Christina Basin Land Use Loading Rates Calculation Tool

Watershed: White Clay Creek **Year: 2012**

prepared by:
Chester County Water Resources Authority (CCWRA)

in consultation with:
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and
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PURPOSE AND LIMITATIONS: This Excel workbook tool was developed for use by municipalities that have MS4 discharges and load reduction responsibilities within the PA portion of the Christina Basin. This tool calculates land use pollutant loading rates for TSS, TN and TP using calculations, methodology, assumptions, and data based on and consistent with the desktop Christina Basin MapShed model, and consistent with PADEP's 2017 TMDL and PRP instructions for MS4s. This tool is not recommended for use in other geographic areas or with other load calculation methodologies, or other land use load data. The desktop Christina Basin MapShed model was developed by CCWRA (2012, revised 2017) in conjunction with Dr. Barry Evans (Pennsylvania State University) and in consultation with Mr. Bill Brown (PADEP).

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Look-Up Table: Christina Basin MapShed Land Use Loading Rates

Christina Basin MapShed Output File Results Converted to Land Use Loading Rates

Watershed: White Clay

Year: 2012

Section 1: Instructions & Overview

INSTRUCTIONS:

Municipalities are to use the Look-Up Table provided herein and copy the loading rates for the applicable watershed, applicable year, and applicable pollutants and use those values in their further calculations. The intention is that the municipality prints out each workbook for the years 1995 and 2012 for each watershed located in their Planning Area(s). It is suggested that these workbooks be placed in an appendix in their PA DEP MS4 submittal as documentation of the source of the loading rates they used in their plans and calculations.

OVERVIEW:

Seperate Look-up Tables have been created for 3 Christina Basin watersheds (Brandywine, White Clay or Red Clay) for the years 1995 and 2012. This workbook is one of six workbook files that have been provided; each file contains loading rates for pollutants Sediment, Nitrogen and Phosphorus.

The Christina Basin MapShed model and the methodology used herein to calcute Chrsitina MapShed Land Use Loading Rates were developed by Chester County Water Resources Authority in conjunction with and direction from Dr. Barry Evans (Penn State) and Bill Brown (PADEP).

Municipalties Do NOT need to enter values into this workbook. This workbook serves as a Look-up Table.

THIS WORKBOOK CONTAINS:

Section 2 (Land Use Loading Rates Look-Up Table) contains the Look-Up Table with final Christina MapShed land use loading rates that incorporate Land Use (upland source), Stream Bank (erosion) and Farm Animal Loads. **The bolded Total (pollutant) Loading Rate values in this Table are to be used by municipalities to calculate their Baseline and Existing loads and urban BMP load reductions. The "From Land Use" values in this Table are to be used to calculate street sweeping load reductions.**

***** In the MapShed model, Stream Bank and Farm Animal loads are modeled as separate sources/outputs, and therefore must be apportioned into the land use loads. This calculation has been completed herein and the results are summarized on the Look-up Table. Stream Bank loads are mostly attributable to developed lands. Farm Animal loads are attributed to Cropland and Hay/Pasture land uses.

***** The Look-Up Table also shows loads calculated by the Christina MapShed model from septic, groundwater and point sources, however, per PA DEP guidance, these loads are NOT included in the land use loading rates presented in the Table. These loads are not loads that enter the MS4 and therefore these loads are not a pollutant load that is required to be addressed in the MS4 program. Please note, when comparing the nitrogen and phosphorus loading rates to other literature values for a watershed, the rates in this workbook may appear lower by land use for nutrients because of these adjustments. Groundwater loading of nitrogen and phosphorus are generally attributed to long-term agricultural practices.

Section 3 (Christina Basin MapShed Output) contains the actual Christina MapShed output file data that are used for calculations throughout this workbook. DO NOT USE THESE DATA. This section is for CCWRA Use only.

Section 4 (Map) Contains a Map of Chester County's portion of the Christina Basin watershed.

Sections 5 through 8 Contain supporting documentation that show how the calculations were performed to arrive at the values for the watershed that were presented in the Look-up Table in Section 2.

Section 9 Contains a table that presents EPA Christina TMDL Baseline Pollutant Loadings, MS4 Wasteload Allocations, and required volume and Percent Reductions for each municipality by watershed. These data were taken from the tables in the EPA TMDL reports by Chester County Water Resources Authority in 2012.

Look-Up Table: Christina Basin MapShed Loading Rates

Watershed: White Clay

Year: 2012

Source File: 2012WCnewrun_noatten-Summary_sum.csv

Section 2: Land Use Loading Rates Look-Up Table

TOTAL WATERSHED ANNUAL LOADS from Christina MapShed

ANNUAL LAND USE LOADING RATES (lbs/acre) based on land use, stream bank and farm animal sources

