Total Maximum Daily Load (TMDL)

Little Juniata River Watershed
Blair County

December, 2004

Table of Contents

1. Introduction

1.1 Watershed Characteristics

The Little Juniata River is part of State Water Plan subbasin 11A (Frankstown Branch, Juniata River) and is located within and north of the City of Altoona in Blair County, Pennsylvania (Figure 1). The Little Juniata is approximately 30 miles in length, with 5 miles designated as impaired. As designated under Chapter 93 in Title 25 of the Pa. Code (Commonwealth of Pennsylvania, 2001), streams in this watershed are protected for aquatic life uses including trout stocking (mainstem Little Juniata River), warm water fishery (Homer Gap Run, Kettle Creek, Spring Run, and unnamed tributaries), and cold water fishery (Riggles Gap Run and Sandy Run).

1.1.1 Topography & Geology:

The impaired region of the Little Juniata River watershed is located primarily in the Ridge and Valley physiographic province. The northwest portion of the impaired region is located in the Appalachian Plateaus physiographic province. The major geologic formations in the watershed are interbedded sedimentary, shale and carbonate. The average slope of the Little Juniata River within the impaired reach is .34%. Tributaries entering the Little Juniata originate on the ridge tops at an approximate elevation of 700 feet and flow downstream to the confluence with the Little Juniata at an elevation of approximately 350 feet. The slope of the tributaries is greater than that of the Little Juniata, averaging 4.2%.

1.1.2 Land Use:

Land use in the Little Juniata River basin is approximately 18% developed, 17% agriculture, 63% wooded, and 2% transitional, and has approximately 73 miles of streams.

1.1.3 Surface Water Quality:

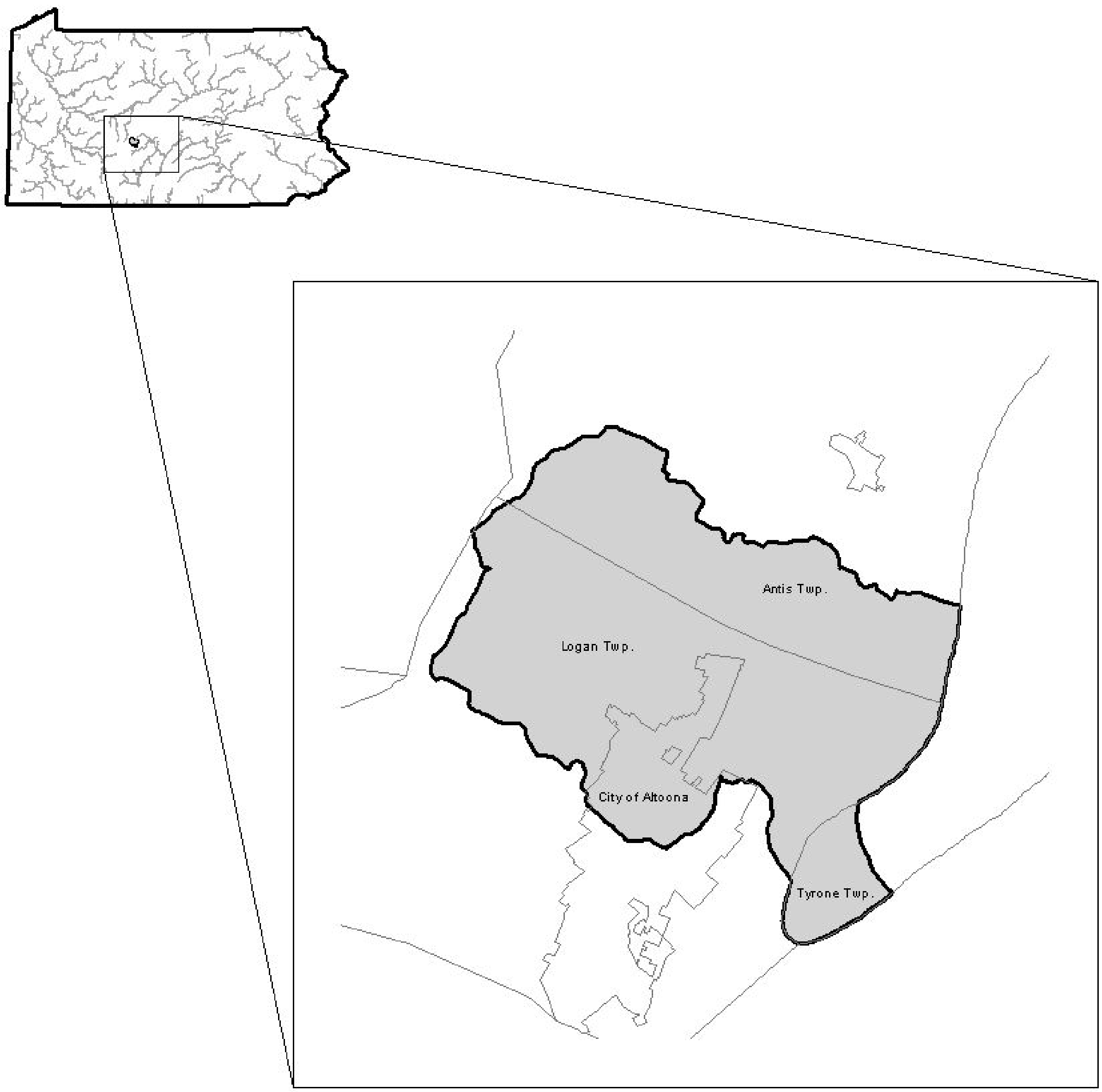
Pennsylvania's 2003 303(d) list identified 4.81 miles of the Little Juniata River as impaired by siltation from urban runoff and storm sewers, and organic enrichment from municipal point source dischargers (Table 1). The impairments on the Little Juniata begin at the headwaters in the city of Altoona and terminate at the downstream end of the study reach. In addition to impairments on the Little Juniata River, portions of Spring Run and Kettle Creek tributaries are also identified on the Pennsylvania 2003 303(d) list as being impaired by siltation from urban runoff and storm sewers. Respectively, 1.65 and 0.97 miles of Spring Run and Kettle Creek are listed for these impairments.

Table 1. Pennsylvania 2003 303(d)-listed streams within the Little Juniata River study area

Stream Name	Segment ID	Source	Cause	Miles Impaired
Little Juniata River	6555	Municipal Point Source	Organic Enrichment/Low D.O	4.81
		Urban Runoff/Storm Sewers	Cause Unknown	

Spring Run	20000317-1001-TAS	Small Residential Runoff	Siltation	1.65
		Urban Runoff/Storm Sewers	Siltation	
Kettle Creek	20000314-1246-TAS	Urban Runoff/Storm Sewers	Siltation	0.97

Figure 1. Little Juniata River watershed, Blair County



1.2 Approach to TMDL Development

1.2.1 Pollutants & Sources

Siltation from urban runoff, and organic enrichment from both nonpoint source runoff and municipal point source discharges have been identified as the pollutants causing designated use impairments in the Little Juniata River watershed.

1.2.2 TMDL Endpoints

The TMDL developed for the Little Juniata River watershed addresses non-point source impacts from sediment and point source phosphorus discharges. Implementing Best Management Practices (BMPs) will reduce siltation in the stream. Reduction of nonpoint source phosphorus loading along with the regulation of phosphorus discharges from the two municipal sewage treatment facilities in the watershed will lead to a decrease in organic enrichment and the associated low dissolved oxygen levels. The TMDL method used in this report will outline reductions required to restore the applicable designated uses.

In an effort to address the nutrient impairments found in the Little Juniata River watershed, Total Maximum Daily Loads (TMDLs) were developed for sediment and total phosphorus. The total phosphorus TMDL is intended to address current nutrient impairments in the Little Juniata River watershed, including impairments that were first identified in Pennsylvania's 1996 303(d) list. The decision to use phosphorus load reductions to address nutrient impairments was based on an understanding of the relationship between nitrogen, phosphorus, and organic enrichment in stream systems. Elevated nutrient loads (nitrogen and phosphorus in particular) can lead to increased productivity of plants and other organisms (Novotny and Olem, 1994). In aquatic ecosystems the quantities of trace elements are typically plentiful; however, nitrogen and phosphorus may be in short supply. The nutrient that is in the shortest supply is called the 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 ground water.

In most freshwater systems, phosphorus is the limiting nutrient for aquatic growth. In some cases, however, the determination of which nutrient is the most limiting is difficult. For this reason, the ratio of the amount of N to the amount of P is often used to make this determination (Thomann and Mueller, 1987). If the N/P ratio is less than 10, nitrogen is limiting. If the N/P ratio is greater than 10, phosphorus is the limiting nutrient. For Little Juniata River, the N/P ratio is estimated to be near 20 above the point source influences, which points to phosphorus as the limiting nutrient. Controlling the phosphorus loading to Little Juniata River will limit plant growth, thereby helping to eliminate use impairments currently being caused by excess nutrients.

2. Little Juniata Sediment TMDL

2.1 The Reference Watershed Approach

The TMDL developed for the Little Juniata River watershed addresses sediment. Because neither Pennsylvania nor EPA has in-stream numerical water quality criteria for sediment, a method was developed to implement the applicable narrative criteria. The method employed for this TMDL is termed the "Reference Watershed Approach." Meeting the water quality objectives specified by 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 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, or slightly lower than, the loading rate in the non-impaired, reference segment. This load reduction will result in conditions favorable to the return of a healthy biological community to the impaired stream segments.

2.2 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 Department 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 Little Juniata River that would satisfy the above characteristics was done by means of a desktop screening using several GIS coverages, including the Multi-Resolution Land Characteristics (MRLC), Landsat-derived land cover/use grid, the Pennsylvania's 305(b) assessed streams database, and geologic rock types

The Blair Gap Run watershed is located in Allegheny and Juniata Townships, approximately 17 miles southwest of the Little Juniata River. Blair Gap Run was selected as the reference watershed for developing the Little Juniata River sediment TMDL (Figure 2). The watershed is located in State Water Plan subbasin 11A and protected uses include trout stocking, warm water fishery, and cold water fishery as designated under Chapter 93 in Title 25 of the Pa. Code (Commonwealth of Pennsylvania, 2001).

Drainage area, location, and other physical characteristics of the Little Juniata River watershed were compared to the Blair Gap Run watershed (Table 2). Agriculture and forest are the dominant land use categories in both watersheds. Overall, the Little Juniata River watershed consists of 3,143 acres compared to the Blair Gap Run with 3,316 acres. Since urban runoff was the source of impairment identified, the first comparison was the amount of developed land, whereby 17% of Little Juniata River is developed versus 9% for Blair Gap Run. The surface geology in both watersheds is similar, comprised of carbonate, interbedded sedimentary, sandstone and shale.

Blair Gap Run and the Little Juniata River Watershed although very similar as stated above have very different stormwater management practices in place to control runoff. Stormwater management in Blair Gap Run includes surface water detention basins (drinking water supplies) that collect runoff and release it slowly. The retention and slow release of stormwater allows for the settling of sediment in these basins, less severe impacts to stream bank erosion as a result of the reducing peak stream flows, and less sedimentation deposition in the stream channel of Blair Gap Run.

Figure 2. Blair Gap Run Reference Watershed, Blair County

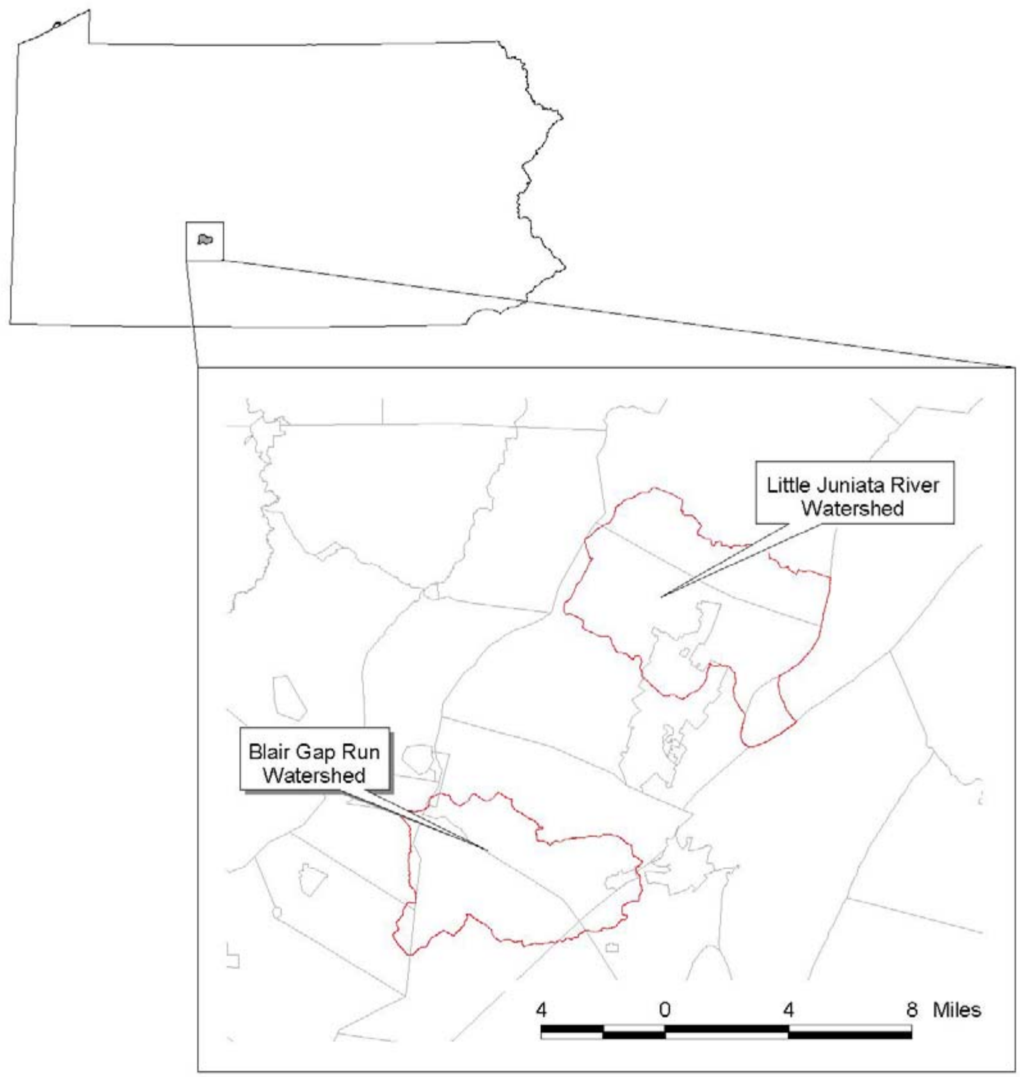


Table 2. Comparison between the Little Juniata River and Blair Gap Run watersheds.

