2 Section 2: Average Loads

2.1 Introduction

A land use average load is defined in the Chesapeake Bay Program's (CBP) Phase 6 Watershed Model (Phase 6) as the spatially-averaged and temporally-averaged nutrient loading export rate to a stream or other waterbody for a given land use. The loading rate is typically expressed in pounds per acre per year. Average loads are developed at the Chesapeake Watershed scale with the assumption of no management practices, and are independent of local nutrient application rates, location within the watershed, and physical characteristics. For example, the average load for forest nitrogen export to streams is 1.68 pounds per acre per year averaged over the simulation period of 1985-2014 and over the entire Chesapeake Bay watershed. For the purposes of this documentation. Loads delivered to streams or other waterbodies are said to be representative of the edge-of- stream (EOS) scale.

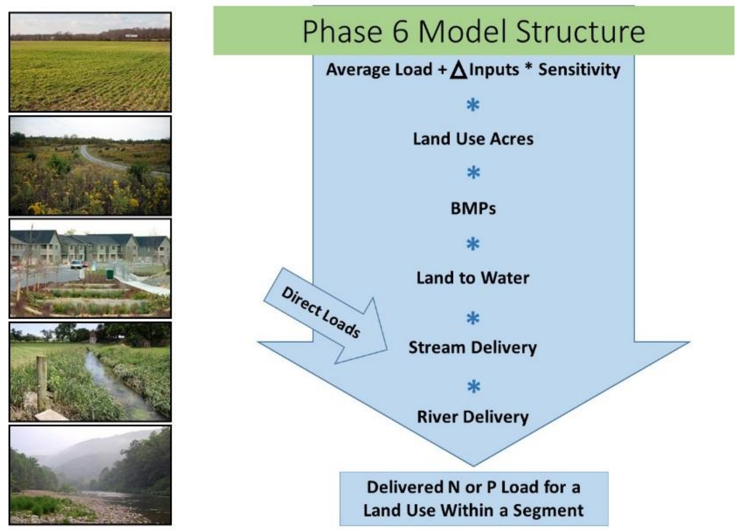


Figure 2-1: Phase 6 Model structure.

Figure 2-1 shows the structure of the overall model and the function of Average Load within the calculations. A full description of the Phase 6 Model structure is provided in Section 1.3.

With oversight by the Modeling Workgroup, average loads were established using literature and multiple water quality models specific to the Chesapeake Bay for four broad land use classes – pasture/hay, crop, developed, and natural. In addition, each of the Water Quality Goal Implementation Team's (WQGIT) source sector workgroups provided expertise to determine the relative loading of land uses under their purview. The WQGIT input supported the calculation of average load for each model land use.

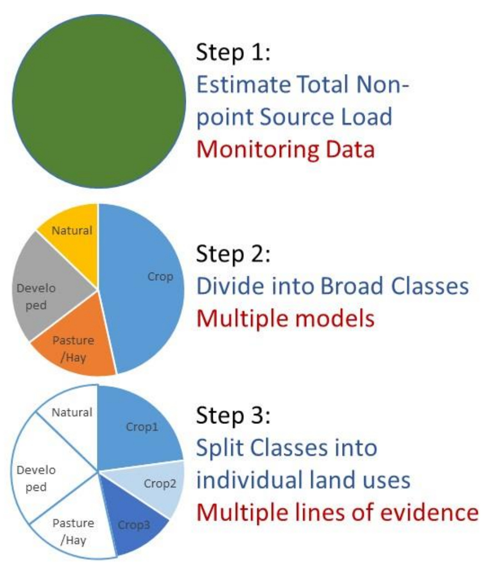


Figure 2-2: Three steps of determining average loads

2.2 Overview of Nutrient Average Loads

The development of land simulation average loads can be broken down into three steps as shown in Figure 2-2. These steps as summarized here and discussed in detail in the following sections. Calculations are performed separately for nitrogen and phosphorus.

First, total landscape loads are estimated from monitoring data. Next, the overall load is divided into broad categories of land use through consideration of multiple models and literature. In the third step, these broad classes are separated into individual land use loads based on the best available information to arrive at average loads.

There are significant nuances to the calculation at each step that are detailed in the sections below.

At this point it is useful to define terms that are specific to the description of the average load calculation.

- **Edge-of-stream load:** Load delivered to streams or other waterbodies
- **Average load:** for the purposes of this section, average loads are annual average loads for the period 1990-2014 and spatially-averaged across the entire Chesapeake Bay Watershed, expressed in pounds per year
- **Average loading rate:** average load per acre, expressed as pounds per acre per year.
- **Total landscape loads**: The total edge-of-stream load averaged from 1990-2014 from all nonpoint sources above monitoring sites.
- **Land class average loading rate**: The average loading rate for a broad land use class.
- **Land use average loading rate**: The average loading rate for an individual land use.

Where data for specific time periods are available, the calculations are carried out to match most closely with the time period of the Phase 6 Watershed Model, which is 1985-2014. This period is known as the calibration load averaging period.

2.2.1 Total Landscape Loads

Total landscape nitrogen and phosphorus loads are estimates of the total average annual edge-of-stream load of nitrogen and phosphorus in the Chesapeake Bay watershed above riverine water quality monitoring sites. These are calculated by summing the loads as reported in the Chesapeake Bay Program indicators from the River Input Monitoring (RIM) stations, which are the most downstream gauged site of the major Chesapeake Bay tributaries, and then adjusting for attenuation, BMPs, and point source loads as described below. The loads from areas downstream of the RIM stations are excluded in the mass-balance calculation because they are unmonitored. The results of the above-RIM station calculations are applied to land uses in areas below the RIM stations.

Langland et al. (2013) discussed the load calculation method. The Chesapeake Bay Program indicator is available on the CBP website for nitrogen, phosphorus, and sediment. Additional observed data and estimated loads are available on the USGS RIM web site. Loads from the indicators are available from 1990 through the last year of data availability. For the purposes of the average load calculation, the years 1990-2014 are used to match most closely with the calibration load averaging period.

As described above, four adjustments to these RIM loads must be made to determine the total edge-of-stream loads prior to BMPs being applied: (1) The estimated effect of BMPs must be removed; (2) Loads that are not land use based, such as wastewater treatment plants, must be removed; and (3) The effects of small streams and large rivers must be accounted for. The following paragraphs document these adjustments applied.

2.2.1.1 Effect of BMPs.

BMP effects are removed by calculating the percent change between the Phase 5.3.2 Watershed Model (EPA 2010a) scenario with and without the annual progress BMPs. This is done for each year, and then averaged across the calibration load averaging period. The scenarios listed in the column "P5.3.2 BMP scenario" in Table 2-1 are a series of scenarios designed to estimate nutrient and sediment loads given a long-term hydrology and the BMP implementation that was in place for that year, including the trend in atmospheric deposition. The scenarios listed in the column "P5.3.2 noBMP scenario" in Table 2-1 are a series of scenarios analogous to the BMP scenarios, but with the BMPs removed.

Table 2-1: Scenarios used to remove BMP effects

Year	TN Percent Change	TP Percent Change	P5.3.2 BMP scenario	P5.3.2 NoBMP Scenario
1990	-2.30%	-1.29%	1990AnnV1N020315RA	1990NAN123014RA
1991	-2.48%	-1.48%	1991AnnV1N020315RA	1991NAN123014RA
1992	-2.91%	-1.91%	1992AnnV1N020315RA	1992NAN123014RA
1993	-2.96%	-2.02%	1993AnnV1N020315RA	1993NAN123014RA
1994	-3.18%	-2.24%	1994AnnV1N020315RA	1994NAN123014RA
1995	-3.42%	-2.53%	1995AnnV1N020315RA	1995NAN123014RA
1996	-3.63%	-2.75%	1996AnnV1N020315RA	1996NAN123014RA
1997	-4.35%	-3.93%	1997AnnV1N020315RA	1997NAN123014RA
1998	-4.31%	-4.47%	1998AnnV1N020315RA	1998NAN123014RA
1999	-4.01%	-3.82%	1999AnnV1N020315RA	1999NAN123014RA
2000	-5.00%	-6.02%	2000AnnV1020315RA	2000NAN123014RA
2001	-5.35%	-6.81%	2001AnnV1N020315RA	2001NAN123014RA
2002	-6.50%	-8.42%	2002AnnV1N020315RA	2002NAN123014RA
2003	-6.36%	-8.61%	2003AnnV1N020315RA	2003NAN123014RA
2004	-6.85%	-9.17%	2004AnnV1N020315RA	2004NAN123014RA
2005	-7.97%	-10.17%	2005AnnV1N020315RA	2005NAN123014RA
2006	-7.15%	-10.02%	2006AnnV1N020315RA	2006NAN123014RA
2007	-7.74%	-10.55%	2007Annv1N020315RA	2007NAN123014RA
2008	-7.97%	-10.94%	2008AnnV1N020315RA	2008NAN123014RA
2009	-9.28%	-11.73%	2009Annv1N020315RA	2009NAN123014RA
2010	-9.16%	-12.27%	2010AnnV1N020315RA	2010NAN123014RA
2011	-9.46%	-13.97%	2011AnnV1N020315RA	2011NAN123014RA
2012	-10.29%	-16.78%	2012AnnV1N123014RA	2012NAN123014RA
2013	-12.48%	-11.83%	2013Prog2013airN030614	2013NoActionN021216RA
2014	-10.08%	-18.90%	2014ProgressV11N031015RA	2014NoActionN021216RA

2.2.1.2 Loads That are not Land Based

Nutrient loads from atmospheric deposition directly to non-tidal water, wastewater treatment plants, industrial sources, combined sewer overflows, animal waste direct loads (feeding space and riparian pasture deposition), septic systems, rapid infiltration basins, and non-agricultural spray irrigation were determined using the Phase 6 Watershed Model methods described in Sections 3 and 8. The loads were averaged over the calibration load averaging period and removed from the RIM loads. Note that some of these loads could be considered nonpoint sources. The defining characteristic for inclusion in the calculation is not point versus nonpoint loads but rather whether or not the loads are otherwise accounted for. Loads from the stream bed and bank load source were not removed. Stream loads are equivalent to the amount by which the delivery factors are decremented, so are already accounted for in the loads.

