City of Cambridge, Massachusetts
Department of Public Works
147 Hampshire Street • Cambridge, MA 02139

APPENDIX A
DRAFT
Best Management Practices

Section 1
Version 3/6/08

Report Prepared By:
Cambridge Department of Public Works and
Malcolm Pirnie, Inc.
601 Edgewater Drive
Suite 360
Wakefield, MA 01880
781-224-4488

5400001

Contents

This is nonprinting text.
DO NOT DELETE THIS TEXT OR THE SECTION BREAK THAT FOLLOWS
(Click ¶ button on Formatting toolbar to display section breaks)

1. SOURCE CONTROLS

1.1. Street and Parking Lot Sweeping

DESCRIPTION

Street and parking lot sweeping includes self-propelled equipment to remove sediment from paved surfaces that can enter storm drains or receiving waters. Sweeping is most effective for removing coarse particles, leaves, and trash. Regularly sweeping reduces catch basin cleaning.

SUGGESTED PRACTICES

- Schedule – every roadway and parking lot swept quarterly.
- Use vacuum sweepers instead of mechanical sweepers where possible.
- Any visible sediment should be swept up (including sand/salt mixtures and granular material).
- Control the number of points where vehicles leave the facilities to allow sweeping to be focused on certain areas in parking lots.
- Sweep up the smallest particles feasible.
- Sweep in pattern to keep spilled material from being pushed into catch basins.
- Before sweeping, manually rake sand from any turf areas onto surfaces to be swept.
- Use hand-held tools to assist with mechanical sweeping.
- If possible, recycle fall leaf sweepings by composting.

MAINTENANCE CONSIDERATIONS

Adjust broom frequently to maximize efficiency of sweeping operations. After sweeping is finished, properly dispose of sweeper wastes. Do not use kick brooms or sweeper attachments that tend to spread dirt. When unloading sweeper, make sure there is no dust or sediment release. Maintain a log and schedule of sweeping activities conducted. Information recorded should include mileage, amount of sweepings removed, and heavily sedimented catch basins, and date of sweeping activities. By recording heavily sedimented areas, prioritizations can be made to sweep these areas or clean catch

TARGETED CONSTITUENTS

- Bacteria (NR)
- Metals (M)
- Nutrients (M)
- Oil and Grease (H)
- Organics (M)
- Oxygen Demand (M)
- Sediment (H)
- Trash (H)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

APPLICABILITY

- Mandatory for all facilities. All roadways and parking lots should be swept.

basins more frequently.

INSPECTION CONSIDERATIONS

Inspect sweeping equipment regularly to make sure it has been properly maintained. Regularly inspect streets and parking lots for debris. Regularly inspect catch basins for debris. Adjust sweeping frequency with debris levels.

STREET SWEEPING IN CAMBRIDGE

- Vacuum sweeping is the preferred method of sweeping.
- All parking lots and roadways must be swept quarterly.
- For information on Cambridge's municipal sweeping program, please visit: http://www.cambridgema.gov/TheWorks/services/strClng.html

1.2. Snow Removal and Deicing

DESCRIPTION

Proper snow management in terms of stockpiling and removal can prevent or minimize runoff and pollutant loading impacts. Snow piles can contain trash, nutrients, sediments, salt, sand, and vehicle pollutants that can be carried directly into surface waters during snowmelt. DPW's policy is to strictly use salt for deicing, though a few municipal facilities do use sand/salt mixtures. Proper road salt and facility applications storage is necessary to prevent contamination to surface and groundwater supplies. Salts are very soluble – once in contact with water, there is no way to remove salt. The major reasons for keeping salt covered and controlling use are that salt: kills vegetation, corrodes infrastructure, blocks storm drains and infiltration systems, increases sedimentation to streams and rivers, and small quantities (5% road salt) contain phosphorus, nitrogen, copper, and cyanide.

TARGETED CONSTITUENTS

- Bacteria (NR)
- Metals (H)
- Nutrients (H)
- Oil and Grease (M)
- Organics (H)
- Oxygen Demand (H)
- Sediment (H)
- Trash (H)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

APPLICABILITY

- Mandatory for all facilities.

SUGGESTED PRACTICES

The City's policy restricts stockpiling of snow. During extreme conditions when stockpiling is necessary, the following practices should be applied:

  - Do not stockpile snow near or within direct drainage to surface waters.
  - Do not stockpile snow in wooded areas, around trees, or in vegetated buffer zones due to sediment and salt damage to vegetation.
  - Stockpile snow in pervious areas where it can slowly infiltrate.

- During plowing activities on pervious surfaces, blading (plow lowers blade below ground surface level and plows the upper layers of soil in addition to overlying snow) should be avoided to prevent erosion.
- Storage facilities for salt and sand/salt mixtures should be covered structures on impervious surfaces.
- Drainage should be diverted away from storage facility.
- Sand/salt handling should be done within storage facility.
- Storage facilities should not be located in a water supply watershed or within 1-percent annual chance floodplain.
- Disposal of sand/salt mixtures should not be done near or in wetlands, surface waters, or well locations and drinking water supplies.
- Establish a low salt area near any water bodies or residential areas.

- When feasible, use higher percentage of sand in sand/salt mixture.
- Regulate the amount of road salt applied to prevent over-salting of motorways and increasing runoff concentrations. Vary the amount of salt applied to reflect site-specific characteristics such as road width and design, traffic concentration, and proximity to surface waters.
- Provide calibration devices for spreaders in trucks to aid maintenance workers in the proper application of road salts.
- Establish air temperature and snow depth conditions favorable for successful use of salt.
- Use alternative materials, such as sand or gravel, in especially sensitive areas or use alternative products such as Magic Salt.
- Removal practices include street cleaning and catch basin cleaning.

MAINTENANCE CONSIDERATIONS

Contain sediments as snow melts and remove every Spring from snow storage areas. This includes sweeping roadways and parking lots or other impervious areas. During plowing activities, avoid blocking drainage structures including catch basins, swales, and channels. Service trucks and calibrate spreaders regularly to ensure accurate, efficient distribution of salt. Educate and train operators on hazards of over-salting to roads and environment at the beginning of the snow season as part of meetings with supervisors and drivers. Repair salt storage structure leaks.

INSPECTION CONSIDERATIONS

Check snow piles for debris that could be windblown. Inspect salt storage structure for leaks on a regular basis including Fall and Spring. Inspect salt application equipment including calibration equipment and spreaders. Inspect salt regularly for lumping or water contamination. Inspect surface areas for evidence of runoff – salt stains in ground near and around the salt storage structure, loading area, or downslope. Inspect for excessive amounts of salt on roads.

SNOW REMOVAL IN CAMBRIDGE

- Use of sand is prohibited unless approved by DPW as a part of the Land Disturbance Permit.
- Snow stockpiling is restricted.
- For information on Cambridge's municipal snow practices, please visit: http://www.cambridgema.gov/TheWorks/services/snow.html

1.3. Lawn and Grounds Maintenance

DESCRIPTION

Nutrient loads generated by suburban lawns as well as municipal properties can be significant, and recent research has shown that lawns produce more surface runoff than previously thought. Pesticide runoff can contribute pollutants that contaminate drinking water supplies and are toxic to both humans and aquatic organisms.

SUGGESTED PRACTICES

- Eliminate or minimize the use of chemicals (insecticide, herbicide, fertilizer).
- Do not apply any chemicals (insecticide, herbicide, or fertilizer) directly to surface waters, unless the application is approved and permitted by the MA DEP.
- Use mulch or other erosion control measures on exposed soils.
- Coordinate application of chemicals with irrigation schedules to prevent pesticides washing away and to minimize non-stormwater discharges.
- Place temporarily stockpiled material away from watercourses and drain inlets, and berm or cover stockpiles to prevent material releases to the stormwater drainage system.
- Use hand or mechanical weeding where practical.
- Employ mowing techniques to maintain a healthy lawn and minimize chemical use – no more than 1” of lawn should be removed from each mowing (grasses kept at 2.5” to 3.0” high are more heat resistant than close-cropped grass). Keep mower blades sharp and leave clippings in place after mowing.
- Water plants in the early morning.
- Follow manufacturers’ recommendations and label directions for fertilizers and pesticides.
- Do not apply insecticides within 100 ft. of surface waters such as lakes, ponds, wetlands, and streams.
- Use less toxic pesticides that will do the job whenever possible and use the minimum amount needed. Avoid use of copper-based pesticides if possible.
- Do not use pesticides if rain is expected and apply pesticides only when wind speeds are low.
- Do not mix or prepare pesticides for application near storm drains.