Attribute	Watershed	
	Little Juniata River	Blair Gap Run
Physiographic Province	Ridge & Valley, Appalachian Plateaus	Ridge & Valley, Appalachian Plateaus
area (mi^2)	38	28
Land Cover	Forest (63%), Developed (18%), Agriculture (17%), Other (2%)	Forest (71%), Developed (9%), Agriculture (17%), Other (3%)
Geology	Carbonate, Interbedded Sedimentary, Sandstone, Shale	Carbonate, Interbedded Sedimentary, Sandstone, Shale
Soils	Hazleton-Dekalb-Buchanan, Leck Kill-Calvin-Klinesville, Berks-Weikert-Bedington, Morrison-Hazleton-Clymer	Hazleton-Dekalb-Buchanan, Leck Kill-Calvin-Klinesville, Berks-Weikert-Bedington, Chenango-Pope-Holly
Soil Hydrologic Group	2% A, 36% B, 45% C, 16% D	3% A, 33% B, 48% C, 15% D
Average Annual Runoff (in)	10.01	3.35

2.3 Watershed Assessment and Modeling

The sediment TMDL for the Little Juniata River watershed was developed using the ArcView Generalized Watershed Loading Function (AVGWLF) model as described in Appendix B. The AVGWLF model was used to establish existing loading conditions for the Little Juniata River watershed and the Blair Gap Run reference watershed. All modeling outputs have been attached to this TMDL as Appendices C and D. DEP staff visited both watersheds in August 2004. These field visits were conducted to get a better understanding of existing conditions that might influence the AVGWLF model.

The AVGWLF model produced information on watershed size, land use, and sediment loading. (Tables 3 and 4). The sediment load represents an annual average over the 11 years simulated by the model (1986 to 1997). This information was then used to calculate existing unit area loading rates for the Little Juniata River and Blair Gap Run watersheds.

Unit area loading rates for sediment were estimated for each watershed by dividing the mean annual loadings (lbs./yr.) by the total area (acres). Unit area load estimates for sediment in the Little Juniata River watershed is 0.642 tons/acre/yr. (Table 3). Unit area load estimates for sediment in the Blair Gap Run reference watershed is 0.397 tons/acre/yr. (Table 4).

Table 3. Existing sediment loads for the Little Juniata River watershed.

Pollutant Source	Area (ac)	Mean Annual Sediment Loading (tons/yr)	Mean Annual Sediment Loading Rate (tons/acre/yr)
Hay/Pasture	1576.5	178.45	0.113
Cropland	2594.6	3657.9	1.410
Coniferous Forest	59.3	0.41	0.007
Mixed Forest	899.5	11.67	0.013
Deciduous Forest	14161.6	418.04	0.030
Unpaved Roads	2.5	8.79	3.516
Quarry	29.7	39.7	1.336
Transitional Land	476.9	2782.9	5.835
Low Intensity Developed	2851.6	157.0	0.055
High Intensity Developed	1453	34.73	0.024
Stream Bank Erosion		8195.1	
Total	24105.2	15484.6	0.642

Table 4. Existing sediment loads for the Blair Gap Run reference watershed

Pollutant Source	Area (ac)	Mean Annual Sediment Loading (tons/yr)	Mean Annual Sediment Loading Rate (tons/acre/yr)
Hay/Pasture	1603.7	195.41	0.122
Cropland	1870.6	2558.7	1.368
Coniferous Forest	205.1	7.1	0.035
Mixed Forest	546.1	8.13	0.015
Deciduous Forest	11836.3	240.11	0.020
Unpaved Roads	9.9	0	0.000
Quarry	61.8	655.82	10.612
Low Intensity Developed	553.5	46.44	0.084
High Intensity Developed	1057.6	38.84	0.037
Stream Bank Erosionank		3288.5	
Total	17744.6	7039.05	0.397

2.4 Sediment TMDL

Targeted TMDL values for the Little Juniata River watershed were established based on current loading rates for sediment in the Blair Gap Run River reference watershed. Reducing the loading rate of sediment in the Little Juniata River basin to levels equal to, or less than, the Blair Gap Run reference watershed will provide conditions favorable for the reversal of current use impairments.

2.4.1 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.

2.4.2 Targeted TMDL

Targeted TMDL values for sediment were determined by multiplying the total area of the Little Juniata River watershed (24,105.2 acres) by the appropriate unit area loading rates for the Blair Gap Run reference watershed (Table 5).

Table 5. Targeted Sediment TMDL for the Little Juniata River watershed.

Pollutant	Area(ac.)	Unit Area Loading Rate Blair Gap Run Ref. Watershed	Targeted TMDL
Sediment	24,105	0.397 tons/ac/yr	9570 tons/yr

Targeted TMDL values were than used as the basis for load allocations and reductions in the Little Juniata River watershed, using the following two equations:

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

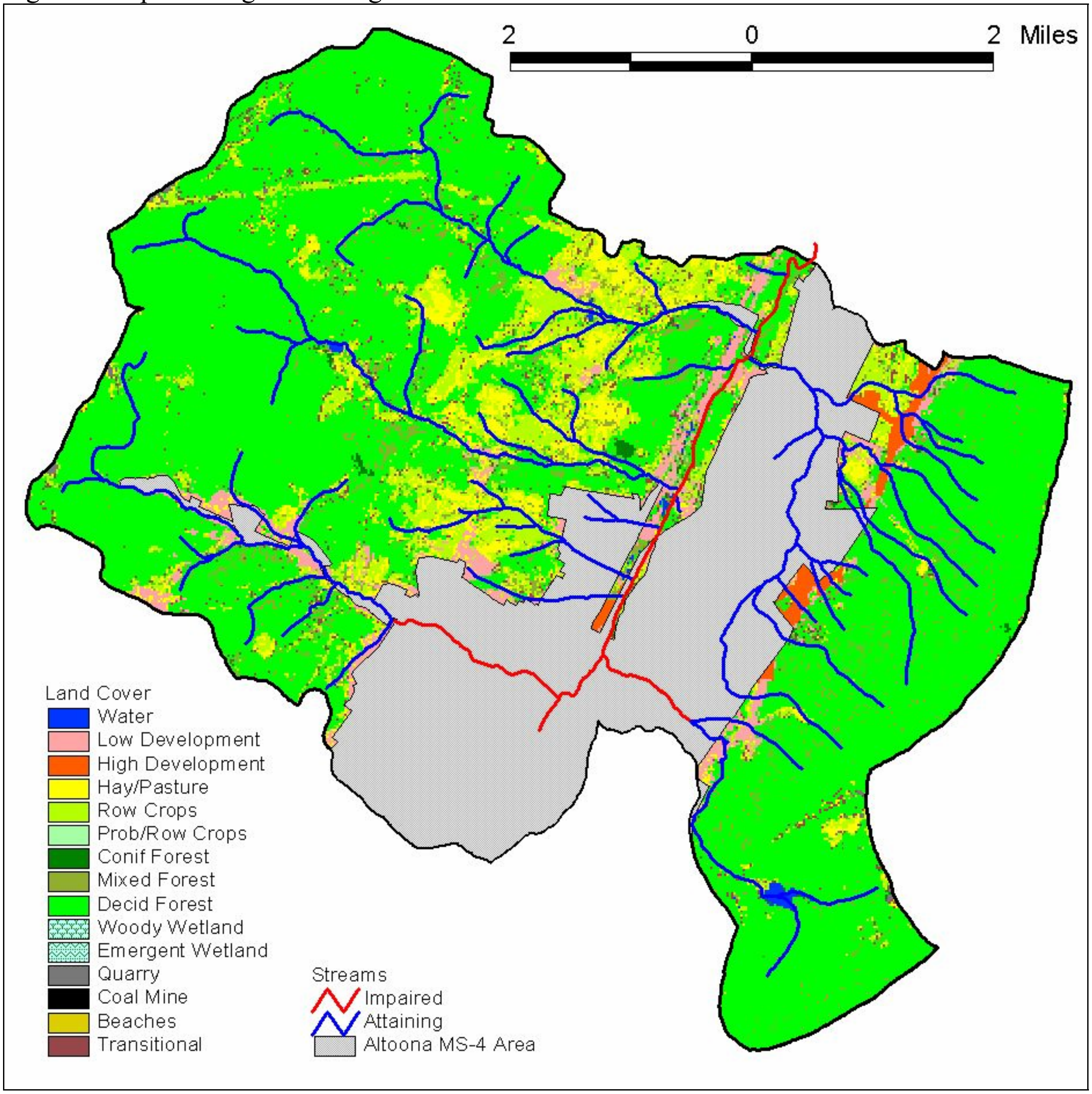
where:

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

2.4.3 Wasteload Allocation

The waste load allocation (WLA) portion of the TMDL equation is the total loading of a pollutant that is assigned to point sources. Approximately 23% of the Little Juniata River watershed area falls in an MS4 designated area (Figure 3). Therefore, a portion of the sediment allocation must be classified as a wasteload allocation. That portion was calculated as the difference between the total allowable load for Little Juniata River and the allowable load from the watershed area not classified as an MS4 area as calculated from the allowable loading rates by land use as shown in Table 6.

Figure 3.Map showing MS4 designated are in the Little Juniata Headwaters Watershed



Thus, the sediment WLA for Little Juniata River watershed is:

WLA = TMDL Load - MOS - Sediment Load from non-MS4 area

WLA = 9570 tons/yr – 957 tons/yr – 6577 tons/yr

WLA = 2036 tons sediment/year

Table 6. Non-MS4 sediment load.

Pollutant Source	Non-MS4 Area (acres)	Mean Annual SedimentLoading Rate (tons/acre/yr)	Mean Annual Sediment Load (tons/year)
Hay/Pasture	1,218.2	0.062	75.0
Cropland	1,821.2	0.767	1,396.2
Coniferous Forest	44.5	0.007	0.3
Mixed Forest	719.1	0.013	9.3
Deciduous Forest	13,459.8	0.030	397.3
Unpaved Roads	2.5	1.912	4.8
Quarry	29.7	0.727	21.6
Transition	370.6	0.544	201.6
Low Intensity Developed	726.5	0.030	21.7
High Intensity Developed	195.3	0.013	2.5
Streambank	59.5 (mi)		4,446.4
Total	18,587.5	0.354	6,576.8

2.4.4 Load Allocation

The load allocation (LA) is the sediment load allocated to non-MS4 areas in the watershed as calculated in Table 6.

LA (Sediment) = 6,577 tons/yr

2.4.5 Margin of Safety

The margin of safety (MOS) is that portion of the pollutant loading that is reserved to account for any uncertainty in the data and computational methodology used for the analysis. For this analysis, the MOS is explicit. Ten percent of the targeted TMDL for sediment was reserved as the MOS. Using 10% of the TMDL load is based on professional judgment and will provide an additional level of protection to the designated uses of Little Juniata River. The MOS for the sediment TMDL was set at 957 tons/yr.

MOS (Sediment) = 9570 tons/yr. (TMDL) x 0.1 = 957 tons/yr.

2.4.6 Adjusted Load Allocation

The adjusted load allocation (ALA) is the actual portion of the LA distributed among those non-point sources receiving reductions. It is computed by subtracting those non-point source loads that are not being considered for reductions (loads not reduced or LNR) from the LA. Since the Little Juniata River watershed TMDL was developed to address impairments resulting from urban runoff and storm sewers, reductions were made to Hay/Pasture, Cropland, Unpaved Roads, Quarry, Transition, Low Intensity Developed, High Intensity Developed, and Streambank Land cover types. Those land uses/sources for which existing loads were not reduced (Coniferous Forest, Mixed Forest, and Deciduous Forest) were carried through at their existing loading values. The ALA for sediment was 6,169 tons/yr.

2.4.7 TMDL

The sediment TMDL established for the Little Juniata River watershed consists of a Load Allocation (LA) and a Margin of Safety (MOS). The individual components of the TMDL are summarized in Table 7.

Table 7. TMDL components (TMDL, WLA, LA, LNR, ALA, MOS) for the Little Juniata River watershed

Component	Sediment (tons/yr)
TMDL (Total Maximum Daily Load)	9,570
WLA (Wasteload Allocation)	2,036
MOS (Margin of Safety)	957
LA (Load Allocation)	6,577
LNR (Loads Not Reduced)	407
ALA (Adjusted Load Allocation)	6,169

2.4.8 Calculation of Sediment Load Reductions

Adjusted load allocations established in the previous section represent the sediment load that is available for allocation between contributing sources in the Little Juniata River watershed. Data needed for load reduction analyses, including land use distribution, were obtained by GIS analysis. The Equal Marginal Percent Reduction (EMPR) allocation method (Appendix E) was used to distribute the ALA between the appropriate contributing land uses.