2.2.1.3 River and Stream Delivery

Loads delivered to the RIM stations are converted to edge-of-stream loads by adding back the nutrients lost in transport in small streams, river reaches, and reservoirs. Delivery factors from the USGS SPARROW Version 4 Chesapeake Bay Model (Ator et al. 2011) were used to adjust the nitrogen loads for both streams and rivers. Section 9 contains the discussion of SPARROW and the stream delivery factors as applied to small streams. For the purpose of this calculation, SPARROW was used for all river segments. The total reduction from stream and river delivery for the RIM stations is 25 percent for nitrogen. This represents a significant difference from previous CBP watershed models reflecting a change in the literature on stream and river attenuation in the mid-Atlantic region.

The Phase 5 riverine attenuation was larger and similar to previous phases of the watershed model and in agreement with statistical models of river attenuation such as Seitzinger et al. 2002b. SPARROW models, however estimate much lower river attenuation and do so over a broader range of models and geographic settings (Alexander et al. 2008, Alexander et al. 2009, Preston et al. 2011, and Ator et al. 2011). These values are more in line with measured denitrification such as those reported in Bohlke et al. 2009 and Seitzinger 1988.

However, applying the SPARROW model to stream and river phosphorus transport in a manner similar to nitrogen produced unacceptable results. Estimated phosphorus loads at edge-of- stream were lower than necessary for a successful calibration and considerably lower than in Phase 5.3.2. Investigation showed that the phosphorus reductions in reservoirs predicted by SPARROW were much lower than reductions calculated for the Lower Susquehanna Reservoir system (Zhang et al. 2016a). For the purposes of the river and stream delivery calculation, aquatic phosphorus transport is calculated separately for reservoir and non-reservoir effects and is also calculated separately for streams and rivers as described in Table 2-2. For reservoirs on rivers, the estimated effects are divided between Conowingo, other reservoirs simulated with HSPF, and reservoirs that are not simulated with HSPF.

Table 2-2: Information Sources for Phosphorus Losses in Rivers and Streams

Stream or River	Type	Information Source
Stream	Reservoir	SPARROW
Stream	Non-reservoir	Assume no loss, consistent with Ator et al. 2011 and Noe et al. 2015a, 2015b
River	Non-reservoir	Assume no loss, consistent with Ator et al. 2011 and Noe et al. 2015a, 2015b

River	Lower Susquehanna Reservoir System	WRTDS (after Zhang et al. 2016)
River	Other Simulated Reservoirs	Phase 5.3.2 losses 0.57 Million lbs
River	Non-simulated Reservoirs	SPARROW

An area of considerable uncertainty is the phosphorus losses in stream reaches that are not reservoirs. Ator et al. 2011, and Noe et al. 2015a and 2016b indicate that the losses in free-flowing streams and rivers are relatively small. The Phase 5.3.2 Watershed Model had a significant loss of 12.8 million pounds of P in these systems. Calibrations of some beta versions of the Phase 6 Model used assumptions of high riverine losses and therefore had higher average land use loads for phosphorus. In the final version, no net loss in non-reservoir streams and rivers was assumed.

2.2.1.3.1 Phosphorus Losses in Lower Susquehanna Reservoir System

The USGS statistical method Weighted Regression on Time, Discharge, and Seasonality (Hirsch et al. 2010) was applied to the Lower Susquehanna Reservoir System building from prior work on the Susquehanna (Hirsch 2012, Zhang et al. 2013, Zhang 2016, Zhang et al. 2016a, Zhang et al. 2016b). Table 2-3 shows various estimates of phosphorus loss in the Lower Susquehanna Reservoir System over the period of the calibration 1985-2014. Section 10.7 of the Phase 6 Model documentation gives a more detailed description of the methods used to generate Table 2-3.

Table 2-3: Estimates of phosphorus loss in the Lower Susquehanna Reservoir System

	Average	low	high	**F**illed	**W**RTDS & P532	Average **ASW**
Input (Mlb/yr)	8.9	7.8	11.1	9.8	9.4	9.4
Output (Mlb/yr)	6.2	5.3	7.3	6.3	6.2	6.2
Loss (Mlb/yr)	2.7	2.5	3.8	3.5	3.3	3.2

The first three columns are from the WRTDS estimate of load using all available data. To calculate the full mass balance unmonitored inputs to the Lower Susquehanna Reservoir System between Marietta and Conowingo, a ratio of the areas of Pequea Creek and the Conestoga River to the remainder of the unmonitored area were estimated. The column marked as 'filled' uses WRTDS runs on original samples plus artificial samples. The artificial samples were inserted on days were concentration was measured at either Conowingo or Marietta, but not both, during six major storm events between 1986 and 2014. On days when only Conowingo was measured, that concentration measurement was also assumed to apply to Marietta and conversely. If it is assumed there is no net scour during the storms for which there are incomplete data, the estimate of overall trapping increases slightly as scour that may have occurred is lost from the analysis. The column labeled 'WRTDS & P532' was calculated with standard WRTDS except that loads for the unmonitored portion of the catchment were obtained from the Phase 5.3.2 Model rather than the area. Using the Phase 6 principle of multiple models, the average of 3.2

million pounds per year phosphorus loss is assumed for the Lower Susquehanna Reservoirs for the calibration period.

2.2.1.4 Calculation of Above-RIM Edge-of-Stream Landscape Loads

Table 2-4 details the calculation for the total edge-of-stream load based on the discussion of the listed factors in Section 2.2.1. For an average year, 227.9 million pounds of nitrogen and 12.9 million pounds of phosphorus is estimated to be introduced from land-based sources to streams above the monitored RIM stations.

Table 2-4: Calculation of total landscape loads for above the RIM stations.

Component	Total Nitrogen		Total Phosphorus	
	Factor (%) or Amount (million pounds per year)	Load (million pounds per year)	Factor (%) or Amount (million pounds per year)	Load (million pounds per year)
Monitored Load at RIM Stations	NA	210.3	NA	13.8
BMP Effects Removed	16.2	226.5	1.5	15.3
River Attenuation Removed	83.70%	270.6	98.50%	15.5
Lower Susquehanna reservoir plus simulated reservoirs	NA	270.6	3.75	19.2
Wastewater Removed	30.8	239.8	5.2	14.1
Animal Feeding Space Removed	18.2	221.7	0.7	13.4
Riparian Pasture Deposition Removed	5.8	215.9	1.8	11.6
Atm. Deposition on Water Removed	6.5	209.4	0.2	11.4
Septic Systems Removed	5.9	203.5	NA	11.4
Rapid Infiltration Basin	0.1	203.5	0.002	11.4
Small Stream Attenuation Removed	89.30%	227.9	88.20%	12.9
Total Edge of Stream Load	NA	227.9	NA	12.9

2.2.2 Land Class Average Loading Rates

Total landscape loads, calculated in the previous section, from above RIM stations are divided into four land classes: 1) cropland, 2) pasture plus hay, 3) developed land, and 4) natural land including forest. Ratios of relative loading rates in pounds per acre between cropland and each of the other land classes are developed as discussed below. The total landscape loads, in combination with the relative loading rates and land class acreage, determine the absolute values of the land class loading rates. This may be represented for nitrogen or phosphorus as:

Equation 2-1

$$G = \sum_{i=1}^{4} C * R_i * A_i$$

Where:
G = Total Landscape Loads (pounds per year)
C = Land Class Average Loading Rate for Crop (pounds per acre per year)
R_i = Land Class Average Loading Rate relative to Crop Land Class (dimensionless)
A_i = Area in Land Class (acres)

Equation 2-1 has a single unknown, the Land Class Average Loading Rate for Crop. Once Land Class Average Loading Rate for Crop is known, the land class average loading rates for each land class *i* is C * R_i.

