Total Maximum Daily Load (TMDL) For Nutrients and Sediments in the Donegal Creek

Lancaster County

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Office of Water Management, Bureau of Watershed Conservation
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TMDLs for Donegal Creek Watershed

Executive Summary

The Donegal Creek watershed in Lancaster County is 17.2 square miles. The protected uses of the watershed are water supply, recreation and aquatic life. The aquatic use for the main stem Donegal Creek is trout stocking fishes, for the unnamed tributaries is cold water fishes, and for Donegal Springs is high quality cold water fishes.

Total Maximum Daily Loads or TMDLs were developed for the Donegal Creek watershed to address the impairments noted on Pennsylvania's 1996 and 1998 Clean Water Act Section 303(d) Lists. The impairments were found during biological surveys of the aquatic life in the stream. The impairments are caused by excess nutrient and sediment loads from agriculture. The nutrient portion of the TMDL focuses on control of phosphorus. Phosphorus is generally held to be the limiting nutrient in a waterbody when the nitrogen/phosphorus ratio exceeds 10 to 1; in Donegal Creek the ratio is 37 to1.

Pennsylvania does not currently have water quality criteria for sediment or phosphorus. For this reason, we developed a reference watershed approach to identify the TMDL endpoints or water quality objectives for phosphorus and sediment in the impaired segments of the Donegal Creek watershed. By comparison to a similar non-impaired watershed, Pennsylvania estimated that the amount of phosphorus loading that will meet the water quality objectives for Donegal Creek is 3,287 pounds per year. Sediment loading must be limited to 792,998 pounds per year. When these values are met, Donegal Creek will support its aquatic life uses.

The TMDLs for Donegal Creek are allocated as shown in the table below.

TMDL for Donegal Creek

Pollutant	TMDL (lb/yr)	LA (lb/yr)	WLA (lb/yr)	MOS (lb/yr)
Phosphorus	3,287	2,958	0	329
Sediment	792,998	713,698	0	79,300

The TMDLs are allocated to the agricultural non-point sources (Load Allocations - LAs) with 10% of the allowable loading reserved as a margin of safety (MOS). There are no wasteload allocations (WLA) for point sources because there are no known point source discharges in the impaired areas of the watershed. The TMDLs cover a total of 9.67 miles of the main stem Donegal Creek and an Unnamed Tributary. The TMDL establishes a reduction for phosphorus loading of 50% from the current yearly loading of 5,924 pounds, and a reduction in sediment loading of 61% from the current yearly loading of 1,813,165 pounds.

A more complete discussion of the Donegal Creek TMDLs and TMDLs in general are contained in the Information Sheet and the body of this document.

Introduction

Total Maximum Daily Loads or TMDLs were developed for the Donegal Creek watershed to address the impairments noted on Pennsylvania's 1996 and 1998 Clean Water Act Section 303(d) Lists.

It was first determined that Donegal Creek was not meeting its designated water quality uses for protection of aquatic life based on a 1994 aquatic biological survey, which included kick screen analysis and habitat surveys. In 1997, the Department again surveyed the stream and found the stream to still be impaired. As a consequence of the surveys, Pennsylvania listed Donegal Creek and an unnamed tributary on the 1996 and 1998 Section 303(d) Lists of Impaired Waters. The 1998 list did not add any new segments to the 1996 list although the affected miles increased. The stream was listed because of impacts by sediments, nutrients, organic enrichment, and low dissolved oxygen from agriculture. Pennsylvania is using a method to develop TMDLs based on comparing the impacted watershed to a reference watershed to determine the appropriate watershed loading for nutrients and sediments. Based on the predominance of agricultural land use in the watershed, nutrients and sediments are the most likely pollutants causing Donegal Creek to violate the aquatic life use. Therefore, the TMDLs proposes reducing the phosphorus and sediment loadings in Donegal Creek watershed to levels consistent with Brubaker Run watershed, the reference watershed. Because of the similarities in landuse between the two watersheds, achieving phosphorus and sediment loadings in the Donegal Creek TMDL will ensure that the aquatic life use is achieved and maintained as evidenced in Brubaker Run.

Table 1. 1996 Section 303(d) Listing for Donegal Creek Watershed

Segment ID	Stream Code	Stream	Source Code	Cause Code	Miles Degraded
7036	07920	Donegal Creek	Agriculture	Suspended Solids	1.5
				Organic enrichments/DO	0.5
				Nutrients	2.1
6424	07920	UNT Donegal Creek	Agriculture	Suspended Solids	1.7
				Organic Enrichments	0.4
				Nutrients	0.1

Table 2. 1998 Section 303(d) Listing for Donegal Creek Watershed

Segment ID	Stream Code	Stream Name	Source	Cause	Miles
7036	07920	Donegal Creek	Agriculture	Siltation	2.53
			Agriculture	Organic Enrichments/Low DO	
			Agriculture	Nutrients	7.14

The primary method that the Department has adopted for evaluating the waters of the Commonwealth changed between the publication of the 1996 and 1998 303(d) lists. The Department is now using a modification of EPA's Rapid Bioassessment Protocol II (RPB-II) as the primary mechanism to assess Pennsylvania's unassessed waters. The assessment method requires selecting stream sites that would reflect impacts from surrounding land uses that are representative of the stream segment being assessed. The biologist selects as many sites as necessary to establish an accurate assessment for a stream segment. At each site, a biological assessment is conducted using the modified RBP II method. The length of stream that can be assessed per site varies. There are several factors that determine site location and how long a "single site" assessed segment can be. Some of these factors are distinct changes in stream characteristics, surface geology, riparian land use, point-source and nonpoint-source discharge locations, and the pollutant that is causing impairment.

For the purpose of TMDL development it is often necessary to aggregate 303(d) listed stream segments together. The primary reason to address multiple segments is compatibility with data used in TMDL analysis, as in impairment caused by excess nutrient and sediment. For these TMDL analyses the primary data sources are geographic information system (GIS) derived data. The land cover data set used for this analysis is represented by 100 meter squares. If the stream segment area for TMDL development is too small error is introduced by using the data beyond its capability. For this reason we have aggregated the two segments listed in the Donegal Creek watershed. This results in completing TMDLs for both segments, although the analysis was completed as one watershed area.

Neither Pennsylvania nor EPA currently has water quality criteria for sediment or nutrients. It is for this reason, we developed a reference watershed approach to identify the TMDL endpoints or water quality objectives for nutrients and sediment in the impaired segments of the Donegal Creek watershed. The nutrient portion of the TMDL for this watershed only addresses phosphorus because it was determined that phosphorus was the limiting nutrient in the stream. Phosphorus is generally held to be the limiting nutrient in a waterbody when the nitrogen/phosphorus ratio exceed 10 to 1, the ratio in Donegal Creek is 37 to1.