The load allocation and EMPR procedures were performed using MS Excel and results are presented in Appendix F. Table 8 contains the results of the EMPR for sediment and the appropriate contributing land uses in Little Juniata River watershed. The load allocation for each land use is shown, along with the percent reduction of current loads necessary to reach the targeted LA.

Table 8. Total sediment load allocations and reductions for the Little Juniata River watershed.

Pollutant Source	Acres	Pollutant Loading (tons/yr)		Unit Area Loading Rate (tons/ac./yr.)		% Reduction
		Current	Allowable	Current	Allowable (LA)	
Hay/Pasture	1577	178.5	97.0	0.11	0.06	46%
Cropland	2595	3657.9	1989.2	1.41	0.77	46%
Transitional Land	477	2782.9	1513.4	5.84	0.54	46%
Low Intensity Developed	2852	157.0	85.4	0.06	0.03	46%
High Intensity Developed	1453	34.7	18.9	0.02	0.01	46%
Unpaved Roads	3	8.8	4.8	3.52	1.91	46%
Quarry	30	39.7	21.6	1.34	0.73	46%
Stream Bank Erosion	-	8195.1	4446.4	-	-	46%
Total	8985	15054.5	8176.6	-	-	

2.5 Consideration of Critical Conditions

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

2.6 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.

2.7 Recommendations for Implementation

TMDLs represent an attempt to quantify the pollutant load that may be present in a waterbody and still ensure attainment and maintenance of water quality standards. The Little Juniata River TMDL identifies the necessary overall load reduction for sediment currently causing use impairments and distributes the reduction goals to the appropriate non-point sources. Reaching the reduction goal established by this TMDL will only occur through changes in current land use practices, including the incorporation of more stormwater "best management practices" (BMPs).

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 throughout the Little Juniata River watershed to help limit siltation. Determining the most appropriate BMPs, where they should be installed, and actually putting them into practice, will require the development and implementation of a comprehensive watershed restoration plan. Development of any restoration plan will involve the gathering of site-specific information regarding current land uses and existing conservation practices. The required level of detail is outside the scope of this TMDL document and is an activity best accomplished at the local level. Successful implementation of the activities necessary to address current use impairments to Little Juniata River will require local citizens taking an active interest in the watershed and the enthusiastic cooperation of local landowners.

By developing a TMDL for the Little Juniata River watershed, the Department has set the stage for local citizens to design and implement restoration plans to correct current use impairments. The Department will support local efforts to develop and implement watershed restoration plans based on the reduction goals specified in the TMDLs. Interested parties should contact the appropriate Watershed Manager in the Department's Northeast Regional Office (570-826-2360) for information regarding technical and financial assistance currently available. Individuals and/or local watershed groups interested in "fixing" the identified problems in the Little Juniata River watershed are strongly encouraged to avail themselves of funding sources available through DEP and other state and federal agencies (e.g., Growing Greener or 319 Program).

3. Phosphorus TMDL

This section of the TMDL addresses impairment originally documented on the 1996 303(d) list due to "organic enrichment/low D.O." These stream segments were listed due to problems associated with municipal point source discharges within the Little Juniata River watershed. Based upon field assessments completed under the State's Unassessed Waters Program, 4.81 miles were listed as impaired. . Such problems are primarily related to excess nutrients. In some areas where point source discharges are located, problems with nutrient-enriched sediment from agricultural and urban areas also occur. These latter problems have been identified and addressed in Section 1. In such cases, TMDLs were developed to address this type of problem.

In past TMDLs we have used the Reference Watershed approach for setting the phosphorus reduction objectives for a watershed. This method has worked well as a starting point on how we solve nutrient related problem in our waterways, especially in watersheds dominated by NPS pollution. As we have progressed and completed more TMDLs we have acknowledged the need to have instream concentration targets for determining the appropriate loading allowed to a waterbody. We are currently in the process of developing phosphorus criteria, and these should be available in two to three years. Part of this criteria development process is taking an in depth look at how periphyton (attached algae) growth is affected by phosphorus. The primary pigment in algae is chlorophyll-a and it is used as the indicator of nutrient enrichment. As part of the TMDL process in the Skippack Creek watershed[1] a relationship between the periphyton and phosphorus concentration was established. A range of phosphorus concentration values was determined through a regression analysis. The range of acceptable phosphorus concentration values was based on maintaining a standing crop of periphyton between 50 and 100 mg/m^2 measured as chlorophyll-a. This range for benthic chlorophyll-a is established in literature as the level above which nuisance algae conditions exist . The phosphorus concentration values that result in chlorophyll-a levels of 50 to 100 mg/m2 in the Skippack Creek watershed are 70 and 236 ug/l. We currently do not have enough information to either confirm that the values shown in the Skippack study would be appropriate for use in the Little Juniata, or to perform an equivalent analysis. For this reason we will be collecting site specific data during the 2005 calendar year to support a planned revision to the TMDL that will occur by December of 2007.

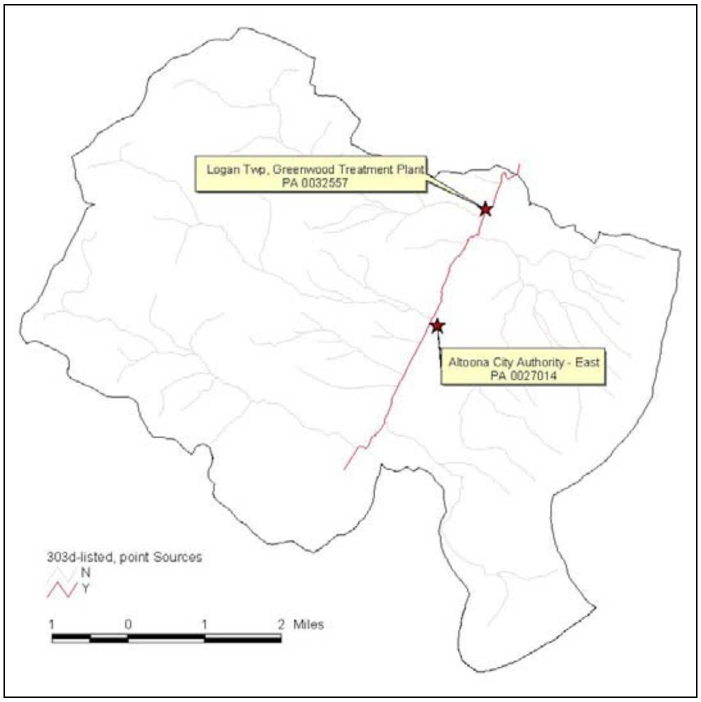
This section addresses stream segments listed due to problems associated with municipal point source discharges within the Little Juniata River watershed. Such problems are primarily related to excess nutrients. Information pertaining to segments impaired by municipal point sources is summarized in Table 9, and the segments themselves are graphically depicted in Figure 4. Based upon field assessments completed under the State's Unassessed Waters Program, 4.81 miles of the 73.85 stream miles in the watershed have been listed as being impaired by municipal point sources on the State's current 303(d) List since 1996. As can be seen in Figure 4, there are several stream segments listed for municipal point sources that are located upstream of the two point sources that are currently in operation within the watershed. These segments include Segment IDs 15664_29.3646_29.4125, 15664_29.4125_29.7166, 15664_29.7166_30.2014, 15664_30.2014_30.3539, 15664_30.3539_30.8818, 15664_30.8818_31.461, and 15664_31.461_31.7769. Impairment in these reaches has likely been caused by storm sewers and urban runoff. As such, these impaired segments were addressed in the sediment TMDL outlined above and are not considered in this analysis. Subtracting the lengths of these segments from the total point source impaired stream length, 2.55 miles in the Little Juniata are impaired by point sources, and will be addressed in this section. While neither the Altoona City Authority – East nor the Logan Twp. – Greenwood facility currently have phosphorus-specific effluent it is apparent that regulation of the phosphorus loads discharged from these facilities is needed in order to achieve acceptable water quality conditions.

Table 9. Segment impaired by municipal point source discharges as described on Pennsylvania's current 303(d) list.

Stream Name	Segment ID	Source	Cause	Miles Impaired
Little Juniata River	15664	Municipal Point Source	Organic Enrichment/Low D.O	4.81

[1] **Using periphyton to estimate TMDL endpoints and assess impairment in an urban-suburban stream (Skippack Creek, Pennsylvania)**

Figure 4. Map depicting location of streams impaired (Y) or not impaired (N) by point source discharges as noted on DEP's current 303(d) list.



As detailed in the previous section, the AVGWLF modeling approach was used to support the development of non-point source sediment TMDLs for the Little Juniata River watershed. With this approach, AVGWLF was used to estimate unit-area loading rates for sediment in the impaired watershed (Little Juniata) and compare the loads against similarly-derived loads in a reference watershed (Blair Gap Run).

In this section, both the AVGWLF and STREAMPLAN-PA models were used. AVGWLF was first used to estimate non-point source flow and nutrient concentrations in the Little Juniata River. The AVGWLF results were then provided as input to the STREAMPLAN-PA model, which combines the background flow and pollutant concentration conditions with point source discharge data to estimate in-stream nutrient concentrations. As will be seen below, estimated in-stream concentrations for different discharge scenarios were compared to assess potential point source discharge allocations and reductions.

Currently, neither the Altoona City Authority – East nor the Logan Twp – Greenwood facility currently have phosphorus effluent concentration limits and normally only report phosphorus discharge concentrations quarterly (four times per year). Therefore, it is difficult to establish baseline effluent concentrations for the two plants. Both of the plants had limited phosphorus information, a summary of which is provided along with discharge rates in Table 10.

Table 10. Discharge and phosphorus concentration data for permitted dischargers in the Little Juniata River watershed, January 1999 – February 2004.

Municiple Facility Name	NPDES Permit	Discharge (average, mgd)	Plant Design Discharge (mgd)	Phosphorus (Average of Samples, mg/L)
Altoona City Authority - East	PA 0027014	6.360	8.0	3.27
Logan Twp. - Greenwood Facility	PA 0032557	0.469	0.7	1.88

Discharge information is available from both plants on a daily basis. However, similar to phosphorus, neither facility has a discharge limit. Since neither facility has either discharge or phosphorus concentration limits, there are no compliance issues to mention regarding these two constituents.

In addition to the discharge monitoring reports completed by each of the point source facilities, a limited amount of additional information is available in two Water Quality Protection Reports, completed in 1999 and 2000 for the Altoona and Logan facilities respectively. A biological survey conducted to support the development of the Logan facility Water Quality Protection Report indicates that water quality in the Little Juniata River is poor. While biological organism density is good, most organisms found were facultative or pollution-tolerant. Phosphorus levels measured in the stream were about 2 mg/L. Dissolved oxygen (DO) concentrations in the stream were at critical levels. A DO concentration of <2.0 was measured on 7/20/1999 and a DO of 3.0 mg/L was measured on 8/20-21/1999. An algal assay conducted in conjunction with this report suggests that phosphorus concentrations are so high, that nitrogen is the limiting nutrient. While this may be the case, nitrogen levels in the stream are acceptable when compared to healthy streams in the region. To reduce nitrogen levels enough to result in a significant reduction in algal productivity is not a feasible solution to the problem due to naturally high ambient nitrogen concentrations. Therefore, phosphorus levels will need to be reduced to mitigate the water quality conditions in the Little Juniata River watershed.

3.1 In-stream Phosphorus Endpoint

Based upon the results presented in the Water Quality Protection Reports discussed above, it is apparent that nutrient impairments exist on the main stem of Little Juniata River. This TMDL is designed to remove impairments in these waters and meet water quality standards.

Pennsylvania's criterion for nutrients is included in 25 Pa. Code § 93.6, general water quality criteria, as a narrative. There is currently no numeric criterion for phosphorus in the water quality standards. The narrative criterion must be interpreted in order to define the water quality for nutrients - in this case, phosphorus - that will demonstrate the TMDL will address the stream impairment. As mentioned earlier in this document, the Department has recognized the need for an in-stream evaluation mechanism and is currently developing nutrient criteria. The Department will also be collecting site specific data that will be used in the amended TMDL.

The impact of phosphorus on the watershed is nuisance algae growth. In this watershed, the impairment is attributable primarily to point source discharges, and the critical period occurs under extreme low flows.