TARGETED CONSTITUENTS

- Bacteria (M)
- Metals (M)
- Nutrients (H)
- Oil and Grease (M)
- Organics (M)
- Oxygen Demand (H)
- Sediment (H)
- Trash (H)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

APPLICABILITY

- Facilities with open space and vegetated areas.

- Calibrate fertilizer distributors to avoid excessive application.
- Work fertilizers into the soil rather than dumping or broadcasting them onto the surfaces.
- Irrigate slowly to prevent runoff and then only as much as is needed.
- Use up the pesticides. Rinse containers, and use rinse water as product. Dispose of unused pesticide as hazardous waste. Dispose of empty pesticide containers according to the instructions on the container label.
- Implement storage requirements for pesticide products with guidance from the local fire department and the Massachusetts Department of Agricultural Resources. Provide secondary containment for pesticides.
- Compost or mulch yard waste. Use yard waste as mulch and topsoil.
- Sweep up yard debris instead of hosing down.
- Clean pavement and sidewalk if fertilizer is spilled on these surfaces before applying irrigation water.
- Do not leave yard waste in the street or sweep into storm drains or surface waters.

MAINTENANCE CONSIDERATIONS

Sweep paved areas regularly to collect loose particles. Wipe up spills with rags and other absorbent material immediately. Do not hose down the area to a storm drain. Keep mower blades sharp.

INSPECTION CONSIDERATIONS

Inspect irrigation system periodically to ensure that the right amount of water is being applied and that excessive runoff is not occurring. Minimize excess watering, and repair leaks in the irrigation system as soon as they are observed. Inspect and remove accumulated debris from grounds. Routinely monitor lawns to identify problems during their early stages. Identify nutrient/water needs of plats. Inspect for problems by testing soils.

LAWN AND GROUNDS MAINTENANCE IN CAMBRIDGE

- Eliminate or minimize use of chemicals.
- Never wash clippings or yard waste into storm drains.
- For information on Cambridge's municipal grounds maintenance, please visit: http://www.cambridgema.gov/TheWorks/departments/parks/parkMaint.html

1.4. Materials and Waste Management

DESCRIPTION

Materials management entails the selection of the individual product, the correct use and storage of the product, and the proper disposal of associated waste(s). It is important to be responsible with common chemicals and solvents including paints, cleaners, and automotive products to reduce contamination to stormwater runoff. Improper storage and handling of solid wastes can allow toxic compounds, oils and grease, heavy metals, nutrients, suspended solids, and other pollutants to enter stormwater runoff.

TARGETED CONSTITUENTS

- Bacteria (M)
- Metals (H)
- Nutrients (H)
- Oil and Grease (M)
- Organics (M)
- Oxygen Demand (M)
- Sediment (H)
- Trash (H)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

APPLICABILITY

- Mandatory for all facilities.

SUGGESTED PRACTICES

- Identify all hazardous and non-hazardous substances by reviewing purchase orders and conducting a walk-through of facility.
- Compile Material Safety Data Sheets (MSDS) for all chemicals. These should be readily accessible to all facility employees.
- Label all containers of significant materials that include cleaners, fuels, and other hazards.
- Identify handling, storage, and disposal requirements of all chemicals.
- Use environmentally friendly or non-hazardous substitutes when appropriate that include but not limited to H_2Orange$_2$, Orange Thunder, and Simple Green®.
- Keep hazardous materials and waste off the ground.
- All drums and containers should be in good condition and properly labeled.
- Loose materials including any gravel piles should be covered or placed in shelter.
- Trash storage bins, dumpsters, and disposal areas should be clean and free of debris, especially those located near catch basins.
- Dumpsters should be maintained in good condition and securely closed at all times.
- Clean up equipment and materials.
- Dispose of wastes within local, state, and federal laws. This includes Section 8.24 of the City Ordinance.
- Temporary trash storage should be inspected weekly before being taken to the local privately owned transfer station.
- Debris piles including sweepings, construction, and wood debris

should be inspected weekly before removed off site.

- Cover storage containers with leak proof lids or keep inside.
- Cover all waste piles (plastic tarps are acceptable coverage) and prevent stormwater runon and runoff with a berm.
- Sweep and clean the storage area regularly. If it is paved, do not hose down the area to a storm drain.
- Use drip pans or absorbent materials whenever grease containers are emptied by vacuum trucks or other means.
- Dispose of rinse and wash water from cleaning waste containers into a sanitary sewer; do not discharge wash water to the street or storm drain.
- Post "No Littering" signs and enforce anti-litter laws.
- Provide a sufficient number of litter receptacles for the facility.

MAINTENANCE CONSIDERATIONS

Repair or replace any leaking/defective containers, and replace labels as necessary. Maintain caps and/or covers on containers. Maintain aisle space for inspection of products/wastes. Routinely clean work spaces and properly collect/dispose of waste. Routinely maintain and inspect vehicles and equipment. Regularly and when new products enter the facility, train employees on proper use, storage, disposal, and safety concern. MSDS should be reviewed and readily accessible in a central facility location. Review any Spill Prevention Control and Countermeasure (SPCC) Plan.

INSPECTION CONSIDERATIONS

Inspect floor drains to verify that they are sealed or directed to the sanitary sewer and not the stormwater drainage system. Regularly inspect material storage areas (inside and outside) to verify items are not exposed to precipitation. Regularly inspect stormwater discharge locations and onsite stormwater drainage infrastructure regularly for evidence of blockages and contaminants. Inspect waste management areas for leaking containers or spills.

MATERIALS AND WASTE MANAGEMENT IN CAMBRIDGE

- Keep materials and wastes covered or inside.
- Have spill prevention and response plans in place.
- Always dispose of wastes properly within local, state, and federal laws.
- For information on Cambridge's municipal waste management and recycling programs, please visit: http://www.cambridgema.gov/TheWorks/services/recycling.html

1.5. Roof Gardens

DESCRIPTION

Roof gardens, or green roofs, are vegetated roof systems that retain and filter stormwater and provide aesthetic and energy conservation benefits. A green roof is built on top of a new or existing roof and consists of a special root repelling membrane, a drainage system, a lightweight growing medium, and plants.

DESIGN CONSIDERATIONS

- To ensure that an existing roof can adequately support the weight of a roof garden, a detailed structural analysis of the existing building is required prior to construction.
- The system should include a 6" soil bed, with a silt loam texture.
- The soil bed should be underlain with a 2" gravel layer, and these two layers should be separated by a layer of filter fabric.
- An impermeable layer should be placed between the rooftop and the gravel layer.
- The roof should have a maximum slope of 25%.
- The roof should be designed to hold an additional 25 lbs/sf, beyond minimum design criteria.
- Vegetation should be established within two growing seasons and should consist of hardy, low-growing, drought-resistant, fire-resistant plants that provide dense cover and are able to withstand heat, cold, and high winds. Varieties commonly used include succulents such as sedum (stonecrop) and delosperma (ice plant).
- Vegetation should require minimal fertilization and watering.
- 2" mulch layer should be immediately placed above the soil layer to prevent erosion.

MAINTENANCE CONSIDERATIONS

Rooftop gardens need to be watered and weeded, similar to any other garden. Climate conditions and the types of plants used will determine the frequency of watering, Generally, maintenance is required when leaks occur, unwanted vegetation appears, or vegetation shows signs of stress. Pesticides and herbicides should not be used. After construction, plants should be replaced once per month as needed during establishment period. Regular maintenance activities (monthly or as needed) include supplementing soil substrate/growth medium and controlling any existing erosion, removing obstructions from the drainage inlet, repairing/replacing drain inlet pipe, removing all fallen leaves and debris from

TARGETED CONSTITUENTS

- Bacteria (H)
- Metals (H)
- Nutrients (H)
- Oil and Grease (M)
- Organics (H)
- Oxygen Demand (H)
- Sediment (H)
- Trash (L)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

APPLICABILITY

- Applicable to industrial, commercial and residential buildings.
- Can be incorporated into new construction or during re-roofing of existing building.
- Excellent for dense urban areas, and areas where infiltration is difficult due to tight soils, shallow bedrock or potential for groundwater contamination.
- Soil considerations not applicable.
- Should not be used where groundwater recharge is a priority.

ADVANTAGES

- Utilize the biological, physical, and chemical processes found in the plant and soil complex to prevent surrounding roof area, removing dead vegetation and weeds, replacing plants to maintain 90% plant cover, and repairing/replacing parts of irrigation systems.

