Attachment D2: Attachment B - Developed Land Loading Rates for PA Counties

ATTACHMENT B

DEVELOPED LAND LOADING RATES FOR PA COUNTIES[1,2,3]

County	Category	Acres	TN lbs/acre/yr	TP lbs/acre/yr	TSS (Sediment) lbs/acre/yr
Adams	impervious developed	10,373.2	33.43	2.1	1,398.77
	pervious developed	44,028.6	22.99	0.8	207.67
Bedford	impervious developed	9,815.2	19.42	1.9	2,034.34
	pervious developed	19,425	17.97	0.68	301.22
Berks	impervious developed	1,292.4	36.81	2.26	1,925.79
	pervious developed	5,178.8	34.02	0.98	264.29
Blair	impervious developed	3,587.9	20.88	1.73	1,813.55
	pervious developed	9,177.5	18.9	0.62	267.34
Bradford	impervious developed	10,423	14.82	2.37	1,880.87
	pervious developed	23,709.7	13.05	0.85	272.25
Cambria	impervious developed	3,237.9	20.91	2.9	2,155.29
	pervious developed	8,455.4	19.86	1.12	325.3
Cameron	impervious developed	1,743.2	18.46	2.98	2,574.49
	pervious developed	1,334.5	19.41	1.21	379.36
Carbon	impervious developed	25.1	28.61	3.97	2,177.04
	pervious developed	54.2	30.37	2.04	323.36
Centre	impervious developed	7,828.2	19.21	2.32	1,771.63
	pervious developed	15,037.1	18.52	0.61	215.84
Chester	impervious developed	1,838.4	21.15	1.46	1,504.78
	pervious developed	10,439.8	14.09	0.36	185.12
Clearfield	impervious developed	9,638.5	17.54	2.78	1,902.9
	pervious developed	17,444.3	18.89	1.05	266.62
Clinton	impervious developed	7,238.5	18.02	2.80	1,856.91
	pervious developed	11,153.8	16.88	0.92	275.81
Columbia	impervious developed	7,343.1	21.21	3.08	1,929.18
	pervious developed	21,848.2	22.15	1.22	280.39
Cumberland	impervious developed	8,774.8	28.93	1.11	2,065.1
	pervious developed	26,908.6	23.29	0.34	306.95
Dauphin	impervious developed	3,482.4	28.59	1.07	1,999.14
	pervious developed	9,405.8	21.24	0.34	299.62
Elks	impervious developed	1,317.7	18.91	2.91	1,556.93
	pervious developed	1,250.1	19.32	1.19	239.85
Franklin	impervious developed	13,832.3	31.6	2.72	1,944.85
	pervious developed	49,908.6	24.37	0.76	308.31
Fulton	impervious developed	3,712.9	22.28	2.41	1,586.75
	pervious developed	4,462.3	18.75	0.91	236.54
Huntington	impervious developed	7,321.9	18.58	1.63	1,647.53
	pervious developed	11,375.4	17.8	0.61	260.15
Indiana	impervious developed	589	19.29	2.79	1,621.25
	pervious developed	972	20.1	1.16	220.68
Jefferson	impervious developed	21.4	18.07	2.76	1,369.63
	pervious developed	20.4	19.96	1.24	198.60
Juniata	impervious developed	3,770.2	22.58	1.69	1,903.96
	pervious developed	8,928.3	17.84	0.55	260.68
Lackawana	impervious developed	2,969.7	19.89	2.84	1,305.05
	pervious developed	7,783.9	17.51	0.76	132.98
Lancaster	impervious developed	4,918.7	38.53	1.55	1,480.43
	pervious developed	21,649.7	22.24	0.36	190.93
Lebanon	impervious developed	1,192.1	40.58	1.85	1,948.53
	pervious developed	5,150	27.11	0.4	269.81
Luzerne	impervious developed	5,857	20.43	3	1,648.22
	pervious developed	13,482.9	19.46	0.98	221.19
Lycoming	impervious developed	10,031.7	16.48	2.57	1,989.64
	pervious developed	19,995.5	16	0.84	277.38

County	Category	Acres	TN lbs/acre/yr	TP lbs/acre/yr	TSS (Sediment) lbs/acre/yr
McKean	impervious developed	38.7	20.93	3.21	1,843.27
	pervious developed	5.3	22.58	1.45	249.26
Mifflin	impervious developed	5,560.2	21.83	1.79	1,979.13
	pervious developed	16,405.5	21.13	0.71	296.07
Montour	impervious developed	5,560.2	21.83	1.79	1,979.13
	pervious developed	16,405.5	21.13	0.71	296.07
Northumberland	impervious developed	8,687.3	25.73	1.54	2,197.08
	pervious developed	25,168.3	24.63	0.54	367.84
Perry	impervious developed	5,041.1	26.77	1.32	2,314.7
	pervious developed	9,977	23.94	0.51	343.16
Potter	impervious developed	2,936.3	16.95	2.75	1,728.34
	pervious developed	2,699.3	17.11	1.09	265.2
Schuylkill	impervious developed	5,638.7	30.49	1.56	1,921.08
	pervious developed	14,797.2	29.41	0.57	264.04
Snyder	impervious developed	4,934.2	28.6	1.11	2,068.16
	pervious developed	14,718.1	24.35	0.4	301.5
Somerset	impervious developed	1,013.6	25.13	2.79	1,845.7
	pervious developed	851.2	25.71	1.14	293.42
Sullivan	impervious developed	3,031.7	19.08	2.85	2,013.9
	pervious developed	3,943.4	21.55	1.31	301.58
Susquehanna	impervious developed	7,042.1	19.29	2.86	1,405.73
	pervious developed	14,749.7	20.77	1.21	203.85
Tioga	impervious developed	7,966.9	12.37	2.09	1,767.75
	pervious developed	18,090.3	12.22	0.76	261.94
Union	impervious developed	4,382.6	22.98	2.04	2,393.55
	pervious developed	14,065.3	20.88	0.69	343.81
Wayne	impervious developed	320.5	18.69	2.89	1,002.58
	pervious developed	509	21.14	1.31	158.48
Wyoming	impervious developed	3,634.4	16.03	2.53	2,022.32
	pervious developed	10,792.9	13.75	0.7	238.26
York	impervious developed	10,330.7	29.69	1.18	1,614.15
	pervious developed	40,374.8	18.73	0.29	220.4
All Other Counties	impervious developed	-	23.06	2.28	1,839
	pervious developed	-	20.72	0.84	264.96

Notes:

1 These land loading rate values may be used to derive existing pollutant loading estimates under DEP's simplified method for PRP development. MS4s may choose to develop estimates using other scientifically sound methods.

