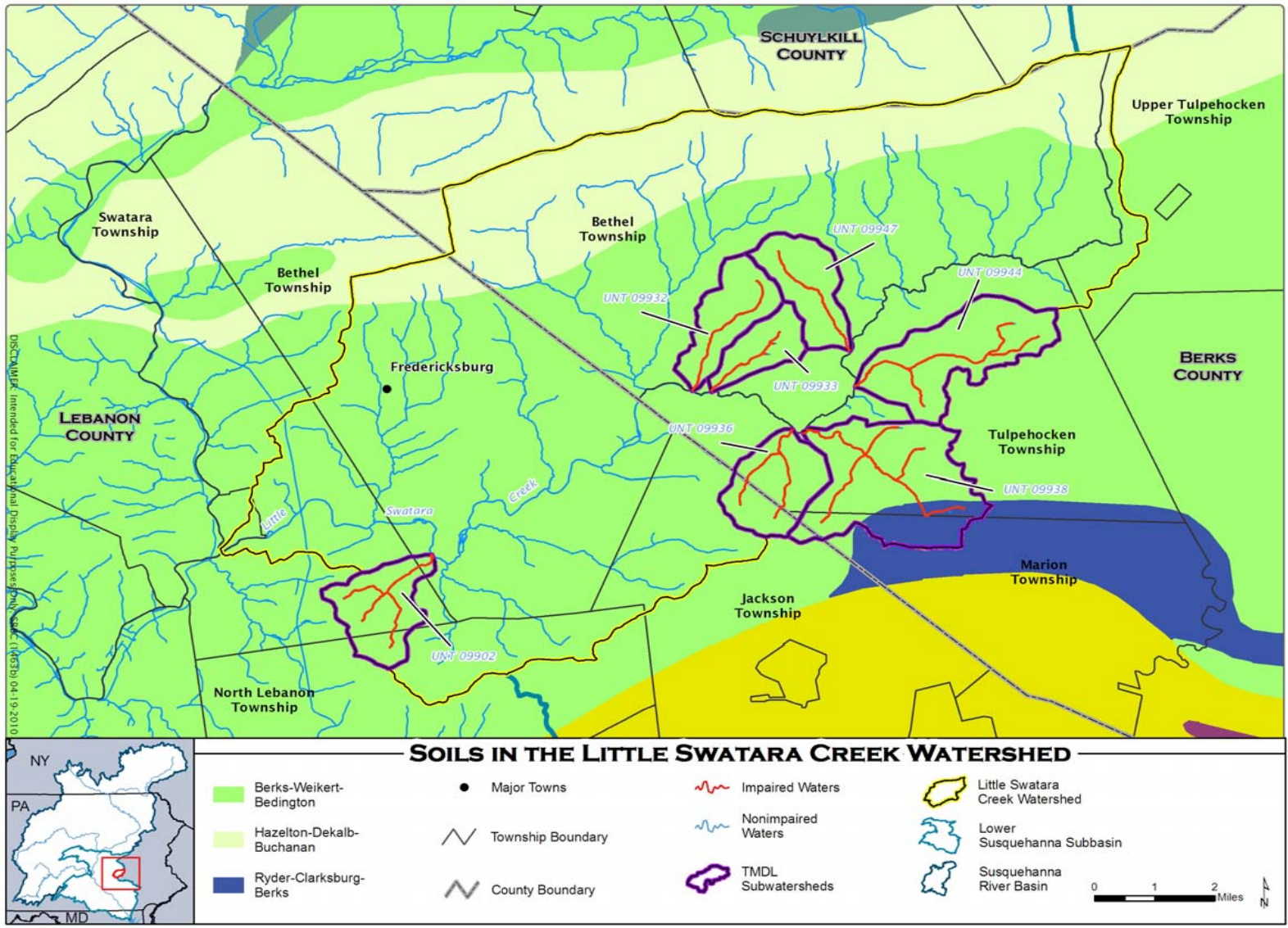


Figure 2. Soils Map of Little Swatara Creek Watershed

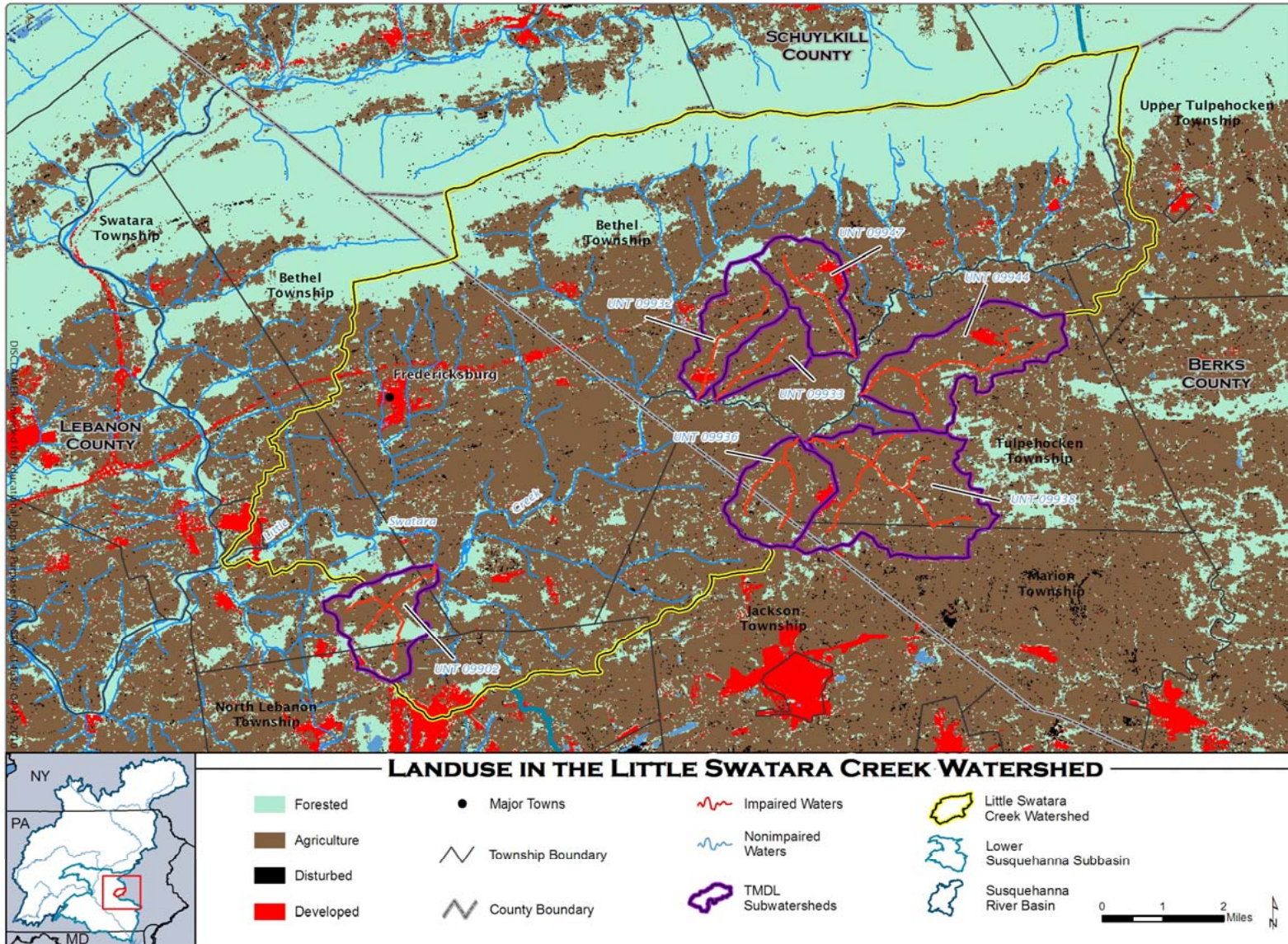


Figure 3. Land Use Map of Little Swatara Creek Watershed



*Figure 4. Evidence of Lack of Riparian Vegetation and Streambank Erosion in the Little Swatara Creek Watershed*

### **Surface Water Quality**

Pennsylvania's 2008 303(d) list identifies 30.35 miles of the Little Swatara Tributaries Subwatersheds as impaired by suspended solids, organic enrichment/low dissolved oxygen (DO), and nutrients emanating from agricultural practices (Table 1).

**Table 1. Integrated Water Quality Monitoring and Assessment Report Listed Segments**

State Water Plan (SWP) Subbasin: 7D				
HUC: 02050305 – Lower Susquehanna-Swatara				
Watershed – Little Swatara Creek Watershed				
Source	EPA 305(b) Cause Code	Miles	Designated Use	Use Designation
Agriculture	Nutrients	26.23	CWF	Aquatic Life
Agriculture	Siltation	15.51	CWF	Aquatic Life
On Site Wastewater	Organic Enrichment/ Low D.O.	6.89	CWF	Aquatic Life
Urban Runoff/Storm Sewers	Siltation	2.6	CWF	Aquatic Life

\* Please reference Attachment I – Little Swatara Creek Impairments for more details.

In general, soil erosion is a major problem in the Little Swatara Tributaries Subwatersheds. Unrestricted access of livestock to streams results in trampled streambanks, excessive stream sedimentation, increased nutrient levels, and sparse streamside buffers and riparian vegetation. Large areas of row crops and use of conventional tillage, as well as unrestricted cattle access to streams, combine to leave the soil vulnerable to erosion. Many of the streams in the subbasin are extremely muddy for several days after summer thunderstorms. The resulting high sediment can make water unfit to drink, smother aquatic life and fish eggs, clog fish gills, and block sunlight into the creeks and rivers. Most highways and major roads in the subbasin are overcrowded and are being expanded and upgraded. Runoff from road construction also can be an additional, although temporary, source of stream sedimentation and increased nutrient levels.

## **APPROACH TO TMDL DEVELOPMENT**

### **Pollutants & Sources**

Nutrients and sediment have been identified as the pollutants causing designated use impairments in the Little Swatara Tributaries Subwatersheds, with the sources listed as agricultural and small residential activities. At present, there are no point source contributions within the segments addressed in these TMDLs.

As stated in previous sections, the land use is dominantly agriculture. Pasture and croplands extend right up to the streambanks with little to no riparian buffer zones present. Livestock have unlimited access to streambanks throughout most of the watershed. Based on visual observations, streambank erosion is severe in most reaches of the streams.

### **TMDL Endpoints**

In an effort to address the sediment and nutrients problem found in the Little Swatara Tributaries Subwatersheds, a TMDL was developed to establish loading limits for sediment and nutrients.

The TMDL is intended to address sediment and nutrient impairments from developed land uses that were first identified in Pennsylvania's 1998 303(d) list, as well as other nonpoint sources such as agriculture. The decision to use phosphorus load reductions to address nutrient enrichment is based on an understanding of the relationship between nitrogen, phosphorus, and organic enrichment in stream systems. Elevated nutrient loads from human activities (nitrogen and phosphorus in particular) can lead to increased productivity of aquatic plants and other organisms, resulting in the degradation of water quality conditions through the depletion of dissolved oxygen in the water column (Novotny and Olem, 1994; Hem, 1983). 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 limiting nutrient because its relative quantity affects the rate of production (growth) of aquatic biomass. If the limiting nutrient load to a waterbody 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 waterbodies, emphasis is placed on the limiting nutrient. However, this is not always the case. For example, if nitrogen is the limiting nutrient, it still may be more efficient to control phosphorus loads if the nitrogen originates from difficult to control sources, such as nitrates in 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 nitrogen to the amount of phosphorus is often used to make this determination (Thomann and Mueller, 1987). If the nitrogen/phosphorus (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 the Little Swatara Tributaries Subwatersheds, the average N/P ratio is approximately 18, which indicates that phosphorus is the limiting nutrient. Controlling the phosphorus loading to the Little Swatara Tributaries Subwatersheds will limit plant growth, thereby helping to eliminate use impairments currently being caused by excess nutrients.

### **Reference Watershed Approach**

The TMDL developed for the Little Swatara Tributaries Subwatersheds addresses sediment and nutrients. Because neither Pennsylvania nor the U.S. Environmental Protection Agency (USEPA) has instream numerical water quality criteria for sediment and phosphorus, 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.

### **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 PADEP 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 Little Swatara Tributaries TMDL to 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 streams database, and geologic rock types.

Mill Creek was selected as the reference watershed for developing the Little Swatara Tributaries TMDL. Mill Creek is located just east of Bethel, in Berks, Pa. (Figure 5). The watershed is located in State Water Plan subbasin 7D, a tributary to the Little Swatara Creek, and protected uses include aquatic life and recreation. The tributary is currently designated as a Cold Water Fishery (25 Pa. Code Chapter 93). Based on PADEP assessments, Mill Creek is currently attaining its designated uses. The attainment of designated uses is based on sampling done by PADEP in 1997, as part of its State Surface Water Assessment Program.

Drainage area, location, and other physical characteristics of the impaired segments of the Little Swatara Tributaries Subwatersheds were compared to the Mill Creek Watershed (Table 2). Agricultural land is the dominant land use category in all the impaired segments of the Little Swatara Tributaries Subwatersheds (51.57-77.65 percent) and Mill Creek (29.73 percent). The geology, soils, and precipitation in both are also similar (Table 2).

