CHAPTER 13

EROSION AND SEDIMENT POLLUTION CONTROL

13.0 INTRODUCTION

Pennsylvania's Clean Streams Law of 1937 (Act 394), as amended, prohibits the discharge to the waters of the Commonwealth of any pollutive materials whether from industrial or domestic sources. It also allows the Pennsylvania Department of Environmental Protection (PA DEP) to regulate any activity which creates a danger of pollution or has a potential for pollution. Pennsylvania's program for the control of erosion and sediment pollution has been adopted under the authority of Chapter 102 of PA DEP's Rules and Regulations. To explain the requirements of this program pursuant to the Chapter 102, PA DEP's Bureau of Soil and Water Conservation published in April 1990 an implementation manual titled, "Erosion and Sediment Pollution Control Program Manual". (It was updated in March 2000.) Other related programs adopted by PA DEP are Chapter 105 (Dam Safety and Waterway Management) and Chapter 106 (Flood Plain Management) regulations. Pertinent regulations regarding the Storm Water Management Act of 1978 (Act 167) are addressed separately in Chapter 10, Drainage Design and Related Procedures.

Also, as stipulated in the Federal-Aid Policy Guide, 23 CFR 650, Subpart B, it is the policy of the Federal Highway Administration (FHWA) that Federal-aid highways and highways constructed under the direct supervision of FHWA shall be located, designed, constructed and operated according to standards that minimize erosion and sediment damage to the highway and adjacent properties and abate pollution of surface and ground water resources.

Water pollution degrades surface waters making them unsafe for drinking, fishing, swimming, and other activities. As authorized by the Federal Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. Point sources are discrete conveyances such as pipes or man-made ditches. In most cases, the NPDES permit program is administered by authorized states. Since its introduction in 1972, the NPDES permit program is responsible for significant improvements to our Nation's water quality. Section 13.5.B discusses the NPDES permit program for Pennsylvania in greater detail.

Soil erosion is the process by which the land surface is worn away by the action of wind, water, ice and gravity. Under natural conditions, erosion occurs at a very slow and uniform rate and is a vital requirement in maintaining environmental balance. Sedimentation is the process involving the gravitational deposit of transported material in flowing or standing water. Erosion and sedimentation are normal geologic processes and are a matter of concern when accelerated by highway related activities. Such activities include the removal of the natural protective vegetative cover, the disturbance of the soil or other significant changes in topography.

The disturbance of land during construction is frequently accompanied by sudden, drastic increases in soil erosion. This accelerated erosion can be minimized by prudent scheduling of construction activities. Control measures can reduce sediment production. PA DEP's Chapter 102 regulations require that all persons or municipalities engaged in earthmoving activities shall develop, implement and maintain erosion and sediment pollution control measures which effectively minimize accelerated erosion and prevent sediment pollution. Section 13.1 provides highlights of the Chapter 102 regulations.

13.1 CONSIDERATIONS RELEVANT TO CONSTRUCTION

Effective erosion control planning begins during the preliminary design phase of highway project development. Control of construction activities and knowledge of the soils encountered are basic to determine measures for preventing erosion and the movement of sediment. Control measures shall be designed to fit the environment, topography, soils, rainfall, land use and construction schedules. A highway location selected with consideration of the problems associated with these basic elements can greatly reduce erosion problems during and after construction.

Prevention of sediment pollution of waterways involves the following principles: (1) schedule construction activities to reduce soil area exposed; (2) control erosion at the source; (3) control water that flows across the right-of-way and (4) perform timely seeding and mulching operations to stabilize disturbed areas as soon as possible. The key to controlling sediment pollution is to control soil erosion at the source.

Special precautions should be taken in the use of construction equipment to prevent operations which promote erosion. Wheel tracks from heavy equipment are vulnerable to erosion from the concentration of water. Fording of streams with equipment shall be kept to a minimum and, where required, shall be performed in accordance with the requirements of Chapter 10, Drainage Design and Related Procedures, and regulatory permit requirements. Regulatory permit requirements take precedence over any design manuals.

Embankment slopes that encroach on or near stream channels should be adequately protected against erosion. Where possible, a protective buffer of vegetative cover should be preserved or established between the top of cuts or bottom of fills and the adjacent ditch or drainage way. The buffer area should be identified on the typical sections and plans and protected from construction activity.

Borrow pits and waste disposal areas should be selected with full consideration of erosion control requirements during borrow or disposal operations and during the final treatment or restoration of the area. Wherever located, special precautions shall be taken to control erosion and sediment problems and off-site effects. The disposal of waste in wetlands or in the flood channel area of any stream is prohibited. Regardless of the responsibility of the selection of borrow areas, plans of operation and of restoration, cleanup, shaping, seeding and mulching shall be approved by the Engineer.

Plans for the control of runoff must include measures to keep sediment from entering waterways before borrow or disposal operations begin. Diversion channels and sediment traps or sediment basins may be used for this purpose. Topsoil from the borrow pit area shall be salvaged for use in restoring the borrow area. Topsoil from a waste area should also be salvaged if it is needed for restoration. Stockpiled topsoil shall be protected from erosion. Final restoration of borrow and waste disposal areas shall include grading, establishment of vegetative cover and other treatments that blend the area into the surrounding landscape. The restored areas shall be well drained, unless approval is given to convert the pit area into wetlands or lakes for fish and wildlife, recreation, stock water or irrigation. Erosion and sediment pollution control shall be provided and maintained at wetland mitigation sites until they become established.

Where practical, erosion and sediment pollution control measures, also referred to as best management practices (BMPs), should be located within the normal right-of-way. However, when necessary, additional right-of-way acquisition may be required and shall be considered prior to completion of the right-of-way plans. If erosion and sediment pollution control measures will be removed during the construction contract, a temporary area for construction may be utilized. The control of the water across the right-of-way shall be completed prior to or concurrent with clearing and grubbing for the roadway. This may require offsetting the culverts from the natural drainage course to transport the water across the work area. All earth ditches or channels shall be stabilized before use to prevent erosion. Runoff from work areas shall be collected and controlled prior to entering a natural watercourse. All water originating outside of the project should be kept separate from that originating within the construction area.

Accelerated erosion can be minimized by the use of the following: (1) slopes which are rounded and blended into the natural terrain; (2) drainage channels properly designed with regard to location, width, depth, slope alignment and protective treatment; (3) proper facilities for ground water interception; (4) dikes; (5) berms and other protective devices; (6) protective ground covers and plantings and (7) properly designed sedimentation removal devices.

Erosion and sediment pollution control BMPs should be indicated on the construction drawings, as required, and so located that they do not interfere with the normal construction operations. The use of several smaller BMPs off the main stream has the advantage of not interfering with fish life and has less detrimental consequences in case of failure or overtopping of BMPs, since failure from overtopping is not likely to occur at all of the small BMPs simultaneously. BMPs located within a waterway may require a Chapter 105 permit from PA DEP.

Most erosion and sediment pollution control BMPs will be temporary, since most of the soil erosion occurs only during construction. Permanent detention basins provided for stormwater management purposes may be used as sediment basins during highway construction. Those basins located in a regulated watershed pursuant to the Storm

Water Management Act shall be designed and constructed in accordance with the standards of the individual watershed stormwater management plans. In some special cases, a multipurpose detention basin may be installed to provide water quality and wildlife habitat enhancements. Permanent erosion and sediment pollution control BMPs shall have a plan of maintenance. Temporary erosion and sediment pollution control BMPs shall be cleaned and maintained to assure proper functioning for the expected period of use. Some basins or ponds, because of size or location, may require protective fencing to limit unauthorized access.

Erosion and sediment pollution control BMPs shall be provided for all phases of construction activities including those items which are not normally specified in construction drawings. These BMPs also may be required for testing operations such as those for archeology and drilling.

13.2 SEEDING AND MULCHING STABILIZATION

Seeding with various grass or grass and leguminous plant mixtures is necessary to restore vegetative cover to soil surfaces exposed during excavation operations. Restoring the vegetative cover with deep-rooted, long lived and persistent adapted plant species is the most effective measure to prevent extensive soil erosion and any accompanying sedimentation loss and deposit in undesired areas. The use of permanent or temporary seeding or temporary mulching must be anticipated during earthwork operations.

A. Standard Highway Seeding Mixtures. Publication 408, *Specifications,* Section 804 lists several standard seeding mixture formulas which should be used on typical construction slopes for highway construction projects. A general description and guideline for their use is as follows:

1. Formula B. This is a refined lawn type, sod forming grass formula containing a large percentage of Kentucky bluegrasses with perennial ryegrass and red fescues. This mixture is generally used on non-steep surfaces where a more highly maintained and mowed surface, such as a lawn, is desired. Use only on areas which have topsoil.

2. Formula C. This is a mixture of predominantly crownvetch (leguminous plant) with a nurse crop of annual ryegrass. The ryegrass will hold the soil in place until the slower growing crownvetch establishes itself. This mixture is generally used on slopes steeper than 1V:3H where mowing is not anticipated or desired. Crownvetch is the state's official Soil Conservation Plant. Crownvetch will normally hinder the invasion of adjacent native vegetation for many years. Topsoil application is not necessary in areas to receive Formula C. Do not use within 6.0 m (20 ft) of areas where evergreen trees, shrubs, seedlings or vines are to be planted.

Although this plant species is good for erosion control, Formula C has the capability of moving beyond the right-of-way. It can "creep" over and shade out other low growing vegetation. It can also cling to low hanging branches and onto right-of-way fence. The Pennsylvania Department of Conservation and Natural Resources (DCNR) considers Formula C to be a problematic, invasive plant in certain areas when it establishes outside of the right-of-way into residential and agricultural properties or other native plant communities.

3. Formula D. This is a rougher grass type, sod forming mixture containing a large percentage of tall and fine fescues. This mixture is generally used on most highway slope areas not receiving Formula C where mowing may or may not be designated. In non-mowed areas, this formula will eventually allow invasion and succession by adjacent native woody plants or wildflowers. Normally used in drainage channels or swales requiring permanent seeding.

4. Formula E. This is a 100% crop of annual ryegrass which is generally used to quickly stabilize exposed soil surfaces since it generally germinates within 2 weeks when climate conditions are favorable. Since the life cycle of this grass averages 1 to 2 years, this formula is considered most often for temporary use on unfinished graded areas during construction.

5. Formula L. This is a fine textured, sod forming mixture of hard fescue, red fescue with a nurse crop of annual ryegrass. This mixture can be used on low maintenance slope areas which will not be normally mowed and on flatter areas which will not receive more than 2 mowing cycles per year. Mixture should not be used where mowing height will be less than 150 mm (6 in). Cutting less than 150 mm (6 in) is severely detrimental

to establishment. Mixture has limited seedhead production and is not very adaptive to consistently wet soil conditions.

6. Formula W. This is a rough textured blend of tall fescue and birdsfoot trefoil (leguminous plant) with a nurse crop of redtop. This formula can be used on a wide assortment of conditions ranging from fairly dry to fairly wet soils where non-mow conditions are desired such as wetland replacement areas or wildlife habitat areas. This formula will eventually allow the desired invasion and succession of adjacent native plant material.

All areas of use for each seed formula will be shown on applicable typical sections and on the tabulation sheets.

Crownvetch crowns or potted plants can be used in lieu of Formula C seeding where a more positive and earlier establishment of crownvetch cover is essential or where successful seeding is questionable such as top of cut slopes or in areas of poor, erosive soil. Space plants 0.9 m × 0.9 m (3 ft × 3 ft) in a diamond pattern or under extreme conditions, 0.6 m × 0.6 m (2 ft × 2 ft). Show areas of use and spacing on applicable Typical Sections and on the Tabulation Sheets. Potted plants of flatpea may also be used in this way to establish a quicker vegetative cover.

Other seeding formulas for various specialty areas such as wetland replacements, wildlife habitat areas, wildflower establishment or other soil conservation areas can be developed on a project by project basis.

Permanent soil protection and drainage facilities should be completed as early as practical, particularly diversion channels and similar controls that will divert runoff from work areas and unprotected soil. Areas of bare soil and the length of their exposure to erosion processes should be minimized by the following:

1. Temporary Seeding. When project areas are constructed in a rough graded condition and erosion may be accelerated, or establishment of a temporary vegetative cover on exposed soil areas is desired, specify Formula E, according to Section 804 and mulch according to Publication 408, *Specifications,* Section 805. Mulch alone (such as wood chips, straw, hay or other approved material) can be used to protect constructed slopes and other bare areas brought to finished grade when seeding operations are unfavorable. In all cases, temporary seeding and/or mulching will be installed on all disturbed areas where additional grading, topsoiling, etc. will not occur for 20 or more days.

2. Permanent Seeding. When project areas are constructed to finished grade and seeding operations are required within the dates specified in Publication 408, *Specifications,* Section 804.3(a), specify Formulas B, C, D, W, L or other approved seed formulas to minimize erosion by timely scheduling and limiting the work areas. Immediately begin permanent seeding and mulching operations as ground surfaces are brought to final grade.

Limit the use of sod to situations where new construction adjoins established lawns or other fine turf or where the immediate establishment of vegetative cover is required (i.e., between sidewalks and curb).

All seeding, soil supplements and mulching items shall be placed in accordance with the requirements of Publication 408, *Specifications,* Sections 804 and 805 or other approved special provisions.

B. Other Soil Conservation Seed Mixtures. Seeding mixtures of soil conservation type plantings for areas within the right-of-way limits other than typical highway construction slopes can include other seed types than the specified seed formulas listed in Publication 408, *Specifications*. These areas could include habitat replacement areas, wetlands, ponds, dam or stream banks, dikes, spillways, spoil areas, borrow pits or other special areas affected by the highway construction.

Some persistent type species for consideration are:

Legumes	Grasses	
Crownvetch	Tall Fescue	Redtop
Birdsfoot Trefoil	Deertongue	Switchgrass
Flatpea	Big Bluestem	Fine Fescues
Showy Tick Trefoil	Little Bluestem	Indiangrass

Other useful species include: Weeping Lovegrass and Perennial Ryegrass.

Recommended Seed Varieties

* Indiangrass - 'Rumsey', 'Holt' or 'Lometa'
* Tall Fescue - 'Kentucky 31' for low maintenance sites, turf-type varieties for high maintenance sites. If endophyte - free tall fescue is desired, use 'Johnstone ', 'Barcel ' or 'Festorina'.
* Perennial Ryegrass - Any fine-leaf turf-type variety
* Fine Fescue - Any named variety
  Redtop - Common seed, 'Streaker' or other named varieties
  Switchgrass - 'Blackwell' for droughty site, 'Shelter' for habitat, 'Cave-in-Rock ' for forage, 'Alamo'
  Deertongue - 'Tioga'
* Birdsfoot Trefoil - Any two of the following: 'Empire ', 'Norcen', 'Leo', 'Maitland' or 'Dawn'
  Flatpea - 'Lathco'
  Weeping Lovegrass - Common seed or 'Morpa'
* Crownvetch - 'Penngift'
  Big Bluestem - 'Niagara' or 'Kaw'
  Little Bluestem - 'Aldous', 'Camper' or 'Blaze'

* Use named varieties that originated in Pennsylvania or Northeastern United States whenever possible since they are generally more resistant to unfavorable soil conditions than are varieties of the same plant kind that originated in Midwest or western states.

C. General Design Guidelines.

1. Lespedeza species are often recommended in various literature as a good cover and food source for wildlife. However, Lespedeza species are not recommended for use in Pennsylvania due to survival limitations caused by varying climate conditions and its limited seed production.

2. Simple mixtures are easier to seed, establish and manage than complex mixtures containing 6 or more species.

3. Most species used for conservation plantings will only root where pH soil conditions are within a range of 5.5 to 7.0 and sufficient fertility is available to support plant growth.

4. For best results, seed in spring during March, April and May.

5. Grasses generally require 4-5 weeks of growth prior to hard frosts in order to survive winter conditions.

6. Legumes generally require 10-12 weeks to produce a seedling large enough to survive winter conditions. Seed legumes before July 15th in northern and western Pennsylvania and before August 15th in southeastern Pennsylvania. If seeding is necessary later than these dates, specify at least 30-35% or more of the legume seed to contain hard seed.

7. Inoculate legume seeds immediately prior to seed application with a selected culture of nitrogen fixing bacteria.

D. Species Guidelines (Also see Table 13.1):

1. Birdsfoot Trefoil (Lotus corniculatus):

a. Does not spread vegetatively from roots but spreads readily from seed. Perennial legume, deep rooted, long lived, prolific seed producer. Adaptable to wide range of soil types and moisture requirements. Will tolerate imperfectly drained soils.

b. Adapted over the entire state, except in the extreme southeast, where crown and root rot may injure stands.

c. Establishment can be suppressed by excessive competition from associated species.

d. Showy yellow flowers during summer.

e. Provides good food source and cover for many types of wildlife.