2 Acres and land loading rate values for named counties in the Chesapeake Bay watershed are derived from CAST. (The column for Acres represents acres within the Chesapeake Bay watershed). For MS4s located outside of the Chesapeake Bay watershed, the land loading rates for "All Other Counties" may be used to develop PRPs under Appendix E; these values are average values across the Chesapeake Bay watershed.

3 For land area outside of the urbanized area, undeveloped land loading rates may be used where appropriate. When using the simplified method, DEP recommends the following loading rates (for any county) for undeveloped land:

- TN – 10 lbs/acre/yr
- TP – 0.33 lbs/acre/yr
- TSS (Sediment) – 234.6 lbs/acre/yr

These values were derived by using the existing loads for each pollutant, according to the 2014 Chesapeake Bay Progress Run, and dividing by the number of acres for the unregulated stormwater subsector.

Attachment D3: Pollutant Load Calculations

Table 1: Land Use					
Land Use	**% Impervious**	**Acres**	**Coverage (%)**	**Developed Impervious (Acres)**	**Developed Pervious (Acres)**
Highspire Borough	49%	469.10	0.0	229.86	239.24
Total		**469.10**	**0.0**	**229.86**	**239.24**

Table 2: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Dauphin County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	229.86	1,999.14	459,520
Developed Pervious	239.24	299.62	71,681
Total	**469.10**		**531,202**

Table 3: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Dauphin County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	229.86	1.07	246
Developed Pervious	239.24	0.34	81
Total	**469.10**		**327**

Table 4: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Dauphin County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	229.86	28.59	6,572
Developed Pervious	239.24	21.24	5,081
Total	**469.10**		**11,653**

Railroad and Right-of-Way (R-O-W) Load Reductions				
	Acres	**% Impervious**	**Impervious Acres**	**Pervious Acres**
R-O-W	38.00	49%	18.62	19.38
		Total	**18.62**	**19.38**

Right-of-Way (R-O-W) Loading: Sediment Loading			
Land Use	**Acres**	**Loading Rate - Dauphin County (lbs per acre per year)**	**Sediment Loading (lbs/year)**
Developed Impervious	18.62	1,999.14	37,224
Developed Pervious	19.38	299.62	5,807
Total	**38.00**		**43,031**

Right-of-Way (R-O-W) Loading: Phosphorus Loading			
Land Use	**Acres**	**Loading Rate - Dauphin County (lbs per acre per year)**	**Phosphorus Loading (lbs/year)**
Developed Impervious	18.62	1.07	20
Developed Pervious	19.38	0.34	7
Total	**38.00**		**27**

Right-of-Way (R-O-W) Loading: Nitrogen Loading			
Land Use	**Acres**	**Loading Rate - Dauphin County (lbs per acre per year)**	**Nitrogen Loading (lbs/year)**
Developed Impervious	18.62	28.59	532
Developed Pervious	19.38	21.24	412
Total	**38.00**		**944**

Final Baseline Pollutant Loads (lbs/year)				
Pollutant	**Pollutant Load from Outfall**	**BMP Reductions**	**Right-of-Way (R-O-W) Reductions**	**Final Pollutant Loading**
Sediment Load	531,202	0	43,031	**488,171**
Phosphorus Load	327	0	27	**301**
Nitrogen Load	11,653	0	944	**10,709**

Section E

SECTION E - SELECT BMPs TO ACHIEVE THE MINIMUM REQUIRED REDUCTIONS IN POLLUTANT LOADING

Highspire Borough has identified the minimum required reductions in pollutant loading as follows:

Watershed	Required 10% Sediment Reduction (lbs/year)	Required 5% Phosphorus Reduction (lbs/year)	Required 3% Nitrogen Reduction (lbs/year)
Chesapeake Bay Watershed	48,817	15	321

These required reductions may be achieved by implementing a 1,090 LF urban stream restoration project on a section of Burd Run (Reach Code 02050305003283), a small stream that flows south through Highspire Borough into the Susquehanna River.

Burd Run flows south and parallel to Lumber Street until it reaches Penn Street where it takes a sharp turn toward the east. The stream crosses beneath Lumber Street and flows east through Memorial Park for approximately 1,100 LF until it takes another sharp turn the south. To achieve the required sediment reductions, the Borough has selected to restore/stabilize approximately 1,090 LF of the streambank located within Memorial Park. Stream restoration improves water quality by minimizing the amount of sediment and attached nutrients delivered downstream by unstable and actively eroding streambanks. The proposed reductions are calculated based on the effectiveness values identified in the PA DEP BMP Effectiveness Table as follows:

Sediment: 44.88 lbs/ft/yr
Phosphorus: 0.068 lbs/ft/yr
Nitrogen: 0.075 lbs/ft/yr

Proposed BMP	Watershed	Calculated Sediment Reduction (lbs/yr)	Calculated Phosphorus Reduction (lbs/yr)	Presumptive Nitrogen Reduction (lbs/yr)
1,090 LF Urban Stream Restoration - Burd Run	Chesapeake Bay	48,919	74	321*
* Highspire Borough is using the presumptive approach to estimate the nitrogen reductions as allowed by PA DEP.				

This project exceeds the minimum required sediment reduction by 102 lbs/year and achieves the required pollutant reductions set forth by Appendix D of the PA DEP MS4 General Permit.

Attachments
E1: PA DEP BMP Effectiveness Values
E2: Expert Panel - Stream Restoration
E3: Urban Stream Restoration Fact Sheet

Attachment E1: PA DEP BMP Effectiveness Values

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF CLEAN WATER

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES) STORMWATER DISCHARGES FROM SMALL MUNICIPAL SEPARATE STORM SEWER SYSTEMS BMP EFFECTIVENESS VALUES

This table of BMP effectiveness values (i.e., pollutant removal efficiencies) is intended for use by MS4s that are developing and implementing Pollutant Reduction Plans and TMDL Plans to comply with NPDES permit requirements. The values used in this table generally consider pollutant reductions from both overland flow and reduced downstream erosion, and are based primarily on average values within the Chesapeake Assessment Scenario Tool (CAST) (www.casttool.org). Design considerations, operation and maintenance, and construction sequences should be as outlined in the Pennsylvania Stormwater BMP Manual, Chesapeake Bay Program guidance, or other technical sources. The Department of Environmental Protection (DEP) will update the information contained in this table as new information becomes available. Interested parties may submit information to DEP for consideration in updating this table to DEP's MS4 resource account, RA-EPPAMS4@pa.gov. Where an MS4 proposes a BMP not identified in this document or in Chesapeake Bay Program expert panel reports, other technical resources may be consulted for BMP effectiveness values. Note – TN = Total Nitrogen and TP = Total Phosphorus.