INSPECTION CONSIDERATIONS

Automated systems should be tested to ensure proper operation. Irrigation systems need to be checked for water leaks and proper drainage. Water not absorbed into soil and plants must be effectively transported and drained from the rooftop. Drainage systems need to be inspected, including gutters, downspouts, drains and screens that prevent erosion to growing media and clogging of drainage pipes. Roof systems need to be inspected for water damage. Other regular (monthly or as needed) inspection activities include: inspecting for evidence of erosion from wind or water, inspecting vegetation for health and checking if plant growth is interfering with planter operation, inspecting membrane and roof structure for proper operations.

GREEN ROOFS IN CAMBRIDGE

- Harvard University - http://www.greencampus.harvard.edu/hpbs/green_roofs.php
- Genzyme Corporate Headquarters - http://www.mass.gov/envir/smart_growth_toolkit/pages/CS-lid-genzyme.html

airborne pollutants from entering the storm drain system.

- Reduce the runoff volume and peak discharge rate by holding back and slowing down the water that would otherwise flow quickly into the storm drain system.
- Aesthetic benefits
- Reduce city “heat island” effect
- Reduce CO_2 impact
- Reduce summer air conditioning cost and reduce winter heat demand
- Potentially lengthen roof life 2 to 3 times
- Treat nitrogen pollution in rain and negate acid rain effect

LIMITATIONS

- Load restrictions.
- Slopes greater than 15% require a wooden lath grid or other retention system to hold substrate in place until plants form a thick vegetation mat.
- Initial construction cost is higher than conventional roofs.

REFERENCE

- Santa Clara Valley Urban Runoff Pollution Prevention Program Guidance Manual
- Northern Virginia Regional Commission – Maintaining Stormwater Systems Guidebook
- Stormwater Manager's Resource Center (SMRC) Website www.stormwatercenter.net
- Massachusetts Low Impact Development Toolkit www.mapc.org/lid

1.6. Other Source Controls

More information on source controls including vehicle maintenance, spill prevention and response, sidewalk cleaning and repair, mosquito control, and graffiti cleaning is available in the City's Good Housekeeping Manual. This is nonprinting text.

DO NOT DELETE THIS TEXT OR THE SECTION BREAK THAT FOLLOWS
(Click ¶ button on Formatting toolbar to display section breaks)

City of Cambridge, Massachusetts

Department of Public Works

147 Hampshire Street • Cambridge, MA 02139

APPENDIX A
Best Management Practices

Section 2

Version 02/12

Contents

This is nonprinting text.
DO NOT DELETE THIS TEXT OR THE SECTION BREAK THAT FOLLOWS
(Click ¶ button on Formatting toolbar to display section breaks)

2. CONSTRUCTION CONTROLS

2.1. Construction Sequencing/Scheduling

DESCRIPTION

Scheduling is the development of a written plan that includes sequencing of construction activities and the implementation of BMPs such as erosion control and sediment control while taking local climate (rainfall, wind, etc.) into consideration. The purpose is to reduce the amount and duration of soil exposed to erosion by wind, rain, runoff, and vehicle tracking, and to perform the construction activities and control practices in accordance with the planned schedule. Construction site sequencing involves disturbing only part of a site at a time to prevent erosion from dormant parts. Grading activities and construction are completed and soils are effectively stabilized on one part of the site before grading and construction commence at another part.

DESIGN CONSIDERATIONS

- Locate temporary soil stockpiles and staging areas to prevent additional land disturbance.
- Establish a "trigger" for beginning a phase (e.g. percent of previous phase stabilized).
- Address both temporary and permanent stormwater management in each phase. Manage runoff separately in each phase.
- Ensure that later upstream phases address potential impacts to already completed downstream phases.
- Avoid rainy periods. Schedule major grading operations during dry months when practical. Allow enough time before rainfall begins to stabilize the soil with vegetation or physical means or to install sediment trapping devices.
- Plan the project and develop a schedule showing each phase of construction. Clearly show how the rainy season relates to soil disturbing and re-stabilization activities. Identify which measures should be installed before other activities are started.

Source: California Stormwater BMP Handbook, January 2003.

TARGETED CONSTITUENTS

- Bacteria (NR)
- Metals (NR)
- Nutrients (NR)
- Oil and Grease (NR)
- Organics (NR)
- Oxygen Demand (NR)
- Sediment (H)
- Trash (NR)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

OBJECTIVES

- Erosion Control
- Sediment Control
- Site Planning and Management

APPLICABILITY

- Should be incorporated into every construction project.

- Include on the schedule implementation and deployment of: erosion control BMPs, sediment control BMPs, tracking control BMPs, wind erosion control BMPs, and source control BMPs.
- Include dates for activities that may require non-stormwater discharges such as dewatering, sawcutting, grinding, drilling, boring, crushing, blasting, painting, hydro-demolition, mortar mixing, pavement cleaning, etc.
- Work out the sequencing and timetable for the start and completion of each item such as site clearing and grubbing, grading, excavation, paving, foundation pouring, utilities installation, etc., to minimize the active construction area at any given time.
- Sequence trenching activities so that most open portions are closed before new trenching begins.
- Incorporate staged seeding and re-vegetation of graded slopes as work progresses.
- Schedule establishment of permanent vegetation during appropriate planting time for specified vegetation.
- Non-active areas should be stabilized as soon as practical after the cessation of soil disturbing activities or one day prior to the onset of precipitation.
- Monitor the weather forecast for rainfall. When rainfall is predicted, adjust the construction schedule to allow the implementation of soil stabilization and sediment treatment controls on all disturbed areas prior to the onset of rain.
- Be prepared year round to deploy erosion control and sediment control BMPs. Erosion may be caused during dry seasons by un-seasonal rainfall, wind, and vehicle tracking. Keep the site stabilized year round, and retain and maintain sediment trapping devices in operational condition.
- Apply permanent erosion control to areas deemed substantially complete during the project's defined seeding window.
- Provide construction access in each phase separate from access for permanent residents to prevent conflicts between residents living in completed stages of the site and construction equipment working on later stages.
- Balance earthwork in each phase (e.g. "cut" and "fill" amounts are equal).

ADVANTAGES

- Use of other, more costly yet less effective, erosion and sediment control BMPs may often be reduced through proper construction sequencing.

LIMITATIONS

- Environmental constraints such as nesting season prohibitions reduce the full capabilities of this BMP.
- Weather constraints, especially during the winter months.

REFERENCE

- California Stormwater BMP Handbook for Construction
- Stormwater Manager's Resource Center (SMRC) Website www.stormwatercenter.net
- US EPA National Menu of Best Management Practices

MAINTENANCE CONSIDERATIONS

If progress deviates, take corrective actions. Amend the schedule when changes are warranted and prior to the rainy season to show updated information on construction site BMPs.

INSPECTION CONSIDERATIONS

Inspections should be performed in accordance with Section 4 of the Cambridge Stormwater Management Guidelines. Inspectors should verify that work is progressing in accordance with schedule.

CONSTRUCTION SCHEDULING IN CAMBRIDGE

- A construction schedule is required for all construction activities as part of an approved Erosion and Sediment Control Plan.

2.2. Preservation of Natural Vegetation

DESCRIPTION

Carefully planned preservation of existing vegetation minimizes the potential of removing or injuring existing trees, vines, shrubs, and grasses that protect soil from erosion.

DESIGN CONSIDERATIONS

- Provide for preservation of existing vegetation prior to the commencement of clearing and grubbing operations or other soil disturbing activities in areas where no construction activity is planned or will occur at a later date. Consider tree vigor, age, species, and wildlife benefits when selecting trees for preservation.
- Clearly mark areas to be preserved with temporary fencing. Include sufficient setback to protect roots. Orange colored plastic mesh fencing works well. Use appropriate fence posts and adequate post spacing and depth to completely support the fence in an upright position. Extend and mark the boundaries around contiguous natural areas and tree drip lines to protect the root zone from damage.
- Prepare a site map with the locations of trees, boundaries of environmentally sensitive areas, and buffer zones to be preserved. Locate temporary roadways, stockpiles, and layout areas to avoid stands of trees, shrubs, and grass. Follow natural contours and maintain preconstruction drainage patterns – if grading is not done properly, it could result in hydrology changes that kill vegetation. Make sure vegetation to be preserved will not interfere with installation and maintenance of utilities.
- Clear only the land that is needed for building activities and vehicle traffic.
- Maintain existing irrigation systems where feasible. Temporary irrigation may be required.
- Use barriers to prevent equipment from approaching protected areas. Instruct employees and subcontractors to honor protective devices. Prohibit heavy equipment, vehicular traffic, or storage of construction materials within the protected area.
- Do not nail boards to trees.
- Do not cut roots inside the tree drip line.
- During final site cleanup, remove barriers from around

St. Peter's Field parking lot – Cambridge, MA.