2. Perennial Ryegrass (Lolium perenne) and Annual Ryegrass (Lolium multiflorum):

a. Substitute approved perennial ryegrass varieties for annual ryegrass in most mixtures, since the vigorous annual ryegrass can prevent or retard the longer-lived but slower establishing grasses or legumes from becoming established.

b. Rye grasses germinate and establish relatively quickly if soil and climate conditions are optimum.

c. Use "turf" type varieties of perennial ryegrass.

3. Redtop (Agrostis alba):

a. Do not exceed recommended application rates. Seeds are very small and numerous. Excessive seeding rate can retard or suppress establishment of more persistent species in a mixture. Rapid germination under good conditions.

b. Creeping growth habit forming a coarse, loose turf, short lived.

c. Very adaptable to poor soil and wet or dry soils.

4. Weeping Lovegrass (Eragrostis curvula):

a. Short lived, perennial, "warm season" grass, often winter kills under Pennsylvania conditions. Drought resistant. Tolerant to low pH and aluminum soils such as reclaimed strip mined soils where high-sulfur material has been unearthed.

b. Useful in mixtures since it furnishes a quick cover until slower growing species such as deertongue can become established. Will not establish as quickly as ryegrass or some cereal grains.

c. Do not exceed recommended application rate since seeds are very small and numerous. Excessive seeding rate can suppress other specie development.

5. Switchgrass (Panicum virgatum):

a. Range type, bunch perennial "warm season" grass. Long-lived and deep rooted with good tolerance to relatively low soil pH and low fertility.

b. May often require 2-3 years or more to develop an acceptable dense vegetative cover.

c. Good for mine spoil areas and wildlife habitat replacement areas.

d. Compatible with Birdsfoot Trefoil.

6. Deertongue (Panicum clandestinum):

a. Do not plant in mixtures with Tall Fescue, Fine Fescues, Kentucky Bluegrass, Redtop, Reed Canarygrass, Annual or Perennial Ryegrasses, Crownvetch or Flatpea since it will not tolerate competition from these species.

b. May often require 2-3 years or more to develop an acceptable dense vegetative cover.

c. Seed 2-3 years old if of high vigor often germinates more readily than seed from previous years harvest.

d. Stratification of seed for 3-4 weeks at a temperature of 2-8 °C (35-45 °F) is often helpful in breaking seed dormancy.

e. Perennial "warm season" grass, useful in acid or infertile soils and droughty and moist soils.

f. Compatible with Birdsfoot Trefoil.

7. Crownvetch (Coronilla varia):

a. Perennial legume, somewhat slow to establish. Once established, it is a long lived, very vigorous grower and tends to dominate stands because of its ability to produce new plants from its roots.

b. Suppresses invasion of other plant species. Will "climb" onto fences and other low vegetation within reach.

c. Can also be planted using potted plants and crowns.

d. Herbaceous top growth dies back to ground each year.

e. Does best in a well-drained soil with pH of 6.0 or above, but has also been successfully established in soils with a pH as low as 5.4.

8. Flatpea (Lathyrus sylvestris):

a. Perennial, persistent, long lived, legume. Provides a dense mat of foliage.

b. Once established, it is very vigorous and spreads by underground rhizomes. Normal two year establishment.

c. Suppresses other invasive vegetation.

d. May also be planted using potted plants.

e. Food source and cover plant for many types of wildlife.

f. Herbaceous top growth dies back to ground each year.

g. Requires a well-drained soil with pH of 6.0 or above.

9. Tall Fescue (Festuca arundinacea):

a. Aggressive, deep rooted, tufted, long lived perennial.

b. Grows well on wet, poorly drained soil but also on drier soils and soils of low fertility. Withstands hot, dry weather.

c. Spreads by short underground stems.

10. Fine Fescues (Festuca spp):

a. Fine fescues include Creeping Red, Chewings, Hard and Sheep fescue.

b. Finest leaf of any lawngrass. Blends well with most other "cool-season" grasses.

c. Usually used in combination with another grass and a legume for soil conservation purposes.

d. Tolerates a wide range of light conditions from full sun to fairly dense shade.

e. Tolerates dry soils but does poorly on saturated soils. Performs well on roadsides with infrequent high mowing.

f. Not overly competitive in seedling stage. Fairly rapid germination and seedling establishment.

11. Big Bluestem (Andropogan gerardi)

a. Tall growing, perennial, deep rooted, vigorous bunch grass, sod forming. More drought tolerant than other "warm season" grasses. Grows 1 to 2 m (3 to 6 ft) tall.

b. Grows well on most soil types but can be used on excessively drained soil with low water holding capacity. Good tolerance to low pH and low fertility. Can be used on coal waste areas or strip-mined soils.

c. Generally takes 2 years to reach its maximum growth potential because of slow germination and seedling growth.

d. Seed is chaffy and will not flow well unless debearded. Specify 'Debearded' seed only. (Note: There are several specially designed seedbox seeders that will accommodate 'fluffy' seed.)

e. Important forage grass in the Midwest prairie states.

f. Wildlife use by songbirds and white-tailed deer for food and for nesting and escape cover.

Refer to Table 13.2 for various seed mixtures recommended for permanent cover for soil conservation planting areas.

Other seed mixtures than those listed in Table 13.2 may also be developed for selected areas but shall be approved by the Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section.

Refer to Table 13.3 for various specialty soil conservation areas where the recommended seed mixtures listed in Table 13.2 can be used.

Refer to Table 13.4 to convert the seeding rates listed in Table 13.2 to kg/1000 m^2 (lb/1000 SY) which is the standard area measurement for Department seeding applications.

TABLE 13.1
SPECIES FOR EROSION CONTROL AND SOIL CONSERVATION PLANTINGS

SPECIES	GROWTH HABIT[1]	TOLERATES					PERSISTENCE[4]	MINIMUM SEED SPECIFICATIONS[5]					
		WET SOIL	DRY SITE	LOW FERTILITY	ACID SOIL (pH 5-5.5)[2]	ALUMINUM[3]		PURITY (%)	READY GERM (%)	HARD SEED (%)	TOTAL GERM (%)	SEEDS/kg (1000's)	SEEDS/lb (1000's)
Warm-Season Grasses													
Deertongue grass	bunch	yes	yes	yes	yes	H	L	95	75	—	75	551	250
Weeping lovegrass	bunch	no	yes	yes	yes	M	S to M	97	75	—	75	3307	1500
Switchgrass	bunch	yes	yes	yes	yes	M	L	95	75	—	75	860	390
Big Bluestem	bunch	yes	yes	yes	yes	M	L	60 PLS				331	150
Cool-Season Grasses													
Tall fescue	bunch	yes	no	yes	no	L	M to L	95	80	—	80	500	227
Redtop	sod	yes	yes	yes	yes	L	M	92	80	—	80	11 023	5000
Fine fescues	sod	no	no	yes	no	L	L	95	80	—	80	882	400
Perennial ryegrass	bunch	yes	no	no	no	L	S to M	95	85	—	85	500	227
Annual ryegrass	bunch	yes	no	yes	no	L	S	95	85	—	85	500	227
Legumes													
Crownvetch	sod	no	yes	yes	no	L	L	98	40	30	70	265	120
Birdsfoot trefoil	bunch	yes	no	yes	yes	L	L	98	60	20	80	882	400
Flatpea	sod	no	no	yes	yes	L	L	98	55	20	75	22	10

NOTES

[1] Growth habit refers to the ability of the species either to form a dense sod by vegetative means (stolons, rhizomes, or roots) or to remain in a bunch or single plant form. If seeded heavily enough, even bunch formers can produce a very dense stand. This is sometimes called a sod but not in the sense of a sod formed by vegetative means.

[2] Once established, plants may grow at somewhat lower pH, but cover generally is only adequate at pH 6.0 or above.

[3] Tolerance to aluminum is relative. Soil and spoils must be limed to a pH of 5.5 to 5.7 to eliminate possible aluminum and manganese toxicity. Tolerance ratings: H = high; M = medium; L = low.

[4] Persistence under favorable conditions: L = long duration; M = moderate duration; S = short duration (1 year or less).

[5] MINIMUM SEED SPECIFICATIONS ARE TRULY MINIMUM, AND SEEDLOTS TO BE USED FOR REVEGETATION PURPOSES SHOULD EQUAL OR EXCEED THESE STANDARDS. Thus, deertongue grass should germinate 75% or better. Crownvetch should have at least 40% readily germinable seed and 30% hard seed. Commonly, seedlots are available that equal or exceed the minimum specifications. Remember that disturbed sites are adverse for plant establishment. Ready germination refers to seed that germinates during the period of the germination test and that would be expected, if conditions are favorable, to germinate rapidly when planted. The opposite of ready germination is dormant seed, of which hard seed is one type.

TABLE 13.2 (METRIC)
RECOMMENDED SEED MIXTURES FOR PERMANENT COVER FOR SOIL CONSERVATION PLANTINGS

MIXTURE NUMBER	SPECIES	SEEDING RATE (kg/ha) PLS**	
		MOST SITES	ADVERSE SITES ****
1***	tall fescue, or	67	84
	fine fescue	39	45
	plus redtop*, or	3.4	3.4
	perennial ryegrass	17	22
2	birdsfoot trefoil, plus	6.7	11
	tall fescue, plus	34	39
	redtop*	3.4	5.6
3	birdsfoot trefoil, plus	6.7	11
	crownvetch, plus	11	22
	tall fescue	22	34
4	flatpea, plus	22	34
	tall fescue, or	22	34
	perennial ryegrass	22	28
5	tall fescue, plus	45	67
	fine fescue	11	17
6	deertongue grass, plus	17	22
	weeping lovegrass*, plus	1.1	1.1
	birdsfoot trefoil	6.7	11
7	switchgrass, or Big Bluestem	17	22
	plus		
	weeping lovegrass*, plus	1.1	1.1
	birdsfoot trefoil	6.7	11

**** Soil conditions that are very acidic, infertile, severely eroded or possibly toxic and where liming, fertilization or other seedbed preparations are difficult to accomplish.

*** This mixture suitable for frequent mowing. Do not cut shorter than 100 mm.

** PLS means Pure Live Seed. PLS is the product of the percentage of pure seed times percentage germination divided by 100. For example, to secure the actual planting rate for switchgrass, divide 13 kg PLS by the PLS percentage shown on the seed tag. Thus, if the PLS content of a given seed lot is 35%, divide 13 PLS by 0.35 to obtain 37 kg of seed (35 percent PLS), the amount of seed required to plant 1 ha. All mixtures in Table 13.2 are shown in terms of PLS.

* Keep seeding rate of that recommended in table. These species have many seeds per kilogram and are very competitive. To seed small quantities of small seeds such as weeping lovegrass and redtop, dilute with dry sawdust, sand, rice hulls, buckwheat hulls, etc.

TABLE 13.2 (ENGLISH)
RECOMMENDED SEED MIXTURES FOR PERMANENT COVER FOR SOIL CONSERVATION PLANTINGS

MIXTURE NUMBER	SPECIES	SEEDING RATE (lb/acre) PLS**	
		MOST SITES	ADVERSE SITES ****
1***	tall fescue, or	60	75
	fine fescue	35	40
	plus redtop*, or	3	3
	perennial ryegrass	15	20
2	birdsfoot trefoil, plus	6	10
	tall fescue, plus	30	35
	redtop*	3	5
3	birdsfoot trefoil, plus	6	10
	crownvetch, plus	10	20
	tall fescue	20	30
4	flatpea, plus	20	30
	tall fescue, or	20	30
	perennial ryegrass	20	25
5	tall fescue, plus	40	60
	fine fescue	10	15
6	deertongue grass, plus	15	20
	weeping lovegrass*, plus	1	1
	birdsfoot trefoil	6	10
7	switchgrass, or Big Bluestem	15	20
	plus		
	weeping lovegrass*, plus	1	1
	birdsfoot trefoil	6	10

**** Soil conditions that are very acidic, infertile, severely eroded or possibly toxic and where liming, fertilization or other seedbed preparations are difficult to accomplish.

*** This mixture suitable for frequent mowing. Do not cut shorter than 4 in.

** PLS means Pure Live Seed. PLS is the product of the percentage of pure seed times percentage germination divided by 100. For example, to secure the actual planting rate for switchgrass, divide 12 lb PLS by the PLS percentage shown on the seed tag. Thus, if the PLS content of a given seed lot is 35%, divide 12 PLS by 0.35 to obtain 34.3 lb of seed (35 percent PLS), the amount of seed required to plant 1 acre. All mixtures in Table 13.2 are shown in terms of PLS.

* Keep seeding rate of that recommended in table. These species have many seeds per pound and are very competitive. To seed small quantities of small seeds such as weeping lovegrass and redtop, dilute with dry sawdust, sand, rice hulls, buckwheat hulls, etc.

TABLE 13.3
SOIL CONSERVATION PLANTING AREAS

SEED MIXTURE APPLICATION, TYPE OF AREA	TABLE 13.2 SEED MIXTURE NUMBERS
Slopes and banks (non-mowed)	
(a) Well-drained	4 or 7
(b) Variable drainage	2 or 3
Slopes and banks (mowed)	
(a) Well-drained	1 or 5
Gullies and eroded areas	2, 3 or 7
Conservation structures	
(a) Sod waterways, spillways and other frequent water flow areas	1 or 2
(b) Drainage ditches	
(1) shallow, less than 1.0 m (3 ft)	1 or 2
(2) deep, non-mowed	3
(c) Pond banks, dikes, levees, dams, diversion channels and occasional water flow areas	2 or 3
Sanitary landfill areas	2, 3, 6 or 7
Strip-mine spoils, mine wastes, fly ash, slag, settling-basin residues and other severely disturbed areas	2, 3, 4, 6 or 7

TABLE 13.4 (METRIC)
SEEDING APPLICATION RATE CONVERSION CHART
1 ha = 10 000 m^2

kg/ha	kg/1000 m^2	kg/ha	kg/1000 m^2
1.1	0.11	17	1.7
2.2	0.22	22	2.2
3.4	0.34	28	2.8
4.5	0.45	34	3.4
5.6	0.56	39	3.9
6.7	0.67	45	4.5
9.0	0.90	56	5.6
11	1.1	67	6.7
13	1.3	84	8.4

TABLE 13.4 (ENGLISH)
SEEDING APPLICATION RATE CONVERSION CHART
1 acre = 43,560 SF = 4,840 SY

lb/acre	lb/1,000 SY	lb/acre	lb/1,000 SY
1	0.25 (4 oz)	15	3
2	0.5 (8 oz)	20	4
3	0.6 (10 oz)	25	5
4	0.8 (13 oz)	30	6.25
5	1	35	7.25
6	1.25	40	8.25
8	1.75	50	10.5
10	2	60	12.5
12	2.5		

Seeding design selections are also controlled by several physical and chemical factors which must be considered prior to selecting a seed mixture. Some design considerations are as follows:

1. Soil analysis including composition, acidity, fertility, moisture content or any toxic properties.

2. Site conditions such as full sun, partial or heavy shade as well as directional slope exposures.

3. Slope criteria including steepness, embankment (fill) or cut surfaces.

4. Desired long term or short term longevity of selected plants including plant specie competition from species in the mixture and from adjacent vegetation.

5. Anticipated maintenance requirements.

A logical guideline procedure for seeding design would include:

1. Carefully analyze any limiting site factors, both physical and chemical.

2. Select an appropriate combination of adaptable plant species.

3. Select an appropriate set of establishment procedures consistent with the needs of the plant species to be seeded and the need to overcome any limiting site factors.

4. Only use seed of proper plant species or varieties of high germination capacity and vigor.

The proper use of lime and fertilizers and the addition of various soil amendments can rectify many unfavorable soil conditions and result in establishing an adequate vegetative cover with desired species.

E. Specification Preparation and Approvals. Seeding specifications for soil conservation plantings shall be prepared to include the following format: (1) soil supplements, (2) specie selections, (3) purity and germination percentages, (4) application rates and (5) construction requirements.

Refer to Figure 13.1 for seeding special provision format.

All seeding specifications and proposed seeding locations for soil conservation plantings shall be approved by the Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section.

F. Seed Quality. All seed sold in Pennsylvania must, by law, have a tag or label listing the tested percentages of pure seed, inert matter, crop seed and weed seed as well as germination percentage and test date. Seed with a test date older than nine months should not be used.

Certified seed is the best assurance of obtaining seed of high physical quality and known genetic identity especially for named varieties. For erosion control and conservation plantings, seed should be high in germination and purity rates.