BMP Name	BMP Effectiveness Values			BMP Description
	TN	TP	Sediment	
Wet Ponds and Wetlands	20%	45%	60%	A water impoundment structure that intercepts stormwater runoff then releases it to an open water system at a specified flow rate. These structures retain a permanent pool and usually have retention times sufficient to allow settlement of some portion of the intercepted sediments and attached nutrients/toxics. Until recently, these practices were designed specifically to meet water quantity, not water quality objectives. There is little or no vegetation living within the pooled area nor are outfalls directed through vegetated areas prior to open water release. Nitrogen reduction is minimal.
Dry Detention Basins and Hydrodynamic Structures	5%	10%	10%	Dry Detention Ponds are depressions or basins created by excavation or berm construction that temporarily store runoff and release it slowly via surface flow or groundwater infiltration following storms. Hydrodynamic Structures are devices designed to improve quality of stormwater using features such as swirl concentrators, grit chambers, oil barriers, baffles, micropools, and absorbent pads that are designed to remove sediments, nutrients, metals, organic chemicals, or oil and grease from urban runoff.
Dry Extended Detention Basins	20%	20%	60%	Dry extended detention (ED) basins are depressions created by excavation or berm construction that temporarily store runoff and release it slowly via surface flow or groundwater infiltration following storms. Dry ED basins are designed to dry out between storm events, in contrast with wet ponds, which contain standing water permanently. As such, they are similar in construction and function to dry detention basins, except that the duration of detention of stormwater is designed to be longer, theoretically improving treatment effectiveness.

BMP Name	BMP Effectiveness Values			BMP Description
	TN	TP	Sediment	
Infiltration Practices w/ Sand, Veg.	85%	85%	95%	A depression to form an infiltration basin where sediment is trapped and water infiltrates the soil. No underdrains are associated with infiltration basins and trenches, because by definition these systems provide complete infiltration. Design specifications require infiltration basins and trenches to be built in good soil, they are not constructed on poor soils, such as C and D soil types. Engineers are required to test the soil before approval to build is issued. To receive credit over the longer term, jurisdictions must conduct yearly inspections to determine if the basin or trench is still infiltrating runoff.
Filtering Practices	40%	60%	80%	Practices that capture and temporarily store runoff and pass it through a filter bed of either sand or an organic media. There are various sand filter designs, such as above ground, below ground, perimeter, etc. An organic media filter uses another medium besides sand to enhance pollutant removal for many compounds due to the increased cation exchange capacity achieved by increasing the organic matter. These systems require yearly inspection and maintenance to receive pollutant reduction credit.
Filter Strip Runoff Reduction	20%	54%	56%	Urban filter strips are stable areas with vegetated cover on flat or gently sloping land. Runoff entering the filter strip must be in the form of sheet-flow and must enter at a non-erosive rate for the site-specific soil conditions. A 0.4 design ratio of filter strip length to impervious flow length is recommended for runoff reduction urban filter strips.
Filter Strip Stormwater Treatment	0%	0%	22%	Urban filter strips are stable areas with vegetated cover on flat or gently sloping land. Runoff entering the filter strip must be in the form of sheet-flow and must enter at a non-erosive rate for the site-specific soil conditions. A 0.2 design ratio of filter strip length to impervious flow length is recommended for stormwater treatment urban filter strips.
Bioretention – Raingarden (C/D soils w/ underdrain)	25%	45%	55%	An excavated pit backfilled with engineered media, topsoil, mulch, and vegetation. These are planting areas installed in shallow basins in which the storm water runoff is temporarily ponded and then treated by filtering through the bed components, and through biological and biochemical reactions within the soil matrix and around the root zones of the plants. This BMP has an underdrain and is in C or D soil.
Bioretention / Raingarden (A/B soils w/ underdrain)	70%	75%	80%	An excavated pit backfilled with engineered media, topsoil, mulch, and vegetation. These are planting areas installed in shallow basins in which the storm water runoff is temporarily ponded and then treated by filtering through the bed components, and through biological and biochemical reactions within the soil matrix and around the root zones of the plants. This BMP has an underdrain and is in A or B soil.

BMP Name	BMP Effectiveness Values			BMP Description
	TN	TP	Sediment	
Bioretention / Raingarden (A/B soils w/o underdrain)	80%	85%	90%	An excavated pit backfilled with engineered media, topsoil, mulch, and vegetation. These are planting areas installed in shallow basins in which the storm water runoff is temporarily ponded and then treated by filtering through the bed components, and through biological and biochemical reactions within the soil matrix and around the root zones of the plants. This BMP has no underdrain and is in A or B soil.
Vegetated Open Channels (C/D Soils)	10%	10%	50%	Open channels are practices that convey stormwater runoff and provide treatment as the water is conveyed, includes bioswales. Runoff passes through either vegetation in the channel, subsoil matrix, and/or is infiltrated into the underlying soils. This BMP has no underdrain and is in C or D soil.
Vegetated Open Channels (A/B Soils)	45%	45%	70%	Open channels are practices that convey stormwater runoff and provide treatment as the water is conveyed, includes bioswales. Runoff passes through either vegetation in the channel, subsoil matrix, and/or is infiltrated into the underlying soils. This BMP has no underdrain and is in A or B soil.
Bioswale	70%	75%	80%	With a bioswale, the load is reduced because, unlike other open channel designs, there is now treatment through the soil. A bioswale is designed to function as a bioretention area.
Permeable Pavement w/o Sand or Veg. (C/D Soils w/ underdrain)	10%	20%	55%	Pavement or pavers that reduce runoff volume and treat water quality through both infiltration and filtration mechanisms. Water filters through open voids in the pavement surface to a washed gravel subsurface storage reservoir, where it is then slowly infiltrated into the underlying soils or exits via an underdrain. This BMP has an underdrain, no sand or vegetation and is in C or D soil.
Permeable Pavement w/o Sand or Veg. (A/B Soils w/ underdrain)	45%	50%	70%	Pavement or pavers that reduce runoff volume and treat water quality through both infiltration and filtration mechanisms. Water filters through open voids in the pavement surface to a washed gravel subsurface storage reservoir, where it is then slowly infiltrated into the underlying soils or exits via an underdrain. This BMP has an underdrain, no sand or vegetation and is in A or B soil.
Permeable Pavement w/o Sand or Veg. (A/B Soils w/o underdrain)	75%	80%	85%	Pavement or pavers that reduce runoff volume and treat water quality through both infiltration and filtration mechanisms. Water filters through open voids in the pavement surface to a washed gravel subsurface storage reservoir, where it is then slowly infiltrated into the underlying soils or exits via an underdrain. This BMP has no underdrain, no sand or vegetation and is in A or B soil.
Permeable Pavement w/ Sand or Veg. (A/B Soils w/ underdrain)	50%	50%	70%	Pavement or pavers that reduce runoff volume and treat water quality through both infiltration and filtration mechanisms. Water filters through open voids in the pavement surface to a washed gravel subsurface storage reservoir, where it is then slowly infiltrated into the underlying soils or exits via an underdrain. This BMP has an underdrain, has sand and/or vegetation and is in A or B soil.