TARGETED CONSTITUENTS

- Bacteria (NR)
- Metals (NR)
- Nutrients (NR)
- Oil and Grease (NR)
- Organics (NR)
- Oxygen Demand (NR)
- Sediment (H)
- Trash (NR)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

OBJECTIVES

- Erosion Control
- Site Planning and Management

APPLICABILITY

- Suitable for use on most projects. Large projects often provide the greatest opportunity for use.
- Areas within the site where no construction activity occurs, or occurs at a later date. Especially suitable for multi-year projects.
- Areas where natural vegetation exists and is designed for preservation.
- Areas where local, state, and federal government require preservation, such as vernal pools, wetlands, etc.
- Where vegetation designated for

preserved areas and trees.

MAINTENANCE CONSIDERATIONS

- During construction, the limits of disturbance should remain clearly marked at all times. Irrigation or maintenance of existing vegetation should be described in the Erosion and Sediment Control Plan.
- If fertilization is needed, apply fertilizer at the minimum rate and to the minimum area needed. Work fertilizer deeply into soil to reduce exposure of nutrients to stormwater runoff. Apply fertilizer at lower application rates with higher application frequency. Limit hydroseeding (simultaneously applies lime and fertilizer). Ensure that erosion and sediment controls are in place to prevent fertilizer and sediment from being transported off site.

If damage to protected vegetation still occurs, maintenance guidelines described below should be followed:

- Repair or replace damaged vegetation immediately to maintain the integrity of the natural system. Choose vegetation that enhances existing vegetation.
- If a tree or shrub is damaged, remove and replace it with a tree of the same or similar species with a 2-in or larger caliper width from balled and burlaped nursery stock when construction activity is complete.
- Serious tree injuries should be attended to by an arborist. Damage to the crown, trunk, or root system of a retained tree shall be repaired immediately.
- Trench as far from tree trunks as possible, usually outside of the tree drip line or canopy. Curve trenches around trees to avoid large roots or root concentrations. If roots are encountered, consider tunneling under them. When trenching or tunneling near or under trees to be retained, place tunnels at least 18 in. below the ground surface, and not below the tree center to minimize impact on the roots. Fill trenches and tunnels as soon as possible. Careful filling and tamping will eliminate air spaces in the soil, which can damage roots.
- Do not leave tree roots exposed to air. Cover exposed roots with soil as soon as possible. If soil covering is not practical, protect exposed roots with wet burlap or peat moss until the tunnel or trench is ready for backfill.
- Cleanly remove the ends of damaged roots with a smooth cut.
- If bark damage occurs, cut back all loosened bark into the undamaged area, with the cut tapered at the top and bottom and

ultimate removal can be temporarily preserved and be utilized for erosion control and sediment control.

- Especially beneficial for floodplains, wetlands, stream banks, steep slopes, and other areas where erosion controls would be difficult to establish, install, or maintain.

ADVANTAGES

- Protects desirable vegetation from damage during development.
- Saves money on site stabilization and landscaping.
- Moderates temperature changes and provides shade for land and surface water habitats.
- Natural vegetation can process higher quantities of runoff than newly seeded areas and has a higher filtering capacity.
- Does not require time to establish.
- Provides screening against noise and visual disturbance.
- Usually requires less maintenance than planting new vegetation.
- Enhances aesthetics.

LIMITATIONS

- Requires forward planning by the owner/developer, contractor, and design staff.
- Limited opportunities for use when project plans do not incorporate existing vegetation into the site design.
- For sites with diverse topography, it is often difficult and expensive to save existing trees while grading the site satisfactory for the planned development.

REFERENCE

- California Stormwater BMP Handbook for Construction
- Massachusetts Erosion and Sediment Control Guidelines for

drainage provided at the base of the wood. Limit cutting the undamaged area as much as possible.

- Aerate soil that has been compacted over a trees root zone by punching holes 12 in deep with an iron bar, and moving the bar back and forth until the soil is loosened. Place holes 18 in. apart throughout the area of compacted soil under the tree crown.
- Fertilize stressed or damaged broadleaf trees to aid recovery. Fertilize trees in late fall or early spring. Apply fertilizer to the soil over the feeder roots and in accordance with label instructions, but never closer than 3 ft. to the trunk. Increase the fertilized area by one-fourth of the crown area for conifers that have extended root systems.
- Retain protective measures until all other construction activity is complete to avoid damage during site cleanup stabilization.

INSPECTION CONSIDERATIONS

Inspections should be performed in accordance with Section 4 of the Cambridge Stormwater Management Guidelines. Inspect preserved areas regularly to ensure barriers have not been removed or failed. Inspect vegetation to ensure it has not been damaged. Restore damaged protection measures and vegetation immediately.

PRESERVATION OF NATURAL VEGETATION IN CAMBRIDGE

- Cambridge has established a Tree Ordinance which affects development projects meeting certain criteria. Please visit http://www.cambridgema.gov/TheWorks/departments/parks/TreeOrdinanceLink.html for specific information.

Urban and Suburban Areas

- US EPA National Menu of Best Management Practices

2.3. Chemical Stabilization

DESCRIPTION

Chemical stabilizers, also known as soil binders or soil palliatives, provide temporary soil stabilization. Vinyl, asphalt, or rubbers are sprayed onto the surface of exposed soils to hold the soil in place and minimize erosion from runoff and wind. These materials are easily applied to the surface of the soil, can stabilize areas where vegetation cannot be established, and provide immediate protection.

DESIGN CONSIDERATIONS

- A chemical stabilizer must be environmentally benign (non-toxic to plant and animal life), easy to apply, easy to maintain, economical, and should not stain paved or painted surfaces. Chemical stabilizers should not pollute stormwater. Some chemical stabilizers may not be compatible with existing vegetation.
- Performance depends on temperature, humidity, and traffic across treated areas.
- Some chemical stabilizers reduce how pervious a soil is. Chemical stabilizers that reduce the soils capability to drain shall be used in limited quantities. Areas where the type of stabilizer is used shall have the top 4-inches of soil removed once stabilizer is no longer needed.

Selection: Factors to consider when selecting a chemical stabilizer include the following:

- Suitability to situation – Consider where the chemical stabilizer will be applied, if it needs a high resistance to leaching or abrasion, and whether it needs to be compatible with any existing vegetation. Determine the length of time soil stabilization will be needed, and if the chemical stabilizer will be placed in an area where it will degrade rapidly. In general, slope steepness is not a discriminating factor for the listed chemical stabilizers.
- Soil types and surface materials – Fines and moisture content are key properties of surface materials. Consider a chemical stabilizer's ability to penetrate, likelihood of leaching, and ability to form a surface crust on the surface materials.
- Frequency of application – The frequency of application can be affected by subgrade conditions, surface type, climate, and maintenance schedule. Frequent applications could lead to high costs. Application frequency may be minimized if the chemical stabilizer has good penetration, low evaporation and good longevity. Consider also that frequent application will require frequent equipment clean up.

Source: Erosion Control at www.forester.net.

