Recommendations of the Expert Panel to Define Removal Rates for Erosion and Sediment Control Practices

FINAL REPORT

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The following is a list of common acronyms used throughout the text:

ATS	Active Treatment Systems
BMP(s)	Best Management Practice(s)
CBP or CBPO	Chesapeake Bay Program Office
CBWM	Chesapeake Bay Watershed Model
CGP	Construction General Permit
CTS	Chemical Treatment Systems
DIN	Dissolved inorganic Nitrogen
EoF	Edge of Field
EoS	Edge of Stream
ESC	Erosion and Sediment Control
EMC	Event Mean Concentration
HSG	Hydrologic Soil Group
LOD	Limits of Disturbance
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
NTUs	Nephelometric Turbidity Units
PAM	Polyacrylamide
Rv	Runoff Coefficient
RUSLE	Revised Universal Soil Loss Equation
ST	Stormwater Treatment (adjustor curve)
TMDL	Total Maximum Daily Load
TN or N	Total Nitrogen
TP or P	Total Phosphorus
TSS	Total Suspended Solids
USWG	Urban Stormwater Work Group
WIP	Watershed Implementation Plan
WQGIT	Water Quality Goal Implementation Team

EXECUTIVE SUMMARY

Construction sites are estimated to comprise about 84,500 acres of the watershed, but deliver about 16% of the total annual sediment load from the urban sector to the Bay, based on current model estimates. An expert panel was convened to review past estimates of the sediment and nutrient removal rates associated with erosion and sediment control (ESC) practices.

In recent years, all of the Bay states have strengthened their ESC requirements for construction sites, through more sophisticated practice specifications, new technology, and more stringent inspection and enforcement procedures. In 2011, West Virginia requested a new BMP review panel for enhanced ESC practices, and proposed an interim efficiency for these enhanced practices (See Appendix E). West Virginia noted that the more stringent design and inspection requirements contained in their most recent construction general permit should produce higher sediment and nutrient removal efficiencies than the existing rates of 25% (TN) and 40% (TSS and TP).

Based upon a review of current literature and monitoring data, the Panel devised a four tier system to classify the overall sediment removal performance of ESC practices based on past, current and future ESC implementation.

The Panel conducted an extensive review of the available science to define construction site hydrology, analyzed TSS outflow concentrations, and used the Simple Method to compute annual sediment loads for 3 of the 4 levels of ESC practice under normal conditions. The Panel also estimated sediment loss during periods where ESC practices are considered to be functionally deficient in their capacity to trap sediments. Based on this analysis, the Panel recommends the following sediment removal rates be applied to construction sites in the current version of the watershed model.

ESC Scenario	Discharged Load	Effective Removal Rate
ESC Sites Operating at Level 1	3.1 t/ac/yr	**74%**
ESC Sites Operating at Level 2	1.75 t/ac/yr	**85%**
ESC Sites Operating at Level 3	1.25 t/ac/yr	**90%**
ESC Sites Operating at Level 4	No estimate	No estimate

All of the Bay states are currently operating at an enhanced Level 2 performance rate, although several may be progressing to Level 3, which relies on greater use of polyacrylamide (PAM) to reduce construction site turbidity levels. The Panel encouraged states and localities to improve their ESC programs to achieve a higher and more reliable level of turbidity control.

The fine-grained particles that create turbidity are likely to have a higher delivery ratio to the Chesapeake Bay, given that it takes days or even weeks for them to settle out of the water column. Jurisdictions that improve their ESC program to shift to Level 3 ESC practice would have the further benefit of reducing the impact of turbidity on aquatic health and diversity in the streams, lakes and estuaries that discharge to the Bay.

The Panel also evaluated existing nutrient data for construction sites, and determined that there was no clear evidence that ESC practices can actually reduce nutrients, and some evidence that they may actually become a nutrient source. Consequently, the Panel assigned a zero nutrient removal efficiency for all four levels of ESC practice and supports the existing Chesapeake Bay Watershed Model (CBWM) target loads of 26.4 lbs/ac/yr for Total Nitrogen (TN) and 8.8 lbs/ac/yr for Total Phosphorus (TP).

Fertilizer wash-off appears to be a major risk for nutrient export, based on the prevailing fertilizer application rates used for vegetative stabilization at construction sites in the Bay watershed, as well as observations of high spikes in nutrient concentrations in several monitoring studies. The Panel urgently recommends additional monitoring studies to define the potential risk of fertilizer wash-off.

The Panel concluded that the existing ESC inspection and enforcement system was sufficient to verify this annual practice, and provided states with two options to estimate annual construction acreage.

Future Model Refinements:

The Panel recommends the modeling team consider the following refinements in the next phase of CBWM development.

1. Eliminate the simulation of the no-ESC baseline condition for construction sites, and instead simulate construction land use as its own BMP. Under this scenario, there would be four categories of construction land that correspond to the four ESC performance levels (factoring in the additional load from functionally deficient ESC sites).

2. The no-ESC condition has been a historic artifact for several decades now, and virtually every construction site in the Bay watershed employs ESC practices of one kind or another. The Panel was particularly concerned about the quality of the limited historical data used to derive calibration target loads for the no-ESC condition. If a no-ESC condition is required for modeling purposes, the Panel recommends that the target load be lowered to no more than 12 tons/acre/year.

3. Refine the parameters in the construction site simulation in PERLAND to explicitly simulate as many of the nutrient loss pathways as possible. At a minimum, construction sites should be subject to a weighted unit acre fertilization rate (which the model currently lacks).

4. Explicitly simulate sediment loss for construction sites located on the coastal plain physiographic region, which should be lower than other parts of the Bay watershed due to their gentle slopes, longer slope/length distances, and less erodible soil types.

Section 1
Charge and Membership of the Panel

The roster of the expert panel for erosion and sediment control practices can be found in the Table below.

EXPERT BMP REVIEW PANEL	
Panelist	***Affiliation***
Megan Grose	West Virginia Dept of Environmental Protection
Randy Greer	Engineer VI, Sediment and Stormwater Program, DE Dept. of Natural Resources and Environmental Control
Summer Kunkel, Dean Auchenbach	Pennsylvania Department of Environmental Protection
Dr. Shirley Clark	Pennsylvania State University, Harrisburg
Don Lake	State University of New York-College of Environmental Science and Forestry
Dr. Richard A. McLaughlin	Dept. of Soil Science. North Carolina State University
Dr. Albert Jarrett	Professor Emeritus, Pennsylvania State University
Bruce Young	St. Mary's Soil Conservation District (Maryland)
Kip Mumaw	Ecosystem Services
John McCutcheon	Virginia Department of Environmental Quality
Dr. Neely Law	Center for Watershed Protection, Chesapeake Bay Sediment Coordinator
Tom Schueler	Chesapeake Stormwater Network, Panel Co-facilitator
Jeremy Hanson	Chesapeake Research Consortium, Panel Co-facilitator
Non-panelists: Norm Goulet – Chair, USWG; Cecilia Lane, CSN; Chris Mellors – Tetratech. Special thanks to the CBPO Modeling Team: Guido Yactayo – UMCES, CBPO; Gary Shenk – EPA; Matt Johnston – UMD, CBPO; Jeff Sweeney – EPA	

Background on Panel:

Erosion and Sediment Control (ESC) Practices are required to be employed at construction sites in all of the Bay states. After considerable controversy, the Urban Stormwater Workgroup (USWG) approved sediment and nutrient reduction rates for ESC practices in 2007 (see Table 1). At that time, the Panel was limited to research studies conducted before 1995, and lacked any data on nutrient loadings from construction sites, or any nutrient removal rates by ESC practices.

The Panel noted in its report that they had low confidence in their findings due to the limited available research, and that the relatively low rates reflected a discount due to real world issues related to poor installation and maintenance of practices.

Table 1 – Removal Rates for ESC Practices for Construction Sites			
	TSS	TP	TN
Existing CBP-Approved Rate [1]	40	40	25
Interim Rate Requested by WV [2]	80	80	80
[1] approved by USWG, August 15, 2007 [2] interim rate requested by WV 9/15/2011 for enhanced ESC controls (see Appendix E)			

Since that time, all of the Bay states have strengthened their ESC regulations and construction general permits, improved their ESC technology, and developed more effective compliance and enforcement methods at construction sites. In 2011, the West Virginia Department of Environmental Protection (WVDEP) requested that higher sediment and nutrient removal rates be offered to reflect these "enhanced ESC practices". The Chesapeake Bay Program (CBP) granted an interim placeholder value for loading rates from bare construction to pervious land ("bar to pul"), subject to subsequent review by an expert panel (see Appendix E).

The initial charge of this Expert Panel was to review all of the available science on the nutrient and sediment removal performance associated with erosion and sediment control practices that are applied to construction sites.

The Panel was specifically requested to:

- Evaluate how construction sites are simulated in the context of CBWM version 5.3.2 (e.g., bare land use).
- Review available literature on the nutrient and sediment loading rates associated with construction sites, and the effect of conventional and enhanced ESC practices in reducing them.
- Provide specific definitions of "enhanced" and "conventional" ESC practices, and describe the qualifying conditions under which a locality can receive a nutrient and/or sediment reduction credit for each.
- Evaluate whether the existing CBP approved nutrient removal rates for conventional ESC practices developed in 2007 are still reliable.
- Define the proper units to report ESC practices for inclusion into the Watershed Model.
- Recommend procedures to report, track, and verify that conventional and enhanced ESC practices are actually being implemented and maintained until the site is fully stabilized.
- Critically analyze any unintended consequences associated with the sediment and nutrient removal rates and any potential for double or over-counting of the credit.

While conducting its review, the Panel followed the procedures and process outlined in the *Protocol for Development, Review and Approval of Loading and Effectiveness Estimates for Nutrient and Sediment Controls* (WQGIT, 2013). The meeting minutes for the expert panel can be found in Appendix F. Appendix G documents the Panel's conformity with the BMP review protocol requirements.

Section 2
Definitions and ESC Performance Levels

Construction sites are highly dynamic throughout the construction process, from initial clearing and grading, earthmoving, installation of streets and storm drains, building construction and finally, the final stabilization of the site. Consequently, the hydrology of a construction site constantly changes, based on soil exposure, new slopes, the growing season, grass cover, addition of hard surfaces, efficiency of stormwater conveyance, and the condition and performance of ESC practices. As a result, construction site erosion potential changes constantly over time, although significant soil loss is always expected during heavy or intense rainfall events.

The term erosion and sediment control refers to a combination of many different erosion prevention and sediment control practices that are progressively applied and maintained at site during the different stages of construction (Figure 1). *Erosion controls* are intended to prevent exposed soils from eroding, while *sediment controls* capture sediment that has eroded and traps it before it can leave the construction site.

A developer must submit an ESC plan for their construction project that specifies a unique combination of erosion and sediment controls for the unique conditions of the site. The plan is reviewed as part of the state and/or local land development approval process, and the ESC practices must be installed prior to construction activity. Construction sites are inspected periodically to ensure the practices are intact and working properly to prevent off-site sediment discharge.

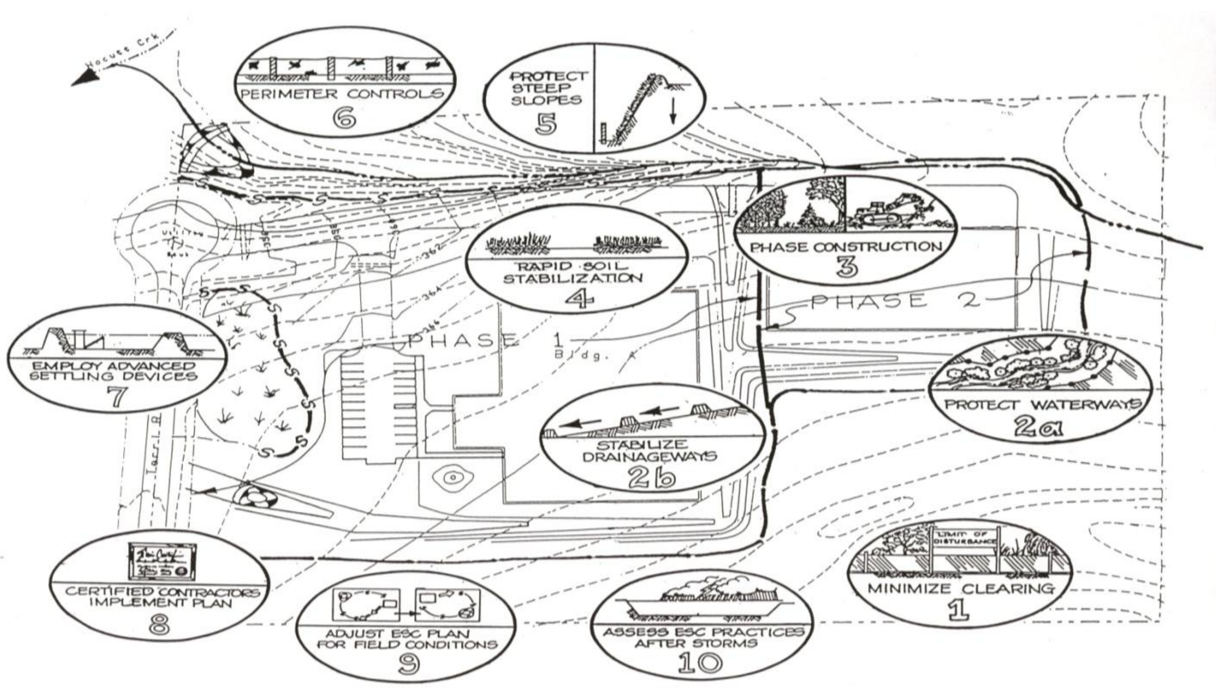


Figure 1: Elements of Erosion and Sediment Controls at Construction Sites (Source: Schueler and Holland, 2000)

The Panel defined the following terms to be consistent throughout the report:

Construction site: The total area of a site disturbed by construction activity (in acres). If the disturbed area is one acre or greater, a construction general permit or other NPDES permit is required from the state that includes implementation of an ESC plan. Many Bay states have lower disturbance area thresholds that trigger requirements for ESC practices, some of which can be as low as 2500 square feet.