PLS (Pure Live Seed) is a method of defining the planting quality of chaffy seeds such as various wildflowers and switchgrass. The PLS number is calculated by multiplying the % of pure seed by the % of germination and then dividing by 100. Example: 72% pure seed × 85% germination ÷ 100 = 61% PLS. This allows the amount of seed required to be adjusted to compensate for low purity and germination (see Table 13.2 note for an example of how the seed application rate is adjusted for the desired PLS number).

Generally "common seed" or seed of unknown genetic origin can be used for soil conservation plantings if certified seed is not available.

FIGURE 13.1
SPECIAL PROVISION FORMAT FOR SPECIAL SEEDING MIXTURES

SAMPLE SPECIAL PROVISION

Item 9804 - ×××× - Seeding and Soil Supplements - (Insert appropriate name)

DESCRIPTION - This work is furnishing and placing seed and soil supplements of the type specified.

MATERIALS -

(a)	Pulverized Agricultural Limestone	Section 804.2(a)1
(b)	Commercial Fertilizer	Section 804.2(a)2
(c)	Slow-Release Nitrogen Fertilizer	Section 804.2(a)3
(d)	Inoculant (When Applicable)	Section 804.2(c)
(e)	Seed Formula	

SEEDING RATE kg/1000 m^2 (lb/1000 SY)	MIN% PURITY/GERMINATION	MAX% WEED SEED

(Insert Desired Seed Formula)

Seed to meet applicable requirements of Section 804.2(b) for seed tests, PA Dept of Agriculture regulations, PA Seed Act of 1965, Act No. 187 and delivery of seed to work area.

CONSTRUCTION -

Loosen or roughen soil surface on all areas to receive seed to a depth of at least 50 mm (2 in).

Apply soil supplements in accordance with Section 804.3(c). Prior to project completion apply slow-release nitrogen fertilizer to soil surface.

When applicable, inoculate leguminous seed in accordance with Section 804.3(d).

Apply seed in accordance with Section 804.3(e). Spread seed where indicated and at the specified rate within the following dates, or as directed.

(Insert Desired Seeding Dates)

Follow Sections 804.3(i) and (j) for liability and maintenance requirements.

Mulch seeded area with straw in accordance with Section 805.

MEASUREMENT AND PAYMENT -

(a) Seeding and Soil Supplements. Kilograms (Pounds).
(b) Mulching. Section 805.4(a).

Some seeds, generally unscarified seeds of legumes such as crownvetch, birdsfoot trefoil and flatpea may have a watertight seedcoat. The seedcoat is eventually broken by either frost action or microbial action and germination will then produce a seedling. Seeds impervious to water are termed hard seed. The percentage of hard seeds in a given lot is added to the percentage of readily germinating seed to yield the total germination percentage. Legume seed lots should contain a certain minimum amount of hard seed as an insurance factor.

G. Seed Bed Preparation. Prior to seed application, soil supplements such as pulverized agricultural limestone and various fertilizer applications are required to prepare the area to be seeded.

Formula E does not normally require any applications of soil supplements. However, separate applications of lime, fertilizer or both may be necessary to establish the temporary grass cover in certain situations where anticipated soil conditions would not be conducive to good grass germination and growth.

Formulas B, C, D, L and W require soil supplement applications as specified in Publication 408, *Specifications*, Section 804.

Special soil conditions may require altering the standardized soil supplement application rates. All revisions shall be approved by the Bureau of Project Delivery.

Finished slopes should be seeded and mulched in increments of approximately 4.5 m (15 ft) with permanent in-season seeding at the full application rates specified for soil supplements, seed and mulch. If out-of-season seeding is approved, apply either the full specified quantities for supplements, seed and mulch or apply full supplements and 50% of the seed application rate to be followed by the remaining 50% within the next seeding dates. Full mulch rate applications will be required for each seeding application to prevent soil erosion until seed germinates.

H. Mulching. All seeded areas should be mulched with an appropriate approved mulch to reduce the potential for erosion while the seeds germinate. Mulch also aids seed germination by conserving moisture in the soil, encouraging water infiltration and helping to regulate soil temperature from excessive exposure to the sun's heat.

Several mulch materials such as straw, hay, wood fiber, pellet mulch and bonded fiber matrixes are approved for use with seeding operations. Wood chips have also been successfully used in some conservation type seeding areas if application depths are strictly followed.

1. Straw. This material is one of the most preferred and one of the least expensive mulches for most seeding operations. Use on all topsoiled areas. Straw needs to be secured in place with either approved mulch control binders or mulch control netting to prevent loss of material by natural winds or breezes caused by vehicular movement.

2. Hay. This material is more adaptable to steeper slope conditions than straw but is more apt to introduce undesirable weed seeds. This application may have wide use for development of wildlife habitat areas where it helps to introduce more diverse plant types. Use on untopsoiled areas. Hay needs to be secured in place with either approved mulch control binders or mulch control netting to prevent loss of material by wind.

3. Wood Fiber. This material is applied with hydraulic mulching/seeding equipment and after drying, provides a thin protective cover. Wood fiber does not provide as much erosion protection or moisture retention for seed germination as straw or hay. The wood fiber must adhere to the soil surface and its protective longevity is less than other mulches. Use on areas where fire hazard potential for straw or hay is high or where a less conspicuous mulch appearance is desired. No weed seeds are introduced with this material.

4. Wood Chips. Placing wood chips in thin mulch layers not deeper than 50 mm (2 in) has been successfully used in conservation type seeding areas. Thicker mulch layers of 75 mm (3 in), 100 mm (4 in) or deeper can be used without seed in temporary areas to provide erosion control until the permanent soil surface is prepared.

5. Pellet Mulch. This mulch is compressed pellets of shredded recycled paper which lose their pellet shape and adhere to other pellets, after water application, to form a thin protective cover. Pellet mulch is best used on flatter areas where a more refined turf grass, such as a lawn, is desired. Pellet mulch will not blow away.

Pellets are applied using rotary or drop-spreader equipment; therefore, slope steepness must be considered. No weed seeds are introduced with this material.

6. Bonded Fiber Matrix (BFM). This mulch is composed of fibrous material bonded together with adhesive agents to form a continuous, porous, erosion resistant protective cover which also adheres to the soil surface. BFM must be applied using hydro-mulching/seeding equipment and is applied at higher rates than standard wood fiber mulch. Generally use BFM on steep slopes where access and soil preparation is difficult. Use also on flatter areas where tacked straw or hay are prone to blow away or as an alternate to erosion control mats or blankets on slopes. Avoid using in direct water flow areas such as ditches, channels and swale centerlines, etc.

All areas of mulch use for seeding will be shown on the applicable typical sections and on the tabulation sheets.

Apply mulches at the rates specified in Publication 408, *Specifications,* Section 805.

13.3 OTHER STABILIZATION METHODS

A. Discussion. In most flat slope areas and areas where water generally does not have a concentrated flow, applying only mulch to the seeded area will be sufficient to provide the initial protection until the grass cover is established. On steeper slope areas, highly erodible soils, and drainage channels, other erosion control material will be necessary to provide the required protection to the seed and soil. Erosion control mats and blankets are commonly used for these applications. Turf reinforcement mats can artificially reinforce or augment the grass surface to permanently increase or enhance its resistance to erosion, and reduce the risk of grass failure due to localized poor cover establishment.

On the other hand, there are situations where grass establishment is not the most appropriate or, perhaps, cost-effective means of stabilization. Acceptable non-vegetated stabilization options are listed below.

Design guidance for all of the stabilization measures listed below can be found in Publication 584, *PennDOT Drainage Manual*, Chapter 8, Open Channels and Chapter 12, Erosion and Sediment Pollution Control.

B. Approved Measures.

1. Rolled Erosion Control Products (RECPs). Most provide temporary stabilization. Turf reinforcement mats are considered long-term, permanent stabilization measures.

a. Organic Erosion Control Blankets/Mats (ECBs).

- Erosion Control Mats.
- Erosion Control Mulch Blankets.
- High Velocity Erosion Control Mulch Blankets.

b. Synthetic Erosion Control and Revegetation Mats (ECRMs).

c. Turf Reinforcement Mats (TRMs).

2. Spray on Mulches. Method of applying mulch (usually also seed and fertilizer) as a spray from a hydraulic tanker truck.

3. Geocell Slope Confinement. Cellular HDPE material that is typically used to stabilize steep side slopes.

4. Articulated Concrete Block Revetment System (ACBR). Interlocking or tied blocks of concrete used to permanently stabilize slopes.

5. Gabions. Wire baskets filled with stone or riprap that can be stacked and somewhat deformed, if necessary.

13.4 EROSION CONTROL MEASURES

A. Discussion. Erosion control measures, or Best Management Practices (BMPs) are used to prevent the erosion of earth by the forces in stormwater runoff. Erosion of unstabilized and unprotected earth can occur very easily. The previous section dealt primarily with protecting disturbed slopes while vegetation is being established or where vegetation alone is not sufficient. Most of the erosion control BMPs in this section are associated with the protection of slopes or channels receiving concentrated flow, such as from an upstream channel, pipe, or culvert.

B. Approved Measures. A number of erosion control BMPs that are appropriate for use on highway projects have been approved by the Department. The list below contains the names and brief descriptions of some of these approved BMPs. Additional information on these devices can be found in Publication 584, *PennDOT Drainage Manual*, Chapter 8, Open Channels and Chapter 12, Erosion and Sediment Pollution Control. Plan drawing details for most of the BMPs are located in the Publication 72M, *Roadway Construction Standards*; these should be included in the Erosion & Sediment Pollution Control (E&SPC) Plan.

1. Channel Lining. Flexible (grass, RECPs, rock, etc.) or rigid (concrete) materials used to protect the underlying soil from erosion. Publication 584, *PennDOT Drainage Manual*, Chapter 8, Open Channels contains relevant design procedures and information.

2. Paved Energy Dissipator. Section of concrete channel lining containing partially embedded stones designed to dissipate energy in channels with velocities greater than 4.2 m/s (14 ft/s).

3. Rock Apron. Used to prevent scour and dissipate energy at pipe or channel outfalls where anticipated discharge velocities do not exceed 4.3 m/s (14.5 ft/s) and where the apron can be installed on a level grade.

4. Rock Basin or Rock Energy Dissipator. Pre-formed scour holes that are used to dissipate energy and control erosion at pipe outlets where outlet velocities exceed the allowable limits of the soil or channel lining, but are 5.7 m/s (19 ft/s) or less.

5. Stilling Well. Concrete energy dissipator constructed below grade at the outlet end of pipes and culverts.

6. Temporary Slope Pipe Drain. Installed to transport stormwater runoff safely down the face of a cut or fill slope to a stabilized area. Should be used prior to the installation of permanent facilities and/or growth of adequate ground cover on the slopes.

7. Diversion Ditch. Any type of channel that is constructed above a disturbed area to intercept and convey offsite runoff or runoff from undisturbed areas away from unstabilized areas.

C. Design Flows. In general, the temporary erosion control BMPs listed above must be designed to resist erosion for the 2-year storm event. Exceptions to this must be made for disturbances within Special Protection Watersheds (SPW) and for measures that will become permanent stormwater management or drainage facilities. Channels within a SPW must be provided with temporary lining able to resist erosion for the 5-year storm event. Permanent channel lining in any watershed must be resistant to erosion for the 10-year storm event, at a minimum. Temporary pipes, and outlet protection for temporary pipes, must be designed for the 2-year storm event (5-year storm event for SPW). Permanent outlet protection shall be designed for the maximum anticipated velocity from the discharging pipe.

13.5 SEDIMENT POLLUTION CONTROL DEVICES

A. Discussion. Sediment pollution control devices, which are also referred to as BMPs, are installed in and around construction sites to prevent sediments from being transported away from the site. Sediments can be carried off site by stormwater runoff and wind, or they can be attached to construction vehicles and deposited on roads adjacent to or near the site. Some sediment control BMPs temporarily hold runoff to allow sediments to settle out by gravity. Other BMPs filter runoff by straining sediment-laden water through a fine medium, such as filter fabric or gravel. The type of BMP used depends on the specific area of application.

B. Approved Devices. A number of sediment pollution control BMPs that are appropriate for use on highway projects have been approved by the Department. The list below contains the names and brief descriptions of the approved BMPs. Additional design and plan information on the devices listed in this section can be found in Publication 584, *PennDOT Drainage Manual*, Chapter 12, Erosion and Sediment Pollution Control. Plan drawing details for most of the BMPs are located in the Publication 72M, *Roadway Construction Standards*; these should be included in the E&SPC Plan.

1. Rock Construction Entrance. Used to remove mud from the tires of construction vehicles leaving the site. Required whenever vehicular access onto unpaved areas is necessary.

2. Rock Filter Outlet. Used to replace damaged sections of silt barrier fence or to fill in space between the end of a section of silt barrier fence and a slope.

3. Compost Filter Sock. A perimeter control device that filters runoff in the form of sheet flow. Use at the bottom of disturbed slopes that would normally drain across the right-of-way line or into a channel. Consists of compost material wrapped in a geotextile container.

4. Compost Filter Berm. Same as compost filter sock, except that the compost is mounded instead of being wrapped in a geotextile container.

5. Silt Barrier Fence. Same application as a compost filter sock. Geotextile fabric is fastened to stakes that are driven vertically into the ground.

6. Heavy Duty Silt Barrier Fence. Should be used when slope lengths exceed the capacity of standard silt barrier fence. Fabric is reinforced with wire mesh backing and metal posts are used instead of wood stakes.

7. Vegetated Filter Strip. Well-established perennial grassy area located below a disturbed area used to remove sediment from runoff prior to it reaching receiving waters.

8. Pumped Water Filter Bag. Used to filter out sediments from water pumped from excavation holes associated with bridge piers and abutments. Also used to dewater trenches and filter water pumped from sediment traps and basins.

9. Storm Inlet Protection. Used to filter or settle out sediment in runoff from disturbed areas before it enters the storm sewer. Includes inlet filters, traps, and berms.

10. Rock Barrier. Temporary stone dam installed across a channel to remove sediment originating from flow in the channel before vegetation is fully established.

11. Sediment Trap. Temporary storage area used to detain sediment-laden runoff from small, disturbed areas. Types include embankment, Type M inlet, and riser sediment traps.

12. Sediment Basin. Large ponding area used to detain sediment-laden runoff from large, disturbed areas.

13.6 PREPARATION AND PROCESSING OF EROSION AND SEDIMENT POLLUTION CONTROL PLANS

A. Plan Preparation. In order to minimize accelerated erosion and to control sediment pollution during highway construction, proper preparation and adherence to implementation of the scheduled sequence of operation of E&SPC Plans is of primary importance.

Erosion and sediment pollution control should be initially considered in the preliminary design stage and plans fully developed during the final design stage of a highway project.

The purpose of the E&SPC Plan is to identify potential erosion problems and to define effective and economical measures to be used in conjunction with construction activities to minimize erosion and sediment pollution. The E&SPC Plans for a project shall be prepared and processed in accordance with Publication 14M, Design Manual,

Part 3, *Plans Presentation*, Chapter 6. All erosion and sediment pollution control BMPs shall be indicated by the applicable symbols presented in Publication 14M, Design Manual, Part 3, *Plans Presentation*, Chapter 13.

An E&SPC Plan, as applied to Department projects, shall consist of three parts: (1) maps and drawings showing the topography of the area, the proposed alteration to the area and the erosion and sediment pollution control BMPs; (2) a narrative report describing the project and indicating the purpose and the engineering assumptions and calculations for control BMPs; and (3) detailed instruction in the contract proposal and/or the plan, as extracted from the narrative report data, to define staging, sequencing and scheduling of earthmoving activities and the installation of the erosion and sediment pollution control BMPs. The staging should be determined on the basis of such factors as: (1) drainage divide, (2) grade line direction, (3) efficient and economical construction operation, (4) earthwork balancing, (5) protection of traffic, and (6) maintenance consideration.

The following references located in Publication 584, *PennDOT Drainage Manual*, is useful information for developing PennDOT E&SPC Plans:

- Chapter 8 – Design procedure and guidance for channel lining
- Chapter 12 – Design guidance for approved BMPs
- Chapter 12, Appendix B – Recommended notes for E&SPC Plans
- Chapter 12, Appendix C – Recommended standards for E&SPC Plans

B. Implementation and Maintenance. Implementation of the E&SPC Plan on the project site and maintenance of BMPs thereafter are the responsibilities of the party performing the work, which is either the Department or the contractor. Every E&SPC Plan shall contain a sequence of earthwork activities that includes installation and removal of all proposed temporary and permanent BMPs. The contractor will be responsible for implementing the plan per this sequence. The contractor shall also be notified of his responsibilities, which include but are not limited to the following:

- Ensure that the E&SPC Plan is properly and completely implemented in accordance with the drawings and the technical specifications.
- Perform maintenance inspections on all BMPs after each rainfall event and, at a minimum, on a weekly basis, and document the inspections using inspection log sheets. All preventative and remedial work must be performed immediately.
- Obtain approval from the appropriate county conservation district or PA DEP regional office if deviation from the E&SPC Plan is necessary or desired.
- Maintenance of all permanent BMPs becomes the responsibility of the owner in perpetuity upon completion of construction and acceptance by owner, subject to the terms of the warranty period specified in the contract documents.
- Fines and related costs resulting from the contractor's failure to provide adequate protection against soil erosion and for any violations of the Clean Streams Law and the rules and regulations promulgated thereunder shall be borne by the contractor.