	Source	Area	Sediment	Total Nitrogen	Total Phosphorus	SEDIMENT: From Land Use	SEDIMENT: From Stream Banks ①	SEDIMENT: TOTAL SEDIMENT LOADING RATE	NITROGEN: From Land Use	NITROGEN: From Stream Banks ①	NITROGEN: From Farm Animals ②	NITROGEN: TOTAL NITROGEN LOADING RATE	PHOSPHORUS: From Land Use	PHOSPHORUS: From Stream Banks ①	PHOSPHORUS: From Farm Animals ②	PHOSPHORUS: TOTAL PHOSPHORUS LOADING RATE	
	Units	*Acres*	*Tons*	*Pounds*	*Pounds*	lbs/acre	lbs/acre	lbs/acre	lbs/acre	lbs/acre	lbs/acre	lbs/acre	lbs/acre	lbs/acre	lbs/acre	lbs/acre	
						Tons * 2000 lbs/ton acres of a land use		Sum of previous two sources	Tons * 2000 lbs/ton acres of a land use			Sum of previous three sources	Tons * 2000 lbs/ton acres of a land use			Sum of previous three sources	
MapShed Land Use Categories	Hay/Past	111.20	2.02	78.07	25.31	36.33	146.79	**183.12**	0.70	0.07	0.35	**1.12**	0.23	0.03	0.07	**0.33**	Hay/Past
	Cropland	18,953.00	12,746.11	102,651.12	26,516.64	1,345.02	146.79	**1,491.81**	5.42	0.07	0.35	**5.84**	1.40	0.03	0.07	**1.50**	Cropland
	Forest	14,186.30	116.29	1,447.60	216.21	16.39	146.79	**163.18**	0.10	0.07	n/a	**0.17**	0.02	0.03	n/a	**0.05**	Forest
	Wetland	121.10	0.11	49.80	2.71	1.82	146.79	**148.61**	0.41	0.07	n/a	**0.48**	0.02	0.03	n/a	**0.05**	Wetland
	Disturbed	1,583.90	62.49	311.34	137.19	78.91	146.79	**225.70**	0.20	0.07	n/a	**0.27**	0.09	0.03	n/a	**0.12**	Disturbed
	Turfgrass	1,220.70	23.75	1,529.43	822.35	38.91	146.79	**185.70**	1.25	0.07	n/a	**1.32**	0.67	0.03	n/a	**0.70**	Turfgrass
	Open_Land	252.00	19.72	334.97	28.35	156.51	146.79	**303.30**	1.33	0.07	n/a	**1.40**	0.11	0.03	n/a	**0.14**	Open_Land
	Bare_Rock	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	n/a	**0.00**	0.00	0.00	n/a	**0.00**	Bare_Rock
	Sandy_Areas	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	n/a	**0.00**	0.00	0.00	n/a	**0.00**	Sandy_Areas
	Unpaved_Road	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	n/a	**0.00**	0.00	0.00	n/a	**0.00**	Unpaved_Road
	Ld_Mixed	98.80	2.54	117.79	12.65	51.42	543.43	**594.85**	1.19	0.27	n/a	**1.46**	0.13	0.10	n/a	**0.23**	Ld_Mixed
	Md_Mixed	1,171.30	134.03	7,342.66	781.16	228.86	1,124.77	**1,353.62**	6.27	0.56	n/a	**6.83**	0.67	0.20	n/a	**0.87**	Md_Mixed
	Hd_Mixed	2,723.10	315.27	18,308.20	1,944.98	231.55	1,674.68	**1,906.23**	6.72	0.84	n/a	**7.56**	0.71	0.30	n/a	**1.01**	Hd_Mixed
	Ld_Residential	14,888.10	424.43	19,387.10	2,089.12	57.02	543.43	**600.45**	1.30	0.27	n/a	**1.57**	0.14	0.10	n/a	**0.24**	Ld_Residential
	Md_Residential	810.50	90.30	4,685.04	505.41	222.83	1,124.77	**1,347.59**	5.78	0.56	n/a	**6.34**	0.62	0.20	n/a	**0.82**	Md_Residential
	Hd_Residential	239.70	27.67	1,567.73	166.54	230.87	1,674.68	**1,905.55**	6.54	0.84	n/a	**7.38**	0.69	0.30	n/a	**0.99**	Hd_Residential

Addt'l Sources	Source	Sediment	Total Nitrogen	Total Phosphorus
	Units	*Tons*	*Pounds*	*Pounds*
	Farm Animals		6,684.76	1,296.72
	Tile Drainage	0.00	0.00	0.00
	Stream Bank	10,341.22	10,339.67	3,747.85

Notes:

- Separate worksheets are used to calculate and apportion the loading rates from the **Stream Bank** source loads (for sediment, total nitrogen, and total phosphorus) from the Christina MapShed Output file into each land use category, using methodology provided from Dr. Barry Evans (Pennsylvania State University), the author of MapShed, and with concurrence from Mr. Bill Brown (PADEP).

- A separate worksheet is used to calculate and apportion the "Total Nitrogen" and "Total Phosphorus" loading rates from the **Farm Animals** source load from the Christina Basin MapShed Output file into the two agricultural land uses, Hay/Pasture and Cropland, based on area weighting. The methodology was provided by Dr. Barry Evans (Pennsylvania State University), the author of MapShed, and with concurrence from Mr. Bill Brown (PADEP). Additionally, since the **Farm Animals** source loads do not apply to other land use catergories, the values in those cells are "n/a".

Look-Up Table: Christina Basin MapShed Land Use Loading Rates

Watershed: White Clay

Year: 2012

Section 3: Christina Basin MapShed Output

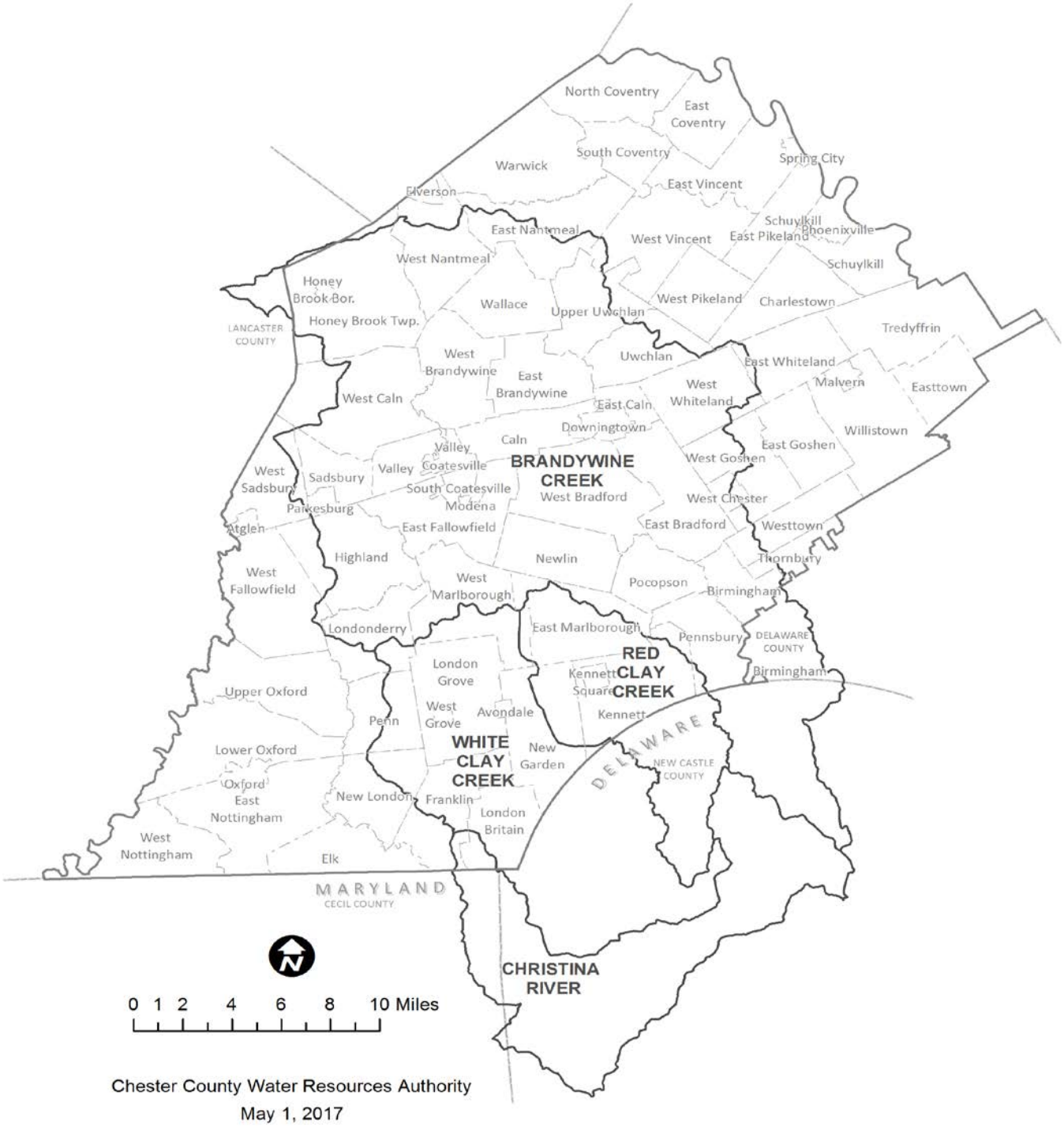
This page is where the output data from Christina Basin MapShed model is entered into this workbook and is the source data for calculations throughout the workbook. DO NOT USE OR CHANGE THE VALUES BELOW.
For use by CCWRA only.
Instructions followed by Chester County Water Resources Authority staff: Enter the data below from the MapShed output file without any modifications. Only enter data in the cells shaded blue.
1. Source File Name - filename for the output file from Christina Basin Version of MapShed.
2. Watershed Name - Name of Watershed for which land use loading rates were calculated (Brandywine Creek, White Clay Creek and Red Clay Creek).
3. Source file - The annual pollutant data, in English Units, is copied directly from the Christina Basin MapShed output file to the table below.
4. Year - the year modeled.