Disturbed acres: The portion of a construction site subject to any grubbing, grading, or earth disturbance activity that removes pre-construction vegetation, or where dirt has been stockpiled or wasted.

Edge of field (EoF): The sediment load discharged at the boundary of the construction site, some of which may not be delivered to the stream

Edge of stream (EoS): The sediment load that is actually conveyed to a stream and available for transport downstream.

Event Mean Concentration (***EMC***): The flow-weighted concentration of a pollutant as measured by an automated sampler over the full duration of a storm event. A median EMC is computed when many storms are monitored at an individual site, and this concentration value is used as an important parameter to calculate annual pollutant loads using the Simple Method (Schueler, 1987).

Limits of Disturbance (***LOD***): The boundary around the disturbed acres within a construction site, as defined in the construction plan or permit. Perimeter controls, such as silt fence, berms, or diversion ditches are used to mark the LOD and protect streams, wetlands and forest conservation areas located outside of the LOD from any runoff or construction disturbance.

Regulatory Inspection: An on-site visit conducted by an authorized local, county, conservation district or state employee (or certified third party inspector) to ensure that the construction site is in compliance with its applicable ESC plan or permit requirements and take enforcement action if it is not.

Runoff Coefficient (Rv): The volumetric fraction of the rainfall on the site that is converted into storm runoff. Operationally, Rv is defined as r/p, where r and p are measured volume of storm runoff and rainfall in acre-inches, respectively. The Rv for a site is influenced by soils, topography and surface cover. In this report, the runoff coefficient is used as an important input parameter in the Simple Method, which is used to calculate annual sediment loads.

Sediment Load: The total mass of all soil particles that is discharged from the construction site, reported in tons/acre/year. In the context of this report, this load is also referred to as the "edge of field" sediment load.

Sediment Delivery Ratio: In the context of this report, it is the fraction of the edge of field sediment load that is (a) actually delivered to a stream and (b) is transported through the stream and river network of the watershed to reach the Chesapeake Bay. Sediments can be trapped, deposited or otherwise stored in hill-slopes, channels and floodplains, so the ratio is always less than one.

Sediment load with ESC: The total edge of field sediment load discharged from a construction site (tons/acre/year) for one of four ESC performance levels, based on recent monitoring studies.

Sediment load without ESC: The total edge of field sediment load discharged from a construction site (tons/acre/year) assuming that no erosion or sediment control practices were in place, as determined by historic monitoring studies.

Self-Inspection: A periodic check of the condition of ESC practices by a qualified individual that works for the contractor or construction company to maintain the integrity of ESC practices and keep the site in compliance. An on-site log of self-inspection reports must be maintained which is subject to review during regulatory inspections. Individuals that conduct self-inspections may be subject to training and/or certification requirements in the jurisdiction in which they are working.

Temporary Stabilization: An ESC practice where exposed soils are seeded and covered with straw or mulch to rapidly establish vegetation that helps to minimize future soil erosion. Most Bay states require that soils exposed after clearing be temporarily stabilized within 7 to 14 days of the earth-moving activity. In the context of this report, temporary stabilization frequently involves high N and P fertilizer applications which may be vulnerable to wash off.

Turbidity: A measure of water clarity that is sampled by sensors and reported in nephelometric turbidity units (NTUs). Turbidity is created by the presence of clay, silt, colloidal particles, organic and inorganic compounds, algae and microbial organisms. Turbidity levels measured in excess of 150 to 200 NTUs in receiving waters are harmful to aquatic life and may be considered a water quality standard violation in several Bay states.

2.1 Defining Levels of ESC Performance

The Panel was mindful that both the performance and implementation of ESC practices have continuously evolved and improved over the last three decades. Consequently, the Panel agreed that ESC practices can be classified into four broad levels of practice, based on key differences in ESC sizing, stabilization, treatment and inspection requirements. The Panel further hypothesized that sediment and nutrient removal rates for ESC practices may differ depending on which performance level they fall into. The basic classification scheme is portrayed in Table 2.

The ESC performance level is based on whether a state or local program meets the *majority* of the technical design criteria, timing requirements, inspection and enforcement provisions outlined in Table 2. The Panel acknowledges that each local and state ESC program is unique, and that not all of the criteria for each level of classification may apply within their jurisdiction.

Table 2: 4 Levels of ESC Practice, as Defined by the Panel

Practices	Level 1 ESC	Level 2 ESC	Level 3 ESC
Protect Natural Resources	Locate natural areas and mark LOD (up to edge of natural area)	Do #1 and add buffers to LOD to prevent discharge to natural area	Do # 2, and provide enhanced perimeter controls at LOD boundary for sensitive areas
Minimize Disturbance	No numeric construction phasing requirement	Construction phasing required for largest projects (e.g., 25 + acres)	Construction phasing required for smaller projects
Stabilize Soils	Stabilize w/in 14 to 21 days	Stabilize w/in 7 -14 days	Stabilize w/in a week
Internal Drainage	Temporary swales	Swales/diversions with check-dams and erosion control blankets	Do #2, but enhance with passive use of polymer (e.g., floc logs or wattles)
Perimeter Controls	Standard Controls (e.g., hay bales, entrance stabilization)	Reinforced silt fence and berms/diversions	Enhanced perimeter controls (i.e., super silt fence, compost logs, and filtering practices).
Sediment Traps and Basins	Sediment traps, filters, and basins that meet the 0.5" (1,800 cu.ft/acre) standard	Sediment basins that meet the 1.0" (3,600 cu.ft/ac) standard, with permanent pools and/or dewatering control devices (e.g., skimmers)	Do # 2, but enhance performance with passive use of chemical additives to improve settling, filtration and surface outlets
Inspections	Monthly	Every 1 to 3 weeks	Inspections once every seven days and after each precipitation event > 1.0"
Level 4 ESC	Do Level 3 and employ active chemical treatment system (ATS) with fully automated pumps, controls, settling tanks, and sand filters that are specifically designed to achieve low numeric turbidity effluent concentrations for construction site discharge		

Level 1 ESC: Includes ESC practices implemented under historical performance standards from approximately 2000 or before. The sediment trapping requirements were typically 1800 cubic feet/acre, stabilization requirement were less rapid, and inspections occurred less frequently, among other factors. At one point, all of the Bay states operated at this performance level; none of them are doing so now. Level 1 ESC practices are assumed during the calibration phase of the CBWM (1985-2005).

Level 2 ESC: This level of performance reflects the more stringent ESC requirements that have been adopted by local and state governments in the Bay watershed over the last several years, and generally conform to the standard requirements in EPA's 2012 Construction General Permit.

These include a greater sediment treatment capacity (typically 3600 cf/ac), surface outlets, more rapid vegetative cover for temporary and permanent stabilization, and improved design specifications for individual ESC practices to enhance sediment trapping or removal. In addition, many states now have construction phasing requirements for larger sites and all require more frequent self-inspections and regulatory inspections. As of this writing, all Bay states are operating at this level of performance.

***Level 3 ESC*:** This level of performance reflects the gradual shift in several Bay states to improve performance by expanded use of passive chemical treatment within Level 2 ESC practices. Chemical treatment involves the passive use of polyacrylamide (PAM) and other flocculants. The treatment relies solely on gravity to dose the sediments in construction site runoff (e.g., adding PAM granules to a check dam, erosion control fabric, or running basin flows across a block or sock containing flocculants).

This approach also integrates other design features to enhance the performance of individual practices, such as skimmers, baffles, surface outlets, compost, and stronger geo-textiles. Level 3 also involves more frequent inspection and maintenance, and more stringent requirements for phasing and resource protection. While several Bay states are experimenting with some of these techniques, none of them are currently requiring them on a widespread basis. Therefore, no Bay state yet qualifies for Level 3 practice at this time. The Panel outlined quantitative benchmarks for states and localities to achieve a Level 3 of ESC practice (Section 7.4) as they continue to improve their programs in future years.

Level 4 ESC: The highest level of performance is associated with active treatment systems (ATS) that are employed for turbidity and suspended solids control. The ATS captures and pumps muddy water to a location where PAM or other flocculants can be injected or introduced. ATS are specifically designed to achieve low numeric turbidity effluent concentrations for construction site discharge. A typical ATS is fully automated and includes pumps, controls, settling tanks, and sand filters.

Consequently, ATS is very expensive and requires extensive manpower for operation. While some ATS have been tested and refined in California and the Pacific Northwest, they have been rarely applied and never required at construction sites in the Chesapeake Bay watershed. Indeed, several Bay states have been concerned about the possible environmental impacts associated with flocculants on downstream ecosystems, and have been cautious about expanding their use.

Functionally Deficient ESC Sites: The four levels of ESC practice assume proper installation and maintenance of practices, as well as normal rainfall conditions that are within the design capacity of the practices. These assumptions are violated at some proportion of construction sites, and all sites during extreme storm events.

Three levels of functional deficiency were defined based on hydrologic considerations (Section 5.4). *Minor* deficiency refers to the routine problems that are encountered and fixed during regular inspections of construction sites. *Moderate deficiency* occurs for rainfall events that exceed the designed sediment trapping capacity of ESC practices, whereas *Extreme functional deficiency* occurs for major storm events that exceed certain rainfall intensity or volume thresholds, and overwhelms ESC treatment capacity.

Section 3
Background on Construction in the Bay States

According to CBP, the actual disturbed area by construction sites in the Bay watershed is estimated to be around 84,500 acres or about 132 square miles each year. This amounts to about 0.02% of the total area of the Chesapeake Bay watershed. In any given year, the total construction acres may fluctuate up or down, depending on the level of development activity.

According to the Watershed Implementation Plans (WIP) developed for the Chesapeake Bay Total Maximum Daily Load (TMDL), construction runoff produces an estimated 16% of the delivered sediment load from the urban sector, and 3% of the load from all sectors combined (Sweeney, 2013). Watershed sources of sediment comprise about 60% of the total input to the Bay estuary, with the remainder coming from the ocean, shoreline erosion and internal re-suspension (Langland and Cronin, 2003).

On a unit area basis, construction sites are simulated to have the highest annual EoF sediment loads of any land use category in the Bay watershed, even when ESC practices are applied, assuming the original rate approved by CBP (see Table 3). There are some other notable sediment hotspots in the watershed, such as degraded riparian pasture, and uncontrolled extractive mining.

Table 3: Comparison of Edge of Field Sediment Loads By Land Use in the Bay Watershed (CBWM 5.3.2)

Bay Model Land Use Category	Annual EoF Sediment Load (tons/acre/year)
Construction Sites, No ESC Practices	24.4
Construction Sites, with ESC Practices [1]	14.6
Degraded Riparian Pasture	14.0
Extractive, Uncontrolled	10.0
Crops, Conventional Till	5.8
Urban Impervious Cover	5.0
Crops, Conservation Till	3.9
Pasture	1.6
Hay	1.5
Urban Pervious Cover	1.2
Forest (un-harvested)	0.3

Sources: Table 9-1 and 9-12 in Chesapeake Bay Phase 5.3 Community Watershed Model (EPA CBP, 2011)
Note: Application of BMPs can reduce sediment loads as shown above
[1] ESC practices are assumed to have a 40% removal rate, per the existing CBP-approved removal rate

Also, it should be noted that the actual sediment load *delivered* from a construction site to the Bay (or for that matter, any land use) will be lower than the EoF load. Also, the unit loads in each land river segment will vary depending on terrain factors, watershed location, proximity to the Bay and trapping by any downstream reservoirs, floodplains or river channels.

Section 3.1 How ESC is Currently Regulated in the Bay States

All Bay States have significantly strengthened their ESC sizing, design specifications and inspection requirements over the last decade, which suggests that a re-evaluation of rates is warranted. A generalized comparison of the key ESC requirements in each Bay state is provided in Table 4. More detail on how each state runs its individual ESC programs can be found in Appendix D.

Table 4
Summary characteristics of Bay States' Erosion & Sediment Control Programs

	Delaware	**Maryland**	**New York**	**Pennsylvania**	**Virginia**	**West Virginia**
First ESC regulations/ permits took effect	1991	1970	1993	1972	1973	1992
Most recent ESC Design Manual or Regulations	2013	2011 Manual effective 1/9/13	2005	Manual - 2012 Regulations – 2010	Manual--1992; Regulations--2013	2006 Manual
Area threshold for regulations	5,000 sf	5,000 sf	1 acre 5,000 sf#	5,000 sf	10,000 sf or 2,500 sf in CBPA	1 acre
Sizing requirement for on-site retention	3,600 cf/acre or one inch	3,600 cf/acre or one inch	3,600 cf/acre or one inch	6,000 cf/acre (basin); 2,000 cf/acre (trap)	3,600 cf/acre or one inch	3,600 cf/ acre; half wet, half dry
Stabilization requirement *	14 days	7 days or less	7-14 days	within 4 days	7-14 days	7- 14 days
Regulatory inspection requirements	Weekly	Every other week	Weekly. more frequent at larger sites	Every 30 days	Every 2 weeks and within 48 hrs. of a runoff event	At least one visit for all sites ≥ 3 ac.
Self-inspection requirements	Weekly	Weekly and next day after a storm event	Daily	Weekly and after each storm event.	Daily to Bi-weekly, and after each storm event	Every 7 days and within 24 hrs after storm
Construction phasing	Phasing required to keep LoD < 20 acres	Required for projects with 20 + acres	Required on all projects.	Not required	Not required	Not required

* requirements may differ for temporary vs. final stabilization
# 5,000 square feet threshold applies to the East of Hudson New York City watershed

Each state takes a unique approach to their ESC standards and specifications, and links to their core ESC programs and ESC design manuals can be found in Table 5.

