Total Maximum Daily Loads (TMDLs)

UNT to Swatara Creek Watershed
Lebanon County

Pennsylvania Department of Environmental Protection
Central Office
Office of Water Management

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Summary of the UNT 09749 Total Maximum Daily Load (TMDL)

1. The unnamed tributary (UNT) 09749 TMDL was developed for an UNT to Swatara Creek located northwest of Palmyra in Lebanon County, Pennsylvania. Interstate 81 bisects the watershed. Access to the watershed is available by exiting I-81 at the Grantville exit, and traveling south to Route 22. Traveling approximately 2 miles east on Route 22 will bring you to the middle of the UNT 09749 watershed. For the purposes of developing the TMDL, two subbasins were delineated within the UNT 09749 watershed.

2. The TMDL for the UNT 09749 watershed was developed to address use impairments from agricultural activities, caused by organic enrichment and low dissolved oxygen (DO). UNT 09749 first appeared on Pennsylvania's 303(d) list in 1996, when 2.0 miles of the tributary were listed as impaired by organic enrichment and low DO emanating from agricultural activities. The miles impaired were then increased on Pennsylvania's 1998 303(d). As part of the Pa. DEP's ongoing Unassessed Waters (UW) program and in anticipation of TMDL development, assessments were conducted in the UNT 09749 watershed in 1999. Information collected during theses assessments identified designated use impairments for most of the UNT 09749 watershed. These impairments also are being caused by agricultural activities in the watershed. The 1999 impairments document flow alterations from crop-related agriculture, and are expected to be included on Pennsylvania's 2002 303(d) list. The total phosphorus TMDL was developed to address organic enrichment and low dissolved oxygen associated with agricultural activities, as originally listed on the 1996 303(d) list. In order to ensure attainment and maintenance of water quality standards in UNT 09749, mean annual loading of total phosphorus will need to be limited to 1,575 and 1,218 lbs/yr, for subbasins 1 and 2, respectively.

   The major components of the UNT 09749 watershed TMDLs are summarized below:

Component	Subbasin 1 Total Phosphorus (lbs/yr)	Subbasin 2 Total Phosphorus (lbs/yr)
TMDL (Total Maximum Daily Load)	1,575.07	1,218.36
WLA (Wasteload Allocation)	700.00	0.00
MOS (Margin of Safety)	157.51	121.84
LA (Load Allocation)	717.56	1,096.52

3. Mean annual total phosphorus loading is estimated to be 1,865.22 lbs/yr and 1,816.56 lbs/yr for subbasins 1 and 2, respectively. To meet the TMDL, subbasins 1 and 2 will require a 16% and 33% reduction, respectively.

4. There is one known point source of total phosphorus located in the UNT 09749 watershed. The waste load allocation (WLA) was set at 700 lbs/yr for Subbasin 1, to account for the contribution of phosphorus from a sewage treatment plant. Load allocations (LA) for total phosphorus were made

to the following nonpoint sources: hay and pasture lands; croplands; coniferous forest; mixed forest; deciduous forest; developed areas; disturbed areas; and groundwater. The loads emanating from streambanks were included in the allocations made to hay and pasture lands since streambank erosion occurs almost exclusively within those lands.

5. The total phosphorus TMDL includes a nonpoint source LA of 717.56 lbs/yr and 1,096.52 lbs/yr for subbasins 1 and 2, respectively. Allocations to sources receiving reductions (hay/pasture, cropland, developed, and disturbed) add up to 192.25 lbs/yr for subbasin 1. Allocations to sources receiving reductions (hay/pasture, cropland, and developed) add up to 633.63 lbs/yr for subbasin 2. Total phosphorus loadings from all other sources were maintained at 525.30 lbs/yr and 462.9 lbs/yr for subbasins 1 and 2, respectively. Allocations of total phosphorus to all nonpoint sources in the UNT 09749 watershed are summarized below:

Subbasin 1
Load Allocations for Nonpoint Sources of Total Phosphorus

Source	Current Loading (lbs/yr)	Load Allocation (lbs/yr)	% Reduction
Hay and Pasture	359.22	91.85	74%
Cropland	546.90	91.85	83%
Developed	9.50	4.54	52%
Disturbed	8.40	4.01	52%
Loads Not Reduced	525.30	525.30	0%
Total	1,449.32	717.55	50%

Subbasin 2
Load Allocations for Nonpoint Sources of Total Phosphorus

Source	Current Loading (lbs/yr)	Load Allocation (lbs/yr)	% Reduction
Hay and Pasture	496.66	277.05	44%
Cropland	851.40	353.46	58%
Developed	5.60	3.12	44%
Loads Not Reduced	462.90	462.89	-
TOTALS	1,816.56	1,096.52	39%

6. Ten percent of the UNT 09749 total phosphorus TMDL was set-aside as a margin of safety (MOS). The MOS is that portion of the pollutant loading that is reserved to account for any uncertainty in the data and computational methodology used for the analysis. The MOS for the total phosphorus TMDL was set at 157.51 lbs/yr and 121.84 lbs/yr, for subbasins 1 and 2, respectively.

7. The continuous simulation model used for developing the UNT 09749 TMDL considers seasonal variation through a number of mechanisms. Daily time steps are used for weather data and water balance calculations. The model requires specification of the growing season and hours of daylight for each month. The model also considers the months of the year when manure is applied to the land. The combination of these actions accounts for seasonal variability.

I. Introduction

A. Watershed Description

The TMDL contained in this report was developed for an UNT to Swatara Creek, located in Lebanon County, Pennsylvania. The UNT's 5-digit stream code is 09749 and will be identified throughout this report as UNT 09749. UNT 09749 is part of State Water Plan subbasin 03C (Swatara Creek) and is located northwest of Palmyra in Lebanon County, Pennsylvania (Figure 1). Interstate 81 bisects the watershed. Access to the watershed is available by exiting I-81 at the Grantville exit, and traveling south to Route 22. Traveling approximately 2 miles east on Route 22 will bring you to the middle of the UNT 09749 watershed. The stream originates in the northeast corner East Hanover Township, draining a section of Blue Mountain. The stream flows for approximately 5 miles in a southerly direction to its confluence with Swatara Creek. The total watershed area for UNT 9794 is approximately 10 miles. Protected uses of UNT 09749 include aquatic life, water supply, and recreation. The entire basin is currently designated as warm water fishes (WWF) under §93.9f in Title 25 of the Pa. Code (Commonwealth of Pennsylvania, 2001).

B. Topography & Geology

The UNT 09749 to Swatara Creek is located in the Great Valley and Appalachian Mountain Sections of the Ridge and Valley Province in eastern Pennsylvania. The watershed is typical of watersheds in the Ridge and Valley Province. It has a fairly uniform elevation in the valley section ranging from 360 to 520 feet and then rises sharply at the ridge from 600 to a maximum height of 1,273 feet. In general, the elevation decreases from northwest to southeast and the drainage follows this pattern. This area receives approximately 40 inches of precipitation per year.

The surficial geology of the UNT 09749 watershed is 100% sedimentary. The strata include the Hamburg Sequence that is interbedded sedimentary units composed of shale with limestone and graywacke, the Martinsburg Formation that is a shale unit on the ridge, and the Tuscarora Formation that is a resistant sandstone unit that lies on the top of the ridge on Blue Mountain.

The soils found in the UNT 09749 watershed are moderately deep and well drained with moderate to rapid permeability. A large extent of the soil is used for pasture and cropland; the remaining areas are typically forested. The erodibility (k) factor is a measure of inherent soil erosion potential based on the soils texture and composition. Soil erosion is not a major concern since the k factor for these soils range from 0.18 to 0.24.

C. Land Use

Based on GIS datasets, land use values were calculated for the UNT 09749 watershed. Agriculture was the dominant land use at 59.75 percent. Forested areas account for 36.94 percent of the watershed. Developed areas are 2.52 percent of the watershed, comprised predominantly of low intensity residential and some commercial land. Water or disturbed areas cover the remaining 0.79 percent of the watershed area. Riparian buffer zones are nearly nonexistent in the hay and pasture lands. Livestock have unlimited access to streambanks throughout most of the watershed, resulting in streambank trampling and severe erosion.