Data Entered By: Chester County Water Resources Authority
Date Data Entered: 5/12/2017
Source File Name: 2012WCnewrun_noatten-Summary_sum.csv
Watershed: White Clay
Year: 2012

CHRISTINA BASIN MapShed OUTPUT DATA

Source	Area	Runoff	Erosion	Sediment	Dis N	Tot N	Dis P	Tot P
Units	*acres*	*inches/year*	*tons/year*	*tons/year*	*lbs/year*	*lbs/year*	*lbs/year*	*lbs/year*
Hay/Past	111.20	3.70	14.82	2.02	70.00	78.07	22.93	25.31
Cropland	18,953.00	4.15	94,426.66	12,746.11	51,666.68	102,651.12	5,547.68	26,516.64
Forest	14,186.30	1.61	855.14	116.29	982.44	1,447.60	51.72	216.21
Wetland	121.10	9.48	0.72	0.11	49.38	49.80	2.60	2.71
Disturbed	1,583.90	8.55	492.42	62.49	61.35	311.34	30.67	137.19
Turfgrass	1,220.70	2.07	175.56	23.75	1,434.37	1,529.43	789.10	822.35
Open_Land	252.00	8.97	144.09	19.72	256.07	334.97	5.11	28.35
Bare_Rock	-	-	-	-	-	-	-	-
Sandy_Areas	-	-	-	-	-	-	-	-
Unpaved_Road	-	-	-	-	-	-	-	-
Ld_Mixed	98.80	4.29	-	2.54	33.09	117.79	4.67	12.65
Md_Mixed	1,171.30	11.10	-	134.03	2,376.21	7,342.66	309.02	781.16
Hd_Mixed	2,723.10	16.35	-	315.27	5,940.48	18,308.20	770.62	1,944.98
Ld_Residential	14,888.10	4.64	-	424.43	5,434.17	19,387.10	773.38	2,089.12
Md_Residential	810.50	6.82	-	90.30	1,498.70	4,685.04	198.70	505.41
Hd_Residential	239.70	9.58	-	27.67	508.16	1,567.73	65.94	166.54
Farm Animals						6,684.76		1,296.72
Tile Drainage				-		-		-
Stream Bank				10,341.22		10,339.67		3,747.85
Groundwater					777,459.57	777,459.57	51,700.54	51,700.54
Point Source					27,414.45	27,414.45	2,686.99	2,686.99
Septic Systems					66,561.35	66,561.35	1,759.29	1,759.29

Section 4: Map of Chester County's portion of the Christina Basin Watersheds



Look-Up Table: Christina Basin MapShed Loading Rates

Watershed: White Clay

Year: 2012

Section 5: Farm Animals TN and TP Loading Rates Worksheet

This worksheet calculates and apportions the "Total Nitrogen" and "Total Phosphorus" loading rates from the "Farm Animals" source load from the Christina Basin MapShed Output file into the two applicable agricultural land uses, Hay/Pasture and Cropland, based on area weighting. The methodology was provided by Dr. Barry Evans (Stroud Water Research Center, Pennsylvania State University), the author of MapShed, and with concurrence from Mr. Bill Brown (PADEP).

The MapShed output file provides the Farm Animals "Total Nitrogen" and "Total Phosphorus" loads in pounds.

Step 1. The Farm Animal "Total Nitrogen" and "Total Phosphorus" load, in pounds, and land areas for each land use category, in acres, from the Christina MapShed Output file are presented below.

Christina MapShed Total Watershed Load

	Total Nitrogen	Total Phosphorus	
Nutrient Load from Farm Animals	6,684.76	1,296.72	pounds

①

Note: The loads are taken from cells G33 and I33 from the Christina Basin MapShed Output worksheet

Land Use Categories from MapShed

Source	Area (acres)
Hay/Pasture	111.20
Cropland	18,953.00

- Since only the 'Hay/Pasture' and 'Cropland' land uses are apportioned Farm Loading Rates, the remaining land use categories are not applicable to this worksheet.

Step 2. Total Acres in "Hay/Pasture" and "Cropland" land uses are summed.

Area of Hay/Pasture & Cropland, acres	19,064.20	acres	=	[111.2 acres + 18953 acres]

Step 3. Calculate the unit area Farm Animals loading rate (lbs/ac) to Total Nitrogen and Total Phosphorus for each land use by dividing the Farm Animal Load by the land use acres.

	Total Nitrogen	Total Phosphorus	
Nutrient Load from Farm Animals	6,684.76	1,296.72	pounds, from Step 1
Area of Hay/Pasture & Cropland	19,064.20	19,064.20	acres, from Step 2
Loading Rate for Hay/Pasture & Cropland	**0.35**	**0.07**	**pounds per acre**

Step 4. Add these Farm Animals loading rates to the Land Use (upland) and Stream Bank loading rates for Hay/Pasture and Cropland to calculate the Toal Nitrogen and Total Phosphorus loading rates as shown on the Land Use Loading Rates Look-Up Table.

Look-Up Table: Christina Basin MapShed Loading Rates

Watershed: White Clay

Year: 2012

Section 6: Stream Bank Sediment Loading Rates Worksheet

This worksheet calculates and apportions the loading rates from the Stream Bank source load for sediment from the Christina MapShed Output file into each land use category, using methodology provided from Dr. Barry Evans (Pennsylvania State University), the author of MapShed, and with concurrence from Mr. Bill Brown (PADEP).

The MapShed output file provides the sediment load in tons, which are converted to pounds to be consistent with the loading rates for Total Nitrogen and Total Phosphorus.