Table 5 Weblinks to Each Bay State ESC Program Page and ESC Manual		
State	**Type**	**Link**
DE	Program	http://www.dnrec.delaware.gov/swc/pages/sedimentstormwater.aspx
	Manual	http://www.dnrec.state.de.us/DNREC2000/Divisions/Soil/Stormwater/New/Delaware%20ESC%20Handbook_06-05.pdf
MD	Program	http://www.mde.state.md.us/programs/Water/StormwaterManagementProgram/SoilErosionandSedimentControl/Pages/Programs/WaterPrograms/SedimentandStormwater/erosionsedimentcontrol/index.aspx
	Manuals	http://www.mde.state.md.us/programs/Water/StormwaterManagementProgram/SoilErosionandSedimentControl/Documents/2011%20MD%20Standard%20and%20Specifications%20for%20Soil%20Erosion%20and%20Sediment%20Control.pdf
NY	Program	http://www.dec.ny.gov/chemical/8694.html
	Manual	http://www.dec.ny.gov/chemical/29066.html
PA	Program	http://www.portal.state.pa.us/portal/server.pt/community/chapter_102_soil_erosion_and_sedimentation_control/10600
	Manual	http://www.elibrary.dep.state.pa.us/dsweb/View/Collection-8300
VA	Program	http://www.deq.virginia.gov/Programs/Water/StormwaterManagement/ErosionandSedimentControl.aspx
	Manual	http://www.deq.virginia.gov/Programs/Water/StormwaterManagement/Publications/ESCHandbook.aspx
WV	Page	http://www.dep.wv.gov/WWE/Programs/stormwater/csw/Pages/home.aspx
	Manual	http://www.dep.wv.gov/WWE/PROGRAMS/STORMWATER/CSW/Pages/ESC_BMP.aspx

Section 3.2 How CBWM simulates loads from construction sites

In the current Chesapeake Bay Watershed Model (CBWM), *bare-construction* is treated as a transitional land use as forest or agricultural land uses are developed. Maryland, Pennsylvania, and West Virginia provided data on the number of permitted construction acres for Bay counties for use in the Phase 5.3.2 CBWM. Maryland and Pennsylvania provided several years of permitted acres and West Virginia provided data for 2010.

The permitted construction acres were set to be proportional to the change in impervious area in the given watershed model segment to determine the ratio of permitted acres to impervious change. The state median ratio or the Bay median ratio (for states that had not submitted construction data) were used to calculate construction acreage from 1982 to 2025. The ratios are subject to change as the states provide additional data through their annual progress submissions. The ratios based on the 2012 Progress Run are summarized in Table 6.

Table 6: Estimation of state construction area, based on IC change

Area	**Ratio (Permitted acres: Impervious change)**
Chesapeake Bay Watershed	7.6
Maryland	11.8
Pennsylvania	7.1
Virginia	6.16
West Virginia	42.8

During the calibration of the CBWM, very little monitoring data was available to set target sediment loads for construction sites, with a reliance on the historic studies and literature reviews shown in Table 7.

Table 7
Summary of literature cited in CBWM documentation to determine sediment erosion from construction sites

Source (year)	**Result**	**Unit**	**Comment**
Guy and Ferguson (1962)	39 to 78	ton/ac-yr	
USEPA (2005)	7.2 to 500	ton/ac-yr	
Schueler (1987)	35 to 45	ton/ac-yr	Literature review
CBWM 5.3	***40***	***ton/ac-yr***	*discounted to **24.4 ton/ac-yr** to account for estimated exposure and duration of construction phases*

The CBWM was then calibrated to calculate sediment loads using expected annual average EoF sediment erosion target load for construction land of 24.4 tons per acre per year.

The target load accounts for the estimated exposure of bare soils, assuming an erosion rate of 40 tons/acre/year for bare disturbed areas; this value is derived from the middle range of values in Table 7 above. The target loading rate was further adjusted to account for differential soil cover that occurs during a typical year in the construction process, as shown in Table 8.

The resulting target erosion rate of 24.4 ton/ac-yr *does not include erosion and sediment control practices*, but is discounted based on estimated exposure time and duration of construction phases, summarized in Table 8. The final target load used in the CBWM calibration is considered edge of field (EoF, see Figure 3).

Associated losses of sediment in overland flow and in low-order streams diminish the sediment load to an edge of stream (EoS) input. The sediment loss between the EoF and EoS is incorporated into the CBWM as a sediment delivery ratio. Figure 2 illustrates this process.

Table 8
Estimated construction phase duration and sediment load in the CBWM

Construction phase	(A) Portion of area exposed	(B) Portion of Year for Phase	(C) Lit. Value (tons/ac-yr)	(D) = A*B*C Yield for phase (tons/ac-yr)
Clearing & grubbing for E&S controls	10%	5%	40	0.2
Clearing & grubbing for remainder of site	75%	5%	40	1.5
Grade site to rough grade, install sewer, water, roads, etc	75%	25%	40	7.5
Partial stabilization	66%	50%	40	13.2
Project completion, final grade and stabilization	34%	15%	40	2.0
Total Annual Sediment Load				**24.4**

Figure 2 – Edge of Stream Sediment Delivery Factors in the CBWM

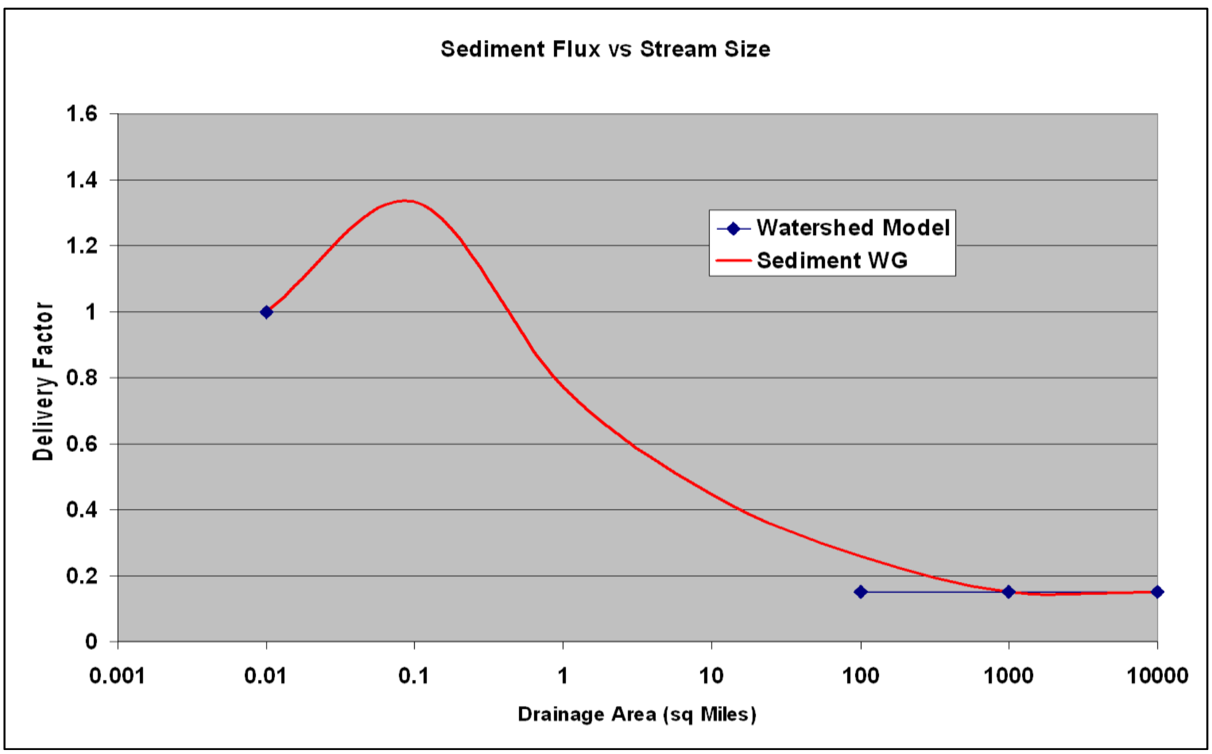
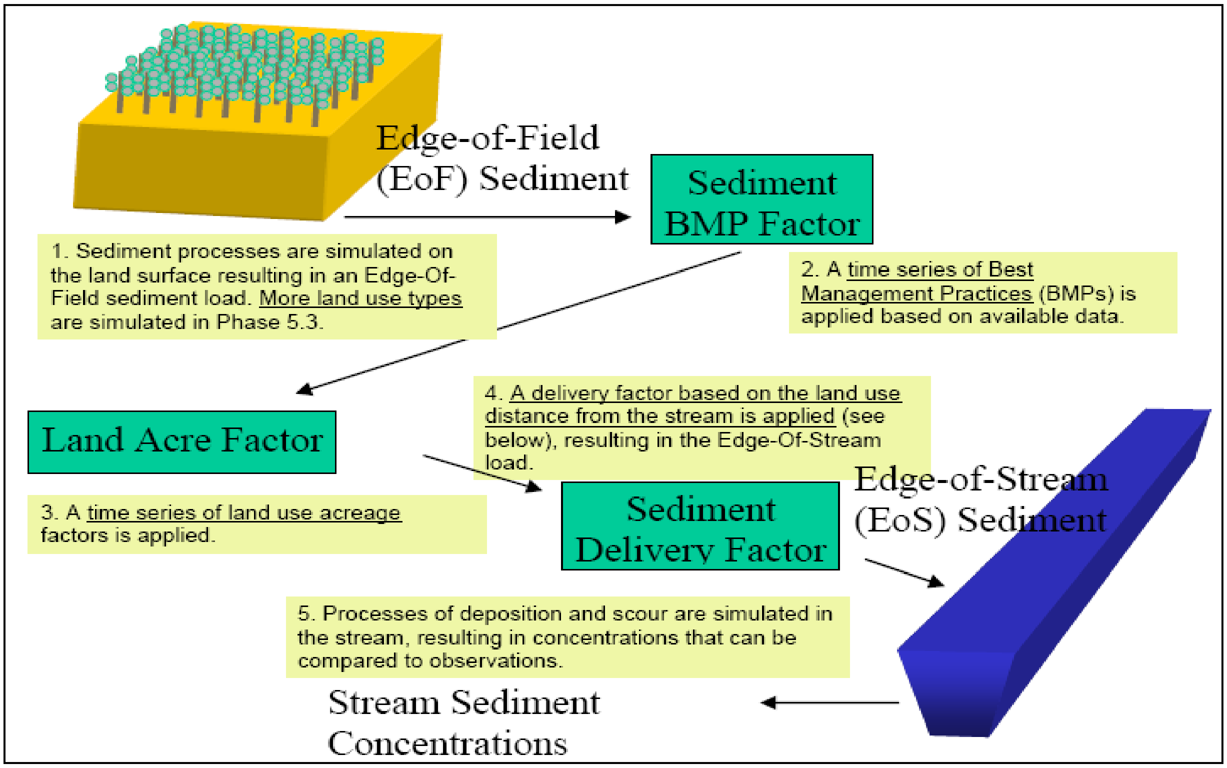


Figure 3 –Edge-of-Field (EoF), Edge-of-Stream (EoS), and Delivered Loads in the CBWM



The CBWM assumes that nutrient inputs to the bare-construction land use are from atmospheric deposition only, and simulate nutrient export based on the wash-off of the atmospheric load and the nutrients attached to soils that are eroded downstream. Target construction nutrient loading rates used to calibrate the Phase 5.3 CBWM were based on very limited literature which is summarized in Table 9.

Based on these two studies, median target values of 26.4 lb/ac-yr and 8.81 lb/ac-yr for TN and TP, respectively, were chosen. Once again, these target values are the estimated nutrient export from the bare-construction land use, assuming no erosion and sediment control practices (i.e., a "pre-BMP" condition).

Table 9
Sources of construction site nutrient loading rates in the CBWM

Source	TN load (lb/ac-yr)	TP load (lb/ac-yr)	Comment
Line and White (2001)	7.2	2.6	Residential, ESC 1
Daniel et al (1979)	12.2 to 49.5	6.7 to 17.9	Residential, ESC 1
Median target selected for CBWM	26.4	8.81	

Section 3.3 Derivation of Current and Interim Removal for ESC practices

Following a previous review of erosion and sediment control practices, the reduction efficiency for ESC practices was set at 25% for TN, and 40% for TSS and TP (Baldwin et al, 2007). The technical basis for the old removal rate was very limited and supported by two EPA literature reviews composed of studies conducted in the early 1990's or before (EPA 2000 and EPA 2005). Baldwin et al (2007) noted they had very little confidence in their effectiveness estimates, and heavily discounted them to reflect perceived real world ESC implementation problems.

In 2011, West Virginia, citing the low reduction efficiencies, requested a new BMP review for conventional ESC practices and proposed an interim efficiency for enhanced ESC practices (See Appendix E). West Virginia pointed out that various requirements in their general permit (e.g., basin storage volume, dewatering time, etc.) implied much greater nutrient and sediment removal efficiencies. The proposed interim rate for "enhanced" ESC practices were established as 80% removal for TN, TP and TSS, pending the work of this expert panel.

Section 4
Review of the Available Science: Construction Site Hydrology

4.1 Review of Construction Site Runoff Coefficients

The Panel began by reviewing construction site hydrology research as it concluded that a good understanding of the runoff volume generated from construction sites would be crucial factor in developing more accurate and reliable estimates of sediment loading.

The monitoring and modeling literature for construction site hydrology was rather sparse, but the Panel did analyze four independent lines of evidence that converged on a common estimate for the annual runoff coefficient for construction sites. The runoff coefficient (Rv) expresses what fraction of annual rainfall volume is converted to construction site runoff volume (Schueler, 1987), as measured by on-site rainfall gauges and automated flow measurements.

The first line of evidence was the only known study that actually comprehensively monitored the hydrologic response of a construction site to rainfall over the long term. Line and White (2007) measured the runoff coefficient during construction, final stabilization and post- construction conditions at residential development site in the NC Piedmont with soils in the HSG D category.

The storm-weighted Rv for the construction phase was 0.50 and rose to 0.60 during the landscape establishment phase (Table 10). These Rv's indicate that 50 to 60% of the rainfall over the construction site was converted into storm runoff. The key point is that construction sites are not just bare soil, but have compacted soils, impervious cover and storm drains installed during the construction process.