2.2.3 Calculation of the Relative Land Class Loading Rates

In order to incorporate multiple models, land class average loading rates are based on the average of the relative differences among the loading ratios for each land class from three models: 1) Phase 5.3.2 of the CBP Watershed Model, 2) NRCS's Conservation Effects Assessment Program (CEAP) Chesapeake Bay Model, and 3) USGS's SPARROW model. Ideally, the land class loading ratios generated by these models would apply to the calibration years 1985-2014, would be without the effect of management practices since management practice effects are added further down in the calculation shown in Figure 2-1, and would be at the edge-of-stream scale. The relative land class loading ratio of pasture, developed, and natural land to cropland was determined for each model. Then these relative ratios from the three models were averaged.

For the Phase 5.3.2 Model, edge-of-stream loads for the No BMP scenario for the 2007 scenario was chosen as the most representative scenario. Loads at the edge-of-stream scale without the influence of BMPs are the goal of the Phase 6 average load calculation. The year 2007 was chosen because it is close to the midpoint of the calibration (2000) and has high quality input data. Land use data tend to be better in later years and 2007 is a year where data are available from the Census of Agriculture (USDA-NASS 2007). Data from the 2002 Census of Agriculture were less suitable because they were affected by low rainfall.

The available CEAP data were with the 2011 no practices condition delivered to watershed outlets at the HUC-8 scale. The Modeling Workgroup determined that it was inappropriate to use the CEAP loading rate for developed land because it was not a focus of the CEAP study.

The Version 4 Chesapeake Bay SPARROW model (Ator and other 2011) was run with land uses as the independent variables such that the regression coefficients are equivalent to land class loading rates. Version 4 SPARROW estimates are edge-of-stream for the management year 2002 and long-term hydrology. They include BMP effects which were removed by determining the percent difference in edge-of-stream loads for each land class between the Phase 5.3.2 Watershed Model 2002 Progress and No Action scenarios. The SPARROW coefficients were increased by this percent difference. Additionally, for SPARROW the animal feeding space load is assumed to be co-located with pasture and would increase the pasture coefficient in SPARROW. Therefore, animal feeding space loads were removed from SPARROW estimates of pasture load based on the relative loads in the Phase 5.3.2 Watershed Model calibration scenario as shown in Equation 2-2.

Equation 2-2: SPARROW Pasture/Hay Adjustment

Modified SPARROW Pasture and Hay coefficient = SPARROW Pasture and Hay coefficient * (Phase 5.3.2 Watershed Model pasture and hay loads) / (Phase 5.3.2 Watershed Model pasture, hay, and animal waste loads)

For a full description of SPARROW, see Section 7.2. The Phase 5.3.2 Watershed Model and the CEAP Chesapeake Bay Model are discussed in Section 4.

Table 2-6 summarizes the calculation of the land class average loading rates for phosphorus. The last row in the tables below was calculated by applying Equation 2-1 and then calculating the land class average loading rate as the crop average loading rate times the relative land class loading rate.

Table 2-5: Total nitrogen land class loads and average loading rates above RIM stations

Land class	Crop	Pasture/Hay	Developed	Natural
Acres in millions above the RIM stations	2.6	4.5	2.7	21.5
P532 No BMP Loading Rate (pounds per acre per year)	47.51	14.95	16.80	4.21
CEAP Loading Rate (pounds per acre per year)	42.52	10.19	Not used	1.61
SPARROW Loading Rate with BMP effects removed (pounds per acre per year)	22.35	7.30	8.35	0.40
Average Ratio to Cropland Rate	1.00	0.29	0.36	0.05
Average Land class Loading Rate (pounds per acre per year)	38.22	11.22	13.90	1.84
Total Land class Load (million pounds per year)	100.16	50.88	37.39	39.45

Table 2-6: Total phosphorus land class loads and average loading rates above RIM stations

Land class	Crop	Pasture/Hay	Developed	Natural
Acres in millions above the RIM stations	2.6	4.5	2.7	21.5
P532 Loading Rate (pounds per acre per year)	2.23	1.48	1.22	0.12

Land class	Crop	Pasture/Hay	Developed	Natural
CEAP Loading Rate (pounds per acre per year)	3.12	1.29	Not used	0.10
SPARROW Loading Rate with BMP effects removed (pounds per acre per year)	0.94	0.22	0.34	0.06
Average Ratio to Crop Rate	1.00	0.44	0.46	0.05
Average Land class Loading Rate (phosphorus pounds per acre per year)	1.87	0.81	0.85	0.09
Total Land class Load (million pounds per year)	4.89	3.69	2.38	1.98

2.2.4 Land Use Average Loading Rates

The following description applies to nitrogen land use average loading rates for all land uses and to phosphorus land use average loading rates for non-agricultural land uses. The calculation of land use average loading rates for land uses within a land class follows the same method as described in the previous section, with total land class loads playing the role of total landscape loads and the land use average loading rate playing the role of the land class average loading rates. That is, the loading rate for all land uses in a land class is determined relative to an anchor land use, then the loading rate is calculated by solving for the loading rate of a single land use in terms of the land class load (Equation 2-3).

Equation 2-3

$$D = \sum_{i=1}^{N} T * R_i * A_i$$

Where:
D = Land class total loads (pounds per year)
N = number of land uses in the land class
T = Land use average loading rate for the anchor land use in that land class (ex. ‘grain without manure’ in the crop land class) (pounds per acre per year)
R_i = land use average loading rate relative to T (unitless)
A_i = area of land use (acres)

The variable T is the only unknown in Equation 2 3, so it is easily determined, and the average loading rates and loads from other land uses are calculated. The average loading rate for each land use for total nitrogen is in Table 2-7.

Table 2-7: Total nitrogen land use acres, relative rates, and average loading rate

Land class	Land Use	Acres	Loading Rate Ratio	Loading Rate (pounds per acre per year)

Cropland	Double Cropped Land	165,396	0.79	30.87
	Full Season Soybeans	282,456	0.71	27.74
	Grain with Manure	389,811	1.4	54.7
	Grain without Manure: Reference land use	451,318	1.00	39.07
	Other Agronomic Crops	417,838	0.45	17.58
	Silage with Manure	392,156	1.62	63.30
	Silage without Manure	69,204	1.16	45.33
	Small Grains and Grains	291,677	0.84	32.82
	Specialty Crop High	35,525	1.34	52.36
	Specialty Crop Low	125,509	0.31	12.11
Developed	CSS Buildings and Other	39,580	0.81	18.08
	CSS Construction	1,516	1.19	26.80
	CSS Roads	10,849	1.02	22.87
	CSS Tree Canopy over Impervious	4,466	0.91	20.49
	CSS Tree Canopy over Turfgrass	15,934	0.38	8.53
	CSS Turf Grass	29,800	0.50	11.19
	MS4 Buildings and Other	164,843	0.81	18.08
	MS4 Construction	65,955	1.19	26.80
	MS4 Roads	59,965	1.02	22.87
	MS4 Tree Canopy over Impervious	24,896	0.91	20.49
	MS4 Tree Canopy over Turfgrass	102,715	0.38	8.53
	MS4 Turf Grass	311,048	0.50	11.19
	Non-Regulated Buildings and Other	295,033	0.81	18.08

	Non-Regulated Roads: Reference Land Use	211,292	1.02	22.45
	Non-Regulated Tree Canopy over Impervious	78,512	0.91	20.49
	Non-Regulated Tree Canopy over Turfgrass	255,214	0.38	8.53
	Non-Regulated Turf Grass	1,121,002	0.50	11.19
Natural	CSS Forest	25,062	1.00	1.68
	CSS Mixed Open	11,193	1.46	2.45
	Harvested Forest	264,474	7.07	11.88
	Headwater or Isolated Wetland	350,820	1.00	1.68
	Mixed Open	895,240	1.46	2.45
	Non-tidal Floodplain Wetland	397,778	1.00	1.68
	True Forest: Reference Land Use	19,550,675	1.00	1.68
Pasture	Ag Open Space	140,316	0.43	5.07
	Legume Hay	728,148	0.74	8.72
	Other Hay	1,294,306	1.04	12.26
	Pasture: Reference Land Use	2,372,549	1.00	11.78

The calculation for phosphorus loading rates for agricultural land uses is a bit different. A Chesapeake Bay Program group, The Agricultural Land Use Loading Rate Subgroup of the Agricultural Modeling Subcommittee, which is a part of the Agricultural Workgroup, determined that the phosphorus loading rate for cropland and pasture land uses is a function of inputs and sensitivities which are defined in Sections 3 and 4 of this documentation rather than land use (Jordan and Yagow, 2015). Therefore, the phosphorus relative loading rates for cropland and pasture land uses were not subdivided. The values for loading rate are given to the 1/10th of a pound per acre. This does not imply confidence at that level of precision. One or two significant digits would be more reflective of the level of confidence, however the significant digits through the tenth of a pound are kept to reflect the values used in the model and to maintain the ratios specified by the Subgroup. The results of the phosphorus calculation are presented in Table 2-8.