These responsibilities and others specific to the project shall be described in the E&SPC Plan. Maintenance instructions for each BMP to be used on a project must be provided on the plan.

C. Other Necessary Actions for Project Compliance. To assure compliance with regulatory requirements and to provide additional emphasis on erosion and sediment pollution control, necessary actions should be taken to comply with the following:

1. The E&SPC Plans should be judiciously developed and implemented in accordance with the procedures and criteria specified in Publication 584, *PennDOT Drainage Manual*, Design Manuals, and Publication 72M, *Roadway Construction Standards*. If the proposed measures and facilities deviate from the specified procedures or criteria, it should be demonstrated that the alteration shall also result in prevention of accelerated erosion and sedimentation.

In general, only one E&SPC Plan needs to be developed throughout the life of a project. This plan would normally cover all staged earthmoving activities. However, on major highway projects, it may be necessary to

develop two or more control plans to address earthmoving activities which will occur before or after the prime construction project, or to be performed by a separate contractor or consultant.

2. A National Pollutant Discharge Elimination System (NPDES) permit is required for those highway projects in which the total project earth disturbance area is equal to or greater than 0.4 ha (1 acre). In Pennsylvania, the NPDES permit program is delegated to and administered by PA DEP. PA DEP has delegated the management of the NPDES program to most of the County Conservation Districts. PA DEP and County Conservation Districts jointly regulate construction activities utilizing existing state regulations concerning erosion control and NPDES permits to implement the Federal requirements.

The 1972 amendments to the Federal Water Pollution Control Act (Clean Water Act or CWA) prohibit the discharge of any pollutant to Navigable Waters of the United States from a point source unless the discharge is authorized by a NPDES permit. The U.S. Environmental Protection Agency (EPA) has promulgated rules for the NPDES permit process:

- Phase I: Established in 1990, Phase I addresses discharges from large construction activities disturbing 5 acres or more of land.

- Phase II: Established on December 8, 1999, Phase II covers small construction activities that result in a land disturbance of equal to or greater than 1 acre and less than 5 acres. Site activities disturbing less than 1 acre are also to be regulated as a small construction activity if they are part of a larger common plan of development or sale with a planned disturbance of equal to or greater than 1 acre and less than 5 acres.

PA DEP issues two types of NPDES permits for Stormwater Discharges Associated with Construction Activities – a General Permit (PAG-2) and an Individual Permit. PAG-2 covers most projects; however, an Individual Permit is needed for projects in "special protection" watersheds (high quality, exceptional value, and exceptional value wetlands). Copies of the NPDES permit application forms, instructions, and other related documents are available through PA DEP's website (www.dep.state.pa.us).

Each local municipality and county involved shall be notified, pursuant to Act 14, P.L. 834, to the effect that an application for the NPDES has been filed with PA DEP and the documentation of this notification included in the application submitted. No permit application fee is required for any application submitted by the Department. The NPDES shall be processed by the Engineering District through the County Conservation District, or PADEP, according to the established procedure. If construction of the project can not be completed within the time limit normally specified in a permit, a longer time limit to cover the entire construction period should be requested when the permit application is submitted.

3. An NPDES permit is not required for those highway projects which involve a total project earth disturbance area of less than 1.0 acre. However, the erosion and sediment pollution control measures and plans must comply with PA DEP's Chapter 102 regulations.

4. Best Management Practices (BMPs) must be utilized for all earth disturbances, regardless of area. Standards for the BMPs are contained in Publication 584, *PennDOT Drainage Manual*, Chapter 12.

5. A written E&SPC Plan must be prepared for projects that disturb 5000 ft^2 or more. (Note: Two additional conditions which may require a written plan are listed in PA Code Section 102.4(b)(2).)

6. An Erosion and Sediment Control Permit is required for roadway maintenance projects that disturb 25 acres or more.

7. Special protection BMPs are required when earth disturbance activities may result in a discharge into a water classified under Chapter 93 of the PA Code as High Quality (HQ) or Exceptional Value (EV), including EV wetlands.

8. The current standard special provisions for the E&SPC, as indicated in the Department's Contract Management System, should be included in all applicable contract proposals.

9. The necessary E&SPC practices must be fully implemented and monitored during the construction of the highway project.

10. One copy of the E&SPC Plan should be sent by the Engineering District to the Central Office, Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section for information and review at the time the plan is submitted to the County Conservation District.

11. The County Conservation Districts have been delegated responsibilities for PA DEP's Erosion and Sediment Control Program. Under this program, authority is delegated to Conservation Districts at three different levels: Level I, Level II, and Level III. Level I delegation (four counties) includes providing information on PA DEP's Erosion and Sediment Control Program, the review and processing of Erosion and Sediment Control Permit applications, and the review of Erosion and Sediment Control Plans. Level II delegation (51 counties) includes Level I responsibilities, plus responsibilities of complaint investigation and site inspections. Level III delegation (10 counties) includes Level I and II responsibilities, plus enforcement responsibilities such as administrative hearings, equity actions, summary or misdemeanor actions, and assessment of civil penalties.

In addition to the Erosion and Sediment Control Program, 60 Level II and III Conservation Districts are also delegated responsibilities for processing National Pollutant Discharge Elimination System (NPDES) Permits for Stormwater Discharges Associated with Construction Activities. (Note: Philadelphia County does not have a County Conservation District.)

12. During construction, it is encouraged that PA DEP's Area Office staff be contacted to assist in implementing the erosion and sedimentation control measures and facilities. All significant changes, additions and/or deletions to the plans approved with a permit which will affect erosion and sediment pollution controls shall be approved by PA DEP prior to construction.

13. Generally, individual PennDOT construction projects will be issued one NPDES permit for the entire project, and this permit will apply inclusively to borrow and spoil areas.

14. NPDES permits are issued during the final design phase.

15. After spoil and borrow areas are identified, and before any earth moving activities occur in them, E&SPC Plans must be submitted and approved. Once approved, these E&SPC Plans automatically become amendments to the project's original NPDES permit.

16. Since there is only one NPDES permit issued to PennDOT for the entire project, if this permit is violated and subsequently suspended or revoked, that action will affect the entire project.

13.7 ANTIDEGRADATION AND POST CONSTRUCTION STORMWATER MANAGEMENT POLICY

A. Background. PennDOT performs a broad spectrum of activities in order to maintain and improve the state's roadway system. Highway improvement projects involve, to varying degrees, altering the existing landscape through a combination of clearing, compaction, and impervious cover. These activities disrupt the natural hydrologic processes that reduce surface runoff, such as interception and infiltration. It has been well-documented that the development of land into less pervious areas generally leads to an increase in stormwater runoff volume, higher peak flows, higher average temperature of runoff, collection of a larger mass of pollutants (due to lack of infiltration capacity), and an increased flooding hazard for downstream waterways. All of these factors contribute to degradation – changes in the physical, chemical, and biological properties – of the receiving waters.

That being said, not all projects are created equal in terms of their potential to impact receiving waters. Many land development projects involve the clearing of forests and meadows, and developing productive farmlands. On the other hand, the vast majority of PennDOT projects involve improvements within an existing legal right-of-way, which has already been largely disturbed in order to construct the highway facility. Thus, PennDOT improvement

and maintenance projects tend to have less of an effect on runoff characteristics than other types of development projects. However, there are effects associated with most non-maintenance activities, and those effects are generally proportional to the amount of additional impervious area being proposed.

Among Pennsylvania's water quality standards are antidegradation requirements, which are described in Section 93.4a of the PA Code. The antidegradation requirements are aimed at protecting the existing instream uses of surface waters, in addition to maintaining and protecting the water quality of High Quality (HQ) and Exceptional Value (EV) waters. Stormwater runoff is considered a point source discharge which has the potential to impact existing uses and water quality, so it is regulated by PA DEP.

Three key measures are used to assess the potential for impacts from stormwater runoff – volume, rate, and quality. The goal of post construction stormwater management (PCSM) is to prevent or minimize any increase in the quantity (rate and volume) of runoff while also minimizing the factors affecting the quality. The best way to achieve antidegradation is to mimic the natural, pre-development hydrologic conditions, which are usually dominated by infiltration and evapotranspiration (ET – see definitions). This is a two-fold solution because stormwater management strategies that address quantity normally also address quality. However, the inherent characteristics of highway projects sometimes limit the options for volume reduction. Therefore, it is also important to have a combination of strategies that reduce the amount of runoff being generated.

PCSM is required whenever a project (1) requires an NPDES construction stormwater permit (Section 13.7.B.2), or (2) is located in a watershed with an approved Act 167 stormwater management plan. PennDOT recognized that a policy on antidegradation and PCSM was needed in order to establish guidelines for addressing project-induced changes in runoff. This policy is a tool for achieving a target, which is consistency with Pennsylvania's antidegradation regulations and federal NPDES requirements. The guidelines that are provided were developed with the most common types of PennDOT construction projects and circumstances in mind. However, it is important to keep in mind that there will be projects with circumstances that require considerations beyond those recommended for these typical situations. The following sections describe the specifics of the policy.

B. Policy on Antidegradation and Post Construction Stormwater Management. This policy outlines PennDOT's proactive approach to protecting the surface waters of the Commonwealth from degradation. Most of the information in this section is related to the implementation of a standardized approach for selecting PCSM best management practices (BMPs) on projects. However, this is just one component of an overall program to enable PennDOT to adapt to current practices and maintain consistency with evolving stormwater requirements. PennDOT will use a comprehensive "E^5" strategy for addressing stormwater management issues, which is consistent with PennDOT's MS4 permit. The goal is to integrate each of the E^5 components into the overall design process in order to achieve a program that is sustainable and efficient. The E^5 strategy includes:

- **E**ncouraging low impact practices for preventing runoff;
- **E**valuating site characteristics and BMP needs early in the design process;
- **E**ngaging PA DEP through pre-application meetings;
- **E**stablishing a process to evaluate new technologies, assess the performance of existing ones in the field, and update/expand the BMP toolbox; and
- **E**ducating PennDOT staff, consultants, and contractors on stormwater policy and implementation.

This comprehensive approach to stormwater management is needed in order to address the many challenges presented by runoff from PennDOT's facilities. In Pennsylvania, the three primary concerns related to the effects of runoff on water resources from roadway facilities are:

- Stream channel erosion and flooding resulting from increases in runoff rate and volume;
- Water quality impacts to streams and groundwater aquifers from particulates, floatables, hydrocarbons, and deicing materials; and
- Thermal impact on streams caused by heat transfer from pavement to runoff and loss of riparian buffer vegetation.

Chapter 7 of the PA Stormwater BMP Manual (PA DEP, 2006), herein referred to as the "BMP Manual," lists a number of additional common pollutant constituents in highway runoff. Many, if not most of these constituents occur in relatively small concentrations and are usually addressed when the increases in the rate and volume of

runoff are mitigated. The items listed above are the primary concerns related to potential water resources impacts and are discussed below in more detail.

1. Increases in Runoff Rate and Volume. It is well documented that a direct relationship exists between the imperviousness of a watershed and the impairment of its surface waters. Unmitigated increases in the rate and volume of runoff discharging from developing areas have a cumulative effect, which has been shown to cause flooding and erosion of streams. Increases in the rate and volume of runoff are mostly dependent on the amount of impervious area replacing pervious area, the amount of disturbance, and the time it takes for the runoff to concentrate and leave the site. Some types of projects add relatively little (or no) impervious area and require minimal disturbance, while other types of projects create large areas of impervious cover and disturbance. Increased discharges can often be prevented in the former case by implementing qualitative and non-structural measures; whereas the latter case usually requires structural measures for peak flow and volume mitigation. Because there is a wide range of activities affecting stormwater and an array of potential BMP solutions, it is necessary to group the activities and BMPs in order to create a standard approach that applies to most PennDOT projects. This approach is described in detail in Section 13.7.C.

The peak rate and volume control achieved through application of the BMP Manual guidance results in treatment of a major fraction of pollutants associated with particulates from impervious surfaces, in addition to flood and stream channel protection during most storms. It should be noted, however, that solutes will continue to be transported in runoff throughout the storm, regardless of its magnitude.

2. Winter Maintenance Materials. Chlorides and other soluble chemicals in deicing materials and salts can spike concentrations in groundwater. In addition, the fine sediments that make up anti-skid materials can be carried into an adjacent stream or accumulate over and clog an infiltration facility. The BMP Manual and PennDOT's MS4 permit list several good housekeeping approaches that PennDOT is working on to minimize pollutant loadings from winter maintenance materials, including

- Monitoring and minimizing the volume of winter maintenance materials used;
- Protecting salt storage and loading areas from weather influences; and
- Cleaning around the area where materials are dispensed immediately after deicing operations have ceased.

3. Thermal Impact. In warm months, heat transferred from stormwater runoff to cold-water streams can be a potential source of thermal impacts. This type of effect is pronounced in urban areas. Runoff is heated as it passes over impervious surfaces with large heat storage due to solar radiation. As the magnitude of impervious surfaces and open water ponds or basins increase, or when riparian areas (i.e., vegetated buffer zones) decrease, there is a potential for increasing summer stream temperatures. Other studies have shown similar effects in the winter, except that impervious areas cool the runoff below the stream's ambient temperature. Thermal impacts are also particularly important for surface waters that have a fishery classification of Cold Water Fishes or Trout Stocking; this includes waters that are High Quality waters due to an existing or designated use as a Class A wild trout stream by the PA Fish and Boat Commission. PA DEP and PennDOT have developed strategies to reduce potential thermal impacts, which include the following:

- Limit the use of curb and gutter sections as much as practicable;
- Limit the use of storm sewers as much as practicable;
- Consider alternative methods of energy dissipation at culvert and storm sewer outfalls;
- Discharge storm sewers into non-EV wetland areas or vegetated swales as much as practicable;
- Consider vegetated islands in-lieu of concrete islands; and
- Maintain naturally occurring vegetation (i.e., buffer zones, including wetland and riparian) along streams, rivers and other surface waters for shading and thermal protection.

Two additional factors that should be considered when evaluating a project's potential for thermal impacts are (1) the distance from the impervious areas to the surface water and (2) the size of the surface water relative to the amount of runoff generated by the impervious areas. Generally speaking, the longer the travel time through vegetated or shaded areas, the cooler the runoff will be when it eventually reaches the surface water. Although the use of vegetated swales for stormwater conveyance is preferred, storm sewers are buried and generally stay cool; thus, a significant amount of heat loss can take place in a long sewer run before the runoff reaches the

surface water. The size of the receiving surface water is an important factor due to mixing phenomena. Large highway projects that are adjacent to headwaters have the potential to adversely affect the temperature regime because runoff from the highway may produce a significant percentage of the total surface flow in the headwater. In this type of situation, it is particularly important to address potential thermal impacts using the strategies outlined above. However, it is more likely that the runoff produced by the road during a storm is insignificant compared to the flow in the receiving surface water. Additionally, the water quality criteria do not preclude the allowance of a reasonable mixing zone if there is no significant effect on the ambient temperature of the stream outside the mixing zone.

C. Project Categories. The most common types of construction projects that PennDOT engages in are grouped into three categories – bridges, highway restoration, and new construction – and presented in Table 13.5. Descriptions for each type of project are provided in the table. PCSM levels, which are located in the right-hand column of the table, are determined by:

- the potential for generating increased stormwater discharges (volume or rate) as a result of the activity;
- the potential for causing thermal impacts to receiving surface waters; and
- the potential for discharging high concentrations of pollutants (e.g., salt storage facilities).

The projects in Table 13.5 are assigned a PCSM level, from 1 to 3, which represents a scale of low potential (Level 1) to high potential (Level 3) for the items listed above. For example, a project involving a highway interchange reconfiguration (Level 3) has a greater potential for generating increased runoff than a project proposing to add a center-turning lane to a local intersection (Level 2).

In addition to factors listed above, the sensitivity of the area or the watershed receiving runoff from the project is an important consideration in the analysis of increased runoff impacts. In fact, a project should be considered PCSM Level 4, regardless of the type of project it is, when it has the potential to discharge into one of the following sensitive areas, which are noted in Table 13.6:

- HQ or EV waters, or EV wetlands,
- stormwater-impaired surface waters,
- combined sewer systems, and
- surface waters containing critical habitat for threatened or endangered species.