Table 10 Summary of Monitoring Results (N= 106 storms)
Line and White (2007) NC Piedmont [5]

STAGE	Runoff Coefficient	TSS (tons/acre)
Construction [1]	0.50	13
Establishment [2]	0.60	2.8
Post Construction [3]	0.55	0.9
Undeveloped [4]	0.21	0.16

[1] from initial clearing , grading, installation of infrastructure and seeding (0.7 years)
[2] Most homes constructed, and lawns and landscaping are becoming established (1.4 years)
[3] After home build out (3.6 years)
[4] Undeveloped reference watershed
[5] 6 years of sampling during and after construction at a 10 acre residential subdivision, compared to an undeveloped reference forest catchment less than a mile away (also sampled for same 5.6 years)

The second line of evidence was a national modeling assessment by EPA (2009). The EPA analysis of construction site loading included the derivation of runoff coefficients and discharged sediment loads for construction sites. The RUSLE model was used for the analysis, which was done for several hundred subwatersheds nationwide, using many recent data sources to define model parameters.

Of particular interest to the Panel were their estimates of the runoff coefficient , as documented in Sections 9 and 10 of their report (EPA, 2009). Table 11 shows the "annual" volumetric runoff coefficients for a typical construction site throughout the year, based on HSG, as well as higher Rv associated with a single high intensity event (the 2 year design storm event).

Table 11
Reported Volumetric Runoff Coefficient (Rv) for Construction Sites by Hydrologic Soil Groups

	HSG A	HSG B	HSG C	HSG D
Annual Rv [1]	0.15	0.27	0.39	0.49
Rv for 2 year Design Storm	0.37	0.57	0.70	0.79

[1] for the technical assumptions, see Section 9 and 10 of EPA (2009)

EPA (2009) also reported the fraction of acres within the four hydrological soil groups (HSG) for the Bay states, which is shown in Table 12. Based on the EPA analysis, the Panel computed a HSG-weighted average Rv for the typical "annual" construction site in the Bay watershed, by multiplying the values of in Table 11 and 12 together, which are shown in Table 13.

Table 12 Percent of each of the 4 HSG's in each Bay State [1]

Bay State	HSG A	HSG B	HSG C	HSG D
Delaware	21	31	13	35
Maryland	10	39	26	25
Pennsylvania	6	28	54	12
New York	10	19	51	21
Virginia	2	54	32	12
West Virginia	7	22	54	17
Mean of States [2]	**9%**	**32%**	**38%**	**21%**
Bay-Weighted MEAN [3]	**6%**	**38%**	**40%**	**16%**

[1] State-wide from STATSGO
[2] Value shown is simply the mean of the six Bay states, including non-Bay watershed area
[3] Mean adjusted to account for fraction of total state area that is located in Bay watershed

While the EPA (2009) data did not permit a precise calculation of an Rv for the portion of each state contained with the Bay watershed, Table 13 does show that the computed Bay-wide and individual state -wide construction Rvs were fairly consistent at about 0.35

.

Table 13 Computed Annual Construction Rv Using the EPA (2009) method	
State	Annual Rv
Delaware	0.34
Maryland	0.34
Pennsylvania	0.35
New York	0.37
Virginia	0.33
West Virginia	0.36
Mean of States [2]	**0.35**
Bay-Weighted MEAN [3]	**0.35**

The third line of evidence was a long-term analysis of the hydrologic response of Birmingham, Alabama construction sites to rainfall conducted by Pitt (2004). The study computed a weighted volumetric runoff coefficient for construction sites of 0.36, based on three decades of rain fall analysis. Pitt did not provide any information as to the hydrologic soil group that was assumed for the construction site analysis. Pitt noted that runoff coefficients were as low as 0.27 for rainfall events less than a half inch, and climbed to 0.48 for storms above 3 inches.

The last line of evidence on construction site hydrology used the NRCS TR-55 model, which is widely used in the design of ESC practices. An event based Rv can be derived through curve number calculations. Don Lake, who served on the panel, provided calculations for three construction scenarios, assuming they were located on HSG C soils during a **two inch** rain event. The back-calculated Rv's were:

Scenario A: Residential Construction Site: 0.50
Scenario B: Commercial Construction Site: 0.63
Scenario C: Highway Construction Site: 0.68

4.2 Panel Findings and Recommendations

The Panel reviewed the four lines of evidence and they converged in several respects. First, construction site runoff coefficients were much higher than would be simply indicated by a "bare soil" condition since impervious cover is progressively added during construction operations. The Rv increases with greater rainfall depth and intensity and also as soils move from HSG A to HSG D categories. Given that there is good distribution data on HSG for each Bay state, it was possible to compute weighted state average that were useful to characterize aggregate soil conditions for construction sites (which ranges around 0.35 on an annual basis).

The Panel considered that its estimates of construction site Rv to be conservative, primarily because the reliance on HSG for determining runoff assumes that soils are not compacted. The very nature of construction operations violates this assumption, given grading and scraping by earth moving equipment, engineered compaction for structural and stability purposes, and tracking and compression by construction vehicles.

Consequently, construction site soils are likely to have a greater runoff response than would be predicted from their undisturbed hydrologic soil group alone. At the present time, however, there is no research available to enable a more precise definition of the increased Rv associated with soil disturbance at construction sites.

In addition, the Panel noted that the runoff volumes produced by intense storms can overwhelm the trapping capacity of ESC practices, thereby diminishing their sediment removal performance. Consequently, the Panel developed operational definitions of this functional deficiency based on rainfall depth and intensity.

Section 5
Review of the Available Science: Sediment Loads and Turbidity Discharged from Construction Sites

5.1 Historic Studies of Construction Site Sediment Loads, without ESC Practices

The Panel evaluated historical research to determine the sediment load from construction sites in the absence of any erosion and sediment controls, and expand on the literature reviewed by the original expert panel report.

Several important points need to be kept in mind when looking at historical construction monitoring data:

> The first point to consider is the difference in how land was developed during the era in which data was collected (i.e., 1960' and 1970's), and in particular, the lack of environmental regulations. During this era, there were no clearing or grading restrictions, and one could build in streams, non-tidal wetlands, floodplains and steep slopes. There were also no stream or shoreline buffer, resource protection or forest conservation requirements in place to limit land disturbance.
>
> Consequently, extensive mass grading occurred over most, if not the entire site, during this era. Road construction techniques during this era also tended to promote massive erosion. Given the many different environmental regulations that now govern land development, it is probable that current construction site sediment loads would be lower, even in the absence of any ESC practices.
>
> The second point is that ESC requirements have been in place for decades at construction sites throughout the Bay watershed, so that it is virtually impossible to obtain monitoring data for construction sites that mimics the historical bare soil condition (i.e., nearly all construction sites have some kind of erosion control and sediment control practices in place that reduce sediment loads).
>
> The third point is that the monitoring and data analysis methods used in the historic construction research were probably less accurate, as researchers of the time did not have modern automated samplers, rain gauges, computers, and electronic laboratory analyzers. Grab samples were used to measure sediment concentrations, and the various devices used to measure flow were less accurate.
>
> The last point is that many of the historic studies were not able to segregate out stream channel and hill-slope erosion from their sediment load estimates. Consequently, the extremely high construction site sediment loads may be biased a bit high (which is not to diminish their critical influence in getting the first erosion and sediment control laws enacted).

The Panel reviewed five of the historic studies, which are shown in the shaded cells in Table 14. The historical sediment loads from construction sites without ESC practices ranged from about 50 to 300 tons/acre/year, which is well above the 24.4 tons/acre/year assumed in CBWM.

Six studies were discovered that measured sediment loads for construction sites that employed ESC practices, and these ranged from about 2 to 20 tons/acre/year. When the loads from historic construction studies are compared with recent studies for sites served by ESC practices, it is clear that ESC practices sharply reduce sediment loads from construction sites, even if the sample size is small, and given the provisos cited earlier about the quality of historic monitoring data.

Table 14
Measured Sediment Loading Rates for Construction Sites, w or w/o ESC.

Study	Region	Tons/acre/year	ESC Used?	Notes
CBWM	Bay	24.4	No	Model Assumption
Yorke and Herb, 1978	MD	33	No	
Nelson, 1984	SE US	100 to 300	No	
Cleaves et al, 1970	SE US	218.9	No	
Likens and Borman, 1974	NE US	48.4	No	
Cywin and Hendricks, 1969	SE US	134	No	
Line and White,2007	NC	13.0	Yes	Residential
Daniel et al, 1979	WI	7.8	Yes	Residential
Line, 2007	NC	18.5	Yes	Highway
Line and White, 2001	NC	4.4	Yes	Residential
Owens et al, 2000	WI	1.7-6.7	Yes	Resid./Comm.
Lee and Ziegler, 2010	KS	0.5 to 2.5	Yes	Residential

The Panel developed estimates of sediment loads from construction sites in the absence of erosion and sediment controls using the Simple Method (Schueler, 1987) to estimate annual loads. Model parameters (Rv, EMC) were developed for a worst case, average case or best case scenario, and a composite average of all three scenarios was used to derive an annual sediment load estimate. The technical assumptions for the computations are provided in Appendix A.

Based on these methods, construction sites are estimated to have an annual sediment load of 12 tons/acre/year in the absence of ESC practices. This represents about 50% of the current target sediment load used in the CBWM.

Section 5.2 TSS Concentrations Discharged from Construction Sites, as Modified by ESC Practices

The Panel concluded that it was important to characterize sediment concentrations discharged from construction sites with ESC practices. The primary data sources were about a dozen monitoring studies that measured inflow and outflow TSS concentrations from construction sites, usually from a sediment basin discharge located at its drainage outflow.

The Panel classified each study/monitoring site according to the three levels of ESC performance as previously defined in Section 2. None of the studies could be classified as Level 3 or 4; 17 sites that were classified as either Level 1 or Level 2. Table 15 shows the inflow and outflow TSS concentrations that were measured, and the differences noted between Level 1 and 2 ESC practice.

The first key finding is that TSS inflow concentrations are exceptionally variable across construction sites, and ranged from about 300 mg/l to 17,000 mg/l. The high variability is not surprising given the influence of soil, slope, cover, ESC practice level, storm size and intensity and other factors on sediment erosion. It should also be noted that the TSS inflow concentrations were presumably influenced by up-slope erosion control practices used to increase soil cover.

Table 15 TSS Concentrations in relationship to ESC Practice Level, Summary

ESC Level	Study	TSS IN (Mg/l)	TSS OUT (Mg/l)	Efficiency	Region	Notes
1	Schueler and Lugbill (1990)	359 4623 625 415 2670	224 127 322 91 876	18 99 55 80 67	Piedmont MD	5 Residential Basins and Traps
1	Horner et al 1990	1087	63	--	Seattle WA	Highway Sediment Basin
1	Line and White (2007)	--	--	59-69	NC	Residential with Sed trap
1	Islam et al 1998	2932	3507	35%	Ohio	Basins
1	Kalainsan, 2008	314	77	15 %	PA	Basins
1	Cleveland and Fashokun (2006)	1227	2018	Nsd	TX	Basin
LEVEL 1 MEANS		**1583**	**812**	**49%/50%**	First is based on level 1 means, second is mean percent removal	
2	Fennessy and Jarrett, 1997	1260	300	~ 90%	PA	Basins
2	Jarrett, 1996	9700	800	94.2	PA	Basin
2	Gharabaghi et al 2007	Nd	177	99%	ONT	Basins
2	Babcock and McLaughlin 2008	4601	1509	68%	NC	Cut slopes
2	Horner et al 1990	17,438 3502	154 626	99% 75%	WA	Experimental basins
2	McLaughlin, 2007	220-300	50 to 100	Significantly different	NC	PAM/mulch
2	Soupir et al 2004	6537	369-4800	46-93%	NC	Test plots, low PAM excluded
Level 2 MEAN		**6188**	**557**	**90%/83%**	First is based on level 1 means, second is mean percent removal	
Grand Mean, All Levels		**3598**				

The second finding is that the data indicate a difference in the performance of practices designed to Level 1 and Level 2. The mean outflow TSS concentrations from construction sites served by Level 1 practices was 812 mg/l, or about a 50% reduction of the inflow concentration.

By contrast, the mean outflow TSS concentration from Level 2 practices was 557 mg/l, which represented an 80 to 90% decrease from their TSS inflow concentration(which was higher for Level 2 practices than Level 1 practices).

Several researchers have noted that as much as 50% of the construction site TSS concentrations appear to be internally generated within individual ESC practices (i.e., erosion within temporary dikes, ditched and channel, as well as erosion of bed and banks of sediment basins and traps -- Madaras and Jarrett, 2000, Fennessey, 1994 and Kang et al 2013).

Given the variability in TSS concentrations, the Panel developed a method to define the performance of Level 1, 2 and 3 ESC practices. The method computed an annual sediment load using the Simple Method, based on technical assumptions as to what range of event mean concentrations (EMC) and runoff coefficients (Rv) would best characterize Level 1, 2 and 3 ESC practices. The analysis entailed three different construction site scenarios -- worst case, mid-range and best case. The average of the three scenarios was then used to compute a "best estimate" for annual sediment load for each ESC level under normal conditions, as shown in Table 16. For a full description of the technical assumptions involved in each scenario, consult Appendix A.

Table 16 Comparative Summary of ESC Scenarios (tons/ac/yr)

ESC Scenario	Worst Case	Mid-point Case	Best Case	**Best Estimate**
Construction w/o ESC	22.3	8.6	5.1	**12.0**
Sites Operating at Level 1	2.5	1.8	1.1	**1.8**
Sites Operating at Level 2	1.6	1.0	0.7	**1.1**
Sites Operating at Level 3	1.05	0.57	0.31	**0.65**
Sites Operating at Level 4	ND	ND	ND	**ND**
Important Note: Actual sediment loads for all 4 ESC levels will be higher when moderate and extreme storms exceed or overwhelm ESC capacity, and thus create functional deficiency, and much lower removal rates. ND= No data				

The Panel compared these estimates to other monitoring and modeling studies of Level 1 ESC sites. For example, a national RUSLE modeling study calculated annual sediment loss for construction sites that had a defined baseline of ESC practice that generally corresponds to Level 1 (EPA, 2009). Nationally, EPA estimated that construction site sediment loss averaged 3.03 tons/acre/yr, and state-wide averages for individual Bay states ranged from 1.56 to 3.42 tons/acre/year.