Table 2-8: Total phosphorus land use acres, relative rates, and average loading rate

Land class	Land Use	Acres	Loading Rate Ratio	Loading Rate (pounds per acre per year)
Cropland	Double Cropped Land	165,396	1*	1.87*
	Full Season Soybeans	282,456		
	Grain with Manure	389,811		
	Grain without Manure	451,318		
	Other Agronomic Crops	417,838		
	Silage with Manure	392,156		
	Silage without Manure	69,204		
	Small Grains and Grains	291,677		
	Specialty Crop High	35,525		
	Specialty Crop Low	125,509		
Developed	CSS Buildings and Other	39,580	0.83	0.69
	CSS Construction	1,516	3.89	3.21
	CSS Roads	10,849	1.04	0.86
	CSS Tree Canopy over Impervious	4,466	0.91	0.75
	CSS Tree Canopy over Turfgrass	15,934	0.79	0.65
	CSS Turf Grass	29,800	1.04	0.86
	MS4 Buildings and Other	164,843	0.83	0.69
	MS4 Construction	65,955	3.89	3.21
	MS4 Roads	59,965	1.04	0.86
	MS4 Tree Canopy over Impervious	24,896	0.91	0.75
	MS4 Tree Canopy over Turfgrass	102,715	0.79	0.65
	MS4 Turf Grass	311,048	1.04	0.86
	Non-Regulated Buildings and Other	295,033	0.83	0.69
	Non-Regulated Roads	211,292	1.04	0.83
	Non-Regulated Tree Canopy over Impervious	78,512	0.91	0.75
	Non-Regulated Tree Canopy over Turfgrass	255,214	0.79	0.65
	Non-Regulated Turf Grass	1,121,002	1.04	0.86
Natural	CSS Forest	25,062	1	0.08
	CSS Mixed Open	11,193	5.69	0.43
	Harvested Forest	264,474	3.12	0.24
	Headwater or Isolated Wetland	350,820	1	0.08
	Mixed Open	895,240	5.69	0.43
	Non-tidal Floodplain Wetland	397,778	1	0.08
	True Forest	19,550,675	1	0.08
Pasture	Ag Open Space	140,316	1*	.81*

	Legume Hay	728,148		
	Other Hay	1,294,306		
	Pasture	2,372,549		

** At the direction of the Agriculture Land Use Loading Rate Subgroup, the entire crop category was treated as a single unit. The weighted average of all crop types is 1.87 lbs/acre. They are differentiated by inputs and sensitivities as described in Sections 3 and 4. Similarly, pasture is treated as a single unit with a weighted average of 0.81 lbs/acre.*

2.2.4.1 Developing Relative Loading Rates Within Each Land Class

Source sector workgroups evaluated literature reviews and other sources of data to establish relative loading rates among the land uses in each land class. These relative rates were reviewed by the Modeling Workgroup for consistency in methods and to ensure the logic was consistent with the assumptions in the Watershed Model.

The four land classes, developed, natural, pasture, and cropland, have associated source sector workgroups of the Water Quality Goal Implementation Team. These source sector workgroups are the Urban Stormwater Workgroup, the Forestry Workgroup, and the Agriculture Workgroup. The Agricultural Modeling Subcommittee is a group that reports to the Agriculture Workgroup on technical issues and the Land Use Loading Rate Subgroup was a temporary task group reporting to the Agricultural Modeling Subcommittee specifically on loading rates.

2.2.4.1.1 Developed Land Uses

Developed land uses are split into six land use classifications: turfgrass, roads, buildings and other, construction, tree canopy over turfgrass, and tree canopy over impervious. Additionally, these seven land use classifications are subdivided by three management zones: Combined Sewer System (CSS), Municipal Separate Storm Sewer System (MS4), and non-regulated. The overlay of classifications and management zones creates 18 developed land use, but since construction is always regulated, the acres in non-regulated construction is zero. The ratio of average loading rates relative to all road land uses are in Table 2-9. Note that the coefficients for the roads land uses are not equal to 1. This is because the loads are relative to the weighted average of the road land uses which include ‘roads’ and ‘tree canopy over impervious’. This was calculated by determining the total load from CSS, MS4, and non-regulated roads and also from CSS, MS4, and non-regulated tree canopy over impervious. This combined total load was divided by the combined total acres to calculate the weighted average of the two land uses.

Table 2-9: Developed loading rates relative to roads.

Land Use	Total Nitrogen	Total Phosphorus
CSS Construction	1.19	3.89
MS4 Construction	1.19	3.89
CSS Roads	1.02	1.04
MS4 Roads	1.02	1.04
Non-Regulated Roads	1.02	1.04
CSS Tree Canopy over Impervious	0.91	0.91
MS4 Tree Canopy over Impervious	0.91	0.91
Non-Regulated Tree Canopy over Impervious	0.91	0.91
CSS Buildings and Other	0.81	0.83

Land Use	Total Nitrogen	Total Phosphorus
MS4 Buildings and Other	0.81	0.83
Non-Regulated Buildings and Other	0.81	0.83
CSS Turfgrass	0.50	1.04
MS4 Turfgrass	0.50	1.04
Non-Regulated Turfgrass	0.50	1.04
CSS Tree Canopy over Turfgrass	0.38	0.79
MS4 Tree Canopy over Turfgrass	0.38	0.79
Non-Regulated Tree Canopy over Turfgrass	0.38	0.79

2.2.4.1.1.1 Developed Impervious Roads, Developed Pervious Turfgrass, Developed Pervious Open Space, and Developed Impervious Buildings Parking Lots Etc.

Loading rate data for developed land uses were taken from the *Land Use Loading Literature Review Task Summary and Results* technical memo (Sievers, 2014). The data used from the memo originally came from the National Stormwater Quality Database (NSQD) (http://www.bmpdatabase.org/index.htm). The NSQD data is at the edge-of-field scale. Data were copied from the report and a crosswalk of the literature review land uses to Phase 6 land use was created. For example, “commercial” loading rates were considered in specifying the “developed impervious buildings, parking lots, etc.” land use. After meeting with the Urban Stormwater Workgroup (USWG) on October 21, 2014, it was determined that the data were relevant only for the four pervious and impervious land uses, not construction or tree canopy over pervious and/or impervious. The USWG indicated that the residential high density land use should be considered impervious. Recreation and golf course categories were removed since the percentage of turfgrass is unknown. It also was determined that it was unnecessary to have roads broken out by level of annual average daily traffic (AADT) and thus would remain a single land use category. All mixed land use categories were used as a secondary source of data to bolster or document differences with the other literature review loading rates.

The literature review provided concentrations rather than loading rates. The conversion factors are in Equation 2-4.

Equation 2-4

Load (lb/acre/year) = Concentration (mg/l) * Runoff (inches/year) * (1 lb/ 453590 mg) * (28.317 liters / cubic foot) * (43560 square feet / acre) * (1 foot/ 12 inches)

The literature loading rates generally are represented by the minimum, maximum, average, median, and 25th and 75th percentiles. Many of the land uses show the data to be skewed, so the median was used in the above calculation.

2.2.4.1.1.2 Construction

The Erosion and Sediment Control BMP Expert Panel final report, approved April 14, 2014, recommended a total suspended solid average load of 12 tons per acre under the assumption of a no BMP condition. The Erosion and Sediment Control BMP further reduces this load. The Panel further recommended that the total nitrogen and total phosphorus annual average loading rates for the construction land use be maintained at the Phase 5.3.2 Watershed Model levels of 26.4 and 8.81 pounds per acre, respectively. The assumption is that that erosion and sediment controls are in place, which is consistent with the Expert Panel's recommendation of zero nutrient reduction for the erosion and sediment BMP. Therefore, the nutrient reduction from erosion and sediment (E&S) control is inherent in the average loading rate for the construction land use and the E&S BMPs are estimated to only reduce total suspended solids. The decisions were made at the December 16, 2014 USWG meeting, where it was determined that the barren land use data from the literature review should be excluded because it is unrepresentative of any Phase 6 land use. It was also decided that E&S management practices tend to only increase the nutrient loads on construction land uses since fertilization is not simulated.

2.2.4.1.1.3 Tree Canopy Over Turfgrass and Tree Canopy Over Impervious

The land use and associated loading rate were determined through the Forestry Workgroup and Tree Canopy Expert Panel. The recommended load for tree canopy loading rates was reviewed through multiple workgroups of the Water Quality Goal Implementation Team, and finally through the Water Quality Goal Implementation Team. The tree canopy over turfgrass loading rate is a 23.8 percent nitrogen and phosphorus reduction from turfgrass. The tree canopy over impervious is an 8.5 percent nitrogen reduction and 11 percent phosphorus reduction from the roads and buildings and other land uses. The loading rate for the land uses that tree canopy shades—turfgrass, roads, and buildings and other—were established using data from the National Stormwater Quality Database (NSQD). These data do not separate land areas covered in tree canopy. To accurately add tree canopy land uses, the effect of tree canopy is removed from the parent land uses of turfgrass, roads, and buildings and other, resulting in an increased loading rate for those three land uses.