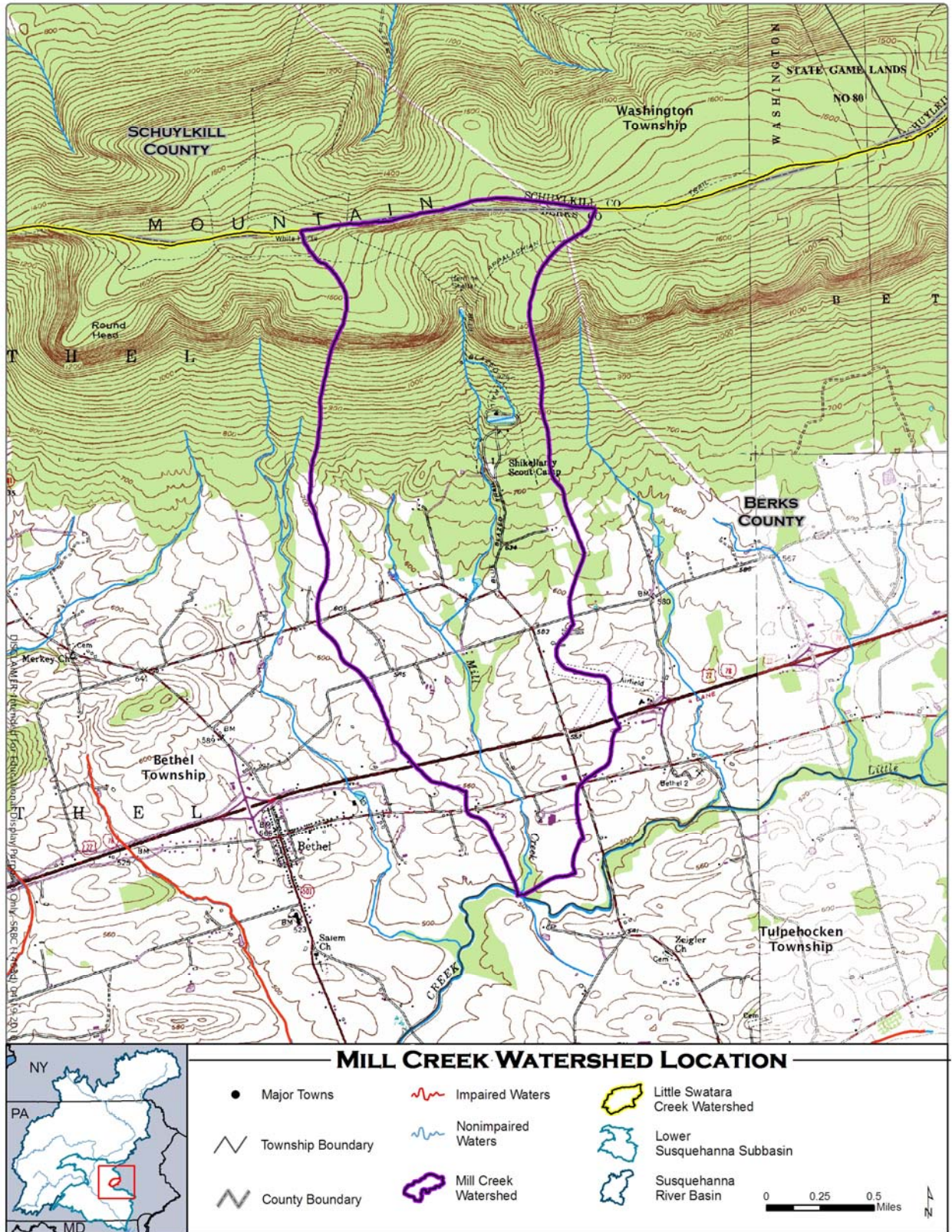


Figure 5. Location Map for Reference Watershed Mill Creek

**Table 2. Comparison between Impaired Segments of Little Swatara Creek TMDL Subwatersheds and Mill Creek Watershed**

Attribute	Watershed	
	Impaired Segments*	Mill Creek
<b>Physiographic Province</b>	Great Valley Section: Ridge and Valley (100%)	Great Valley Section: Ridge and Valley (100%)
<b>Area (mi<sup>2</sup>)</b>	1.21-5.20	3.03
<b>Land Use</b>	Agriculture (51.57-77.65%) Development (7.95-19.20%) Forested (12.74-40.48%)	Agriculture (29.73%) Development (6.10%) Forested (64.17%)
<b>Geology</b>	Hamburg Sequence (20-90%) Hamburg Seq.-Shale with Graywacke (0-80%) Hamburg Seq.-Graywacke (0-40%) Hershey and Myerstown Formation Undivided (0-10%) Hamburg Seq.-Shale and Limestone (0-10%) Jonestown Volcanic Suite (0-15%)	Hamburg Seq.-Shale with Graywacke (80%) Shawahgunk Formation (20%)
<b>Soils</b>	Berks-Weikert-Bedington (80-100%) Ryder-Clarksburg-Berks (0-20%)	Berks-Weikert-Bedington (70%) Hazleton-Dekalb-Buchanan (30%)
<b>Dominant HSG</b>	Berks-Weikert-Bedington A (0%) B (13%) C (52%) D (35%)  Ryder-Clarksburg-Berks A (0%) B (16%) C (76%) D (8%)	Berks-Weikert-Bedington A (0%) B (13%) C (52%) D (35%)  Hazleton-Dekalb-Buchanan A (2%) B (45%) C (53%) D (0%)
<b>K Factor</b>	Berks-Weikert-Bedington (0.24) Ryder-Clarksburg-Berks (0.31) Hazleton-Dekalb-Buchanan (0.18)	Berks-Weikert-Bedington (0.24) Hazleton-Dekalb-Buchanan (0.18)
<b>20-Yr. Ave. Rainfall (in)</b>	46.5-48.5	48.5
<b>20-Yr. Ave. Runoff (in)</b>	0.27-0.33	0.25

Please refer to Attachment C for specific information on individual watershed.

## WATERSHED ASSESSMENT AND MODELING

The TMDL for the impaired segments of the Little Swatara Tributaries Subwatersheds was developed using the ArcView Generalized Watershed Loading Function model (AVGWLF) as described in Attachment D. The AVGWLF model was used to establish existing loading conditions for the impaired segments of the Little Swatara Tributaries Subwatersheds and the Mill Creek reference watershed. All modeling inputs have been attached to this TMDL as Attachments E and F. SRBC staff visited the watershed in the winter and spring of 2010. The field visits were conducted to get a better understanding of existing conditions that might influence the AVGWLF model.

The AVGWLF model produced information on watershed size, land use, nutrients, and sediment loading. The nutrient and sediment loads represent an annual average over a 24-year period, from 1975 to 1998, and for the Little Swatara Creek Tributaries Watershed and Mill Creek Watershed, respectively. This information was then used to calculate existing unit area loading rates for UNT 09902, 09932, 09933, 09936, 09938, 09944, and 09947 subwatersheds, and Mill Creek reference watershed. Acreage, sediment, and phosphorus loading information for both the impaired watershed and the reference watershed are shown in Tables 3, 4, and 5, respectively.

*Table 3. Land Use Comparisons in Acres*

<b>Land Use</b>	<b>UNT 09902</b>	<b>UNT 09932</b>	<b>UNT 09933</b>	<b>UNT 09936</b>	<b>UNT 09938</b>	<b>UNT 09944</b>	<b>UNT 09947</b>	<b>Mill Creek</b>
HAY/PAST	388.0	341.0	316.3	474.4	1,124.3	795.7	360.8	286.6
CROPLAND	301.5	462.1	284.2	439.8	1,339.3	963.7	491.7	291.6
FOREST	523.9	227.3	101.3	237.2	528.8	252.0	192.7	1,245.4
WETLAND	17.3	14.8	4.9	2.5	49.4	44.5	19.8	2.5
TRANSITION	9.9	4.9	4.9	4.9	2.5	7.4	4.9	7.4
LO_INT_DEV	91.4	177.9	59.3	269.3	9.9	264.4	165.6	111.2
HI_INT_DEV	4.9		2.5		274.3			
<b>TOTAL</b>	<b>1,336.9</b>	<b>1,228.0</b>	<b>773.4</b>	<b>1,428.1</b>	<b>3,328.5</b>	<b>2,327.7</b>	<b>1,235.5</b>	<b>1,944.7</b>

**Table 4. Existing Phosphorus Loads and Yields**

<b>Land use</b>	<b>UNT 09902 (lbs/day) (lbs/ac/day)</b>	<b>UNT 09932 (lbs/day) (lbs/ac/day)</b>	<b>UNT 09933 (lbs/day) (lbs/ac/day)</b>	<b>UNT 09936 (lbs/day) (lbs/ac/day)</b>	<b>UNT 09938 (lbs/day) (lbs/ac/day)</b>	<b>UNT 09944 (lbs/day) (lbs/ac/day)</b>	<b>UNT 09947 (lbs/day) (lbs/ac/day)</b>	<b>Mill Creek (lbs/day) (lbs/ac/day)</b>
HAY/PAST	0.3155 0.0008	0.2555 0.0007	0.1967 0.0006	0.3784 0.0008	0.7612 0.0007	0.5128 0.0006	0.2685 0.0007	0.2016 0.0007
CROPLAND	1.8420 0.0061	2.3075 0.0050	0.5444 0.0019	2.2711 0.0052	8.0147 0.0060	2.7337 0.0028	2.1134 0.0043	0.8958 0.0031
FOREST	0.0247 0.0000	0.0054 0.0000	0.0012 0.0000	0.0053 0.0000	0.0105 0.0000	0.0070 0.0000	0.0037 0.0000	0.1039 0.0001
WETLAND	0.0005 0.0000	0.0004 0.0000	0.0001 0.0000	0.0001 0.0000	0.0016 0.0000	0.0015 0.0000	0.0006 0.0000	0.0001 0.0000
TURF GRASS					0.0016 0.0006			
TRANSITION	0.0660 0.0067	0.0215 0.0044	0.0104 0.0021	0.0202 0.0041	0.0532 0.0054	0.0467 0.0063	0.0175 0.0036	0.0252 0.0034
LO_INT_DEV	0.0152 0.0002	0.0292 0.0002	0.0097 0.0002	0.0443 0.0002	0.0451 0.0002	0.0435 0.0002	0.0272 0.0002	0.0183 0.0002
HI_INT_DEV	0.0094 0.0019		0.0048 0.0019					
Streambank (lbs/day)	0.0041	0.0036	0.0015	0.0055	0.0112	0.0060	0.0032	0.0050
Groundwater (lbs/day)	0.3169	0.3497	0.2286	0.4178	0.9310	0.6768	0.3413	0.4141
Septic Systems (lbs/day)	0.0100	0.0050	0.0050	0.0100	0.0150	0.0000	0.0050	0.0000
<b>TOTAL</b>	2.6044 0.0019	2.9779 0.0024	1.0024 0.0013	3.1526 0.0022	9.8451 0.0030	4.0279 0.0017	2.7803 0.0023	1.6639 0.0009

**Table 5. Existing Sediment Loads and Yields**

Land use	Mill Creek (lbs/day) (lbs/ac/day)	UNT 09932 (lbs/day) (lbs/ac/day)	UNT 09936 (lbs/day) (lbs/ac/day)	UNT 09938 (lbs/day) (lbs/ac/day)	UNT 09944 (lbs/day) (lbs/ac/day)	UNT 09947 (lbs/day) (lbs/ac/day)
HAY/PAST	73.3151 0.2558	70.5205 0.2068	105.7532 0.2229	273.5342 0.2433	146.0274 0.1835	77.5890 0.2150
CROPLAND	1,124.6027 3.8567	2,198.4658 4.7576	1,880.2192 4.2752	6,806.4658 5.0821	1,737.2055 1.8026	2,050.0822 4.1694
FOREST	169.2603 0.1359	4.0000 0.0176	3.2877 0.0139	5.5342 0.0105	4.0548 0.0161	2.4658 0.0128
WETLAND	0.0000 0.0000	0.0548 0.0037	0.0000 0.0000	0.3288 0.0067	0.2192 0.0049	0.0548 0.0028
TURF GRASS				0.4932 0.1973		
TRANSITION	33.8082 4.5687	20.1644 4.1152	16.1096 3.2877	42.9041 4.3337	34.3562 4.6427	16.3836 3.3436
LO_INT_DEV	21.6438 0.1946	38.5753 0.2168	76.5479 0.2842	78.4110 0.2859	54.4658 0.2060	41.3151 0.2495
Streambank (lbs/day)	225.7582	164.3233	248.6612	511.3550	274.8945	412.8020
<b>TOTAL</b>	1,648.3884 0.8476	2,496.1041 2.0327	2,330.5790 1.6319	7,719.0262 2.3191	2,251.2232 0.9671	2,330.6924 1.8864

### TMDLS

The targeted TMDL value for the Little Swatara Creek Tributaries Watershed was established based on current loading rates for sediment and phosphorus in the Mill Creek reference watershed. Biological assessments have determined that Mill Creek is currently attaining its designated uses. Reducing the loading rate of sediment and phosphorus in the Little Swatara Creek Tributaries Watershed to levels equivalent to those in the reference watershed will provide conditions favorable for the reversal of current use impairments.

### Background Pollutant Conditions

There are two separate considerations of background pollutants within the context of this TMDL. 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.

### Targeted TMDLs

The targeted TMDL value for phosphorus was determined by multiplying the total area of the UNT 09902 subwatershed (1,336.9 acres) by the appropriate unit-area loading rate for the Mill Creek reference watershed (Table 6). The existing mean annual loading of phosphorus to UNT

09902 (2.6044 lbs/day) will need to be reduced by 54 percent to meet the targeted TMDL of 1.2032 lbs/day.

**Table 6. Targeted TMDL for the UNT 09902 Subwatershed**

<b>Pollutant</b>	<b>Area (ac)</b>	<b>Unit Area Loading Rate Mill Creek Reference Watershed (lbs/ac/day)</b>	<b>Targeted TMDL for UNT 09902 (lbs/day)</b>
<b>Phosphorus</b>	1,336.9	0.0009	1.2032

The targeted TMDL value for sediment and phosphorus was determined by multiplying the total area of the UNT 09932 subwatershed (1,228.0 acres) by the appropriate unit-area loading rate for the Mill Creek reference watershed (Table 7). The existing mean annual loading of sediment and phosphorus to UNT 09932 (2,496.1041 lbs/day and 2.9779 lbs/day, respectively) will need to be reduced by 58 percent and 63 percent, respectively, to meet the targeted TMDL of 1,040.8528 lbs/day and 1.1052 lbs/day, respectively.

**Table 7. Targeted TMDL for the UNT 09932 Subwatershed**

<b>Pollutant</b>	<b>Area (ac)</b>	<b>Unit Area Loading Rate Mill Creek Reference Watershed (lbs/ac/day)</b>	<b>Targeted TMDL for UNT 09932 (lbs/day)</b>
<b>Sediment</b>	1,228.0	0.8476	1,040.8528
<b>Phosphorus</b>	1,228.0	0.0009	1.1052

The targeted TMDL value for phosphorus was determined by multiplying the total area of the UNT 09933 subwatershed (773.4 acres) by the appropriate unit-area loading rate for the Mill Creek reference watershed (Table 8). The existing mean annual loading of phosphorus to UNT 09933 (1.0024 lbs/day) will need to be reduced by 31 percent to meet the targeted TMDL of 0.6961 lbs/day.

**Table 8. Targeted TMDL for the UNT 09933 Subwatershed**

<b>Pollutant</b>	<b>Area (ac)</b>	<b>Unit Area Loading Rate Mill Creek Reference Watershed (lbs/ac/day)</b>	<b>Targeted TMDL for UNT 09933 (lbs/day)</b>
<b>Phosphorus</b>	773.4	0.0009	0.6961

The targeted TMDL value for sediment and phosphorus was determined by multiplying the total area of the UNT 09936 subwatershed (1,428.1 acres) by the appropriate unit-area loading rate for the Mill Creek reference watershed (Table 9). The existing mean annual loading of sediment and phosphorus to UNT 09936 (2,330.5790 lbs/day and 3.1526 lbs/day, respectively) will need to be reduced by 48 percent and 59 percent, respectively, to meet the targeted TMDL of 1,210.4576 lbs/day and 1.2853 lbs/day, respectively.

**Table 9. Targeted TMDL for the UNT 09936 Subwatershed**

<b>Pollutant</b>	<b>Area (ac)</b>	<b>Unit Area Loading Rate Mill Creek Reference Watershed (lbs/ac/day)</b>	<b>Targeted TMDL for UNT 09936 (lbs/day)</b>
<b>Sediment</b>	1,428.1	0.8476	1,210.4576
<b>Phosphorus</b>	1,428.1	0.0009	1.2853

The targeted TMDL value for sediment and phosphorus was determined by multiplying the total area of the UNT 09938 subwatershed (3,328.5 acres) by the appropriate unit-area loading rate for the Mill Creek reference watershed (Table 10). The existing mean annual loading of sediment and phosphorus to UNT 09938 (7,719.0262 lbs/day and 9.8451 lbs/day) will need to be reduced by 63 percent and 70 percent to meet the targeted TMDL of 2,821.2366 lbs/day and 2.9957 lbs/day, respectively.

**Table 10. Targeted TMDL for the UNT 09938 Subwatershed**

<b>Pollutant</b>	<b>Area (ac)</b>	<b>Unit Area Loading Rate Mill Creek Reference Watershed (lbs/ac/day)</b>	<b>Targeted TMDL for UNT 09938 (lbs/day)</b>
<b>Sediment</b>	3,328.5	0.8476	2,821.2366
<b>Phosphorus</b>	3,328.5	0.0009	2.9957

The targeted TMDL value for sediment and phosphorus was determined by multiplying the total area of the UNT 09944 subwatershed (2,327.7 acres) by the appropriate unit-area loading rate for the Mill Creek reference watershed (Table 11). The existing mean annual loading of sediment and phosphorus to UNT 09944 (2,251.2232 lbs/day and 4.0279 lbs/day) will need to be reduced by 12 percent and 48 percent to meet the targeted TMDL of 1,972.9585 lbs/day and 2.0949 lbs/day, respectively.

**Table 11. Targeted TMDL for the UNT 09944 Subwatershed**

<b>Pollutant</b>	<b>Area (ac)</b>	<b>Unit Area Loading Rate Mill Creek Reference Watershed (lbs/ac/day)</b>	<b>Targeted TMDL for UNT 09944 (lbs/day)</b>
<b>Sediment</b>	2,327.7	0.8476	1,972.9585
<b>Phosphorus</b>	2,327.7	0.0009	2.0949

The targeted TMDL value for sediment and phosphorus was determined by multiplying the total area of the UNT 09947 subwatershed (1,235.5 acres) by the appropriate unit-area loading rate for the Mill Creek reference watershed (Table 12). The existing mean annual loading of sediment and phosphorus to UNT 09947 (2,330.6924 lbs/day and 2.7803 lbs/day) will need to be reduced by 55 percent and 60 percent to meet the targeted TMDL of 1,047.2098 lbs/day and 1.1120 lbs/day, respectively.