A Wisconsin monitoring study of small construction sites operating at Level 1 by Owens et al (2000) reported annual sediment loads of 1.65 tons/ac/yr at a residential site and 6.7 tons/ac/yr for a commercial site. A more recent study of Kansas constructions sites operating at Level 1 reported annual sediment loads ranging from 0.5 to 2.5 tons/ac/yr (Lee and Ziegler, 2010).

Based on these comparisons, the Panel felt the computed loads for construction sites in the Bay watershed as shown in Table 16 are technically justified for normal site conditions, but need to be adjusted upward to account for higher loadings during periods of moderate to extreme functional deficiency.

While the Panel primarily focused on the cumulative impact of the entire set of ESC practices installed at a construction site, it did review many research studies that evaluated the sediment removal performance of individual ESC practices, with an eye toward the specific design features that promote greater sediment removal, some of which are profiled in Appendix C.

Section 5.3 Turbidity Levels Discharged From Construction Sites

Table 17 shows a representative summary of turbidity levels discharged from construction sites. Once again, the Panel classified each study according to its presumed ESC performance level.

Table 17 Turbidity in relationship to ESC Practice Level, Summary of Literature (NTUs)

Level	Study	Turbidity IN	Turbidity OUT	reduction	State	Notes
1	Schueler and Lugbill , 1990	600	200	++	MD	Basins and Traps
1	Kayhansana, 2000	--	702		CA	
1	McLaughlin et al 2009	6700	7014	-	NC	
1	Bhardwaj 2008	227	155	+	NC	Test basin
1	Cleveland & Fakoshun, 2006	141	159	-	OH	Basins
2	McLaughlin and King, 2008	2139	3449	--	NC	JACK
2	McLaughlin and King, 2008	5100	4790	+	NC	BUNC
2	McLaughlin and King, 2008	1381	382	++	NC	WAKE
2	Kang et al, 2013	--	420		NC	
LEVEL 1 and 2 MEANS		**2327**	**1919**			
3	Bhardwaj 2008			++	NC	PAM
3	Hayes et al, 2005	461	103	++	NC	PAM
3	McLaughlin, 2007	250-400	50 to 100	++	NC	PAM
3	McLaughlin et al 2009	1990	276	++	NC	PAM
3	McLaughlin et al 2009	3117	278	++	NC	PAM
3	Kang et al 2013	--	94	++	NC	PAM
LEVEL 3 MEANS		**1473**	**165**	**++**		

One of the key findings is the enormous variability in inflow turbidity levels, which can range from about 150 NTUs to more than 7000 NTUs. To put that into perspective, several Bay states have adopted turbidity standards for the protection of aquatic life that define a threshold level of 150 to 200 NTU for a water quality standard violation.

The second key finding is that it is much harder to control turbidity than TSS at construction sites. As can be seen, most construction sites served by Level 1 and 2 ESC practices have limited ability to achieve turbidity reductions, and some sites actually experienced negative turbidity efficiencies.

The six experimental studies on Level 3 ESC practices that used PAM show much more capability to reduce turbidity levels to around 50 to 300 NTU, but more research is needed to make a definitive conclusion. It should be noted that no Bay state currently requires Level 3 or Level 4 ESC practices on a state-wide basis.

5.4 Defining the Sediment Removal Performance of Functionally Deficient Sites

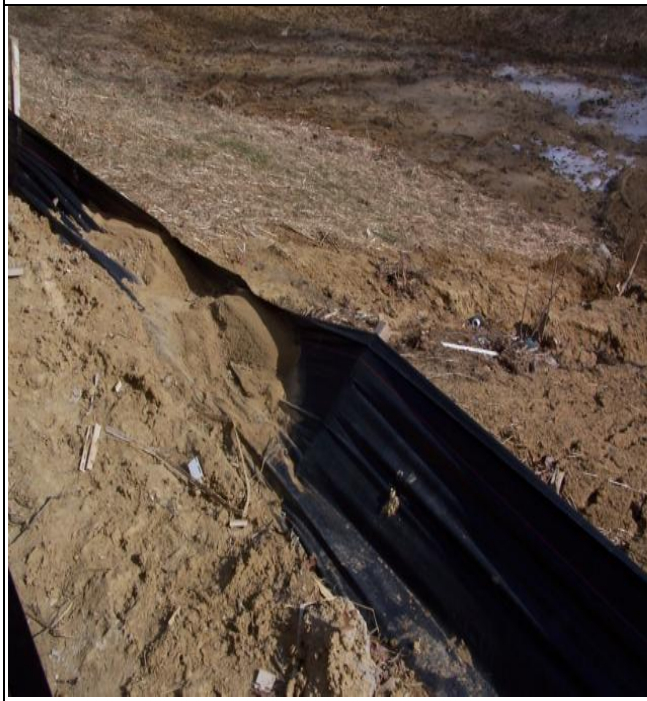
The Panel agreed that some fraction of construction sites in the watershed are functionally deficient, and will discharge sediment at levels well above those computed for the four ESC levels shown in Table 16. The photos shown in Table 18, all of which were taken in the last few years, clearly show major failures of ESC practices that significantly compromise their sediment removal function.

ESC sites can become functionally deficient even when local and state governments operate effective ESC programs for several reasons. First, weather factors such as intense thunderstorms, tropical depressions, extended droughts, exceptionally wet seasons, hard winters and early frosts cannot be eliminated, and each of these factors can quickly diminish the overall performance of any ESC practice. Failure caused by these weather conditions can eventually be fixed with diligent maintenance and repairs, but there will frequently be short periods where the system is not functioning as designed.

The second reason is the failure of the many different contractors involved in the construction process to understand and properly implement and maintain the prescribed practices in the ESC plan or permit. In other cases, the operator at the construction site may not to want incur additional costs associated to install, maintain, and especially repair ESC practices unless they are forced to by a regulatory authority.

Consequently, the Panel decided to define the fraction of construction sites that are functionally deficient over some part of the year, and thereby be subject to a lower sediment removal rate. The Panel distinguished three levels of functional deficiency -- minor, moderate and extreme.

Table 18:
Photos of Construction Sites with Functionally Deficient Practices

	
Silt fence that was overpowered in a heavy rain. Soil has collapsed the fence and erosion has formed a small gully. *Photo credit: Bruce Young*	Residential construction area where controls have been overwhelmed and large amounts of soil have eroded into the street. *Photo credit: Randy Greer*
	
Erosion and sedimentation due to poor design, lack of maintenance and insufficient stabilization. *Photo credit: Bruce Young*	The construction entrance and silt fence failed to keep soil from eroding onto the street. *Photo credit: Randy Greer*

Minor deficiencies include the normal problems that are routinely noted during a regulatory inspection (i.e., fixing a fallen section of silt fence, cleaning out a sediment basin, repairing an eroded dike). These individual problems certainly need to be quickly fixed, but they usually will not compromise the entire function of the system of ESC practices as a whole. Indeed, most of the monitoring studies for which sediment loads were computed were likely to have minor deficiencies at some point in the construction process.

Moderate deficiency occurs when the depth of rainfall exceeds the hydrologic design capacity of the ESC controls at the site, thereby diminishing their performance. For example, Level 1 ESC practices are designed to trap a half inch of rainfall, whereas Level 2 and 3 ESC practices are designed to treat one inch of rainfall. Storms in excess of these rainfall depths cause runoff bypass or overflow, as well as significant degradation of individual ESC practices.

Two previous Urban Expert Panels derived long-term rainfall frequency analyses (1977-2007) and developed adjustor curves to define sediment removal rates based on the design capacity of stormwater treatment (ST) practices up to 2.5 inches/day (SPSEP, 2012, SREP, 2012). Based on these curves, this Panel concluded that Level 1 ESC practices are exposed to moderate deficiency conditions during approximately 25% of the annual rainfall volume, whereas Level 2/3 ESC practices are exposed to moderate deficiency about 15% of the time (see Appendix A).

During periods of moderate functional deficiency, the sediment removal function ESC practices is sharply diminished, but does not go to zero. The Panel estimated an average of sediment loading for ESC practices under moderate functional deficiency of 4.3 tons/acre/year, which was then pro-rated by the fraction of the year in which this condition occurs (see Table A-5 in Appendix A). This loading rate is adjusted to apply for the proportion of the year for which a site is expected to experience moderately deficient conditions, and is added to the base loading rate for the appropriate level of ESC practice.

Extreme functional deficiency occurs during the rare storms that completely overwhelm the treatment capacity of ESC practices such that their collective sediment removal function is severely compromised. These conditions are expected to occur when hourly or daily rainfall intensities meet or exceed the following thresholds in any CBWM time step:

- 2.5 inches per day
- 1.5 inches per hour

During these extreme conditions, the ESC practices at construction sites are expected to fail completely, and discharge sediment at the no-ESC level of 12 tons/acre/year. For the technical assumptions the Panel used to define the no-ESC level, see Appendix A.

5.5 Panel Findings and Recommended Sediment Removal Rates

Based on the preceding review, the Panel recommends the sediment removal rates for the four levels of ESC practices for construction sites, as shown in Table 19. The sediment removal rates are expressed relative to the no-ESC condition of 12 tons/acre/year, as defined by the Panel in Appendix A. These rates should be applied to the construction site sediment loads generated under the existing CBWM. At the present time, all construction acres in each state are assumed to be operating at ESC Level 2.

Table 19 Computation of Sediment Removal Rates for Four Levels of ESC

ESC Scenario	Discharged Load [1]	Removal Rate	MFD [2] Adjustment	Effective Removal Rate [3]
Sites Operating at ESC Level 1	1.8	85%	3.1	**74%**
Sites Operating at ESC Level 2	**1.1**	**92%**	**1.8**	**85%**
Sites Operating at ESC Level 3	0.6	95%	1.3	**90%**
Sites Operating at ESC Level 4	ND	ND	ND	**ND**

[1] Best estimate for normal ESC site conditions from Table 16
[2] Additional sediment load discharged during conditions of moderate functional deficiency added to the discharged load
[3] Actual loads for all ESC Levels will be slightly higher to reflect extreme functional deficiency during the rare storms that exceed the rainfall volume/intensity thresholds.
ND: No monitoring data was available to compute an estimates for Level 4 ESC

The Panel also concluded that the current CBWM non-ESC target sediment load of 24.4 tons/ac/year too generous and recommends that it be reduced to 12 tons/acre/year in the next version of the CBWM.

Lastly, the Panel concluded that states and localities should strive to improve their ESC programs to achieve a higher and more reliable level of turbidity control. The fine-grained particles that create turbidity are likely to have a higher delivery ratio to the Chesapeake Bay, given that it takes days or even weeks for them to settle out of the water column. ESC program improvements to shift a Level 3 ESC practice would have the further benefit of reducing the impact of turbidity on aquatic health and diversity in the streams, lakes and estuaries that discharge to the Bay.

Section 6
Review of the Available Science:
Nutrient Dynamics on Construction Sites

6.1 Current Construction Site Nutrient Loading Assumptions in CBWM

The Panel began by examining the current target TN and TP unit area loading rates for construction sites used in the CBWM, and see how they compared to the EMC concentrations for post-construction runoff (Table 20 and 21). In the case of TN, construction sites had an average storm event mean concentration (EMC) of around 5 to 6 mg/l, which is 2.5 to 3 times the EMC for post construction storm runoff, as measured or modeled. The same basic trend was also observed for TP, in which the construction site EMC was three to five times higher than the post-construction EMC, as defined by monitoring data or model simulations.

Table 20
Summary of Modeled and Measured TN Yield from Construction Sites (lbs/acre/year)

Method	Load	Implied EMC mg/l	Notes
CBWM No ESC Practices	26.4	6.22	
CBWM w/ ESC Practices	21.2	4.98	25% Removal Rate
Median Urban Runoff		2.0	N=3100 (Pitt et al, 2004)
CBWM: Impervious Cover	16.6	2.14	Atmospheric deposition
CBWM: Urban Pervious Cover	12.4	1.6	

Table 21
Comparison of Modeled and Measured TP Yield from Construction Sites (lbs/acre/year)

Method	Load	Implied EMC mg/l	Notes
CBWM No ESC Practices	8.8	2.08	
CBWM w/ ESC Practices	5.3	1.25	40% Removal Rate
Median Urban Runoff		0.30	N=3100 (Pitt et al, 2004)
CBWM: Impervious Cover	1.9	0.25	
CBWM: Urban Pervious Cover	0.8	0.41	

6.2 Potential Nutrient Loss Pathways at Construction Sites

At least five potential pathways could produce nutrient export from construction sites:

1. Nutrients attached to eroded soils
2. Wash off of fertilizer due to hydro-seeding and permanent stabilization
3. Wash-off of nutrients deposited from the atmosphere
4. Decay of organic material used to cover soil (i.e., compost, mulches, erosion control blankets, etc)
5. Leaching into groundwater (primarily nitrate).

Pathway 1: Nutrients Attached to Eroded Soil

The first pathway involves the loss of nutrients that are attached to eroded sediments that leave the site. Although sediment loads are high at construction sites, the soils are not highly enriched with nutrients. The main reason is the sharp decline in soil nutrient content as one goes down the soil profile (i.e., from topsoil (horizon O), lower soil layers (Horizon A/B) and finally the sub soils. Topsoil is highly enriched with nutrients (Table 22), but nutrient content drops sharply through the A and B horizon, and is even lower in sub-soils.

The significance of this fact is that most of the nutrient-rich topsoil at construction sites are removed and stock-piled at the onset of construction operations. Topsoil is a valuable commodity at most construction sites and is either sold or used as a top-dressing during final stabilization. Consequently, the majority of excavated soils exposed to erosion have a very low nutrient content.