Each of the four PCSM levels corresponds to a different set of stormwater BMPs, which is called a "BMP toolbox." The BMPs within that toolbox may be used to prevent or control runoff from that particular project after the BMPs in the lower level toolboxes have been considered. The lower level BMPs are generally focused on minimizing the potential impacts from runoff by applying preventative design and construction measures, which are applicable on most projects. There may be circumstances that warrant the use of BMPs from a higher-level toolbox (e.g., a Level 2 project that uses BMPs in the Level 3 toolbox). In these cases, the PennDOT project manager should be consulted.

TABLE 13.5
PCSM LEVELS FOR PROJECTS LOCATED IN NON-SENSITIVE AREAS

Type of Project		Description	PCSM Level
Bridges	New or Replacement over Water	Total bridge length is 200 feet or less, or at least 75% of total bridge length is over water for longer bridges.	1
		Bridges longer than 200 feet and more than 25% of length over land.	2
	Replacement over Land	Similar to 3R widening.	2
	New over Land	Bridge over pervious area is similar to new road alignment; if new bridge over existing impervious, subtract impervious area below the bridge.	3
Highway Restoration (3R)	Pavement	Replace portions, overlay, or mill and resurface the roadway's surface.	1
	Widening	Increase the width of the existing travel lanes (no new lanes added) and shoulders, or extension of acceleration/deceleration ramps in existing shoulder areas.	2
	Shoulders	Resurface, stabilize, upgrade (dirt or gravel to paved), or widen the existing shoulders within the existing footprint.	1
	Intersection	Nominal channelization of intersections and addition of turning lanes.	2
	Alignment	Change the roadway by either reducing or eliminating horizontal and vertical curves.	2
	Pull-offs	New, as part of a larger project or by itself.	2
	Other	Replace and/or repair guide rail, signs, traffic signals, and drainage systems to their original specifications; various minor safety improvements.	1
New Construction	Major Widening	Addition of one or more travel lanes, including acceleration and deceleration lanes, to an existing road.	3
	New Alignment	New roadway corridor.	3
	Interchange	Reconfiguration of ramps, lane modification within interchange area, etc.	3
	Facilities	New stockpile sites, park-and-ride lots, rest stops, etc.	3

TABLE 13.6
PCSM LEVELS FOR PROJECTS LOCATED IN SENSITIVE AREAS

Type of Area	Description	PCSM Level
HQ/EV waters or EV wetlands	Any portion of a project having a potential to discharge into waters with existing or designated HQ or EV uses per 25 PA Code 93, or EV wetlands per 25 PA Code 105.	4
Impaired watershed	Any portion of a project discharging into a watershed identified by PA DEP as having impairments due to stormwater.	4
Combined sewer systems	Any portion of a project discharging into a combined sewer system.	4
Threatened and endangered species and critical habitat	Any portion of a project that has the potential to have an adverse effect, either directly or indirectly, on threatened or endangered Federal or Pennsylvania species, or critical habitat for threatened or endangered species (e.g., bog turtle wetlands).	4

1. PCSM Level 1. These types of projects involve restoring an existing roadway to its original condition; pervious areas are generally not being converted into impervious areas. Level 1 projects do not measurably change the post-construction rate, volume, or quality (including temperature) of runoff from the site. The BMPs listed in Table 13.7 should be employed and the designer should attempt to maintain pre-development stormwater conditions. Also refer to the E&S procedures and BMPs outlined in PennDOT's Drainage Manual for designing measures to prevent polluted discharges from the construction site. If one or more of the BMPs in Table 13.7 can be used for a substantial portion of a project, calculations for peak flow, volume, and water quality are usually not required for Level 1 projects.

Level 1 Target – Minimal disturbance.

TABLE 13.7
LEVEL 1 BMP TOOLBOX

Stormwater BMP	Reference[1]	Application
Minimize compaction	[8] Ch 5.6.2	Designate areas for construction vehicle traffic to prevent unintended compaction
Preserve trees and re-vegetate using native species	[8] Ch 5.6.3	Preserve trees by clearing only those that are safety hazards and that are necessary for construction; preserve riparian buffers; clearly mark overall limits of disturbance; re-vegetation of abandoned alignment; re-vegetate temporary staging areas
Maintenance of dual-purpose E&S/PCSM BMPs	[7] Ch 12	Proper maintenance and conversion of E&S control facilities, such as sediment basins, into permanent PCSM facilities, such as infiltration basins
Restoration of temporary staging areas	[8] Ch 6.7.3	Restore areas used for temporary staging or storage of materials by replacing or supplementing the soil and re-vegetating the disturbed areas

1 – List of References: [7] PennDOT, 2007; [8] PA DEP, 2006

2. PCSM Level 2. Level 2 projects typically involve a minor addition of impervious area relative to existing conditions and do not generally change the direction of runoff or the potential for pollutants in the runoff. For

example, widening existing travel lanes or shoulders for improved safety does not increase the volume of traffic; thus, the amount of potential pollutants deposited and the amount of deicing materials used on the road are not expected to increase. A relatively small volume of additional runoff is generated by the new impervious area, in part because the pervious areas within the right-of-way are highly compacted and exhibit runoff qualities similar to impervious areas. The primary focus of a Level 2 project analysis should be to compare the existing and proposed runoff characteristics. In many cases, the existing road and right-of-way will contain very few, if any, BMPs that significantly contribute to improving water quality and reducing runoff volume. The additional runoff can often be dealt with using non-structural and restoration BMPs when the roadway runoff does not discharge directly to surface waters.

TABLE 13.8
LEVEL 2 BMP TOOLBOX

Stormwater BMP		Reference[1]	Application
Non-Structural	Street sweeping	[9] Ch 11 [8] Ch 5.9.1	Most effective in urban areas for removing debris and sediment on roads; bridges over HQ/EV waters
	Impervious disconnection	[8] Ch 5.8.2	Disconnect road from storm sewer; eliminate curb/gutter where possible and provide curb cuts to allow flow into parallel BMPs
	Slope roughening	N/A	Includes surface roughening, grooving, tracking, stepping, etc.; use on slopes to reduce erosion potential and increase ET
	Pavement width reduction	[8] Ch 5.7.1	Use minimum allowable pavement widths; consider design exceptions where adjacent road sections are narrow
Structural – Restoration	Riparian buffers	[8] Ch 6.7.1	Reestablish buffer areas along stream; minimum 10.5 m (35 ft) width from top of bank
	Landscaping and planting	[8] Ch 6.7.2	Use non-invasive native species vegetation in lawn areas and on slopes, to enhance water uptake and the storage of certain pollutants in plant tissue. Use sod-forming grasses adjacent to the roadway shoulders and for vegetated swales to serve as filters for suspended solids and metals.
	Soil amendments	[9] Ch 13 [8] Ch 6.7.3	Replace poorly draining soils in swales or other areas receiving runoff with a permeable/organic mix of soil
Structural	Vegetated swales	[9] Ch 14	Convert ordinary shoulder swales and rock-lined ditches to vegetated swales (see BMP descriptions); use check dams; supplement with subsurface storage if necessary
	Bioretention	[9] Ch 5 [8] Ch 6.4.5	Convert median areas on low-volume roads and intersections to vegetated areas or replant existing vegetated areas with species that offer greater ET
	Vegetated filter strip	[8] Ch 6.4.9	Receives sheet flow directly from pavement edge; used on embankment slopes of fill sections and adjacent to flat sections
	Constructed wetlands / Wet ponds	[8] Ch 6.6.1 [8] Ch 6.6.2	Retrofitting an existing dry detention basin only

1 – List of References: [8] PA DEP, 2006; [9] Transportation Research Board, 2006

The structural BMPs listed in Table 13.8 can be used where they can be retrofitted within the existing footprint without affecting safety, and where the roadway facility would normally discharge directly into a conveyance system or surface water. Examples of swale retrofitting include: replacing earth material and/or vegetation in swales to encourage evapotranspiration and/or infiltration; adding an organic layer (i.e., compost) to encourage

bioretention; replanting with species that offer greater evapotranspiration opportunities (i.e., larger root systems); and retrofitting ditches with check dams to provide storage in the channel. The vegetation for filter strips may be comprised of (1) turf grasses, (2) meadow grasses, shrubs, and native vegetation, including trees, and (3) indigenous areas of woods and vegetation. The BMP references [1, 6, 7, 8, 9, 11] should be consulted for information on increasing the capacity and efficiency of the structural BMPs. In addition, a combination of BMPs is preferred over a single BMP treatment because they can compliment each other and provide a more effective means of treatment.

Level 2 Target – Where existing swales and median areas can be retrofitted with structural BMPs without adversely affecting safety, BMPs should be designed to (1) capture 50 mm (2.0 in) of runoff from all impervious areas contributing to the BMPs; (2) permanently remove the first 25 mm (1.0 in) of runoff from new impervious areas by assimilating through infiltration and/or evapotranspiration; and (3) infiltrate the first 13 mm (0.5 in) of runoff from new impervious areas. Where retrofitting existing swales and medians is not feasible, the designer should maximize the use of non-structural and restoration-type BMPs that encourage and/or enhance evapotranspiration in order to attempt to maintain pre-development stormwater runoff conditions. Peak discharge rates should be calculated where the use of structural BMPs is not feasible and a measurable difference between pre- and post-construction rates is anticipated.

The Level 2 target is in alignment with Control Guideline 2 (CG-2) in the BMP Manual. Level 2 projects exceeding 0.40 ha (1.0 ac) of disturbance should apply the above guidelines, even though the BMP Manual recommends limiting the application of CG-2 to 0.40 ha (1.0 ac) of disturbance. Disturbance to 0.40 ha (1.0 ac) of clustered land has a high potential to affect an adjacent surface water receiving runoff from the site. Given this scenario, the ratio of receiving waters to disturbed area is 1-to-1. On the other hand, a 3R project that proposes 0.6 m (2 ft) of shoulder widening on both sides of the road would have to be 3.2 km (2 mi) long to equal 0.40 ha (1.0 ac) of disturbed area. Assuming that there are five small tributaries per 1.6 km (1 mi) for this particular project, the ratio of receiving waters to disturbed area (and added impervious area) is 10-to-1. Although the actual number of receiving waters varies from project to project, these types of ratios are typical and provide justification for the recommended PCSM target for Level 2 projects in this policy.

3. PCSM Level 3. These projects typically involve a significant increase in an existing roadway's footprint or, as in a new alignment, significant changes in topography and cover. By altering the landscape, these projects generally produce higher volumes and rates of runoff. The structural BMPs in Table 13.9 should be considered for integration into the design of the stormwater management and drainage systems. Most of these BMPs reduce runoff volume through a combination of infiltration and evapotranspiration, while all of the BMPs have some capacity for peak reduction and water quality.

Level 1 and 2 BMPs should be examined first before Level 3 BMPs are considered. In addition, incorporate low impact design concepts such as (1) maintaining natural drainage divides, (2) preserving naturally vegetated areas, (3) grading to encourage sheet flow, and (4) directing runoff into or across vegetated areas.

Level 3 Target – Reduce the post-construction runoff peak rate to the pre-construction peak rate for the 1-year through 100-year storm events. Reduce the post-construction runoff volume to the pre-construction runoff volume for the 2-year 24-hour storm event and smaller. The plans must also comply with the water quality requirements established by 25 PA Code 93.

TABLE 13.9
LEVEL 3 BMP TOOLBOX

Stormwater BMP	Reference[1]	Application
Vegetated swales	[9] Ch 14 [8] Ch 6.4.8	Shoulder swales, medians, top of cut ditches, storm sewer outlet channels; use check dams to increase volume capacity; plant with salt-tolerant vegetation such as creeping bentgrass and switchgrass
Bioretention	[9] Ch 5	Divided highway medians; can combine with infiltration trench to increase volume capacity
Bioslopes	[9] Ch 6	Embankments with engineered soil media; similar to vegetated filter strip except filtering occurs below the surface
Dry extended detention basin	[7] Ch 14 [8] Ch 6.6.3	Traditional detention basins; use where infiltration is not feasible and wet ponds are undesirable (safety concerns, etc.)
Infiltration trench	[9] Ch 9 [8] Ch 6.4.4	Design as part of a storm sewer system using perforated pipes: virtually no release of small storm events and normal conveyance of large events; can incorporate with vegetated swales; limited use in karst topography
Infiltration basin	[8] Ch 6.4.2	Use in conjunction with an extended stormwater detention for peak flow detention; limited use in karst topography; ideal in interchanges
Infiltration berm	[8] Ch 6.4.10	Locate between roadway and adjacent surface water; place parallel to contours on 4:1 or flatter slopes; can be combined with an infiltration trench; limited use in karst topography

1 – List of References: [7] PennDOT, 2007; [8] PA DEP, 2006; [9] Transportation Research Board, 2006;

4. PCSM Level 4. Level 2 or 3 projects that have the potential to discharge into surface waters that (1) have existing or designated HQ or EV uses (including EV wetlands), (2) have impairments due to stormwater, (3) are connected to combined sewer systems, or (4) have the potential to have an adverse effect on threatened or endangered species, or critical habitat for such species, are elevated to PCSM Level 4. Level 4 BMPs in Table 13.10 should be considered only after BMPs for Levels 1 through 3 are applied, where appropriate, to address the runoff from the additional impervious surfaces. Generally, PCSM BMPs that address quantity (rate and volume) also address quality. To demonstrate this determination, water quality requirements will be met when there is no net change in the pre/post runoff volume comparison for the 2-year 24-hour storm event, rate is controlled for the 1-year through 100-year storm events, and the nitrate removal efficiency of the proposed BMPs has been documented (see FAQ #6).

If the approved BMPs in this policy cannot accomplish the non-discharge alternative (a no net change in runoff for rate, volume, and quality), then Antidegradation Best Available Combination of Technologies (ABACT) BMPs need to be incorporated. ABACT BMPs include practices that, in combination, provide (1) cost-effective treatment, (2) land disposal, (3) pollution prevention, and (4) stormwater reuse technology approaches. In the Antidegradation Analysis Section of the NPDES permit, which applies only to Special Protection waters, the applicant must describe how these items have been satisfied. All but the last item, stormwater reuse technology approaches, can be satisfied using the BMPs described in this policy. Except for possibly PennDOT buildings, park-and-ride lots, and maintenance facilities, stormwater reuse is not feasible for PennDOT projects. Table 13.11 lists the BMPs in this policy according to which ABACT category they can be applied. Prior approval from the PennDOT project manager is required for using BMPs that are not listed in this table. Manufactured products, such as water quality inlets and underground detention units, require special approval from the Bureau of Project Delivery, Highway Delivery Division, Highway Design and Technology Section, and will be assessed on a project-by-project basis.

TABLE 13.10
LEVEL 4 BMP TOOLBOX

Stormwater BMP	Reference[1]	Application
Constructed wetlands / Wet ponds	[8] Ch 6.6.1 [8] Ch 6.6.2	Significant detention of peak flow rates is needed and the contributing drainage area is large; retrofit existing detention basins or construct new in open median or interchange areas
Permeable pavement	[9] Ch 10 [8] Ch 6.4.1	Limited to park-and-ride sites and parking lots
Manufactured products: subsurface storage, water quality inlets, etc.	[9] Ch 6.6.3 [9] Ch 6.6.4	Subsurface storage products are designed to temper peak runoff events through infiltration and/or discharge rate reduction. Storm sewer inlet structures or inserts are designed to minimize the discharge of solids, floatables, and oil/grease pollutants. Regular maintenance of these products is necessary and is an important factor in assessing the feasibility of using one of these products.

1 – List of References: [8] PA DEP, 2006; [9] Transportation Research Board, 2006

Level 4 Target – Reduce the post-construction runoff peak rate to the pre-construction peak rate for the 1-year through 100-year storm events. Reduce the post-construction runoff volume to the pre-construction runoff volume for the 2-year 24-hour storm event and smaller. The plans must also comply with the water quality requirements established by 25 PA Code 93.

TABLE 13.11
BMPS BY ABACT CATEGORY

Treatment BMPs	Land Disposal	Pollution Prevention
Vegetated swale	Bioslope	Street sweeping
Bioretention	Bioretention	Impervious disconnection
Constructed wetland	Vegetated filter strip	Slope roughening
Wet pond	Impervious disconnection	Pavement width reduction
Infiltration trench		Riparian buffers
Infiltration basin		Landscaping and planting
Infiltration berm		Soil amendments
Permeable pavement		

D. Act 167 Plans and Municipal Ordinances. In Pennsylvania, Act 167 stormwater management plans provide a model set of ordinances to municipalities for regulating stormwater discharges from developing areas, which are based on extensive studies of the watershed's runoff characteristics. Because the watersheds being studied reach across many municipal boundaries, counties oversee the development of the plans. Once a plan is approved by PA DEP, the municipalities within that watershed must adopt and enforce ordinances that are at least as restrictive as the model ordinance in the Act 167 plan.