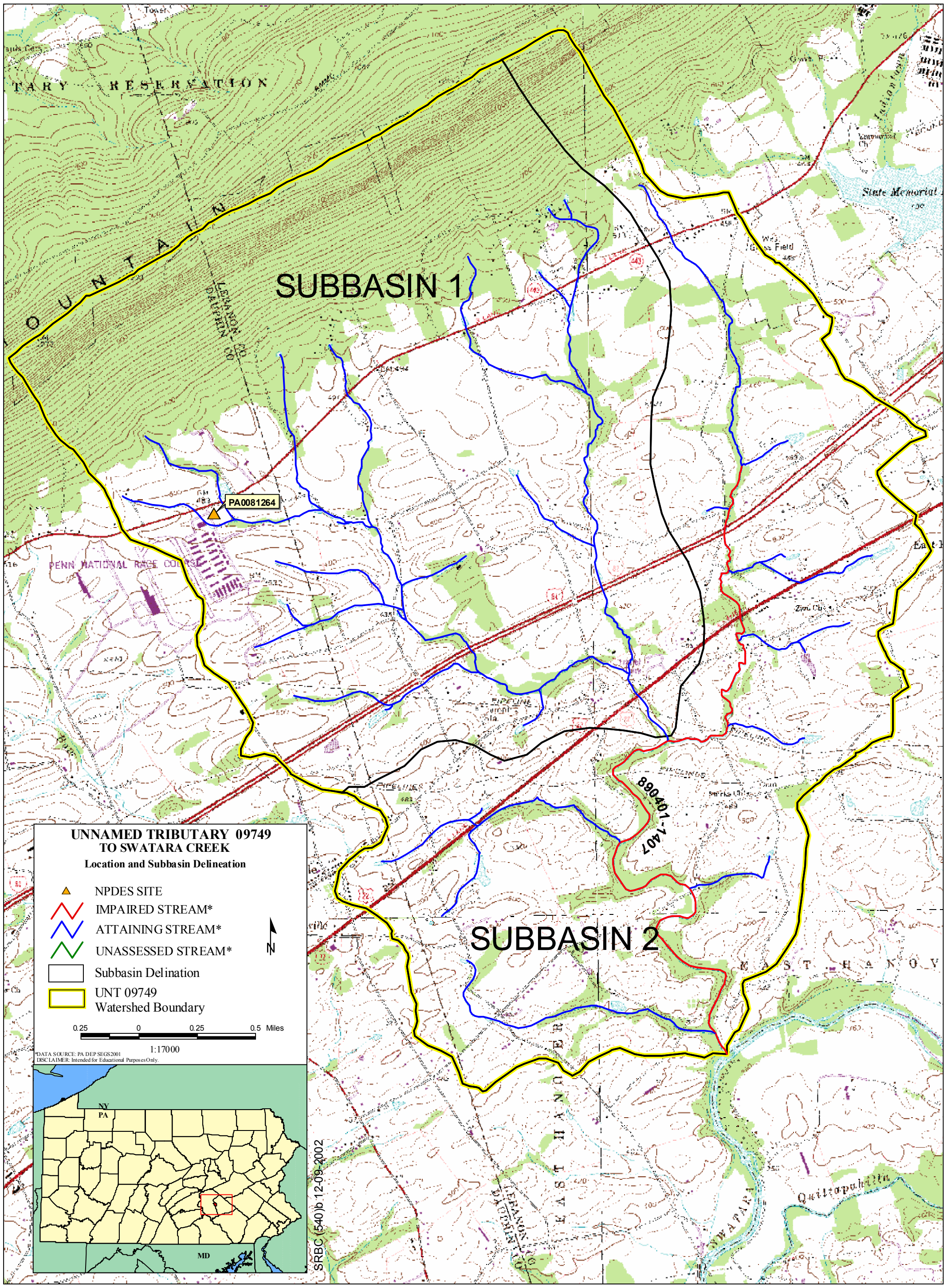


Figure 1. UNT 09749 Watershed Lebanon County showing the stream segment on the 1996 & 1998 303(d) Lists

D. Surface Water Quality

Pennsylvania's 1996 303(d) list identified 2.0 miles of an UNT to Swatara Creek as impaired by nutrients emanating from agricultural activities in the basin (Table 1). The miles impaired were then increased on Pennsylvania's 1998 303(d). Figure 1 shows the segment addressed by this TMDL. The total phosphorus TMDL was developed to address organic enrichment and low dissolved oxygen associated with agricultural activities, as originally listed in the 1996 303(d) list and the current 305(b) database.

As part of the Pa. DEP's ongoing Unassessed Waters (UW) program and in anticipation of TMDL development, assessments were conducted in the UNT 09749 watershed in 1999. Although there are additional listings for designated use impairments on the 2002 303(d) list, this TMDL does not address those listings since the impairments are related to flow and habitat alterations. TMDLs are not the appropriate mechanism to address this type of stream impairment. TMDLs are designed to address pollutant loadings that cause a violation of water quality standards. There is no pollutant loading to address for this type of impairment.

<table>
<tr><th colspan="6">Table 1. 1996 & 1998 303(d) Listings UNT 09749 Watershed</th></tr>
<tr><th colspan="6">1996 303(d) LIST</th></tr>
<tr><td colspan="2">STREAM NAME</td><td>STREAM CODE</td><td>SOURCE</td><td>CAUSE</td><td>MILES</td></tr>
<tr><td colspan="2">UNT to Swatara Creek</td><td>09749</td><td>Agriculture</td><td>DO/BOD</td><td>2.0</td></tr>
<tr><th colspan="6">1998 303(d) LIST</th></tr>
<tr><td>SEGMENT ID</td><td>WATERSHED</td><td>STREAM CODE</td><td>SOURCE</td><td>CAUSE</td><td>MILES</td></tr>
<tr><td>1407</td><td>Swatara Creek</td><td>09749</td><td>Agriculture</td><td>Organic Enrichment / Low DO</td><td>4.33</td></tr>
</table>

II. Approach to TMDL Development

A. Pollutants & Sources

Organic enrichment and low DO have been identified as the pollutants causing designated use impairments in the UNT 09749 watershed, with the source listed as agricultural activities. There is one wastewater discharge present in the watershed. Best Management Practices (BMPs) are very limited in the watershed. Pastures 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, stream bank erosion is very apparent in some reaches of the stream.

B. TMDL Endpoints

In an effort to address the excessive nutrient and low DO impairments found in the UNT 09749 watershed, TMDLs were developed for phosphorus. The phosphorus TMDL is intended to address nutrient impairments from agriculture land uses that were first identified in Pennsylvania's 1996 303(d) list. The decision to use phosphorus load reductions to address organic enrichment and low DO impairments was based on an understanding of the relationship between nitrogen, phosphorus, and organic enrichment in stream systems. Elevated nutrient loads (nitrogen and phosphorus in particular) can lead to increased productivity of plants and other organisms (Novotny and Olem, 1994). In aquatic ecosystems the quantities of trace elements are typically plentiful; however, nitrogen and phosphorus may be in short supply. The nutrient that is in the shortest supply is called the limiting nutrient because its relative quantity affects the rate of production (growth) of aquatic biomass. If the limiting nutrient load to a water body can be reduced, the available pool of nutrients that can be utilized by plants and other organisms will be reduced and, in general, the total biomass can subsequently be decreased as well (Novotny and Olem, 1994). In most efforts to control the eutrophication processes in water bodies, emphasis is placed on the limiting nutrient. This is not always the case, however. For example, if nitrogen is the limiting nutrient, it still may be more efficient to control phosphorus loads if the nitrogen originates from difficult to control sources, such as nitrates in 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 UNT 09749, the average N/P ratio is approximately 22 for the two subbasins, which points to phosphorus as the limiting nutrient. Controlling the phosphorus loading to UNT 09749 will limit plant growth, thereby helping to eliminate use impairments currently being caused by excess nutrients.

C. Reference Watershed Approach

The TMDL developed for the UNT 09749 watershed addresses phosphorus. Because neither Pennsylvania nor the U.S. Environmental Protection Agency (USEPA) has in-stream numerical water quality criteria for nutrients, a method was developed to implement the applicable narrative criteria for this pollutant. The method employed for this TMDL 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 must have similar land use/cover distributions. Other features such as base geologic formation should be matched to the extent possible; however, most variations can be adjusted for in the model. The objective of the process is to reduce the loading rate of pollutants in the impaired stream segment to a level equivalent to the loading rate in the nonimpaired, reference stream segment. This load reduction will result in conditions favorable to the return of a healthy biological community to the impaired stream segments.

D. Selection of the Reference Watershed

In general, three factors are considered when selecting a suitable reference watershed. The first factor is to use a watershed that the Pa. DEP has assessed and determined to be attaining water quality standards. The second factor is to find a watershed that closely resembles the impaired watershed in physical properties such as land cover/land use, physiographic province, and geology. Finally, the size of the reference watershed should be within 20-30% of the impaired watershed area. The search for a reference watershed for UNT 09749, that would satisfy the above characteristics, was done by means of a desktop screening using several GIS coverages, including the Multi-Resolution Land Characteristics (MRLC), Landsat-derived land cover/use grid, the Pennsylvania's 305(b) assessed streams database, and geologic rock types

An unnamed tributary to Little Swatara Creek, UNT 09905 (UNTREF), was selected as the reference watershed for developing the UNT 09749 watershed TMDL. UNTREF is located north of Lebanon in Lebanon County, Pennsylvania (Figure 3). The watershed is located in State Water Plan subbasin 7D, upstream of UNT 09749, and protected uses include aquatic life, water supply, and recreation. The entire basin is currently designated as WWF under §93.9z in Title 25 of the Pa. Code (Commonwealth of Pennsylvania, 2001). Based on the Department's 305(b) report database, UNTREF is currently attaining its designated uses. The attainment of designated uses is based on sampling done by the Department in 1997. The UNTREF watershed has no point source discharges.

Drainage area, location, and other physical characteristics of the UNT 09749 watershed were compared to the reference portion of the UNTREF watershed (Table 2). Land cover/use distributions in both watersheds are similar. Agricultural is the dominant land use category in both the UNTREF watershed (74%) and subbasins 1 (48%) and 2 (73%) of UNT 09749 watershed. Surficial geology in the UNTREF watershed and the two UNT 09749 subbasins also were compared. Surface geology in both watersheds is comprised almost entirely of sedimentary rocks. Bedrock geology primarily affects surface runoff and background nutrient loads through its influences on soils, landscape, fracture density, and directional permeability. UNT 09749 and the UNTREF watersheds are nearly identical in terms of average runoff, precipitation, soil types, and soil K factor (Table 2).

Table 2. Comparison Between UNT 09749 and UNTREF Watersheds

Attribute	Watershed		
	UNT 09749		UNTREF
Physiographic Province	Ridge & Valley (100%)		Ridge & Valley (100%)
Area (mi^2)	Subbasin 1 5.8	Subbasin 2 4.5	5.0
Land Use	Subbasin 1 Agriculture (48%) Forested (46%) Development (6%)	Subbasin 2 Agriculture (73%) Forested (25%) Development (2%)	Agriculture (74%) Forested (21%) Development (5%)
Geology	Sedimentary (100%)		Sedimentary (94%) Igneous/Metamorphic (6%)
Soils	Berks-Weikert-Bedington (82%) Hazleton-Dekalb-Buchanan (18%)		Berks-Weikert-Bedington (100%)
Dominant HSG	Berks Series B (13%) C (52%) D (35%)	Hazleton Series A (2%) B (45%) C (53%)	B (13%) C (52%) D (35%)
K Factor	0.18 (Hazleton Series) - 0.24 (Berks Series)		0.24
20-Yr. Ave. Rainfall (in)	40.5		41.2
20-Yr. Ave. Runoff (in)	3.1		3.6