TARGETED CONSTITUENTS

- Bacteria (NR)
- Metals (NR)
- Nutrients (NR)
- Oil and Grease (NR)
- Organics (NR)
- Oxygen Demand (NR)
- Sediment (H)
- Trash (NR)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

OBJECTIVES

- Erosion Control

APPLICABILITY

- Typically applied to disturbed areas requiring short term temporary protection.
- Suitable for use on stockpiles.
- Good alternative to mulches in areas where grading activities will soon resume.
- Regional soil types will dictate appropriate chemical stabilizers to be used.
- Use chemical stabilizers alone in areas where other methods of stabilization are not effective because of environmental constraints, or

The table below lists types of chemical stabilizers and their general properties. For more information on specific chemical stabilizers, please visit: http://www.cabmphandbooks.com/Construction.asp

Table 1 Properties of Soil Binders for Erosion Control

Evaluation Criteria	Binder Type			
	Plant Material Based (Short Lived)	Plant Material Based (Long Lived)	Polymeric Emulsion Blends	Cementitious-Based Binders
Relative Cost	Low	Low	Low	Low
Resistance to Leaching	High	High	Low to Moderate	Moderate
Resistance to Abrasion	Moderate	Low	Moderate to High	Moderate to High
Longevity	Short to Medium	Medium	Medium to Long	Medium
Minimum Curing Time before Rain	9 to 18 hours	19 to 24 hours	0 to 24 hours	4 to 8 hours
Compatibility with Existing Vegetation	Good	Poor	Poor	Poor
Mode of Degradation	Biodegradable	Biodegradable	Photodegradable/ Chemically Degradable	Photodegradable/ Chemically Degradable
Labor Intensive	No	No	No	No
Specialized Application Equipment	Water Truck or Hydraulic Mulcher	Water Truck or Hydraulic Mulcher	Water Truck or Hydraulic Mulcher	Water Truck or Hydraulic Mulcher
Liquid/Powder	Powder	Liquid	Liquid/Powder	Powder
Surface Crusting	Yes, but dissolves on rewetting	Yes	Yes, but dissolves on rewetting	Yes
Clean Up	Water	Water	Water	Water
Erosion Control Application Rate	Varies [(1)]	Varies [(1)]	Varies [(1)]	4,000 to 12,000 lbs/acre

Source: California Stormwater BMP Handbook, January 2003

Application: After selecting an appropriate chemical stabilizer, the untreated soil surface must be prepared before applying the stabilizer. The untreated soil surface must contain sufficient moisture to assist the agent in achieving uniform distribution.

- Follow manufacturer's written recommendations for application rates, pre-wetting of application area, and cleaning of equipment after use.
- Prior to application, roughen embankment and fill areas.
- Consider the drying time for the selected chemical stabilizer and apply with sufficient time before anticipated rainfall. Chemical stabilizers should not be applied during or immediately before rainfall. Generally, chemical stabilizers require a minimum curing time of 24 hours before they are fully effective. Refer to manufacturer's instructions for specific cure time.
- Avoid over spray onto roads, sidewalks, drainage channels, existing vegetation, etc.

use them in combination with vegetative or perimeter practices to enhance erosion and sediment control.

ADVANTAGES

- Provides temporary dust, wind, and soil stabilization.

LIMITATIONS

- Temporary in nature and may need reapplication.
- Require a minimum curing time until fully effective, as prescribed by the manufacturer. Curing time may be 24 hours or longer, and some chemical stabilizers may not cure if low temperatures occur within 24 hours of application.
- Generally experience spot failures during heavy rainfall events.
- Do not hold up to pedestrian or vehicular traffic across treated areas.
- May not penetrate soil surfaces made up primarily of silt and clay, particularly when compacted.
- May not perform well with low relative humidity. Under rainy conditions, may become slippery or leach out of the soil.
- If improperly applied, can pool and create impervious surfaces where water cannot infiltrate and could increase stormwater runoff.
- Generally more expensive than vegetative practices.
- Water quality impacts of chemical stabilizers are relatively unknown.
- Reduces soils ability to drain.

- Chemical stabilizers should not be applied to frozen soil, areas with standing water, under freezing or rainy conditions, or when the temperature is below 40°F during the curing period.
- More than one treatment is often necessary, although the second treatment may be diluted or have a lower application rate.

For liquid agents:

- Crown or slope ground to avoid ponding
- Uniformly pre-wet ground at 0.03 to 0.3 gal/yd^2 or according to manufacturer's recommendations.
- Apply solution under pressure. Overlap solution 6 to 12 in.
- Allow treated area to cure for the time recommended by the manufacturer – typically at least 24 hours.
- Apply second treatment before first treatment becomes ineffective, using 50 percent application rate.
- In low humidity, reactivate chemicals by re-wetting with water at 0.1 to 0.2 gal/yd^2.

MAINTENANCE CONSIDERATIONS

Areas where erosion is evident should be repaired and chemical stabilizers reapplied as soon as possible. Care should be exercised to minimize the damage to protected areas while making repairs, as any area damaged will require reapplication. Reapply the selected chemical stabilizer as needed to maintain effectiveness.

INSPECTION CONSIDERATIONS

Inspections should be performed in accordance with Section 4 of the Cambridge Stormwater Management Guidelines. Inspect for exposed soil.

CHEMICAL STABILIZERS IN CAMBRIDGE

- A sampling and analysis plan must be incorporated into the SWPPP as chemical stabilizers could be a source of non-visible pollutants.

REFERENCE

- California Stormwater BMP Handbook for Construction
- US EPA National Menu of Best Management Practices

2.4. Geotextiles and Mats

Source: Stony Brook-Millstone Watershed Association, New Jersey

DESCRIPTION

Geotextiles are porous fabrics also known as filter fabrics, road rugs, synthetic fabrics, construction fabrics, or simply fabrics. Geotextiles and mattings of natural materials are used to cover the soil surface to reduce erosion from rainfall impact, hold soil in place, and absorb and hold moisture near the soil surface. Additionally, matting may be used to stabilize soils until vegetation is established.

TARGETED CONSTITUENTS

- Bacteria (NR)
- Metals (NR)
- Nutrients (NR)
- Oil and Grease (NR)
- Organics (NR)
- Oxygen Demand (NR)
- Sediment (H)
- Trash (NR)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

OBJECTIVES

- Erosion Control
- Runoff Control

APPLICABILITY

- Commonly applied on short, steep slopes (generally steeper than 3:1), where erosion potential is high and vegetation will be slow to establish.
- Stream banks where moving water at velocities between 3 ft/s and 6 ft/s is likely to wash out new vegetation, channels with flows exceeding 3.3 ft/s, and channels to be vegetated. Also used on slopes adjacent to water bodies of environmentally sensitive areas.
- When seeding cannot occur (e.g., late season construction and/or the arrival of an early rain season).
- Should be considered when the soils are fine grained and potentially erosive.
- Slopes and disturbed soils where mulch must be anchored and disturbed areas

DESIGN CONSIDERATIONS

- The choice of matting should be based on the size of area, side slopes, surface conditions such as hardness, moisture, weed growth, and availability of materials. For more information on material selection, visit: http://www.cabmphandbooks.com/Construction.asp
- **Site Preparation:** Proper site preparation is essential to ensure complete contact of the blanket or matting with the soil. Grade and shape the area of installation. Remove all rocks, clods, vegetation or other obstructions so that the installed blankets or mats will have complete, direct contact with the soil. Prepare the seedbed by loosening 2 to 3 in. of topsoil.
- **Seeding:** Seed the area before blanket installation for erosion control and revegetation. Seeding after mat installation is often specified for turf reinforcement application. When seeding prior to blanket installation, all check slots and other areas disturbed during installation must be re-seeded. Where soil filling is specified, seed the matting and the entire disturbed area after installation and prior to filling with the mat and soil. Fertilize and seed in accordance with seeding specifications or other types of landscaping plans. When using jute matting on a seeded area, apply approximately half the seed before laying the mat and remainder after laying the mat. The protective matting can be

laid over areas where grass has been planted and the seedings have emerged. Where vines or other ground covers are to be planted, lay the protective matting first and then plant through matting according to design of planting.

- **Check Slots:** Check slots are made of glass fiber strips, excelsior matting strips or tight folded jute matting blanket or strips for use on steep, highly erodible watercourses. The check slots are placed in narrow trenches 6 to 12 in. deep across the channel and left flush with the soil surface. They are to cover the full cross section of designed flow.
- **Laying and Securing Matting:** Before laying the matting, all check slots should be installed and the friable seedbed made free from clods, rocks, and roots. The surface should be compacted and finished according to the requirements of the manufacturer's recommendations. Mechanical or manual lay down equipment should be capable of handling full rolls of fabric and laying the fabric smoothly without wrinkles or folds. The equipment should meet the fabric manufacturer's recommendations or equivalent standards.
- **Anchors:** U-shaped wire staples, metal geotextile stake pins, or triangular wooden stakes can be used to anchor mats and blankets to the ground surface. Wire staples should be made of minimum 11 gauge steel wire and should be U-shaped with 8 in. legs and 2 in. crown. Metal stake pins should be 0.188 in. diameter steel with a 1.5 in. steel washer at the head of the pin, and 8 in. in length. Wire staples and metal stakes should be driven flush to the soil surface.
- **Installation on Slopes:** Installation should be in accordance with the manufacturer's recommendations. In general, these will be as follows. Begin at the top of the slope and anchor the blanket in a 6 in. deep by 6 in. wide trench. Backfill trench and tamp earth firmly. Unroll blanket down slope in the direction of water flow. Overlap the edges of adjacent parallel rolls 2 to 3 in. and staple every 3 ft. When blankets must be spliced, place blankets end over end (shingle style) with 6 in. overlap. Staple through overlapped area, approximately 12 in. apart. Lay blankets loosely and maintain direct contact with the soil. Do not stretch. Staple blankets loosely and maintain direct contact with the soil. Do not stretch. Staple blankets sufficiently to anchor blanket and maintain contact with the soil. Staples should be placed down the center and staggered with the staples placed along the edges. Steep slopes, 1:1 to 2:1, require a minimum of 2 staples/yd^2. Moderate slopes, 2:1 to 3:1, require a minimum of 1 ½ staples/yd^2.

where plants are slow to develop.