PennDOT must be consistent with the standards of watershed-based stormwater management plans approved by PA DEP and implemented under the Storm Water Management Act (1978 Act 167); however, PennDOT is not required

to comply with individual local ordinances, including ordinances adopted under an Act 167 plan. PennDOT does, however, strive to maintain good relations with local municipalities and, at PennDOT's discretion, wishes to be consistent with local ordinances when feasible and practicable. Municipal stormwater ordinances should not be used to design stormwater facilities on a project unless specifically directed by the PennDOT project manager.

Consistency with an Act 167 plan does not necessarily mean that the antidegradation requirements for an NPDES permit have been satisfied. From 1980 to 2003, Act 167 plans that were developed focused on controlling the peak rate of discharge to protect downstream persons and property. Act 167 plans developed since 2003 have targeted a broader range of stormwater runoff issues related to development including: minimizing increases in runoff volume, controlling peak discharge rates, maintaining groundwater recharge, and protecting water quality. The former addresses one component of antidegradation and PCSM, while the latter addresses most of the issues. Volume control and water quality requirements of the NPDES permit will usually govern because the majority of existing plans do not include volume and water quality standards. On the other hand, the peak discharge standards in an Act 167 plan may be more restrictive than NPDES requirements and would thereby govern. In any case, the more restrictive requirements between the NPDES permit and the PA DEP-approved Act 167 plan govern the design of PCSM for PennDOT projects.

E. Applicable Laws. A number of Commonwealth and federal laws directly related to stormwater management affect the way PennDOT manages runoff from its roadways and facilities.

1. Federal Clean Water Act, Section 402. This section is referred to as the NPDES permit, which requires a permit for the discharge of any pollutant into navigable waters.

2. Federal NPDES Regulations at 40 CFR Part 122. Contains provisions for implementing the NPDES program.

3. PA Storm Water Management Act. Known as Act 167, this law requires counties to develop stormwater management plans for each watershed within their county. The purpose of this act is to manage stormwater runoff in order to preserve and restore the flood carrying capacity of streams (thereby preventing flooding), preserve the hydrologic balance of the watershed, and protect and conserve groundwater resources and groundwater recharge areas. Any project funded by the Commonwealth must be conducted in a manner consistent with the Act 167 plan that has been approved by PA DEP. Act 167 plans normally contain provisions for peak rate reduction and improving water quality.

4. PA Clean Streams Law. Establishes the general authority for the PA DEP in establishing standards for the protection, maintenance and restoration of the Commonwealth's water resources.

5. 25 PA Code 92. This chapter sets forth permitting, monitoring, and compliance requirements with regard to the PA DEP implementation of the NPDES program. The PA DEP permit process for the NPDES Permit for Stormwater Discharges Associated with Construction Activities is promulgated, in part, through this regulation.

6. 25 PA Code 93. Chapter 93 establishes requirements to protect designated and existing water quality uses of surface waters. It also provides for the implementation of antidegradation requirements for activities that have the potential to discharge to Special Protection watersheds (HQ and EV). For special protection waters, non-discharge alternatives must be evaluated that are environmentally sound and will (1) minimize accelerated erosion and sedimentation during the earth disturbance activity, and (2) achieve no net change from pre-development to post-development volume, rate and concentration of pollutants in water quality. Where no environmentally sound and cost-effective non-discharge alternatives exist, Chapter 93 requires that the applicant demonstrate that the discharge will maintain and protect the existing quality of receiving surface waters. This is accomplished when a new, additional or increased discharge uses the Antidegradation Best Available Combination of Technologies (ABACT). The NPDES permit application form includes an Antidegradation Analysis Module for evaluating impacts to designated and existing uses in HQ and EV watersheds.

7. 25 PA Code 96. The purpose of this chapter is to establish the process for achieving and maintaining water quality standards.

8. 25 PA Code 102. This chapter of the PA Code addresses requirements for earth disturbances, including the application of erosion and sediment control as it relates to construction and maintenance projects

9. 25 PA Code 105. Section 105.17 defines EV wetlands. Section 105.18a outlines the requirements that must be met in order for PA DEP to grant a Chapter 105 (water obstructions and encroachments) permit. The requirement that is most directly related to stormwater discharges applies to wetlands and provides, "The project will not cause or contribute to pollution of groundwater or surface water resources or diminution of resources sufficient to interfere with their uses."

F. Definitions.

1. Additional Impervious Surfaces. Refers to the difference between post-development and pre-development impervious surfaces.

2. Best Management Practices (BMPs). Schedules of activities, prohibitions of practices, maintenance procedures and other management practices to prevent or reduce pollution to surface waters of the Commonwealth. The function of many stormwater BMPs is to prevent or minimize increases in runoff rate and volume caused by changes in the landscape.

3. Combined Sewer Systems (CSSs). A single pipe sewer system designed, permitted, and constructed to convey both sewage and stormwater during periods of excess precipitation (runoff).

4. Degradation. For HQ and EV watersheds, degradation is an adverse effect that results in a negative change in the existing water quality of the receiving surface water. For non-HQ and non-EV watersheds, it is a negative change in the existing or designated in-steam water use or the level of water quality necessary to protect the use.

5. Evapotranspiration (ET). The sum of evaporation and plant transpiration of water. Evapotranspiration accounts for a significant portion of the rainfall that is lost (not returned to streams via surface runoff) in Pennsylvania watersheds. The amount of water that is lost by evapotranspiration is influenced mostly by the types of vegetation and land use in a watershed. Because water transpired through leaves comes from the roots, plants with deep reaching roots can more constantly transpire water. Thus, herbaceous plants transpire less than woody plants because herbaceous plants usually lack a deep taproot. Also, woody plants keep their structure over long winters while herbaceous plants must grow up from seed in the spring in seasonal climates, and will contribute almost nothing to evapotranspiration in the spring.

6. Impaired Stream. A stream that does not meet the water quality criteria for its designated or existing use.

7. Infiltration. The process by which surface water penetrates through the ground surface into the soil. The soil texture and structure, vegetation types and cover, water content of the soil, soil temperature, and rainfall intensity all play a role in controlling infiltration rate and capacity. For example, coarse-grained sandy soils have large spaces between each grain and allow water to infiltrate quickly. Vegetation creates more porous soils by both protecting the soil from pounding rainfall, which can close natural gaps between soil particles, and loosening soil through root action. This is why forested areas have the highest infiltration rates of any vegetative types.

8. Long Term Control Plan. A plan developed by municipalities and/or municipal authorities designed to mitigate the impact of combined sewer system discharges and meet water quality standards.

9. Municipal Separate Storm Sewer System (MS4). Certain small municipal separate storm sewer systems in urbanized areas, as defined in 40 CFR Part 122, that discharge stormwater into surface waters of the Commonwealth (including intermittently flowing streams and drainage channels) are required to have the discharges authorized by an NPDES stormwater permit. The MS4 classification includes a conveyance or system of conveyances (including roads with drainage systems, streets, catch basins, curbs, gutters, ditches, man-made channels or storm drains) primarily used for collecting and conveying stormwater runoff.

10. Net Change. Refers to the change from pre-development to post-development conditions.

11. Non-discharge Alternative. For activities requiring coverage under an NPDES Permit for Stormwater Discharges Associated with Construction Activities, means no "net change" in existing stormwater runoff conditions (volume, rate, and quality) per watershed. Non-discharge alternative does not mean that there can be no discharge from the site.

12. Pre-development. Refers to runoff condition that exists onsite immediately before the planned project occurs. Pre-development is not intended to be interpreted as the period before any human-induced land disturbance activity has occurred.

13. Post Construction Stormwater Management (PCSM). The term "post-construction" is used to differentiate PCSM from discharges during construction. Erosion and sediment (E&S) pollution control plans are required for most construction projects to show that runoff from disturbed areas during construction is properly managed. PCSM deals with runoff from the project after the earth disturbance is completed and the site has been stabilized.

14. Surface Waters. Perennial and intermittent streams, rivers, lakes, reservoirs, ponds, wetlands, springs, natural seeps and estuaries.

15. Thermal Impact. Per 25 PA Code 93, thermal degradation is a two degree (or more) change during a one-hour period in mean water temperature of the receiving surface water. The water quality criteria do not preclude the allowance of a reasonable mixing zone if there is no significant effect on the ambient temperature of the stream outside the mixing zone.

16. Total Maximum Daily Load (TMDL). The amount of pollutant loading that a waterbody can assimilate and meet water quality standards. The TMDL process is a planning tool to develop pollution reduction goals that will improve impaired waters to meet water quality standards.

G. Limitations. There are a number of factors that may preclude the use of a BMP, even if it otherwise appears to be applicable. The most common factors limiting their use include karst topography, high groundwater table, limiting soil zones, shallow depth to bedrock, and compacted soils. A few of these factors are described below. It should be noted that the presence of limiting factors does not exempt a project from analyzing the post-construction stormwater conditions and potential impacts to receiving waters.

1. Structural Infiltration BMPs. The use of structural infiltration systems is challenging in cold-climate states such as Pennsylvania. Frozen soils can dramatically reduce, or stop, the rate of infiltration, chlorides may pose a risk to groundwater, and sand used as abrasives on roads may clog infiltration practices. Consequently, designers need to make modifications to these BMPs to make them effective in cold climates. Minimum soil infiltration rates should be increased (from base criteria) to account for the clogging potential from road abrasives and somewhat for the reduced infiltration rates during the winter season. Additional design guidelines for infiltration systems can be found in Appendix C of the BMP Manual. When infiltration practices are used next to a road or pavement, they should be set back in order to avoid potential frost heave conditions. Infiltrated water can contribute to ice lenses that form beneath the road surface, aggravating frost heave and potentially causing damage. The maximum ponding elevation in a facility should be no higher than the minimum subgrade elevation of the road. Setback restrictions can be avoided by using other measures to protect pavement. For example, pavement can be insulated or underlain with a very thick gravel to protect against frost damage.

Roadway runoff generates high levels of suspended solids and should not be discharged directly to infiltration systems without first reducing sediment loads. Structural infiltration BMPs are appropriate for roadway systems but must be designed in conjunction with a pre-treatment measure (structural or non-structural) that reduces the amount of sediment and other particulate matter in roadway runoff prior to infiltration. There are a variety of options that will reduce sediment loads, including:

- Vegetated systems such as grassed swales, filter strips, and bioretention;
- During construction, sediment filter bags on inlets and various other E&S BMPs; and
- Maintenance measures such as street sweeping and vacuuming.

Using one or more of these measures before discharging to an infiltration BMP will minimize the accumulation of sediment that could lead to failure of an infiltration BMP. All measures for sediment reduction require regular maintenance.

2. Karst Topography. Karst terrain is characterized by sinkholes, depressions, caves, and underground drainage, and is generally underlain by soluble rocks such as limestone and dolomite. Thick sequences of carbonate bedrock underlie a sizeable area in central and southeastern Pennsylvania [9]. Because natural filtration through soil is limited in karst areas, pollutants in highway stormwater runoff can directly infiltrate underground sources of drinking water and environments that are habitats for sensitive species. Although there is an abundance of literature concerning karst groundwater quality, relatively little research has been conducted addressing the specific impacts of highway runoff to groundwater in karst areas.

It is important to evaluate the appropriateness of structural infiltration BMPs in karst areas on a project-by-project basis. In general, areas with less than 300 mm (4 ft) of soil over carbonate bedrock should be avoided, and ponding depths in infiltration systems should be shallow. Infiltration trenches are not recommended in areas with pronounced karst topography due to the potential for sinkhole formation and groundwater contamination. These limitations should not preclude infiltration altogether. Structural infiltration BMPs may be provided where runoff can be spread over a large area with a shallow maximum ponding depth. This should be done on existing grades, if possible, to avoid excavation and maintain sufficient soil depth above the bedrock. Where infiltration is not feasible, maximize the use of non-structural BMPs and consider structural BMPs with high evapotranspiration characteristics, such as bioretention. Additional information on the use of BMPs in karst areas can be found in Chapter 7 of the BMP Manual.

H. Special Considerations.

1. Building and Maintenance Facilities. PennDOT should consider alternative stormwater solutions at PennDOT buildings and maintenance facilities, since these areas have less limiting factors than roadway systems. For example, porous pavement and other subsurface infiltration methodologies may be considered on park-and-ride sites and parking areas. Dry wells and other subsurface infiltration methodologies may be considered for building roof drains.

2. Combined Sewer Systems. Combined sewer systems (CSSs) can be found in cities and towns throughout Pennsylvania, including Pittsburgh, Harrisburg, and Philadelphia. These systems were designed to collect stormwater runoff, domestic sewage, and industrial wastewater all in the same pipe. Most of the time, combined sewer systems transport all of their wastewater to a sewage treatment plant. However, during periods of heavy rainfall or melting snow the volume of wastewater can exceed the capacity of the CSS pipes, and excess wastewater empties directly into nearby streams, rivers, or other water bodies. New construction of CSS systems is prohibited, and the old CSS infrastructure in Pennsylvania is gradually being replaced with separate stormwater and sewer systems. The volume and quality of PennDOT stormwater discharges to CSSs can contribute to water quality impacts to receiving surface waters. At a minimum, peak discharge rates into a CSS should not increase as a result of a project, and practicable alternatives that reduce discharges into a CSS should be considered. PennDOT designs should evaluate conditions and alternatives that facilitate the removal of headwater streams from local collection and conveyance systems. PennDOT projects located in CSS communities should evaluate and incorporate, where feasible, water quality improvement designs to minimize runoff volume and pollutant content, including solids, floatables, and oil/grease. PennDOT will coordinate and evaluate its project design proposals to be consistent with local Long Term Control Plans and its objectives.

I. Non-Structural BMP Descriptions. This section includes brief descriptions of each of the non-structural PCSM measures in the BMP toolboxes. These descriptions should supplement the technical guidance that can be found in the BMP Manual and other similar publications listed under References in Section 13.7.L.

1. Minimize Compaction. The post-construction runoff from a project can be reduced by minimizing the amount of area that is compacted. Compaction of a previously undisturbed area can significantly reduce the infiltration capacity of that soil. This non-structural BMP can be applied to almost every project. Compaction is normally a planned construction activity, but it can also occur unintentionally, such as by the weight of construction vehicles. Well-planned staging of construction activities can reduce the need to disturb uncompacted areas outside of the construction footprint. Areas specifically designated for staging and temporary construction measures should be described in the E&S plans and clearly marked in the field by the

contractor. Additional information on minimizing compaction can be found in Section 5.6.1 and 5.6.2 of the BMP Manual.

2. Preserve Trees and Re-vegetate Using Native Species. Clearing of forested areas, including riparian buffers, should be limited to only those areas that are essential for construction operations. Well-planned staging of construction activities can reduce the need to disturb wooded areas outside of the construction footprint. Similar to minimizing compaction, this non-structural BMP can be applied to almost every project. Highway projects involving new alignments sometimes involve abandoning existing sections of highway. These areas may provide opportunities to offset the stormwater-related impacts of the new alignment. By removing pavement and planting the abandoned areas with native vegetation, the abandoned areas can be made to resemble pre-existing conditions. Additional details including costs and plant references can be found in Section 5.6.3 of the BMP Manual.

3. Street Sweeping. Street sweeping is an effective non-structural BMP for removing pollutants before they are carried away by runoff into storm sewers or an adjacent stream. Applications may be limited to projects with highly impervious surroundings and few opportunities for vegetative or structural BMPs. It is effective in removing all three of the representative pollutants in the BMP Manual: TSS, TP, and TN. Sweeping frequencies and cleaning routes should be chosen to optimize overall sweeping efficiencies. For example, sweeping should be assessed before any regional wet season to remove accumulated sediments. Certain conditions, such as streets with high traffic volumes and streets with high erosion zones, may also warrant increased sweeping frequencies. The maintenance manager in the District where the project is located should be consulted prior to submitting a permit where this BMP is proposed.

4. Impervious Disconnection. A number of potential stormwater impacts can be reduced or eliminated by installing BMPs in between impervious areas and storm sewers. Direct connection is primarily an issue with curbed roadways, where runoff is forced into catch basins, which are part of the storm sewer collection system. This common type of design quickly and efficiently removes runoff from the roadway to prevent ponding hazards. The problem with this system is that it usually results in (1) a decreased time of concentration, (2) an increase the peak flow rate, (3) an increase in the total runoff volume, and (4) no removal of pollutants from the runoff. Two ways to achieve disconnection are to (1) eliminate curbs and gutters, and (2) redirect road and driveway runoff into grassed swales or other vegetated systems designed to receive stormwater. Where curb and gutter cannot be eliminated for safety, right-of-way, or other practical reasons, carefully designed curb cuts may be used to allow runoff to spill into an adjacent vegetated BMP.