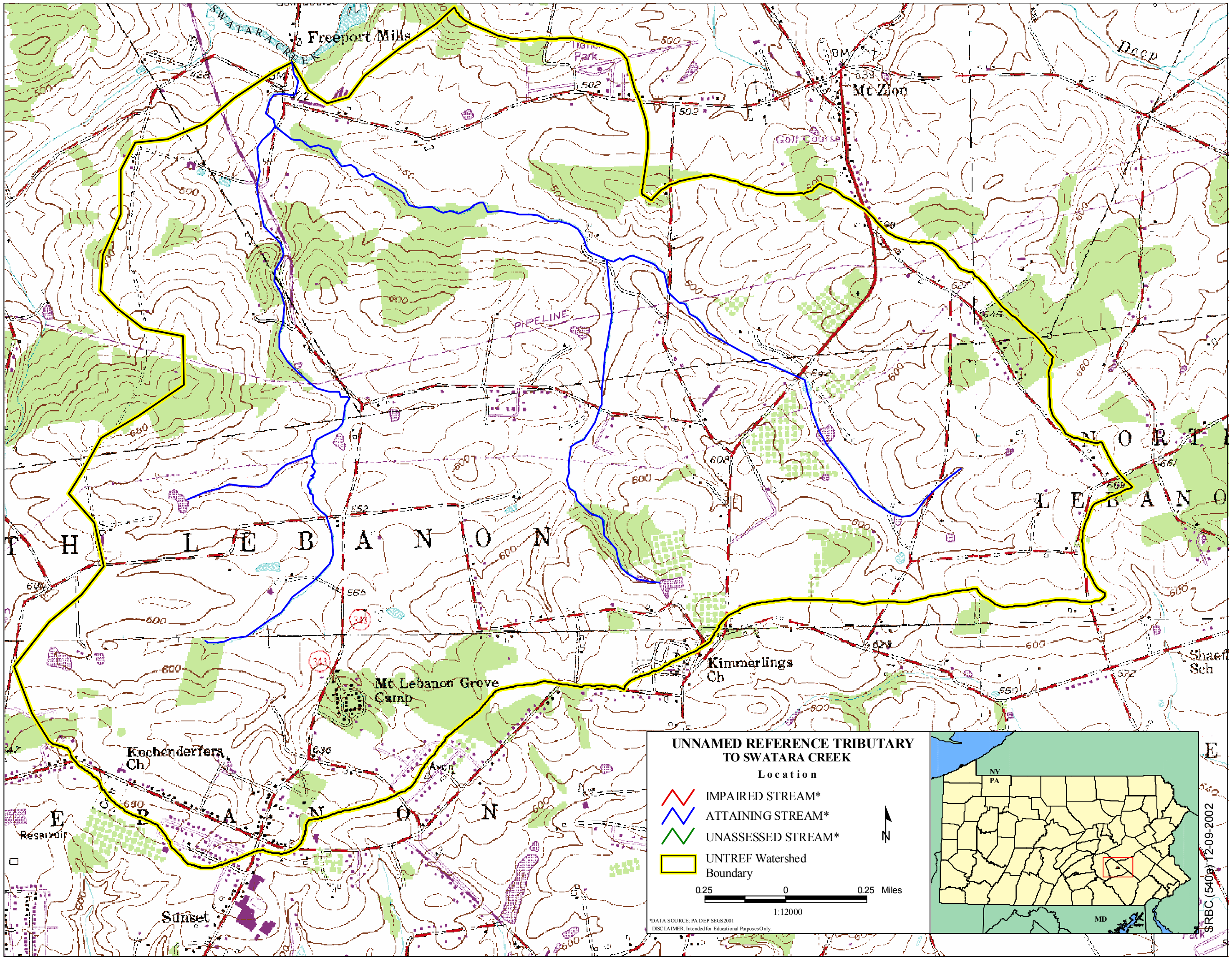


Figure 2. UNTREF Watershed

III. Watershed Assessment and Modeling

TMDLs for the UNT 09749 watershed were developed using the ArcView Generalized Watershed Loading Function model (AVGWLF) as described in Appendix B. The AVGWLF model was used to establish existing loading conditions for the UNT 09749 watershed and the reference portion of the UNTREF watershed. All modeling inputs have been attached to this TMDL as Appendices C and D. Susquehanna River Basin Commission staff visited the UNT 09749 and UNTREF watersheds in the fall of 2001. The field visits were conducted to get a better understanding of existing conditions that might influence the AVGWLF model. General observations of the individual watershed characteristics include:

UNT 09749 Watershed

- Local geology dominated by sedimentary rocks.
- Significant presence of grazing horses and cattle.
- General lack of strip cropping and contour plowing.
- Severely limited riparian buffer zones, with croplands and pastures extending right up to streambanks (Figure 4).

UNTREF Watershed

- Local geology dominated by sedimentary rocks.
- More hay and other cover crops.
- Forest buffers along streams (Figure 5).
- Abundant silt-free gravel substrate throughout the entire watershed.

Adjustments made to specific AVGWLF model parameters, based on existing land use practices in each of the watersheds, included:

UNT 09749 Watershed (both subbasins)

- Reset default C factor for cropland (0.21) and 0.40 to reflect the presence of large continuous cornfields and a general lack of strip cropping, contour plowing, and cover crops. Hay/pasture (0.03) was reset to 0.40 as well to reflect the effects of heavily grazed pastureland.
- Reset default P factors for cropland and hay/pasture land uses (0.52) to 0.60 to account for:
  - Pastures and cropland generally extending right up to stream banks with unrestricted livestock access to the streams.
  - Poor quality riparian vegetation resulting in many exposed banks.

UNTREF Watershed

- Reset C factor for cropland (0.21) to 0.18, respectively to account for prevalent use of strip cropping, contour plowing, and cover crops.
- Reset P factor for cropland (0.52) and hay/pasture (0.52) land uses to 0.30, respectively to account for the pervasiveness of riparian buffer zones, stream bank fencing, and stable stream banks.
- The nutrient concentrations in runoff and manure also were set to match the correct background levels for North Lebanon Township, where the UNTREF watershed is located. Using the default values, the UNTREF watershed had abnormally high nutrient concentrations

in relation to the activities present within the watershed. The model was introducing large concentrations to the UNTREF nutrient input file based on turkey/chicken operations located in the southern portion of the zip code area, which is outside of the UNTREF watershed area. There are no animal operation activities in the actual UNTREF modeled area, so nutrient concentrations in manure and runoff were changed to reflect the normal background conditions for Lebanon County.

Figure 3. Typical Riparian Zone in the UNT 09749 Watershed

Figure 4. Typical Riparian Zone in the UNTREF Watershed

The AVGWLF model produced information on watershed size, land use, and phosphorus loading (Appendices C and D). The phosphorus loads represent an annual average over a 20-year period (1976 to 1996). This information was then used to calculate existing unit area loading rates for the UNT 09749 and UNTREF watersheds. Phosphorus loading information for both subbasins and the reference watershed are shown in Tables 3, 4, and 5.

Table 3. Existing Phosphorus Loads for Subbasin 1

Pollutant Source	Acreage	Phosphorus	
		Mean Annual Loading (lbs/yr)	Unit Area Loading (lbs/ac/yr)
HAY/PAST	822.90	345.90	0.42
CROPLAND	988.40	546.90	0.55
CONIF_FOR	249.60	5.70	0.02
MIXED_FOR	321.20	4.90	0.02
DECID_FOR	1141.60	21.80	0.02
UNPAVED_RD	2.50	2.40	0.96
TRANSITION	4.90	6.00	1.22
LO_INT_DEV	113.70	0.00	0.00
HI_INT_DEV	54.40	0.10	0.00
Streambank		13.32	
Groundwater		492.90	
Point Source		415.90	
Septic Systems		9.40	
Total	3699.20	1865.22	0.50

Table 4. Existing Phosphorus Loads for Subbasin 2			
		Phosphorus	
Pollutant Source	Acreage	Mean Annual Loading (lbs/yr)	Unit Area Loading (lbs/ac/yr)
HAY/PAST	879.70	481.90	0.55
CROPLAND	1210.80	851.40	0.70
CONIF_FOR	111.20	1.10	0.01
MIXED_FOR	93.90	0.50	0.01
DECID_FOR	506.60	2.40	0.00
LO_INT_DEV	44.50	0.00	0.00
HI_INT_DEV	12.40	0.00	0.00
Streambank		14.76	
Groundwater		458.90	
Point Source		0.00	
Septic Systems		5.60	
Total	2859.10	1816.56	0.64

Table 5. Existing Phosphorus Loads for UNTREF			
		Phosphorus	
Pollutant Source	Acreage	Mean Annual Loading (lbs/yr)	Unit Area Loading (lbs/ac/yr)
HAY/PAST	1050.20	197.00	0.19
CROPLAND	1373.90	593.50	0.43
CONIF_FOR	46.90	0.20	0.00
MIXED_FOR	69.20	0.30	0.00
DECID_FOR	558.50	3.20	0.01
LO_INT_DEV	145.80	0.10	0.00
HI_INT_DEV	14.80	0.00	0.00
Streambank		33.62	
Groundwater		540.00	
Point Source		0.00	
Septic Systems		5.60	
Total	3259.30	1373.52	0.42

IV. TMDLs

Targeted TMDL values for the UNT 09749 watershed were established based on current loading rates for phosphorus in the UNTREF reference watershed. Biological assessments have determined that

UNTREF is currently attaining its designated uses. Reducing the loading rate of phosphorus in the UNT 09749 watershed to levels equivalent to those in the reference portion of the UNTREF watershed will provide conditions favorable for the reversal of current use impairments.

A. Background Pollutant Conditions

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

B. Targeted TMDLs

Targeted TMDL values for phosphorus were determined by multiplying the total area of subbasins 1 and 2 of the UNT 09749 watershed (3,750.16 and 2,900.86 acres, respectively) by the appropriate unit area loading rate for the UNTREF watershed (Table 6). The existing mean annual loading of phosphorus to subbasin 1 (1,865.22 lbs/yr) will need to be reduced by 16% to meet the targeted TMDL of 1,575.07 lbs/yr. Meeting the targeted phosphorus TMDL of 1,218.36 lbs/yr for subbasin 2 will require a 33% reduction in the current mean annual loading (1,816.56 lbs/yr).

Table 6. Targeted TMDLs for the UNT 09749 Watershed

Pollutant	Area (ac)	Unit Area Loading Rate UNTREF Watershed (lbs/ac/yr)	Targeted TMDL (lbs/yr)
Subbasin 1	3,750.16	0.42	1,575.07
Subbasin 2	2,900.86	0.42	1,218.36

Targeted TMDL values were than used as the basis for load allocations and reductions in the UNT 09749 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

C. Wasteload Allocation

The WLA portion of the TMDL equation is the total loading of a pollutant that is assigned to point sources. Reviewing the Pa. DEP's permitting files identified one point source discharge (PA 0081264) in subbasin 1 of the UNT 09749 basin. Penn National Race Course operates a wastewater treatment plant that serves a horse and auto racing facility, as well as a motel. The facility discharges an average load of 415.90 lbs/yr. This average phosphorus loading was used in the model to determine the existing load for subbasin 1. The design flow for the facility is 0.23 million gallons per day (MGD), with a phosphorus limit of 2.0 milligrams per liter (mg/L). However, this design capacity would generate a phosphorus loading of 1,401.11 lbs/yr, representing over three times the existing loading. For this reason, the WLA for subbasin 1 of the UNT 09749 TMDL is set at 700 lbs/yr to account for any increased phosphorus load emanating from point source discharges in order to prevent a violation of water quality standards in the UNT 09749 watershed. The load of 700 lbs/yr was used for determining the allocations in the following sections.