Reference Watershed Approach

Since PA has no instream criteria for the pollutants of concern we adopted a reference watershed approach to set allowable loading rates in the affected watersheds. The reference watershed approach is used to estimate the necessary loading reduction of phosphorus and sediment that would be needed to restore a healthy aquatic community and allow the streams in the watershed to achieve their designated uses. The reference watershed approach is based on selecting a non-impaired 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 we 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 non-impaired watershed as a target for loading 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 non-impaired watershed.

GWLF models surface runoff using the Soil Conservation Service Curve Number (SCS-CN) approach with daily weather (temperature and precipitation) inputs. All of the equations used by the model can be viewed in Attachment E, GWLF Users Manuel.

The Donegal Creek Watershed TMDL Information Sheet that is attached to this document provides a primer for TMDLs (What are they and why are we doing them?) and water quality standards (What makes up a water quality standard?). Attachments C and D provide information on the method being used by Pennsylvania for establishment of TMDLs for stream segments impaired by nutrients and sediment and, watershed hydrology and pollutant transport.

Watershed History

The Donegal Creek watershed in Lancaster County is 17.2 square miles in the Ridge and Valley Physiographic Province. The protected uses of the watershed are water supply, recreation and aquatic life. As listed in 25 PA Code Chapter 93 , Section 93.9o, the designated aquatic life use for the main stem Donegal Creek is trout stocking fishes and the Unnamed Tributary is cold water fishes.

In June 1992, the Pennsylvania Fish and Boat Commission published the results of a study of the East Branch of the Donegal Creek, finding the stream to be moderately degraded and nutrient enriched.

In 1994, the Department conducted an aquatic biological survey on Donegal Creek to collect background information on the macroinvertebrate community and to determine the water quality of the stream. Results clearly identified Donegal Creek was degraded due to extensive agricultural activities in the watershed, primarily from lack of riparian vegetation in pastures where cattle have complete access to the stream, causing severe stream bank erosion. Department biologists concluded in the 1994 aquatic investigation report that water quality will remain poor until buffer zones are established to protect the streams.

The primary land use (92%) in the Donegal Creek watershed is agriculture, with areas adjacent to the stream used for row crops and pasture. Cattle generally have free access to the stream. The majority of the stream, during the 1994 survey, had no protected riparian zone. Proper management practices are being conducted along the unimpaired stream segments. These unimpaired areas contribute an insignificant amount of loading to the overall watershed.

The 1997 survey showed that sedimentation was still a problem. Sediment deposited in large quantities on the stream bed degrades the habitat of bottom-dwelling macroinvertebrates. It was also documented that nutrients from agricultural activities were causing increased algal growths.

TMDL Endpoints

The TMDLs address sediment and phosphorus, which was determined to be the limiting nutrient for plant growth in Donegal Creek. Because neither Pennsylvania nor EPA has water quality criteria for phosphorus or sediment, we had to develop a method to determine water quality objectives for these parameters that would result in the impaired stream segments attaining their designated uses. The method employed for these TMDLs is termed the "Reference Watershed Approach".

The Reference Watershed Approach pairs two watersheds, one attaining its uses and one that is impaired based on biological assessment. Both watersheds must have similar land cover and land use characteristics. Other features such as base geologic formation should be matched to the extent possible; however, most variations can be adjusted in the model. The objective of the process is to reduce the loading rate of nutrients and sediment in the impaired stream segment to a level equivalent to or slightly lower than the loading rate in the non-impaired, reference stream segment. This load reduction will allow the biological community to return to the impaired stream segments.

The TMDL endpoints established for this analysis were determined using Brubaker Run as the reference watershed. These endpoints are discussed in detail in the TMDL section.

The biological assessment used EPA waterbody cause code 1200, Organic Enrichment/Low Dissolved Oxygen (D.O.), to describe the impairment seen in this portion of Donegal Creek. The listing was based on visual observation. There were no dissolved oxygen readings used as the basis for this impairment listing. The listing for impairment caused by organic enrichment/ low dissolved oxygen is addressed through reduction to the phosphorus load. A detailed explanation of this process is included in the following section.

Relationship Between Dissolved Oxygen Levels, Nutrient Loads and Organic Enrichment in Stream Systems

As indicated earlier, Donegal Creek was listed as being impaired due to problems associated with dissolved oxygen levels, nutrient loads, and organic enrichment. In stream systems, elevated nutrient loads (nitrogen and phosphorus) can lead to increased productivity of plants and other organisms (Novotny and Olem, 1994). Oxygen in water is used by plants (at night) and organisms in the stream. Excessive nutrient input can lead to elevated levels of productivity, which can subsequently lead to depressed dissolved oxygen levels when an abundance of aquatic life is drawing on a limited oxygen supply. Additional problems arise when these organisms die because the microbes that decompose this organic matter also consume large amounts of oxygen. A second effect of nitrogen (specifically ammonia) occurs when bacteria convert ammonia-nitrogen to nitrate-nitrogen. This process, called nitrification, also results in lower dissolved oxygen levels in streams.

Typically in aquatic ecosystems the quantities of trace elements are 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 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 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 ground water.

In most fresh water bodies, phosphorus is the limiting nutrient for aquatic growth. In some cases, however, the determination of which nutrient is the most limiting is difficult. For this reason, the ratio of the amount of N to the amount of P is often used to make this determination (Thomann and Mueller, 1987). If the N/P ratio is less than 10, nitrogen is limiting; if the N/P ratio is greater than 10, phosphorus is the limiting nutrient. In the case of Donegal Creek, the N/P ratio is approximately 37, which points to phosphorus as the limiting nutrient. Controlling the phosphorus loading to Donegal Creek will limit plant growth and result in raising the dissolved oxygen level.

Selection of the Reference Watershed

Two factors formed the basis to select a suitable reference watershed. The first factor was to use a watershed that had been assessed by the Department using the Unassessed Waters Protocol and had been determined to attain water quality standards. The second factor was to find a watershed that closely resembled the Donegal watershed in physical properties such as land cover/landuse, physiographic province, size, and geology. This was done by means of a desktop screening using several GIS coverages. Map 3 shows the land use characterization for both watersheds. Chart 1 contained in Attachment B presents a bar graph of land use characteristics in each watershed.

The GIS coverages included the USGS named stream watershed coverage, the state water plan boundaries, the satellite image derived land cover grid (MRLC), streams and Pennsylvania's 305(b) assessed streams database.

The first step in determining the reference watershed was to locate a watershed that had been recently assessed and was not impaired. Several watersheds were discovered this way. Step two involved comparing the landcover data coverage by watershed and selecting unimpaired watersheds that looked similar to the Donegal watershed. This step narrowed the selected watersheds to five. The remaining watersheds were analyzed by value counts for each pixel of the GIS coverage to determine landcover types by percentage. Brubaker was the only watershed with all characteristics needed to represent the Donegal as a reference watershed.