Step 1. The Stream Bank Sediment Load, in tons, and land areas for each land use category, in acres, are presented below.

	Sediment		
Stream Bank	10,341.22	tons	Note: The sediment load is taken from Cell E35 in the Christina Basin MapShed Output worksheet

	Source	Area (acres)
Land Use Categories from MapShed	Hay/Pasture	111.20
	Cropland	18,953.00
	Forest	14,186.30
	Wetland	121.10
	Disturbed	1,583.90
	Turfgrass	1,220.70
	Open_Land	252.00
	Bare_Rock	0.00
	Sandy_Areas	0.00
	Unpaved_Road	0.00
	Ld_Mixed	98.80
	Md_Mixed	1,171.30
	Hd_Mixed	2,723.10
	Ld_Residential	14,888.10
	Md_Residential	810.50
	Hd_Residential	239.70
	Total Acres, Watershed	**56,359.70**

Step 2. Convert the Stream Bank Sediment Load to pounds by multiplying tons by 2,000 pounds per ton.

	Sediment Load, pounds		
Stream Bank	20,682,440.00	pounds	= [10341.22 tons x 2,000 pounds per ton]

Step 3. Sum the total acres in the White Clay watershed.

Total Acres in watershed	56,359.70	acres

Watershed: White Clay

Year: 2012

Step 4. Calculate the total acres in the watershed that are considered "Developed," which includes Low Density Mixed (Ld_Mixed), Medium Density Mixed (Md_Mixed), High Density Mixed (Hd_Mixed); and Low Density Residential (Ld_Residential), Medium Density Residential (Md_Residential), and High Density Residential (Hd_Residential).

Area of Developed Lands	*acres*	*percent*	
Low Density Developed	14,986.90	75%	[Ld_Mixed + Ld_Residential]
Medium Density Developed	1,981.80	10%	[Md_Mixed + Md_Residential]
High Density Developed	2,962.80	15%	[Hd_Mixed + Hd_Residential]
Total	19,931.50	100%	[All "Developed" land use categories]

Step 5. Calculate the portion of the Stream Bank Sediment Load resulting from "Developed" Lands
This is A) 40% of the Stream Bank Sediment Load times the percent of developed lands in the watershed plus B) 60% of the Stream Bank Sediment Load:

Stream Bank Sediment Load	20,682,440.00	pounds		from Step 2
Total Developed Acres	19,931.5	acres		from Step 4
Total Acres in watershed	56,359.7	acres		from Step 3
Percent of Developed lands in watershed	35%		=	[19931.5 acres / 56359.7 acres]
A) 40% x Stream Bank Sediment Load x Percent of Developed Lands	2,925,722.12	pounds	=	[40% x 20682440 pounds x 35%]
B) 60% x Stream Bank Sediment Load	12,409,464.00	pounds	=	[60% x 20682440 pounds]
Load Assigned to Developed Lands	15,335,186.12	pounds		

Step 6. Calculate the portion of the Stream Bank Sediment Load from "Developed" Lands that is assigned to each of the land use categories by calculating relative components from "Impervious" surfaces and from the land use as a whole:

Estimated Percent of Impervious Area for corresponding land use categories (MapShed Values)	
Low Density Developed	15%
Medium Density Developed	52%
High Density Developed	87%

Step 7. Calculate how many acres within the watershed are "Impervious" by multiplying the acres in Step 4 by the percent in Step 6:

Estimated Impervious Surfaces for Developed Lands				
Low Density Developed	2,248.04	acres	=	[14986.9 acres x 15 percent]
Medium Density Developed	1,030.54	acres	=	[1981.8 acres x 52 percent]
High Density Developed	2,577.64	acres	=	[2962.8 acres x 87 percent]
Total Developed Impervious Surface Area	5,856.21	acres		

Watershed: White Clay

Year: 2012

Step 8. Calculate the percent of total developed Impervious Surface for each land use:

Percent of Total Impervious Surfaces			
Low Density Developed	38%	=	[2248.04 acres / 5856.21 acres]
Medium Density Developed	18%	=	[1030.54 acres / 5856.21 acres]
High Density Developed	44%	=	[2577.64 acres / 5856.21 acres]
Total	100%		

Step 9. Assign 60% of the "Total Load Assigned to Developed Lands", from Step 5, as a result of "Impervious" surfaces, and assign 40% based on the percent of land area in the land use category:

Load Assigned to Developed Lands	15,335,186.12	pounds	=	[result of Step 5]
60% of Load assigned to Impervious	9,201,111.67	pounds	=	[15335186.12 pounds x 60%]
40% of Load assigned for total land area	6,134,074.45	pounds	=	[15335186.12 pounds x 40%]

Step 10. Apportion Load Assigned to "Impervious" surfaces to each "Developed" land use category by multiplying the 'Percent of Total Impervious Surfaces' (Step 8) by 9201111.67 pounds (calculated in Step 9):

Stream Bank Sediment Load Assigned to Impervious Surface, pounds		
Low Density Developed	3,532,050.88	= [38 % x 9201111.67 pounds]
Medium Density Developed	1,619,149.87	= [18 % x 9201111.67 pounds]
High Density Developed	4,049,910.92	= [44 % x 9201111.67 pounds]

Step 11. Apportion Load Assigned to Total Land Area to each "Developed" land use category by multiplying the 'Percent of Area of Developed Lands' (from Step 4) by 6134074.45 pounds (calculated in Step 9):

Stream Bank Sediment Load Assigned to Total Developed Land Area, pounds		
Low Density Developed	4,612,335.27	= [75 % x 6134074.45 pounds]
Medium Density Developed	609,914.39	= [10 % x 6134074.45 pounds]
High Density Developed	911,824.79	= [15 % x 6134074.45 pounds]

Step 12. Combine the loads apportioned to "Impervious" surfaces, from Step 10, and the loads apportioned to Total Developed Land Area, from Step 11:

Total Stream Bank Sediment Load per Land Use, pounds		
Low Density Developed	8,144,386.15	= [3532050.88 pounds + 4612335.27 pounds]
Medium Density Developed	2,229,064.27	= [1619149.87 pounds + 609914.39 pounds]
High Density Developed	4,961,735.71	= [4049910.92 pounds + 911824.79 pounds]

Watershed: White Clay

Year: 2012

Step 13. Calculate the Stream Bank Loading Rate for each "Developed" Land Use, in pounds per acre, by dividing the load from Step 12 by the acres in Step 4:

Stream Bank Sediment Land Use Loading Rate	pounds	Land Use area, acres	**Stream Bank Sediment Loading Rate, pounds/acre**
Low Density Developed	8,144,386.15	14,986.90	**543.43** = [8144386.15 lbs / 14986.9 acres]
Medium Density Developed	2,229,064.27	1,981.80	**1,124.77** = [2229064.27 lbs / 1981.8 acres]
High Density Developed	4,961,735.71	2,962.80	**1,674.68** = [4961735.71 lbs / 2962.8 acres]