This increase of the turfgrass parent land uses maintains the relationship of the reduction rate from the land use that is modified by the tree canopy land use. The tree canopy over impervious land use is determined as 90 percent from roads and 10 percent from buildings and other. The calculation for nitrogen is described in Equation 2-5.

Equation 2-5

$$\frac{\big((RL * \%\,R + BL * \%\,B) * .085 * CiA\big) + (TL * 0.238 * ChA)}{\big(RA + BA + TA - \big((0.238 * ChA) + (0.085 * CiA)\big)\big)}$$

Where:
L = Loading rate
R = Roads
B = Building and other
Ci = Tree canopy over impervious
T = Turf
Ch =Tree canopy over turf
A = acres

The same calculation is performed for phosphorus using the phosphorus reduction of 11 percent for impervious.

2.2.4.1.2 Natural Land Uses

The loading rates for natural land uses were developed in four tracts: 1) true forest and harvested forest, 2) tree canopy, 3) mixed open, and 4) wetland. Each are discussed below.

Table 2-10: Natural loading rates relative to true forest

Land Use	Total Nitrogen	Total Phosphorus
Harvested Forest	7.07	3.12
CSS Mixed Open	1.46	5.69
Mixed Open	1.46	5.69
CSS Forest	1	1
True Forest	1	1
Non-tidal Floodplain Wetland	1	1
Headwater or Isolated Wetland	1	1

2.2.4.1.2.1 True Forest and Harvested Forest

The Forestry Workgroup used the *Agricultural and Forest Land Use Loading Rate Literature Review—Summary and Results* (January 13, 2015) in addition to additional data to determine the land use loading rates for true forest and harvested forest. This effort was led by members of the Forestry Workgroup, with the analysis conducted by Justin Hynicka of Maryland Department of Natural Resources. Median loading rates for NO_3, NH_4, DON, TKN or Particulate N and PO_4 were determined from multiple sources. Factors considered for including literature are: forest type, sample frequency, and study period. Those studies that were of forest buffers, rather than a forested area were removed from consideration.

One of the questions that arose in examining these data were why the load to forest decreased since 1995 (Figure 2-3). Work by Eshleman et al. (2013) indicates that the declining atmospheric nitrogen deposition has reduced loads. This informed which study period years to use.

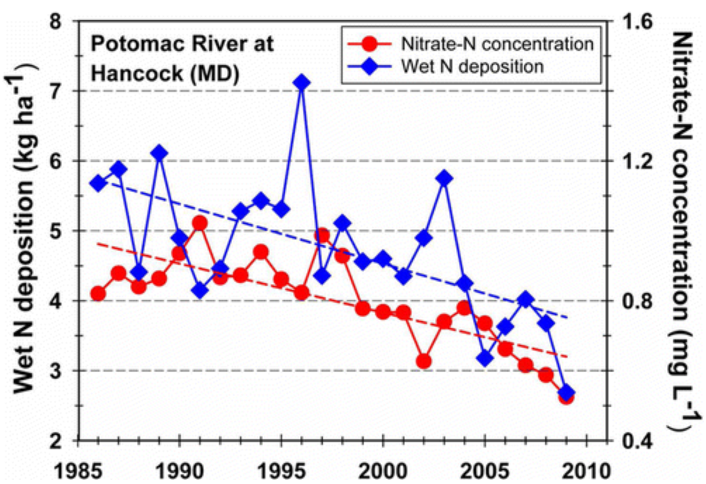


Figure 2-3: Atmospheric deposition and NO_3 concentrations on forest land. From Eshleman and Sabo 2013

The mean ratio of harvest to true forest was calculated. For harvested forest lands, the nutrient loading factors represent the average increases for three years after harvest.

2.2.4.1.2.2 Mixed Open

The open space loading rate was established using data from the urban literature review, discussed in Section 2.2.4.1.1.1.

2.2.4.1.2.3 Non-tidal Floodplain and Headwater or Isolated Wetland

The loading rate for this land use was determined by the Wetland Expert Panel. The Wetland Expert Panel determined that the loading rate was equivalent to true forest. The land use was kept distinct in order to have the capacity to determine the change in wetland acres from BMP reporting and tracking.

2.2.4.1.3 Agricultural Land Uses

Agricultural land use loading rate data were collected as part of three consecutive literature reviews. The first literature review used data from local TMDLs and peer-reviewed published journal articles Tetra Tech 2015). Additional "grey literature" was also researched by Szydlowski (2015). The grey literature was determined to be important because negative results are generally considered to be systematically censored in peer-reviewed publications, however, the negative results provide important information. A third group was established under Virginia Tech. This group is the Agricultural Land Use Loading Rate Subgroup of the Agricultural Modeling Subcommittee of the Agricultural Workgroup. While discussions of this third literature review are not public, a report has been issued which is attached to this documentation as Appendix 2A: Relative Agricultural Land Use Loading Ratios for Calibration of the Phase 6 Chesapeake Bay Watershed Model. The report was approved by the Agriculture Workgroup on January 21, 2016. The relative loading rates for nitrogen determined by the third group are in Table 2-11. The group determined that the relative phosphorus loading rates for cropland and pasture land uses is determined primarily by the factors represented in the sensitivity calculations of Section 4. The differences in land use loading rates between different types of cropland and different types of pasture are determined by soil phosphorus concentrations, stormflow (defined as the sum of HSPF simulated surface outflow and interflow outflow), and sediment washoff rather than being an inherent property of the land use (Jordan and Yagow 2015).

Table 2-11: Cropland and pasture loading rates. Cropland is relative to grain without manure and the pasture group is relative to the pasture land use.

Land class	Land Use	Total Nitrogen	# of observations	Standard Error
cropland	Silage with Manure	1.62	1	NA
cropland	Grain with Manure	1.4	12	0.2
cropland	Specialty Crop High	1.34	1	NA
cropland	Silage without Manure	1.16	NA	NA
cropland	Grain without Manure	1	Reference	Reference
cropland	Small Grains and Grains	0.84	NA	NA
cropland	Double Cropped Land	0.79	2	0.09
cropland	Full Season Soybeans	0.71	6	0.11
cropland	Other Agronomic Crops	0.45	1	NA
cropland	Specialty Crop Low	0.31	NA	NA
pasture	Other Hay	1.04	4	0.24
pasture	Pasture	1	10	0.20
pasture	Legume Hay	0.74	4	0.08
pasture	Ag Open Space	0.43	2	0.04

The loading rates for all land uses, considering the delta inputs and sensitivity, are available in Appendix 10B: Land Use Loading Rates.

2.3 Sediment Edge-of-Field Loads

Figure 2-4 shows the overall calculation of sediment in the Phase 6 Model. The sediment load calculation has two important differences from the nutrient calculation. First, the nutrient loads described in this section represent watershed-wide averages which are subsequently modified by local inputs through sensitivities as depicted in Figure 2-1. In contrast, the spatial variability in sediment loads due to field-scale parameters is included in the estimation of edge-of-field sediment loads. The second major difference is that nutrients are estimated at the edge-of-stream scale while sediment is estimated at the edge-of-field scale. Edge-of-field load estimation methods are available for sediment whereas nutrient load information used in the calculation of Phase 6 loads are at the edge-of-stream scale. The land-to-water factors developed in Section 7 have no aggregate effect for nutrients, but they serve to reduce the edge-of-field sediment load to an edge-of-stream load for sediment.