The geologies of the Donegal and Brubaker watersheds were then compared, but this did not produce a very good match. The Donegal watershed consists of carbonates and interbedded shales and carbonates, and the Brubaker watershed consists primarily of clastics. The model, however, compensates for the disparity in the geology of the two watersheds with data that equates the differences. The bedrock geology influences soil type as well as fractures and directional permeability. The Statsco soil coverage is used to model characteristics of the material derived from the bedrock. The Soilphos coverage provides soil sample data used to set phosphorus and sediment values for the universal soil loss equation (USLE). Well data is used to calculate levels of nitrogen in groundwater to account for the difference of flow in the different rock types.

Data Compilation and Model Overview

The TMDLs were developed using the Generalized Watershed Loading Function or GWLF model. The GWLF model provides the ability to simulate runoff, sediment, and nutrient (N and P) 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 sub-surface loading, the model acts as a lumped parameter model using a water balance approach. No distinctly separate areas are considered for sub-surface flow contributions. Daily water balances are computed for an unsaturated zone as well as a saturated sub-surface 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 and a transport capacity based on average daily runoff are applied to the calculated erosion to determine sediment yield for each source area. Surface nutrient losses are determined by applying dissolved N and P coefficients to surface runoff and a sediment coefficient to the yield portion for each agricultural source area. Point source discharges can also 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. Sub-surface losses are calculated using dissolved N and P coefficients for shallow groundwater contributions to stream nutrient loads, and the sub-surface 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 Attachment E, 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.

GIS Based Derivation of Input Data

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 (see Attachment B). 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 N and P concentrations and cropping practices. Complete GWLF-formatted weather files are also included for eighty-eight weather stations around the state. Table 3 lists the GIS data sets and provides explanation of how they were used for development of the input files for the GWLF model.

State-Wide GIS Data Sets

The following GIS data sets were used during the modeling process using AVGWLF:

Table 3 GIS Data Sets

Censustr	Coverage of Census data including information on individual homes septic systems. The attribute *susew_sept* includes data on conventional systems, and *su_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. This used to calculate landslope and slope length.
Palumrlc	A satellite image derived land cover grid which is classified into 15 different landcover categories. This dataset provides landcover 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 N and P 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 at the 1:24,000 scale set a name stream level???. This coverage is used with the stream network to delineate the desired level watershed.
Statsco	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 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.

As described in the Data Compilation and Model Overview section, the GWLF model provides the ability to simulate surface water runoff, as well as sediment and nutrient loads from a watershed based on landscape conditions such as topography, land use/cover, and soil type. In essence, the model is used to estimate surface runoff and non-point source loads from different areas within the watershed. If point source discharges are identified, and the corresponding nutrient loads are quantified, these loads are summed to represent the total pollutant loads for the watershed.

In the GWLF model, the non-point source (or "background") load calculated is affected by terrain conditions such as amount of agricultural land, land slope, and inherent soil erodibility. It is also affected by farming practices utilized in the area, as well as by background concentrations of nutrients (i.e., N and P) in soil and groundwater. Various parameters are included in the model to account for these conditions and practices. Some of the more important parameters are summarized below:

Areal extent of different land use/cover categories: This is calculated directly from a GIS layer of land use/cover.

Curve number: This determines amounts of precipitation that infiltrates into the ground or enters surface water as runoff. It is based on specified combinations of land use/cover and hydrologic soil type, and is calculated directly using digital land use/cover and soils layers.

K factor: This factor relates to inherent soil erodibility, and affects the amount of soil erosion taking place on a given unit of land.

LS factor: This factor signifies the steepness and length of slopes in an area and directly affects the amount of soil erosion.

C factor: This factor is related to the amount of vegetative cover in an area. In agricultural areas, this factor is largely controlled by the crops grown and the cultivation practices utilized. Values range from 0 to 1.0, with larger values indicating greater potential for erosion.

P factor: This factor is directly related to the conservation practices utilized in agricultural areas. Values range from 0 to 1.0, with larger values indicating greater potential for erosion.

Sediment delivery ratio: This parameter specifies the percentage of eroded sediment that is delivered to surface water and is empirically based on watershed size.

Unsaturated available water-holding capacity: This relates to the amount of water that can be stored in the soil and affects runoff and infiltration. It is calculated using a digital soils layer.

Dissolved nitrogen in runoff: This varies according to land use/cover type, and reasonable values have been established in the literature. This rate, reported in mg/l, can be re-adjusted based on local conditions such as rates of fertilizer application and farm animal populations.

Dissolved phosphorus in runoff: Similar to nitrogen, the value for this parameter varies according to land use/cover type, and reasonable values have been established in the literature. This rate, reported in mg/l, can be re-adjusted based on local conditions such as rates of fertilizer application and farm animal populations.

Nutrient concentrations in runoff over manured areas: These are user-specified concentrations for N and P that are assumed to be representative of surface water runoff leaving areas on which manure has been applied. As with the runoff rates described above, these are based on values obtained from the literature. They also can be adjusted based on local conditions such as rates of manure application or farm animal populations.

Nutrient build-up in non-urban areas: In GWLF, rates of build-up for both N and P have to be specified. In Pennsylvania, this is estimated using historical information on atmospheric deposition.

Background N and P concentrations in groundwater: Subsurface concentrations of nutrients (primarily N) contribute to the nutrient loads in streams. In Pennsylvania, these concentrations are estimated using recently published data from USGS.

Background N and P concentrations in soil: Since soil erosion results in the transport of nutrient-laden sediment to nearby surface water bodies, reasonable estimates of background concentrations in soil must be provided. In Pennsylvania, this information is based on literature values as well as soil test data collected annually at Penn State University. These values can be adjusted locally depending upon manure loading rates and farm animal populations.

Other less important factors that can affect sediment and nutrient loads in a watershed are also included in the model. More detailed information about these parameters and those outlined above can be obtained from the GWLF Users Guide provided in Appendix F of this document. Specific details in this Guide that describe equations and typical parameter values used can be found on pages 15 through 41. Additional descriptions of hydrologic functions and pollutant transport processes that operate within a watershed can be found in Appendix D.

As described in the next section, the GIS interface was first used to derive values for the various GWLF input parameters. Based on subsequent field work in the two watersheds, various parameter values were then adjusted to more accurately reflect local conditions.

Watershed Assessment and Modeling

The AVGWLF model was run in both the Donegal Creek Watershed and the Brubaker Run Watershed to establish existing loading conditions. The initial modeling run produced pollutant loads for the Donegal and Brubaker watersheds that were similar to the results of a study (Quantification of NPS Pollution Loads Within Pennsylvania Watersheds), which estimated loads based on land cover, animal density, population and other landuse activities. This was expected since both watersheds had similar activities and the default values for soil loss and transport to streams were identical. To model nutrient production and transport to streams, a survey of both watersheds was conducted to determine actual land use patterns and management practices. To determine loadings in the Donegal watershed prior to recent improvements, historic records as well as onsite observations were used.