Step 14. Calculate the Stream Bank Loading Rate for "Undeveloped Land" (all other land use categories):

Total Stream Bank Load	20,682,440.00	pounds =	[from Step 3]
Load assigned to Developed La	15,335,186.12	pounds =	[from Step 5]
Remaining Load assigned to Undeveloped Lands	5,347,253.88	pounds =	[20682440 pounds - 15335186.12 pounds]
Acres of Undeveloped Lands	36,428.20	acres =	[sum of "Undeveloped Land" from Step 1]
Stream Bank Sediment Loading rate for Undeveloped Lands	**146.79**	**pounds per acre**	= [5347253.88 pounds / 36428.2 acres]

Step 15. Add these Stream Bank Sediment Land Use Loading Rates to the Land Use (upland source) Loading Rates for each of the corresponding land uses in the Land Use Loading Rates Look-Up Table to calculate the Total Sediment Loading Rate.

Look-Up Table: Christina Basin MapShed Loading Rates

Watershed: White Clay

Year: 2012

Section 7: Stream Bank Nitrogen Loading Rates Worksheet

This worksheet calculates and apportions the loading rates from the Stream Bank source load for Total Nitrogen from the Christina MapShed Output file into each land use category, using methodology provided from Dr. Barry Evans (Pennsylvania State University), the author of MapShed, and with concurrence from Mr. Bill Brown (PADEP).

The MapShed output file provides the nitrogen load in pounds.

Step 1. The land areas for each land use category, in acres, are presented below.

	Source	Area (acres)
Land Use Categories from MapShed	Hay/Pasture	111.20
	Cropland	18,953.00
	Forest	14,186.30
	Wetland	121.10
	Disturbed	1,583.90
	Turfgrass	1,220.70
	Open_Land	252.00
	Bare_Rock	0.00
	Sandy_Areas	0.00
	Unpaved_Road	0.00
	Ld_Mixed	98.80
	Md_Mixed	1,171.30
	Hd_Mixed	2,723.10
	Ld_Residential	14,888.10
	Md_Residential	810.50
	Hd_Residential	239.70
	Total Acres, Watershed	**56,359.70**

Step 2. The Stream Bank Total Nitrogen Load, in pounds, is presented below:

	Total Nitrogen Load, pounds	
Stream Bank	10,339.67	pounds

Step 3. Sum the total acres in the White Clay watershed.

Total Acres in watershed	56,359.70	acres

Watershed: White Clay

Year: 2012

Step 4. Calculate the total acres in the watershed that are considered "Developed," which includes Low Density Mixed (Ld_Mixed), Medium Density Mixed (Md_Mixed), High Density Mixed (Hd_Mixed); and Low Density Residential (Ld_Residential), Medium Density Residential (Md_Residential), and High Density Residential (Hd_Residential):

Area of Developed Lands	*acres*	*percent*	
Low Density Developed	14,986.90	75%	[Ld_Mixed + Ld_Residential]
Medium Density Developed	1,981.80	10%	[Md_Mixed + Md_Residential]
High Density Developed	2,962.80	15%	[Hd_Mixed + Hd_Residential]
Total	19,931.50	100%	[All "Developed" land use categories]

Step 5. Calculate the portion of the Stream Bank Total Nitrogen (TN) Load resulting from "Developed" Lands
This is A) 40% of the Stream Bank Total Nitrogen Load times the percent of developed lands in the watershed plus B) 60% of the Stream Bank Total Nitrogen Load:

Stream Bank TN Load	10,339.67	pounds		from Step 2
Total Developed Acres	19,931.5	acres		from Step 4
Total Acres in watershed	56,359.7	acres		from Step 3
Percent of Developed lands in watershed	35%		=	[19931.5 acres / 56359.7 acres]
A) 40% x Stream Bank TN Load x Percent of Developed Lands	1,462.64	pounds	=	[40% x 10339.67 pounds x 35%]
B) 60% x Stream Bank TN Load	6,203.80	pounds	=	[60% x 10339.67 pounds]
Load Assigned to Developed Lands	7,666.44	pounds		

Step 6. Calculate the portion of the Stream Bank Total Nitrogen Load from "Developed" Lands that is assigned to each of the land use categories by calculating relative components from "Impervious" surfaces and from the land use as a whole:

Estimated Percent of Impervious Area for corresponding land use categories (MapShed Values)	
Low Density Developed	15%
Medium Density Developed	52%
High Density Developed	87%

Step 7. Calculate how many acres within the watershed are "Impervious" by multiplying the acres in Step 4 by the percent in Step 6:

Estimated Impervious Surfaces for Developed Lands				
Low Density Developed	2,248.04	acres	=	[14986.9 acres x 15 percent]
Medium Density Developed	1,030.54	acres	=	[1981.8 acres x 52 percent]
High Density Developed	2,577.64	acres	=	[2962.8 acres x 87 percent]
Total Developed Impervious Surface Area	5,856.21	acres		

Watershed: White Clay

Year: 2012

Step 8. Calculate the percent of total developed Impervious Surface for each land use:

Percent of Total Impervious Surfaces			
Low Density Developed	38%	=	[2248.04 acres / 5856.21 acres]
Medium Density Developed	18%	=	[1030.54 acres / 5856.21 acres]
High Density Developed	44%	=	[2577.64 acres / 5856.21 acres]
Total	100%		

Step 9. Assign 60% of the "Total Load Assigned to Developed Lands", from Step 5, as a result of "Impervious" surfaces, and assign 40% based on the percent of land area in the land use category.

Load Assigned to Developed Lands	7,666.44	pounds	=	[result of Step 5]
60% of Load assigned to Impervious	4,599.87	pounds	=	[7666.44 pounds x 60%]
40% of Load assigned for total land area	3,066.58	pounds	=	[7666.44 pounds x 40%]

Step 10. Apportion Load Assigned to "Impervious" surfaces to each "Developed" land use category by multiplying the 'Percent of Total Impervious Surfaces' (Step 8) by 4599.87 pounds (calculated in Step 9):

Stream Bank Total Nitrogen Load Assigned to Impervious Surface, pounds		
Low Density Developed	1,765.76	= [38 % x 4599.87 pounds]
Medium Density Developed	809.45	= [18 % x 4599.87 pounds]
High Density Developed	2,024.65	= [44 % x 4599.87 pounds]

Step 11. Apportion Load Assigned to Total Land Area to each "Developed" land use category by multiplying the 'Percent of Area of Developed Lands' (from Step 4) by 3066.58 pounds (calculated in Step 9):