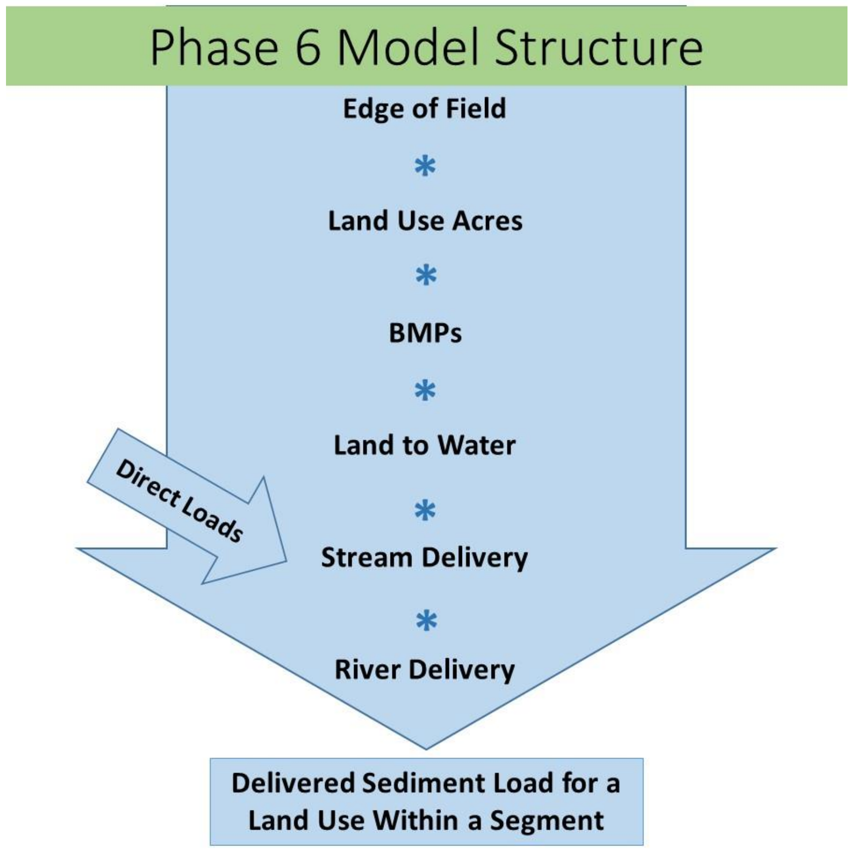


Figure 2-4: Phase 6 Model structure for sediment

2.3.1 RUSLE

Sediment edge-of-field loads are determined based on the Revised Universal Soil Loss Equation (RUSLE) equation (NRCS 2007). The RUSLE equation (A = R * K * LS * C * P) provides an estimate of net erosion rate at the edge of field (EOF) in units of tons per acre per year. The R factor (hundreds of foot-ton-inches per acre per hour) is the rainfall erosivity factor; the K factor (ton-acre-hours per hundred foot-tons per inch) is the soil erodibility factor; the LS factor (dimensionless) is a topographic factor that takes into account slope length and steepness; the C factor (dimensionless) is a crop/vegetation management factor; and the P factor (dimensionless) represents the support practice factor. The P factor is represented by BMPs as described in Section 6. Therefore a value of P is used in the calculation for the P factor to represent the state of no BMPs. The following steps are performed:

1. The R, K, and LS factors are determined at a 10-meter scale. R factors are monthly while the K and LS factors are constant through time
2. The R, K, and LS factors are aggregated to major land use class and land-river segment
3. A monthly C factor is generated for each land use and land-river segment. The land uses in this step are the Phase 6 land uses rather than the aggregated classes from step 2.
4. Monthly sediment washoff is calculated as R * K * LS * C and then aggregated to a long-term average by land use and land-river segment.

Seven pervious land uses were considered as potential sources for erosion: turf grass, tree canopy over turf grass, tree canopy over shrubs, open space, pasture, forest, and cropland. Land uses not considered to be sources include water and wetlands.

2.3.1.1 R, K, and LS Factors

The R, K, and LS factors were determined through separate 10-meter raster analyses

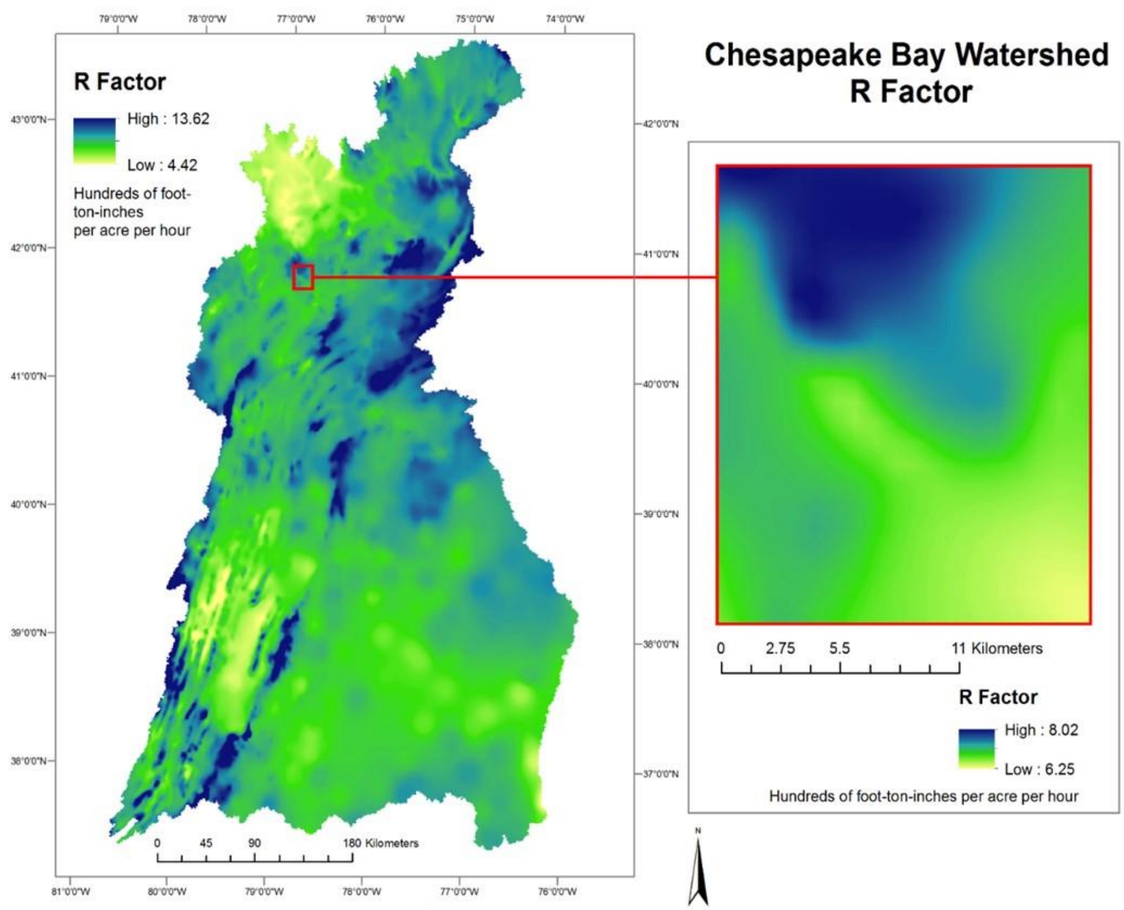


Figure 2-5: Chesapeake Bay watershed R factor

The R factor was calculated for each month using Equation 2-6.

Equation 2-6: monthly R factor

$$R = 1.24P^{1.36}$$

Where P = precipitation in inches. Monthly 30-year normal precipitation data were downloaded from the PRISM Climate Group (800m^2 resolution resampled to 10m^2) and used in the calculation.

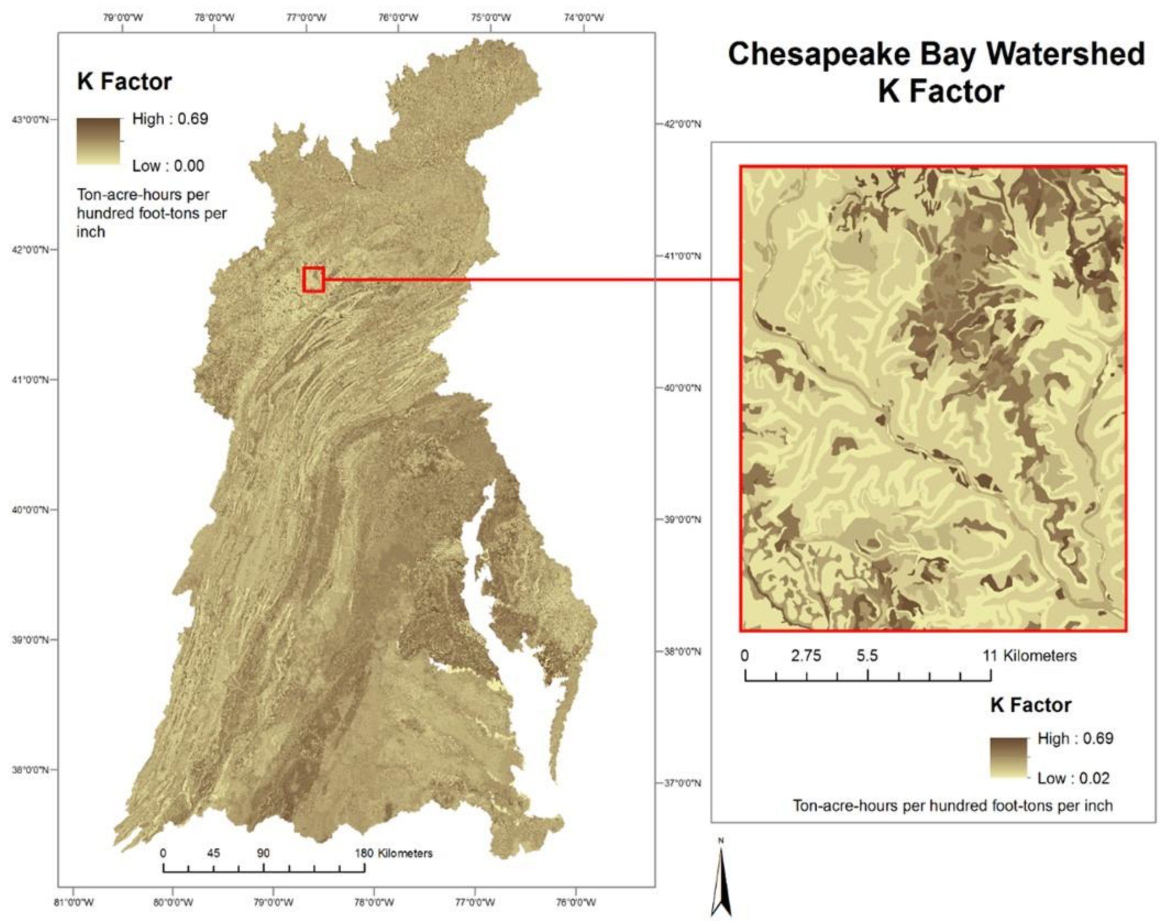


Figure 2-6: Chesapeake Bay watershed K factor

The K factors were derived from the STATSGO and gSSURGO soil datasets. The STATSGO K factors were only used in areas where higher detail gSSURGO K factors were unavailable. The gSSURGO K factors were normalized by mean STATSGO values to reduce stark contrasts in values across county boundaries yet within the same general soil group.