These observations were used to adjust modeling parameters to more accurately reflect conditions in Donegal Creek and Brubaker Run with respect to cropping patterns, conservation practices, animal populations/manure loads, and background N in groundwater.

General observations of watershed characteristics:

Donegal: less topographic relief, more continuous corn crops, more animals (particularly poultry operations), dominated by limestone/dolomite geology (more conducive to N leaching), less evidence of conservation practices.

Brubaker: more topographic relief, more corn-hay rotations, more crop residue left, more use of strip cropping and stream buffers, fewer animals (approximately half the density of Donegal), dominated by shale and metamorphic rock (less conducive to N leaching).

Adjustments to specific GWLF-related parameters:

Donegal:
- re-set "C" factor to 0.38 to account for continuous corn crops
- re-set "P" factor to 0.8 to reflect general lack of conservation practices
- re-set N concentration in runoff over agricultural land to 5.8 mg/l (default is 2.9)
- re-set P concentration in runoff over agricultural land to 0.51 mg/l (default is 0.26)
- re-set N concentration in runoff during manure-spreading periods to 24.4 mg/l (default is 12.2)
- re-set P concentration in runoff during manure-spreading periods to 3.8 mg/l (default is 1.9)
- re-set background concentration of N in groundwater to 10 mg/l to reflect conditions typical of limestone in south-central PA
- re-set background concentration of P in groundwater to 0.020 mg/l to reflect conditions typical of limestone in south-central PA
- re-set background concentration of P in soil to 2100 mg/kg

Brubaker:
- re-set "C" factor to 0.14 to account for corn-hay rotations
- re-set "P" factor to 0.64 to account for use of strip cropping and buffer strips
- re-set N concentration in runoff over agricultural land to 4.4 mg/l (default is 2.9)
- re-set P concentration in runoff over agricultural land to 0.39 mg/l (default is 0.26)
- re-set N concentration in runoff during manure-spreading periods to 18.3 mg/l (default is 12.2)
- re-set P concentration in runoff during manure-spreading periods to 2.9 mg/l (default is 1.9)
- re-set background concentration of N in groundwater to 5 mg/l to reflect conditions typical of shale/metamorphic rock in south-central PA
- re-set background concentration of P in groundwater to 0.02 mg/l to reflect conditions typical of shale/metamorphic rock in south-central PA
- re-set background concentration of P in soil to 1950 mg/kg

Using the above settings, sediment and nutrient loads were estimated with GWLF for the Donegal and Brubaker watersheds. This established the existing conditions for each watershed. The 4-year means for these parameters for each watershed are shown Tables 5 and 6. The Unit Area Load for each pollutant in each watershed was estimated by dividing the mean annual loading(lbs/year) by the total area (acres) resulting in an approximate loading per unit area for the watershed. Table 4 presents an explanation of the header information contained in Tables 5 and 6.

Table 4. Header information for Tables 5 and 6.	
Land Use Category	The land cover classification that was obtained by from the MRLC database
Area (acres)	The area of the specific land cover/land use category found in the watershed.
Total P	The estimated total phosphorus loading that reaches the outlet point of the watershed that is being modeled. Expressed in lbs./year.
Unit Area P Load	The estimated loading rate for phosphorus for a specific land cover/land use category. Loading rate is expressed in lbs/acre/year
Total N	The estimated total nitrogen loading that reaches the outlet point of the watershed that is being modeled. Expressed in lbs./year.
Unit Area N Load	The estimated loading rate for nitrogen for a specific land cover/land use category. Loading rate is expressed in lbs/acre/year
Total Sed	The estimated total sediment loading that reaches the outlet point of the watershed that is being modeled. Expressed in lbs./year.
Unit Area Sed Load	The estimated loading rate for sediment for a specific land cover/land use category. Loading rate is expressed in lbs/acre/year

Table 5. Existing Loading Values for Donegal Creek

Land Use Category	Area (acres)	Total P (lbs/yr)	Unit Area P Load (lbs/acre/yr)	Total N (lbs/yr)	Unit Area N Load (lbs/acre/yr)	Sed Load (lbs/year)	Unit Area Sed Load (lbs/acre/yr)
Hay/Past	2538	265	0.10	2933	1.16	34874	13.74
Row Crops	521	353	0.68	1499	2.88	122455	234.87
Prob Row C	7032	4807	0.68	20154	2.87	1651693	234.87
Coniferous	27	0	0.00	0	0.00	374	13.74
Mixed For	59	0	0.00	0	0.00	815	13.74
Deciduous	215	0	0.00	22	0.10	2954	13.74
Lo Int Dev	351	22	0.06	110	0.31	0	0.00
Hi Int Dev	190	154	0.81	1323	6.95	0	0.00
Quarry	22	0	0.00	22	0.99	0	0.00
Groundwater		331		164736			
Point Source		0		0			
Septic Systems		22		6483			
Total	10956	5954	0.54	197281	18.01	1813165	165.49

Table 6. Existing Loading Values for Brubaker Run							
Land Use Category	Area (acres)	Total P (lbs/yr)	Unit Area P Load (lbs/acre/ yr)	Total N (lbs/yr)	Unit Area N Load (lbs/acre/ yr)	Sed Load (lbs/year)	Unit Area Sed Load (lbs/acre/ yr)
Hay/Past	1495	132	0.09	1,345	0.90	26,414	17.67
Row Crops	398	154	0.39	794	2.00	42,175	106.01
Prob Row C	2923	1,103	0.38	5,843	2.00	309,892	106.01
Coniferous	47	0	0.00	0	0.00	830	17.67
Mixed For	74	0	0.00	0	0.00	1,310	17.67
Deciduous	403	22	0.05	44	0.11	7,116	17.67
Lo Int Dev	12	0	0.00	0	0.00	0	0.00
Hi Int Dev	5	0	0.00	44	8.92	0	0.00
Groundwater		198		48,444		0	
Point Source		0		0			
Septic Systems		22		4,212			
Total	5357	1,632	0.30	60,726	11.34	387,736	72.38

TMDL Computations for Phosphorus and Sediment

The TMDLs established for Donegal Creek consist of a load allocation (LA) and a margin of safety (MOS) for both phosphorus and sediment. There is no wasteload allocation (WLA) for this TMDL because there are no known point source discharges.

Nitrogen was not included in the TMDL because it was determined that the stream was phosphorus limited. If the ratio of nitrogen to phosphorus is greater than 10 to 1 it means that phosphorus will be the limiting nutrient in the stream. In the case of Donegal Creek the nitrogen to phosphorus ratio is 60,726 pounds of nitrogen to 1,632 pounds of phosphorus, or 37 to 1.