Table 22 Example of Nutrient Content by Soil Horizon in USDA Soil Survey

	Silt Loam	Loamy Sand
Organic Content	O Horizon: 5.5% AB Horizon: 1.8%	O Horizon: 9.5% AB Horizon: 1.4%
Cation Exchange Capacity [CEC] (meq/100 g)	O Horizon: 19 AB Horizon: 12	O Horizon: 15 AB Horizon: 11
Total Nitrogen (mg/kg)	O Horizon: 2,900 AB Horizon: 1,000	O Horizon: 4,700 AB Horizon: 700
Total Phosphorus (mg/kg)	O Horizon: 35 AB Horizon: 5	O Horizon: 16 AB Horizon: 2

Pathway 2: Fertilizer Wash-off

The second source of possible nutrient loss are the fertilizers applied during temporary and permanent stabilization. Most Bay state ESC specifications call for high fertilizer applications to establish a dense grass cover in the shortest time possible to prevent soil erosion. Most ESC professionals, as well as the expert panel, agree that rapid and dense vegetative stabilization is a critical element of erosion control, and is a major factor in preventing soil loss.

Table 23 summarizes the current Bay state requirements or recommendations for N and P fertilization rates during temporary and permanent stabilization. The mean application rate in the Bay states for TP is 74 lbs per acre, and TN is 114 lbs per acre, most of which is water-soluble and in readily available forms. Several fertilizer applications can be made during the course of most construction operations.

The initial application typically involves hydro-seeding for temporary stabilization in which a mix of seed, fertilizer, straw mulch, cellulose, tackifiers and water is blown over exposed soils. Hydro-seeding may need to be repeated if the grass does not take. A second application of starter fertilizer is typically made at the end of construction to establish stronger turf and landscaping.

Table 23
Comparison of fertilization recommendations for temporary and permanent stabilization in the Bay states

State	Fertilizer Formulation	Application Rate	N Rate	P Rate	Comment
DE	10-10-10	600 lbs/ac	60 lbs/ac	26.2 lbs/ac	Temp seeding
MD	10-20-20	436 lbs/ac	43.6 lbs/ac	38.1lbs/ac	Temp seeding
	10-20-20	436 lbs/ac	43.6 lbs/ac	38.1 lbs/ac	Perm seeding
NY	5-10-10	600 lbs/ac	30 lbs/ac	26.2 lbs/ac	Perm seeding*
PA	10-10-20	1000 lbs/ac	100 lbs/ac	43.7 lbs/ac	Perm seeding
	10-10-10	500 lbs/ac	50 lbs/ac	21.9 lbs/ac	Temp seeding
VA	10-20-10	500 lbs/ac	50 lbs/ac	43.7 lbs/ac	Perm seeding
	10-10-10	450 lbs/ac	45 lbs/ac	19.7 lbs/ac	Temp seeding
WV	10-20-10	1000 lbs/ac	100 lbs/ac	87.4 lbs/ac	Perm seeding*
Average			**49.7 lbs/ac**	**26.5 lbs/ac**	**Temp seeding**
			64.7 lbs/ac	**47.8 lbs/ac**	**Perm seeding**

*Fertilizer not recommended for temporary seeding
Note: These are the suggested application rates in the absence of soil tests or applicable nutrient management plans.
Source: respective state erosion and sediment control manual (see Table 5 for links)

These high fertilizer inputs are especially vulnerable to wash-off during the three to four weeks it takes for the grass to germinate and become well-established. Any intense storm that occurs during this germination window produces a very high risk of nutrient wash-off, particularly since a third to a half of rainfall that falls on a construction site is converted into runoff.

The risk for wash-off continues to be high even after grass is established. The Urban Nutrient Management Expert Panel identified 12 risk factors that increase the potential for high nutrient loss in its final recommendations (UNMEP, 2013). Most construction sites will typically have seven or more of these high export risk factors. Consequently, construction sites more than qualify as being in the high risk category (5% loss of applied nutrients), according to the UNM panel. Loss rates could easily be higher if intense storms occur during the bare-soil window.

Pathway 3: Wash-off of Atmospherically Deposited Nutrients

The third potential pathway involves the wash-off of nutrients that are deposited from the atmosphere. The potential for wash-off is high due to the fact that a third to a half of all rainfall over the construction sites will be converted into runoff, as compared to a mature lawn, which may experience little or no surface runoff.

Pathway 4: Decay and Wash-off of Organic Material

The fourth potential source of nutrient loss involves the decay of various organic materials that are used to temporarily cover soils and prevent erosion. These materials can include straw, mulch, wood chips, compost, erosion control blankets and organic tackifiers. In addition, certain ESC practices may utilize the same organic materials to improve sediment trapping performance.

As the material decays, there is a risk that nutrients could be exported downstream in either organic or inorganic forms. Relatively little research has been done to define this loss pathway, although Faucette et al (2005 and 2007) has reported significant nutrient export in a controlled study of the effectiveness of mulch and compost blanket practices.

Pathway 5: Leaching to Groundwater

The last pathway involves the infiltration of nutrients into the soils of construction sites and their eventual migration to streams. This could be a significant pathway for nitrate, but is probably not important for phosphorus. No lysimeter or groundwater monitoring data were available to evaluate the risk of leaching.

6.3 Mass Balance Check on CBWM Construction Site Nutrient Loading Rates

The Panel conducted a mass balance analysis to estimate nutrient loss under each of the four pathways that could be estimated, using a series of technical assumptions for best case, average case and worst case conditions. The methods and assumptions that the Panel used are fully described in Appendix B.

The purpose of the mass-balance analysis was to determine if the existing CBWM target nutrient loads for construction sites could be generally validated given how little monitoring data was available to measure them. Table 24 summarizes the mass balance estimates for all four loss pathways for each nutrient, and compares them to modeled loads used in CBWM. As can be seen, the CBWM load estimates fit squarely in the middle of the Panel's mass balance estimates for both nitrogen and phosphorus.

The Panel acknowledges all of the limitations and uncertainties inherent in its mass balance analysis, but was confident that the existing CBWM nutrient loads were consistent with what might be expected at a construction site.

Table 24
Comparison of Nutrient Loadings by all Five Pathways (low, medium or high) (lbs/ac/yr)

	Total Nitrogen			Total Phosphorus		
	Low	Med	High	Low	Med	High
Pathway 1	2.8	11.2	16.8	0.08	0.30	0.46
Pathway 2	1.1	5.7	11.4	0.7	3.7	7.4
Pathway 3	1.3	3.9	6.5	0.07	0.2	0.4
Pathway 4	0.7	2.8	4.2	0.2	0.8	1.2
Total	**5.9**	**23.6**	**38.9**	**1.1**	**5.0**	**9.5**
CBWM	**26.4**			**8.8**		

Note: N migration to groundwater was not included in the analysis, so N load mass balance may be conservative.

6.4 Review of Nutrient Monitoring Data from Construction Sites

The Panel was able to find ten recent research studies that measured nutrient EMCs at construction sites which are compared in Table 25.

Table 25: Comparison of nutrient concentrations in construction site runoff (mg/l)

Study	TN	DIN	TP	Notes
Kayhanina et al 2001	3.5	1.06	0.95	California, N=72 Highway
Line, 2007	1.7		0.47	NC, N=16
Cleveland and Fashokun, 2006		1.26	0.47 *	Above basin
Cleveland and Fashokun, 2006		1.57	0.21 *	Below basin
Kalanaisan et al 2008			0.72 *	Below basin
Soupir et al 2004	57.5	15.96	5.6	Fertilized test Plot
Faucette et al 2008	Nd	Nd	31.8	Fertilized test plot
McLaughlin and King, 2008	5.18	Nd	3.1	JACK
McLaughlin and King, 2008	19.8		34.6	BUNC
McLaughlin and King, 2008	3.78		0.3	WAKE
Horner et al, 1990	--	--	In: 12.3/2.25/0.55 Out: 0.44/0.6/0.14	3 basins in Seattle
Post Construction Stormwater Runoff	2.0	0.6	0.3	NSQD (Pitt et al, 2004)
Only measured as phosphate, not total P				

It should be noted that most studies had a rather small sample size. For comparison purposes, the construction site nutrient EMCs are also compared to EMCs for post construction stormwater runoff.

In general, Table 25 shows a bimodal distribution in nutrient EMCS, with about half of the studies within +/- 50% of the national EMC for urban stormwater runoff, and the other half at least an order of magnitude higher than the national EMC. Some of the highest TN concentrations were in the 20 to 60 mg/l range, and TP levels in the 30 mg/l range were recorded.

The pattern observed in this limited dataset suggests that construction sites appear to have a baseline nutrient concentrations that is slightly higher than post-development stormwater runoff concentration for a good portion of the construction year

Construction sites also appear to occasionally experience very high spikes in nutrient levels which may reflect fertilizer wash off, and possibly other loss mechanisms. Two research studies that monitored fertilized test plots were able to conclusively link these spikes to wash-off of fertilizer and organic matter, but the other studies did not focus on this issue. It should also be noted that most of the nutrients measured in these construction sites were found in organic form.

Line and White (2007) was the only research study that sampled enough storm events to calculate a reliable annual load associated with a construction site. Their results are portrayed in Table 26, and several findings were notable. First, while the TN load during the construction and permanent stabilization phase was general in the range of the annual CBWM load for nitrogen, but the measured phosphorus loads were lower.

It is also interesting to note that nutrient loads increased the most during the establishment phase when young lawns and landscaping were still at risk of fertilizer wash-off. This finding is consistent with the UNM expert panel who noted that initial lawn establishment was a very high risk factor for nutrient export (UNMEP, 2013).

Table 26 Summary of Monitoring Results (N= 106 storms)
Line and White (2007) NC Piedmont

STAGE	Runoff Coefficient	TSS (tons/acre)	TP (lbs/acre)	TN (lbs/ac) [5]
Construction [1]	0.50	13	2.5	9.3
Establishment [2]	0.60	2.8	1.16	28
Post Construction [3]	0.55	0.9	1.51	16
Undeveloped [4]	0.21	0.16	0.44	5.6

[1] from initial clearing , grading, installation of infrastructure and seeding (0.7 years)
[2] Homes constructed, and lawns and landscaping established (1.4 years)
[3] After home build out (3.6 years)
[4] Undeveloped reference watershed
[5] about 70 to 90% of TN was in the form of TKN
5.6 years of sampling during and after construction at a 10 acre residential subdivision, compared to an undeveloped reference forest catchment less than a mile away (also sampled for same 5.6 years)

The Panel could find only three studies that looked at the nutrient dynamics with sediment basins and other ESC practices (Horner et al 1990, Cleveland and Fashokun, 2006 and McLaughlin and King, 2008). The findings from this very limited group of studies were inconclusive, as some showed basins having some effect in reducing nutrients, whereas in others, nutrient concentrations appeared to spike.

Table 27 shows this pattern for the most extensive upstream/downstream study on the impact of ESC practices on nutrient concentrations by McLaughlin and King (2008). Only sampling sites that had more than five paired entrance and exit samples are included.

Table 27
Nutrient Concentrations From Construction Sites in NC
Source: McLaughlin and King (2008)

SITE	Total Nitrogen (mg/l)			Total Phosphorus (mg/l)		
	Entrance	Exit	Change	Entrance	Exit	Change
JACK (N=10)	5.27	5.18	-2%	3.21	3.1	-2%
BUNC (N=6)	7.24	19.8	+++	3.5	34.6	+++
WAKE (N=7)	4.67	3.78	-20%	0.7	0.3	53%

As can be seen, there was no consistent pattern in N or P reduction as they passed through the construction sites. In some cases, a minor reduction was seen, in others a small increase, and a few cases of major nutrient increases in the outflow (e.g., BUNC and JACK sites). The author of the study, who is also a member of the Panel, cautions that the sample size in the study was far too small to make any inferences about the nutrient reduction performance of ESC practices, except that it is predictably variable.

6.5 Panel Findings and Recommended Nutrient Loading Rate

Based on the preceding review, the Panel concluded that the mass balance approach supported the current CBWM unit N and P target loads and should be retained, albeit this finding was based on limited sampling data.

Fertilizer wash-off appears to be a major source of nutrient export from construction sites, based on the high spikes observed in nutrient concentrations in several of the monitoring studies. The limited performance research was equivocal, with no clear evidence that ESC practices can reduce nutrients, and some evidence that they may actually be nutrient sources.

Consequently, the Panel elected to assign a zero N and P removal rate for all four levels of ESC practice, and rely instead on the current CBWM target nutrient loads of 26.4 lbs N/acre/year and 8.8 lbs P/acre/year as our best understanding of the probable nutrient load generated for construction sites with ESC practices.

Section 7
Accountability Mechanisms

The Panel concurred with the conclusion of the National Research Council (NRC, 2011) that verification of BMP installation and subsequent performance is a critical element to ensure that pollutant reductions are actually achieved and sustained across the Bay watershed. The Panel also concurred with the broad principles for urban BMP reporting, tracking and verification contained in the technical memo approved by the Urban Stormwater Workgroup (USWG, 2013). Since ESC is an annual BMP (i.e., reported as ESC acres per year), it does not have the long BMP duration like many other urban practices.

7.1 Adequacy of Existing Construction Site Verification Protocols

The Panel noted that verification is a critical element in existing ESC programs, and that it has improved considerably compared to historic requirements. Each individual construction site is now subject to both self inspections by the contractor and regulatory inspections by the local or state ESC enforcement authority that occur multiple times during the construction year.

In addition, new training, certification and enforcement provisions are frequently in place to improve the outcome of each on-site inspection. Despite the fact that they are in place for a short time (one year in the CBWM), they are subject to more on-site verification than any other urban or agricultural BMP used in the watershed. Current construction inspection protocols are more than sufficient to meet the CBP verification principles for crediting BMPs in the TMDL. Consequently, the Panel does not recommend any additional field verification protocols beyond those that are already in place in the Bay states.