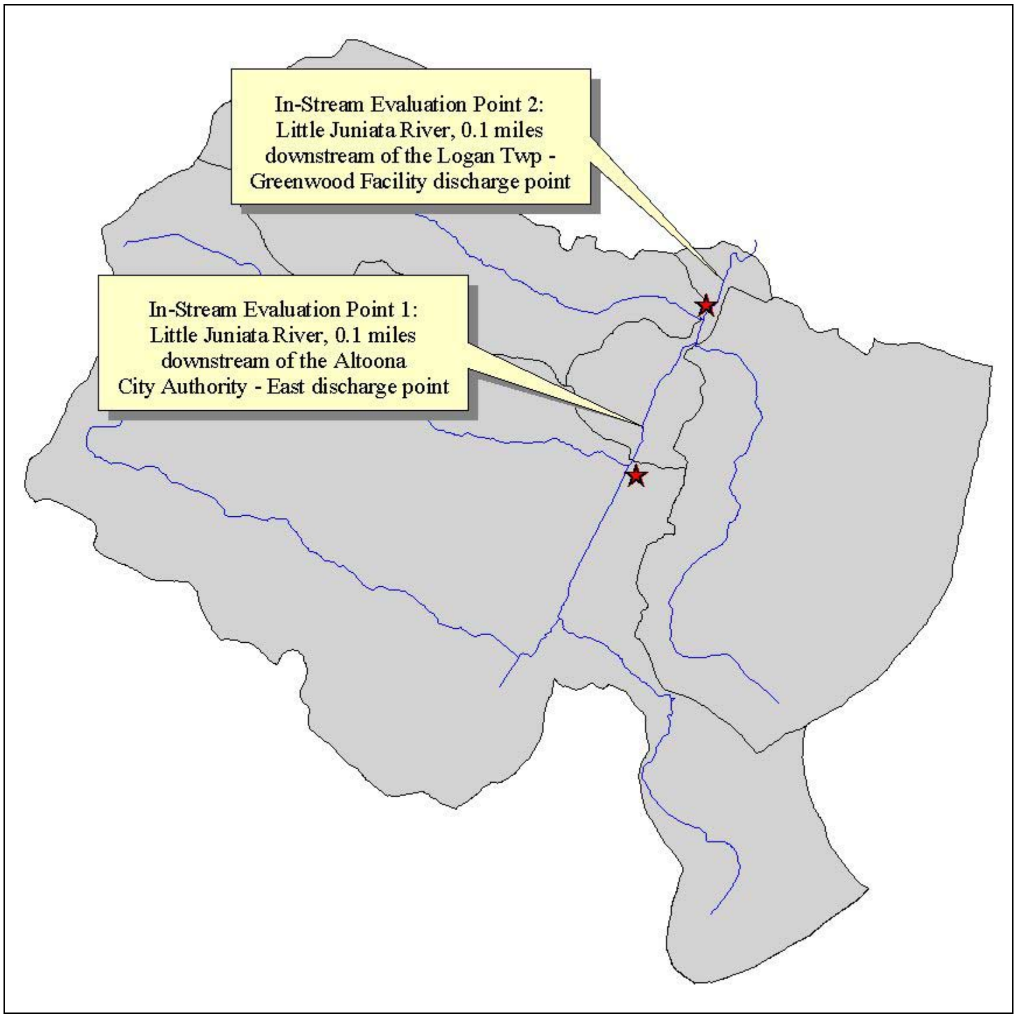
3.2 Approach to Nutrient TMDL for Point Sources

In contrast to what was done for the non-point source related problems discussed in Section 1, a combined approach involving the use of the watershed-based AVGWLF model and the "in-stream" STREAMPLAN-PA model was used. In this case, AVGWLF was first used to estimate non-point source loads to affected streams, and then STREAMPLAN-PA was subsequently used to combine these loads with point source discharge data to estimate in-stream nutrient concentrations. These estimated in-stream concentrations were calculated for critical, low-flow conditions; conditions under which point source-dominated systems such as the segments of the Little Juniata River we are evaluating, are most vulnerable. In-stream phosphorus concentrations under future loading (i.e., discharge) conditions were compared with concentrations under existing loading conditions in order to show a range of possible point source load reductions.

As explained in various sections of this document, a stream water quality model was used to predict in-stream phosphorus concentrations under various pollution reduction scenarios. A TMDL is normally expressed as a load over time; however, it is the in-stream phosphorus concentration under critical, low-flow conditions that must be reduced to remove the nutrient impairments in the Little Juniata River watershed. Therefore, water quality improvements will be evaluated through comparison of water column phosphorus concentrations at the critical condition.

The evaluation of in-stream phosphorus concentration was made at two points, illustrated in Figure 5. In-stream evaluation point 1 is located on the mainstem of the Little Juniata River, approximately 0.1 miles below the Altoona City Authority – East sewage treatment facility. In-stream evaluation point 2 is located on the mainstem of the Little Juniata River approximately 0.1 miles downstream of the Logan Twp – Greenwood sewage treatment facility. Numerous model runs were made to illustrate the range of instream nutrient targets and the reductions needed by the point source discharges to achieve them.

Figure 5. In-stream phosphorus concentration evaluation points.



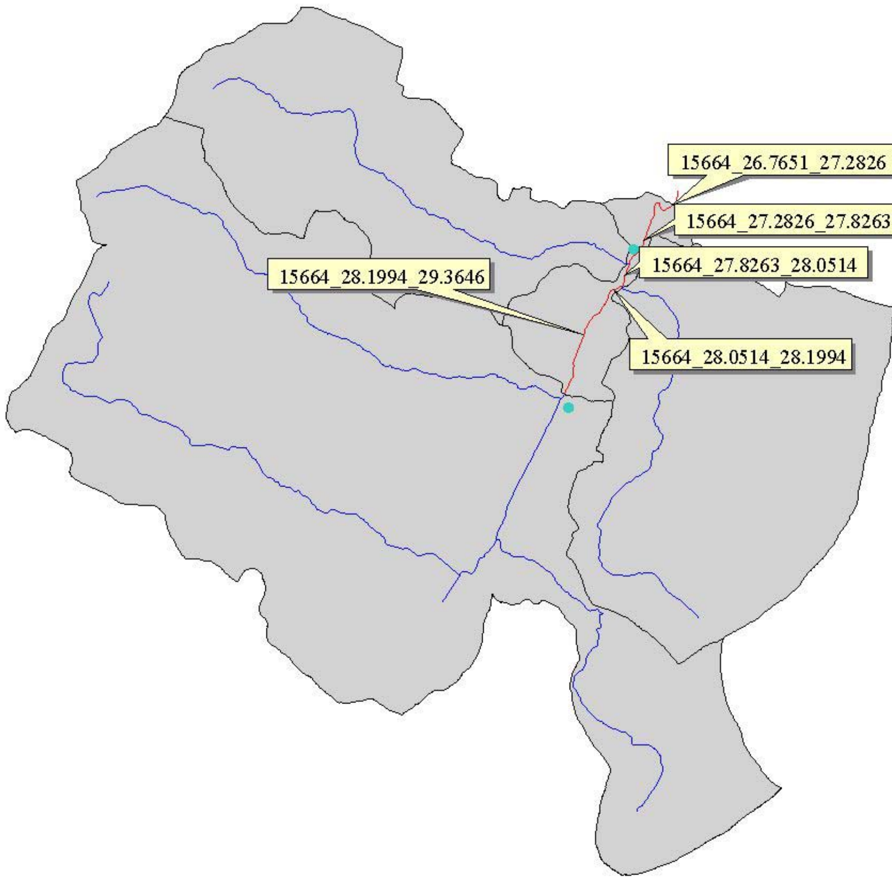
To confirm that prescribed phosphorus reductions correct the impairment, stream conditions will be evaluated following implementation of this TMDL. If the watershed is found to continue to have nuisance algae problems, the TMDL will have to be reassessed and additional nutrient controls will be considered.

3.3 Modeling Overview

As shown earlier in Table 9, twelve (12) stream segments (reaches) on the mainstem of the Little Juniata River have been included on DEP's current 303(d) list as being impaired by municipal point source discharges. Of these segments, 5 are located downstream of the two point source dischargers in the watershed. These 5 stream segments will be addressed in this TMDL and are depicted graphically in Figure 6. As discussed previously, these same segments were also determined to be impaired by storm sewers and urban runoff. These impairments were treated as "sediment-related", and addressed separately in that section.

For modeling purposes, the sub-basin boundaries shown in Figure 6 were delineated for the purpose of more precisely estimating non-point source nutrient loads using AVGWLF within each sub-basin. Within each sub-basin, and cascading through the entire stream network, nutrient loads and concentrations computed for each upstream reach with STREAMPLAN-PA were passed as input to succeeding downstream reaches. More detail on the AVGWLF and StreamPlan-PA models is provided in appendices B and C respectively.

Figure 6. Point source impaired stream reaches evaluated in the TMDL.



The modeling of phosphorus concentrations described in the following sections was conducted under critical conditions (7Q10 flow). It is under these conditions that elevated water column nutrient levels will have the most detrimental effect on the aquatic system. However, elevated nutrient concentrations are harmful to aquatic systems during all flow conditions (i.e. medium, high stream flow). Therefore, prior to establishing the point source phosphorus reductions, average monthly instream phosphorus conditions were evaluated from 1987 – 1996. Using the AVGWLF and StreamPlan-PA models, non-point source phosphorus concentrations were reduced iteratively until in-stream phosphorus concentration remained below the DEP-established in-stream phosphorus concentration criteria during all flow conditions.

After addressing the non-point source phosphorus contributions, point source discharge and phosphorus concentration information was added to the StreamPlan model. Modeled in-stream phosphorus concentration was varied to include a range of values from 0.1 mg/l to 1.8 mg/l. To establish compliance with the in-stream phosphorus objective concentration criteria, point source discharges were set at the plant design discharge (0.7 mgd for Logan Twp., 8 mgd for Altoona – East). The TMDL process requires that the evaluation of point source discharge be completed as a worst case scenario. Point source effluent concentrations were evaluated at the two in-stream points identified in Figures 5 and 6.

3.4 Consideration of Critical Conditions

During low flow conditions (typically between May and October of any given year), the effluent discharged from wastewater treatment plants in the Little Juniata River watershed often comprises over 90% of the total stream flow. In a point source-dominated stream system, such periods are considered to be the most critical in terms of potential water quality impacts (Thomann and Mueller, 1987). Given this, it was determined that the point source load analysis should be performed using low-flow conditions.

PA Title 25 Chapter 96.4 requires that point source discharges be evaluated at the flows specified in table 1. For phosphorus this would be the 7Q10 flow, which is defined as the average stream flow that occurs over 7 consecutive days and has a 10-year recurrence interval, or a 1 in 10 chance of occurring in any given year. Based on a 19-year (1980-1998) flow from the USGS stream discharge gage located on the Little Juniata River at Spruce Creek, a representative critical low-flow period (i.e., 7Q10 flow) for Little Juniata River was determined to occur during August 1995. The USEPA DFLOW tool for low flow analysis (http://epa.gov/waterscience/dflow/) was used to identify this condition. During this period, the GWLF-simulated flow is 0.32 cfs, and point source effluent comprised 97% of the total stream flow (using average point source discharges).

3.5 Estimation of Required Phosphorus Load Reductions

To adequately represent point source discharges in the watershed, data obtained from DEP monthly discharge monitoring reports (1999-present) were used. The GWLF model was used to generate watershed hydrology input for the STREAMPLAN-PA point source model. For GWLF, a weather data set for the 4-week period of August 1995 was used to represent critical, low-flow conditions in the watersheds.

After calculating the monthly non-point source phosphorus concentrations, the in-stream phosphorus conditions were simulated using the low flow watershed conditions simulated by GWLF and the point source DMR data (Table 10). The model was then iteratively run using a range of instream endpoints to determine needed point source load reductions. The overall objective of this modeling exercise was to determine point source phosphorus load values that would satisfy each of the instream phosphorus values shown in the table below.

The simulated in-stream phosphorus concentrations under critical, low-flow conditions at the two in-stream evaluation points identified in Figure 5 are given in Table 11.

Table 11. Estimated in-stream P objectives at the loads from point sources required to meet them

In-stream P Concentration (mg/L)	Logan Twp. Phosphorus Load (lb P/yr)	Altoona East Phosphorus Load (lb P/yr)
0.1	655	2782
0.2	1358	5271
0.3	2122	8082
0.4	2875	10776
0.5	3589	13470
0.6	4009	16340
0.7	4095	19705
0.8	4224	23198
0.9	4311	26599
1.0	4311	29772
1.1	4311	32456
1.2	4311	35384
1.3	4311	38313
1.4	4311	41485
1.5	4311	44413
1.6	4311	47342
1.7	4311	48806
1.8	4311	48806

The table shown above represents a wide range of in-stream phosphorus values and subsequent loads that would need to be met by each discharger to attain that in-stream objective at both evaluation locations. Our current work in the Skippack Creek Watershed has resulted in the selection of 0.24 mg/l as the in-stream objective for phosphorus. This is based on meeting a target value of 100 mg/m2 chlorophyll-a that is measured from the stream bed. The 100 mg/m2 benchmark is defined in literature as the upper bound for a healthy ecosystem. It is very likely that a similar endpoint will be determined from the site-specific data that will be collected by the Department in calendar year 2005 in the Little Juniata watershed.

As a starting point for reducing phosphorus inputs to the Little Juniata River at the locations shown on the map, the Department will apply a phased approach. The two phases of this approach represent two NPDES permit cycles.

The first phase will be based on the requirements contained in PA Title 25 Chapter 96 as amended, which allows for technology based requirements to be applied to discharges of phosphorus where a nutrient problem has been identified, or the allocations prescribed by the Departments Tributary Strategy for the Chesapeake Bay to meet standard set forth by the state of Maryland. PA Title 25 Chapter 96.5 states that a maximum value of 2 mg/l be applied as an effluent limit where nutrient impairment has been identified. During the first permit cycle, the more stringent of 2 mg/l effluent TP limits or Chesapeake Bay tributary strategy allocations for the Altoona East and Logan Township treatment plants will be applied.

The second phase of the TMDL will be implementing the water quality based solution. This will be determined after the in-stream objective is determined for the stream. The water quality based effluent limits that will be determined using the models that have been described earlier along with the in-stream endpoint will be applied during the second permit cycle.

3.6 Additional Expected Phosphorus Reductions from Non-Point Source Loads

As discussed above, a sediment-related TMDL has been developed for the Little Juniata River watershed. Since phosphorus that enters a stream is often attached to sediment eroded from upland areas and stream banks, it is expected that decreases phosphorus loads from non-point sources will also be realized on a mean annual basis due to BMPs implemented to reduce sediment loss in this watershed.

Table 8 shows current and expected sediment loads based on the TMDL target described in above. Based on available data, it is estimated that the soils in Little Juniata River watershed contain 366 mg P/kg soil. Therefore, approximately 4,300 lb P/yr will be reduced as a result of achieving the reductions called for in the sediment TMDL.