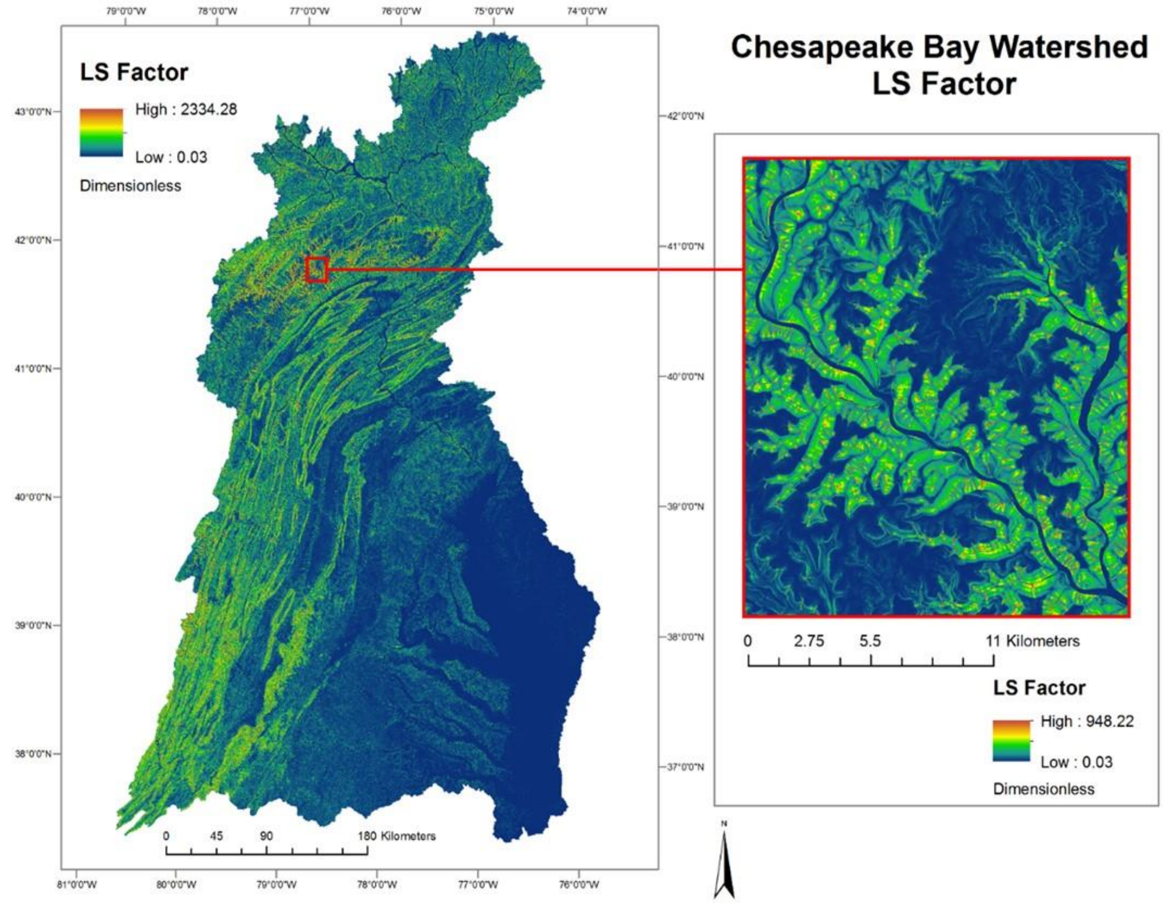


Figure 2-7: Chesapeake Bay watershed LS Factor

The LS factor was calculated by creating flow accumulation and slope rasters from a 10m^2 DEM. The rasters were then used in Equation 2-7 to generate an LS raster:

Equation 2-7: LS raster

$$LS = (\text{Flow Accumulation} \times \text{Cell Resolution} / 22.1)^{0.4} \times (\text{Sin}(\text{Slope} \times 0.01745) / 0.09)^{1.4} \times 1.4$$

Where Cell Resolution is in meters and Slope is in degrees.

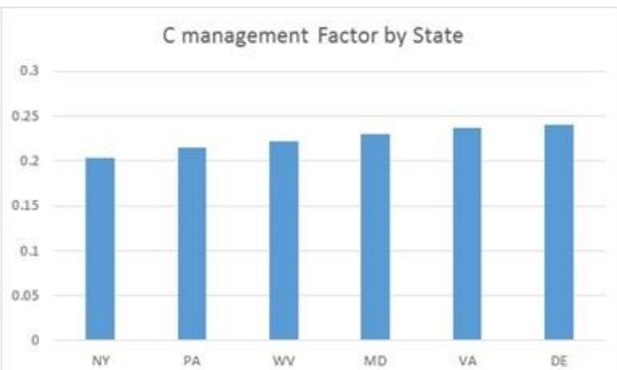
The R, K, and LS factors are physical properties of the landscape. The product of these factors gives a value in tons per acre per year and is defined for the purposes of this discussion as the background erosion rate. Even though the background erosion rate is not a property of the land use, significant spatial correlations exist. Natural areas tend to have the highest values of background erosion since the same factors related to high slope could also make these areas unsuitable for other uses. Note that this does not mean that natural areas have the highest actual erosion rates once cover is included in the calculation. Table 2-12 below shows the average value of R*K*LS, weighted by acres, for the entire Chesapeake Bay watershed. In the Chesapeake watershed, crop tends to be placed on land with the lowest background rate followed by developed areas, pasture, and then natural. Natural land uses have a background erosion rate nearly twice that of the next highest category and over three times that of crop.

*Table 2-12: Average value of R*K*LS by land use*

Major Land Use	R*K*LS (tons/acre/year)
Crop	18
Turfgrass	23
Tree Canopy over Turfgrass	29
Pasture	31
Mixed Open	31
Natural	61

2.3.1.2 C Management Factors

C management factors are a major determinant of differences between land uses. Monthly C factors for crop and pasture land cover were provided through a run of RUSLE2 as described in Section 3 of the Phase 6 Watershed Model documentation (Lightle 2017). These were generated based on crop type, start/end date of planting/grazing, planting technique, and harvesting/grazing technique. The C management factors for non-agricultural lands were taken from Panagos (2015). The C management factor varies considerably by crop type and land use. For agricultural land, C management also varies by region. Figure 2-8 and Table 2-13 give representations of the C management factors.



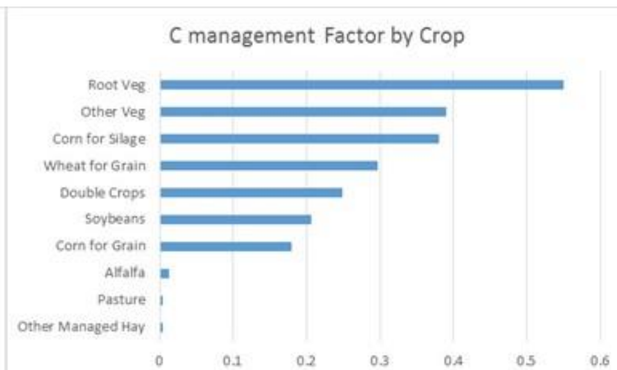


Figure 2-8: C management factor by state and crop

Table 2-13: Non-agricultural C management factors

Land Class	C Literature Range	Phase 6 C Value	Notes
Natural	0.0001 – 0.003	0.001	Middle of the range
Turf Grass	0.01 – 0.08	0.05	High end of natural grasslands
Mixed Open	0.01 – 0.08	0.06	Higher than turf as it includes disturbed areas
Tree Canopy over Turfgrass	0.0003 – 0.05	0.03	Turf grass with additional cover

2.3.1.3 Processing of the Sediment Loads

The R, K, and LS factors were multiplied to create one rate raster per month per land use. The R*K*LS raster was averaged by month, land-river segment, and land class. C management factors were available by crop, county, month, and year. C factors were averaged by land use, land segment, month, and year, and then multiplied by the appropriate R*K*LS for the appropriate month, land-river segment, and land class to arrive at a monthly EOF sediment rate by land use, month, and year, which were then summarized into average annual loads by land-river segment and land use.