**Table 12. Targeted TMDL for the UNT 09947 Subwatershed**

<b>Pollutant</b>	<b>Area (ac)</b>	<b>Unit Area Loading Rate Mill Creek Reference Watershed (lbs/ac/day)</b>	<b>Targeted TMDL for UNT 09947 (lbs/day)</b>
<b>Sediment</b>	1,235.5	0.8476	1,047.2098
<b>Phosphorus</b>	1,235.5	0.0009	1.1120

Targeted TMDL values were used as the basis for load allocations and reductions in the Little Swatara Creek Tributaries Watershed, 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

### **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 TMDLs for sediment and phosphorus were 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 UNTs 09902, 09932, 09933, 09936, 09938, 09944, and 09947 subwatersheds. The MOS used for the sediment and phosphorus TMDLs is shown below.

UNT 09902:

$$\text{MOS (phosphorus)} = 1.2032 \text{ lbs/day (TMDL)} \times 0.1 = 0.1203 \text{ lbs/day}$$

UNT 09932:

$$\text{MOS (sediment)} = 1,040.8528 \text{ lbs/day (TMDL)} \times 0.1 = 104.0853 \text{ lbs/day}$$

$$\text{MOS (phosphorus)} = 1.1052 \text{ lbs/day (TMDL)} \times 0.1 = 0.1105 \text{ lbs/day}$$

UNT 09933:

$$\text{MOS (phosphorus)} = 0.6961 \text{ lbs/day (TMDL)} \times 0.1 = 0.0696 \text{ lbs/day}$$

UNT 09936:

$$\text{MOS (sediment)} = 1,210.4576 \text{ lbs/day (TMDL)} \times 0.1 = 121.0458 \text{ lbs/day}$$

$$\text{MOS (phosphorus)} = 1.2853 \text{ lbs/day (TMDL)} \times 0.1 = 0.1285 \text{ lbs/day}$$

UNT 09938:

MOS (sediment) = 2,821.2366 lbs/day (TMDL) x 0.1 = 282.1237 lbs/day

MOS (phosphorus) = 2.9957 lbs/day (TMDL) x 0.1 = 0.2996 lbs/day

UNT 09944:

MOS (sediment) = 1,972.9585 lbs/day (TMDL) x 0.1 = 197.2959 lbs/day

MOS (phosphorus) = 2.0949 lbs/day (TMDL) x 0.1 = 0.2095 lbs/day

UNT 09947:

MOS (sediment) = 1,047.2098 lbs/day (TMDL) x 0.1 = 104.7210 lbs/day

MOS (phosphorus) = 1.1120 lbs/day (TMDL) x 0.1 = 0.1112 lbs/day

### Adjusted Load Allocation

The 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. Sediment reductions were made to the hay/pasture, cropland, developed areas (sum of LO\_INT\_DEV, HI\_INT\_DEV, UNPAVED ROADS, QUARRY, TRANSITION), and streambanks. Those land uses/sources for which existing loads were not reduced (FOREST, WETLANDS, Groundwater, and Septic Systems) were carried through at their existing loading values (Tables 13-19).

*Table 13. Load Allocations, Loads not Reduced, and Adjusted Load Allocation for UNT 09902*

Component	Phosphorus (lbs/day)
Load Allocation	1.0829
Loads not Reduced	0.3521
FOREST	0.0247
WETLANDS	0.0005
Groundwater	0.3169
Septic Systems	0.0100
Adjusted Load Allocation	0.7308

*Table 14. Load Allocations, Loads not Reduced, and Adjusted Load Allocation for UNT 09932*

Component	Phosphorus (lbs/day)	Sediment (lbs/day)
Load Allocation	0.9947	936.7675
Loads not Reduced	0.3605	4.0548
FOREST	0.0054	4.0000
WETLANDS	0.0004	0.0548
Groundwater	0.3497	0.0000
Septic Systems	0.0050	0.0000
Adjusted Load Allocation	0.6342	932.7127

**Table 15. Load Allocations, Loads not Reduced, and Adjusted Load Allocation for UNT 09933**

<b>Component</b>	<b>Phosphorus (lbs/day)</b>
<b>Load Allocation</b>	0.6265
<b>Loads not Reduced</b>	0.2349
<b>FOREST</b>	0.0012
<b>WETLANDS</b>	0.0001
<b>Groundwater</b>	0.2286
<b>Septic Systems</b>	0.0050
<b>Adjusted Load Allocation</b>	0.3916

**Table 16. Load Allocations, Loads not Reduced, and Adjusted Load Allocation for UNT 09936**

<b>Component</b>	<b>Phosphorus (lbs/day)</b>	<b>Sediment (lbs/day)</b>
<b>Load Allocation</b>	1.1568	1,089.4118
<b>Loads not Reduced</b>	0.4332	3.2877
<b>FOREST</b>	0.0053	3.2877
<b>WETLANDS</b>	0.0001	0.0000
<b>Groundwater</b>	0.4178	0.0000
<b>Septic Systems</b>	0.0100	0.0000
<b>Adjusted Load Allocation</b>	0.7236	1,086.1241

**Table 17. Load Allocations, Loads not Reduced, and Adjusted Load Allocation for UNT 09938**

<b>Component</b>	<b>Phosphorus (lbs/day)</b>	<b>Sediment (lbs/day)</b>
<b>Load Allocation</b>	2.6961	2,539.1129
<b>Loads not Reduced</b>	0.9581	5.8630
<b>FOREST</b>	0.0105	5.5342
<b>WETLANDS</b>	0.0016	0.3288
<b>Groundwater</b>	0.9310	0.0000
<b>Septic Systems</b>	0.0150	0.0000
<b>Adjusted Load Allocation</b>	1.7380	2,533.2499

**Table 18. Load Allocations, Loads not Reduced, and Adjusted Load Allocation for UNT 09944**

<b>Component</b>	<b>Phosphorus (lbs/day)</b>	<b>Sediment (lbs/day)</b>
<b>Load Allocation</b>	1.8854	1,775.6627
<b>Loads not Reduced</b>	0.6853	4.2740
<b>FOREST</b>	0.0070	4.0548
<b>WETLANDS</b>	0.0015	0.2192
<b>Groundwater</b>	0.6768	0.0000
<b>Septic Systems</b>	0.0000	0.0000
<b>Adjusted Load Allocation</b>	1.2001	1,771.3887

**Table 19. Load Allocations, Loads not Reduced, and Adjusted Load Allocation for UNT 09947**

<b>Component</b>	<b>Phosphorus (lbs/day)</b>	<b>Sediment (lbs/day)</b>
<b>Load Allocation</b>	1.0008	942.4888
<b>Loads not Reduced</b>	0.3506	2.5206
<b>FOREST</b>	0.0037	2.4658
<b>WETLANDS</b>	0.0006	0.0548
<b>Groundwater</b>	0.3413	0.0000
<b>Septic Systems</b>	0.0050	0.0000
<b>Adjusted Load Allocation</b>	0.6502	939.9682

### **TMDLs**

The sediment and phosphorus TMDLs established for the UNTs 09902, 09932, 09933, 09936, 09938, 09944, and 09947 subwatersheds consist of a LA, ALA, and MOS. The individual components of the TMDL are summarized in Tables 20-26.

**Table 20. Load Allocations, Loads not Reduced, and Adjusted Load Allocation for UNT 09902**

<b>Component</b>	<b>Phosphorus (lbs/day)</b>
<b>TMDL (Total Maximum Daily Load)</b>	1.2032
<b>MOS (Margin of Safety)</b>	0.1203
<b>LA (Load Allocation)</b>	1.0829
<b>LNR (Loads not Reduced)</b>	0.3521
<b>ALA (Adjusted Load Allocation)</b>	0.7308

**Table 21. Load Allocations, Loads not Reduced, and Adjusted Load Allocation for UNT09932**

<b>Component</b>	<b>Phosphorus (lbs/day)</b>	<b>Sediment (lbs/day)</b>
<b>TMDL</b>	1.1052	1,040.8528
<b>MOS</b>	0.1105	104.0853
<b>LA</b>	0.9947	936.7675
<b>LNR</b>	0.3605	4.0548
<b>ALA</b>	0.6342	932.7127

**Table 22. Load Allocations, Loads not Reduced, and Adjusted Load Allocation for UNT 09933**

<b>Component</b>	<b>Phosphorus (lbs/day)</b>
<b>TMDL</b>	0.6961
<b>MOS</b>	0.0696
<b>LA</b>	0.6265
<b>LNR</b>	0.2349
<b>ALA</b>	0.3916

**Table 23. Load Allocations, Loads not Reduced, and Adjusted Load Allocation for UNT 09936**

<b>Component</b>	<b>Phosphorus (lbs/day)</b>	<b>Sediment (lbs/day)</b>
<b>TMDL</b>	1.2853	1,210.4576
<b>MOS</b>	0.1285	121.0458
<b>LA</b>	1.1568	1,089.4118
<b>LNR</b>	0.4332	0.2349
<b>ALA</b>	0.7236	1,086.1241

**Table 24. Load Allocations, Loads not Reduced, and Adjusted Load Allocation for UNT 09938**

<b>Component</b>	<b>Phosphorus (lbs/day)</b>	<b>Sediment (lbs/day)</b>
<b>TMDL</b>	2.9957	2,821.2366
<b>MOS</b>	0.2996	282.1237
<b>LA</b>	2.6961	2,539.1129
<b>LNR</b>	0.9581	5.8630
<b>ALA</b>	1.7380	2,533.2499

**Table 25. Load Allocations, Loads not Reduced, and Adjusted Load Allocation for UNT 09944**

<b>Component</b>	<b>Phosphorus (lbs/day)</b>	<b>Sediment (lbs/day)</b>
<b>TMDL</b>	2.0949	1,972.9585
<b>MOS</b>	0.2095	197.2959
<b>LA</b>	1.8854	1,775.6627
<b>LNR</b>	0.6853	4.2740
<b>ALA</b>	1.2001	1,771.3887

**Table 26. Load Allocations, Loads not Reduced, and Adjusted Load Allocation for UNT 09947**

<b>Component</b>	<b>Phosphorus (lbs/day)</b>	<b>Sediment (lbs/day)</b>
<b>TMDL</b>	1.1120	1,047.2098
<b>MOS</b>	0.1112	104.7210
<b>LA</b>	1.0008	942.4888
<b>LNR</b>	0.3506	2.5206
<b>ALA</b>	0.6502	939.9682

## **CALCULATION OF SEDIMENT AND PHOSPHORUS LOAD REDUCTIONS**

The ALA established in the previous section represents the rate of sediment load that is available for allocation between contributing sources in the UNTs 09902, 09932, 09933, 09936, 09938, 09944, and 09947 subwatersheds. The ALA for sediment and phosphorus was allocated between agriculture, developed areas, and streambanks. LA and reduction procedures were applied to the entire UNTs 09902, 09932, 09933, 09936, 09938, 09944, and 09947 subwatersheds using the Equal Marginal Percent Reduction (EMPR) allocation method (Attachment G). The LA and EMPR procedures were performed using MS Excel, and results are presented in Attachment H.

In order to meet the sediment and phosphorus TMDL, the load currently emanating from controllable sources must be reduced (Tables 20-26). This can be achieved through reductions in

current sediment and phosphorus loadings from cropland, from hay/pasture, developed areas, and streambanks (Tables 27-33).

**Table 27. Phosphorus Load Allocations and Reductions for UNT 09902**

Pollutant Source	Acres	Unit Area Loading Rate (lbs/ac/day)		Pollutant Loading (lbs/day)		% Reduction
		Current	Allowable	Current	Allowable (LA)	
<b>Phosphorus</b>						
Hay/Pasture	388.0	0.0008	0.0005	0.3155	0.2021	36
Cropland	301.5	0.0061	0.0016	1.8420	0.4681	75
Developed	106.2	0.0009	0.0005	0.0906	0.0580	36
Streambanks	-	-	-	0.0041	0.0026	36
Total				2.2522	0.7308	68

**Table 28. Sediment and Phosphorus Load Allocations and Reductions for UNT 09932**

Pollutant Source	Acres	Unit Area Loading Rate (lbs/ac/day)		Pollutant Loading (lbs/day)		% Reduction
		Current	Allowable	Current	Allowable (LA)	
<b>Sediment</b>						
Hay/Pasture	341.0	0.2068	0.1573	70.5205	53.6374	24
Cropland	462.1	4.7576	1.5352	2,198.4658	709.4151	68
Developed	182.8	2.9817	2.2679	58.7397	44.6770	24
Streambanks	-	-	-	164.3233	124.9832	24
Total				2,492.0493	932.7127	63
<b>Phosphorus</b>						
Hay/Pasture	341.0	0.0007	0.0005	0.2555	0.1716	33
Cropland	462.1	0.0050	0.0009	2.3075	0.4261	82
Developed	182.8	0.0003	0.0002	0.0507	0.0341	33
Streambanks	-	-	-	0.0036	0.0024	33
Total				2.6173	0.6342	76

**Table 29. Phosphorus Load Allocations & Reductions for UNT 09933**

Pollutant Source	Acres	Unit Area Loading Rate (lbs/ac/day)		Pollutant Loading (lbs/day)		% Reduction
		Current	Allowable	Current	Allowable (LA)	
<b>Phosphorus</b>						
Hay/Pasture	316.3	0.0006	0.0004	0.1967	0.1253	36
Cropland	284.2	0.0019	0.0009	0.5444	0.2494	54
Developed	66.7	0.0004	0.0002	0.0249	0.0159	36
Streambanks	-	-	-	0.0015	0.0010	36
Total				0.7675	0.3916	49

**Table 30. Sediment and Phosphorus Load Allocations and Reductions for UNT 09936**

Pollutant Source	Acres	Unit Area Loading Rate (lbs/ac/day)		Pollutant Loading (lbs/day)		% Reduction
		Current	Allowable	Current	Allowable (LA)	
<b>Sediment</b>						
Hay/Pasture	474.4	0.1579	0.2229	105.7534	74.9163	29
Cropland	439.8	1.7495	4.2752	1,880.2192	769.4159	59
Developed	274.2	0.2394	0.3379	92.6575	65.6391	29
Streambanks	-	-	-	248.6612	176.1529	29
Total				2,327.2913	1,086.1241	53
<b>Phosphorus</b>						
Hay/Pasture	474.4	0.0008	0.0005	0.3784	0.2336	38
Cropland	439.8	0.0052	0.0010	2.2711	0.4467	80
Developed	274.2	0.0002	0.0001	0.0645	0.0398	38
Streambanks	-	-	-	0.0055	0.0034	38
Total				2.7195	0.7236	73

**Table 31. Sediment and Phosphorus Load Allocations and Reductions for UNT 09938**

Pollutant Source	Acres	Unit Area Loading Rate (lbs/ac/day)		Pollutant Loading (lbs/day)		% Reduction
		Current	Allowable	Current	Allowable (LA)	
<b>Sediment</b>						
Hay/Pasture	1,124.3	0.2433	0.1792	273.5342	201.4364	26
Cropland	1,339.3	5.0821	1.3929	6,806.4658	1,865.5388	73
Developed	286.7	0.4249	0.3129	121.8083	89.7022	26
Streambanks	-	-	-	511.3550	376.5726	26
Total				7,713.1633	2,533.2499	67
<b>Phosphorus</b>						
Hay/Pasture	1,124.3	0.0007	0.0005	0.7612	0.5068	33
Cropland	1,339.3	0.0060	0.0009	8.0147	1.1572	86
Developed	286.7	0.0003	0.0002	0.0999	0.0665	33
Streambanks	-	-	-	0.0112	0.0075	33
Total				8.8870	1.7380	80

**Table 32. Sediment and Phosphorus Load Allocations and Reductions for UNT 09944**

Pollutant Source	Acres	Unit Area Loading Rate (lbs/ac/day)		Pollutant Loading (lbs/day)		% Reduction
		Current	Allowable	Current	Allowable (LA)	
<b>Sediment</b>						
Hay/Pasture	795.7	0.1835	0.1447	146.0274	115.1211	21
Cropland	963.7	1.8026	1.4211	1,737.2055	1,369.5307	21
Developed	271.8	0.3268	0.2576	88.8220	70.0231	21
Streambanks	-	-	-	274.8945	216.7138	21
Total				2,246.9494	1,771.3887	21
<b>Phosphorus</b>						
Hay/Pasture	795.7	0.0006	0.0004	0.5128	0.3402	34
Cropland	963.7	0.0028	0.0008	2.7337	0.7961	71
Developed	271.8	0.0003	0.0002	0.0902	0.0598	34
Streambanks	-	-	-	0.0060	0.0040	34
Total				3.3427	1.2001	64

**Table 33. Sediment and Phosphorus Load Allocations and Reductions for UNT 09947**

Pollutant Source	Acres	Unit Area Loading Rate (lbs/ac/day)		Pollutant Loading (lbs/day)		% Reduction
		Current	Allowable	Current	Allowable (LA)	
<b>Sediment</b>						
Hay/Pasture	360.8	0.2150	0.1660	77.5890	59.8750	23
Cropland	491.7	4.1694	1.4752	2,050.0822	725.3680	65
Developed	170.5	0.3384	0.2611	57.6987	44.5258	23
Streambanks	-	-	-	142.8020	110.1995	23
Total				2,328.1719	939.9682	60
<b>Phosphorus</b>						
Hay/Pasture	360.8	0.0007	0.0005	0.2685	0.1806	33
Cropland	491.7	0.0043	0.0009	22.1134	0.4373	79
Developed	170.5	0.0000	0.0000	0.0447	0.0301	33
Streambanks	-	-	-	0.0032	0.0022	33
Total				2.4298	0.6502	73

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

## **CONSIDERATION OF SEASONAL VARIATIONS**

The continuous simulation model used for these analyses 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.