The basis for the load reduction calculations in Donegal Creek are based on the current loading rates for phosphorus and sediment in Brubaker Run, the reference watershed for this analysis. Based on biological assessment, it was determined that Brubaker Run was attaining its Aquatic life uses. Brubaker Run is designated as a cold water fishery (CWF). The phosphorus and sediment loading rates were computed for Brubaker Run using the AVGWLF model. These loading rates were then used as the basis for establishing the TMDLs for Donegal Creek.

The TMDL equation is as follows: TMDL = WLA + LA + MOS

The WLA (wasteload allocation) portion of this equation is the total loading that is assigned to point sources. The LA (load allocation) is the portion of this equation that is assigned to non-point sources. The MOS (margin of safety) is the portion of loading that is reserved to account for any uncertainty in the data and computational methodology used for the analysis. Table 7 presents the TMDLs for Donegal Creek.

Table 7. TMDLs for Donegal Creek				
Pollutant	**TMDL (lb/yr)**	**LA (lb/yr)**	**WLA (lb/yr)**	**MOS (lb/yr)**
Phosphorus	3,287	2,958	0	329
Sediment	792,998	713,698	0	79,300

The individual components of the TMDLs are discussed in detail below.

TMDL Computation

The TMDL for both pollutants of concern was computed in the same manner. Each pollutants unit loading rate in Brubaker Run was multiplied by the total watershed area of Donegal Creek to give the TMDL value. Table 8 presents this information.

Table 8. TMDL Computation			
Pollutant	Unit Area Loading Rate in Brubaker Run (lbs/acre/year)	Total Watershed Area in Donegal Creek (acres)	TMDL Value (lbs/year)
Phosphorus	0.30	10956	3,287
Sediment	72.38	10956	792,998

Margin of Safety

The Margin of Safety (MOS) for this analysis is explicit. Ten percent of each of the TMDLs was reserved as the MOS. Using ten percent of the TMDL load is based on professional judgement and will provide an additional level of protection to the uses of the waterbody.

Phosphorus – 3,287 x 0.1 = 329 lbs/year
Sediment - 792,998 x 0.1 = 79,300 lbs/year

Load Allocation

The load allocation (LA) for the entire watershed was computed by subtracting the margin of safety value from the TMDL value. Individual load allocations were then assigned to each land uses/ sources that are shown in Table 9. Not all land use/ source categories were included in the allocation because they are difficult to control, or provide an insignificant portion of the total load. Loading values for land uses/ sources that were not part of the allocation were carried through at their existing loading value. The following section shows the allocation process in detail.

Phosphorus

1. The margin of safety value was subtracted from the TMDL value. This quantity represents the load allocation (LA).

   LA = 3,287 – 329
   LA = 2958 lbs/year

2. The loads not considered in the reduction scenario were subtracted from the LA value. These are the loads: Lo Int Dev (Low Intensity Development), Hi Int Dev (High Intensity Development), Groundwater, Septic systems. The total load for these land uses/sources is 529 lbs. This quantity was subtracted from the LA.

   Adjusted LA = 2958 – 529
   Adjusted LA = 2429 lbs.year

   This is the portion of the load that is available to allocate among the contributing sources. This is termed the allocable load.

3. This quantity was allocated among the three remaining land use/sources. The allocation method used was Equal Marginal Percent Reduction (EMPR).

   EMPR is carried out in the following manner. Each land use/source load will be compared with the allocable load to determine if any contributor would exceed the allocable load by itself. The evaluation is carried out as if each source is the only contributor to the pollutant load to the receiving waterbody. If the contributor exceeds the allocable load, that contributor would be reduced to the allocable load. This is the baseline portion of EMPR. After any necessary reductions have been made in the baseline the multiple analysis is run.

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

4. The results of the Load Allocation are presented in Table 9. The LA for each land use is shown along with the reduction necessary for each source.

Sediment

1. The margin of safety value was subtracted from the TMDL value. This quantity represents the load allocation (LA).

   LA = 792,998 – 79,300 lbs/year
   LA = 713,698 lbs/year

2. The loads not considered in the reduction scenario were subtracted from the LA value. These are the loads: Coniferous Forest, Mixed Forest, Deciduous Forest. The total load for these land uses/sources is 4143 lbs. This quantity was subtracted from the LA.

   Adjusted LA = 713,698 - 4143
   Adjusted LA = 709,555 lbs.year

   This is the portion of the load that is available to allocate among the sources contributing sources. This is termed the allocable load.

3. This quantity was allocated among the three remaining land use/sources. The allocation method used was Equal Marginal Percent Reduction (EMPR). The allocation method is discussed above in the phosphorus section.

4. The results of the Load Allocation are presented in Table 9. The LA for each land use is shown along with the reduction necessary for each source.

Table 9. Load Allocation by Land Use/ Source

		Phosphorus				Sediment			
Source		Unit Area Loading Rate	Annual average load	LA (annual average)	% Reduction	Unit Area Loading Rate	Annual average load	LA (annual average)	% Reduction
	acres	lbs/acre/ year	lbs/year	lbs/year		lbs/acre/ year	lbs/year	lbs/year	
Hay/Past	2538	0.10	265	211	20%	13.74	34,874	28,545	18%
Row Crops	521	0.68	353	281	20%	234.87	122,455	100,231	18%
Prob Row C	7032	0.68	4,807	1937	60%	234.87	1,651,693	580,780	65%
Coniferous	27	0.00	0	0	0%	13.74	374	374	
Mixed For	59	0.00	0	0	0%	13.74	815	815	
Deciduous	215	0.00	0	0	0%	13.74	2,954	2,954	
Lo Int Dev	351	0.06	22	22	0%				
Hi Int Dev	190	0.81	154	154	0%				
Quarry	22	0.00	0	0	0%				
Groundwater			331	331	0%				
Point Source			0	0	0%				
Septic Systems			22	22	0%				
Total	**10,956**	**0.54**	**5,954**	**2958**	**50%**	**165.49**	**1,813,165**	**713,698**	**61%**

<u>Consideration of Critical Conditions</u>

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

<u>Consideration of Seasonal Variations</u>

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.

Reasonable Assurance of Implementation

The pollutant reductions in the TMDLs are allocated entirely to agricultural activities in the watershed. Implementation of best management practices (BMPs) in the affected areas should achieve the loading reduction goals established in the TMDLs. Remediation activities in the watershed have already begun. The primary remediation activities for the watershed are stream bank stabilization and fencing. Stabilizing the stream bank will reduce instream erosion. Fencing keeps livestock out of the stream and provides a riparian zone along the stream that traps sediment and phosphorus, keeping these pollutants from reaching the stream. Improvements have already been seen in the streamside habitat and aquatic biologic community following the implementation of these agricultural best management practices (BMPs) along affected streams. The following section presents loading reduction calculations projected for the watershed based on the BMPs that have been installed.