3.7 Consideration of Critical Conditions

Federal Regulations (40 CFR 130.7(1)) require TMDLs to consider critical conditions for streamflow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality in waterbodies is protected during periods when they are most vulnerable. Accordingly, the point source-related TMDLs for Little Juniata River and its tributaries were developed using critical, low-flow (i.e., 7Q10) conditions. During such periods, effluent discharges comprise over 90% of the total streamflow. Critical conditions for nutrient (i.e., phosphorus) loads were considered by determining WLAs based on maximum flows from dischargers specified in NPDES permits for each facility. At present, the cumulative discharged flow from all facilities is about 78% of the cumulative maximum flow (based upon plant design specifications). Use of design maximum discharge flow in TMDL determination provides additional assurance that when design flows are reached, the water quality in affected streams will continue to meet water quality criteria.

3.8 Consideration of Seasonal Variations

Higher nutrient concentrations typically occur during the summer low-flow period. During this period, there is reduced stream capacity to assimilate point source discharges due to less streamflow available for dilution, lower stream velocities, greater light penetration, etc. Also, the activity of aquatic biota varies seasonally as a function of streamflow and temperature, with greater impacts associated with warmer, low-flow conditions. Since biological activity was an important consideration in DEP's original listing of the stream segments as impaired due to nutrients, attention to the summer low-flow period was critical. It is assumed that if the stream segments are protected during this critical period, then other periods of lower temperatures, less biological activity, and more assimilative stream capacity will be protected as well.

3.9 Reasonable Assurance of Implementation

Implementation of the municipal sewage treatment facility and non-point source phosphorus reductions (in conjunction with nutrient reductions associated with sediment TMDL described in Section 1) should achieve the loading reduction goals established in the nutrient TMDL discussed in this section. The nutrient TMDL and WLA reported in this section are contingent upon the assumption that current phosphorus limits reflected in the NPDES permits for regulated facilities within the Little Juniata River watershed will be reduced during critical, low-flow periods over a two permit cycle time-frame. In the first permit cycle, dischargers will receive mass limits for TP in upcoming permits consistent with the loads allocated in Pennsylvania's Chesapeake Bay Tributary Strategy document. Over the course of the first permit cycle, the Department will perform the field data collection, discussed earlier and, required to develop the site-specific in-stream phosphorus requirements to meet local water quality standards. The WQBEL will then be included in the next permit.

New and expanded discharges will also be required to meet the established WQBEL limit. This control strategy encourages the use of pollution prevention techniques designed to reduce the volume of point source discharges to the streams when growth occurs. Methods that limit additional flows, such as reducing inflow & infiltration, water conservation and re-use, land application, and others, provide environmentally sound ways to accommodate growth in the watershed and still achieve the benefits of improved water quality. It may also be possible to design a pollutant trading scheme that will both satisfy local water quality and Chesapeake Bay requirements.

4. Public Participation

A notice of availability for comments on the draft Little Juniata River watershed TMDLs was published in the PA Bulletin on February 12, 2005 and on the Department's web page shortly thereafter. In addition, a public meeting was held on February 15, 2005 at the Antis Township Building in Bellwood, PA to address any outstanding concerns regarding the draft TMDLs. A notice on the public meeting was published in the XXXXXXXX newspaper on February XX, 2005. A 30-day period (ending on March 07, 2005) was provided for the submittal of comments. Notice of final TMDL approvals will be posted on the Department's website.

Appendix A - Information Sheet for Little Juniata River Watershed TMDL

What is being proposed?
A Total Maximum Daily Load (TMDL) plan has been developed to improve water quality in the Little Juniata River watershed.

Who is proposing the plan? Why?
The Pennsylvania Department of Environmental Protection (PADEP) is proposing to submit the plan to the U.S. Environmental Protection Agency (U.S. EPA) for review and approval as required by federal regulation. In 1995, U.S. EPA was sued for not developing TMDL when Pennsylvania failed to do so. PADEP has entered into an agreement with U.S. EPA to develop TMDL for certain specified waters over the next several years. This TMDL has been developed in compliance with the state/U.S. EPA 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 sources of the pollutant on that water body. A TMDL plan includes waste load allocations for point sources, load allocations for non-point sources, and a margin of safety. The Clean Water Act requires states to submit their TMDLs to U.S. EPA for approval. Also, if a state does not develop the TMDL, the Clean Water Act states that U.S. EPA must do so.

What is a water quality standard?
The Clean Water Act sets a national minimum goal that all waters are to 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 meet and the water is said to be in violation of water quality standards.

What is the purpose of the plans?
Little Juniata River is impaired by excess siltation. This TMDL plan includes a calculation of sediment loading that will meet water quality objectives.

Why was the Little Juniata River watershed selected for TMDL development?

In 1996, Pa. DEP listed a portion of the Little Juniata River watershed under Section 303(d) of the federal Clean Water Act as impaired due to excess siltation from urban runoff and storm sewers.

What pollutants do these TMDLs address?
The proposed plans provide calculations of the stream's total capacity to accept nutrients and sediment. In-stream phosphorus is being used to address organic enrichment, while sediment loading is being used to address siltation.

Where do the pollutants come from?
The sediment related impairment in the Little Juniata River watershed come from non-point sources (NPS) of pollution, primarily overland runoff and storm sewers.

How was the TMDL developed?
PADEP used a reference watershed approach to estimate the necessary loading reduction of sediment that would be needed to restore a healthy aquatic community. 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, PADEP used the AVGWLF model (the Pennsylvania State University Institutes of the Environment'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 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 non-impaired watershed. The reference stream approach was used to set allowable loading rates in the affected watershed because neither Pennsylvanian nor U.S. EPA has water quality criteria for sediment.

How much pollution is too much?
The allowable amount of pollution in a water body varies depending on several conditions. TMDLs are set to meet water quality standards at the critical flow condition. For a free flowing stream impacted by non-point source pollution loading of sediment and nutrients, the TMDL is expressed as an annual loading. This accounts for pollution contributions over all stream flow conditions. PADEP established the water quality objectives for sediment by using the reference watershed approach. This approach assumes that the impairment is eliminated when the impaired watershed achieves loadings similar to the reference watershed. Reducing the current loading rate for sediment in the impaired watershed to the current loading rate 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 at during the business hours of 8:00 a.m. to 3:00 p.m., Monday through Friday. One may also contact by mail at the Water Management Program, or by e-mail at

How can I comment on the proposal?
You may provide e-mail or written comments postmarked no later than to the above addresses.

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

The TMDL for the Little Juniata River watershed was 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 transport capacities 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 GWLF Users Manuel, available from the Department's Bureau of Watershed Conservation, Division of Assessment and Standards.

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 N and P concentrations and cropping practices. Complete GWLF-formatted weather files are also included for eighty weather stations around the state. The following table lists the statewide GIS data sets and provides an explanation of how they were used for development of the input files for the GWLF model.

GIS Data Sets	
DATASET	DESCRIPTION
Censustr	Coverage of Census data including information on individual homes septic systems. The attribute *usew_sept* includes data on conventional systems, and *sew_other* provides data on short-circuiting and other systems.
County	The County boundaries coverage lists data on conservation practices, which provides C and P values in the Universal Soil Loss Equation (USLE).
Gwnback	A grid of background concentrations of N in groundwater derived from water well sampling.
Landuse5	Grid of the MRLC that has been reclassified into five categories. This is used primarily as a background.
Majored	Coverage of major roads. Used for reconnaissance of a watershed.
MCD	Minor civil divisions (boroughs, townships and cities).
Npdespts	A coverage of permitted point discharges. Provides background information and cross check for the point source coverage.
Padem	100-meter digital elevation model. This 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 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 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 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. StreamPlan-PA Model Overview

The point source modeling software used in this evaluation was derived from STREAMPLAN (A **S**preadsheet **T**ool for **R**iver **E**nvironment **A**ssessment, **M**anagement, and **Plan**ning). The STREAMPLAN model, developed by the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria, was designed as a decision support system to assist in the evaluation of water quality management strategies at the river basin level (De Marchi et al., 1996). In its original form STREAMPLAN allowed decision makers to investigate the implications of water management policy on water quality given set performance standards and financial resources.

STREAMPLAN is a spreadsheet-based computer software package that is used to model river basin water quality within the Microsoft EXCEL computing environment. The model is based upon widely used, simple mathematical representations of the hydrologic system in a steady-state formulation. The EXCEL spreadsheet format provides the user with greater flexibility and understanding of the processes involved when investigating in-stream hydrologic systems. The original version of STREAMPLAN contains four basic modeling components including: hydraulic, water quality, socio-economic, and optimization models.

A modified version of the STREAMPLAN software is currently being used to support Total Maximum Daily Load (TMDL) assessments requiring an analysis of in-stream conditions in impaired Pennsylvania watersheds. For the purposes of in-stream water quality modeling, the socio-economic and optimization routines have been removed from the STREAMPLAN framework. The model has been further adapted to calculate loads and in-stream concentrations at the monthly time step over a period of interest specified by the user. Additionally, a software link has been developed for the purpose of providing more precise estimates of "background" nutrient loads (i.e., non-point source loads) for STREAMPLAN based on output from AVGWLF.

Simply put, STREAMPLAN uses a "bucket" approach to model in-stream concentrations and loads of nutrients, sediment, dissolved oxygen, and carbonaceous biochemical oxygen demand. In STREAMPLAN, the watershed is modeled as a river network and a set of pollution inputs along it. The stream network is broken up into river reaches based upon the location of point sources, confluence of tributaries, and hydrologic characteristics. The model collects information for the upstream node of each river reach including:

1. Flow from upstream reaches
2. Flow from tributaries (if any) entering the river reach
3. Flow and concentration estimates of point source discharges
4. Flow and concentration estimates of non-point source inputs

Items 1,2, and 3 are calculated and provided by the STREAMPLAN modeling routines. Item 4, flow and concentration estimates of non-point source inputs, are generated for a sub-basin containing the river reach(s) using AVGWLF. The sub-basin estimate of non-point source pollution is then distributed to each river reach within the basin based upon a contributing area to total area ratio.

Using this information, along with the hydraulic characteristics and temperature of the river reach, the flow and pollutant concentration at the downstream node are calculated. This information is then passed to the upstream node of the next river reach, additional inputs are assessed, and the concentration and flow at the downstream node of that reach are calculated.

Two sub-models, discussed below, are used in conjunction with the hydraulic characteristics and pollution source information to estimate pollutant concentration and load in each river reach. These two models are the hydraulic sub-model and the water quality sub-model. The hydraulics routine is responsible for calculating mean velocity and mean depth in each river reach, while the water quality routine estimates both pollutant load and concentration within each river reach.

The Hydraulic Sub-model

The hydraulic sub-model calculates mean stream velocity and depth in each river reach. This information can either be entered manually if detailed watershed information is available, or estimated using reach slope, reach length, average reach roughness coefficients, and cross-sectional area information. Calculation of the mean stream velocity and depth provide the required input for the water chemistry calculations conducted in the water quality sub-model.

In order to calculate in-stream concentrations and loads of various pollutants, the water quality sub-model requires information on the mean water depth in the reach. Mean water depth is defined as the ratio of water surface area to the top width (m), and is calculated using the following equation:

$$H = cQ^d$$

where:

H = mean depth of water in the reach, defined as the ratio of water surface area to the top width (m)
Q = discharge in the reach (m^3/s)
c, d = coefficients

In the absence of field measurement, Q is derived by multiplying the reach cross-sectional area by stream velocity. Reach cross-sectional area is geometrically obtained using streambed width and mean water depth. Stream velocity is estimated using Manning's equation. Once these variables have been calculated for each river reach in the stream network, coefficients c and d are obtained by regression analysis, using these parameters. It is important to note that, in the absence of field measurement, estimates of velocity, stream geomorphology measurements, and discharge are derived by assuming that each river reach can be approximated by an idealized semi-circular or trapezoidal cross-section of the stream, which remains constant over the length of that reach.

The Water Quality Sub-model

To simulate water quality conditions in each river reach, several additional assumptions are made, including:

1. River reach flow is uniform
2. Flows and emissions are steady
3. Complete mixing is assumed at all nodes (points between segments)
4. Only advective transport is supported; no dispersion is allowed
5. Distributed flows and emissions to the river reaches are not explicitly considered
6. Flow and water quality constituents are only calculated at the upstream and downstream nodes of each river reach

Pollutant concentrations at the downstream node of each river reach are calculated based upon these assumptions using standard constituent degradation equations such as those found in Thomann and Mueller (1987). For example, phosphorus concentration is computed using the following equation.