The dependence of C management factors on crop type means that the average C management factor for a land use and land segment will change over scenarios. Due to the linear nature of the RUSLE equation, sediment loads vary by scenario based on the ratio of the C management factor for a scenario to the C management factor for the average of the calibration years. A calculation is made for each scenario to modify the RUSLE edge-of-field rate by this ratio.

RUSLE calculations are available by major land class and land-river segment. However, the land sediment simulation is on the land use and land segment basis. Annual average loads were aggregated to the land segment and major land use scale using the area-weighted average. The land-river segment information was preserved by reintroducing the variability through the sediment delivery ratios, as described in Section 7. Assignment from land class is described in Section 2.3.2.

Several land segments had values for developed and natural categories, but no values for crop or pasture. Crop and pasture were given a loading based on the local load variability for forest and the watershed-wide value for agricultural land. The ratio of the local forest land to the watershed-wide area-weighted average of forest was multiplied by the watershed-wide area-weighted averages for the crop and pasture to arrive at a local value.

2.3.2 Assignment to all Land Uses

The RUSLE work described in the previous section covers all agricultural land uses and major land classes for non-agricultural land uses. Table 2-14 describes how RUSLE outputs for major land classes were translated to the detailed Phase 6 land uses for non-agricultural land uses.

Table 2-14: Translation from land classes to Phase 6 land uses

Land class	Land Class	Phase 6 Land Use	Factor
Natural	Forest	True Forest	1.0
Natural	Forest	True Forest in Combined Sewer area	1.0
Natural	Forest	Harvested Forest	10.0
Natural	Forest	Headwater or Isolated Wetland	1.0
Natural	Forest	Non-tidal Floodplain Wetland	1.0
Natural	Mixed Open	Mixed Open	1.0
Natural	Mixed Open	Mixed Open in Combined Sewer area	1.0
Developed	TC Turfgrass	Non-Regulated Tree Canopy over Turfgrass	1.0
Developed	TC Turfgrass	Non-Regulated Tree Canopy over Impervious	3.0
Developed	Turfgrass	Non-Regulated Roads	3.0
Developed	Turfgrass	Non-Regulated Buildings and Other	3.0
Developed	Turfgrass	Non-Regulated Turf Grass	1.0
Developed	TC Turfgrass	MS4 Tree Canopy over Turfgrass	1.0
Developed	TC Turfgrass	MS4 Tree Canopy over Impervious	3.0

Land class	Land Class	Phase 6 Land Use	Factor
Developed	Turfgrass	MS4 Construction	12 tons/ac
Developed	Turfgrass	MS4 Roads	3.0
Developed	Turfgrass	MS4 Buildings and Other	3.0
Developed	Turfgrass	MS4 Turf Grass	1.0
Developed	TC Turfgrass	Combined Sewer Tree Canopy over Turfgrass	1.0
Developed	TC Turfgrass	Combined Sewer Tree Canopy over Impervious	3.0
Developed	Turfgrass	Combined Sewer Construction	12 tons/ac
Developed	Turfgrass	Combined Sewer Roads	3.0
Developed	Turfgrass	Combined Sewer Buildings and Other	3.0
Developed	Turfgrass	Combined Sewer Turf Grass	1.0

2.3.3 Description of Coefficients in Translation Table (Table 2-14)

Construction is set at 12 tons/acre/year as a watershed-wide average by the Sediment and Erosion Control BMP Panel (Clark and others 2014), which was approved by the WQGIT on 4/14/14. The spatial pattern of the land segment loads is based on the turf grass loads.

The WQGIT approved the inclusion of wetlands with a forest loading rate on 9/14/2015.

Manured land in generally lower in sediment runoff in the literature. Wortmann et al. 2005, Little et al. 2005, Mishra et al. 2006, Ramos et al. 2005, Verbree et al. 2010, and Mueller et al. 1984 show approximately a 10 percent reduction from manured areas. Lightle (2017) included local application trends in the C management factor work so this effect is included in the loads.

The RUSLE work described above does not provide an estimate of impervious loads. A relationship between pervious and impervious loads was determined based on the difference in concentration and flow from these two general land use types. On page 3 of their October 2015 technical memorandum (CWP 2015), the Center for Watershed Protection summarizes statistically significant differences in outfall event mean concentrations for four different land use types in the National Stormwater Quality Database. These concentrations were exclusively from outfalls, so they are representative of the land use loads only, not the stream contribution as a result of imperviousness. Phase 5.3.2 provides an estimate (USEPA 2010a-08) that the overall annual average stormflow from impervious land is 89 percent higher than the stormflow from pervious developed land and an estimate of the impervious fractions of the four land uses (USEPA 2010a-09). Multiplying the event mean concentrations by the relative flow gives a relative loading rate for each land use. The calculations are detailed in Table 2-15.

Table 2-15: Calculation of relative pervious and impervious sediment loading rates

Land use type	Percent Impervious	EMC (g/l)	Flow Relative to Pervious	Relative Load
Open Space	5%	0.09939	1.04	0.104

Land use type	Percent Impervious	EMC (g/l)	Flow Relative to Pervious	Relative Load
Residential	25%	0.12348	1.22	0.151
Commercial	80%	0.11297	1.71	0.194
Industrial	90%	0.16784	1.80	0.303

The above data are plotted in Figure 2-9. Using the equation of the line, it can be estimated that impervious lands load sediment to outfalls in developed areas at a rate 2.92 as high as pervious lands. Note that this does not include the downstream effect on stream sources of sediment, which will be considered as a separate effect of imperviousness in Section 9: stream to river.

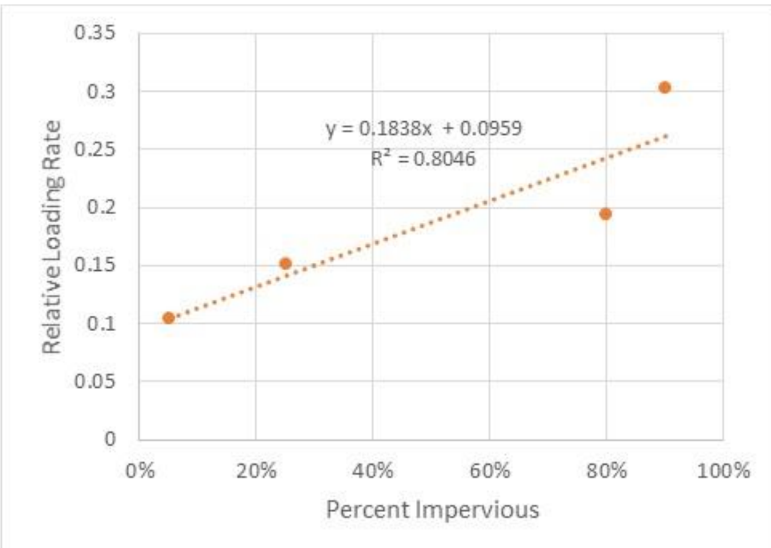


Figure 2-9: Relationship between relative loading rate and percent impervious

2.3.4 Results

Applying the methods above results in sediment loads in Table 2-16. The ratios listed in Table 2-14 are applied at the land-river segment scale. Aggregating land uses spatially results in an average load ratio among land uses that varies from the ratio in Table 2-14.

Table 2-16: Average sediment load by Phase 6 land use

Land Class	Phase 6 Land use	Average Load (tons/acre)
cropland	Double Cropped Land	2.21
cropland	Full Season Soybeans	2.98
cropland	Grain with Manure	3.07
cropland	Grain without Manure	3.38
cropland	Other Agronomic Crops	0.44
cropland	Silage with Manure	8.19
cropland	Silage without Manure	8.19
cropland	Small Grains and Grains	5.38

cropland	Specialty Crop High	7.59
cropland	Specialty Crop Low	8.52
developed	CSS Buildings and Other	1.11
developed	CSS Construction	13.48
developed	CSS Roads	1.08
developed	CSS Tree Canopy over Impervious	1.21
developed	CSS Tree Canopy over Turfgrass	0.09
developed	CSS Turf Grass	0.40
developed	MS4 Buildings and Other	1.04
developed	MS4 Construction	15.61
developed	MS4 Roads	0.94
developed	MS4 Tree Canopy over Impervious	0.90
developed	MS4 Tree Canopy over Turfgrass	0.08
developed	MS4 Turf Grass	0.38
developed	Non-Regulated Buildings and Other	1.38
developed	Non-Regulated Roads	1.49
developed	Non-Regulated Tree Canopy over Impervious	0.30
developed	Non-Regulated Tree Canopy over Turfgrass	0.10
developed	Non-Regulated Turf Grass	0.47
natural	CSS Forest	0.06
natural	CSS Mixed Open	2.35
natural	Harvested Forest	0.60
natural	Headwater or Isolated Wetland	0.04
natural	Mixed Open	2.36
natural	Non-tidal Floodplain Wetland	0.04
natural	True Forest	0.07
pasture	Non-Permitted Feeding Space	2.28
pasture	Permitted Feeding Space	1.47
pasture	Ag Open Space	0.08
pasture	Legume Hay	0.29
pasture	Other Hay	0.09
pasture	Pasture	0.08