- Can be used on stockpiles.
- Generally not suitable for excessively rocky sites or areas where the final vegetation will be mowed (since staples and netting can catch in mowers).
- Not suitable for areas that have heavy foot traffic (tripping hazard).
- Can be used as a separator between riprap and soil. This "sandwiching" prevents the soil from being eroded beneath the riprap and maintains the riprap base.

ADVANTAGES

- Fabrics are relatively inexpensive for certain applications.
- A wide variety of geotextiles to match specific needs is available.

LIMITATIONS

- Mattings are more costly than other BMPs, limiting their use to areas where other BMPs are ineffective (e.g. channels, steep slopes).
- Installation is critical and requires experienced contractors.
- May delay seed germination due to reduction in soil temperature.
- Must be removed and disposed of prior to application of permanent soil stabilization measures.
- Plastic sheeting is easily vandalized, easily torn, photodegradable, and must be disposed of at a landfill. Plastic results in 100% runoff, which may cause serious erosion problems in

- **Installation in Channels:** Installation should be in accordance with the manufacturer's recommendations. In general, these will be as follows. Dig initial anchor trench 12 in. deep and 6 in. wide across the channel at the lower end of the project area. Excavate intermittent check slots, 6 in. deep and 6 in. wide across the channel at 25 to 30 ft. intervals along the channels. Cut longitudinal channel anchor trenches 4 in. deep and 4 in. wide along each side of the installation to bury edges of matting, whenever possible extend matting 2 to 3 in. above the crest of the channel side slopes. Beginning at the downstream end and in the center of the channel, place the initial end of the first roll in the anchor trench and secure with fastening devices at 12 in. intervals (note: matting will initially be upside down in anchor trench). In the same manner, position adjacent rolls in anchor trench, overlapping the preceding roll a minimum of 3 in. Secure these initial ends of mats with anchors at 12 in. intervals, backfill and compact soil. Unroll center strip of matting upstream. Stop at next check slot or terminal anchor trench. Unroll adjacent mats upstream in similar fashion, maintaining a 3 in. overlap. Fold and secure all rolls of matting snugly into all transverse check slots. Lay mat in the bottom of the slot then fold back against itself. Anchor through both layers of mat at 12 in. intervals, then backfill and compact soil. Continue rolling all mat widths upstream to the next check slot or terminal anchor trench. Alternate method for non-critical installations: Place two rows of anchors on 6 in. centers at 25 to 30 ft. intervals in lieu of excavated check slots. Staple shingled lap spliced ends a minimum of 12 in. apart on 12 in. intervals. Place edges of outside mats in previously excavated longitudinal slots; anchor using prescribed staple pattern, backfill, and compact soil. Anchor, fill, and compact upstream end of mat in a 12 in. by 6 in. terminal trench. Secure mat to ground surface using U-shaped wire staples, geotextile pins, or wooden stakes. Seed and fill turf reinforcement matting with soil, if specified.
- **Soil filling (if specified for turf reinforcement):** Always consult the manufacturer's recommendations for installation. Do not drive tracked or heavy equipment over mat. Avoid any traffic over matting if loose or wet soil conditions exist. Use shovels, rakes, or brooms for fine grading and touch up. Smooth out soil filling just exposing top netting of mat. Temporary soil stabilization removed from the site of the work must be disposed of if necessary.

the areas receiving the increased flow.

- Geotextiles, mats, plastic covers, and erosion control covers have maximum flow rate limitations; consult the manufacturer for proper selection.

REFERENCE

- California Stormwater BMP Handbook for Construction
- Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas
- Stormwater Manager's Resource Center (SMRC) Website www.stormwatercenter.net
- US EPA National Menu of Best Management Practices

MAINTENANCE CONSIDERATIONS

Areas where erosion is evident should be repaired and geotextiles reapplied as soon as possible. Care should be exercised to minimize the damage to protected areas while making repairs, as any area damaged will require reapplication. If washout or breakage occurs, re-install the material after repairing the damage to the slope or channel.

INSPECTION CONSIDERATIONS

Inspections should be performed in accordance with Section 4 of the Cambridge Stormwater Management Guidelines. Make sure matting is uniformly in contact with the soil at all times. Check that all the lap joints are secure. Check that staples are flush with the ground. Check that disturbed areas are seeded.

2.5. Mulching

DESCRIPTION

Mulches, which are chopped up organic material, have two purposes on construction sites. They are used to protect seeds from erosion, moisture loss and animals (e.g. birds and small mammals) and are used alone when seeds cannot be established, such as outside the growing season. Mulches are one of the most important, effective, and economical erosion control practices.

DESIGN CONSIDERATIONS

- There are many types of mulches. Selection of the appropriate type of mulch should be based on the type of application, site conditions, and compatibility with planned or future uses.
- Green Material: This type of mulch is produced by the recycling of vegetation trimmings such as grass, shredded shrubs, and trees. Methods of application are generally by hand although pneumatic methods are available. Green material can be used as a temporary ground cover with or without seeding and should be evenly distributed on site to a depth of not more than 2 in.
- Shredded Wood: Suitable for ground cover in ornamental or revegetated plantings. Shredded wood/bark is conditionally suitable – see applicability. Distribute by hand or use pneumatic methods. Evenly distribute the mulch across the soil surface to a depth of 2 to 3 in.
- Hydraulic Mulch: Hydraulic mulch consists of applying a mixture of shredded wood fiber or a hydraulic matrix, and a stabilizing emulsion or tackifier with hydro-mulching equipment, which temporarily protects exposed soil from erosion by raindrop impact or wind.
- Prior to application, after existing vegetation has been removed, roughen embankment and fill areas by rolling with a device such as a punching type roller or by track walking. The construction application procedures for mulches vary significantly depending upon the type of mulching method specified.
- Avoid mulch placement onto roads, sidewalks, drainage channels, existing vegetation, etc.
- Organic mulch materials such as straw, wood chips, bark, and wood fiber have been found to be the most effective, although straw is preferred.
- On steeper slopes and critical areas such as waterways, use netting or anchoring with mulch to hold it in place.

Grass mulching is applied to stabilize exposed soils and to reduce stormwater runoff velocity

Source: US EPA National Menu of Best Management Practices

TARGETED CONSTITUENTS

- Bacteria (NR)
- Metals (NR)
- Nutrients (NR)
- Oil and Grease (NR)
- Organics (NR)
- Oxygen Demand (NR)
- Sediment (H)
- Trash (NR)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

OBJECTIVES

- Erosion Control

APPLICABILITY

- Suitable for soil disturbed areas requiring temporary protection until permanent stabilization is established.
- Not suitable for use on slopes steeper than 3:1 (H:V). Best suited to flat areas or gentle slopes or 5:1 (H:V) or flatter.
- Not suitable for areas exposed to concentrated flows.

ADVANTAGES

- Instant protection of exposed areas.
- Conserves moisture and reduces the need for

- For more information on mulch materials and installation, please visit: http://mass.gov/dep/water/esfull.pdf

MAINTENANCE CONSIDERATIONS

Areas where erosion is evident should be repaired and mulch reapplied as soon as possible. Care should be exercised to minimize the damage to protected areas while making repairs, as any area damaged will require reapplication. Regardless of the mulching technique selected, the key consideration in inspection and maintenance is that the mulch needs to last long enough to achieve erosion control objectives. If the mulch is applied as a standalone erosion control method over disturbed areas (without seed, it should last the length of time the site will remain barren or until final re-grading and revegetation. Where vegetation is not the ultimate cover, such as ornamental and landscape applications of bark or wood chips, inspection and maintenance should focus on longevity and integrity of the mulch. Reapply mulch when bare earth becomes visible. If netting used to anchor, care should be taken during mowing to keep the mower height high.

INSPECTION CONSIDERATIONS

Inspections should be performed in accordance with Section 4 of the Cambridge Stormwater Management Guidelines. Inspection procedures should focus on longevity and integrity of the mulch. Inspect for movement of mulch and bare areas.

irrigation.