## **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 Little Swatara Creek Tributaries TMDL identifies the necessary overall load reductions for sediment and phosphorus 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 Best Management Practices (BMPs). BMPs that would be helpful in lowering the amounts of sediment and phosphorus reaching Little Swatara Creek include the following: streambank stabilization and fencing; riparian buffer strips; strip cropping; conservation tillage; stormwater retention wetlands; and heavy use area protection, among many others.

The Natural Resources Conservation Service maintains a *National Handbook of Conservation Practices* (NHCP), which provides information on a variety of BMPs. The NHCP is available online at [http://www.ncg.nrcs.usda.gov/nhcp\\_2.html](http://www.ncg.nrcs.usda.gov/nhcp_2.html). Many of the practices described in the handbook could be used in the Little Swatara Tributaries Subwatersheds to help limit sediment and phosphorus impairments. Determining the most appropriate BMPs, where they should be installed, and actually putting them into practice, will require the development and implementation of restoration plans. Development of any restoration plan will involve the gathering of site-specific information regarding current land uses and existing conservation practices. This type of assessment has been ongoing in the Little Swatara Tributaries Subwatersheds, and it is strongly encouraged to continue.

By developing a sediment and phosphorus TMDL for the Little Swatara Tributaries Subwatersheds, PADEP continues to support design and implementation of restoration plans to correct current use impairments. PADEP welcomes local efforts to support watershed restoration plans. For more information about this TMDL, interested parties should contact the appropriate watershed manager in PADEP's Northcentral Regional Office (570-327-3636).

## **PUBLIC PARTICIPATION**

A notice of availability for comments on the draft Little Swatara Creek Tributaries TMDL was published in the Pa. Bulletin on June 5, 2010, and *Republican Herald* newspaper on June 1, 2010, to foster public comment on the allowable loads calculated. A public meeting was held on June 16, 2010, at the Pine Grove Township building to discuss the proposed TMDL. The public participation process (which ended on July 5, 2010) was provided for the submittal of comments.

Comments and responses are summarized in Attachment J. There were no public comments received for this TMDL.

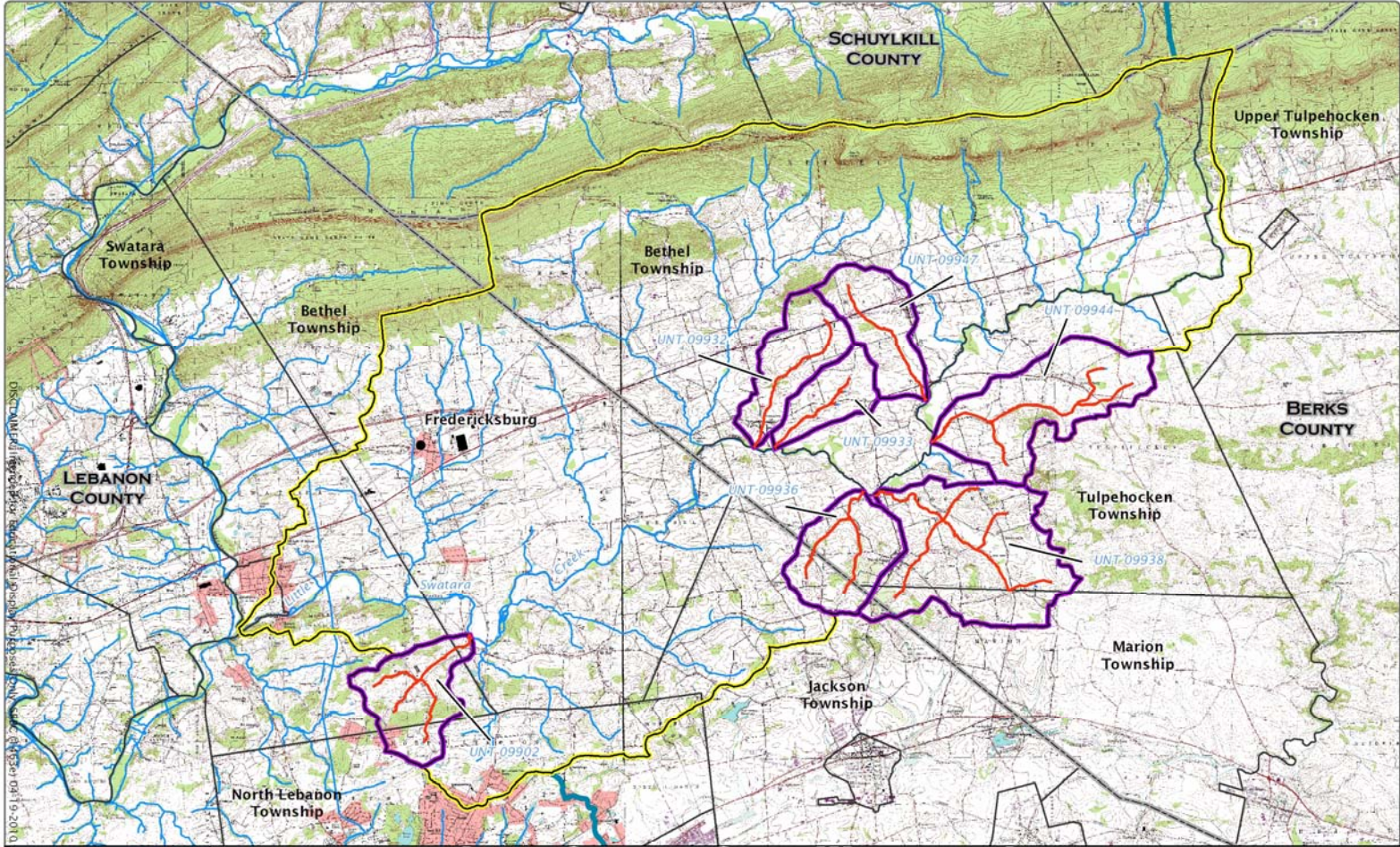
Notice of final TMDL approval will be posted on the PADEP's web site.

## REFERENCES

- Commonwealth of Pennsylvania. 2001. Pennsylvania Code. Title 25 Environmental Protection. Department of Environmental Protection. Chapter 93. Water Quality Standards. Harrisburg, Pa.
- Hem, J.D. 1983. Study and Interpretation of the Chemical Characteristics of Natural Water. U.S. Geological Survey Water Supply Paper 1473.
- Novotny, V. and H. Olem. 1994. Water Quality: Prevention, Identification, and Management of Diffuse Pollution. Van Nostrand Reinhold, N.Y.
- Thomann, R.V. and J.A. Mueller. 1987. Principles of Surface Water Quality Modeling and Control. Harper & Row, N.Y.

# **Attachment A**

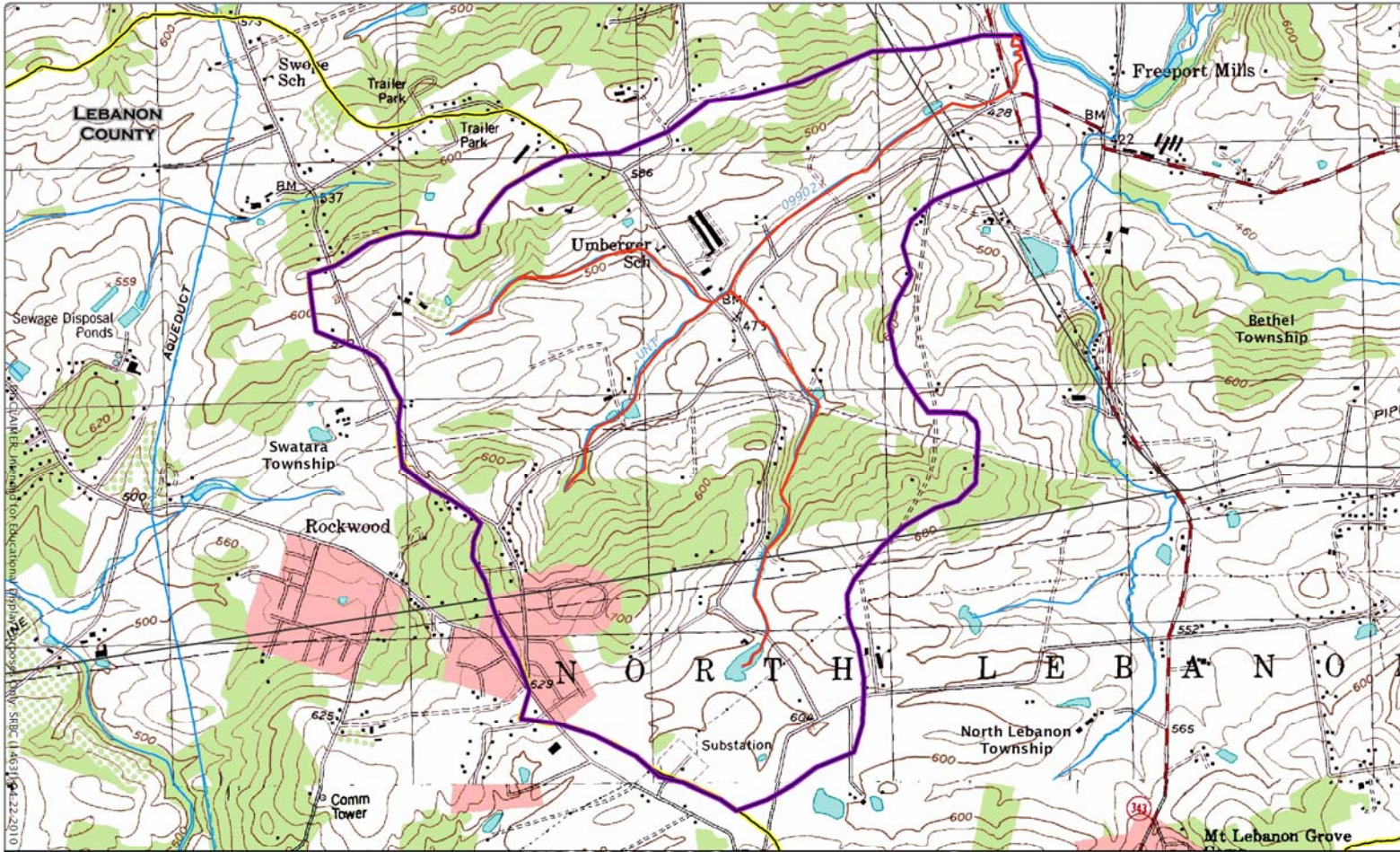
## **Little Swatara Creek Tributaries TMDL Impaired Waters**



**LITTLE SWATARA CREEK WATERSHED LOCATION**

● Major Towns	Impaired Waters	Little Swatara Creek Watershed
Township Boundary	Nonimpaired Waters	Lower Susquehanna Subbasin
County Boundary	TMDL Subwatersheds	Susquehanna River Basin

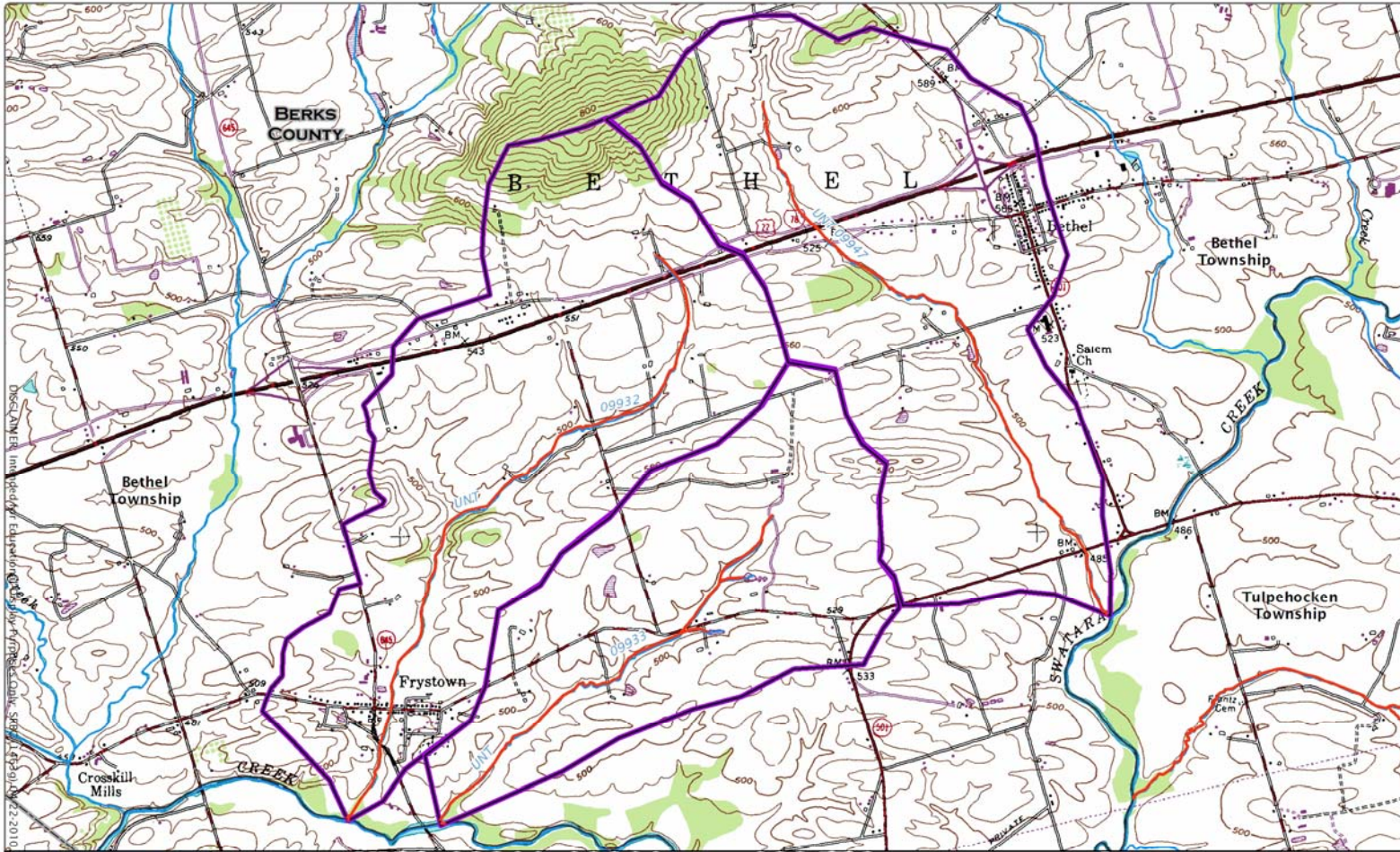
0 1 2 Miles



**UNT 09902 SUBWATERSHED LOCATION**

- Major Towns
- Township Boundary
- County Boundary
- Impaired Waters
- Nonimpaired Waters
- TMDL Subwatersheds
- Little Swatara Creek Watershed
- Lower Susquehanna Subbasin
- Susquehanna River Basin