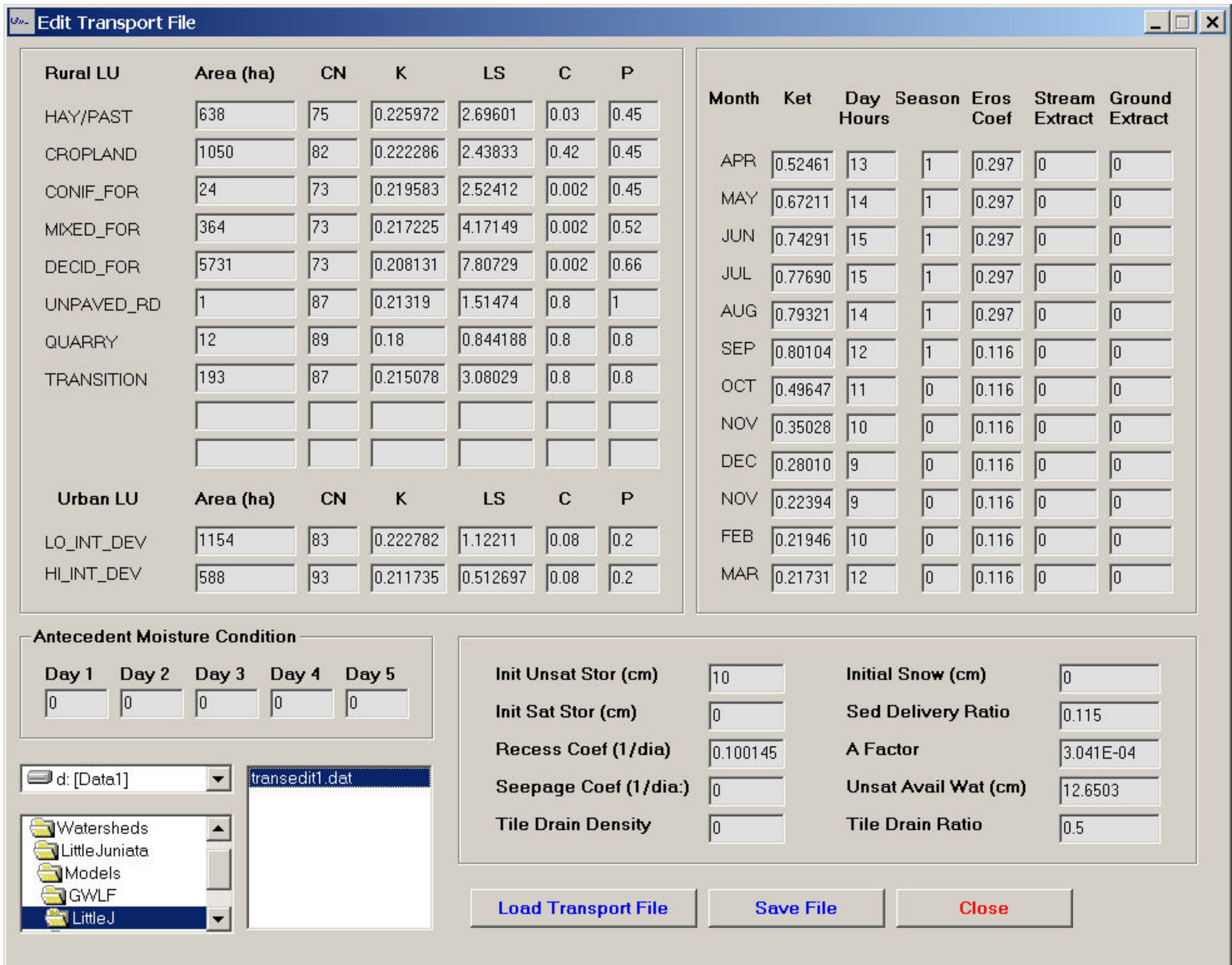
$$Z_1(t) = e^{(-k \cdot t)} Z_1(0)$$

where:

$Z_1(t)$ = total phosphorus concentration at the downstream node of the river reach
k = loss rate of total phosphorus
t = travel time for the river reach, calculated by the hydraulics model using reach length and stream velocity
$Z_1(0)$ = initial total phosphorus concentration, calculated at the upstream node of the river reach

The downstream node concentration estimates are then passed along with flow to the upstream node of the adjacent river reach. This information is combined with point and non-point source inputs to the reach and the calculations are repeated. For all pollutants considered, default values for loss rates, reaeration coefficients, transfer coefficients, etc. are based on those presented by Brown and Barnwell (1987). More detailed information on equations and procedures used within STREAMPLAN can be found at http://www.iiasa.ac.at/Research/WAT/docs/stream.html.

Appendix D - AVGWLF Model Outputs for the Little Juniata River Watershed



Edit Transport File

Rural LU	Area (ha)	CN	K	LS	C	P
HAY/PAST	638	75	0.225972	2.69601	0.03	0.45
CROPLAND	1050	82	0.222286	2.43833	0.42	0.45
CONIF_FOR	24	73	0.219583	2.52412	0.002	0.45
MIXED_FOR	364	73	0.217225	4.17149	0.002	0.52
DECID_FOR	5731	73	0.208131	7.80729	0.002	0.66
UNPAVED_RD	1	87	0.21319	1.51474	0.8	1
QUARRY	12	89	0.18	0.844188	0.8	0.8
TRANSITION	193	87	0.215078	3.08029	0.8	0.8

Urban LU	Area (ha)	CN	K	LS	C	P
LO_INT_DEV	1154	83	0.222782	1.12211	0.08	0.2
HI_INT_DEV	588	93	0.211735	0.512697	0.08	0.2

Month	Ket	Day Hours	Season	Eros Coef	Stream Extract	Ground Extract
APR	0.52461	13	1	0.297	0	0
MAY	0.67211	14	1	0.297	0	0
JUN	0.74291	15	1	0.297	0	0
JUL	0.77690	15	1	0.297	0	0
AUG	0.79321	14	1	0.297	0	0
SEP	0.80104	12	1	0.116	0	0
OCT	0.49647	11	0	0.116	0	0
NOV	0.35028	10	0	0.116	0	0
DEC	0.28010	9	0	0.116	0	0
NOV	0.22394	9	0	0.116	0	0
FEB	0.21946	10	0	0.116	0	0
MAR	0.21731	12	0	0.116	0	0

Antecedent Moisture Condition

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

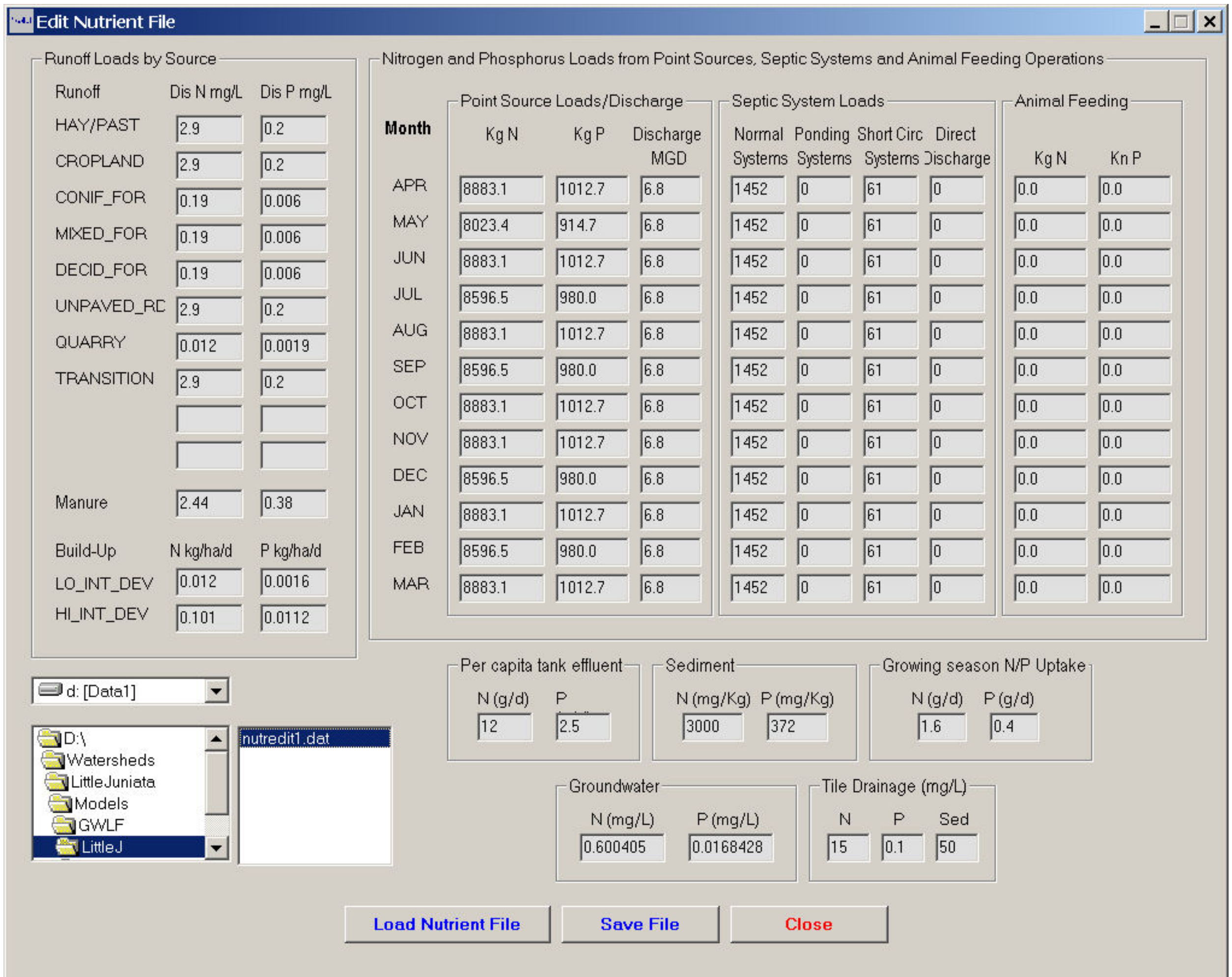
Init Unsat Stor (cm)	10	Initial Snow (cm)	0
Init Sat Stor (cm)	0	Sed Delivery Ratio	0.115
Recess Coef (1/dia)	0.100145	A Factor	3.041E-04
Seepage Coef (1/dia:)	0	Unsat Avail Wat (cm)	12.6503
Tile Drain Density	0	Tile Drain Ratio	0.5

d: [Data1]

transedit1.dat

Watersheds
LittleJuniata
Models
GWLF
LittleJ

Load Transport File
Save File
Close


Edit Nutrient File
Runoff Loads by Source
Runoff Dis N mg/L Dis P mg/L
HAY/PAST 2.9 0.2
CROPLAND 2.9 0.2
CONIF_FOR 0.19 0.006
MIXED_FOR 0.19 0.006
DECID_FOR 0.19 0.006
UNPAVED_RD 2.9 0.2
QUARRY 0.012 0.0019
TRANSITION 2.9 0.2
Manure 2.44 0.38
Build-Up N kg/ha/d P kg/ha/d
LO_INT_DEV 0.012 0.0016
HI_INT_DEV 0.101 0.0112
Nitrogen and Phosphorus Loads from Point Sources, Septic Systems and Animal Feeding Operations
Point Source Loads/Discharge
Septic System Loads
Animal Feeding
Month Kg N Kg P Discharge MGD Normal Systems Ponding Systems Short Circ Systems Direct Discharge Kg N Kn P
APR 8883.1 1012.7 6.8 1452 0 61 0 0.0 0.0
MAY 8023.4 914.7 6.8 1452 0 61 0 0.0 0.0
JUN 8883.1 1012.7 6.8 1452 0 61 0 0.0 0.0
JUL 8596.5 980.0 6.8 1452 0 61 0 0.0 0.0
AUG 8883.1 1012.7 6.8 1452 0 61 0 0.0 0.0
SEP 8596.5 980.0 6.8 1452 0 61 0 0.0 0.0
OCT 8883.1 1012.7 6.8 1452 0 61 0 0.0 0.0
NOV 8883.1 1012.7 6.8 1452 0 61 0 0.0 0.0
DEC 8596.5 980.0 6.8 1452 0 61 0 0.0 0.0
JAN 8883.1 1012.7 6.8 1452 0 61 0 0.0 0.0
FEB 8596.5 980.0 6.8 1452 0 61 0 0.0 0.0
MAR 8883.1 1012.7 6.8 1452 0 61 0 0.0 0.0
d: [Data1]
D:\
Watersheds
LittleJuniata
Models
GWLF
LittleJ
nutredit1.dat
Per capita tank effluent
N (g/d) 12
P 2.5
Sediment
N (mg/Kg) 3000
P (mg/Kg) 372
Growing season N/P Uptake
N (g/d) 1.6
P (g/d) 0.4
Groundwater
N (mg/L) 0.600405
P (mg/L) 0.0168428
Tile Drainage (mg/L)
N 15
P 0.1
Sed 50
Load Nutrient File
Save File
Close

Average Hydrology by Month in Standard Units

GWLF Transport Summary for LittleJ

Period of analysis 11 years, from Apr 1986 to Mar 1997

Units in Inches

Month	Prec	ET	Extraction	Runoff	Subsurface Flow	Point Src Flow	Tile Drain	Stream Flow
APR	3.73	0.89	0.00	0.29	3.08	0.32	0.00	3.69
MAY	4.21	1.93	0.00	0.05	2.57	0.29	0.00	2.91
JUN	3.61	3.16	0.00	0.07	1.41	0.32	0.00	1.80
JUL	5.08	3.92	0.00	0.38	1.22	0.31	0.00	1.90
AUG	3.16	3.24	0.00	0.08	0.36	0.32	0.00	0.76
SEP	4.24	1.83	0.00	0.18	0.98	0.31	0.00	1.47
OCT	3.06	0.68	0.00	0.20	1.55	0.32	0.00	2.06
NOV	3.80	0.23	0.00	0.25	2.56	0.32	0.00	3.13
DEC	3.45	0.07	0.00	0.38	2.75	0.31	0.00	3.44
JAN	3.40	0.04	0.00	0.49	2.26	0.32	0.00	3.07
FEB	2.55	0.05	0.00	0.54	2.19	0.31	0.00	3.04
MAR	4.41	0.17	0.00	1.02	3.42	0.32	0.00	4.76
Total	44.70	16.21	0.00	3.94	24.33	7.52	0.00	35.79