D. Margin of Safety

The MOS is that portion of the pollutant loading that is reserved to account for any uncertainty in the data and computational methodology used for the analysis. For this analysis, the MOS is explicit. Ten percent of the targeted TMDL for phosphorus was reserved as the MOS. Using 10% of the TMDL load is based on professional judgment and will provide an additional level of protection to the designated uses of UNT 09749. The MOS used for the phosphorus TMDL was 157.51 lbs/yr and 121.84 lbs lbs/yr for subbasins 1 and 2, respectively.

MOS (Subbasin 1) = 1,575.07 lbs/yr (TMDL) x 0.1 = 157.51 lbs/yr
MOS (Subbasin 2) = 1,218.36 lbs/yr (TMDL) x 0.1 = 121.84 lbs/yr

E. Load Allocation

The LA is that portion of the TMDL that is assigned to nonpoint sources. The LA was computed by subtracting the WLA and MOS values from the targeted TMDL value. LA for subbasins 1 and 2 were 717.56 lbs/yr and 1,096.52 lbs/yr, respectively.

LA (Subbasin 1) = 1,575.07 lbs/yr (TMDL) – 700.00 lbs/yr (WLA) – 157.51 lbs/yr (MOS) = 717.56 lbs/yr
LA (Subbasin 2) = 1,218.36 lbs/yr (TMDL) - 0 lbs/yr (WLA) – 121.84 lbs/yr (MOS) = 1,096.52 lbs/yr

F. Adjusted Load Allocation

The adjusted load allocation (ALA) is the actual portion of the LA distributed among those nonpoint sources receiving reductions. It is computed by subtracting those nonpoint source loads that are not being considered for reductions (loads not reduced or LNR) from the LA. Phosphorus reductions were made to the hay/pasture, cropland, developed (sum of LO_INT_DEV, HI_INT_DEV and septic systems), and disturbed (sum of Unpaved Roads, Transition, Quarry, etc.). Those land uses/sources for which existing loads were not reduced (CONIF_FOR, MIXED_FOR, DECID_FOR, and groundwater) were carried through at their existing loading values (Table 7). The ALA for subbasins 1 and 2 were 192.26 lbs/yr and 633.62 lbs/yr, respectively.

Table 7. Load Allocations, Loads Not Reduced, and Adjusted Load Allocations for UNT 09749 Watershed Phosphorus TMDL		
	Subbasin 1 Total Phosphorus (lbs/yr)	Subbasin 2 Total Phosphorus (lbs/yr)
Load Allocation	717.56	1,096.52
Loads Not Reduced	525.30	462.90
CONIF_FOR	5.70	1.10
MIXED_FOR	4.90	0.50
DECID_FOR	21.80	2.40
Groundwater	492.90	458.90
Adjusted Load Allocation	192.26	633.62

G. TMDLs

The phosphorus TMDL established for the UNT 09749 watershed consists of a LA, a WLA, and a MOS. No TMDL was established for nitrogen because the stream is phosphorus limited. The individual components of the TMDL are summarized in Table 8.

Table 8. TMDL, WLA, MOS, LA, LNR, and ALA for the UNT 09749 Watershed		
Component	**Subbasin 1 (lbs/yr)**	**Subbasin 2 (lbs/yr)**
TMDL (Total Maximum Daily Load)	1,575.07	1,218.36
WLA (Wasteload Allocation)	700.00	0.00
MOS (Margin of Safety)	157.51	121.84
LA (Load Allocation)	717.56	1,096.90
LNR (Loads Not Reduced)	525.30	462.90
ALA (Adjusted Load Allocation)	192.26	633.62

V. Calculation of Phosphorus Load Reductions

ALAs established in the previous section represent the annual total phosphorus loads that are available for allocation between contributing sources in the UNT 09749 watershed. The ALA for phosphorus was allocated between agricultural land uses. LA and reduction procedures were applied to the entire UNT 09749 watershed using the Equal Marginal Percent Reduction (EMPR) allocation method (Appendix E).

The LA and EMPR procedures were performed using MS Excel and results are presented in Appendix F.

In order to meet the phosphorus TMDL for subbasin 1 (1,575.07 lbs/yr), the load currently emanating from controllable sources (924.02 lbs/yr) must be reduced to 192.26 lbs/yr (Table 9). This can be achieved through reductions in current phosphorus loadings of 78% from hay/pasture, 81% from cropland, 52% from developed, and 52% from disturbed land uses. Meeting the total phosphorous TMDL for subbasin 2 (1,218.36 lbs/yr) will require a reduction of current agriculture related phosphorous loading (1,353.66 lbs/yr) to 633.63 lbs/yr (Table 9). This is achievable through total phosphorous load reductions from cropland and hay/pasture of 58% and 44%, respectively, along with a 44% reduction for developed lands.

The loadings from stream banks were included in the allocation to hay and pasture lands, since the bank erosion is occurring in areas where livestock have unrestricted access to the stream. Under such conditions, trampling of the banks is resulting in stream bank instability. The loadings from septic systems were included in the allocation to developed areas.

Table 9. Phosphorus Load Allocations & Reductions for the UNT 09749 Watershed						
Subbasin 1						
Pollutant Source	**Acres**	**Unit Area Loading Rate (lbs/ac/yr)**		**Pollutant Loading (lbs/yr)**		**Percent Reduction**
		Current	**Allowable**	**Current**	**Allowable (LA)**	
HAY/PASTURE (includes stream banks)	799.41	0.45	0.25	359.22	80.78	78
CROPLAND	1,018.54	0.54	0.26	546.90	102.93	81
Developed	166.46	0.06	0.03	9.50	4.54	52
Disturbed	12.25	0.69	0.38	8.40	4.01	52
Total				**924.02**	**192.26**	**79**
Subbasin 2						
Pollutant Source	**Acres**	**Unit Area Loading Rate (lbs/ac/yr)**		**Pollutant Loading (lbs/yr)**		**Percent Reduction**
		Current	**Allowable**	**Current**	**Allowable (LA)**	
HAY/PASTURE (includes stream banks)	923.81	0.54	0.30	496.66	277.05	44
CROPLAND	1,193.56	0.71	0.30	851.40	353.46	58
Developed	50.04	0.12	0.06	5.60	3.12	44
Total				**1,353.66**	**633.63**	**53**

VI. Consideration of Critical Conditions

The AVGWLF model is a continuous simulation model, which uses daily time steps for weather data and water balance calculations. Monthly calculations are made for nutrient loads, based on the daily water balance accumulated to monthly values. Therefore, all flow conditions are taken into account for loading calculations. Because there is generally a significant lag time between the introduction of nutrients to a waterbody and the resulting impact on beneficial uses, establishing these TMDLs using average annual conditions is protective of the waterbody.

VII. Consideration of Seasonal Variations

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

VIII. Recommendations for Implementation

TMDLs represent an attempt to quantify the pollutant load that may be present in a waterbody and still ensure attainment and maintenance of water quality standards. The UNT 09749 TMDL identifies the necessary overall load reductions for those pollutants currently causing use impairments and distributes those reduction goals to the appropriate nonpoint sources. Reaching the reduction goals established by this TMDL will only occur through BMPs. BMPs that would be helpful in lowering the amount of nutrients reaching UNT 09749 include stream bank fencing, riparian buffer strips, strip cropping, contour plowing, conservation crop rotation, and heavy use area protection, among many others.

The Swatara Creek Watershed has been the focus of numerous assessment and restoration initiatives. Since 2000, funding for projects to restore the health of the watershed has exceeded $2 million. For fiscal year 2003, Lebanon County Conservation District will receive over $300,000 to continue with installation of agricultural BMPs. Numerous other entities, both public and private, have assisted with these efforts throughout county. Specific BMPs implemented in the county include stream fencing, manure storage systems, treatment of runoff from animal confinement areas, and treatment of milk house waste. A number of projects in the Swatara Creek Watershed are also addressing stream bank erosion through the use of natural stream design and stabilization.

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. Many of the practices described in the handbook could be used on agricultural lands in the UNT 09749 watershed to help limit nutrient impairments. Determining the most appropriate BMPs, where they should be installed, and actually putting them into practice, will require the development and implementation of comprehensive watershed restoration plans. Development of any restoration plan will involve the gathering of site-specific information regarding current land uses and existing conservation practices. Many of these types of assessments have either been completed or are ongoing in the Swatara Creek Watershed.

By developing TMDLs for the UNT 09749 watershed, the Pa. DEP has set the stage for the design and implementation of restoration plans to correct current use impairments. The Pa. DEP welcomes local efforts to support these watershed restoration plans. For more information about this TMDL, interested parties should contact the appropriate Watershed Manager in the Pa. DEP's Southcentral Regional Office (717-705-4700).

IX. Public Participation

A notice of availability for comments on the draft UNT 09749 watershed TMDL was published in the PA Bulletin on December 14, 2002. The document is on the Pa. DEP's web page, at http://www.dep.state.pa.us/watermanagement_apps/tmdl. In addition, a public meeting was held on January 13, 2003, at 7 PM in the East Hanover Township Building, Lebanon County to address any outstanding concerns regarding the draft TMDLs. A 60-day period (ended on February 14, 2003) was provided for the submittal of comments. Comments and responses are summarized in Appendix G.

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

Literature Cited

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

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

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

Appendix A. Information Sheet for the UNT 09749 Watershed TMDL

What is being proposed?

Total Maximum Daily Load (TMDL) plans have been developed to improve water quality in an unnamed tributary (UNT 09749) to Swatara Creek.

Who is proposing the plans? Why?

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

What is a TMDL?

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

What is a water quality standard?

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

What is the purpose of the plans?

The UNT 09749 watershed is impaired due to organic enrichment and low dissolved oxygen. The plans include a calculation of the loading for nutrients that will correct the problem and meet water quality objectives.

Why was the UNT 09749 watershed selected for TMDL development?

In 1996, Pa. DEP listed a portion of the UNT 09749 watershed under Section 303(d) of the federal Clean Water Act as impaired due to organic enrichment and low dissolved oxygen from agricultural activities.

What pollutants do these TMDLs address?

The proposed plans provide calculations of the stream's total capacity to accept phosphorus. Based on an evaluation of the concentrations of nutrients in UNT 09749, phosphorus is the cause of nutrient impairment to the stream.