BMP Name	BMP Effectiveness Values			BMP Description
	TN	**TP**	**Sediment**	
Permeable Pavement w/ Sand or Veg. (A/B Soils w/o underdrain)	80%	80%	85%	Pavement or pavers that reduce runoff volume and treat water quality through both infiltration and filtration mechanisms. Water filters through open voids in the pavement surface to a washed gravel subsurface storage reservoir, where it is then slowly infiltrated into the underlying soils or exits via an underdrain. This BMP has no underdrain, has sand and/or vegetation and is in A or B soil.
Permeable Pavement w/ Sand or Veg. (C/D Soils w/ underdrain)	20%	20%	55%	Pavement or pavers that reduce runoff volume and treat water quality through both infiltration and filtration mechanisms. Water filters through open voids in the pavement surface to a washed gravel subsurface storage reservoir, where it is then slowly infiltrated into the underlying soils or exits via an underdrain. This BMP has an underdrain, has sand and/or vegetation and is in C or D soil.
Stream Restoration	0.075 lbs/ft/yr	0.068 lbs/ft/yr	44.88 lbs/ft/yr	An annual mass nutrient and sediment reduction credit for qualifying stream restoration practices that prevent channel or bank erosion that otherwise would be delivered downstream from an actively enlarging or incising urban stream. Applies to 0 to 3rd order streams that are not tidally influenced. If one of the protocols is cited and pounds are reported, then the mass reduction is received for the protocol.
Forest Buffers	25%	50%	50%	An area of trees at least 35 feet wide on one side of a stream, usually accompanied by trees, shrubs and other vegetation that is adjacent to a body of water. The riparian area is managed to maintain the integrity of stream channels and shorelines, to reduce the impacts of upland sources of pollution by trapping, filtering, and converting sediments, nutrients, and other chemicals. (Note – the values represent pollutant load reductions from stormwater draining through buffers).
Tree Planting	10%	15%	20%	The BMP effectiveness values for tree planting are estimated by DEP. DEP estimates that 100 fully mature trees of mixed species (both deciduous and non-deciduous) provide pollutant load reductions for the equivalent of one acre (i.e., one mature tree = 0.01 acre). The BMP effectiveness values given are based on immature trees (seedlings or saplings); the effectiveness values are expected to increase as the trees mature. To determine the amount of pollutant load reduction that can credited for tree planting efforts: 1) multiply the number of trees planted by 0.01; 2) multiply the acreage determined in step 1 by the pollutant loading rate for the land prior to planting the trees (in lbs/acre/year); and 3) multiply the result of step 2 by the BMP effectiveness values given.
Street Sweeping	3%	3%	9%	Street sweeping must be conducted 25 times annually. Only count those streets that have been swept at least 25 times in a year. The acres associated with all streets that have been swept at least 25 times in a year would be eligible for pollutant reductions consistent with the given BMP effectiveness values.

BMP Name	BMP Effectiveness Values			BMP Description
	TN	TP	Sediment	
Storm Sewer System Solids Removal	0.0027 for sediment, 0.0111 for organic matter	0.0006 for sediment, 0.0012 for organic matter	1 – TN and TP concentrations	This BMP (also referred to as "Storm Drain Cleaning") involves the collection or capture and proper disposal of solid material within the storm system to prevent discharge to surface waters. Examples include catch basins, stormwater inlet filter bags, end of pipe or outlet solids removal systems and related practices. Credit is authorized for this BMP only when proper maintenance practices are observed (i.e., inspection and removal of solids as recommended by the system manufacturer or other available guidelines). The entity using this BMP for pollutant removal credits must demonstrate that they have developed and are implementing a standard operating procedure for tracking the material removed from the sewer system. Locating such BMPs should consider the potential for backups onto roadways or other areas that can produce safety hazards. To determine pollutant reductions for this BMP, these steps must be taken: 1) Measure the weight of solid/organic material collected (lbs). Sum the total weight of material collected for an annual period. Note – do not include refuse, debris and floatables in the determination of total mass collected. 2) Convert the annual wet weight captured into annual dry weight (lbs) by using site-specific measurements (i.e., dry a sample of the wet material to find its weight) or by using default factors of 0.7 (material that is predominantly wet sediment) or 0.2 (material that is predominantly wet organic matter, e.g., leaf litter). 3) Multiply the annual dry weight of material collected by default or site-specific pollutant concentration factors. The default concentrations are shown in the BMP Effectiveness Values columns. Alternatively, the material may be sampled (at least annually) to determine site-specific pollutant concentrations. DEP will allow up to 50% of total pollutant reduction requirements to be met through this BMP. The drainage area treated by this BMP may be no greater than 0.5 acre unless it can be demonstrated that the specific system proposed is capable of treating stormwater from larger drainage areas. For planning purposes, the sediment removal efficiency specified by the manufacturer may be assumed, but no higher than 80%.

Attachment E2: Expert Panel - Stream Restoration

Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects

Joe Berg, Josh Burch, Deb Cappuccitti, Solange Filoso, Lisa Fraley-McNeal,
Dave Goerman, Natalie Hardman, Sujay Kaushal, Dan Medina, Matt Meyers, Bob Kerr,
Steve Stewart, Bettina Sullivan, Robert Walter and Julie Winters

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Prepared by:
Tom Schueler, Chesapeake Stormwater Network
and
Bill Stack, Center for Watershed Protection

Table of Contents

List of common acronyms used throughout the text:

BANCS	Bank Assessment for Nonpoint Source Consequences of Sediment
BEHI	Bank Erosion Hazard Index
BMP	Best Management Practices
CAST	Chesapeake Assessment Scenario Tool
CBP	Chesapeake Bay Program
CBWM	Chesapeake Bay Watershed Model
GIS	Geographic Information Systems
IBI	Index of Biotic Integrity
lf	Linear feet
LSR	Legacy Sediment Removal
MS4	Municipal Separate Storm Sewer System
NBS	Near Bank Stress
NCD	Natural Channel Design
RR	Runoff Reduction
RTVM	Reporting, Tracking, Verification and Monitoring
RSC	Regenerative Stormwater Conveyance
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
WIP	Watershed Implementation Plan
WQGIT	Water Quality Group Implementation Team

WTWG	Watershed Technical Work Group

Summary of Panel Recommendations

Over the last few decades, the Chesapeake Bay states have pioneered new techniques to restore urban streams using diverse approaches such as natural channel design, regenerative stormwater conveyance, and removal of legacy sediments. In the future, several Bay states are considering greater use of stream restoration as part of an overall watershed strategy to meet nutrient and sediment load reduction targets for existing urban development under the Chesapeake Bay TMDL.