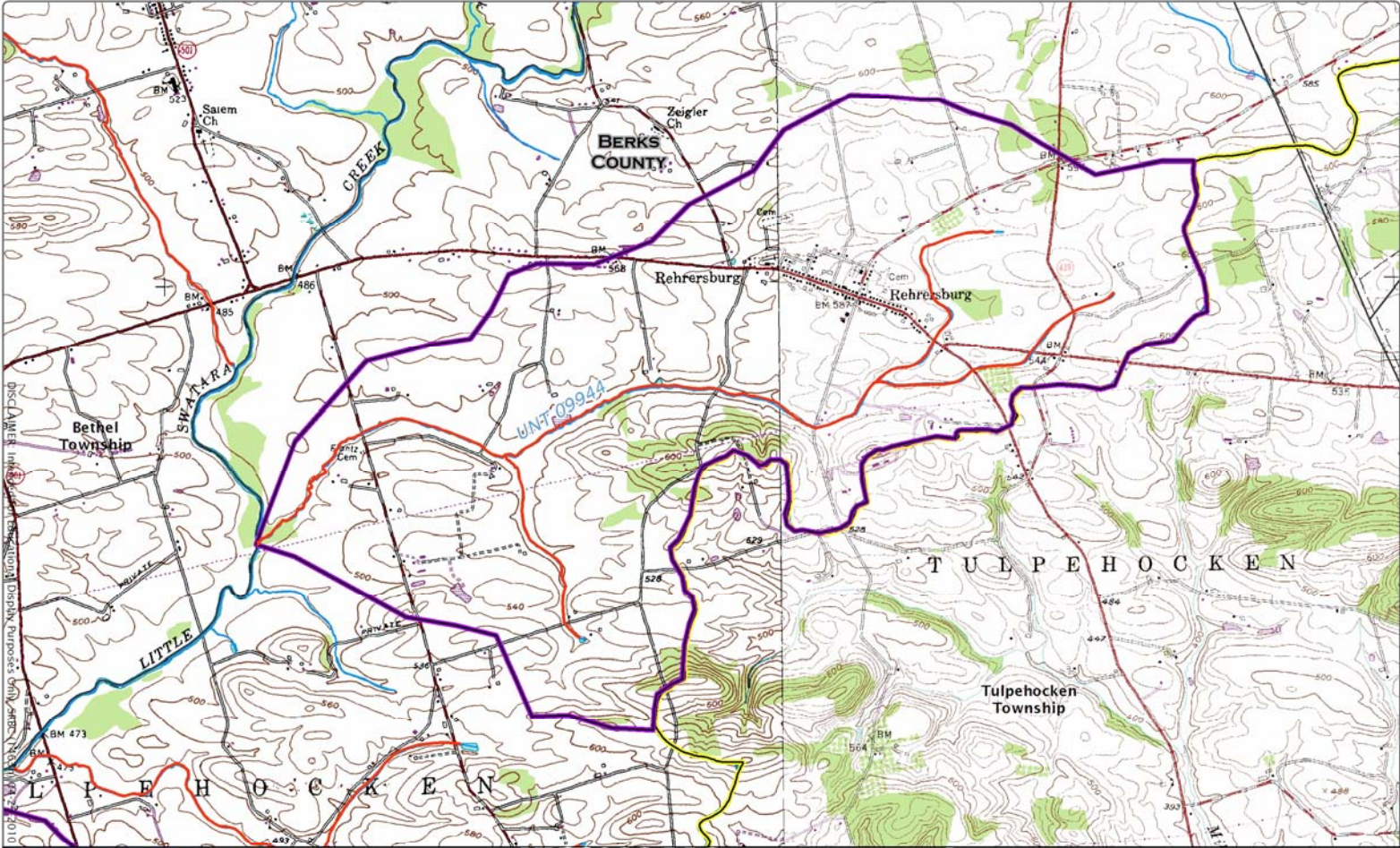




**UNTs 09932, 09933, AND 09947 SUBWATERSHED LOCATIONS**

- Major Towns
- Township Boundary
- County Boundary
- Impaired Waters
- Nonimpaired Waters
- TMDL Subwatersheds
- Little Swatara Creek Watershed
- Lower Susquehanna Subbasin
- Susquehanna River Basin

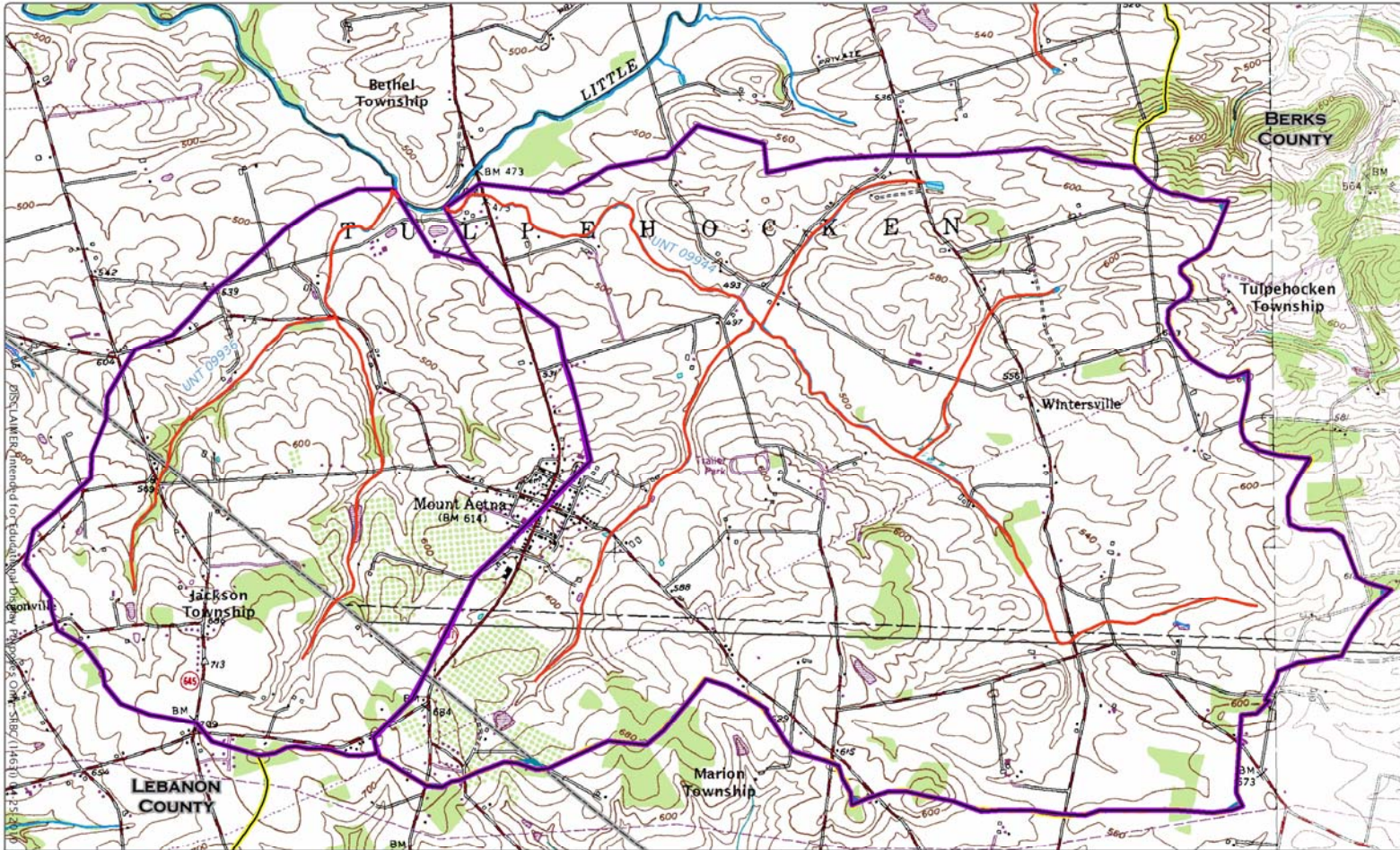




**UNT 09944 SUBWATERSHED LOCATION**

- Major Towns
- Township Boundary
- County Boundary
- Impaired Waters
- Nonimpaired Waters
- TMDL Subwatersheds
- Little Swatara Creek Watershed
- Lower Susquehanna Subbasin
- Susquehanna River Basin





**UNT's 09938 AND 09936 SUBWATERSHED LOCATIONS**

- Major Towns
  - ⚡ Impaired Waters
  - ⚡ Little Swatara Creek Watershed
  - ⚡ Nonimpaired Waters
  - ⚡ Lower Susquehanna Subbasin
  - ⚡ TMDL Subwatersheds
  - ⚡ Susquehanna River Basin
- ∩ Township Boundary  
 ∩ County Boundary
- 0 0.25 0.5 Miles N

# **Attachment B**

## **Information Sheet for the Little Swatara Tributaries TMDL**

***What is being proposed?***

Total Maximum Daily Load (TMDL) plans have been developed to improve water quality in the Little Swatara Tributaries TMDL.

***Who is proposing the plans? Why?***

The Pennsylvania Department of Environmental Protection (PADEP) 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. PADEP 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 waterbody. 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 Little Swatara Tributaries TMDL is impaired due to sediment and phosphorus emanating from agricultural runoff and other nonpoint sources. The plans include a calculation of the loading for sediment and phosphorus that will correct the problem and meet water quality objectives.

***Why was the Little Swatara Tributaries selected for TMDL development?***

In 2008, PADEP listed segments of the Little Swatara Tributaries TMDL under Section 303(d) of the federal Clean Water Act as impaired due to causes linked to sediment and phosphorus.

***What pollutants do these TMDLs address?***

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

***Where do the pollutants come from?***

The sediment and phosphorus related impairments in the Little Swatara Tributaries TMDL come from nonpoint sources of pollution, primarily overland runoff from developed areas and agricultural lands, as well as from streambank erosion.

***How was the TMDL developed?***

PADEP used a reference watershed approach to estimate the necessary loading reduction of sediment and phosphorus 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, PADEP 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 Pennsylvania nor USEPA has instream numerical water quality criteria for sediment and phosphorus.

***How much pollution is too much?***

The allowable amount of pollution in a waterbody 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 sediment and phosphorus, the TMDL is expressed as an annual loading. This accounts for pollution contributions over all streamflow conditions. PADEP established the water quality objectives for sediment and phosphorus 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 sediment and phosphorus 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 William Brown at (717) 783-2938 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 [wbrown@state.pa.us](mailto:wbrown@state.pa.us).

***How can I comment on the proposal?***

You may provide e-mail or written comments postmarked no later than July 5, 2010 to the above address.

# **Attachment C**

## **Comparison between Impaired Segments and Mill Creek**

**Table C1. Comparison between UNT 09902 and Mill Creek Watersheds**

Attribute	Watershed	
	UNT 09902	Mill Creek
<b>Physiographic Province</b>	Appalachian Mountain Section: Ridge and Valley (100%)	Great Valley Section: Ridge and Valley (100%)
<b>Area (mi<sup>2</sup>)</b>	2.09	3.03
<b>Land Use</b>	Agriculture (51.57%) Development (7.95%) Forested (40.48%)	Agriculture (29.73%) Development (6.10%) Forested (64.17%)
<b>Geology</b>	Hamburg Sequence (30%) Hamburg Seq.-Graywacke (40%) Jonestown Volcanic Suite (15%) Hamburg Seq.-Graywacke (15%)	Hamburg Seq.-Shale with Graywacke (80%) Shawahgunk Formation (20%)
<b>Soils</b>	Berks-Weikert-Bedington (100%)	Berks-Weikert-Bedington (70%) Hazleton-Dekalb-Buchanan (30%)
<b>Dominant HSG</b>	Berks-Weikert-Bedington A (0%) B (13%) C (52%) D (35%)	Berks-Weikert-Bedington A (0%) B (13%) C (52%) D (35%)  Hazleton-Dekalb-Buchanan A (2%) B (45%) C (53%) D (0%)
<b>K Factor</b>	Berks-Weikert-Bedington (0.24)	Berks-Weikert-Bedington (0.24) Hazleton-Dekalb-Buchanan (0.18)
<b>20-Yr. Ave. Rainfall (in)</b>	46.5	48.5
<b>20-Yr. Ave. Runoff (in)</b>	0.27	0.25

**Table C2. Comparison between UNT 09932 and Mill Creek Watersheds**

Attribute	Watershed	
	UNT 09932	Mill Creek
<b>Physiographic Province</b>	Great Valley Section: Ridge and Valley (100%)	Great Valley Section: Ridge and Valley (100%)
<b>Area (mi<sup>2</sup>)</b>	1.92	3.03
<b>Land Use</b>	Agriculture (65.40%) Development (14.89%) Forested (19.72%)	Agriculture (29.73%) Development (6.10%) Forested (64.17%)
<b>Geology</b>	Hamburg Sequence (40%) Hamburg Seq.-Shale with Graywacke (60%)	Hamburg Seq.-Shale with Graywacke (80%) Shawahgunk Formation (20%)
<b>Soils</b>	Berks-Weikert-Bedington (100%)	Berks-Weikert-Bedington (70%) Hazleton-Dekalb-Buchanan (30%)
<b>Dominant HSG</b>	Berks-Weikert-Bedington A (0%) B (13%) C (52%) D (35%)	Berks-Weikert-Bedington A (0%) B (13%) C (52%) D (35%)  Hazleton-Dekalb-Buchanan A (2%) B (45%) C (53%) D (0%)
<b>K Factor</b>	Berks-Weikert-Bedington (0.24)	Berks-Weikert-Bedington (0.24) Hazleton-Dekalb-Buchanan (0.18)
<b>20-Yr. Ave. Rainfall (in)</b>	46.5	48.5
<b>20-Yr. Ave. Runoff (in)</b>	0.32	0.25

**Table C3. Comparison between UNT09933 and Mill Creek Watersheds**

Attribute	Watershed	
	UNT 09933	Mill Creek
<b>Physiographic Province</b>	Great Valley Section: Ridge and Valley (100%)	Great Valley Section: Ridge and Valley (100%)
<b>Area (mi<sup>2</sup>)</b>	1.21	3.03
<b>Land Use</b>	Agriculture (77.65%) Development (8.62%) Forested (13.73%)	Agriculture (29.73%) Development (6.10%) Forested (64.17%)
<b>Geology</b>	Hamburg Sequence (80%) Hamburg Seq.-Shale with Graywacke (20%)	Hamburg Seq.-Shale with Graywacke (80%) Shawahgunk Formation (20%)
<b>Soils</b>	Berks-Weikert-Bedington (80-100%)	Berks-Weikert-Bedington (70%) Hazleton-Dekalb-Buchanan (30%)
<b>Dominant HSG</b>	Berks-Weikert-Bedington A (0%) B (13%) C (52%) D (35%)	Berks-Weikert-Bedington A (0%) B (13%) C (52%) D (35%)  Hazleton-Dekalb-Buchanan A (2%) B (45%) C (53%) D (0%)
<b>K Factor</b>	Berks-Weikert-Bedington (0.24)	Berks-Weikert-Bedington (0.24) Hazleton-Dekalb-Buchanan (0.18)
<b>20-Yr. Ave. Rainfall (in)</b>	46.5	48.5
<b>20-Yr. Ave. Runoff (in)</b>	0.31	0.25