7.2 State Options for Reporting Construction Acres Each Year

States have two options for the determining the number of acres that are under construction each year.

> (1) The first option is to do nothing and simply accept the CBP estimate of state construction acres that is currently used which is described in Section 3.2 of this report
>
> (2) The second option is for the state to aggregate permitted construction acreage in their portion of the Bay watershed every year, based on the CGP data reported to them by individual construction permitees. Most Bay states now have some kind of tracking system or database to analyze the CGP permits that are issued, although some additional post-processing may be needed to ensure the acres are within the Bay watershed, and are assigned to the proper river-basin segment.

While the Panel encourages states to develop more reliable statistics on year to year state-wide construction site acreage, it also recognized that it is hard to tease the actual construction area from CGP permit data alone. Given the year to year variability in the activity of the construction industry, the lack of accurate mapping data, and the internal mechanics of the CBWM, the Panel concluded that the existing CBP method used to provide a long term average estimate of state construction acres is acceptable for the modeling purposes.

7.3 *Other Local and State ESC Reporting Requirements*

The Panel recommends no additional reporting requirements to qualify for the sediment removal credit, beyond the existing state reporting requirements under their MS4, CGP or state ESC regulations.

The reporting requirements for the Bay states are also minimal, and are limited to notifying the CBP if they are still performing at the Level 2 ESC practice level on a state-wide basis, or have shifted to a higher level of performance (e.g., Level 3 ESC).

7.4 Qualifying Criteria to Achieve Level 3 ESC Practice

Most Bay states are solidly within Level 2 ESC practice, and are gradually implementing several aspects of Level 3. The Panel anticipates that some states and/or localities may formally request a shift from Level 2 to Level 3 for qualifying construction sites at some point in the future. To this end, the Panel outlined a series of criteria to define when a jurisdiction crosses over the threshold to Level 3 ESC, as follows:

- Passive chemical treatment is utilized within the construction site by adding PAM or other flocculants to:
  - Hydro-seeding mixes used for temporary stabilization
  - Fiber logs, socks, wattles or check dams installed in internal diversions, ditches, or channels
  - Sediment basins or traps
- Enhanced sediment basin design to include baffles, surface outlets, and skimmers
- ESC maintenance inspections at least once a week
- Enhanced measures for perimeter controls and natural resource buffers
- More stringent stabilization and construction phasing requirements than currently required

Section 8
Future Research and Management Needs

8.1 The Panel's Confidence in its Recommendations

One of the key elements of the CBP BMP Review Protocol is that each expert panel should express its confidence in the BMP removal rates that they ultimately recommend (WQGIT, 2013). While the Panel concluded that its recommendations for sediment and nutrient removal rates for Level 1, 2 and 3 ESC practices are based on a much stronger scientific foundation than the previous panel estimate, it also clearly acknowledges that major gaps exist in our understanding the nutrient and sediment dynamics of construction sites in the Bay watershed. The Panel's greatest uncertainties include:

- The limited and variable monitoring data that was available to characterize the nutrient concentrations in construction site discharges, and in particular, the risk of fertilizer wash off, during and after temporary and permanent stabilization.

- The monitoring data was insufficient to derive sediment removal rates for Level 4 ESC practices. This is not a major concern at present since no Bay states currently operate at this level of ESC performance, but it could become an future issue if local or state ESC programs evolve to that level.

- The estimates of the proportion of functionally defective ESC sites was primarily based on a hydrologic definition of failure, and further monitoring and modeling of construction sites under large storm and extreme storm conditions would improve confidence in this estimate.

Given these significant gaps, the Panel agreed that the recommended rates should be reevaluated by a new panel when better research data on ESC performance becomes available.

8.2 High Priority Research and Management Recommendations

The Panel urges state and federal authorities to provide funding for a short-term and intensive monitoring study that focuses on the nutrient concentrations in construction site discharges during the period of high fertilizer wash off risk that occurs during and after site stabilization.

The scope of the study might involve a total of 100 to 200 flow-weighted composite samples to measure nutrient concentrations at 10 to 15 different construction sites in the Bay region. The objective of this urgent sampling effort is to define more accurate EMC estimates for N and P, which would provide a more technically sound basis to compute annual nutrient loads for construction sites.

Should the short-term monitoring study indicate that construction site nutrient loads are equal to or greater than the target CBWM nutrient loads, a longer term study should commence. The focus of the long term study should be to determine whether fertilization rate or formulation recommendations, vegetative stabilization methods and/or down-gradient ESC practices could be modified in order to reduce nutrient export, while still maintaining effective vegetative and soil cover during the entire construction process.

In particular, the potential benefits of incorporating low doses of PAM to hydro-seeding mixes on erosion-prone soils should be investigated. Lastly, the nutrient dynamics within individual ESC practices should be investigated to ascertain whether some practices or design variations promote greater nutrient reduction.

One potential mechanism to finance this critical research is for states to allow localities to pool a portion of their existing MS4 stormwater outfall monitoring budgets to fund a regional monitoring consortium that could undertake the research or hire a university to do so.

Shifting to a higher level of ESC practice in future years will require several key management initiatives. Jurisdictions will need to continue to strengthen their ESC requirements and specifications. This will probably require a major re-analysis of monitoring and field data to determine how to optimize the use of passive chemical treatment and enhanced ESC practices to maximize sediment and turbidity removal in a cost-effective fashion.

Once the next generation of Level 3 ESC technology has been developed, a comprehensive training program will be needed so that designers, plan reviewers, contractors and inspectors can all effectively implement it on the ground.

8.3 Proposed Refinements in Next Phase of Bay Watershed Model

The Panel recommends the modeling team consider the following refinements in the next phase of CBWM development.

1. Eliminate the simulation of the no-ESC baseline condition for construction sites, and instead simulate construction land use as its own BMP. Under this scenario, there would be four categories of construction land that correspond to the four ESC performance levels (factoring in the additional load from functionally deficient ESC sites).

2. The no-ESC condition has been a historic artifact for several decades now, and virtually every construction site in the Bay watershed employs ESC practices of one kind or another. The Panel was particularly concerned about the quality of the limited historical data used to derive calibration target loads for the no-ESC condition. If a no-ESC condition is required for modeling purposes, the Panel recommends that the target load be lowered to no more than 12 tons/acre/year.

3. Refine the parameters in the construction site simulation in PERLAND to explicitly simulate as many of the five nutrient loss pathways described in this

report as possible. At a minimum, construction sites should be subject to a weighted unit acre fertilization rate (which the model currently lacks).

4. Explicitly simulate sediment loss for construction sites located on the coastal plain physiographic region, which should be lower than in other portions of the Bay watershed due to their gentle slopes, longer slope/length distances, and less erodible soil types.

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Appendix A
Technical Rationale for Estimating Sediment Loads at Construction Sites for Different Levels of ESC Practice

The Panel decided to take an empirical approach to estimate the average annual sediment load generated by construction sites with various levels of ESC controls. The Simple Method is an empirical equation developed by Schueler (1987) to estimate annual pollutant loads in stormwater runoff using easily derived parameters. It computes loads for storm events only, and is best applied to individual drainage areas or catchments. The basic equation is:

$$L = [P * Pj * Rv /12] [EMC * A * 2.72]$$

Where:

L = Annual load (lbs)
P = Annual rainfall (in)
Pj = Fraction of storms producing runoff (0.9)
Rv = Construction Site runoff coefficient
EMC = TSS event mean concentration (mg/l)
A = Site Area (acres)
2.72 = Unit conversion factor

L is divided by 2000 to get tons of sediment per acre per year.

In the analysis, the following parameters were held constant:

P = 40 inches/yr
Pj = 0.9
A = 1 acre

Parameter values for Rv and EMC were based on the review of construction site monitoring data for five sediment loading scenarios:

Scenario 1: NO ESC: Historical construction sites without ESC controls
Scenario 2: ESC 1: Construction sites with Level 1 ESC controls
Scenario 3: ESC 2: Construction sites with Level 2 ESC controls
Scenario 4: ESC 3: Construction sites with Level 3 ESC controls
Scenario 5: MFD: Construction sites with moderate functional deficiency.

The Panel evaluated three different technical assumptions for each scenario -- parameter values that defined a worst case, average case, and best case for potential sediment loading in each scenario. For each case, the annual sediment load was computed using the Simple Method, and the final load was determined by averaging all three values. The results for the five scenarios are shown in Tables A-1 to A-5

Table A-1 Scenario 1: Historical Construction Site without ESC			
Parameter	Worst Case	Average	Best Case
Rv	0.65 [1]	0.50 [3]	0.35 [5]
EMC TSS OUT	8,400 [2]	4,200 mg/l [4]	3600 mg/l [6]
COMPUTED LOAD	**22.3 tons/ac/yr**	**8.6 tons/ac/yr**	**5.1 tons/ac/yr**

Notes on Technical Assumptions:
[1] Assumes historic construction sites w/o ESC had an Rv 30% higher than the one measured at a construction site with ESC control
[2] TSS EMC is double the 4,200 mg/l reported by Yorke and Herb (1978)
[3] Measured value, see Table 10
[4] Average concentration derived from Yorke and Herb (1978)
[5] Bay-wide average Rv for construction sites (Table 13)
[6] Grand mean of all ESC studies for TSS EMC IN (Table 15)

Table A-2 Scenario 2: Construction Sites Operating at Level 1 ESC Practice			
Parameter	Worst Case	Average	Best Case
Rv	0.50 [1]	0.43 [3]	0.35 [5]
EMC TSS OUT	1,200 mg/l [2]	1,000 mg/l [4]	800 mg/l [6]
COMPUTED LOAD	**2.5 tons/ac/yr**	**1.8 tons/ac/yr**	**1.1 tons/ac/yr**

Notes on Technical Assumptions:
[1] Measured value, see Table 10
[2] Most conservative, assumes bigger storm events produce greater annual EMC
[3] Intermediate value between measured value and the Bay-wide average
[4] Conservative rounding up, given TSS variability
[5] Bay-wide average Rv for construction sites (Table 13)
[6] Mean TSS OUT for Level 1 ESC sites, as shown in Table 15

Table A-3 Scenario 3: Construction Sites Operating at Level 2 ESC Practice			
Parameter	Worst Case	Average	Best Case
Rv	0.50 [1]	0.43 [3]	0.35 [5]
EMC TSS OUT	800 mg/l [2]	557 mg/l [4]	500 [6]
COMPUTED LOAD	**1.6 tons/ac/yr**	**1.0 tons/ac/yr**	**0.7 tons/ac/yr**

Notes on Technical Assumptions:
[1] Measured value, see Table 10
[2] Most conservative, assumes bigger storm events produce greater annual EMC
[3] Intermediate value between measured value and the Bay-wide average
[4] Mean TSS OUT for Level 1 ESC sites, as shown in Table 15
[5] Bay-wide average Rv for construction sites (Table 13)
[6] Rounding down, given the effect of the outliers in Table 15

Table A-4 Scenario 4: Construction Sites Operating at Level 3 ESC Practice			
Parameter	Worst Case	Average Case	Best Case
Rv	0.43 [1]	0.35 [3]	0.27 [5]
EMC TSS OUT	600 [2]	400 [4]	280 [6]
COMPUTED LOAD	**1.05 t/ac/yr**	**0.57 t/ac/yr**	**0.31 t/ac/yr**

Notes on Technical Assumptions:
[1] Intermediate value between measured value and the Bay-wide average (i.e., Level 3 ESC practices act to reduce site Rv).
[2] Mean TSS OUT for level 2 ESC in Table 15, rounded up
[3] Bay-wide average Rv for construction sites (Table 13)
[4] Best professional judgment that Level 3 can reduce Level 2 TSS outflow concentrations by approximately 30%
[5] Best professional judgment that Level 3 practice can reduce site Rv by approximately 25%
[6] Best professional judgment that Level 3 can reduce TSS outflow concentrations by 50% below current level 2 practice

Table A-5 Scenario 5: Construction Sites w/ Moderate Functional Deficiency			
Parameter	Maximum	Average	Minimum
Rv	0.50 [1]	0.43 [3]	0.35 [5]
EMC TSS OUT	3,600 [2]	2100 [4]	1400 [6]
COMPUTED LOAD	**7.3 tons/ac/yr**	**3.7 tons/ac/yr**	**2.0 tons/ac/yr**

Notes on Technical Assumptions:
[1] Measured value, see Table 10
[2] Rounded grand mean TSS IN in Table 15, presumes some effect of upland erosion practices, but complete failure of sediment controls
[3] Intermediate value between measured value and the Bay-wide average
[4] Assumes that sediment controls work at 40% removal, compared to the grand mean
[5] Bay-wide average Rv for construction sites (Table 13)
[6] Assumes that sediment controls work at 60% removal, compared to the grand mean

Notes on How Moderate Functional Deficiency was Derived:

Two previous expert panels conducted long-term rainfall frequency analyses (1977-2007) and developed adjustor curves to define sediment removal rates based on the design capacity of stormwater practices up to 2.5 inches/day (SPSEP, 2012, SREP, 2012). The stormwater treatment (ST) curve for sediment removal is shown in Figure A-1, which portrays how sediment removal rates increase as a direct function of the runoff depth captured per impervious acre by a stormwater BMP.

The Panel reasoned that the ST curve could not be used to define ESC sediment removal rates (primarily because ESC practices are subject to incoming TSS levels that are an order of magnitude higher than for urban stormwater runoff, and contain sediment particles that are much easier to settle out).