The Panel conducted an extensive review of recent research on the impact of stream restoration projects in reducing the delivery of sediments and nutrients to the Bay. A majority of the Panel decided that the past practice of assigning a single removal rate for stream restoration was not practical or scientifically defensible, as every project is unique with respect to its design, stream order, landscape position and function.

Instead, the Panel elected to craft four general protocols to define the pollutant load reductions associated with individual stream restoration projects.

> *Protocol 1: Credit for Prevented Sediment during Storm Flow* -- This protocol provides an annual mass nutrient and sediment reduction credit for qualifying stream restoration practices that prevent channel or bank erosion that would otherwise be delivered downstream from an actively enlarging or incising urban stream.
>
> *Protocol 2: Credit for Instream and Riparian Nutrient Processing during Base Flow* -- This protocol provides an annual mass nitrogen reduction credit for qualifying projects that include design features to promote denitrification during base flow within the stream channel through hyporheic exchange within the riparian corridor.
>
> *Protocol 3: Credit for Floodplain Reconnection Volume*-- This protocol provides an annual mass sediment and nutrient reduction credit for qualifying projects that reconnect stream channels to their floodplain over a wide range of storm events.
>
> *Protocol 4: Credit for Dry Channel Regenerative Stormwater Conveyance (RSC) as an Upland Stormwater Retrofit*-- This protocol provides an annual nutrient and sediment reduction *rate* for the contributing drainage area to a qualifying dry channel RSC project. The rate is determined by the degree of stormwater treatment provided in the upland area using the retrofit rate adjustor curves developed by the Stormwater Retrofit Expert Panel.

The protocols are additive, and an individual stream restoration project may qualify for credit under one or more of the protocols, depending on its design and overall restoration approach however the WTWG recommends that the aggregate load reductions from a practice should not exceed estimated loads in the Watershed Model for any given land-river segment. These approaches are based on the best available data as of November 2013.

Summary of Stream Restoration Credits for Individual Restoration Projects [1, 2]					
Protocol	*Name*	*Units*	*Pollutants*	*Method*	*Reduction Rate*
1	Prevented Sediment (S)	Pounds per year	Sediment TN, TP	Define bank retreat using BANCS or other method	Measured N/P content in streambed and bank sediment
2	Instream Denitrification (B)	Pounds per year	TN	Define hyporheic box for reach	Measured unit stream denitrification rate
3	Floodplain Reconnection (S/B)	Pounds per year	Sediment TN, TP	Use curves to define volume for reconnection storm event	Measured removal rates for floodplain wetland restoration projects
4	Dry Channel RSC as a Retrofit (S/B)	Removal rate	Sediment TN, TP	Determine stormwater treatment volume	Use adjustor curves from retrofit expert panel
[1] Depending on project design, more than one protocol may be applied to each project, and the load reductions are additive. [2] Sediment load reductions are further reduced by a sediment delivery ratio in the CBWM (which is not used in local sediment TMDLs) S: applies to stormflow conditions, B: applies to base flow or dry weather conditions					

The report also includes examples to show users how to apply each protocol in the appropriate manner. In addition, the Panel recommended several important qualifying conditions and environmental considerations for stream restoration projects to ensure they produce functional uplift for local streams. *Historic projects and new projects that cannot conform to recommended reporting requirements as described in Section 7.1 may be able to receive credit through a revised interim rate which will be referred to as the default rate (Table 3, Row 3). Refer to Section 2.4 for additional details.*

The Panel recognizes that the data available at this time does not allow a perfect understanding or prediction of stream restoration performance. As a result, the Panel also stressed that verification of the initial and long term performance of stream restoration projects is critical to ensure that projects are functioning as designed. To this end, the Panel recommends that the stream restoration credits be limited to 5 years, although the credits can be renewed based on a field inspection that verifies the project still exists, is adequately maintained and is operating as designed and the critical assumptions (e.g., upstream hydrology) used in the protocols haven't changed.

Important Disclaimer: The Panel recognizes that stream restoration projects as defined in this report may be subject to authorization and associated requirements from federal, State, and local agencies. The recommendations in this report are not intended to supersede any other requirements or standards mandated by other government authorities. Consequently, some stream restoration projects may conflict with other regulatory requirements and may not be suitable or authorized in certain locations.

Section 1: Charge and Membership of the Expert Panel

Expert BMP Review Panel for Urban Stream Restoration	
Panelist	***Affiliation***
Deb Cappuccitti	Maryland Department of Environment
Bob Kerr	Kerr Environmental Services (VA)
Matthew Meyers, PE	Fairfax County (VA) Department of Public Works and Environmental Services
Daniel E. Medina,Ph.D, PE	Atkins (MD)
Joe Berg	Biohabitats (MD)
Lisa Fraley-McNeal	Center for Watershed Protection (MD)
Steve Stewart	Baltimore County Dept of Environmental Protection and Sustainability (MD)
Dave Goerman	Pennsylvania Department of Environmental Protection
Natalie Hardman	West Virginia Department of Environmental Protection
Josh Burch	District Department of Environment
Dr. Robert C. Walter	Franklin and Marshall College
Dr. Sujay Kaushal	University of Maryland
Dr. Solange Filoso	University of Maryland
Julie Winters	US Environmental Protection Agency CBPO
Bettina Sullivan	Virginia Department of Environmental Quality
Panel Support	
Tom Schueler Bill Stack	Chesapeake Stormwater Network (facilitator) Center for Watershed Protection (co-facilitator)
Other Panel Support: Russ Dudley – Tetra Tech, Debra Hopkins – Fish and Wildlife Service, Molly Harrington, CBP CRC, Norm Goulet, Chair Urban Stormwater Work Group, Gary Shenk, EPA CBPO, Jeff Sweeney, EPA CBPO, Paul Mayer, EPA ORD	

The initial charge of the Panel was to review all of the available science on the nutrient and sediment removal performance associated with qualifying urban stream restoration projects in relation to those generated by degraded urban stream channels.

The Panel was specifically requested to:

- Provide a specific definition of what constitutes effective stream restoration in the context of any nutrient or sediment reduction credit, and define the qualifying conditions under which a local stream restoration project may be eligible to receive the credit.

- Assess whether the existing Chesapeake Bay Program-approved removal rate is suitable for qualifying stream restoration projects, or whether a new protocol needs to be developed to define improved rates. In doing so, the Panel was asked to consider project specific factors such as physiographic region, landscape position, stream order, type of stream restoration practices employed and upstream or subwatershed conditions.