Projected Loading Reductions based on BMP Implementation

It is anticipated that sediment and nutrient loading along the stream will be reduced by 75% where BMPs have been installed. The 75% reduction in loading from BMP implementation is derived from empirical data from previous studies of BMP effectiveness and is described below. Map 1 of Attatchment B shows the location of BMPs recently installed along impaired stream segments.

The average annual phosphorus loads calculated in each case were 5,954 lbs/year for Donegal and 1,632 lb/yr for Brubaker. The loading rates for Donegal and Brubaker Run were estimated to be 0.54 lb/ac/yr and 0.30 lb/ac/yr, respectively. Both of these rates are below the unit area loads reported by Nizeyimana and Evans (1997), but are believed to be more realistic estimates of the loads in these areas since these calculations reflect actual conditions more accurately than the larger scale report.

The average annual sediment loads calculated in each case were 907 tons /yr for Donegal and 194 tons/yr for Brubaker. These values are far less than those derived earlier by DEP using a soil loss rate of 4 tons/acre as reported in the Soil Survey Report for Lancaster County. We have found that it is erroneous to use the soil loss rates reported in soil surveys since such soil loss rates account for both soil erosion and deposition. The GWLF modeled load is much more accurate since is represents only that amount actually delivered to surface water. Attachment A contains the modeling output for both watersheds

BMPs discussed below are described in the context of reducing sediment and phosphorus loads in Donegal Creek. The reduction of sediment loads is also expected to reduce phosphorus loads since much of the phosphorus that reaches a stream is attached to sediment particles, particularly in agricultural areas.

Streambank stabilization and fencing will be used to reduce phosphorus and sediment loads in the affected areas. A reduction coefficient of 75% for nutrients and sediment is reasonable to expect with this particular BMP. This level of reduction has been reported by Qiu and Prato (1998) and the Illinois EPA (1986), and is also used by the Susquehanna River Basin Commission in their efforts to model pollutant reductions that may result from various BMP reduction strategies (SRBC, 1996).

Load calculations for Donegal Creek after BMP implementation were compared to the reference watershed Brubaker Run in two ways to determine the effectiveness of the BMPs.

The first comparison applied the 75% reduction (allowing a loading of 25% of current load) to the entire watershed. The resulting loadings after BMP implementation are as follows:

Phosphorus
Loading after BMP implementation in all impaired segments:
0.25 (0.54 lb/ac/yr) = 0.14 lb/ac/yr

Sediment
Loading after BMP implementation in all impaired segments:
0.25 (165.5 lb/ac/yr) = 41.4 lb/ac/yr

The second comparison calculated reductions only for that portion of the Donegal watershed draining into impaired streams. As shown in Map 2, approximately 2/3 or 66% of the watershed drains into impaired streams. Therefore, the unit area loads for each pollutant were reduced by 75% for 2/3 of the watershed. This estimate is conservative because it does not reduce the loading in unimpaired areas and in areas where BMPS have already been installed. The new "weighted" unit area loads for the entire watershed were re-computed as follows:

Phosphorus
Loading after BMP implementation in impaired areas only:
0.25 (0.39 lb/ac/yr) = 0.10 lb/ac/yr
Weighted avg. load: 0.66 (0.10 lb/ac/yr) + 0.34 (0.39 lb/ac/yr) = 0.27 lb/ac/yr

Sediment
Loading after BMP implementation in impaired areas only:
0.25 (165.5 lb/ac/yr) = 41.4 lb/ac/yr
Weighted avg. load: 0.66 (41.4 lb/ac/yr) + 0.34 (165.5 lb/ac/yr) = 83.6 lb/ac/yr

Table 10. Loading Projection for Donegal Creek Based on BMP Implementation

	Phosphorus	Sediment
	lbs/ac/yr	lbs/ac/yr
Donegal – before BMPs	0.54	165.5
Donegal – after BMPs	0.14-0.27	41.4-83.6
Brubaker (reference)	0.30	72.3

Remediation Plan

An extensive watershed restoration effort is currently underway. In April 1995, the Lancaster County Conservation District and the Donegal Fish and Conservation Association entered into an MOU to promote and implement the Donegal Creek Restoration Project. The conservation district agreed to administer grant funds, oversee and design cattle crossings, oversee installation of riprap and fish enhancement structures and provide technical assistance to landowners for the design and installation of best management practices. The Donegal Fish and Conservation Association currently works with cooperating landowners and help install and maintain improvements.

The Donegal Creek Restoration Project received $110,557 funding from Section 319 FY 96 Grant. The project involves the following agencies:

Pennsylvania Fish and Boat Commission
Chesapeake Bay foundation
Alliance for the Chesapeake Bay
Pennsylvania association of Conservation Districts
Pennsylvania department of Conservation and Natural Resources
Donegal Fish and Conservation Association
Lancaster County conservation District

The Donegal Creek Restoration project includes the following activities to reduce sediment and phosphorus loadings to the stream and restore designated uses:

Best Management Practices	Pollutant Reduction
1. 4.9 miles of streambank fencing	75%
2. 6.67 miles of stream stabilization measures; bioengineering methods/riprap	75%
3. 21 stone ford cattle crossings with fencing	
4. 200 fish enhancement structures	

Assessment of Measures and Follow-up Monitoring

Installation of recommended practices is already underway. Water quality and habitat monitoring are being done by the Donegal Fish and Conservation Association at eight different stations in the watershed. Monitoring began prior to the installation of BMPs and includes biota, water chemistry and bank stability. The DEP will make the final determination regarding the stream's recovery. Although stream quality has shown steady improvement, it has not yet fully recovered from the impairments. The 1998 list designated more impaired stream than the 1996 303(d) list, reflecting a more accurate means of reporting water quality status. The Department has completed a stream GIS coverage at the 1:24,000 scale. In addition, the use of dynamic segmentation to accurately delineate the impaired segments has resulted in adding minor streams that had not been previously reported.

Recent surveys conducted by DEP biologists have documented an approximate 90% reduction of silt in some areas. Riparian zones have stabilized and narrowed stream channels. Several stations in the watershed were described as being capable of supporting a reproducing trout population. Follow-up surveys will continue to be conducted to document stream conditions.

A publication entitled “Fixing a Broken Trout Stream, the Donegal Creek Restoration Project” has been published and is available from the Lancaster County Conservation District.

Public Participation

Notice of the draft TMDLs was published in the *Lancaster Intelligencer* on December 4, 1999 and in the *PA Bulletin* on November 20, 1999 to foster public comment on the allowable loads calculated. . A public meeting with watershed residents will be held to discuss the TMDLs. A public meeting was held on December 9, 1999 at the East Donegal Township Municipal Building, located at 190 Rock Point Road, Marietta, PA 17547, to discuss the proposed TMDL. The public comment period of 60 days closed on January 20, 2000.