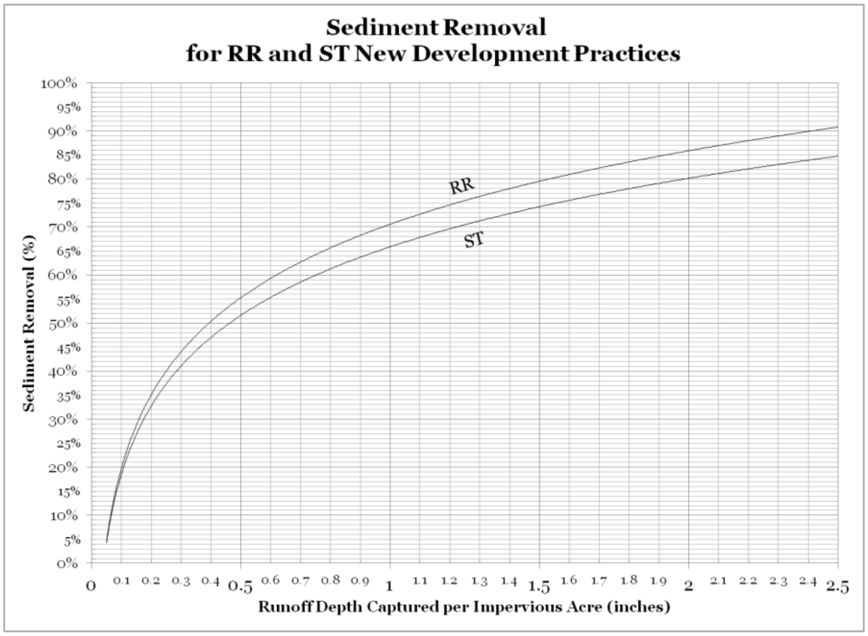

Figure A-1 Stormwater Adjustor Curve from SPSEP, 2012

The Panel did conclude that the ST curve could be used to define the annual fraction of runoff volume that would exceed the design capacity of ESC practices. Level 1 ESC practices are designed on a half-inch of runoff capture per acre, whereas Level 2 practices are designed based on one-inch of rainfall capture. Periods of moderate functional deficiency are operationally defined as runoff depths that exceed the design capacity of the ESC facility from its normal capacity up to the 2.5 inch runoff depth. The rainfall frequency analysis that was used to construct the curves for this range of storm events was then used to determine the fraction of annual runoff volume generated under moderate deficiency conditions.

The analysis indicated that Level 1 ESC practices are exposed to moderate deficiency conditions during approximately 25% of the average annual runoff volume, whereas Level 2/3 ESC practices are exposed to moderate deficiency about 15% of the time. During these periods, the sediment removal function of ESC practices is sharply diminished, but does not go zero.

A best estimate of the annual sediment loading rate under moderate deficient conditions is presented in Table A-5. The annual loading rate is then pro-rated over the fraction of the annual runoff volume for which a site is expected to experience moderately deficient conditions, and is this additional fractional load is added to the base loading rate for the appropriate level of ESC practice.

For ESC Level 2, this was computed as (0.15) (4.3 tons/acre/year), or an additional 0.65 tons/acre/year to be added to the base load.

Defining Extreme Functional Deficiency:

Extreme functional deficiency occurs during the rare storms that completely overwhelm the treatment capacity of ESC practices such that they fully compromise their collective sediment removal function. In the best professional judgment of the Panel, these conditions are expected to occur when hourly or daily rainfall intensities meet or exceed the following thresholds in any CBWM time step:

- 2.5 inches per day (the top end of the ST curve)
- 1.5 inches per hour (an intense thunderstorm

During these extreme conditions, the ESC practices at construction sites are expected to fail completely, and discharge sediment at a bare soil estimate of sediment loading of 12 tons/acre/year (Table A-1).

For the current version of the CBWM, this would imply a 50% reduction, since the target load for version 5.3.2 is 24 tons/acre/year.

Overall Summary

Table A-6 summarizes how the five scenarios compare.

Table A-6
Comparative Summary of the Five Scenarios (tons/ac/yr)

ESC Scenario	Worst Case	Mid-point Case	Best Case	**Best Estimate**
1. Construction w/o ESC	22.3	8.6	5.1	**12.0**
2. Sites Operating at Level 1	2.5	1.8	1.1	**1.8**
3. Sites Operating at Level 2	1.6	1.0	0.7	**1.1**
4. Sites Operating at Level 3	1.05	0.57	0.31	**0.65**
5. Moderate Functional Deficiency	7.3	3.7	2.0	**4.3**

Important Note: Actual sediment loads for all 3 ESC levels will be higher when moderate and extreme storms exceed or overwhelm ESC capacity, and thus create functional deficiency, and much lower removal rates.

Appendix B
Mass Balance Analysis of Nutrient Loss Pathways at Construction Sites

Given that construction sites exported about three times more nutrients than developed land, the Panel created a simple mass balance model to analyze the nutrient loss pathways at construction sites. The objective of the analysis was to check whether the higher unit nutrient loads used in CBWM could be supported by various nutrient inputs, sources and pathways that occur in construction sites.

Pathway 1: Nutrients Attached to Eroded Soil. The first pathway involves the loss of nutrients that are attached to eroded sediments that leave the site. The Panel tested this proposition through a simple mass balance approach as shown in Table B-1. Three levels of construction site sediment loss were assumed, based on the data analysis in Section 5, and multiplied by an estimate of nutrient content for urban soils. The median nitrogen and phosphorus levels in the top 5 inches of urban soils were based on Pouyat et al (2007) survey of nutrient content of a wide range of soil types in Baltimore metro area. These values were discounted by 50% to reflect the fact that most exposed soils at construction sites would have a lower nutrient content.

As can be seen in Table B-1, the mass balance suggests that loss of nutrients attached to eroded sediment can explain a significant fraction of potential nutrient export, especially when sediment loss conditions are high.

Table B-1 Nutrient Loss Pathway 1:
Potential N and P Loss Attached to Eroded Sediments (lbs/acre/year)

Nutrient	12 tons/ac/yr erosion rate	8 tons/ac/yr erosion rate	2 tons/ac/yr erosion rate
Total P	0.46	0.30	0.08
Total N	16.8	11.2	2.8

Based on Pouyat et al (2007) measurements of median soil nutrient content in Baltimore metro area soils, N = ~ 110. These values were reduced by a factor of two to reflect the fact that Pouyat's measurements were taken in 0 and A soil horizons.

Pathway 2: Fertilizer Wash-off. The second source of possible nutrient loss is the fertilizers applied during temporary and permanent stabilization. Once again, the Panel analyzed the potential contribution of fertilizer wash-off through a simple mass balance approach as shown in Table B-2. Three levels of fertilizer loss were used (1%, 5% and 10%), assuming a single fertilizer application at the Bay state average as shown in Table 23.

Table B-2 Nutrient Loss Pathway 2 Potential N and P Loss Using Fertilizer Wash off (lbs/acre/year)			
Nutrient	1% Loss	5% Loss	10% Loss
Total P	0.7	3.7	7.4
Total N	1.1	5.7	11.4
Assume 114 lbs/acre/year application for TN and 74.3 lbs/acre/year for TP, which is average of required fertilization rate specified in Bay state temporary and final stabilization specs (see Table 23). It was conservatively assumed that only one application would occur over the course of a construction year.			

Based on the mass balance, fertilizer wash-off can account for most, if not all, of the modeled phosphorus load at the 5 and 10% loss rates. The effect is less pronounced for nitrogen. Fertilizer wash-off could potentially account for a third to a half of the modeled nitrogen load. It should be noted that the CBWM does not account for any fertilizer inputs to construction sites at the current time.

Pathway 3: Wash-off of Atmospherically Deposited Nutrients

The third potential pathway involves the wash-off of nutrients that are deposited from the atmosphere. For purposes of mass balance, the Panel used regional data on annual nutrient deposition rates, and three different assumptions regarding the risk for wash-off (10%, 30% and 50%). The results, shown in Table B-3, indicate that wash-off of the deposited nutrients is a significant loss pathway, that can account for about 15 to 30% of the modeled nitrogen loads under moderate and high wash-off conditions. By contrast, the loss pathway does not appear to be very significant for phosphorus.

Table B-3 Nutrient Loss Pathway 3 Potential N and P Wash-off of Atmospherically Deposited Nutrients (lbs/acre/year)			
Nutrient	10% Wash-off	30% Wash-off	50% Wash-off
Total P	0.07	0.21	0.35
Total N	1.3	3.9	6.5
Assume 13 lbs/acre/year for TN and 0.7 lbs/acre/year for TP, based on regional wet and dry atmospheric deposition rates, reported in CSN (2011). Wash-off rates based on assumption that wash-off cannot exceed the runoff coefficient			

Pathway 4: Decay and Wash-off of Organic Material

The fourth potential source of nutrient loss involves the decay of various organic materials that are used to temporarily cover soils and prevent erosion. These materials can include straw, mulch, wood chips, compost, erosion control blankets and organic tackifiers. In addition, certain ESC practices may utilize the same organic materials to improve sediment trapping performance.

The assumptions in the mass balance to analyze the potential loss pathway were fairly simplistic, and assumed three levels of organic material loss that were a tenth of the three sediment loss rates used in Pathway 1 mass balance. Several recent studies that have analyzed the nutrient content of vegetative detritus in catch basins and storm drain outfalls were used to define the potential nutrient content of these organic materials. As shown in Table B-4, the wash-off of organic matter does not appear to be a major loss pathway for either nitrogen or phosphorus.

Table B-4 Nutrient Loss Pathway 4
Potential N and P Loss Via Organic Matter Degradation (lbs/acre/year)

Nutrient	0.6 tons/ac/yr	0.4 tons/ac/yr	0.1 tons/ac/yr
Total P	1.2	0.8	0.2
Total N	4.2	2.8	0.7

Assume 2 lbs/ton for TP and 7 lbs/ton for TN, based on nutrient content of vegetation measured in catch basins outfalls (CSN, 2012)
Assume 5% of sediment yield is actually organic matter rather than eroded soil

Summary of Nutrient Losses From all Pathways. The purpose of the mass-balance analysis was to determine if the existing CBWM target nutrient loads for construction sites could be generally validated given how little monitoring data was available to measure them. Table B-5 summarizes the mass balance estimates for all four loss pathways for each nutrient, and compares them to modeled loads used in CBWM. As can be seen, the CBWM load estimates fit squarely in the middle of the Panel's mass balance estimates for both nitrogen and phosphorus. The Panel acknowledges all of the limitations and uncertainties inherent in its mass balance analysis, but also gained more confidence that the existing CBWM nutrient loads were in the ball park of what might be expected at a construction site.

Table B-5 Mass Balance Comparison of Nutrient Loadings by Loss Pathways

	Total Nitrogen (lbs/ac/yr)			Total Phosphorus (lbs/ac/yr)		
	Lo	Med	High	Lo	Med	High
Pathway 1	2.8	11.2	16.8	0.08	0.30	0.46
Pathway 2	1.1	5.7	11.4	0.7	3.7	7.4
Pathway 3	1.3	3.9	6.5	0.07	0.2	0.4
Pathway 4	0.7	2.8	4.2	0.2	0.8	1.2
Total	**5.9**	**23.6**	**38.9**	**1.1**	**5.0**	**9.5**
CBWM		**26.4**			**8.8**	

Note: N migration to groundwater was not included in the analysis, so N load mass balance may be conservative.

Appendix G:
Conformity with WQGIT BMP Review Protocol

The BMP review protocol established by the Water Quality Goal Implementation Team (WQGIT, 2010) outlines the expectations for the content of expert panel reports. This appendix references the specific sections within the report where the panel addressed the requested protocol criteria.

1. **Identity and expertise of panel members:** *See Table in Section 1*

2. **Practice name or title:** *Erosion and Sediment Control, which consists of four levels of ESC practice at construction sites.*

3. **Detailed definition of the practice:** *See section 2.1 for detailed definitions of ESC levels 1, 2, 3 and 4.*

4. **Recommended N, P and TSS loading or effectiveness estimates:** *See Table 19 (Section 5.5) and Appendix A for recommended TSS removal rates for use in the Phase 5.3.2 Watershed Model. The panel recommended a zero N and P removal rate for all four levels of ESC practice.*

5. **Justification of selected effectiveness estimates:** *See Sections 4 and 5 to understand how the panel derived the effectiveness estimates for sediment removal. See Section 6 for an explanation of the recommended zero nutrient removal credit.*

6. **List of references used:** *See page 41*

7. **Detailed discussion on how each reference was considered:** *See Sections 3, 4, and 5 for details on the review of available science.*

8. **Land uses to which BMP is applied:** *ESC practices are applied to the bare-construction land use in the Phase 5.3.2 WSM and the equivalent land use in the future Phase 6 WSM.*

9. **Load sources that the BMP will address and potential interactions with other practices:** *The ESC BMP will address runoff from construction sites in the Bay watershed. It is the only BMP that is eligible and applicable to the construction land use and therefore does not interact with other BMPs.*

10. **Description of pre-BMP and post-BMP circumstances and individual practice baseline:** *See Sections 3, 4, 5, and 6, As well as Appendix A and B for a discussion of pre- and post-BMP site hydrology and pollutant runoff.*

11. **Conditions under which the BMP works/not works:** *See Section 5.4 for a discussion of functionally deficient sites.*

12. **Temporal performance of BMP including lag times between establishment and full functioning:** *No lag time is assumed. In recent years each state has adopted more stringent ESC standards that, among other things, require rapid stabilization of bare soil on construction sites.*

13. **Unit of measure:** *Acres*

14. **Locations in CB watershed where the practice applies:** *All acres of construction sites in the Bay watershed*

15. **Useful life of the BMP:** *Varies by specific ESC practice and duration of specific construction project. For the purposes of this report, however, the useful life of the practice is annual.*

16. **Cumulative or annual practice:** *Annual*

17. **Description of how BMP will be tracked and reported:** *See Section 7.1 and 7.2 for discussion of how state governments can track and report to the Bay Program. More details are also available in the "Technical Requirements for Scenario Builder" document accompanying this report.*

18. **Ancillary benefits, unintended consequences, double counting:** *Increasing the Level of ESC practice can reduce turbidity levels which can harm aquatic life. No unintended consequences or issues with double counting*

19. **Timeline for a re-evaluation of the panel recommendations:** *Depends on continued research*

20. **Outstanding issues:** *See Section 8 for a discussion of outstanding issues and future research needs*

Appendix H:
Technical Requirements for Entering ESC Practices into Scenario Builder