Go Back | Loads by Month | Print | Export to JPEG | Close

Average Loads by Month in English Units

GWLF Transport Summary for LittleJ

Period of analysis 11 years, from Apr 1986 to Mar 1997

	Tons		Nutrient Loads (Pounds)			
Month	**Erosion**	**Sediment**	**Dis N**	**Total N**	**Dis P**	**Total P**
APR	6753.50	1022.17	30872.07	31918.75	2599.55	2757.10
MAY	8601.99	796.76	26266.02	26696.32	2275.11	2350.56
JUN	8607.08	586.93	24436.24	25071.79	2397.46	2490.98
JUL	15263.08	1238.29	24268.87	29781.35	2445.35	3140.86
AUG	8127.42	361.71	21067.80	22275.99	2293.88	2448.39
SEP	4408.00	634.25	22891.94	25029.06	2305.34	2579.58
OCT	2986.64	890.48	25446.03	27681.38	2435.31	2729.40
NOV	3583.39	1183.98	29006.11	31916.26	2544.31	2928.05
DEC	1811.59	1513.10	29352.52	33322.08	2594.69	3114.32
JAN	454.55	2171.48	28788.12	37177.58	2674.30	3739.51
FEB	700.28	2001.29	28112.05	35556.13	2617.09	3564.62
MAR	2089.66	3084.17	35018.32	47682.00	2829.50	4431.35
Total	63387.19	15484.61	325526.09	374108.70	30011.89	36274.70

Go Back | Loads by Source | Print

Export to JPEG | Close

Average Loads by Month in English Units

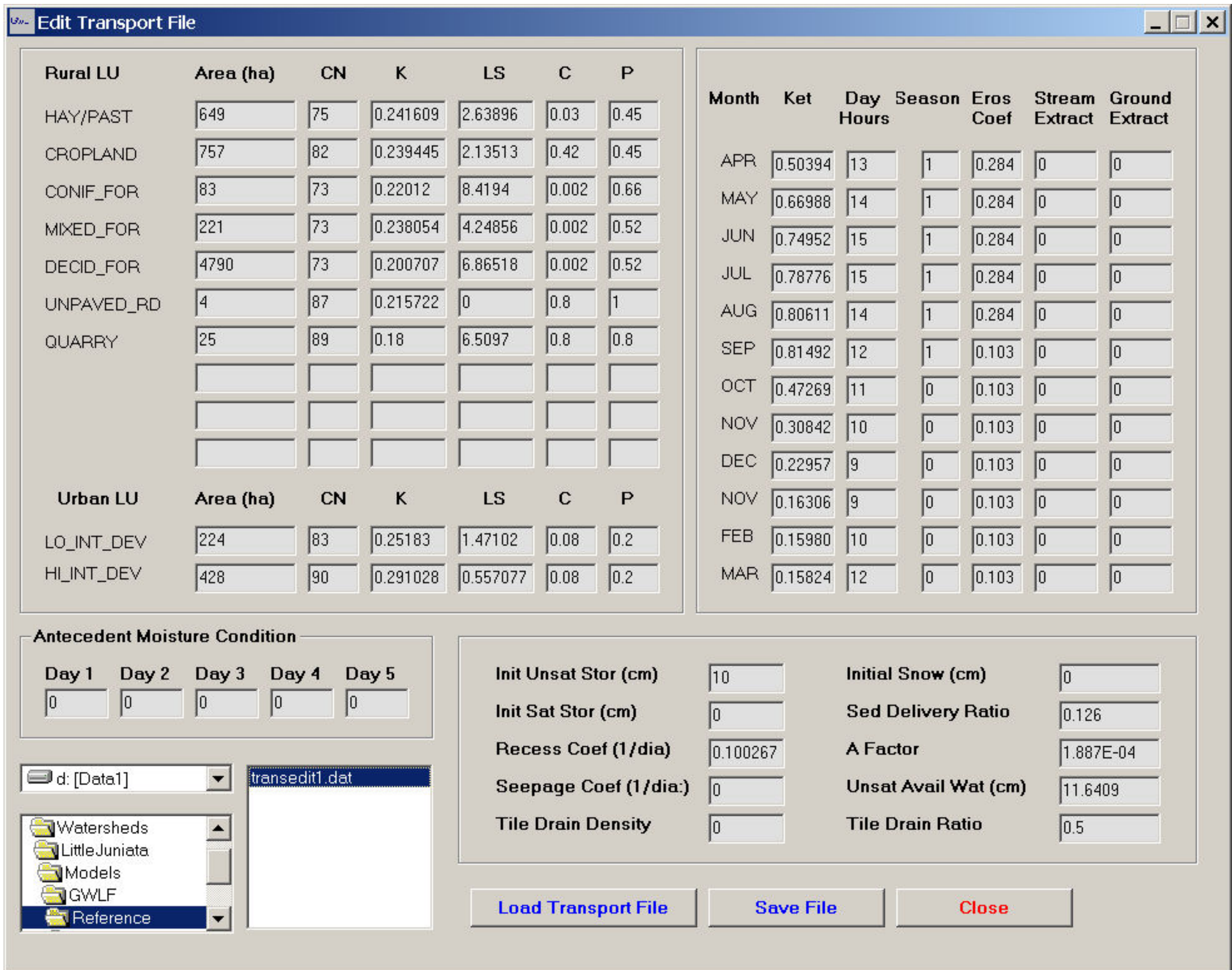
GWLF Total Loads for LittleJ

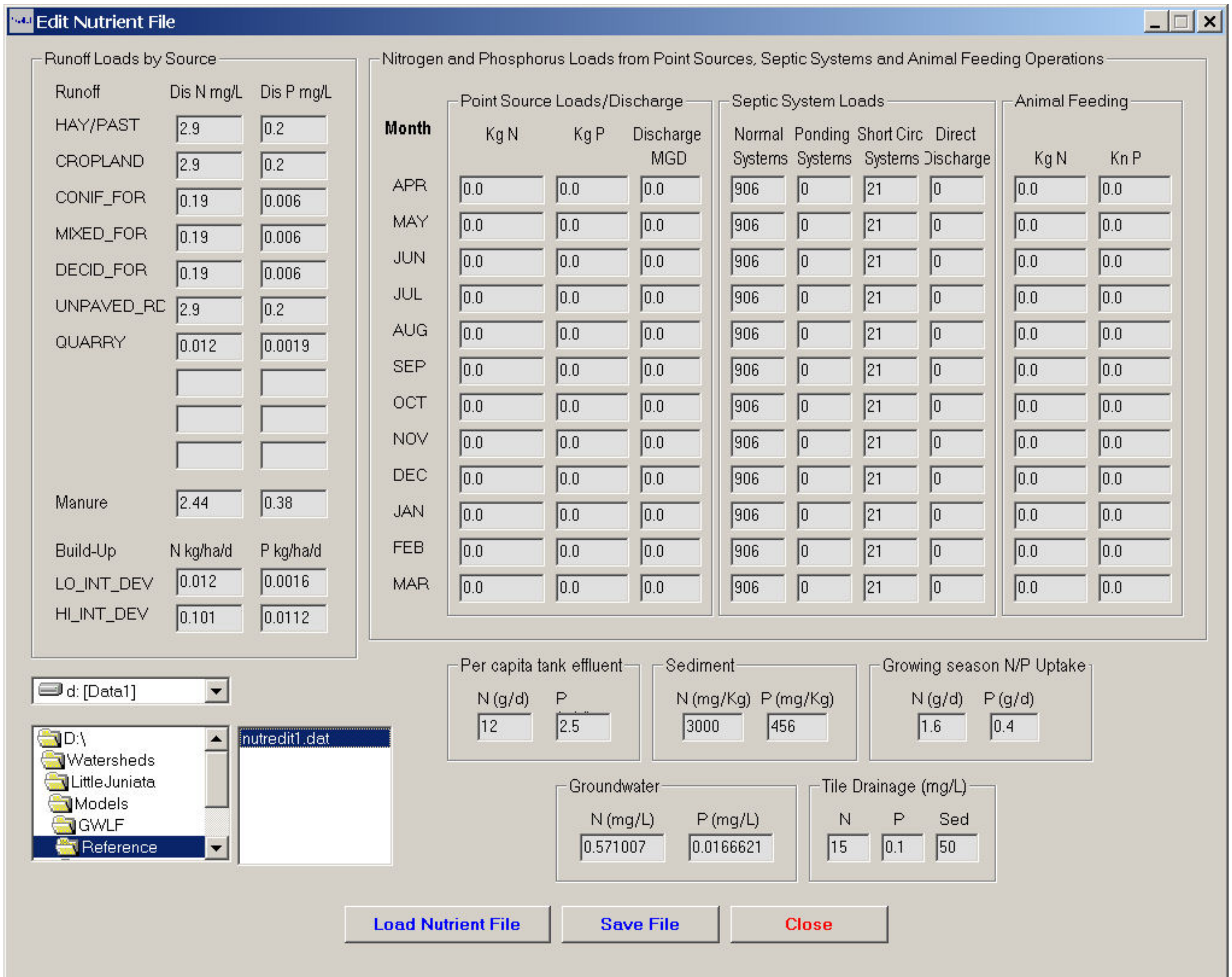
Period of analysis: 11 years, from Apr 1986 to Mar 1997

			Tons		Total Loads (Pounds)			
Source	**Area (Acres)**	**Runoff (in)**	**Erosion**	**Sediment**	**Dis N**	**Total N**	**Dis P**	**Total P**
HAY/PAST	1576.5	2.86	1551.70	178.45	2739.63	3810.31	293.53	426.29
CROPLAND	2594.6	5.09	31807.65	3657.88	8021.51	29968.79	859.10	3580.56
CONIF_FOR	59.3	2.43	3.54	0.41	6.20	8.64	0.20	0.50
MIXED_FOR	899.5	2.43	101.44	11.67	94.00	164.00	2.97	11.65
DECID_FOR	14161.6	2.43	3635.12	418.04	1480.05	3988.28	46.74	357.76
UNPAVED_RD	2.5	7.85	76.40	8.79	12.75	65.46	0.88	7.42
QUARRY	29.7	9.44	345.10	39.69	0.76	238.88	0.12	29.65
TRANSITION	476.9	7.85	24199.27	2782.92	2460.19	19157.69	169.67	2240.16
LO_INT_DEV	2851.6	5.54	1364.95	156.97	0.00	1442.57	0.00	192.34
HI_INT_DEV	1453.0	14.26	302.01	34.73	0.00	2583.37	0.00	286.47
Tile Drainage				0.00		0.0		0.0
Stream Bank				8195.08		819.51		360.58
Groundwater					79806.03	79806.03	2238.75	2238.75
Point Sources					230583.92	230583.92	26286.98	26286.98
Septic Systems					321.05	321.05	112.96	112.96
Totals	24105.1	3.90	63387.2	15484.6	325526.09	372958.49	30011.90	36132.08

Go Back | Export to JPEG | Print | Close

Appendix E - AVGWLF Model Outputs for the Blair Gap Run Watershed




Edit Nutrient File
Runoff Loads by Source
Runoff
Dis N mg/L
Dis P mg/L
HAY/PAST 2.9 0.2
CROPLAND 2.9 0.2
CONIF_FOR 0.19 0.006
MIXED_FOR 0.19 0.006
DECID_FOR 0.19 0.006
UNPAVED_RD 2.9 0.2
QUARRY 0.012 0.0019
Manure 2.44 0.38
Build-Up
N kg/ha/d
P kg/ha/d
LO_INT_DEV 0.012 0.0016
HI_INT_DEV 0.101 0.0112
Nitrogen and Phosphorus Loads from Point Sources, Septic Systems and Animal Feeding Operations
Month
Point Source Loads/Discharge
Kg N
Kg P
Discharge MGD
Septic System Loads
Normal Systems
Ponding Systems
Short Circ Systems
Direct Discharge
Animal Feeding
Kg N
Kn P
APR 0.0 0.0 0.0 906 0 21 0 0.0 0.0
MAY 0.0 0.0 0.0 906 0 21 0 0.0 0.0
JUN 0.0 0.0 0.0 906 0 21 0 0.0 0.0
JUL 0.0 0.0 0.0 906 0 21 0 0.0 0.0
AUG 0.0 0.0 0.0 906 0 21 0 0.0 0.0
SEP 0.0 0.0 0.0 906 0 21 0 0.0 0.0
OCT 0.0 0.0 0.0 906 0 21 0 0.0 0.0
NOV 0.0 0.0 0.0 906 0 21 0 0.0 0.0
DEC 0.0 0.0 0.0 906 0 21 0 0.0 0.0
JAN 0.0 0.0 0.0 906 0 21 0 0.0 0.0
FEB 0.0 0.0 0.0 906 0 21 0 0.0 0.0
MAR 0.0 0.0 0.0 906 0 21 0 0.0 0.0
d: [Data1]
D:\
Watersheds
LittleJuniata
Models
GWLF
Reference
nutredit1.dat
Per capita tank effluent
N (g/d) 12
P 2.5
Sediment
N (mg/Kg) 3000
P (mg/Kg) 456
Growing season N/P Uptake
N (g/d) 1.6
P (g/d) 0.4
Groundwater
N (mg/L) 0.571007
P (mg/L) 0.0166621
Tile Drainage (mg/L)
N 15
P 0.1
Sed 50
Load Nutrient File
Save File
Close

Average Hydrology by Month in Standard Units

GWLF Transport Summary for LJ_Reference

Period of analysis 11 years, from Apr 1986 to Mar 1997

Month	Prec	ET	Extraction	Runoff	Subsurface Flow	Point Src Flow	Tile Drain	Stream Flow
	Units in Inches							
APR	3.73	0.86	0.00	0.26	3.21	0.00	0.00	3.47
MAY	4.21	1.93	0.00	0.03	2.63	0.00	0.00	2.65
JUN	3.61	3.19	0.00	0.05	1.42	0.00	0.00	1.47
JUL	5.08	3.97	0.00	0.32	1.23	0.00	0.00	1.55
AUG	3.16	3.25	0.00	0.06	0.36	0.00	0.00	0.42
SEP	4.24	1.87	0.00	0.14	1.02	0.00	0.00	1.16
OCT	3.06	0.65	0.00	0.16	1.56	0.00	0.00	1.72
NOV	3.80	0.20	0.00	0.21	2.62	0.00	0.00	2.82
DEC	3.45	0.06	0.00	0.32	2.82	0.00	0.00	3.14
JAN	3.40	0.03	0.00	0.43	2.33	0.00	0.00	2.76
FEB	2.55	0.04	0.00	0.48	2.26	0.00	0.00	2.74
MAR	4.41	0.12	0.00	0.90	3.55	0.00	0.00	4.45
Total	44.70	16.16	0.00	3.35	25.01	0.00	0.00	28.36