**Table C4. Comparison between UNT 09936 and Mill Creek Watersheds**

Attribute	Watershed	
	UNT 09936	Mill Creek
<b>Physiographic Province</b>	Great Valley Section: Ridge and Valley (100%)	Great Valley Section: Ridge and Valley (100%)
<b>Area (mi<sup>2</sup>)</b>	2.23	3.03
<b>Land Use</b>	Agriculture (64.02%) Development (19.20%) Forested (16.79%)	Agriculture (29.73%) Development (6.10%) Forested (64.17%)
<b>Geology</b>	Hamburg Sequence (90%) Hamburg Seq.-Shale and Limestone (10%)	Hamburg Seq.-Shale with Graywacke (80%) Shawahgunk Formation (20%)
<b>Soils</b>	Berks-Weikert-Bedington (80-100%)	Berks-Weikert-Bedington (70%) Hazleton-Dekalb-Buchanan (30%)
<b>Dominant HSG</b>	Berks-Weikert-Bedington A (0%) B (13%) C (52%) D (35%)	Berks-Weikert-Bedington A (0%) B (13%) C (52%) D (35%)  Hazleton-Dekalb-Buchanan A (2%) B (45%) C (53%) D (0%)
<b>K Factor</b>	Berks-Weikert-Bedington (0.24)	Berks-Weikert-Bedington (0.24) Hazleton-Dekalb-Buchanan (0.18)
<b>20-Yr. Ave. Rainfall (in)</b>	46.5	48.5
<b>20-Yr. Ave. Runoff (in)</b>	0.32	0.25

**Table C5. Comparison between UNT 09938 and Mill Creek Watersheds**

Attribute	Watershed	
	UNT 09938	Mill Creek
<b>Physiographic Province</b>	Great Valley Section: Ridge and Valley (100%)	Great Valley Section: Ridge and Valley (100%)
<b>Area (mi<sup>2</sup>)</b>	5.20	3.03
<b>Land Use</b>	Agriculture (74.02%) Development (8.62%) Forested (17.37%)	Agriculture (29.73%) Development (6.10%) Forested (64.17%)
<b>Geology</b>	Hamburg Sequence (85%) Hershey and Myerstown Formation Undivided (10%) Hamburg Seq.-Shale and Limestone (5%)	Hamburg Seq.-Shale with Graywacke (80%) Shawahgunk Formation (20%)
<b>Soils</b>	Berks-Weikert-Bedington (80%) Ryder-Clarksburg-Berks (20%)	Berks-Weikert-Bedington (70%) Hazleton-Dekalb-Buchanan (30%)
<b>Dominant HSG</b>	<p>Berks-Weikert-Bedington A (0%) B (13%) C (52%) D (35%)</p> <p>Ryder-Clarksburg-Berks A (0%) B (16%) C (76%) D (8%)</p>	<p>Berks-Weikert-Bedington A (0%) B (13%) C (52%) D (35%)</p> <p>Hazleton-Dekalb-Buchanan A (2%) B (45%) C (53%) D (0%)</p>
<b>K Factor</b>	Berks-Weikert-Bedington (0.24) Ryder-Clarksburg-Berks (0.31)	Berks-Weikert-Bedington (0.24) Hazleton-Dekalb-Buchanan (0.18)
<b>20-Yr. Ave. Rainfall (in)</b>	46.5	48.5
<b>20-Yr. Ave. Runoff (in)</b>	0.32	0.25

**Table C6. Comparison between UNT 09944 and Mill Creek Watersheds**

Attribute	Watershed	
	UNT 09944	Mill Creek
<b>Physiographic Province</b>	Great Valley Section: Ridge and Valley (100%)	Great Valley Section: Ridge and Valley (100%)
<b>Area (mi<sup>2</sup>)</b>	3.64	3.03
<b>Land Use</b>	Agriculture (75.58%) Development (11.68%) Forested (12.74%)	Agriculture (29.73%) Development (6.10%) Forested (64.17%)
<b>Geology</b>	Hamburg Sequence (55%) Hamburg Seq.-Shale with Graywacke (40%) Hamburg Seq.-Shale and Limestone (5%)	Hamburg Seq.-Shale with Graywacke (80%) Shawahgunk Formation (20%)
<b>Soils</b>	Berks-Weikert-Bedington (100%)	Berks-Weikert-Bedington (70%) Hazleton-Dekalb-Buchanan (30%)
<b>Dominant HSG</b>	Berks-Weikert-Bedington A (0%) B (13%) C (52%) D (35%)	Berks-Weikert-Bedington A (0%) B (13%) C (52%) D (35%)  Hazleton-Dekalb-Buchanan A (2%) B (45%) C (53%) D (0%)
<b>K Factor</b>	Berks-Weikert-Bedington (0.24)	Berks-Weikert-Bedington (0.24) Hazleton-Dekalb-Buchanan (0.18)
<b>20-Yr. Ave. Rainfall (in)</b>	48.5	48.5
<b>20-Yr. Ave. Runoff (in)</b>	0.33	0.25

**Table C7. Comparison between UNT 09947 and Mill Creek Watersheds**

Attribute	Watershed	
	UNT 09947	Mill Creek
<b>Physiographic Province</b>	Great Valley Section: Ridge and Valley (100%)	Great Valley Section: Ridge and Valley (100%)
<b>Area (mi<sup>2</sup>)</b>	1.93	3.03
<b>Land Use</b>	Agriculture (69.00%) Development (13.80%) Forested (17.20%)	Agriculture (29.73%) Development (6.10%) Forested (64.17%)
<b>Geology</b>	Hamburg Sequence (20%) Hamburg Seq.-Shale with Graywacke (80%)	Hamburg Seq.-Shale with Graywacke (80%) Shawahgunk Formation (20%)
<b>Soils</b>	Berks-Weikert-Bedington (100%)	Berks-Weikert-Bedington (70%) Hazleton-Dekalb-Buchanan (30%)
<b>Dominant HSG</b>	Berks-Weikert-Bedington A (0%) B (13%) C (52%) D (35%)	Berks-Weikert-Bedington A (0%) B (13%) C (52%) D (35%)  Hazleton-Dekalb-Buchanan A (2%) B (45%) C (53%) D (0%)
<b>K Factor</b>	Berks-Weikert-Bedington (0.24)	Berks-Weikert-Bedington (0.24) Hazleton-Dekalb-Buchanan (0.18)
<b>20-Yr. Ave. Rainfall (in)</b>	48.5	48.5
<b>20-Yr. Ave. Runoff (in)</b>	0.33	0.25

# **Attachment D**

## **AVGWLF Model Overview & GIS-Based Derivation of Input Data**

The TMDL for the Little Swatara Tributaries Subwatersheds 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 the 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 values 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 Manual.

For execution, the model requires three separate input files containing transport-, nutrient-, and weather-related data. The transport (TRANSPRT.DAT) file defines the necessary parameters for each source area to be considered (e.g., area size, curve number, etc.), as well as global parameters (e.g., initial storage, sediment delivery ratio, etc.) that apply to all source areas. The

nutrient (NUTRIENT.DAT) file specifies the various loading parameters for the different source areas identified (e.g., number of septic systems, urban source area accumulation rates, manure concentrations, etc.). The weather (WEATHER.DAT) file contains daily average temperature and total precipitation values for each year simulated.

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.

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

# **Attachment E**

## **AVGWLF Model Inputs for the Little Swatara Tributaries**

## UNT 09902 Nutrient Input File

Runoff Coefficients by Source			Nitrogen and Phosphorus Loads from Point Sources and Septic Systems								
Rural Runoff	Dis N mg/L	Dis P mg/L	Point Source Loads/Discharge			Septic System Populations					
Hay/Past	4.35	0.13	Month	Kg N	Kg P	Discharge MGD	Normal Systems	Pond Systems	Short Cir Systems	Discharge Systems	
Cropland	4.35	0.13	Jan	0.0	0.0	0.0	112	0	2	0	
Forest	0.19	0.006	Feb	0.0	0.0	0.0	112	0	2	0	
Wetland	0.19	0.006	Mar	0.0	0.0	0.0	112	0	2	0	
Transition	2.9	0.2	Apr	0.0	0.0	0.0	112	0	2	0	
	0	0	May	0.0	0.0	0.0	112	0	2	0	
	0	0	Jun	0.0	0.0	0.0	112	0	2	0	
	0	0	Jul	0.0	0.0	0.0	112	0	2	0	
	0	0	Aug	0.0	0.0	0.0	112	0	2	0	
Manure	3.66	0.57	Sep	0.0	0.0	0.0	112	0	2	0	
Urban Build-Up	N Kg/ha/d	P Kg/ha/d	Oct	0.0	0.0	0.0	112	0	2	0	
Lo_Int_Dev	0.012	0.002	Nov	0.0	0.0	0.0	112	0	2	0	
Hi_Int_Dev	0.101	0.011	Dec	0.0	0.0	0.0	112	0	2	0	
Groundwater (mg/L)			Tile Drainage (mg/L)			Per capita tank effluent		Growing season N/P uptake		Sediment	
N (mg/L)	P (mg/L)		N	P	Sed	N (g/d)	P (g/d)	N (g/d)	P (g/d)	N (mg/Kg)	P (mg/Kg)
2.112	0.026		15	0.1	50	12	2.5	1.6	0.4	3000.0	1180.0

## UNT 09902 Transport Input File

Rural LU							Month	Ket	Day Hours	Season	Eros Coef	Stream Extract	Ground Extract
Area (ha)	CN	K	LS	C	P								
Hay/Past	157	75	0.24	0.507	0.03	0.45	Jan	0.66	9.4	0	0.12	0	0
Cropland	122	82	0.24	0.613	0.42	0.45	Feb	0.71	10.4	0	0.12	0	0
Forest	212	73	0.24	0.951	0.002	0.45	Mar	0.74	11.8	0	0.12	0	0
Wetland	7	87	0.24	0.11	0.01	0.1	Apr	0.92	13.2	1	0.3	0	0
	0	0	0	0	0	0	May	1.02	14.3	1	0.3	0	0
	0	0	0	0	0	0	Jun	1.08	14.9	1	0.3	0	0
	0	0	0	0	0	0	Jul	1.11	14.6	1	0.3	0	0
	0	0	0	0	0	0	Aug	1.13	13.6	1	0.3	0	0
	0	0	0	0	0	0	Sep	1.14	12.2	1	0.3	0	0
	0	0	0	0	0	0	Oct	1.15	10.8	1	0.12	0	0
	0	0	0	0	0	0	Nov	1.0	9.7	0	0.12	0	0
	0	0	0	0	0	0	Dec	0.91	9.1	0	0.12	0	0
Bare Land													
Area (ha)	CN	K	LS	C	P								
Transition	4	87	0.24	0.201	0.8	0.8							
Urban LU													
Area (ha)	CN	K	LS	C	P								
Lo_Int_Dev	37	83	0.24	0.68	0.08	0.2							
Hi_Int_Dev	2	93	0.24	0.152	0.08	0.2							
Init Unsat Stor (cm)							Initial Snow (cm)		Recess Coefficient				
Init Sat Stor (cm)							Sed Delivery Ratio		Seepage Coefficient				
Unsat Avail Wat (cm)							Tile Drain Ratio		Sediment A Factor				
							Tile Drain Density		Sed A Adjustment Factor				
10							0		0.1				
0							0.191		0				
9.301							0.5		1.0031E-03				
							0		1				

## UNT 09932 Nutrient Input File

Runoff Coefficients by Source			Nitrogen and Phosphorus Loads from Point Sources and Septic Systems							
Rural Runoff	Dis N mg/L	Dis P mg/L	Point Source Loads/Discharge			Septic System Populations				
Hay/Past	4.35	0.115	Month	Kg N	Kg P	Discharge MGD	Normal Systems	Pond Systems	Short Cir Systems	Discharge Systems
Cropland	4.35	0.115	Jan	0.0	0.0	0.0	56	0	1	0
Forest	0.19	0.006	Feb	0.0	0.0	0.0	56	0	1	0
Wetland	0.19	0.006	Mar	0.0	0.0	0.0	56	0	1	0
Transition	2.9	0.2	Apr	0.0	0.0	0.0	56	0	1	0
	0	0	May	0.0	0.0	0.0	56	0	1	0
	0	0	Jun	0.0	0.0	0.0	56	0	1	0
	0	0	Jul	0.0	0.0	0.0	56	0	1	0
	0	0	Aug	0.0	0.0	0.0	56	0	1	0
	0	0	Sep	0.0	0.0	0.0	56	0	1	0
Manure	3.66	0.57	Oct	0.0	0.0	0.0	56	0	1	0
Urban Build-Up	N Kg/ha/d	P Kg/ha/d	Nov	0.0	0.0	0.0	56	0	1	0
Lo_Int_Dev	0.012	0.002	Dec	0.0	0.0	0.0	56	0	1	0
	0	0								
Groundwater (mg/L)		Tile Drainage (mg/L)		Per capita tank effluent		Growing season N/P uptake		Sediment		
N (mg/L)	P (mg/L)	N	P	Sed	N (g/d)	P (g/d)	N (g/d)	P (g/d)	N (mg/Kg)	P (mg/Kg)
2.816	0.03	15	0.1	50	12	2.5	1.6	0.4	3000.0	844.0

## UNT 09932 Transport Input File

Rural LU	Area (ha)	CN	K	LS	C	P	Month	Ket	Day Hours	Season	Eros Coef	Stream Extract	Ground Extract
Hay/Past	138	75	0.24	0.384	0.03	0.52	Jan	0.64	9.4	0	0.12	0	0
Cropland	187	82	0.24	0.631	0.42	0.52	Feb	0.69	10.4	0	0.12	0	0
Forest	92	73	0.24	0.567	0.002	0.45	Mar	0.72	11.8	0	0.12	0	0
Wetland	6	87	0.24	0.104	0.01	0.1	Apr	0.91	13.2	1	0.3	0	0
	0	0	0	0	0	0	May	1.01	14.4	1	0.3	0	0
	0	0	0	0	0	0	Jun	1.08	14.9	1	0.3	0	0
	0	0	0	0	0	0	Jul	1.11	14.6	1	0.3	0	0
	0	0	0	0	0	0	Aug	1.13	13.6	1	0.3	0	0
	0	0	0	0	0	0	Sep	1.15	12.2	1	0.3	0	0
	0	0	0	0	0	0	Oct	1.15	10.8	1	0.12	0	0
	0	0	0	0	0	0	Nov	0.99	9.6	0	0.12	0	0
	0	0	0	0	0	0	Dec	0.89	9.1	0	0.12	0	0
<b>Bare Land</b>	<b>Area (ha)</b>	<b>CN</b>	<b>K</b>	<b>LS</b>	<b>C</b>	<b>P</b>							
Transition	2	87	0.24	0.185	0.8	0.8							
<b>Urban LU</b>	<b>Area (ha)</b>	<b>CN</b>	<b>K</b>	<b>LS</b>	<b>C</b>	<b>P</b>							
Lo_Int_Dev	72	83	0.24	0.393	0.08	0.2							
	0	0	0	0	0	0							
Init Unsat Stor (cm)	10	Initial Snow (cm)	0	Recess Coefficient	0.1								
Init Sat Stor (cm)	0	Sed Delivery Ratio	0.191	Seepage Coefficient	0								
Unsat Avail Wat (cm)	9.301	Tile Drain Ratio	0.5	Sediment A Factor	1.3674E-03								
		Tile Drain Density	0	Sed A Adjustment Factor	1								