5. Slope Roughening. Known as a time of concentration (T_c) practice, slope roughening increase the time it takes for runoff to flow across a site to the drainage point or a BMP. Slowing runoff velocity potentially reduces erosion and increases the potential for infiltration. This BMP can include slope terracing, surface roughening, contouring, benching, and other similar methods of creating stabilized irregularities in graded slopes. Instead of allowing runoff to sheet flow down an embankment, these surface features (1) reduce erosion potential by slowing down the flow, (2) create pockets of small depressions that capture and reduce the total volume of runoff, and (3) encourage infiltration on the slope. When applied to slopes at bridge sites, the turbulence that this BMP creates aids in oxygenating the runoff before it discharges into the stream. Surface roughening has traditionally been used as an E&S measure to reduce erosion potential and prepare a slope to receive vegetation. Slopes steeper than 2:1 should be benched or stepped.

6. Pavement Width Reduction. PennDOT has standard pavement widths for various road classifications. Whenever a proposed design uses shoulder or lane widths that are less than the design standards, it should be noted in the PCSM plan. This is a self-crediting BMP, meaning that by not using the additional pavement width, the total volume of runoff is proportionally reduced. It is a good idea to document the amount of additional runoff that was not generated by using a design exception in the PCSM plan.

J. Structural BMP Descriptions. This section includes brief descriptions and technical information summaries of each of the structural PCSM measures in the BMP toolboxes. Many of these BMPs can be used in series, commonly referred to as a "treatment train", or combined with other BMPs to improve the system's efficiency. The first three BMPs listed in this section are structural-restoration BMPs. These BMPs can be used to return disturbed areas to more natural, vegetated areas with high infiltration and/or evapotranspiration potential. The remaining BMPs in this section are engineered measures for reducing runoff; their descriptions in this section include a technical summary that can be used as a quick reference. This information may be useful in the planning stages of

design, but the technical guidance that can be found in the BMP Manual and other similar publications listed under References in Section 13.7.L should be used to design the BMPs.

1. Riparian Buffer Restoration. Riparian buffers are areas adjacent to streams, ponds, etc., that protect those water resources from pollution, prevent bank erosion, provide wildlife food and cover, and shade the adjacent water, moderating temperatures for aquatic species. Buffers are transition areas between aquatic and upland environments. PennDOT projects that are adjacent to bodies of water with depleted riparian buffers may consider restoration as a structural BMP. Riparian buffers are complicated natural features that require a diverse group of expertise to effectively design restoration strategies. Restoration design should be coordinated with PA DEP early in project development.

2. Landscaping and Planting. Landscape restoration is the general term used for actively sustainable landscaping practices that are implemented outside riparian (or other specially protected) buffer areas. Landscape restoration includes the restoration of forest (i.e. reforestation) and/or meadow and the conversion of turf to meadow. In a truly sustainable site design process, this BMP should be considered only after the areas of development that require landscaping and/or revegetation are minimized. The remaining areas that do require landscaping and/or revegetation should be driven by the selection and use of vegetation (i.e., native species) that does not require significant chemical maintenance by fertilizers, herbicides, and pesticides.

3. Soil Amendments. Soil amendments, which include both soil conditioners and fertilizers, make the soil more suitable for the growth of plants and increase water retention capabilities. Compost amendments and soils for water quality enhancement are also used to enhance native or disturbed and compacted soils. These measures change the physical, chemical, and biological characteristics of the soil allowing it to more effectively reduce runoff volume and filter pollutants. Vegetated swales and grass filter strips can be treated with soil amendments to improve performance and increase their permeability. A variety of techniques are included as potential soil amendments including aerating; fertilizing; and adding compost, other organic matter, or lime to the soil.

4. Vegetated Swale. Vegetated swales are one of the most commonly used BMPs along roads because of their ability to fit within limited right-of-way space while providing both drainage and PCSM functions. Vegetated swales are broad, shallow, typically trapezoidal channels that receive runoff from adjacent impervious surfaces and are designed to slow it down, promote infiltration, and filter pollutants and sediments in the process of conveying the runoff. Vegetated swales can receive runoff from concentrated sources (e.g., pipe outfalls), as well as from lateral sheet flow along the length of the channel. They are well suited for use along roads, either as swales in a cut section of a shoulder or in the median receiving runoff from both sides of a divided highway. They can also be used for storm sewer outlet channels and top of cut ditches.

FIGURE 13.2
VEGETATED SWALE SUMMARY

Location	Median Swale in cut section Top of slope ditch	
Effectiveness	Water quality: High Volume: Medium Peak discharge: Medium	
Key Design Elements	• DA ≤ 2 ha (5 acres) • Min. 600 mm (24 in) between bottom and bedrock/seasonal high GWT • Longitudinal slopes from 1%-6% • Use 150-300 mm (6-12 in) high check dams to increase retention • Side slopes from 3:1 to 5:1 • Bottom width 0.6-2.4 m (2-8 ft)	Vegetated swale along roadside

The simplest form of a vegetated swale consists of a band of dense vegetation that can include a variety of trees, shrubs, and/or grasses. Under the vegetated surface layer is approximately 600 mm (24 in) of permeable soil (minimum 13 mm/hr (0.5 in/hr) infiltration rate) containing a high level of organic matter. An acceptable variation is known as a dry swale, which is essentially a vegetated swale with an infiltration trench. Check dams can also be used to reduce velocities in channels that have a longitudinal slope greater than 3 percent. Check dams used in swales parallel to the roadway must be designed such that the maximum ponding elevation in the swale does not exceed the adjacent subgrade elevation. Turf reinforcement mats can be used to provide enhanced stabilization within the channel to prevent erosion. Salt-tolerant vegetation, such as creeping bentgrass and switchgrass, should be considered in areas with regular deicing of roads in the winter.

Examples of retrofitting existing swales (Level 2 toolbox) include: replacing or modifying poorly draining soils in the swale; adding an organic layer (i.e., compost) to encourage bioretention; replanting with species that offer greater evapotranspiration opportunities; and retrofitting ditches with check dams to provide storage in the channel. A rock-lined ditch that discharges directly into a surface water may be a good candidate for retrofitting with a turf reinforcement mat and vegetation. If it is not practicable to construct swales on both sides of the road, the capacity of the swale can be increased to capture more runoff on one side of the road while releasing all of the runoff from the other side.

5. Bioretention. Bioretention is a method of treating stormwater by pooling water on the surface and allowing filtering and settling of suspended solids and sediment at the mulch layer, prior to entering the plant/soil/microbe complex media for infiltration and pollutant removal. Bioretention cells, also called raingardens, cause retention of runoff through exfiltration into the subsoil (if subsoil has adequate permeability), subsurface storage below the underdrain (if present), and evapotranspiration by vegetation. Detention storage is provided through a combination of surface ponding with control structures and subsurface storage in soil and gravel layers above the underdrain. Common areas of application for highway projects include medians, areas adjacent to local/urban roads and intersections, and parking or median islands. Several examples of road and parking application are shown in the BMP Manual.

FIGURE 13.3
BIORETENTION SUMMARY

Location	Median Swale in cut section Top of slope ditch	
Effectiveness	Water quality: High Volume: Medium Peak discharge: Medium	
Key Design Elements	• DA ≤ 0.2 ha (0.5 acres) • Min. 600 mm (24 in) between bottom and bedrock/seasonal high GWT • Native, perennial vegetation • Provide overflow system	Bioretention along roadside

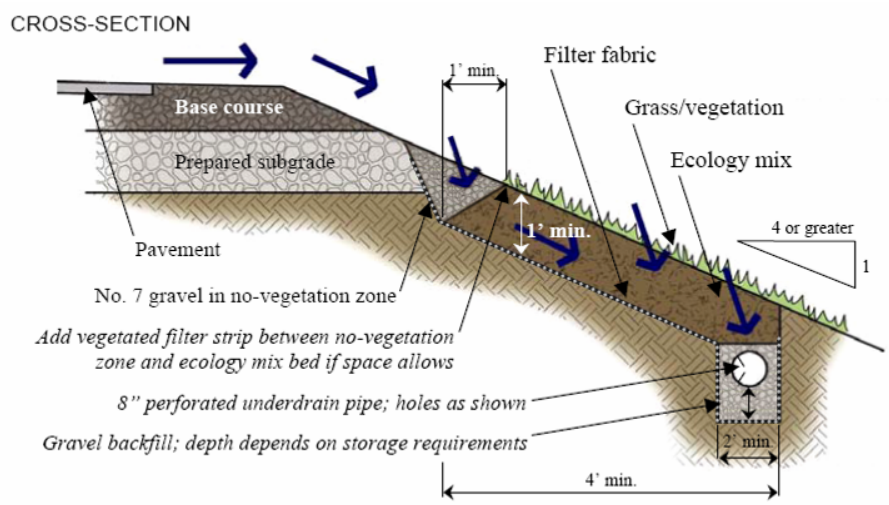
6. Vegetated Filter Strip. Vegetated filter strips are a common and often overlooked BMP. They are gently sloping, densely vegetated areas that filter, slow, and infiltrate sheet flowing stormwater. They are essentially buffers between runoff from impervious areas and a receiving body of water. Filter strips can be best utilized along roads and next to parking areas where runoff flows off the pavement via sheet flow and into a filter strip. This scenario is possible for roads at grade or in a fill condition; it does not work for a section in cut. The effectiveness of filter strips can be improved by adding a pervious berm at the toe of the slope. Check dams can also be implemented on filter strip slopes exceeding 5 percent. Level spreaders can be used to spread flow over a larger area so as to not create a point-source discharge.

FIGURE 13.4
VEGETATED FILTER STRIP SUMMARY

Location	Adjacent to road/shoulder or parking lot	
Effectiveness	Water quality: High Volume: Low/Medium Peak discharge: Low	
Key Design Elements	• Contrib. DA slope ≤ 5% • Filter strip slope < 5% preferred; 8% max. • Min. width should be ≥ width of DA • Effectiveness is a function of slope, vegetative cover, and soil type • Check dams can be used on slopes > 5%	Vegetated filter strip in median

7. Bioslope. Bioslopes (also called "ecology embankments") are embankments that treat runoff by rapid filtering through an engineered soil media commonly known as an ecology mix. Bioslopes use a variety of physical, chemical, and biological processes to improve water quality. Bioslopes are similar to vegetated filter strips, but instead of filtering runoff via sheet flow through thatch and surface soils, runoff is rapidly infiltrated into a gravel trench and then filtered via subsurface flow through the ecology mix. A bioslope is usually indistinguishable from ordinary embankments, and its footprint is usually contained within the embankment.

FIGURE 13.5
BIOSLOPE SCHEMATIC



Bioslopes cause retention of runoff through exfiltration into the subsoil (if subsoil has adequate permeability), storage in the gravel trench below the underdrain (if present), and evapotranspiration by vegetation. Credit for volume reduction should not be taken for any portions of the bioslope footprint that are above compacted soils. Bioslopes have minimal detention storage because they do not allow ponding and because the ecology mix drains rapidly. However, peak discharges are still reduced because of movement across the vegetated surface, percolation through the ecology mix, and infiltration into the subsoil (if subsoil has adequate permeability).

FIGURE 13.6
BIOSLOPE SUMMARY

Location	Median embankment Side slope	
Effectiveness	Water quality High Volume Medium Peak discharge Medium	
Key Design Elements	• Side slope 4:1 to 7:1 preferred; 3:1 max. • Max. 4% longitudinal gradient • Max. slope length is 9 m (30 ft) • Plant with a native grass mix	Bioslope application on embankment

8. Infiltration Trench. An infiltration trench is an excavated trench lined with filter fabric and backfilled with stone. These systems encourage stormwater infiltration into subsurface soils and work well in space-limited applications. Stormwater can enter a trench via sheet flow from open-section roadways or by channelized flow from swales or storm drain outlets. When located adjacent to roadways, the subsurface drainage direction should be to the downhill side (away from pavement subbase), or located lower than the impervious subbase layer. Proper measures should be taken to prevent water infiltrating into the pavement subbase. Infiltration trenches may be used in conjunction with vegetated swales, roadway drainage systems, or both (i.e., a swale over a pipe running between inlets). A common application is to place a flat run of continuously perforated storm sewer in an infiltration trench. The design storm is conveyed through the system the same way it would through a normal storm sewer; however, smaller rain events have time to drain through the perforations and into the gravel bed. Pretreatment of runoff prior to discharging into the infiltration trench is recommended in order to increase the life and effectiveness of the facility. Sediment traps in the storm sewer inlets (inlet invert is 150-300 mm (6-12 in) below pipe invert) and vegetated filters are examples of pretreatment.

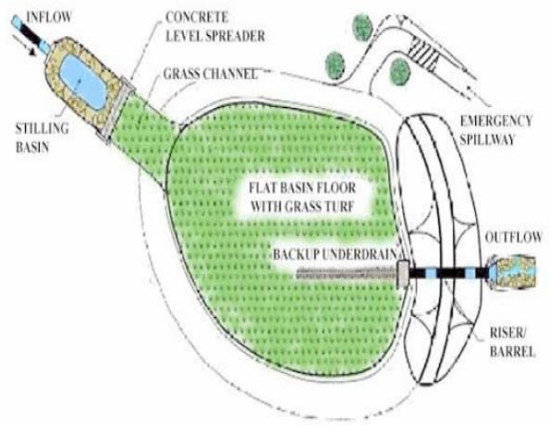
FIGURE 13.7
INFILTRATION TRENCH SUMMARY

Location	Median Shoulder swales Between curb and sidewalk	
Effectiveness	Water quality Medium Volume Medium Peak discharge Medium	
Key Design Elements	• DA ≤ 2 ha (5 ac). • Min. 600 mm (24 in) between bottom and bedrock/seasonal high GWT • Min. 1.5 m (5 ft) from edge of road • Include underdrain if infiltration rate is < 25 mm/h (1 in/h) • Trench invert Elev. < than road subgrade Elev.	Curb opening (impervious disconnection) into an infiltration trench

9. Infiltration Basin. Infiltration basins are shallow, impounded areas designed to temporarily store and infiltrate stormwater runoff. Sizes and shapes can vary from a single large basin to multiple, smaller basins throughout a project site. Infiltration basins reduce the volume of stormwater runoff by infiltration and

evapotranspiration. Poor soils may be amended by adding sand or gravel to the surface layer to increase the permeability.

FIGURE 13.8
INFILTRATION BASIN SUMMARY

Location	Median Interchange areas Rest stop/park-and-ride lot	
Effectiveness	Water quality Medium Volume Low Peak discharge Medium/High	
Key Design Elements	• Uncompacted subgrade • Retain increase in 2-yr storm runoff volume • Min. 600 mm (24 in) between bottom and bedrock/seasonal high GWT • 5:1 max.impervious-to-infiltration area	Conceptual Infiltration Basin

Traditional stormwater management basins can be combined with infiltration basin concepts to provide peak flow detention for larger storms and the required volume control. The combined detention/infiltration basin can be utilized at the discharge points of drainage systems or placed in large median areas where positive basin outflow is provided and subbase drainage is not impeded. During the winter months, there will be many occasions when the soil beneath an infiltration basin is frozen and long-duration ponding will occur; therefore, infiltration basins must be placed in areas where this does not create a safety hazard. When runoff containing salt-based deicers is directed to an infiltration basin, soil may become less fertile and less capable of supporting vegetation. Using salt-tolerant plants and incorporating mulch into the soil can help to mitigate this problem. Infiltration basins should not be used to store snow from highways or parking lots because the sand in the snow can clog the basin, and the chlorides and other pollutants can contaminate the groundwater.

10. Infiltration Berm. An infiltration berm is a mound of compacted earth with sloping sides that is usually located along (i.e., parallel to) a contour in a moderately sloping area. Berms create shallow depressions that collect and temporarily store stormwater runoff, allowing it to infiltrate into the ground and recharge groundwater. Berms are ideal in areas where runoff is free to discharge over slopes. The berm can be installed parallel to the road and intercept runoff prior to being discharged into adjacent areas or bodies of water. Berms can be constructed on disturbed slopes and revegetated as part of the construction process. Infiltration berms may also be constructed in combination with a subsurface infiltration trench at the base of the berm to increase the retention capacity.