Stream Bank Total Nitrogen Load Assigned to Total Developed Land Area, pounds		
Low Density Developed	2,305.82	= [75 % x 3066.58 pounds]
Medium Density Developed	304.91	= [10 % x 3066.58 pounds]
High Density Developed	455.84	= [15 % x 3066.58 pounds]

Step 12. Combine the loads apportioned to "Impervious" surfaces, from Step 10, and the loads apportioned to Total Developed Land Area, from Step 11:

Total Stream Bank Total Nitrogen Load per Land Use, pounds		
Low Density Developed	4,071.58	= [1765.76 pounds + 2305.82 pounds]
Medium Density Developed	1,114.37	= [809.45 pounds + 304.91 pounds]
High Density Developed	2,480.50	= [2024.65 pounds + 455.84 pounds]

Watershed: White Clay

Year: 2012

Step 13. Calculate the Stream Bank Loading Rate for each "Developed" Land Use, in pounds per acre, by dividing the load from Step 12 by the acres in Step 4:

Stream Bank Total Nitrogen Land Use Loading Rate	pounds	Land Use area, acres	**Stream Bank Total Nitrogen Loading Rate, pounds/acre**
Low Density Developed	4,071.58	14,986.90	**0.27** = [4071.58 lbs / 14986.9 acres]
Medium Density Developed	1,114.37	1,981.80	**0.56** = [1114.37 lbs / 1981.8 acres]
High Density Developed	2,480.50	2,962.80	**0.84** = [2480.5 lbs / 2962.8 acres]

Step 14. Calculate the Stream Bank Loading Rate for "Undeveloped Land" (all other land use categories):

Total Stream Bank Load	10,339.67	pounds =	[from Step 3]
Load assigned to Developed Lands	7,666.44	pounds =	[from Step 5]
Remaining Load assigned to Undeveloped Lands	2,673.23	pounds =	[10339.67 pounds - 7666.44 pounds]
Acres of Undeveloped Lands	36,428.20	acres =	[sum of "Undeveloped Land" from Step 1]
Stream Bank Total Nitrogen Loading rate for Undeveloped Lands	**0.07**	**pounds per acre**	= [2673.23 pounds / 36428.2 acres]

Step 15. Add these Stream Bank Total Nitrogen Land Use Loading Rates to the Land Use (upland source) and Farm Animals Loading Rates for each of the corresponding land uses in the Land Use Loading Rates Look-Up Table to calculate the final Total Nitrogen Loading Rate.

Look-Up Table: Christina Basin MapShed Loading Rates

Watershed: White Clay

Year: 2012

Section 8: Stream Bank Phosphorus Loading Rates Worksheet

This worksheet calculates and apportions the loading rates from the Stream Bank source load for Total Phosphorus from the Christina MapShed Output file into each land use category, using methodology provided from Dr. Barry Evans (Pennsylvania State University), the author of MapShed, and with concurrence from Mr. Bill Brown (PADEP).

The MapShed output file provides the Phosphorus load in pounds.

Step 1. The land areas for each land use category, in acres, are presented below.

	Source	Area (acres)
Land Use Categories from MapShed	Hay/Pasture	111.20
	Cropland	18,953.00
	Forest	14,186.30
	Wetland	121.10
	Disturbed	1,583.90
	Turfgrass	1,220.70
	Open_Land	252.00
	Bare_Rock	0.00
	Sandy_Areas	0.00
	Unpaved_Road	0.00
	Ld_Mixed	98.80
	Md_Mixed	1,171.30
	Hd_Mixed	2,723.10
	Ld_Residential	14,888.10
	Md_Residential	810.50
	Hd_Residential	239.70
	Total Acres, Watershed	**56,359.70**

Step 2. The Stream Bank Total Phosphorus Load, in pounds, is presented below:

	Total Phosphorus Load, pounds	
Stream Bank	3,747.85	pounds

Step 3. Sum the total acres in the White Clay watershed.

Total Acres in watershed	56,359.70	acres

Watershed: White Clay

Year: 2012

Step 4. Calculate the total acres in the watershed that are considered "Developed," which includes Low Density Mixed (Ld_Mixed), Medium Density Mixed (Md_Mixed), High Density Mixed (Hd_Mixed); and Low Density Residential (Ld_Residential), Medium Density Residential (Md_Residential), and High Density Residential (Hd_Residential):

Area of Developed Lands	*acres*	*percent*	
Low Density Developed	14,986.90	75%	[Ld_Mixed + Ld_Residential]
Medium Density Developed	1,981.80	10%	[Md_Mixed + Md_Residential]
High Density Developed	2,962.80	15%	[Hd_Mixed + Hd_Residential]
Total	19,931.50	100%	[All "Developed" land use categories]

Step 5. Calculate the portion of the Stream Bank Total Phosphorus (TP) Load resulting from "Developed" Lands
This is A) 40% of the Stream Bank Total Phosphorus Load times the percent of developed lands in the watershed plus B) 60% of the Stream Bank Total Phosphorus Load:

Stream Bank TP Load	3,747.85	pounds		from Step 2
Total Developed Acres	19,931.5	acres		from Step 4
Total Acres in watershed	56,359.7	acres		from Step 3
Percent of Developed lands in watershed	35%		=	[19931.5 acres / 56359.7 acres]
A) 40% x Stream Bank TP Load x Percent of Developed Lands	530.17	pounds	=	[40% x 3747.85 pounds x 35%]
B) 60% x Stream Bank TP Load	2,248.71	pounds	=	[60% x 3747.85 pounds]
Load Assigned to Developed Lands	2,778.88	pounds		

Step 6. Calculate the portion of the Stream Bank Total Phosphorus Load from "Developed" Lands that is assigned to each of the land use categories by calculating relative components from "Impervious" surfaces and from the land use as a whole:

Estimated Percent of Impervious Area for corresponding land use categories (MapShed Values)	
Low Density Developed	15%
Medium Density Developed	52%
High Density Developed	87%

Step 7. Calculate how many acres within the watershed are "Impervious" by multiplying the acres in Step 4 by the percent in Step 6:

Estimated Impervious Surfaces for Developed Lands				
Low Density Developed	2,248.04	acres	=	[14986.9 acres x 15 percent]
Medium Density Developed	1,030.54	acres	=	[1981.8 acres x 52 percent]
High Density Developed	2,577.64	acres	=	[2962.8 acres x 87 percent]
Total Developed Impervious Surface Area	5,856.21	acres		

Page 3 of Stream Bank ***Total Phosphorus Loading Rates*** worksheet

Watershed: White Clay

Year: 2012

Step 8. Calculate the percent of total developed Impervious Surface for each land use:

Percent of Total Impervious Surfaces			
Low Density Developed	38%	=	[2248.04 acres / 5856.21 acres]
Medium Density Developed	18%	=	[1030.54 acres / 5856.21 acres]
High Density Developed	44%	=	[2577.64 acres / 5856.21 acres]
Total	100%		

Step 9. Assign 60% of the "Total Load Assigned to Developed Lands", (from Step 5), as a result of "Impervious" surfaces, and assign 40% based on the percent of land area in the land use category.