- Extremely effective at reducing suspended solids, with efficiencies in the 80% and 90% range.
- Low cost and easy to apply.

LIMITATIONS

- Care must be taken to apply mulch at the specified thickness, as thick mulches can reduce soil temperatures and delay seed germination.
- Wood mulch and compost may introduce unwanted species.
- May need to be removed prior to further earthwork and either composted or landfilled.
- Can be easily blown or washed away by runoff if not secured.
- Some mulch materials such as wood chips may absorb nutrients necessary for plant growth.

REFERENCE

- California Stormwater BMP Handbook for Construction
- Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas
- Stormwater Manager's Resource Center (SMRC) Website www.stormwatercenter.net
- US EPA National Menu of Best Management Practices

2.6. Temporary Seeding

DESCRIPTION

Temporary seeding is used to establish a cover on a disturbed area that will grow rapidly by using annual plants. A temporary vegetative cover is used for areas that have been disturbed and remain untouched for more than 14 calendar days. A temporary vegetative cover will help to reduce damage caused by erosion to a disturbed area by hindering sediment to be transported downstream or to off-site areas. Temporary vegetative covering should also be used when a site is ending construction due to winter conditions. The contractor should place the temporary seed early enough so that it can properly grow before winter. Placing temporary seeding can greatly reduce the cost of other erosion and sediment control devices since the seeding will help reduce the amount of sediment transport greatly.

DESIGN CONSIDERATIONS

- Prior to seeding taking place necessary erosion and sediment control devices such as inlet protection, diversion channels or filter berms should be installed around the area when necessary.
- Plant selection should be based on time of year and site conditions. Refer to the below table for examples of plants that can be used.

Planting Dates	Species	Rate (lbs./ac.)
Aug 15 – Oct. 31	Cereal Rye (Winter Rye)	120
Apr 1 – June 1 Aug 15 – Sept 15	Annual Ryegrass	40
May 1 to June 30	Foxtail Millet	30
Aug 15 to Oct 31	Oats	80

- **Annual Ryegrass and Cereal Rye-**Annual Ryegrass and Cereal Rye should be used for fall and spring seeding since it tolerates cold temperatures and low moisture.
- **German Millet-**Foxtail Millet should be used in the summer months. Foxtail Millet will die from frost and does not tolerate cold weather. This is a summer time planting only.
- **Oats-**Oats should be used as a fall seeding since it tolerates cold temperatures and low moisture

- Seeding that is placed in fall, winter and during hot and dry days

Source: Love the Garden website. www.lovethegarden.com

TARGETED CONSTITUENTS

- Bacteria (NR)
- Metals (NR)
- Nutrients (NR)
- Oil and Grease (NR)
- Organics (NR)
- Oxygen Demand (NR)
- Sediment (H)
- Trash (NR)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

OBJECTIVES

- Erosion Control
- Runoff Control

APPLICABILITY

- Well-suited in areas where permanent, long-lived vegetative cover is the most practical or most effective method of stabilizing soil.
- Use on roughly graded areas that will not be regraded for at least a year.
- Effective on areas where soils are unstable because of their texture or structure, high water table, winds, or steep slope.

should be covered with straw. Hay should not be used since it contains the seeds and maybe considered invasive.

- Areas that fail to establish proper seeding should be re-seeded or another type of ground cover should be selected.
- Hydro-seeding applications with appropriate seed-mulch-fertilizer mixtures may also be applies as temporary seeding.
- Liming maybe used when applied uniformly. Lime should be applied at 2 tons of ground limestone per acre or according to soil test.
- A 10-10-10 fertilizer can be applied to the area at a rate of 400 lbs per acre or as indicated by soil test. Forty percent of the nitrogen should be in organic form.
- Lime and fertilizers should be worked in to a depth of 4 inches using any suitable equipment.

MAINTENANCE CONSIDERATIONS

Maintenance for seeded areas will vary depending on the level of use expected.

Grasses should emerge within 4-28 days and legumes 5-28 days after seeding, with legumes following grasses. A successful stand has the following characteristics: vigorous dark green or bluish (not yellow) seedlings; uniform density, with nurse plants, legumes, and grasses well intermixed; green leaves that remain green throughout the summer – at least at the plant bases.

If a stand has inadequate cover (less than 40% cover), reevaluate the choice of plant materials and quantities of lime and fertilizer. Reestablish the stand following seedbed preparation and seeding recommendations. Depending on the condition of the stand, repair by overseeding or reseeding after complete seedbed preparation. If timing is bad, overseed with rye grain or Foxtail millet to thicken the stand. If vegetation fails to grow, test the soil to determine if low pH or nutrient imbalances are responsible. Use soil tests to determine if more fertilizer needs to be added. Do not fertilize cool season grasses in late May through July. Grass that looks yellow might be nitrogen deficient. Do not use nitrogen fertilizer if the stand contains more than 20 percent legumes.

INSPECTION CONSIDERATIONS

- Especially important for filter strips, buffer areas, vegetated swales, steep slopes and stream banks.
- Major factors that dictate the suitability of plants for a site include climate, soils, and topography.

ADVANTAGES

- Lower initial costs and labor needs.
- Well established grass and ground covers can give an aesthetically pleasing, finished look to a development.
- Usually the most economical way to stabilize large areas.
- Wide variety of grasses and legumes available.
- Ease of establishment in difficult areas, and once established, vegetation will prevent erosion and slow runoff velocities.

LIMITATIONS

- Effectiveness can be limited by high erosion during establishment, the need to reseed areas that fail to establish, limited seeding times, or unstable soil temperature and soil moisture content during germination and early growth.
- Does not immediately stabilize soils – temporary erosion and sediment control measures will be necessary.
- Vegetation and mulch cannot prevent soil slippage and erosion if soil is not inherently stable.
- Coarse, high grasses that aren't mowed can create a fire hazard in some places. Very short mowed grass, however, provides less stability and filtering

Inspections should be performed in accordance with Section 4 of the Cambridge Stormwater Management Guidelines. Inspect seeded areas for failure. Conduct a follow-up weekly survey to ensure the area has been seeded correctly and replace all failed plants.

capacity.

- Grass planted to the edge of a watercourse may encourage fertilization and mowing near water's edge and increase nutrient and pesticide contamination.
- May require regular irrigation to establish and maintain.
- Depends initially on climate and weather for success.

REFERENCE

- California Stormwater BMP Handbook for Construction
- Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas
- US EPA National Menu of Best Management Practices

2.7. Permanent Seeding

DESCRIPTION

Seeding is used to control runoff and erosion on disturbed areas by establishing perennial vegetative cover from seed. It reduces erosion and sediment loss and provides permanent stabilization. Vegetation controls erosion by protecting bare soil surfaces from displacement by raindrop impacts and by reducing the velocity and quantity of overland flow. This practice is economical, adaptable to different site conditions, and allows selection of a variety of plant materials.

DESIGN CONSIDERATIONS

- Seed or plant permanent vegetation in areas 1 to 4 months after the final grade is achieved unless temporary stabilization measures are in place.
- Selection of the right plant materials for the site, good seedbed preparation, timing, and conscientious maintenance are important.
- Prepare and amend the soil on a disturbed site to provide sufficient nutrients for seed germination and seedling growth.
- Loosen the soil surface enough for water infiltration and root penetration.
- If soils are too acidic, increase the pH to between 6.0 and 6.5 with liming or choose plants that are appropriate for the soil characteristics at your site. Protect seeds with mulch to retain moisture, regulate soil temperatures, and prevent erosion during seedling establishment.
- Use long-lived grass perennials that form a tight sod and are fine-leaved for areas that receive extensive use, such as homes, industrial parks, schools, churches, and recreational areas.
- Whenever possible, choose native species that are adapted to local weather and soil conditions to reduce water and fertilizer inputs and lower maintenance overall.
- If non-native plant species are used, they should be tolerant of a large range of growing conditions, as low maintenance as possible, and not invasive.
- Low-maintenance areas are mowed infrequently or not at all and do not receive lime or fertilizer regularly. Plants must be able to persist with minimal maintenance over long periods of time. Use grass and legume mixtures for these sites because legumes fix nitrogen from the atmosphere. Sites suitable for low-maintenance vegetation include steep slopes, stream or channel

Source: Love the Garden website. www.lovethegarden.com

TARGETED CONSTITUENTS

- Bacteria (NR)
- Metals (NR)
- Nutrients (NR)
- Oil and Grease (NR)
- Organics (NR)
- Oxygen Demand (NR)
- Sediment (H)
- Trash (NR)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

OBJECTIVES

- Erosion Control
- Runoff Control

APPLICABILITY

- Well-suited in areas where permanent, long-lived vegetative cover is the most practical or most effective method of stabilizing soil.
- Use on roughly graded areas that will not be regraded for at least a year.

banks, some commercial properties, and "utility" turf areas such as road banks.