FIGURE 13.9
INFILTRATION BERM SUMMARY

Location	Side slope	
Effectiveness	Water quality Medium/High Volume Low/Medium Peak discharge Medium	
Key Design Elements	• Constructed parallel to contours • Min. 600 mm (24 in) between bottom and bedrock/seasonal high GWT • 600 mm (24 in) max. height • Side slope 4:1 max. • Can be retrofitted on slopes w/o causing significant disturbance	Infiltration berm

11. Wet Ponds. Wet ponds, also known as retention basins, are stormwater basins that include a substantial permanent pool for water quality treatment and additional capacity above the permanent pool for temporary runoff storage. Wet ponds are effective for pollutant removal and peak rate mitigation, but do not achieve significant groundwater recharge and volume reduction. Unlike infiltration basins, the permanent pool is a key feature and infiltration is discouraged. Wet ponds should have low permeability soils at the bottom and, where possible, be excavated close to or below the groundwater table. Interchanges are usually ideal for wet ponds because the basin is surrounded by pavement and receives runoff from all directions. Trees and other types of vegetation should be planted around the perimeter to keep the water in the pond cool and reduce potential thermal impacts. In populated areas, wet ponds may not be desired because of potential mosquito issues. Wet ponds are generally not the preferred BMP when the facility discharges directly into temperature-sensitive water (such as those with temperature TMDLs). Extended detention facilities should (1) be designed with a minimal permanent pool; (2) preserve existing shade trees and plant fast growing trees along the shoreline, but not on the constructed embankment; (3) align ponds in a north-south direction; and (4) avoid excessive riprap and concrete channels that impart heat to runoff.

FIGURE 13.10
WET POND SUMMARY

Location	Median Interchange areas Rest stop/park-and-ride lot	
Effectiveness	Water quality Medium Volume Low Peak discharge High	
Key Design Elements	• 2-4 ha (5-10 acres) min. DA needed • Need a natural high GWT • Average depth 0.9-1.8 m (3-6 ft); 2.4 m (8 ft) max. • Relatively impermeable soils or engineered liner • Sediment forebay at inlet • Vegetation type and location is critical	Wet pond with sediment forebay

12. Constructed Wetlands. Constructed wetlands (CWs) are shallow marsh systems planted with emergent vegetation that are designed to treat stormwater runoff. They can provide considerable aesthetic and wildlife benefits, but require a relatively large amount of space and an adequate source of inflow to maintain the permanent water surface. CWs improve runoff quality through settling, filtration, uptake, chemical and biological decomposition, volatilization, and adsorption. They are effective at removing many common stormwater pollutants including suspended solids, heavy metals, total phosphorus, total nitrogen, toxic organics, and petroleum products. Peak rate is primarily controlled through the transient storage above the normal water surface. Although not typically considered a volume-reducing BMP, CWs can achieve some volume reduction through evapotranspiration, especially during small storms. CWs are a good option for retrofitting existing detention basins.

FIGURE 13.11
CONSTRUCTED WETLAND SUMMARY

Location	Median Interchange areas Rest stop/park-and-ride lot	
Effectiveness	Water quality High Volume Low Peak discharge High	
Key Design Elements	• 2-4 ha (5-10 acres) min. DA needed or sustained base flow • 2:1 length to width ratio • Relatively impermeable soils or engineered liner • Sediment forebay at inlet • Can be combined with wet pond design	Constructed wetland next to highway

13. Permeable Pavement. Permeable pavement consists of a pervious surface course underlain by a uniformly graded stone bed that provides temporary storage for peak rate control and promotes infiltration. In northern climates, pervious pavements have less of a tendency to form black ice and often require less plowing. The surface course may consist of porous asphalt, porous concrete, or various porous structural pavers laid on uncompacted soil. Permeable pavements are best suited for areas that will not be subject to high traffic volumes or high rates of travel speed. Paver blocks are not suitable for high rate travel speeds because of the block design, and the open graded asphalt and concrete in permeable pavements does not wear well in travel lanes. Proper construction is critical for permeable pavement to function properly and, therefore, must be undertaken in such a way as to prevent (1) compaction of underlying soil, (2) contamination of stone subbase with sediment and fines, (3) tracking of sediment onto pavement, and (4) drainage of sediment-laden waters onto pervious surface or into constructed bed. Permeable pavement can provide significant stormwater benefits as long as the pavement surface is kept free of debris and sediment. Maintenance involves removing sediments from the pavement by means of a vacuum truck. Sweeping may actually exacerbate the problem by working sediment down into the porous surface.

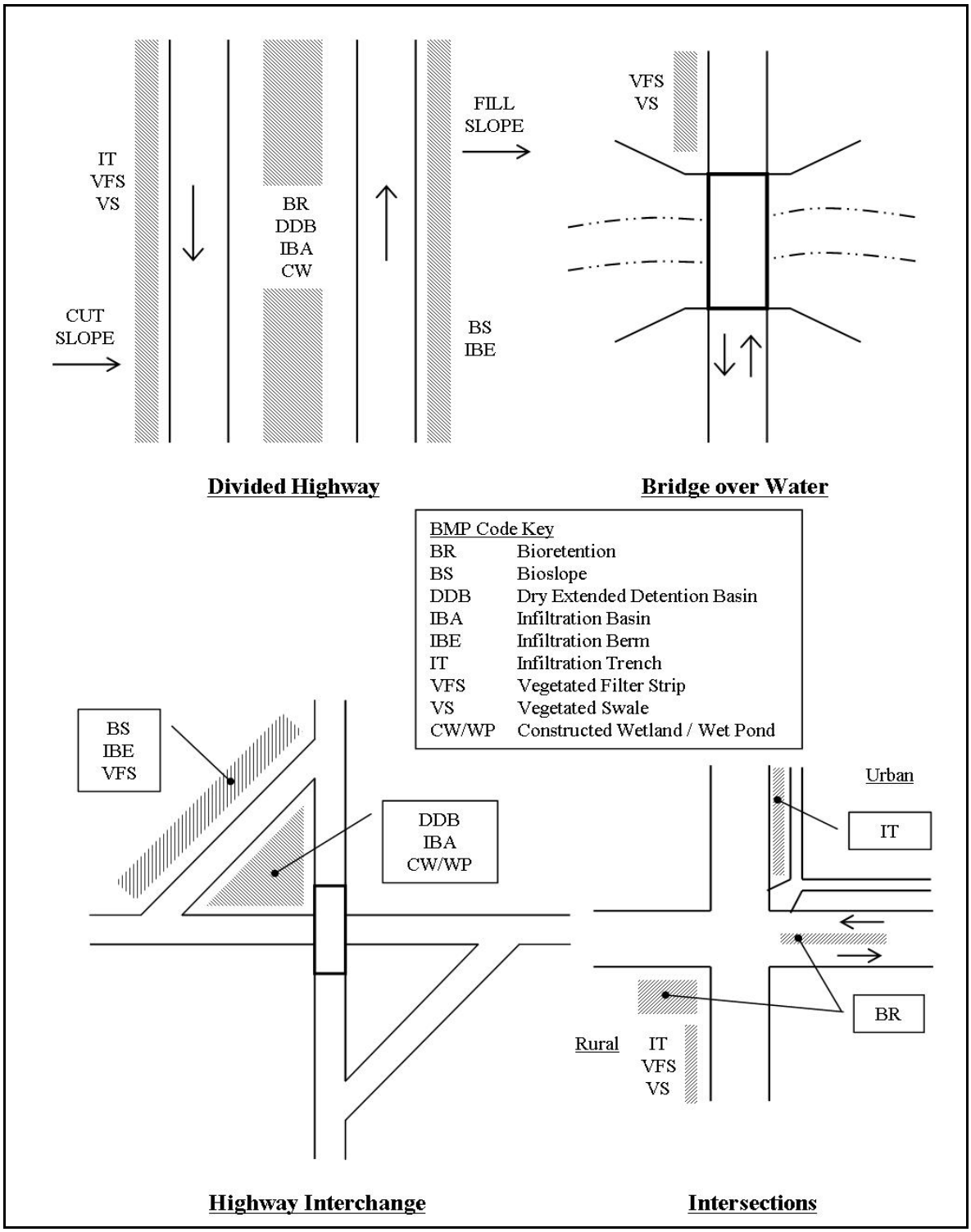
FIGURE 13.12
PERMEABLE PAVEMENT SUMMARY

Location	Park-and-rides Parking lots Pull offs	Walking paths Sidewalks
Effectiveness	Water quality Volume Peak discharge	Medium Medium/High Medium/High
Key Design Elements	• 300-900 mm (12-36 in) typical infiltration bed depth • Uncompacted subgrade • Frequent maintenance required to prevent pavement surface clogging • Backup drainage system needed	

Porous pavement parking lot

Figure 13.13 depicts four typical types of PennDOT projects and the structural BMPs that would most often be applicable for each type of project. This figure does not preclude the use of a BMP in any of these areas if adequate design documentation is provided.

FIGURE 13.13
COMMON STRUCTURAL BMP APPLICATIONS



K. Frequently Asked Questions.

1. ***What is the difference between stormwater management that may discharge to Special Protection waters, or EV wetlands, and all other waters?*** In Special Protection watersheds, or EV wetlands, there can be no measurable change in the rate or volume of runoff from site. For all other waters, there can be no loss in the existing or designated use from a change in the post-construction runoff. The process of analyzing and using non-discharge alternatives, and antidegradation best available control technologies (ABACT), must be documented in HQ and EV watersheds, or EV wetlands. The PA DEP NPDES construction permit includes an Antidegradation Analysis Module so that the applicant can provide information that demonstrates non-degrading discharges.

2. ***Are wetlands and streams treated the same in terms of PCSM requirements?*** For the most part, yes, since they are both considered surface waters. However, a project can also indirectly impact a wetland without even discharging stormwater to it by cutting off the wetland's hydrologic input. The source of hydrology for adjacent, downstream wetlands should be evaluated to ensure that the project does not have adverse impacts. In addition, wetlands can be classified as EV. For example, if a wetland is critical habitat for a threatened or endangered species, that wetland is considered an EV wetland.

3. ***Do all 3R projects require an NPDES construction permit?*** Not all projects exceed one acre of disturbance with a point-source discharge to surface waters, which is the threshold for requiring an NPDES construction permit. In fact, most maintenance projects only disturb a small area outside of the existing roadway footprint and, therefore, do not require a permit. A permit is not required for any project that does not result in a construction activity consisting of 0.4-2.0 ha (1-5 ac) of earth disturbance with a point source discharge to surface waters, or for a construction activity that consists of 2.0 ha (5 ac) or more of earth disturbance.

4. ***A project has between one and five acres of disturbance, but all of the runoff leaves the site via sheet flow. Does the project require an NPDES construction permit?*** No, only when there is a point-source (end of pipe, channel, etc.) discharge with between one and five acres of disturbance is a permit required. However, an E&S plan must be developed and submitted to the applicable county conservation district.

5. ***Is a PCSM analysis required when the project does not require an NPDES construction permit and it is not located in an approved Act 167 plan watershed?*** No, there is no law, per se, that requires PCSM in the absence of an NPDES permit and Act 167 plan. However, PennDOT's MS4 permit outlines BMPs to be used for maintenance facilities and practices. Even if a PCSM plan is not required, the low-impact design concepts and non-structural BMPs described in this policy should be evaluated on a project-by-project basis.

6. ***Is it acceptable to leave parts of the NPDES permit application blank, or can questions be addressed by simply writing "not applicable?"*** No. Any application for NPDES Permits for Stormwater Discharges Associated with Construction Activities, regardless of the type of project or applicant, requires that all sections and parts of the application be completed.

7. ***Chapter 8 of PA DEP's Stormwater BMP Manual provides for water quality calculations – when do these calculations have to be completed for PennDOT projects?*** PCSM plans for Level 3 and 4 projects require a water quality analysis, even if the targets for rate and volume have been met. Infiltration generally satisfies PA DEP's reduction requirements for two of the three representative pollutants: total suspended solids (TSS) and total phosphorus (TP). However, infiltration does not necessarily remove solute from runoff before it enters groundwater flow. PA DEP uses a representative solute, nitrate, as an indicator for solute removal. The designer must use Flow Chart D and the associated worksheets in Chapter 8 of the BMP Manual to document consistency with the pollutant removal guidelines. Since Level 1 and 2 projects should have minimal increases in rate and runoff, and no change in the types or sources of pollutants; therefore, these calculations are not required for Level 1 and 2 projects. Worksheet 10 from Chapter 8 of the PA DEP BMP Manual should be completed for Level 3 and 4 projects.

8. ***What information should the PCSM section of an NPDES permit application submission contain?*** The PCSM plan should contain all of the information listed in the NPDES permit application checklist (note that General and Individual permits have different checklists), which is attached to the permit application form. Worksheets 1-5, which are attached to the application package, must be completed for all NPDES permit

applications, regardless of the PCSM Level. Worksheet 7 from Chapter 8 of the PA DEP BMP Manual must be completed for Level 2 projects, and Worksheet 10 must be completed for all Level 3 and Level 4 projects. Also note that the seal of a qualified licensed professional (Engineer, Land Surveyor, Professional Geologist or Landscape Architect) is required on PCSM plans for engineered structural BMP calculations and specifications.

9. ***The Summary Data Table in the NPDES permit application requires calculations demonstrating the net change in peak discharge rate and volume of runoff. Is it necessary to complete this table for all projects that require an NPDES permit, and what design event should be indicated in the table?*** Yes, the table must be completed for every NPDES permit, and the data in the table must be clearly explained so that the reviewer can recognize how the data was derived and that data demonstrates that rate and volume of stormwater runoff are mitigated. For Level 1 and Level 2 projects, the Summary Data Table should be completed using the targets defined in Section 14.2, which are similar to CG-2, and the appropriate backup calculations should be provided.

Level 3 and Level 4 projects must demonstrate peak rate control for up to the 100-year event, and volume mitigation for the 2-year event using the targets defined in Section 14.2, which are similar to CG-1. The Summary Data Table should be completed for the 2-year storm event, and peak rate control calculations should be provided based on the Act 167 Plan, or for the 2, 10, 25, 50 and the 100-year storm events when an Act 167 Plan has not been approved by the Department.

10. ***Do peak discharge rates and runoff volumes have to be mitigated at each source of disturbance and before runoff goes beyond PennDOT's right-of-way?*** No. Peak rate control must be demonstrated at each point at which discharge from the project reaches the receiving surface water. Areas in between the point where discharge leaves PennDOT's right-of-way and the receiving surface water must be analyzed for erosion potential and flooding impacts. Volume control must be demonstrated within the respective watershed, and analogous when comparing the pre and post drainage areas.

11. ***What information should be contained in the thermal impact analysis section of the NPDES permit?*** Although documentation must be provided with every PCSM plan, thermal impacts are primarily an issue when a project significantly increases impervious area and the resulting runoff is directly connected (i.e., ditch, storm sewer, etc.) to a cold water, headwater stream, or when the activity results in the removal of vegetation within the floodway/stream corridor. The strategies developed by PA DEP and PennDOT in Section 14.1.C are examples of BMPs that can help reduce thermal impacts. The general idea is to break any direct connection between the impervious area and the surface water, and reduce impervious areas, where practicable. In most cases, a narrative discussing the BMPs located between the impervious surface and surface water will be sufficient.

L. References and Additional Guidance. A number of publications are available that provide design, cost, and maintenance information on BMPs for PCSM. The publications listed below were referenced to develop this policy and are good resources for information.

1. Atlanta Regional Commission (2001). *Georgia Stormwater Management Manual.*

2. Dane County Conservation District. *Predicting the Impact of Urban Development on Stream Temperature Using a Thermal Urban Runoff Model (TURM).* Dane County Conservation District, Wisconsin.
Donaldson, B.M. (2004). *Highway Runoff in Areas of Karst Topography.* Virginia Transportation Research Council, Charlottesville, Virginia.

3. Fennessey, Lawrence, A.J., Ph.D., P.E. (2003). "Defining Natural Land Areas Critical for Stormwater Control in Karst Regions." *Proceedings of the 2003 Pennsylvania Stormwater Management Symposium.*

4. FHWA (2003). *Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring.* Federal Highway Administration, U.S. Department of Transportation.

5. LID Center (2006). *Low Impact Development Design Manual for Highway Runoff Control.* Transportation Research Board, Washington, DC.

6. New Jersey Department of Environmental Protection (2004). *New Jersey Stormwater Best Management Practices Manual.* New Jersey Department of Environmental Protection, Trenton, NJ.

7. PennDOT (2010). *PennDOT Drainage Manual*. Publication 584, Pennsylvania Department of Transportation, Bureau of Project Delivery.

8. PA DEP (2006). *Pennsylvania Stormwater Best Management Practices Manual*. Pennsylvania Department of Environmental Protection, Bureau of Watershed Management.

9. Transportation Research Board (2006). *Evaluation of Best Management Practices for Highway Runoff Control.* NCHRP Report 565, Transportation Research Board, Washington, DC.

10. Virginia DCR (1999). *Virginia Stormwater Management Handbook.* Volumes 1 and 2, First Edition, Division of Soil and Water Conservation, Virginia Department of Conservation and Recreation.

11. Washington State DOT (2006). *Highway Runoff Manual.* Washington State Department of Transportation.

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