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COMMENT AND RESPONSE DOCUMENT
Donegal Creek TMDL

General:

Comment: It is unclear if there is authority under state law or regulation for promulgating TMDLs for nonpoint sources or pollution, as 25 PA Code §§ 95.3 and 95.9 clearly authorizes for point sources. Specifically under § 95.9, DEP is authorized only to limit point sources of phosphorus even if nonpoint sources are the predominant source of pollution. (1)

Response: The Department has authority under state law and regulation, including the Clean Streams Law and 25 Pa. Code Section 95.3(d), and federal law and regulation including Section 303(d) of the Clean Water Act and 40 CFR Section 130.7. The authority and legal basis for nonpoint source TMDLs was recently affirmed in the case of Pronsolino v. EPA, N.D. Cal., No. C99-1828 (3/30/00). Finally, Section 95.9 addresses point sources of phosphorus and does not limit the Department's ability to address nonpoint source pollution from phosphorous in any way.

Comment: We appreciate DEP efforts in translating the narrative water quality criteria into a quantitative TMDL and conceptually approve of the modeling technique used. We also recommend that DEP consider developing numeric criteria for phosphorus and sediment. (1)

Response: EPA is currently working with states to develop criteria for nutrients, which are projected for later this year. States will have three years to adopt the recommended criteria into their water quality standards.

Comment: Before listing Donegal Creek as not meeting a nutrient standard, DEP should consider the legal precedent requiring translation of the narrative nutrient criteria into numeric values. (3)

Response: The stream was listed as not attaining standards based on the biology survey. The surveyor's best professional judgement was used to determine the source and cause of the impairment. Nutrients were listed as one of the causes based on the excessive algal growth found in the stream.

Comment: Is Donegal Creek properly designated or should it be WWF, which may be more appropriate for stream through low, high quality agricultural land? (3)

Response: The designated use of a stream is based upon biological surveys that determine the water uses of the stream and not on the surrounding land use. Designated uses are adopted as regulations by the Environmental Quality Board upon recommendations made by the Department. As with other regulations, citizens may petition the Board to change the designated uses of streams.

Comment: The TMDL does not state if the Rapid Bioassessment Protocol described on page 4 was used for the biological surveys that determined the water quality impairment. This should be clarified. (2)

Response: As stated in the TMDL, Donegal Creek was listed in 1996 as the result of a biological assessment that included kick screen analysis and habitat assessments. The follow-up survey in 1997 did use the Rapid Bioassessment Procedure.

Listing Issues:

Comment: Listing documentation does not explain why Donegal Creek was made high priority for TMDL. (3)

Response: States may use judgement in prioritizing streams for TMDLs within two years of listing. Donegal Creek was made high priority for TMDL development because there were already significant BMPs being installed in the watershed and results of the remediation would be apparent in a shorter time from than other streams whose impairment was not being addressed. DEP was developing the new "reference watershed approach" to nonpoint source TMDLS and considered Donegal a good model on which to develop the procedure.

Reference Stream:

Comment: We recommend using a theoretical reference stream in modeling the TMDL. Loading capacity is the maximum concentration of a pollutant at which a stream can attain water quality standards. The TMDL should equal the loading capacity plus a quantitative margin of safety. The reference stream used in this TMDL development is not impaired and therefore, by definition, its pollutant concentrations are significantly lower than the loading capacity. A theoretical reference stream would account for a loading capacity at the exact threshold necessary to maintain water uses. (1)

Response: Establishing the parameters for a theoretical reference stream would be extremely difficult. There is also no actual measure of the instream biodiversity and abundance available for this approach. This is one reason why EPA is in the process of developing nutrient criteria. EPA supports the use of the reference watershed approach.

Comment: The reference watershed approach is to be commended. It offers an interesting promise in TMDL development in focusing on the watershed, land use and land use practices where it belongs. This is better than the eternal data collection and modeling simulation that stalemates water quality improvement. (2)

Response: Thank you for the supportive comment.

Comment: There is insufficient explanation as to why DEP believes the reference watershed meets water quality standards. The geology and topography could also have a significant effect on the water quality. (2)

Response: Brubaker Run meets water quality standards based on the assessment of the biology in the stream.

Comment: The TMDL does not specify how the reference watershed was determined to not be impaired for nutrients or sediment nor if the assessment method accounts for seasonal variability. A reference watershed must meet standards throughout the year. (2)

Response: The reference watershed was assessed using the RBP and determined to meet water quality standards. The RBP provides evaluation of the macroinvertebrate population of a stream, which is an indicator of long term attainment of uses.

Modeling Issues:

Comment: There is no rationale for selecting 10% as the margin of safety. (2)

Response: Ten percent of the TMDL load is based on professional judgement and will provide an additional level of protection to the uses of the waterbody. This statement is included in the TMDL.

Comment: Sensitivity analysis of the model factors should be done and instream data used for factors with highest degree of sensitivity. (3)

Response: There was no instream water chemistry data available to adjust the model variables in this manner. The model has been calibrated on a number of watershed that have water quality network stream monitoring stations on them. This was done to make adjustment to the model algorithms to give the best results using the values that are estimated through the model interface.

Comment: DEP should assess the degree of certainty for each factor in the modeling to determine if an additional 10% margin of safety is necessary to add in the TMDL. (3)

Response: The use of resources to assess the degree of certainty for all the model factors would be huge and would significantly delay the development of TMDLs. DEP's Best Professional Judgement is that10% is a fair margin of safety to use to make up for unknowns in the TMDL development process.

Comment: DEP should attempt to quantify the benefits of the TMDL and its cost so that agencies can assess their need to respond to the proposals. (3)

Response: Costs will be considered in the implemetation phase of this process.

Comment: The TMDL fails to establish a daily load as required by the Clean Water Act, and only offers a yearly load. Daily loadings and streamflows should be calculated for critical or frequent seasonal weather conditions. These could easily be extracted from the internal calculations of the AVGWLF model and would be more useful for monitoring loads and enforcing TMDLs. (2)

Response: The CWA requirement for total maximum daily loads allows for the expression of a TMDL in units of mass per time, toxicity, or other appropriate measures. DEP in consultation with EPA has determined that annual loadings are more appropriate for expression of nonpoint source TMDLs for nutrients and sediment.

Comment: Although DEP uses daily time steps for data to estimate a yearly load, it failed to use the data to calculate a daily load that assures standards are met in all seasons of the year, as required by the CWA. (2)

Response: See previous response.

Comment: The annual TMDL does not explain how it accounts for seasonal variations. Is water quality impaired all year or only during particular periods? (2)

Response: TMDLS for nonpoint sources of pollution are developed to protect the stream from impacts that occur at "critical" conditions. Critical conditions for nonpoint sources are times of runoff usually associated with precipitation. Similar to the way TMDLS protect waters from point source pollution at the critical low flow condition ensures protection at other less critical periods, TMDLs developed to protect the stream from impact of nonpoint sources during runoff ensure protection under all other conditions.