Where do the pollutants come from?

The nutrient related impairment in the UNT 09749 watershed comes from nonpoint sources of pollution, primarily overland runoff from agricultural, developed, and disturbed land uses.

How was the TMDL developed?

Pa. DEP used a reference watershed approach to estimate the necessary loading reduction of 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, Pa. DEP used the AVGWLF model (the Environmental Resources Research Institute of the Pennsylvania State University's Arcview based version of the Generalized Watershed Loading Function model developed by Cornell University). This modeling process uses loading rates in the nonimpaired watershed as a target for load reductions in the impaired watershed. The impaired watershed is modeled to determine the current loading rates and determine what reductions are necessary to meet the loading rates of the nonimpaired watershed. The reference stream approach was used to set allowable loading rates in the affected watershed because neither Pennsylvanian nor USEPA has water quality criteria for phosphorus.

How much pollution is too much?

The allowable amount of pollution in a water body varies depending on several conditions. TMDLs are set to meet water quality standards at the critical flow condition. For a free flowing stream impacted by nonpoint source pollution loading of nutrients, the TMDL is expressed as an annual loading. This accounts for pollution contributions over all stream flow conditions. Pa. DEP established the water quality objectives for 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 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 Bill Brown at (717) 783-2951 between 8:00 a.m. and 3:00 p.m., Monday through Friday. Mr. Brown also can be reached by mail at the Office of Water Management, PADEP, Rachel Carson State Office Building, 400 Market Street, Harrisburg, PA 17105 or by e-mail at willbrown@state.pa.us.

How can I comment on the proposal?

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

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

The TMDL for the UNT 09749 watershed was developed using the Generalized Watershed Loading Function or GWLF model. The GWLF model provides the ability to simulate runoff, sediment, and nutrient (nitrogen and phosphorus) loadings from watershed given variable-size source areas (e.g., agricultural, forested, and developed land). It also has algorithms for calculating septic system loads, and allows for the inclusion of point source discharge data. It is a continuous simulation model, which uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment and nutrient loads, based on the daily water balance accumulated to monthly values.

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

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

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

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

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

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

Adjustments made to specific AVGWLF model parameters, based on existing land use practices in each of the watersheds, included:

UNT 09749 Watershed (both subbasins)

- Reset default C factor for cropland (0.21) and 0.40 to reflect the presence of large continuous cornfields and a general lack of strip cropping, contour plowing, and cover crops. Hay/pasture (0.03) was reset to 0.40 as well to reflect the effects of heavily grazed pastureland.
- Reset default P factors for cropland and hay/pasture land uses (0.52) to 0.60 to account for:
  - Pastures and cropland generally extending right up to streambanks with unrestricted livestock access to the streams.
  - Poor quality riparian vegetation resulting in many exposed banks.

UNTREF Watershed

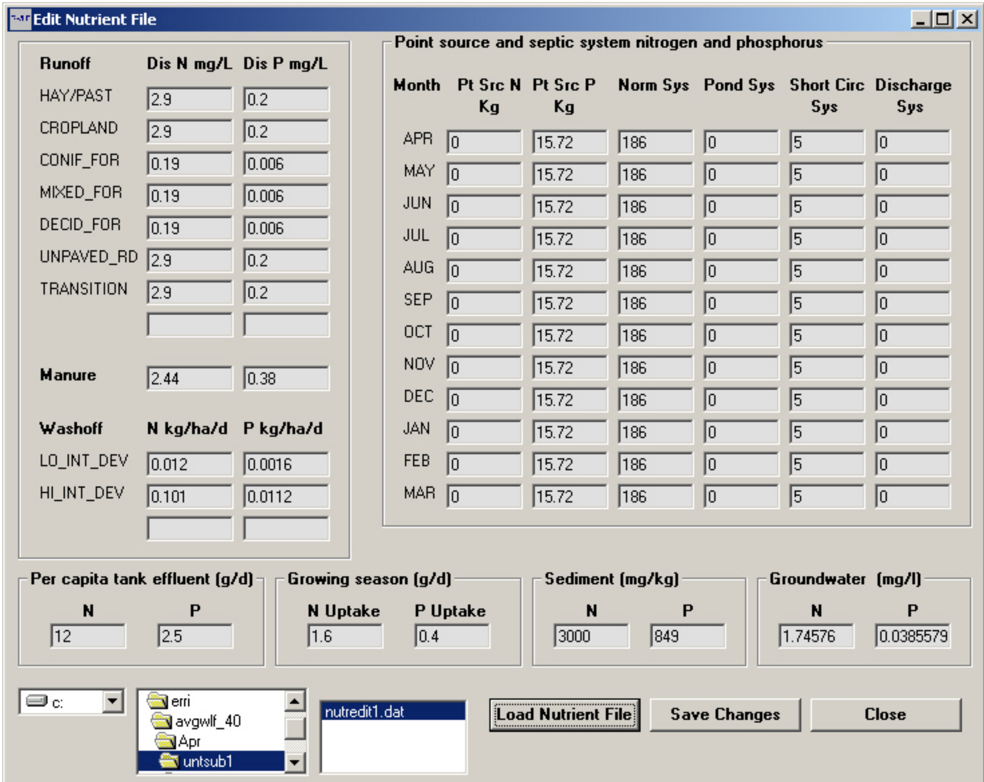
- Reset C factor for cropland (0.21) to 0.18, respectively to account for prevalent use of strip cropping, contour plowing, and cover crops.
- Reset P factor for cropland (0.52) and hay/pasture (0.52) land uses to 0.30, respectively to account for the pervasiveness of riparian buffer zones, streambank fencing, and stable streambanks.
- The nutrient concentrations in runoff and manure also were reset to match the settings for UNT 09749. Using the default values, the UNTREF watershed had abnormally high nutrient concentrations in relation to the activities present in the watershed. Upon comparison of UNT 09749 and UNTREF, there were no significant differences between animal operations present in either watershed. However, the model was introducing large concentrations to the UNTREF nutrient input file based on turkey/chicken operations located in the southern portion of the zip code area. Animal operation activities in the UNTREF area were a better match to those in the UNT 09749 watershed, so nutrient concentrations in manure and runoff were changed to reflect the same conditions.

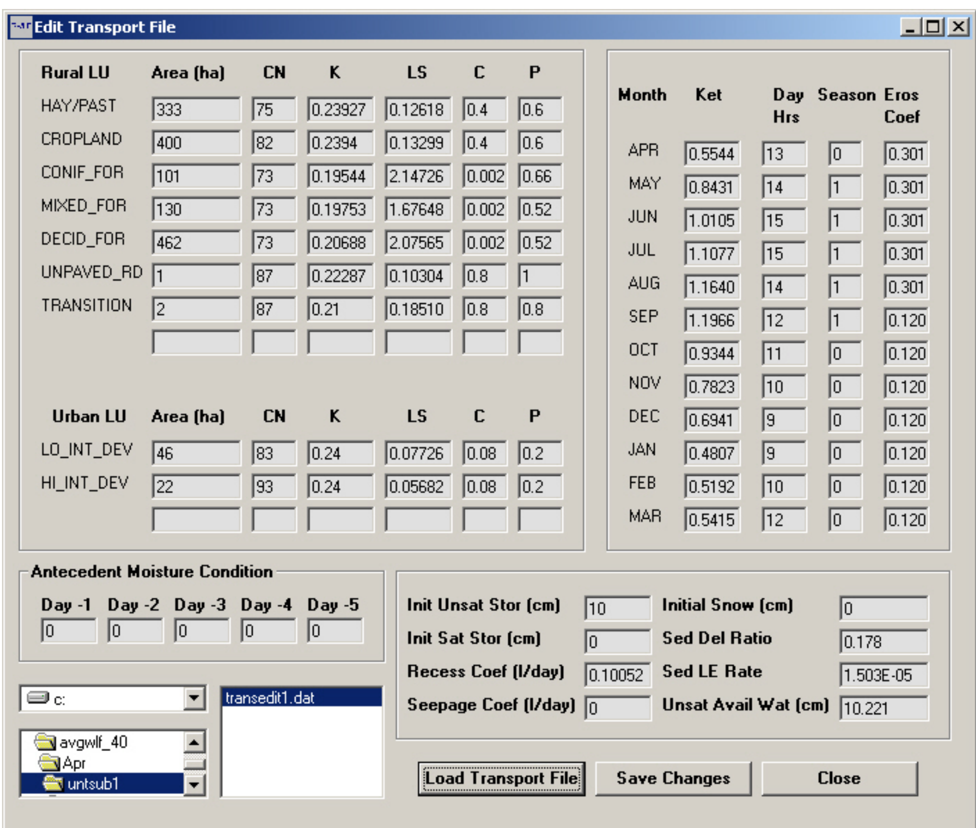
The following table lists the statewide GIS data sets and provides an explanation of how they were used for development of the input files for the GWLF model.

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

Appendix C. AVGWLF Model Outputs for the UNT 09749 Watershed

Subbasin 1





Average Loads by Month

GWLF Nutrient Summary for untsub1

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

	MG (1000 Kg)		Nutrient Loads (Kg)			
Month	Erosion	Sediment	Dis. Nitr.	Tot. Nitr.	Dis. Phos.	Tot. Phos
APR	193.0	5.2	1911.3	1930.0	62.1	67.4
MAY	297.8	7.7	1509.2	1534.9	53.1	60.3
JUN	173.2	7.1	732.9	756.0	39.3	45.9
JUL	311.2	15.3	317.1	363.9	35.9	49.2
AUG	186.2	4.2	91.2	104.2	19.7	23.4
SEP	94.2	16.0	103.8	152.0	22.7	36.4
OCT	73.9	21.9	249.6	315.8	26.9	45.6
NOV	89.7	24.5	774.9	849.6	40.0	61.1
DEC	51.0	29.1	1478.4	1568.0	54.6	79.9
JAN	28.1	55.4	1482.8	1651.4	81.4	129.1
FEB	30.9	55.7	1857.2	2027.0	92.4	140.4
MAR	59.1	40.8	2238.6	2364.1	72.7	108.2
Total	1588.4	282.7	12747.0	13617.0	600.8	846.9

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Average Hydrology by Month in Standard Units