Go Back | Loads by Month | Print | Export to JPEG | Close

Average Loads by Month in English Units

GWLF Transport Summary for LJ_Reference

Period of analysis 11 years, from Apr 1986 to Mar 1997

	Tons		Nutrient Loads (Pounds)			
Month	**Erosion**	**Sediment**	**Dis N**	**Total N**	**Dis P**	**Total P**
APR	3230.57	429.19	8191.55	8696.43	269.72	350.24
MAY	4114.80	321.96	6091.20	6279.59	186.27	218.29
JUN	4117.24	234.03	3397.72	3683.85	115.56	156.87
JUL	7301.17	577.72	3704.62	6494.51	203.93	611.96
AUG	3887.79	147.74	1004.98	1559.10	38.70	116.84
SEP	1955.95	272.36	2792.64	3784.26	100.22	249.48
OCT	1325.25	388.52	4105.14	5221.13	141.24	313.49
NOV	1590.04	510.13	6690.26	8068.03	222.03	435.40
DEC	803.85	668.30	7376.45	9333.65	315.45	620.87
JAN	201.70	1059.13	6558.75	11047.59	322.85	1013.75
FEB	310.73	960.95	6529.58	10461.69	334.86	940.81
MAR	927.24	1469.05	11058.81	17529.61	426.94	1419.26
Total	29766.34	7039.06	67501.70	92159.43	2677.78	6447.27

Go Back | Loads by Source | Print

Export to JPEG | Close

Average Loads by Month in English Units

GWLF Total Loads for LJ_Reference

Period of analysis: 11 years, from Apr 1986 to Mar 1997

Source	Area (Acres)	Runoff (in)	Tons: Erosion	Tons: Sediment	Total Loads (Pounds): Dis N	Total N	Dis P	Total P
HAY/PAST	1603.7	2.86	1550.90	195.41	2786.87	3959.35	298.59	476.81
CROPLAND	1870.6	5.09	20307.12	2558.70	5783.13	21135.31	619.37	2952.90
CONIF_FOR	205.1	2.43	56.37	7.10	21.43	64.05	0.68	7.15
MIXED_FOR	546.1	2.43	64.54	8.13	57.07	105.86	1.80	9.22
DECID_FOR	11836.3	2.43	1905.66	240.11	1237.03	2677.71	39.06	258.05
UNPAVED_RD	9.9	7.85	0.00	0.00	50.99	50.99	3.52	3.52
QUARRY	61.8	9.44	5204.92	655.82	1.59	3936.50	0.25	598.36
LO_INT_DEV	553.5	5.54	368.60	46.44	0.00	82.37	0.00	10.98
HI_INT_DEV	1057.6	10.40	308.23	38.84	0.00	1743.16	0.00	193.30
Tile Drainage				0.00		0.0		0.0
Stream Bank				3288.50		328.85		144.69
Groundwater					57423.18	57423.18	1675.62	1675.62
Point Sources					0.00	0.00	0.00	0.00
Septic Systems					140.41	140.41	38.89	38.89
Totals	17744.6	3.30	29766.3	7039.1	67501.70	91647.75	2677.78	6369.49

Go Back | Export to JPEG | Print | Close

Appendix F - Equal Marginal Percent Reduction (EMPR) Method

The Equal Marginal Percent Reduction (EMPR) allocation method was used to distribute Adjusted Load Allocations (ALAs) between the appropriate contributing non-point sources. The load allocation and EMPR procedures were performed using MS Excel and results are presented in Appendix F. The 5 major steps identified in the spreadsheet are summarized below:

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

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

Step 3: Actual EMPR Process:

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

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

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

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

Equal Marginal Percent Reduction (EMPR) Calculations for the Little Juniata River Watershed

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Step 1:	TMDL Total Load				Step 2:	Adjusted LA = (TMDL total load - MOS) - uncontrollable						
2		Load = TP loading rate in ref. * Acres in Impaired					8177	8177					
3		9563											
4													
5													
6													
7	Step 3:		Annual Average Load	Load Sum	Check	Initial Adjust	Recheck	% reduction allocation	Load Reduction	Initial LA	Acres	Allowable Loading Rate	% Reduction
8		Hay/Past.	178.5	15054.5	good	178	ADJUST	0.01	81	97.0	1577	0.06	45.6%
9		Cropland	3657.9		good	3658	6859	0.24	1669	1989.2	2595	0.77	45.6%
10		Transition	2782.9		good	2783		0.19	1270	1513.4	477	3.17	45.6%
11		Lo_Int_Dev	157.0		good	157		0.01	72	85.4	2852	0.03	45.6%
12		Hi_Int_Dev	34.7		good	35		0.00	16	18.9	1453	0.01	45.6%
13		Unpaved Roads	8.8		good	9		0.00	4	4.8	3	1.91	45.6%
14		Quarry	39.7		good	40		0.00	18	21.6	30	0.73	45.6%
15		Streambank	8195.1		bad	8177		0.54	3730	4446.4	N/A		45.7%
16						15036		1.00		8176.6			
17	Step 4:	All Ag. Loading Rate	0.50										
18													
19													
20	Step 5:		Acres	Allowable (Target) Loading Rate	Final LA	Current Loading Rates	Current Load	% Red.					
21		Hay/Past.	1577	0.06	97	0.11	178	46%					
22		Cropland	2595	0.77	1989	1.41	3658	46%					
23		Transition	477	3.17	1513	5.84	2783	46%					
24		Lo_Int_Dev	2852	0.03	85	0.06	157	46%					
25		Hi_Int_Dev	1453	0.01	19	0.02	35	46%					
26		Unpaved Roads	3	1.91	5	3.52	9	46%					
27		Quarry	30	0.73	22	1.34	40	46%					
28		Streambank	N/A		4446		8195	46%					
29					8177								

Appendix G: Watershed EMPR for Point Source Discharges

NOTE: Phosphorus is the pollutant of concern at this time and this is what we need to be able to apply this method for

Baseline:

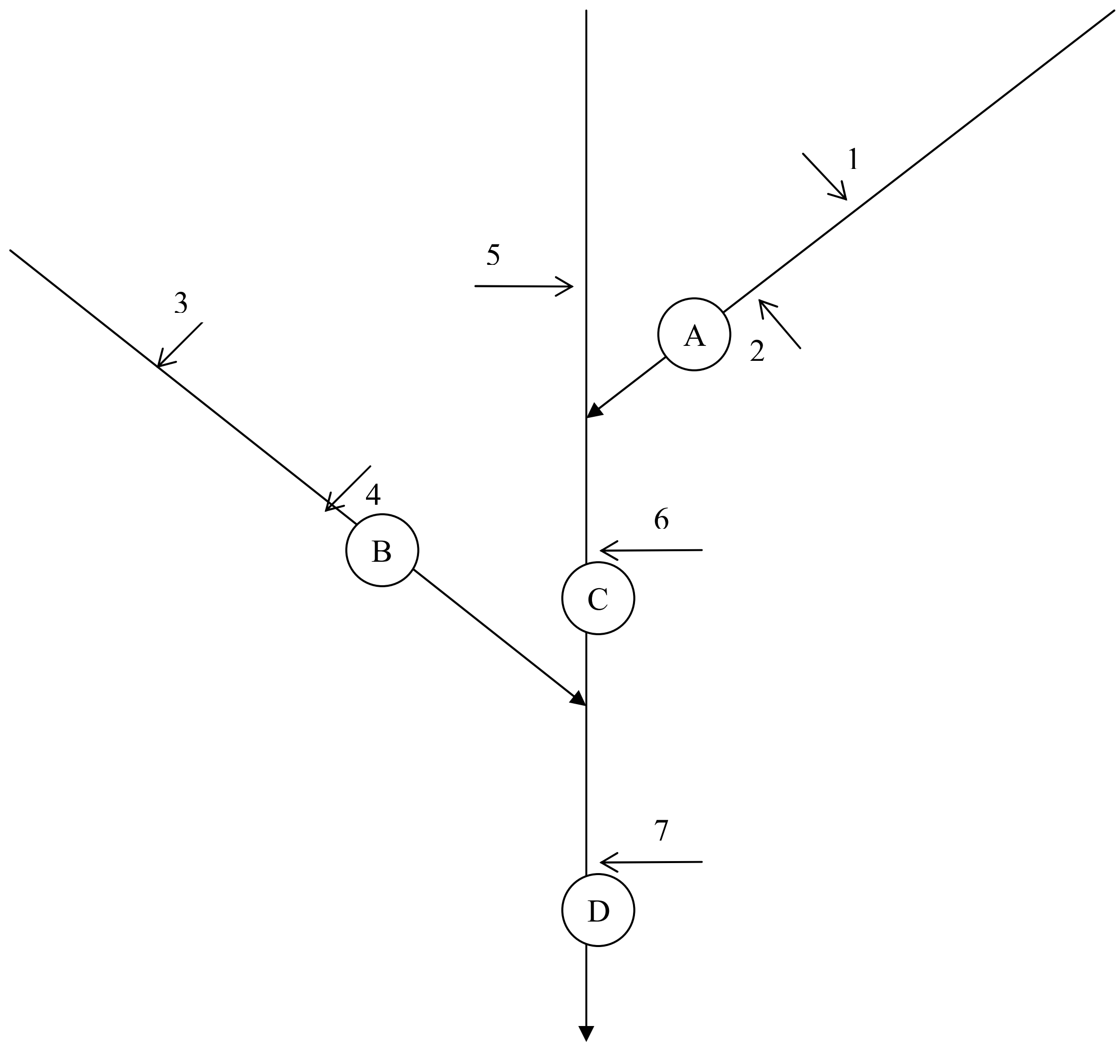
- Each discharge shall be evaluated as if it was the only discharge to the stream. The mass balance equation will only consider flow above the discharge for dilution. Dilution flow shall include overland, subsurface, and groundwater flow, but will not account for upstream point source discharges or water withdrawals. Included in overland flow will be all contributions or discharges from any upstream impoundments.
- No fate or decay will be applied for this portion of the analysis.
- The mass balance calculation will consider the point of compliance to be directly downstream of the discharge.
- For pollutants not covered by our toxics program, complete mix between the discharge and the receiving water will be assumed at the point of discharge. The department may deviate from this assumption based on our flow portioning guidance or other scientific studies that give a better representation of mixing characteristics immediately below the discharge.
- The baseline WLA will be the starting point for the multiple contributor analysis.

Multiple discharge analysis

- Analysis will start with each discharge at their baseline WLA that was determined in the previous step.
- The multiple discharge analysis shall start at the uppermost point in the watershed and work in succession moving downstream until all reaches meet the in stream objective.
- Fate and transport will be applied to each point source discharge from its origin to the point that is being evaluated. Fate and transport will be based on first order kinetics unless otherwise specified. Site-specific data should be used when possible.
- The multiple discharger analysis shall be conducted directly below each point source discharge except where there is no upstream discharge in the watershed being evaluated.
- At each point where the in stream objective is exceeded and equal percent reduction will be made to each of its contributors. This will be considered in proportion to the load delivered to the point of interest.
- The most stringent limit that any discharge could receive is the in-stream objective.

The numbers on the diagram represent point source discharges and the letters represent points where a multiple discharge evaluation is needed.

NOTE: The multiple discharge interaction locations shown as “letters” on the diagram would be evaluated in the reach of the immediate upstream discharge.



In-stream P Concentration (mg/L)	Logan Twp. - Greenwood Facility		Altoona East		Percent Reduction	Logan Twp. Phosphorus Load (lbs P/yr)	Altoona East Phosphorus Load (lbs P/yr)
	Baseline (mg/L)	EMPR (mg/L)	Baseline (mg/L)	EMPR (mg/L)			
0.1	0.32	0.304	0.12	0.114	5%	655	2,782
0.2	0.70	0.630	0.24	0.216	10%	1,358	5,271
0.3	1.07	0.984	0.36	0.331	8%	2,122	8,082
0.4	1.45	1.334	0.48	0.442	8%	2,875	10,776
0.5	1.81	1.665	0.60	0.552	8%	3,589	13,471
0.6	2.00	1.860	0.72	0.670	7%	4,009	16,340
0.7	2.00	1.900	0.85	0.808	5%	4,095	19,706
0.8	2.00	1.960	0.97	0.951	2%	4,224	23,198
0.9	2.00	2.000	1.09	1.090	0%	4,311	26,600
1.0	2.00	2.000	1.22	1.220	0%	4,311	29,772
1.1	2.00	2.000	1.33	1.330	0%	4,311	32,456
1.2	2.00	2.000	1.45	1.450	0%	4,311	35,385
1.3	2.00	2.000	1.57	1.570	0%	4,311	38,313
1.4	2.00	2.000	1.70	1.700	0%	4,311	41,486
1.5	2.00	2.000	1.82	1.820	0%	4,311	44,414
1.6	2.00	2.000	1.94	1.940	0%	4,311	47,342
1.7	2.00	2.000	2.06	2.060	0%	4,311	50,271
1.8	2.00	2.000	2.18	2.180	0%	4,311	53,199
1.9	2.00	2.000	2.30	2.300	0%	4,311	56,127
2.0	2.00	2.000	2.43	2.430	0%	4,311	59,300