- Define the proper units that local governments will use to report retrofit implementation to the states to incorporate into the Chesapeake Bay Watershed Model (CBWM).

Beyond this specific charge, the Panel was asked to;

- Determine whether to recommend that an interim removal rate be established for one or more classes of stream restoration practices prior to the conclusion of the research for Watershed Implementation Plan (WIP) planning purposes.

- Recommend procedures for reporting, tracking, and verifying any recommended stream restoration credits over time.

- Critically analyze possible unintended consequences associated with the credit and the potential for over-counting of the credit, with a specific reference to any upstream BMPs installed.

While conducting its review, the Panel followed the procedures and process outlined in the Water Quality Goal Implementation Team (WQGIT) BMP review protocol (WQGIT, 2012). The process begins with BMP Expert Panels that evaluate existing research and make initial recommendations on removal rates. These, in turn, are reviewed by the Urban Stormwater Workgroup (USWG), the Watershed Technical Workgroup (WTWG) and the WQGIT to ensure they are accurate and consistent with the CBWM framework. Given the implications for stream habitat and wetland permitting, the panel recommendations will also be forwarded to both the Restoration and Habitat GITs for their independent review.

Appendix D documents the process by which the Expert Panel reached consensus, in the form of five meeting minutes that summarize their deliberations. Appendix E documents how the Panel satisfied the requirements of the BMP review protocol. Although not reflected in the minutes, there were several conversations, email exchanges, and edits to the drafts from Panel members that are not reflected in the minutes.

Section 2: Stream Restoration in the Chesapeake Bay

Section 2.1
Urbanization, Stream Quality and Restoration

Declining stream quality in the Chesapeake Bay watershed is a function of historic land use and present day urbanization. Historic land use included land clearing for agricultural development, subsequent reforestation in the 20th century, low-head dam construction, and widespread stream channel straightening/relocation (Knox, 1972; Pizzuto et al., 2000; Merritts et al., 2011). A significant amount of sediment is stored in Piedmont floodplains that was delivered from accelerated erosion during historical land clearing and subsequent upland erosion (Trimble, 1974; Costa, 1975; Jacobson and Coleman, 1986). In addition, present day urbanization has led to stream quality decline, as documented by considerable research over the last two decades in the Chesapeake Bay watershed. Declines in hydrologic, morphologic, water quality and biological indicators have been associated with increased watershed impervious cover (Paul and Mayer, 2001; Schueler et al., 2009). For example, Cianfrani et al. (2006) documented the relationship between impervious cover and degraded channel morphology in 46 urbanizing streams in southeast Pennsylvania.

Further research has shown increased rates of channel erosion and sediment yield in urbanizing streams (Trimble, 1997; Booth and Henshaw, 2001; Langland and Cronin, 2003; Allmendinger et al., 2007; Fraley et al., 2009). Other common impacts associated with urbanization are the hydrologic and hydraulic disconnection of the stream from its floodplain (Groffman et al., 2003), simplification of instream habitat, loss of riparian cover, and loss of diversity in aquatic life indicators.

The effect of urbanization on stream health also diminishes the functional capacity of streams to retain both sediments and nutrients. For example, sediment yields are more than an order of magnitude higher in urban streams compared to rural ones (Langland and Cronin, 2003). Floodplain and channel soils largely derived from historic land clearing practices are highly enriched with respect to nutrients as a result of past soil erosion and subsequent alluvial and colluvial deposition in the stream valley (Merritts et al., 2011). Similarly, stream nitrate levels rise sharply at low levels of urbanization and remain high across greater levels of urbanization (Morgan and Kline, 2010). Other research has shown that degraded streams and disconnected floodplains have less capacity for internal nutrient uptake and processing, particularly with respect to denitrification (Lautz and Fannelli, 2008; Kaushal et al., 2008; Klocker et al., 2009).

In 2008, the Chesapeake Bay Program's Sediment Work Group organized an information exchange workshop entitled "*Fine Sediment and the Chesapeake Bay Watershed" (*Smith et al., 2008) to identify the key knowledge gaps in watershed sediment modeling, monitoring and assessment and to identify the most effective BMPs for reducing fine sediment loads to the Chesapeake Bay. The workshop participants were comprised of watershed managers, scientists, regulators, engineers, and environmental restoration professionals. The conclusions from the workshop are that while much progress has been made in understanding the origins, transport, and fate of sediment, there is no consensus for immediate tools to make quantifiable progress towards improving Chesapeake Bay goals.

Despite this lack of consensus, watershed managers are continuing the widespread implementation of stream restoration to meet local water quality goals and will rely heavily on stream restoration as an important tool in meeting the water quality goals of the WIPs. It is therefore critical to develop a consistent set of protocols that managers can use throughout the Chesapeake Bay watershed that can be adapted as better information becomes available. Stream restoration projects that reduce bank erosion and create in-stream habitat features are a useful strategy as part of a comprehensive watershed approach to reduce sediment and nutrient export from urban and non-urban watersheds. In Section 3, the Panel analyzed the available evidence to define the functional benefits of restored versus non-restored streams.

It is important to note that watersheds can only be comprehensively restored by installing practices in upland areas, the stream corridor, and in appropriate settings, within the stream itself. The CBP currently has completed or launched a half dozen expert panels on urban BMPs, most of which are applied to upland areas, with the goal of providing a wide range of watershed tools to meet restoration goals.

Section 2.2
Stream Restoration Definitions

The discipline of stream restoration has spawned many different terms and nomenclature; therefore, the Panel wanted to precisely define the terms that are employed within this report.

Floodplain – For flood hazard management purposes, floodplains have traditionally been defined as the extent of inundation associated with the 100-year flood, which is a flooding event that has a one-percent probability of being equaled or exceeded in any one year[1]. However, in the context of this document, floodplains are defined as relatively flat areas of land between the stream channel and the valley wall that will receive excess storm flows when the channel capacity is exceeded. Therefore, water accesses the floodplain thus defined much more frequently than what is typically considered a flooding event.

[1] Floodplain management agencies use the term one-percent-annual chance to define this event, in part to dispel the misconception that the 100-year flood occurs once every 100 years. In this report, return periods instead of probabilities are used for convenience.

Floodplain Reconnection Volume - This term quantifies the benefit that a given project may provide in terms of bringing streamflow in contact with the floodplain. The Floodplain Reconnection Volume is the additional annual volume of stream runoff and base flow from an upstream subwatershed that is effectively diverted onto the available floodplain, riparian zone, or wetland complex, over the pre-project volume. The volume is usually calculated using a series of curves provided in this report to convert unit rainfall depth thresholds in the contributing watershed to an effective annual volume expressed in watershed-inches.