Load Assigned to Developed Lands	2,778.88	pounds	=	[result of Step 5]
60% of Load assigned to Impervious	1,667.33	pounds	=	[2778.88 pounds x 60%]
40% of Load assigned for total land area	1,111.55	pounds	=	[2778.88 pounds x 40%]

Step 10. Apportion Load Assigned to "Impervious" surfaces to each "Developed" land use category by multiplying the 'Percent of Total Impervious Surfaces' (Step 8) by 1667.33 pounds (calculated in Step 9):

Stream Bank Total Phosphorus Load Assigned to Impervious Surface, pounds		
Low Density Developed	640.04	= [38 % x 1667.33 pounds]
Medium Density Developed	293.40	= [18 % x 1667.33 pounds]
High Density Developed	733.88	= [44 % x 1667.33 pounds]

Step 11. Apportion Load Assigned to Total Land Area to each "Developed" land use category by multiplying the 'Percent of Area of Developed Lands' (from Step 4) by 1111.55 pounds (calculated in Step 9):

Stream Bank Total Phosphorus Load Assigned to Total Developed Land Area, pounds		
Low Density Developed	835.80	= [75 % x 1111.55 pounds]
Medium Density Developed	110.52	= [10 % x 1111.55 pounds]
High Density Developed	165.23	= [15 % x 1111.55 pounds]

Step 12. Combine the loads apportioned to "Impervious" surfaces, from Step 10, and the loads apportioned to Total Developed Land Area, from Step 11:

Total Stream Bank Total Phosphorus Load per Land Use, pounds		
Low Density Developed	1,475.84	= [640.04 pounds + 835.8 pounds]
Medium Density Developed	403.93	= [293.4 pounds + 110.52 pounds]
High Density Developed	899.11	= [733.88 pounds + 165.23 pounds]

Watershed: White Clay

Year: 2012

Step 13. Calculate the Stream Bank Loading Rate for each "Developed" Land Use, in pounds per acre, by dividing the load from Step 12 by the acres in Step 4:

Stream Bank Total Phosphorus Land Use Loading Rate	pounds	Land Use area, acres	**Stream Bank Total Phosphorus Loading Rate, pounds/acre**
Low Density Developed	1,475.84	14,986.90	**0.10** = [1475.84 lbs / 14986.9 acres]
Medium Density Developed	403.93	1,981.80	**0.20** = [403.93 lbs / 1981.8 acres]
High Density Developed	899.11	2,962.80	**0.30** = [899.11 lbs / 2962.8 acres]

Step 14. Calculate the Stream Bank Loading Rate for "Undeveloped Land" (all other land use categories):

Total Stream Bank Load	3,747.85	pounds =	[from Step 3]
Load assigned to Developed Lands	2,778.88	pounds =	[from Step 5]
Remaining Load assigned to Undeveloped Lands	968.97	pounds =	[3747.85 pounds - 2778.88 pounds]
Acres of Undeveloped Lands	36,428.20	acres =	[sum of "Undeveloped Land" from Step 1]
Stream Bank Total Phosphorus Loading rate for Undeveloped Lands	**0.03**	**pounds per acre**	= [968.97 pounds / 36428.2 acres]

Step 15. Add these Stream Bank Total Phosphorus Land Use Loading Rates to the Land Use (upland source) and Farm Animals Loading Rates for each of the corresponding land uses in the Land Use Loading Rates Look-Up Table to calculate the final Total Phosphorus Loading Rate.

Brandywine-Christina Watershed (HUC # 02040205)
EPA TMDL MS4 Baseline Pollutant Loadings, MS4 Allocations, and Reductions

MUNICIPALITIES LISTED IN TMDL REPORTS	Sediment (tons/year)				Total Nitrogen (kg/day)				Total Phosphorus (kg/day)			
Brandywine Creek Watershed	Baseline MS4 Load[1b.]	MS4 Load Allocation[1b.]	MS4 Load Reduction [1e.]	% Reduction[1b.]	Baseline MS4 Load[2g.]	MS4 Allocation[2a.]	MS4 Load Reduction[2m.]	% Reduction [2m.]	Baseline MS4 Load [2j.]	MS4 Allocation [2d.]	MS4 Load Reduction[2m.]	% Reduction [2m.]
BIRMINGHAM TWP	310.81	130.35	180.46	58.06%								
COATESVILLE CITY	231.29	86.06	145.23	65.52%	16.08	10.86	5.22	32.46%	3.015	2.031	0.984	32.64%
EAST BRADFORD TWP	1185.00	467.17	717.83	60.58%								
EAST BRANDYWINE TWP					54.19	44.44	9.75	17.99%	0.826	0.677	0.149	18.04%
EAST FALLOWFIELD TWP	803.23	426.42	376.81	46.91%	110.54	75.74	34.80	31.48%	22.365	15.348	7.017	31.37%
EAST MARLBOROUGH TWP	366.70	139.44	227.26	61.98%								
HIGHLAND TWP	384.80	238.86	145.94	37.93%								
HONEY BROOK BORO	20.58	13.23	7.35	35.70%	9.61	5.76	3.85	40.06%	0.184	0.11	0.074	40.22%
HONEY BROOK TWP	813.84	558.76	255.08	31.34%	421.64	279.02	142.62	33.83%	7.599	4.956	2.643	34.78%
KENNETT TWP					2.38	2.22	0.16	6.72%	0.213	0.198	0.015	7.04%
MODENA BORO	27.96	12.46	15.50	55.43%	4.80	3.25	1.55	32.29%	0.966	0.656	0.31	32.09%
NEWLIN TWP	144.18	59.59	84.59	58.67%	6.53	4.57	1.96	30.02%	1.337	0.936	0.401	29.99%
PARKESBURG BORO	52.11	32.35	19.76	37.93%								
PENNSBURY TWP	113.98	43.48	70.50	61.85%	47.00	43.71	3.29	7.00%	4.206	3.911	0.295	7.01%
POCOPSON TWP	821.21	320.79	500.42	60.94%								
SADSBURY TWP	289.73	172.13	117.60	40.59%	3.05	2.26	0.79	25.90%	0.329	0.205	0.124	37.69%
THORNBURY TWP	82.17	34.46	47.71	58.06%								
UPPER UWCHLAN TWP					10.92	8.96	1.96	17.95%	0.166	0.137	0.029	17.47%
VALLEY TWP	485.14	164.64	320.50	66.06%	57.57	43.75	13.82	24.01%	6.941	4.726	2.215	31.91%
WALLACE TWP	21.74	17.41	4.33	19.92%	126.53	103.76	22.77	18.00%	1.929	1.582	0.347	17.99%
WEST BRADFORD TWP	283.22	121.6	161.62	57.07%	17.25	12.08	5.17	29.97%	3.532	2.473	1.059	29.98%
WEST BRANDYWINE TWP					136.01	104.78	31.23	22.96%	9.63	8.344	1.286	13.35%
WEST CALN TWP	68.28	43.07	25.21	36.92%	183.72	149.26	34.46	18.76%	9.95	8.649	1.301	13.08%
WEST GOSHEN TWP	461.32	180.51	280.81	60.87%								