## UNT 09933 Nutrient Input File

Runoff Coefficients by Source			Nitrogen and Phosphorus Loads from Point Sources and Septic Systems								
Rural Runoff	Dis N mg/L	Dis P mg/L	Point Source Loads/Discharge			Septic System Populations					
Hay/Past	4.35	0.11	Month	Kg N	Kg P	Discharge MGD	Normal Systems	Pond Systems	Short Cir Systems	Discharge Systems	
Cropland	4.35	0.11	Jan	0.0	0.0	0.0	36	0	1	0	
Forest	0.19	0.006	Feb	0.0	0.0	0.0	36	0	1	0	
Wetland	0.19	0.006	Mar	0.0	0.0	0.0	36	0	1	0	
Transition	2.9	0.2	Apr	0.0	0.0	0.0	36	0	1	0	
	0	0	May	0.0	0.0	0.0	36	0	1	0	
	0	0	Jun	0.0	0.0	0.0	36	0	1	0	
	0	0	Jul	0.0	0.0	0.0	36	0	1	0	
	0	0	Aug	0.0	0.0	0.0	36	0	1	0	
	0	0	Sep	0.0	0.0	0.0	36	0	1	0	
Manure	3.66	0.57	Oct	0.0	0.0	0.0	36	0	1	0	
Urban Build-Up	N Kg/ha/d	P Kg/ha/d	Nov	0.0	0.0	0.0	36	0	1	0	
Lo_Int_Dev	0.012	0.002	Dec	0.0	0.0	0.0	36	0	1	0	
Hi_Int_Dev	0.101	0.011									
Groundwater (mg/L)			Tile Drainage (mg/L)			Per capita tank effluent		Growing season N/P uptake		Sediment	
N (mg/L)	P (mg/L)		N	P	Sed	N (g/d)	P (g/d)	N (g/d)	P (g/d)	N (mg/Kg)	P (mg/Kg)
3.109	0.032		15	0.1	50	12	2.5	1.6	0.4	3000.0	717.0

## UNT 09933 Transport Input File

Rural LU							Month						
Hay/Past	Area (ha)	CN	K	LS	C	P	Month	Ket	Day Hours	Season	Eros Coef	Stream Extract	Ground Extract
	128	75	0.24	0.133	0.03	0.52	Jan	0.67	9.4	0	0.12	0	0
Cropland	115	82	0.24	0.172	0.42	0.52	Feb	0.72	10.4	0	0.12	0	0
Forest	41	73	0.24	0.098	0.002	0.52	Mar	0.75	11.8	0	0.12	0	0
Wetland	2	87	0.24	0.072	0.01	0.1	Apr	0.94	13.2	1	0.3	0	0
	0	0	0	0	0	0	May	1.05	14.4	1	0.3	0	0
	0	0	0	0	0	0	Jun	1.12	14.9	1	0.3	0	0
	0	0	0	0	0	0	Jul	1.15	14.6	1	0.3	0	0
	0	0	0	0	0	0	Aug	1.17	13.6	1	0.3	0	0
	0	0	0	0	0	0	Sep	1.19	12.2	1	0.3	0	0
	0	0	0	0	0	0	Oct	1.19	10.8	1	0.12	0	0
	0	0	0	0	0	0	Nov	1.03	9.6	0	0.12	0	0
	0	0	0	0	0	0	Dec	0.93	9.1	0	0.12	0	0

Init Unsat Stor (cm)	10	Initial Snow (cm)	0	Recess Coefficient	0.1
Init Sat Stor (cm)	0	Sed Delivery Ratio	0.194	Seepage Coefficient	0
Unsat Avail Wat (cm)	9.301	Tile Drain Ratio	0.5	Sediment A Factor	1.0666E-03
		Tile Drain Density	0	Sed A Adjustment Factor	1

# UNT 09936 Nutrient Input File

Runoff Coefficients by Source			Nitrogen and Phosphorus Loads from Point Sources and Septic Systems									
Rural Runoff	Dis N mg/L	Dis P mg/L	Point Source Loads/Discharge			Septic System Populations						
			Month	Kg N	Kg P	Discharge MGD	Normal Systems	Pond Systems	Short Cir Systems	Discharge		
Hay/Past	4.35	0.121	Jan	0.0	0.0	0.0	84	0	2	0		
Cropland	4.35	0.121	Feb	0.0	0.0	0.0	84	0	2	0		
Forest	0.19	0.006	Mar	0.0	0.0	0.0	84	0	2	0		
Wetland	0.19	0.006	Apr	0.0	0.0	0.0	84	0	2	0		
Transition	2.9	0.2	May	0.0	0.0	0.0	84	0	2	0		
	0	0	Jun	0.0	0.0	0.0	84	0	2	0		
	0	0	Jul	0.0	0.0	0.0	84	0	2	0		
	0	0	Aug	0.0	0.0	0.0	84	0	2	0		
	0	0	Sep	0.0	0.0	0.0	84	0	2	0		
Manure	3.66	0.57	Oct	0.0	0.0	0.0	84	0	2	0		
Urban Build-Up	N Kg/ha/d	P Kg/ha/d	Nov	0.0	0.0	0.0	84	0	2	0		
Lo_Int_Dev	0.012	0.002	Dec	0.0	0.0	0.0	84	0	2	0		
Hi_Int_Dev	0.101	0.011										

Groundwater (mg/L)		Tile Drainage (mg/L)			Per capita tank effluent		Growing season N/P uptake		Sediment	
N (mg/L)	P (mg/L)	N	P	Sed	N (g/d)	P (g/d)	N (g/d)	P (g/d)	N (mg/Kg)	P (mg/Kg)
3.008	0.032	15	0.1	50	12	2.5	1.6	0.4	3000.0	977.0

# UNT 09936 Transport Input File

Rural LU							Month	Ket	Day Hours	Season	Eros Coef	Stream Extract	Ground Extract
Area (ha)	CN	K	LS	C	P								
Hay/Past	192	75	0.24	0.416	0.03	0.52	Jan	0.68	9.4	0	0.12	0	0
Cropland	178	82	0.24	0.57	0.42	0.52	Feb	0.73	10.4	0	0.12	0	0
Forest	96	73	0.24	0.446	0.002	0.45	Mar	0.76	11.8	0	0.12	0	0
Wetland	1	87	0.24	0.179	0.01	0.1	Apr	0.93	13.2	1	0.3	0	0
	0	0	0	0	0	0	May	1.03	14.4	1	0.3	0	0
	0	0	0	0	0	0	Jun	1.09	14.9	1	0.3	0	0
	0	0	0	0	0	0	Jul	1.12	14.6	1	0.3	0	0
	0	0	0	0	0	0	Aug	1.14	13.6	1	0.3	0	0
	0	0	0	0	0	0	Sep	1.15	12.2	1	0.3	0	0
	0	0	0	0	0	0	Oct	1.16	10.8	1	0.12	0	0
	0	0	0	0	0	0	Nov	1.01	9.6	0	0.12	0	0
	0	0	0	0	0	0	Dec	0.93	9.1	0	0.12	0	0

Bare Land		Urban LU						
Area (ha)	CN	Area (ha)	CN	K	LS	C	P	
0	0	Lo_Int_Dev	109	83	0.24	0.517	0.08	0.2
0	0		0	0	0	0	0	

Init Unsat Stor (cm)	10	Initial Snow (cm)	0	Recess Coefficient	0.1
Init Sat Stor (cm)	0	Sed Delivery Ratio	0.19	Seepage Coefficient	0
Unsat Avail Wat (cm)	9.301	Tile Drain Ratio	0.5	Sediment A Factor	1.5664E-03
		Tile Drain Density	0	Sed A Adjustment Factor	1

## UNT 09938 Nutrient Input File

Runoff Coefficients by Source			Nitrogen and Phosphorus Loads from Point Sources and Septic Systems										
Rural Runoff	Dis N mg/L	Dis P mg/L	Point Source Loads/Discharge			Septic System Populations							
Hay/Past	2.9	0.123	Month	Kg N	Kg P	Discharge MGD	Normal Systems	Pond Systems	Short Cir Systems	Discharge Systems			
Cropland	2.9	0.123	Jan	0.0	0.0	0.0	173	0	3	0			
Forest	0.19	0.006	Feb	0.0	0.0	0.0	173	0	3	0			
Wetland	0.19	0.006	Mar	0.0	0.0	0.0	173	0	3	0			
Turf_Grass	2.5	0.342	Apr	0.0	0.0	0.0	173	0	3	0			
Transition	2.9	0.2	May	0.0	0.0	0.0	173	0	3	0			
	0	0	Jun	0.0	0.0	0.0	173	0	3	0			
	0	0	Jul	0.0	0.0	0.0	173	0	3	0			
	0	0	Aug	0.0	0.0	0.0	173	0	3	0			
Manure	2.44	0.38	Sep	0.0	0.0	0.0	173	0	3	0			
Urban Build-Up	N Kg/ha/d	P Kg/ha/d	Oct	0.0	0.0	0.0	173	0	3	0			
Lo_Int_Dev	0.012	0.002	Nov	0.0	0.0	0.0	173	0	3	0			
Hi_Int_Dev	0.101	0.011	Dec	0.0	0.0	0.0	173	0	3	0			
Groundwater (mg/L)			Tile Drainage (mg/L)			Per capita tank effluent		Growing season N/P uptake		Sediment			
N (mg/L)	P (mg/L)		N	P	Sed	N (g/d)	P (g/d)	N (g/d)	P (g/d)	N (mg/Kg)	P (mg/Kg)		
2.95	0.031		15	0.1	50	12	2.5	1.6	0.4	3000.0	1035.0		

## UNT 09938 Transport Input File

Rural LU							Month	Ket	Day Hours	Season	Eros Coef	Stream Extract	Ground Extract
Area (ha)	CN	K	LS	C	P								
Hay/Past	455	75	0.255	0.451	0.03	0.52	Jan	0.64	9.4	0	0.12	0	0
Cropland	542	82	0.262	0.655	0.42	0.52	Feb	0.69	10.4	0	0.12	0	0
Forest	214	73	0.254	0.294	0.002	0.52	Mar	0.72	11.8	0	0.12	0	0
Wetland	20	87	0.244	0.188	0.01	0.1	Apr	0.91	13.2	1	0.3	0	0
Turf_Grass	1	71	0.24	0.368	0.08	0.2	May	1.03	14.4	1	0.3	0	0
	0	0	0	0	0	0	Jun	1.09	14.9	1	0.3	0	0
	0	0	0	0	0	0	Jul	1.13	14.6	1	0.3	0	0
	0	0	0	0	0	0	Aug	1.15	13.6	1	0.3	0	0
	0	0	0	0	0	0	Sep	1.17	12.2	1	0.3	0	0
	0	0	0	0	0	0	Oct	1.17	10.8	1	0.12	0	0
	0	0	0	0	0	0	Nov	1.0	9.6	0	0.12	0	0
	0	0	0	0	0	0	Dec	0.9	9.1	0	0.12	0	0
	0	0	0	0	0	0							
Bare Land													
Area (ha)	CN	K	LS	C	P								
Transition	4	87	0.252	0.199	0.8	0.8							
Urban LU													
Area (ha)	CN	K	LS	C	P								
Lo_Int_Dev	111	83	0.25	0.527	0.08	0.2							
	0	0	0	0	0	0							
Init Unsat Stor (cm)			Initial Snow (cm)			Recess Coefficient							
10			0			0.1							
Init Sat Stor (cm)			Sed Delivery Ratio			Seepage Coefficient							
0			0.18			0							
Unsat Avail Wat (cm)			Tile Drain Ratio			Sediment A Factor							
11.0073			0.5			9.1692E-04							
			Tile Drain Density			Sed A Adjustment Factor							
			0			1							

# UNT 09944 Nutrient Input File

Runoff Coefficients by Source			Nitrogen and Phosphorus Loads from Point Sources and Septic Systems							
Rural Runoff	Dis N mg/L	Dis P mg/L	Point Source Loads/Discharge			Septic System Populations				
Hay/Past	2.9	0.129	Month	Kg N	Kg P	Discharge MGD	Normal Systems	Pond Systems	Short Cir Systems	Discharge Systems
Cropland	2.9	0.129	Jan	0.0	0.0	0.0	0	0	0	0
Forest	0.19	0.006	Feb	0.0	0.0	0.0	0	0	0	0
Wetland	0.19	0.006	Mar	0.0	0.0	0.0	0	0	0	0
Transition	2.9	0.2	Apr	0.0	0.0	0.0	0	0	0	0
Transition	2.9	0.2	May	0.0	0.0	0.0	0	0	0	0
	0	0	Jun	0.0	0.0	0.0	0	0	0	0
	0	0	Jul	0.0	0.0	0.0	0	0	0	0
	0	0	Aug	0.0	0.0	0.0	0	0	0	0
Manure	2.44	0.38	Sep	0.0	0.0	0.0	0	0	0	0
			Oct	0.0	0.0	0.0	0	0	0	0
Urban Build-Up	N Kg/ha/d	P Kg/ha/d	Nov	0.0	0.0	0.0	0	0	0	0
Lo_Int_Dev	0.012	0.002	Dec	0.0	0.0	0.0	0	0	0	0
Hi_Int_Dev	0.101	0.011								

Groundwater (mg/L)	Tile Drainage (mg/L)		Per capita tank effluent			Growing season N/P uptake		Sediment	
N (mg/L) P (mg/L)	N	P	Sed	N (g/d)	P (g/d)	N (g/d)	P (g/d)	N (mg/Kg)	P (mg/Kg)
3.003 0.032	15	0.1	50	12	2.5	1.6	0.4	3000.0	1167.0

# UNT 09944 Transport Input File

Rural LU	Area (ha)	CN	K	LS	C	P	Month	Ket	Day Hours	Season	Eros Coef	Stream Extract	Ground Extract
Hay/Past	322	75	0.24	0.352	0.03	0.52	Jan	0.64	9.4	0	0.12	0	0
Cropland	390	82	0.24	0.247	0.42	0.52	Feb	0.7	10.4	0	0.12	0	0
Forest	102	73	0.24	0.535	0.002	0.45	Mar	0.73	11.8	0	0.12	0	0
Wetland	18	87	0.24	0.143	0.01	0.1	Apr	0.92	13.2	1	0.3	0	0
	0	0	0	0	0	0	May	1.03	14.4	1	0.3	0	0
	0	0	0	0	0	0	Jun	1.1	14.9	1	0.3	0	0
	0	0	0	0	0	0	Jul	1.13	14.6	1	0.3	0	0
	0	0	0	0	0	0	Aug	1.15	13.6	1	0.3	0	0
<b>Bare Land</b>	<b>Area (ha)</b>	<b>CN</b>	<b>K</b>	<b>LS</b>	<b>C</b>	<b>P</b>	Sep	1.17	12.2	1	0.3	0	0
Transition	3	87	0.24	0.217	0.8	0.8	Oct	1.17	10.8	1	0.12	0	0
<b>Urban LU</b>	<b>Area (ha)</b>	<b>CN</b>	<b>K</b>	<b>LS</b>	<b>C</b>	<b>P</b>	Nov	1.0	9.6	0	0.12	0	0
Lo_Int_Dev	107	83	0.24	0.385	0.08	0.2	Dec	0.9	9.1	0	0.12	0	0
	0	0	0	0	0	0							

Init Unsat Stor (cm)	10	Initial Snow (cm)	0	Recess Coefficient	0.1
Init Sat Stor (cm)	0	Sed Delivery Ratio	0.185	Seepage Coefficient	0
Unsat Avail Wat (cm)	9.301	Tile Drain Ratio	0.5	Sediment A Factor	7.5066E-04
		Tile Drain Density	0	Sed A Adjustment Factor	1