Comment: DEP concluded that phosphorus is always the limiting nutrient based on an annual ratio of 37:1. Since ground water is a major source of nitrogen, there would be a significant nitrogen source during the dry summer months. Phosphorus enters a stream mainly through overland flow in runoff, mostly during wet, winter months. This changes the N:P ratio seasonally and would require a TMDL for nitrogen for particular seasons. (2)

Response: Although ground water contributions of N will be highest relative to overland runoff contributions during the summer months (May through September), total nitrogen loads will normally be lowest in these months due to low flows and increased plant uptake. Therefore, seasonal implementation of BMPs to control these summer nitrogen loads would not be an effective means of improving the water quality in Donegal Creek as these are not the "critical" conditions assessed in Pennsylvania's nonpoint source TMDLs.

Phosphorus does enter the stream through overland flow in runoff; however, periods of high P exports correspond to periods of high soil loss. During the wet winter months, there is normally enough ground cover to dissipate the erosive energy of precipitation. Total P loads, on a unit area basis, are typically highest in the fall (after harvest when more bare soil is exposed) and in the spring (more intense rainfall events on fields being prepared for planting). However, TN loads are also higher in the fall and spring such that the N:P ratio remains greater than 10.

Comment: If a TMDL for nitrogen is needed because of seasonal variations, the riparian restoration will not adequately reduce nitrogen from groundwater sources. (2)

Response: See previous response regarding the need for a nitrogen TMDL.

Comment: DEP has made a reasonable allocation of the loads of the pollutants, phosphorus and sediment, among the nonpoint sources in the watershed, but we question if those are the only pollutants requiring TMDLs, as discussed above. (2)

Response: Thank you for the supportive comment on the allocation procedure. See previous two comments regarding the need for a TMDL for nitrogen.

Comment: DEP inadequately accounts for the differences (topography, stream density, geology, annual water yield, animal densities, crops and cropping practices) other than watershed size between Donegal Creek and the reference watershed. DEP should make a better attempt to account for the differences.

Response: DEP disagrees with the statement that the modeling analysis does not adequately account for differences in many of the factors listed. Topography and stream density are used in the GIS data derived generation of the Universal Soil Loss Equation (USLE) parameters assigned to model soil erosion. Differences in these factors are realized in the LS factor in the USLE for each watershed. Differences in animal density are accounted for in the model using a GIS coverage of animal populations by zip code as obtained from the U.S. Census of Agriculture. This data layer is used in determining the amount, and nutrient content, of manure applied to cropland in each watershed. Differences in crops and cropping practices are also accounted for both through GIS generation and manual manipulation of the C and P factors in the USLE. Using GIS coverages with typical county-based cropping and BMP implementation practices, C and P factors are generated for each watershed. These factors were further adjusted for Donegal Creek and Brubaker Run based on specific information gleaned through discussions with district conservationists working in these watersheds. The adjustments made to the GIS generated C and P values are documented in the Watershed Assessment and Modeling section of the TMDL document under *Adjustments to specific GWLF-related parameters*. Finally, geologic similarity is used as one of the criteria for choosing a reference watershed. Also, model parameters such as the groundwater recession coefficient are adjusted based on the underlying geology in the watershed. Therefore, differences in groundwater contributions due to dissimilar geology are accounted for in the analysis.

Comment: DEP should look at other factors, not limited to the fate and transport processes that occur as as sediment and nutrients move downstream. (2)

Response: GWLF does not have an in-stream module with which to model the fate (e.g. biological utilization, sequestration in bed sediments) and transformation of nutrients. The model currently uses widely accepted, literature-based delivery ratios to obtain a delivered load from an edge-of-stream load. A process based in-stream module would require the estimation of many state- and rate- variables for which very little, if any, data exist. DEP is exploring the possibility of incorporating a more empirical in-stream module into the AVGWLF framework.

Comment: DEP should normalize watershed loadings by watershed streamflows, that is the loading rate objective for Donegal should be the areal loading rate for the reference multiplied by the ratio of Donegal to reference streamflow yields. (2)

Response: Loading rates discussed in the TMDL are delivered loading rates, not edge-of-stream loading rates. Nutrient loads are calculated based on a modeled constituent concentration in streamflow and streamflow volume; therefore, further normalizing the nutrient loading rates by streamflow would effectively double-count the effects of streamflow on nutrient export.

Follow-up Monitoring:

Comment: DEP or others should quantify the improvement in DO, nitrogen, phosphorus and aquatic life resulting from the BMPs. The data would, among other things, refine modeling efforts. (3)

Response: Although not part of the TMDL, but rather, of the next step in the process – implementation – follow-up monitoring will be used to measure the success of implementing the TMDL. Determining if a stream meets water quality standards will be based primarily on the same criteria that put it on the list originally. In this case, it would be a biological assessment. Nevertheless, the Department supports the collection of chemical data as resources permits.

Implementation, BMPs:

Comment: Implementation of the BMPs in the TMDL is obvious and will stabilize the riparian zone. No TMDL is necessary to justify the implementation of the BMPs already being carried out. (3)

Response: DEP acknowledges that the implementation of BMPs in the Donegal Watershed preceded the development of the TMDL. The TMDL is necessary under 40 CFR Part 130.7 of the federal regulations, which requires TMDLs be developed for all waters listed on the 303(d) list of impaired waters.

Comment: The proposed implementation plan appears reasonable for phosphorus. However, the document states sediment reduction will be met only if BMPs are applied to the whole watershed and it is not specified if BMP implementation is planned for the whole watershed. It is also apparently assumed that all landowners on impaired segments will participate, and no reasonable basis for that assumption is given. (2)

Response: Implementation of the streambank fencing in impaired areas has already occurred. Some further reduction in sediment loading is needed; however, this does not require participation of all landowners in the watershed.

Comment: There is no connection between using the AVGWLF model to develop loading objectives and the selection of practices for implementation from a set of limited and primitive estimates. The model should be a powerful tool for selection of BMPs and should be used for that purpose. (2)

Response: The model does not allow for the direct input of BMPs on the landscape to predict reduction values. GWLF is a lumped parameter model; therefore, assessment of reductions due to BMP implementation in impaired subwatersheds must be done external to the model.

Comment: The generalized reduction coefficients from BMPs do not seem appropriate. The model should be considered more reliable than the generalized values cited as implementation assurance for this TMDL. (2)

Response: The model was used to predict the current loading value for the watershed. Parameter adjustments to account for BMPs would have to be made without a clear method for determining the new values. Therefore, scientifically derived or measured reductions, such as those used in this TMDL as published by the US EPA Chesapeake Bay Program, are felt to be more defensible.

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