	Sediment (tons/year)				Total Nitrogen (kg/day)				Total Phosphorus (kg/day)			
Red Clay Creek Watershed	Baseline MS4 Load[1c.]	MS4 Load Allocation[1c.]	MS4 Load Reduction [1e.]	% Reduction[1c.]	Baseline MS4 Load [2h.]	MS4 Allocation[2b.]	MS4 Load Reduction[2m.]	% Reduction [2m.]	Baseline MS4 Load [2k.]	MS4 Allocation[2e.]	MS4 Load Reduction[2m.]	% Reduction [2m.]
EAST MARLBOROUGH TWP	8791.41	4,193.24	4598.17	52.30%	137.13	68.56	68.57	50.00%	2.742	1.372	1.37	49.96%
KENNETT SQUARE BORO	840.10	405.41	434.69	51.74%	13.26	6.63	6.63	50.00%	0.452	0.151	0.301	66.59%
KENNETT TWP	6751.63	3,312.06	3439.57	50.94%	157.97	97.83	60.14	38.07%	21.517	3.731	17.786	82.66%
NEW GARDEN TWP	4709.65	2,118.72	2590.93	55.01%	77.03	38.52	38.51	49.99%	27.708	2.87	24.838	89.64%
PENNSBURY TWP					4.32	4.32	0.00	0.00%	0.082	0.082	0.00	0.00%

	Sediment (tons/year)				Total Nitrogen (kg/day)				Total Phosphorus (kg/day)			
White Clay Creek Watershed	Baseline MS4 Load[1d.]	MS4 Load Allocation[1d.]	MS4 Load Reduction [1e.]	% Reduction[1d.]	Baseline MS4 Load [2i.]	MS4 Allocation[2c.]	MS4 Load Reduction[2m.]	% Reduction [2m.]	Baseline MS4 Load [2l.]	MS4 Allocation[2f.]	MS4 Load Reduction[2m.]	% Reduction [2m.]
AVONDALE BORO	463.65	140.02	323.63	69.80%	9.16	4.58	4.58	50.00%	0.322	0.135	0.187	58.07%
FRANKLIN TWP	4220.43	2,305.87	1914.56	45.36%	122.01	61.01	61	50.00%	15.219	5.557	9.662	63.49%
KENNETT TWP					2.17	2.17	0.00	0.00%	0.055	0.055	0	0.00%
LONDON BRITAIN TWP	2634.66	1,620.44	1014.22	38.50%	96.47	49.9	46.57	48.27%	15.732	7.333	8.399	53.39%
LONDON GROVE TWP	13616.33	4,842.81	8773.52	64.43%	262.76	128.47	134.29	51.11%	25.875	7.965	17.91	69.22%
NEW GARDEN TWP	6746.50	2,986.66	3759.84	55.73%	167.06	83.83	83.23	49.82%	41.916	13.374	28.542	68.09%
NEW LONDON TWP	1913.97	1,008.60	905.37	47.30%	53.56	26.61	26.95	50.32%	0.65	0.292	0.358	55.08%
PENN TWP	3584.76	1,410.29	2174.47	60.66%	71.23	33.36	37.87	53.17%	0.798	0.359	0.439	55.01%
WEST GROVE BORO	562.29	192.63	369.66	65.74%	9.24	4.36	4.88	52.81%	0.112	0.05	0.062	55.36%

(1) U.S. EPA Region III. 8 April 2005. Total Maximum Daily Loads for Bacteria and Sediment in the Christina River Basin Watershed Pennsylvania, Delaware, and Maryland. Philadelphia, PA.

a. Table 4.2 Fecal coliform TMDL allocations for MS4 municipalities. p 4-5

b. Table 4.8 Sediment allocations for towns in Brandywine Creek Watershed. p 4-16

c. Table 4.9 Sediment allocations for towns in Red Clay Creek Watershed. p 4-16

d. Table 4.10 Preliminary sediment allocations for towns in White Clay Creek Watershed. p 4-16

e. Calculated by CCWRA using Tables listed in 1a.-1d. listed above.
MS4 Reduction = (Baseline MS4 Load) - (MS4 Load Allocation)

(2) U.S. EPA Region III. 26 September 2006. Revisions to Total Maximum Daily Loads for Nutrient and Low Dissolved Oxygen under High-flow Conditions: Christina River Basin Watershed, Pennsylvania, Delaware, and Maryland. Philadelphia, PA.

a. Appendix C -Table C-5b. Total nitrogen MS4 allocations for Brandywine Creek watershed (kg/day) p. C-6

b. Appendix C. Table C-7b. Total nitrogen MS4 allocations for Red Clay Creek watershed (kg/day) p. C-9

c. Appendix C. Table C-9b. Total nitrogen MS4 allocations for White Clay Creek watershed (kg/day) p. C-11

d. Appendix C. Table C-6b. Total phosphorus MS4 allocations for Brandywine Creek watershed (kg/day) p.C-8

e. Appendix C. Table C-8b. Total phosphorus MS4 allocations for Red Clay Creek watershed (kg/day) p. C-10

f. Appendix C. Table C-10b. Total phosphorus MS4 allocations for White Clay Creek watershed (kg/day) p. C-13

g. Appendix C -Table C-5a. Total nitrogen MS4 baseline loads for Brandywine Creek watershed (kg/day) p. C-5

h. Appendix C. Table C-7a. Total nitrogen MS4 baseline loads for Red Clay Creek watershed (kg/day) p. C-8

i. Appendix C. Table C-9a. Total nitrogen MS4 baseline loads for White Clay Creek watershed (kg/day) p. C-10

j. Appendix C. Table C-6a. Total phosphorus MS4 baseline loads for Brandywine Creek watershed (kg/day) p.C-7

k. Appendix C. Table C-8a. Total phosphorus MS4 baseline loads for Red Clay Creek watershed (kg/day) p. C-9

l. Appendix C. Table C-10a. Total phosphorus MS4 baseline loads for White Clay Creek watershed (kg/day) p. C-12

m. Calculated by CCWRA using Tables listed in 2a.-2l. listed above. MS4 Reduction = (MS4 Baseline Load) - (MS4 Allocation);
%Reduction = (MS4 Load Reduction) / (MS4 Baseline Load)