## UNT 09944 Nutrient Input File

Runoff Coefficients by Source			Nitrogen and Phosphorus Loads from Point Sources and Septic Systems							
Rural Runoff	Dis N mg/L	Dis P mg/L	Point Source Loads/Discharge			Septic System Populations				
			Month	Kg N	Kg P	Discharge MGD	Normal Systems	Pond Systems	Short Cir Systems	Discharge Systems
Hay/Past	4.35	0.113	Jan	0.0	0.0	0.0	56	0	1	0
Cropland	4.35	0.113	Feb	0.0	0.0	0.0	56	0	1	0
Forest	0.19	0.006	Mar	0.0	0.0	0.0	56	0	1	0
Wetland	0.19	0.006	Apr	0.0	0.0	0.0	56	0	1	0
Transition	2.9	0.2	May	0.0	0.0	0.0	56	0	1	0
Transition	2.9	0.2	Jun	0.0	0.0	0.0	56	0	1	0
	0	0	Jul	0.0	0.0	0.0	56	0	1	0
	0	0	Aug	0.0	0.0	0.0	56	0	1	0
	0	0	Sep	0.0	0.0	0.0	56	0	1	0
Manure	3.66	0.57	Oct	0.0	0.0	0.0	56	0	1	0
Urban Build-Up	N Kg/ha/d	P Kg/ha/d	Nov	0.0	0.0	0.0	56	0	1	0
Lo_Int_Dev	0.012	0.002	Dec	0.0	0.0	0.0	56	0	1	0
Hi_Int_Dev	0.101	0.011								

Groundwater (mg/L)		Tile Drainage (mg/L)			Per capita tank effluent		Growing season N/P uptake		Sediment	
N (mg/L)	P (mg/L)	N	P	Sed	N (g/d)	P (g/d)	N (g/d)	P (g/d)	N (mg/Kg)	P (mg/Kg)
2.696	0.03	15	0.1	50	12	2.5	1.6	0.4	3000.0	797.0

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## UNT 09944 Transport Input File

Rural LU	Area (ha)	CN	K	LS	C	P	Month	Ket	Day Hours	Season	Eros Coef	Stream Extract	Ground Extract
Hay/Past	146	75	0.24	0.4	0.03	0.52	Jan	0.64	9.4	0	0.12	0	0
Cropland	199	82	0.24	0.553	0.42	0.52	Feb	0.69	10.4	0	0.12	0	0
Forest	78	73	0.24	0.413	0.002	0.45	Mar	0.72	11.8	0	0.12	0	0
Wetland	8	87	0.24	0.1	0.01	0.1	Apr	0.91	13.2	1	0.3	0	0
	0	0	0	0	0	0	May	1.02	14.4	1	0.3	0	0
	0	0	0	0	0	0	Jun	1.08	14.9	1	0.3	0	0
	0	0	0	0	0	0	Jul	1.12	14.6	1	0.3	0	0
Bare Land	Area (ha)	CN	K	LS	C	P	Aug	1.14	13.6	1	0.3	0	0
	0	0	0	0	0	0	Sep	1.15	12.2	1	0.3	0	0
Transition	2	87	0.24	0.15	0.8	0.8	Oct	1.16	10.8	1	0.12	0	0
Urban LU	Area (ha)	CN	K	LS	C	P	Nov	0.99	9.6	0	0.12	0	0
Lo_Int_Dev	67	83	0.24	0.452	0.08	0.2	Dec	0.89	9.1	0	0.12	0	0
	0	0	0	0	0	0							

Init Unsat Stor (cm)	10	Initial Snow (cm)	0	Recess Coefficient	0.1
Init Sat Stor (cm)	0	Sed Delivery Ratio	0.191	Seepage Coefficient	0
Unsat Avail Wat (cm)	9.301	Tile Drain Ratio	0.5	Sediment A Factor	1.3158E-03
		Tile Drain Density	0	Sed A Adjustment Factor	1

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# **Attachment F**

## **AVGWLF Model Inputs for the Mill Creek Reference Watershed**

# Mill Creek Nutrient Input File

Runoff Coefficients by Source			Nitrogen and Phosphorus Loads from Point Sources and Septic Systems							
Rural Runoff	Dis N mg/L	Dis P mg/L	Point Source Loads/Discharge			Septic System Populations				
Hay/Past	4.35	0.102	Month	Kg N	Kg P	Discharge MGD	Normal Systems	Pond Systems	Short Cir Systems	Discharge Systems
Cropland	4.35	0.102	Jan	0.0	0.0	0.0	0	0	0	0
Forest	0.19	0.006	Feb	0.0	0.0	0.0	0	0	0	0
Wetland	0.19	0.006	Mar	0.0	0.0	0.0	0	0	0	0
Transition	2.9	0.2	Apr	0.0	0.0	0.0	0	0	0	0
	0	0	May	0.0	0.0	0.0	0	0	0	0
	0	0	Jun	0.0	0.0	0.0	0	0	0	0
	0	0	Jul	0.0	0.0	0.0	0	0	0	0
	0	0	Aug	0.0	0.0	0.0	0	0	0	0
	0	0	Sep	0.0	0.0	0.0	0	0	0	0
Manure	3.66	0.57	Oct	0.0	0.0	0.0	0	0	0	0
Urban Build-Up	N Kg/ha/d	P Kg/ha/d	Nov	0.0	0.0	0.0	0	0	0	0
Lo_Int_Dev	0.012	0.002	Dec	0.0	0.0	0.0	0	0	0	0
	0	0								
Groundwater (mg/L)		Tile Drainage (mg/L)			Per capita tank effluent		Growing season N/P uptake		Sediment	
N (mg/L)	P (mg/L)	N	P	Sed	N (g/d)	P (g/d)	N (g/d)	P (g/d)	N (mg/Kg)	P (mg/Kg)
1.348	0.021	15	0.1	50	12	2.5	1.6	0.4	3000.0	548.0

# Mill Creek Transport Input File

Rural LU							Month	Ket	Day Hours	Season	Eros Coef	Stream Extract	Ground Extract
Area (ha)	CN	K	LS	C	P								
Hay/Past	116	75	0.24	0.485	0.03	0.52	Jan	0.62	9.4	0	0.12	0	0
Cropland	118	82	0.24	0.523	0.42	0.52	Feb	0.67	10.4	0	0.12	0	0
Forest	504	73	0.211	4.399	0.002	0.52	Mar	0.7	11.8	0	0.12	0	0
Wetland	1	87	0.223	0.152	0.01	0.1	Apr	0.87	13.2	1	0.3	0	0
	0	0	0	0	0	0	May	0.97	14.4	1	0.3	0	0
	0	0	0	0	0	0	Jun	1.03	14.9	1	0.3	0	0
	0	0	0	0	0	0	Jul	1.07	14.6	1	0.3	0	0
	0	0	0	0	0	0	Aug	1.09	13.6	1	0.3	0	0
	0	0	0	0	0	0	Sep	1.1	12.2	1	0.3	0	0
	0	0	0	0	0	0	Oct	1.1	10.8	1	0.12	0	0
	0	0	0	0	0	0	Nov	0.95	9.6	0	0.12	0	0
	0	0	0	0	0	0	Dec	0.86	9.1	0	0.12	0	0

Bare Land		Urban LU						
Area (ha)	CN	Area (ha)	CN	K	LS	C	P	
Transition	3	87	0.24	0.211	0.8	0.8		
Lo_Int_Dev	45	83	0.24	0.359	0.08	0.2		
	0	0	0	0	0	0		

Init Unsat Stor (cm)	10	Initial Snow (cm)	0	Recess Coefficient	0.1
Init Sat Stor (cm)	0	Sed Delivery Ratio	0.187	Seepage Coefficient	0
Unsat Avail Wat (cm)	10.5473	Tile Drain Ratio	0.5	Sediment A Factor	8.7825E-04
		Tile Drain Density	0	Sed A Adjustment Factor	1

# **Attachment G**

## **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 Attachment H. 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 waterbody. If the contributor exceeds the ALA, that contributor would be reduced to the ALA. If a contributor is less than the ALA, it is set at the existing load. This is the baseline portion of 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.

# **Attachment H**

## **Equal Marginal Percent Reduction Calculations for the Little Swatara Creek Tributaries TMDL**























<b>Step 1:</b>	TMDL Total Load				<b>Step 2:</b>	Adjusted LA = (TMDL total load - MOS) - uncontrollable								
	Load = loading rate in ref. * Acres in Impaired					939.9682	940							
	1047.2098													
	SEDIMENT LOADING													
<b>Step 3:</b>	Non-MS4 Daily Average Load	Load Sum	Check	Initial Adjust	Recheck	% reduction allocation	Load Reduction	Initial LA	Acres	Allowable Loading Rate	% Reduction			
	Hay/Past.	77.5890	2328.1719	good	78	ADJUST	0.06	17.714	59.875	360.80	0.166	23%		
	Cropland	2050.0822		bad	940		278	0.77	214.600	725.368	491.70	1.475	65%	
	Developed	57.6987		good	58			0.05	13.173	44.526	170.50	0.261	23%	
	Streambank	142.8020		good	143			0.12	32.603	110.199			23%	
	Total	2328.1719			1218.05792			1.00		939.968				
<b>Step 4:</b>	All Ag. Loading Rate	0.92												
<b>Step 5:</b>	Acres	Allowable (Target) Loading Rate	Final LA	Current Loading Rates	Current Load	% Red.								
	Final Hay/Past. LA	360.80	0.1660	59.8750	0.2150	77.5890	23%							
	Final Cropland LA	491.70	1.4752	725.3680	4.1694	2050.0822	65%							
	Developed	170.50	0.2611	44.5258	0.3384	57.6987	23%							
	Streambank			110.1995		142.8020	23%							
	Total			939.9682		2328.1719	60%							
	<b>UNT09947</b>													

# **Attachment I**

## **Little Swatara Creek Impairments**

**Pennsylvania Integrated Water Quality Monitoring and Assessment Report  
Streams, Category 5 Waterbodies, Pollutants Requiring a TMDL**

**Stream Name**

**Use Designation (Assessment ID)**

**Source**

**Cause**

**Date Listed**

**TMDL Date**

**Hydrologic Unit Code: 02050305 - Lower Susquehanna-Swatara**

**Little Swatara Creek (Unt 09902)**

HUC: 02050305

Aquatic Life (8263) - 3.02 miles; 9 Segment(s)\*

Agriculture

Nutrients

1998

2011

**Little Swatara Creek (Unt 09904)**

HUC: 02050305

Aquatic Life (8263) - 0.81 miles; 1 Segment(s)\*

Agriculture

Nutrients

1998

2011

**Report Summary**

**Watershed Summary**

	Stream Miles	Assessment Units	Segments (COMIDs)
Watershed Characteristics	3.84	1	10

**Impairment Summary**

Source	Cause	Miles	Assessment Units	Segments (COMIDs)
Agriculture	Nutrients	3.84	1	10
		<b>3.84 **</b>	<b>1 **</b>	<b>10 **</b>

\*\*Totals reflect actual miles of impaired stream. Each stream segment may have multiple impairments (different sources or causes contributing to the impairment), so the sum of individual impairment numbers may not add up to the totals shown.

**Use Designation Summary**

	Miles	Assessment Units	Segments (COMIDs)
Aquatic Life	3.84	1	10

**Pennsylvania Integrated Water Quality Monitoring and Assessment Report  
Streams, Category 5 Waterbodies, Pollutants Requiring a TMDL**

**Stream Name**

**Use Designation (Assessment ID)**

**Source**

**Cause**

**Date Listed**

**TMDL Date**

**Hydrologic Unit Code: 02050305 - Lower Susquehanna-Swatara**

**Little Swatara Creek (Unt 09932)**

HUC: 02050305

Aquatic Life (8259) - 2.60 miles; 2 Segment(s)\*

Agriculture	Nutrients	1998	2011
Agriculture	Siltation	1998	2011
Urban Runoff/Storm Sewers	Siltation	1998	2011

**Little Swatara Creek (Unt 09933)**

HUC: 02050305

Aquatic Life (8260) - 1.69 miles; 4 Segment(s)\*

Agriculture	Nutrients	1998	2011
Agriculture	Siltation	1998	2011

**Little Swatara Creek (Unt 09934)**

HUC: 02050305

Aquatic Life (8260) - 0.14 miles; 2 Segment(s)\*

Agriculture	Nutrients	1998	2011
Agriculture	Siltation	1998	2011

**Little Swatara Creek (Unt 09935)**

HUC: 02050305

Aquatic Life (8260) - 0.12 miles; 2 Segment(s)\*

Agriculture	Nutrients	1998	2011
Agriculture	Siltation	1998	2011

**Little Swatara Creek (Unt 09936)**

HUC: 02050305

Aquatic Life (8258) - 3.11 miles; 6 Segment(s)\*

Agriculture	Nutrients	1998	2011
Agriculture	Siltation	1998	2011

**Little Swatara Creek (Unt 09938)**

HUC: 02050305

Aquatic Life (8255) - 3.68 miles; 5 Segment(s)\*

Agriculture	Nutrients	1998	2011
On site Wastewater	Organic Enrichment/Low D.O.	1998	2011

**Little Swatara Creek (Unt 09939)**

HUC: 02050305

Aquatic Life (8255) - 1.51 miles; 1 Segment(s)\*

Agriculture	Nutrients	1998	2011
	Organic Enrichment/Low D.O.	1998	2011

\*Segments are defined as individual COM IDs.

**Pennsylvania Integrated Water Quality Monitoring and Assessment Report  
Streams, Category 5 Waterbodies, Pollutants Requiring a TMDL**

**Stream Name**

**Use Designation (Assessment ID)**

**Source**

**Cause**

**Date Listed**

**TMDL Date**

**Little Swatara Creek (Unt 09940)**

HUC: 02050305

Aquatic Life (8255) - 0.85 miles; 2 Segment(s)\*

Agriculture	Nutrients	1998	2011
On site Wastewater	Organic Enrichment/Low D.O.	1998	2011

**Little Swatara Creek (Unt 09941)**

HUC: 02050305

Aquatic Life (8255) - 0.84 miles; 4 Segment(s)\*

Agriculture	Nutrients	1998	2011
On site Wastewater	Organic Enrichment/Low D.O.	1998	2011

**Little Swatara Creek (Unt 09944)**

HUC: 02050305

Aquatic Life (8257) - 3.68 miles; 5 Segment(s)\*

Agriculture	Nutrients	1998	2011
Agriculture	Siltation	1998	2011

**Little Swatara Creek (Unt 09945)**

HUC: 02050305

Aquatic Life (8257) - 0.80 miles; 2 Segment(s)\*

Agriculture	Nutrients	1998	2011
Agriculture	Siltation	1998	2011

**Little Swatara Creek (Unt 09946)**

HUC: 02050305

Aquatic Life (8257) - 0.97 miles; 1 Segment(s)\*

Agriculture	Nutrients	1998	2011
Agriculture	Siltation	1998	2011

**Little Swatara Creek (Unt 09947)**

HUC: 02050305

Aquatic Life (8256) - 2.39 miles; 2 Segment(s)\*

Agriculture	Nutrients	1998	2011
Agriculture	Siltation	1998	2011

**Report Summary  
Watershed Summary**

	Stream Miles	Assessment Units	Segments (COMIDs)
Watershed Characteristics	58.33	6	113

**Impairment Summary**

Source	Cause	Miles	Assessment Units	Segments (COMIDs)
Agriculture	Nutrients	22.39	6	38

\*Segments are defined as individual COM IDs.

**Pennsylvania Integrated Water Quality Monitoring and Assessment Report  
Streams, Category 5 Waterbodies, Pollutants Requiring a TMDL**

**Stream Name**

**Use Designation (Assessment ID)**

**Source**

**Cause**

**Date Listed**

**TMDL Date**

**Impairment Summary**

Source	Cause	Miles	Assessment Units	Segments (COMIDs)
Agriculture	Siltation	15.51	5	26
On site Wastewater	Organic Enrichment/Low D.O.	6.89	1	12
Urban Runoff/Storm Sewers	Siltation	2.60	1	2
		<b>22.39 **</b>	<b>6 **</b>	<b>38 **</b>

\*\*Totals reflect actual miles of impaired stream. Each stream segment may have multiple impairments (different sources or causes contributing to the impairment), so the sum of individual impairment numbers may not add up to the totals shown.

**Use Designation Summary**

	Miles	Assessment Units	Segments (COMIDs)
Aquatic Life	22.39	6	38

# **Attachment J**

## **Comment & Response Document for the Little Swatara Creek Tributaries TMDL**

No official comments were received for this TMDL.