GWLF Transport Summary for untsub1

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

	Units in Inches				
Month	Precip	Evapotrans	Gr. Wat. Flow	Runoff	Streamflow
APR	3.38	1.07	2.46	0.23	2.69
MAY	4.48	2.73	1.92	0.20	2.12
JUN	3.41	4.65	0.94	0.12	1.05
JUL	4.36	4.73	0.30	0.18	0.48
AUG	3.26	3.65	0.07	0.05	0.13
SEP	3.21	2.24	0.01	0.15	0.15
OCT	2.82	1.35	0.18	0.19	0.37
NOV	3.63	0.64	0.86	0.25	1.11
DEC	2.81	0.25	1.84	0.26	2.10
JAN	2.93	0.11	1.69	0.49	2.19
FEB	2.70	0.18	2.18	0.54	2.72
MAR	3.47	0.57	2.80	0.34	3.15
Total	40.46	22.18	15.25	3.00	18.25

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Average Loads by Source

GWLF Total Loads for untsub1

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

Source	(Ha) Area	(cm) Runoff	Mg (1000 Kg) Erosion	Mg (1000 Kg) Sediment	Total Loads (Kg) Dis. Nitr.	Total Loads (Kg) Tot. Nitr.	Total Loads (Kg) Dis. Phos.	Total Loads (Kg) Tot. Phos.
HAY/PAST	333	6.18	653.73	116.36	553.07	902.16	58.12	156.92
CROPLAND	400	11.07	828.04	147.39	1196.42	1638.59	122.94	248.08
CONIF_FOR	101	5.23	15.16	2.7	10.03	18.12	0.32	2.61
MIXED_FOR	130	5.23	12.13	2.16	12.91	19.39	0.41	2.24
DECID_FOR	462	5.23	55.9	9.95	45.88	75.73	1.45	9.9
UNPAVED_RD	1	17.17	4.98	0.89	4.98	7.64	0.34	1.1
TRANSITION	2	17.17	13.48	2.4	9.96	17.16	0.69	2.72
LO_INT_DEV	46	12.05	3.7	0.66	0.0	0.13	0.0	0.02
HI_INT_DEV	22	31.62	1.3	0.23	0.0	0.34	0.0	0.04
Stream Bank				14.2		21.3		6.0
Groundwater					10123.36	10123.36	223.59	223.59
Point Sources					0	0	188.64	188.64
Septic Syst.					790.4	790.4	4.26	4.26
Totals	1497	7.6	1588.4	296.9	12747.0	13614.36	600.76	846.14

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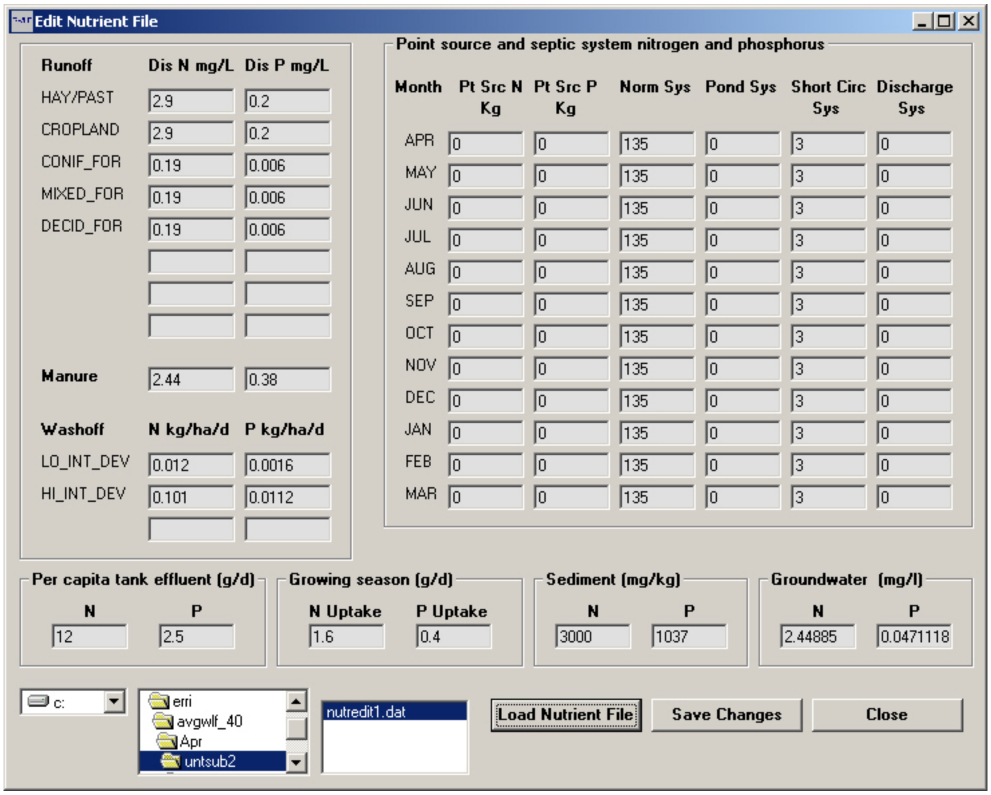
Source	Area (acres)	Runoff (in/yr)	Erosion (tons/yr)	Sediment (tons/yr)	Dis. Nitr (lbs/yr)	Tot. Nitr (lbs/yr)	Dis. Phos (lbs/yr)	Tot. Phos (lbs/yr)
HAY/PAST	822.9	2.43	720.62	128.3	1219.3	1988.9	128.1	345.9
CROPLAND	988.4	4.36	912.75	162.5	2637.7	3612.5	271	546.9
CONIF_FOI	249.6	2.06	16.71	3	22.1	40	0.7	5.7
MIXED_FO	321.2	2.06	13.37	2.4	28.5	42.7	0.9	4.9
DECID_FOI	1141.6	2.06	61.61	11	101.1	167	3.2	21.8
UNPAVED_	2.5	6.76	5.49	1	11	16.8	0.8	2.4
TRANSITIO	4.9	6.76	14.86	2.6	22	37.8	1.5	6
LO_INT_DE	113.7	4.75	4.08	0.7	0	0.3	0	0
HI_INT_DE'	54.4	12.45	1.43	0.3	0	0.7	0	0.1
Stream Banl				15.6893		47.0678		13.3201
Groundwatı					22318.2	22318.2	492.9	492.9
Point Sourc					0	0	415.9	415.9
Septic Syst					1742.5	1742.5	9.4	9.4
TOTAL								

Page 1

UNT-sub1

Subbasin 2



Edit Nutrient File

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

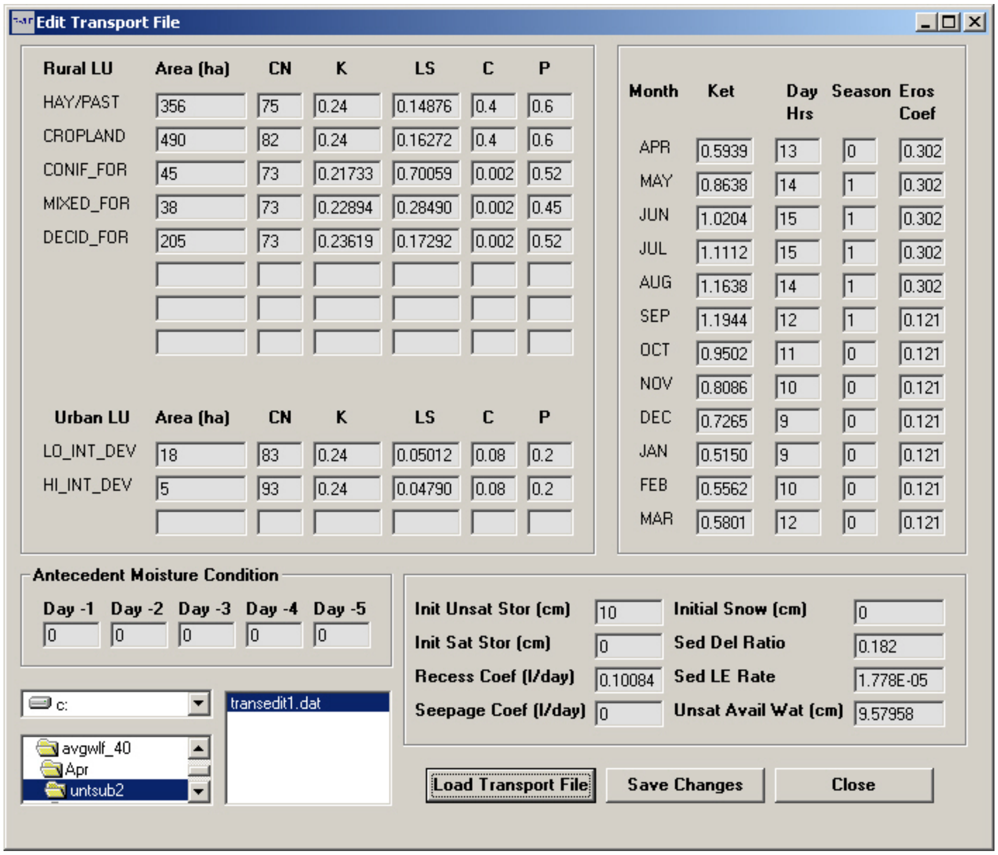
Washoff	N kg/ha/d	P kg/ha/d
LO_INT_DEV	0.012	0.0016
HI_INT_DEV	0.101	0.0112

Point source and septic system nitrogen and phosphorus

Month	Pt Src N Kg	Pt Src P Kg	Norm Sys	Pond Sys	Short Circ Sys	Discharge Sys
APR	0	0	135	0	3	0
MAY	0	0	135	0	3	0
JUN	0	0	135	0	3	0
JUL	0	0	135	0	3	0
AUG	0	0	135	0	3	0
SEP	0	0	135	0	3	0
OCT	0	0	135	0	3	0
NOV	0	0	135	0	3	0
DEC	0	0	135	0	3	0
JAN	0	0	135	0	3	0
FEB	0	0	135	0	3	0
MAR	0	0	135	0	3	0

Per capita tank effluent (g/d) N	P	Growing season (g/d) N Uptake	P Uptake	Sediment (mg/kg) N	P	Groundwater (mg/l) N	P
12	2.5	1.6	0.4	3000	1037	2.44885	0.0471118

c: | erri, avgwlf_40, Apr, untsub2 | nutredit1.dat | Load Nutrient File | Save Changes | Close



Edit Transport File

Rural LU	Area (ha)	CN	K	LS	C	P
HAY/PAST	356	75	0.24	0.14876	0.4	0.6
CROPLAND	490	82	0.24	0.16272	0.4	0.6
CONIF_FOR	45	73	0.21733	0.70059	0.002	0.52
MIXED_FOR	38	73	0.22894	0.28490	0.002	0.45
DECID_FOR	205	73	0.23619	0.17292	0.002	0.52