Functional Uplift - A general term for the ability of a restoration project in a degraded stream to recover hydrologic, hydraulic, geomorphic, physiochemical, or biological indicators of healthy stream function.

Hyporheic Zone - The hyporheic zone is defined as the region below and alongside a stream, occupied by a porous medium where there is an exchange and mixing of shallow groundwater and the surface water in the channel. The dimensions of the hyporheic zone are defined by the hydrology of the stream, substrate material, its surrounding environment, and local groundwater sources. This zone has a strong influence on stream ecology, biogeochemical cycling, and stream water temperatures.

Legacy Sediment - Sediment that (1) was eroded from uplands during several centuries of land clearing, agriculture and other intensive uses; (2) accumulated behind ubiquitous dams in slackwater environments, resulting in thick accumulations of cohesive clay, silt and sand, which distinguishes "legacy sediment" from fluvial deposits associated with meandering streams; (3) collected along stream corridors and within valley bottoms, effectively burying natural floodplains, streams and wetlands; (4)altered and continues to impair the morphologic, hydrologic biologic, riparian and other ecological services and functions of aquatic resources; (5) can also accumulate as coarser grained more poorly sorted colluvial deposits, usually at valley margins; (6) can contain varying amounts of nutrients that can generate nutrient export via bank erosion processes. Widespread indicators of legacy sediment impairment include a history of damming, high banks and degree of channel incision, rapid bank erosion rates and high sediment loads. Other indicators include low channel pattern development, infrequent inundation of the riparian zone, diminished sediment storage capacity, habitat degradation, and lack of groundwater connection near the surface of the floodplain and/or riparian areas.

Legacy Sediment Removal (LSR) - A class of aquatic resource restoration that seeks to remove legacy sediments and restore the natural potential of aquatic resources including a combination of streams, floodplains, and palustrine wetlands. Although several LSR projects have been completed, the major experimental site was constructed in 2011 at Big Spring Run near Lancaster, PA. For additional information on the research project, consult Hartranft (2011).

Natural Channel Design (NCD) - Application of fluvial geomorphology to create stable channels that maintain a state of dynamic equilibrium among water, sediment, and vegetation such that the channel does not aggrade or degrade over time. This class of stream restoration utilizes data on current channel morphology, including stream cross section, plan form, pattern, profile, and sediment characteristics for a stream classified according to the Rosgen (1996) classification scheme, but which may be modified to meet the unique constraints of urban streams as described in Doll et al. (2003).

Non-Urban - A subwatershed with less than 5% impervious cover, and is primarily composed of forest, agricultural or pasture land uses. Individual states may have alternative definitions.

Prevented Sediment - The annual mass of sediment and associated nutrients that are retained by a stable, restored stream bank or channel that would otherwise be eroded and delivered downstream in an actively enlarging or incising urban stream. The mass of prevented sediment is estimated using the field methods and desktop protocols presented later in this document.

Project Reach - the length of an individual stream restoration project as measured by the valley length (expressed in units of feet). The project reach is defined as the specific work areas where stream restoration practices are installed.

Regenerative Stormwater Conveyance (RSC) - Refers to two specific classes of stream restoration as defined in the technical guidance developed by Flores (2011) in Anne Arundel County, Maryland. The RSC approach has also been referred to as coastal plain outfalls, regenerative step pool storm conveyance, base flow channel design, and other biofiltration conveyance. For purposes of this report, there are two classes of RSC: dry channel and wet channel.

> *Dry channel RSC* involves restoration of ephemeral streams or eroding gullies using a combination of step pools, sand seepage wetlands, and native plants. These applications are often located at the end of storm drain outfalls or channels. The receiving channels are dry in that they are located above the water table and carry water only during and immediately after a storm event. The Panel concluded that dry channel RSC should be classified as a stormwater retrofit practice rather than a stream restoration practice.
>
> *Wet channel RSCs* can be located in intermittent streams, but are more typically located farther down the perennial stream network and use instream weirs to spread storm flows across the floodplain at minor increases in the stream stage for events much smaller than the 1.5-year storm event, which has been traditionally been assumed to govern stream geomorphology and channel capacity. Wet channel RSC may also include sand seepage wetlands or other wetland types in the floodplain that increase floodplain connection, reconnection, or interactions with the stream.

Stream Restoration - Refers to any NCD, RSC, LSR or other restoration project that meets the qualifying conditions for credits, including environmental limitations and stream functional improvements. The Panel did not have a basis to suggest that any single design approach was superior, as any project can fail if it is inappropriately located, assessed, designed, constructed, or maintained.

Upland Restoration - The implementation of best management practices outside the stream corridor to reduce runoff volumes and pollutant loads in order to restore the quality of streams and estuaries.

Urban - Generally a subwatershed with more than 5% impervious cover, although individual states may have their own definition.

Section 2.3
Derivation of the Original Chesapeake Bay Program-Approved Rate for Urban Stream Restoration

The original nutrient removal rate for stream restoration projects was approved by CBP in 2003, and was based on a single monitoring study conducted in Baltimore County, Maryland (Stewart, 2008). The Spring Branch study reach involved 10,000 linear feet of stream restoration located in a 481-acre subwatershed that primarily consisted of medium density residential development. The project applied natural channel design techniques as well as 9.7 acres of riparian reforestation.

The original monitoring effort encompassed two years prior to the project and three years after it was constructed. The preliminary results were expressed in terms of pounds reduced per linear foot and these values were subsequently used to establish the initial CBP-approved rate, as shown in Table 1 and documented in Simpson and Weammert (2009).

Table 1. Edge-of-Stream CBP-Approved Removal Rates per Linear foot of Qualifying Stream Restoration (lb/ft/yr)

Source	TN	TP	TSS
Spring Branch N=1	0.02	0.0035	2.55
See also: Simpson and Weammert (2009)			

Baltimore County continued to monitor the Spring Branch site for seven years following restoration and recomputed the sediment and nutrient removal rates for the project reach (Stewart, 2008). Both the nutrient and sediment removal rates increased when the longer term monitoring data were analyzed, regardless of whether they were expressed per linear foot or as a percent reduction through the project reach (see Table 2).

Table 2. Revised Removal Rates per Linear foot for Spring Branch, Based on Four Additional Years of Sampling and Data Re-Analysis (lb/ft/yr)

Source	TN	TP	TSS

Spring Branch N=1	0.227	0.0090	3.69
% Removal in Reach	42%	43%	83%
Source: Stewart (2008) and Steve Stewart presentation to Expert Panel 1/25/2012			

In the last few years, the rates shown in Table 1 have been applied to non-urban stream restoration projects, presumably because of a lack of research on nutrient uptake and sediment removal for restoration projects located in rural or agricultural areas. As a result, the CBWM, Scenario Builder, and CAST all now include non-urban stream restoration rates equal to the urban values in Table 1. The Panel was not able to document when the informal decision was made by the CBP to apply the interim urban stream restoration rate to non-urban stream restoration projects. The Panel recommendations for addressing non-urban stream restoration projects are provided in Section 4.5 of this document.