Urban LU	Area (ha)	CN	K	LS	C	P
LO_INT_DEV	18	83	0.24	0.05012	0.08	0.2
HI_INT_DEV	5	93	0.24	0.04790	0.08	0.2

Month	Ket	Day Hrs	Season	Eros Coef
APR	0.5939	13	0	0.302
MAY	0.8638	14	1	0.302
JUN	1.0204	15	1	0.302
JUL	1.1112	15	1	0.302
AUG	1.1638	14	1	0.302
SEP	1.1944	12	1	0.121
OCT	0.9502	11	0	0.121
NOV	0.8086	10	0	0.121
DEC	0.7265	9	0	0.121
JAN	0.5150	9	0	0.121
FEB	0.5562	10	0	0.121
MAR	0.5801	12	0	0.121

Antecedent Moisture Condition

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

Init Unsat Stor (cm)	10	Initial Snow (cm)	0
Init Sat Stor (cm)	0	Sed Del Ratio	0.182
Recess Coef (l/day)	0.10084	Sed LE Rate	1.778E-05
Seepage Coef (l/day)	0	Unsat Avail Wat (cm)	9.57958

c: | avgwlf_40, Apr, untsub2 | transedit1.dat | Load Transport File | Save Changes | Close

Average Loads by Month

GWLF Nutrient Summary for untsub2

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

	MG (1000 Kg)		Nutrient Loads (Kg)			
Month	Erosion	Sediment	Dis. Nitr.	Tot. Nitr.	Dis. Phos.	Tot. Phos
APR	253.2	7.0	1983.9	2007.5	44.8	53.0
MAY	390.6	10.5	1549.7	1583.4	36.0	47.7
JUN	227.2	9.6	748.0	778.2	23.7	34.2
JUL	408.2	20.8	332.0	395.1	22.2	44.0
AUG	244.2	6.1	97.6	116.2	4.2	10.6
SEP	123.6	21.5	120.7	185.6	8.0	30.4
OCT	96.9	29.0	288.5	376.1	12.4	42.7
NOV	117.6	33.1	880.3	980.9	26.0	60.8
DEC	66.8	38.7	1599.0	1717.4	39.2	80.1
JAN	36.9	73.4	1578.9	1801.4	70.4	147.3
FEB	40.5	74.3	1956.1	2181.6	81.3	159.3
MAR	77.5	55.1	2341.6	2509.8	56.1	114.3
Total	2083.2	379.1	13476.3	14633.1	424.4	824.2

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Average Hydrology by Month in Standard Units

GWLF Transport Summary for untsub2

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

	Units in Inches				
Month	Precip	Evapotrans	Gr. Wat. Flow	Runoff	Streamflow
APR	3.38	1.15	2.39	0.24	2.64
MAY	4.48	2.80	1.84	0.21	2.06
JUN	3.41	4.64	0.89	0.12	1.02
JUL	4.36	4.58	0.28	0.20	0.48
AUG	3.26	3.57	0.07	0.06	0.13
SEP	3.21	2.22	0.01	0.16	0.17
OCT	2.82	1.37	0.20	0.20	0.40
NOV	3.63	0.67	0.91	0.27	1.19
DEC	2.81	0.26	1.86	0.28	2.15
JAN	2.93	0.12	1.68	0.53	2.21
FEB	2.70	0.19	2.14	0.58	2.72
MAR	3.47	0.61	2.74	0.37	3.12
Total	40.46	22.18	15.03	3.23	18.27

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Average Loads by Source

GWLF Total Loads for untsub2

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

Source	(Ha) Area	(cm) Runoff	Mg (1000 Kg) Erosion	Sediment	Total Loads (Kg) Dis. Nitr.	Tot. Nitr.	Dis. Phos.	Tot. Phos.
HAY/PAST	356	6.18	828.97	150.87	591.26	1043.88	62.14	218.59
CROPLAND	490	11.07	1248.12	227.16	1465.61	2147.09	150.6	386.17
CONIF_FOR	45	5.23	1.94	0.35	4.47	5.53	0.14	0.51
MIXED_FOR	38	5.23	0.61	0.11	3.77	4.1	0.12	0.23
DECID_FOR	205	5.23	2.37	0.43	20.36	21.65	0.64	1.09
LO_INT_DEV	18	12.05	0.94	0.17	0.0	0.01	0.0	0.0
HI_INT_DEV	5	31.62	0.25	0.05	0.0	0.02	0.0	0.0
Stream Bank				12.9		19.4		6.7
Groundwater					10819.76	10819.76	208.15	208.15
Point Sources					0	0	0	0
Septic Syst.					571.07	571.07	2.56	2.56
Totals	1157	8.2	2083.2	392.0	13476.31	14632.49	424.35	824.0

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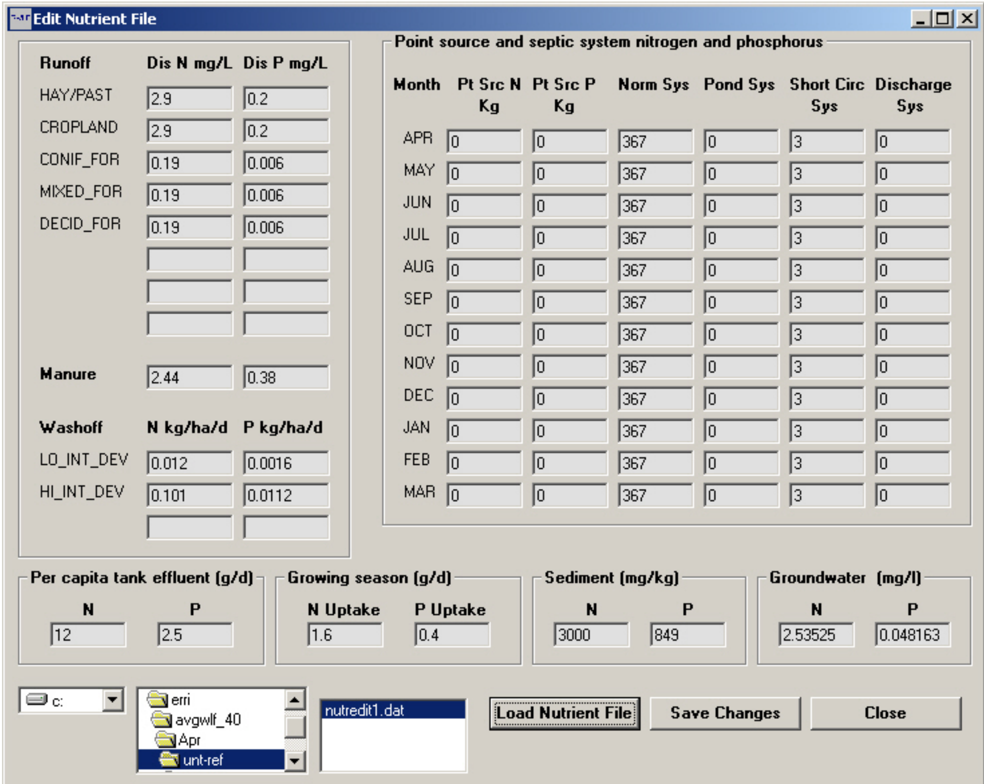
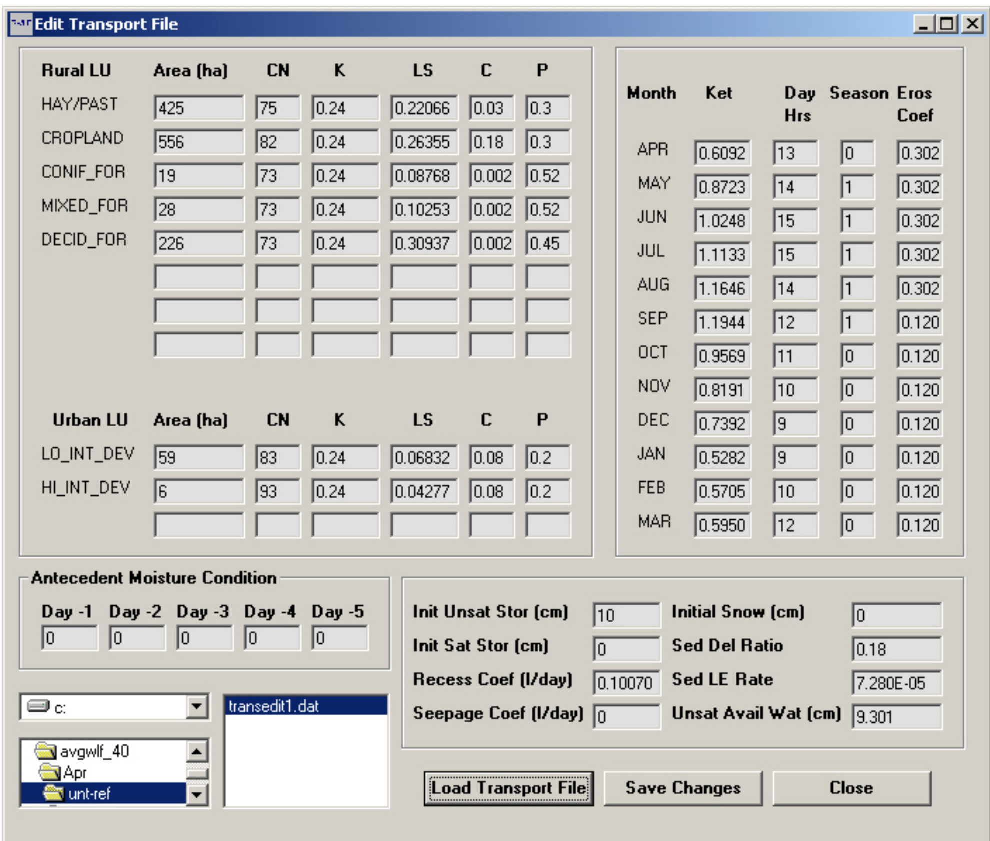
Source	Area (acres)	Runoff (in/yr)	Erosion (tons/yr)	Sediment (tons/yr)	Dis. Nitr (lbs/yr)	Tot. Nitr (lbs/yr)	Dis. Phos (lbs/yr)	Tot. Phos (lbs/yr)
HAY/PAST	879.7	2.43	913.79	166.3	1303.5	2301.4	137	481.9
CROPLANE	1210.8	4.36	1375.82	250.4	3231.1	4733.5	332	851.4
CONIF_FOI	111.2	2.06	2.13	0.4	9.9	12.2	0.3	1.1
MIXED_FO	93.9	2.06	0.67	0.1	8.3	9	0.3	0.5
DECID_FOI	506.6	2.06	2.61	0.5	44.9	47.7	1.4	2.4
LO_INT_DE	44.5	4.75	1.04	0.2	0	0	0	0
HI_INT_DE'	12.4	12.45	0.28	0.1	0	0	0	0
Stream Banl				14.2329		42.6986		14.7595
Groundwat					23853.5	23853.5	458.9	458.9
Point Sourc					0	0	0	0
Septic Syst					1259	1259	5.6	5.6
TOTAL								
			UNT-sub2					

Page 1

Appendix D. AVGWLF Model Inputs for the UNTREF Watershed





Average Loads by Month

GWLF Nutrient Summary for unt-ref

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

	MG (1000 Kg)		Nutrient Loads (Kg)			
Month	Erosion	Sediment	Dis. Nitr.	Tot. Nitr.	Dis. Phos.	Tot. Phos
APR	73.5	2.1	2451.4	2465.2	53.5	57.4
MAY	109.4	3.0	1908.4	1923.6	41.8	46.1
JUN	79.7	4.4	902.1	919.4	30.7	35.6
JUL	142.1	8.4	425.9	453.3	39.8	47.6
AUG	66.6	4.3	195.1	209.1	8.5	12.4
SEP	37.4	7.5	163.0	186.5	9.8	16.4
OCT	35.3	9.9	510.8	542.3	18.3	27.2
NOV	40.2	9.1	1354.3	1385.2	36.5	45.3
DEC	21.1	13.7	2210.8	2258.4	49.8	63.3
JAN	11.7	22.1	2037.1	2109.6	88.9	109.4
FEB	11.0	18.9	2175.2	2238.3	73.3	91.1
MAR	20.4	13.4	2656.4	2703.7	58.6	72.0
Total	648.4	116.7	16990.3	17394.6	509.4	623.8

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Average Hydrology by Month in Standard Units

GWLF Transport Summary for unt-ref

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

	Units in Inches				
Month	Precip	Evapotrans	Gr. Wat. Flow	Runoff	Streamflow
APR	3.41	1.18	2.34	0.29	2.63
MAY	4.48	2.83	1.81	0.23	2.04
JUN	3.50	4.61	0.83	0.17	1.00
JUL	4.92	4.70	0.20	0.36	0.56
AUG	3.22	3.62	0.10	0.13	0.23
SEP	3.32	2.23	0.03	0.17	0.20
OCT	3.17	1.42	0.35	0.23	0.58
NOV	3.79	0.68	1.17	0.33	1.49
DEC	2.85	0.28	2.10	0.30	2.39
JAN	2.92	0.12	1.73	0.61	2.34
FEB	2.42	0.19	2.01	0.40	2.41
MAR	3.24	0.63	2.53	0.33	2.85
Total	41.24	22.50	15.18	3.55	18.73

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Average Loads by Source

GWLF Total Loads for unt-ref

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

Source	(Ha) Area	(cm) Runoff	Mg (1000 Kg) Erosion	Mg (1000 Kg) Sediment	Total Loads (Kg) Dis. Nitr.	Total Loads (Kg) Tot. Nitr.	Total Loads (Kg) Dis. Phos.	Total Loads (Kg) Tot. Phos.
HAY/PAST	425	6.68	61.54	11.08	763.58	796.82	79.96	89.37
CROPLAND	556	11.78	576.93	103.85	1771.62	2083.16	181.03	269.2
CONIF_FOR	19	5.68	0.13	0.02	2.05	2.12	0.06	0.08
MIXED_FOR	28	5.68	0.22	0.04	3.02	3.14	0.1	0.13
DECID_FOR	226	5.68	4.59	0.83	24.4	26.88	0.77	1.47
LO_INT_DEV	59	12.8	4.7	0.85	0.0	0.26	0.0	0.03
HI_INT_DEV	6	32.82	0.3	0.05	0.0	0.02	0.0	0.0
Stream Bank				35.9		53.9		15.3
Groundwater					12894.53	12894.53	244.96	244.96
Point Sources					0	0	0	0
Septic Syst.					1531.13	1531.13	2.56	2.56
Totals	1319	9.0	648.4	152.6	16990.33	17391.94	509.44	623.06

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Source	Area (acres)	Runoff (in/yr)	Erosion (tons/yr)	Sediment (tons/yr)	Dis. Nitr (lbs/yr)	Tot. Nitr (lbs/yr)	Dis. Phos (lbs/yr)	Tot. Phos (lbs/yr)
HAY/PAST	1050.2	2.63	67.84	12.2	1683.4	1756.7	176.3	197
CROPLANI	1373.9	4.64	635.96	114.5	3905.7	4592.6	399.1	593.5
CONIF_FOI	46.9	2.24	0.14	0	4.5	4.7	0.1	0.2
MIXED_FO	69.2	2.24	0.24	0	6.7	6.9	0.2	0.3
DECID_FOI	558.5	2.24	5.06	0.9	53.8	59.3	1.7	3.2
LO_INT_DE	145.8	5.04	5.18	0.9	0	0.6	0	0.1
HI_INT_DE	14.8	12.92	0.33	0.1	0	0	0	0
Stream Banl				39.6011		118.803		33.6213
Groundwat					28427.5	28427.5	540	540
Point Sourc					0	0	0	0
Septic Syst					3375.6	3375.6	5.6	5.6
TOTAL								
			UNT-ref					

Appendix E. Equal Marginal Percent Reduction Method

The Equal Marginal Percent Reduction (EMPR) allocation method was used to distribute Adjusted Load Allocations (ALAs) between the appropriate contributing nonpoint sources. The total phosphorus ALA was distributed between hay/pasture, cropland, developed, and disturbed lands. The EMPR process is summarized below:

1. Each land use/source load is compared with the total allocable load to determine if any contributor would exceed the allocable load by itself. The evaluation is carried out as if each source is the only contributor to the pollutant load of the receiving waterbody. If the contributor exceeds the allocable load, that contributor would be reduced to the allocable load. This is the baseline portion of EMPR.

2. After any necessary reductions have been made in the baseline, the multiple analyses are run. The multiple analyses will sum all of the baseline loads and compare them to the total allocable load. If the allocable load is exceeded, an equal percent reduction will be made to all contributors' baseline values. After any necessary reductions in the multiple analyses, the final reduction percentage for each contributor can be computed.

3. The load allocation and EMPR procedures were performed using MS Excel and results are presented in Appendix F.

Appendix F. Equal Marginal Percent Reduction Calculations for UNT 09749

Step 1:	TMDL Total Load				Step 2:	Adjusted LA = (TMDL total load - MOS) - uncontrollable						
	Load = TP loading rate in ref. * Acres in Impaired					192.26	192.26					
	1575.07											
Step 3:		Annual Average Load	Load Sum	Check	Initial Adjust	Recheck	% reduction allocation	Load Reduction	Initial LA	Acres	Allowable Loading Rate	% Reduction
	Hay/Past.	359.22	924.02	bad	192	ADJUST	0.48	100	91.85	799	0.11	74%
	Cropland	546.90		bad	192	210	0.48	100	91.85	1019	0.09	83%
	Developed	9.50		good	10		0.02	5	4.54	166	0.03	52%
	Disturbed	8.40		good	8		0.02	4	4.01	12	0.33	52%
	Total	924.02			402.42096		1		192.26			
Step 4:	All Ag. Loading Rate	0.10										
Step 5:		Acres	Allowable (Target) Loading Rate	Final LA	Current Loading Rates	Current Load	% Red.					
	Final Hay/Past. LA	799	0.10	80.78	0.45	359.22	78%					
	Final Cropland LA	1019	0.10	102.93	0.54	546.90	81%					
	Developed	166	0.03	4.54	0.06	9.50	52%					
	Disturbed	12	0.33	4.01	0.69	8.40	52%					
				192.26		924.02						
	SUBBASIN 1											

Step 1:	TMDL Total Load				Step 2:	Adjusted LA = (TMDL total load - MOS) - uncontrollable						
	Load = TP loading rate in ref. * Acres in Impaired					633.63	634					
	1218											
Step 3:		Annual Average Load	Load Sum	Check	Initial Adjust	Recheck	% reduction allocation	Load Reduction	Initial LA	Acres	Allowable Loading Rate	% Reduction
	Hay/Past.	496.66	1353.66	good	497	ADJUST	0.44	220	277.05	924	0.30	44.2%
	Cropland	851.40		bad	634	502	0.56	280	353.46	1194	0.30	58.5%
	Developed	5.60		good	6		0.00	2	3.12	50	0.06	44.2%
	Disturbed	0.00		good	0		0.00	0	0.00	0		
	Total	1353.66			1135.89		1		633.63			
Step 4:	All Ag. Loading Rate	0.30										
Step 5:		Acres	Allowable (Target) Loading Rate	Final LA	Current Loading Rates	Current Load	% Red.					
	Final Hay/Past. LA	924	0.30	275	0.54	497	45%					
	Final Cropland LA	1194	0.30	355	0.71	851	58%					
	Developed	50	0.06	3	0.11	6	44%					
	SUBBASIN 2											

Appendix G. Comment & Response Document
UNT 09749 Watershed TMDLs

Comment

Pages 12 and 13 Watershed Assessment and Modeling: If PADEP reset some reference watershed parameters, is it truly a reference – or is it a virtual reference watershed? Please explain in this discussion.

Response

The zip code data for the reference watershed was incorrect, causing the model to introduce large amounts of nutrients from animal operations that are non-existent within the watershed. The model was adjusted to correct for this error, producing model output that is a better representation of actual conditions than if the default parameters were utilized. The explanation in the document was rephrased to be clearer.

Comment

Page 19, Table 8: Point source loading of 700 pounds/year is significant in subbasin 1. Please provide an explanation for not imposing a reduction.

Response

Please see Section IV, Part B. – Wasteload Allocation. The permitted loading for phosphorus is approximately 1,400 lbs/year, so the WLA of 700 lbs/year actually represents a 50 percent reduction in the facility's permitted load. According to the latest PADEP stream assessment data, the facility is not contributing to nutrient impairment (Please note location of point source discharge in relation to nutrient impaired segment in Figure 1).

Comment

Every stream listed in the 1996 and 1998 303(d) lists must have a separate location.

Response

Within the entire UNT Swatara watershed, there is only one stream segment listed for a nutrient-related impairment on the 1996 and 1998 303(d) lists.