Section 2.4
Derivation of the New Default CBP-Approved Rate

Since the first stream restoration estimate was approved in 2003, more research has been completed on the nutrient and sediment dynamics associated with urban stream restoration. These studies indicated that the original credit for stream restoration was too conservative.

Chesapeake Stormwater Network (CSN) (2011) proposed a revised interim credit that was originally developed by the Baltimore Department of Public Works (BDPW, 2006). This credit included five additional unpublished studies on urban stream erosion rates located in Maryland and southeastern Pennsylvania. These additional studies were found to have substantially higher erosion rates than those originally measured at Spring Branch (Table 3).

The rationale of using the Baltimore City data review as the interim rate is based on the assumption that the higher sediment and nutrient export rates are more typical of urban streams undergoing restoration. The Commonwealth of Virginia requested that the higher rate in Table 3 be accepted as a new interim rate in December of 2011, and EPA Chesapeake Bay Program Office (CBPO) approved the rate in January 2012, pending the outcome of this Expert Panel. The Watershed Technical Work Group decided in their April 1, 2013 meeting as part of their review of this report that the interim rate will be used as a default rate and will apply to historic projects and new projects that cannot conform to recommended reporting requirements as described in Section 7.1. As a result of the 6-month Test Drive, several projects resulted in excessively high removal rates when using the default rate, in some cases exceeding the watershed loading estimates. Further review of the studies used to develop the interim rate revealed that a 50% restoration efficiency was applied to the rate for TP, but not to the TN and TSS rates. The Expert Panel met to discuss this and the other observations from the 6-month test drive and determined the default rate should be adjusted for TN and TSS to make it consistent with TP. The only known study with TN and TSS removal efficiencies associated with stream restoration is Spring Branch (Stewart, 2008) in Baltimore County. The Panel felt the efficiencies from this study should be applied to the default rate (37.5% for TN and 80% for TSS; Table 3, Row 3). Additional information about the revised default rate is provided in Appendix G.

Table 3. Edge-of-Stream 2011 Interim Approved Removal Rates per Linear Foot of Qualifying Stream Restoration (lb/ft/yr)			
Source	**TN**	**TP**	**TSS***
Interim CBP Rate	0.20	0.068	56.11
Revised Default Rate	**0.075**	**0.068**	**44.88 non-coastal plain** **15.13 coastal plain**
Derived from six stream restoration monitoring studies: Spring Branch, Stony Run, Powder Mill Run, Moore's Run, Beaver Run, and Beaver Dam Creek located in Maryland and Pennsylvania *To convert edge of field values to edge of stream values a sediment delivery ratio (SDR) was applied to TSS. The SDR was revised to distinguish between coastal plain and non-coastal plain streams. The SDR is 0.181 for non-coastal plain streams and 0.061 for coastal plain streams. Additional information about the sediment delivery ratio is provided in Section 2.5 and Appendix B.			

At its January 25, 2012 research workshop, the Panel concluded that there was no scientific support to justify the use of a single rate for all stream restoration projects (i.e., the lb/ft/yr rates shown in Tables 2 and 3). Sediment and nutrient load reductions will always differ, given the inherent differences in stream order, channel geometry, landscape position, sediment dynamics, restoration objectives, design philosophy, and quality of installation among individual stream restoration projects. Instead, the Panel focused on predictive methods to account for these factors, using various watershed, reach, cross-section, and restoration design metrics.

The Panel acknowledges that the new stream restoration removal rate protocols may not be easily integrated into existing CBP BMP assessment and scenario builder tools used by states and localities to evaluate options for watershed implementation plans (i.e., MAST, CAST, VAST and Scenario Builder). This limitation stems from the fact that each recommended protocol has its own removal rate, whereas the CBP tools apply a universal rate to all stream restoration projects.

Local watershed planners will often need to compare many different BMP options within their community. In the short term, the Panel recommends that CBP watershed assessment tools use the revised default rate (Table 3, Row 3) for general watershed planning purposes. It should be noted that sediment removals will be reduced due to the sediment delivery ratio employed by the CBWM (see Section 2.5).

Over the long term, the Panel recommends that the WTWG develop a more robust average removal rate for planning purposes, based on the load reductions achieved by stream restoration projects reported to the states using the new reporting protocols.

Section 2.5
How Sediment and Nutrients are Simulated in the Chesapeake Bay Watershed Model

It is important to understand how sediment and nutrients are simulated in the context of the CBWM to derive representative stream restoration removal rates that are consistent with the scale and technical assumptions of the model. The technical documentation for how sediment loads are simulated and calibrated for urban pervious and impervious lands in the CBWM can be found in Section 9 and the documentation for nutrients can be found in Section 10 of U.S. EPA (2010). The following paragraphs summarize the key model assumptions that the Panel reviewed.

The scale at which the CBWM simulates sediment dynamics corresponds to basins that average about 60 to 100 square miles in area. The model does not explicitly simulate the contribution of channel erosion to enhanced sediment/nutrient loadings for smaller 1^{st}, 2^{nd}, and 3^{rd} order streams not included as part of the CBWM reach network (i.e., between the edge-of-field and edge-of-stream), that is, scour and deposition with the urban stream channel network with these basins are not modeled.

Due to the scale issue, the CBWM indirectly estimates edge-of-stream sediment loads as a direct function of the impervious cover in the contributing watershed. The empirical relationships between impervious cover and sediment delivery for urban watersheds in the Chesapeake Bay were established from data reported by Langland and Cronin (2003), which included SWMM Model estimated sediment loads for different developed land use categories. A percent impervious was assigned to the land use categories to form a relationship between the degree of imperviousness and an associated sediment load (Figure 1).

The CBWM operates on the assumption that all sediment loads are edge-of-field and that transport and associated losses in overland flow and in low-order streams decrement the sediment load to an edge-of-stream input. The sediment loss between the edge-of-field and edge-of-stream is incorporated into the CBWM as a sediment delivery ratio. The SDF for each land use in a river segment is determined by the average distance that land use is away from the main river simulated in the river reach..
The ratio is multiplied by the predicted edge-of-field erosion rate to estimate the eroded sediments actually delivered to a specific reach.

Riverine transport processes are then simulated by HSPF as a completely mixed reactor at each time step of an hour to obtain the delivered load. Sediment can be deposited in a reach, or additional sediment can be scoured from the bed, banks, or other sources of stored sediment throughout the watershed segment. Depending on the location of the river-basin segment in the watershed and the effect of reservoirs, as much as 70 to 85%