- Consider the microclimate within the development area. Low areas may be frost pockets and require hardier vegetation since cold air tends to sink and flow towards low spots. South-facing slopes may be more difficult to re-vegetate because they tend to be sunnier and drier.
- Divert as much surface water as possible from the area to be planted.
- Remove seepage water that would continue to have adverse effects on soil stability or the protecting vegetation. Subsurface drainage or other engineering practices may be needed and might require permits.
- Provide protection from equipment, trampling and other destructive agents.
- Vegetation cannot be expected to supply an erosion control cover and prevent slippage on a soil that is not stable due to its texture, structure, water movement, or excessive slope.
- Install necessary surface runoff control measures such as gradient terraces, berms, dikes, level spreaders, waterways, and sediment basins prior to seeding or planting.
- Seedbed Preparation: If infertile or coarse-textured subsoil will be exposed during land shaping, it is best to stockpile topsoil and respread it over the finished slope at a minimum 2 to 6 in. depth and roll it to provide a firm seedbed. If construction fill operations have left soil exposed with a loose, rough, or irregular surface, smooth with blade and roll. Loosen the soil to a depth of 3 to 5 in. with suitable agricultural or construction equipment. Areas not to receive top soil should be treated to firm the seedbed after incorporation of the lime and fertilizer so that it is depressed no more than ½ to 1 in. when stepped on with a shoe. Areas to receive topsoil should not be firmed until after topsoiling and lime and fertilizer are applied and incorporated, at which time it should be treated to firm the seedbed as described above. This can be done by rolling or cultipacking.
- Apply lime and fertilizer according to soil test recommendations. In absence of a soil test, apply lime (a pH of 5.5 – 6.0 is desired) at a rate of 2.5 tons per acre and 10-20-20 analysis fertilizer at a rate of 500 pounds per acre (40% of N to be in an organic or slow release form). Incorporate lime and fertilizer into the top 2 to 3 in. of soil.
- Seeding operations should be performed within one of the

- Effective on areas where soils are unstable because of their texture or structure, high water table, winds, or steep slope.
- Especially important for filter strips, buffer areas, vegetated swales, steep slopes and stream banks.
- Major factors that dictate the suitability of plants for a site include climate, soils, and topography.

ADVANTAGES

- Lower initial costs and labor needs.
- Well established grass and ground covers can give an aesthetically pleasing, finished look to a development.
- Usually the most economical way to stabilize large areas.
- Wide variety of grasses and legumes available.
- Ease of establishment in difficult areas, and once established, vegetation will prevent erosion and slow runoff velocities.

LIMITATIONS

- Effectiveness can be limited by high erosion during establishment, the need to reseed areas that fail to establish, limited seeding times, or unstable soil temperature and soil moisture content during germination and early growth.
- Does not immediately stabilize soils – temporary erosion and sediment control measures will be necessary.
- Vegetation and mulch cannot prevent soil slippage and erosion if soil is not inherently stable.

following periods: April 1 – May 31, August 1-September 10, or November 1-December 15 as a dormant seedling (seedling rates should be increased by 50% for dormant seedings.

- Seeding should be performed by one of the following methods: Drill seedings; Broadcast and rolled, cultipacked or tracked with a small track piece of construction equipment; Hydroseeding, with subsequent tracking.
- Seed should be planted to a depth of ¼ to ½ in.
- Mulch the seedings with straw applied at the rate of ½ tons per acre. Anchor the mulch with erosion control netting or fabric on sloping areas.

MAINTENANCE CONSIDERATIONS

Maintenance for seeded areas will vary depending on the level of use expected.

Grasses should emerge within 4-28 days and legumes 5-28 days after seeding, with legumes following grasses. A successful stand has the following characteristics: vigorous dark green or bluish (not yellow) seedlings; uniform density, with nurse plants, legumes, and grasses well intermixed; green leaves that remain green throughout the summer – at least at the plant bases.

If a stand has inadequate cover (less than 40% cover), reevaluate the choice of plant materials and quantities of lime and fertilizer. Reestablish the stand following seedbed preparation and seeding recommendations. Depending on the condition of the stand, repair by overseeding or reseeding after complete seedbed preparation. If timing is bad, overseed with rye grain or German millet to thicken the stand until a suitable time for seeding perennials. If the season prevents resowing, mulch or jute netting is an effective temporary cover. Consider seeding temporary, annual species if the season is not appropriate for permanent seeding. If vegetation fails to grow, test the soil to determine if low pH or nutrient imbalances are responsible. On a typical disturbed site, full plant establishment usually requires refertilization in the second growing season. Use soil tests to determine if more fertilizer needs to be added. Do not fertilize cool season grasses in late May through July. Grass that looks yellow might be nitrogen deficient. Do not use nitrogen fertilizer if the stand contains more than 20 percent legumes. Seeded areas should be fertilized during the second growing season. Lime and fertilize thereafter at periodic intervals.

INSPECTION CONSIDERATIONS

Inspections should be performed in accordance with Section 4 of the

- Coarse, high grasses that aren't mowed can create a fire hazard in some places. Very short mowed grass, however, provides less stability and filtering capacity.
- Grass planted to the edge of a watercourse may encourage fertilization and mowing near water's edge and increase nutrient and pesticide contamination.
- May require regular irrigation to establish and maintain.
- Depends initially on climate and weather for success.

REFERENCE

- California Stormwater BMP Handbook for Construction
- Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas
- US EPA National Menu of Best Management Practices

Cambridge Stormwater Management Guidelines. Inspect seeded areas for failure. Conduct a follow-up survey after 1 year and replace all failed plants.

2.8. Dust Control

DESCRIPTION

Dust control is used to reduce the surface and air movement of dust and other fine particles during land disturbing activities, demolition and other construction activity. Dust control should be important part of all construction activities. Dust control will help prevent airborne substances that may present a health hazard, safety problems or harm animal or plant life throughout the course of construction. Dust control should be applied to all surfaces that are exposed to elements and can become dry quickly. This includes but is not limited to construction access roads, denuded areas and stockpiles.

DESIGN CONSIDERATIONS

- There are many forms of dust control that can be picked. The Engineer/Contractor should choose the appropriate method that correlates to the site and also type of use.
- Types of temporary methods of dust controls are vegetative cover, mulching, tillage, irrigation, spray-on adhesives, stone, barriers, and Calcium Chloride.
- Types of permanent methods of dust control are, permanent vegetation, and stone.
- A contractor shall only expose areas that are currently being worked on. A contractor should never de-nude an entire site at the beginning of a project. Limiting the amount of soil disturbance at one time should be a key objective to reducing the cost of dust control and also maintaining a better site environment.
- Dust Control should be performed when necessary. At no time should visible dust particle be seen in the air around a construction site.
- A contractor should develop a proper site plan that reduces the amount of area needed to be used to lay-down, access roads and other activities that disturb soils.
- Stockpiles should have dust control applied to them daily and should be permanently vegetated if left untouched for 14 days. Stockpiles may be covered with plastic provided they are not greater than 20' in diameter. The plastic should be properly secured at all times and should not move during high wind events.

Source: www.jericoservices.com/images/DustControlPage

TARGETED CONSTITUENTS

- Bacteria (NR)
- Metals (NR)
- Nutrients (NR)
- Oil and Grease (NR)
- Organics (NR)
- Oxygen Demand (NR)
- Sediment (M)
- Trash (NR)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

OBJECTIVES

- Sediment Control
- Erosion Control

APPLICABILITY

- On all sites where bare soils will be exposed and dust can be transported by wind, traffic and other methods.

ADVANTAGES

- Reduce the amount of sediment pollution that can enter the air and effect air quality in nearby areas.
- Site remains clean and free of airborne dust particles

MAINTENANCE CONSIDERATIONS

LIMITATIONS

Depending on the phasing plan, soil type and dust control selection, dust control can either require extensive maintenance or very little maintenance. The contractor should decide on a practice that is best suited for the project. The basic rule is, once dust is starting to be seen in the air either from wind, truck traffic, or other forces a re-application of the dust control measure should be applied.

INSPECTION CONSIDERATIONS

Inspections should be performed in accordance with Section 4 of the Cambridge Stormwater Management Guidelines. Dust control should be re-applied immediately once the appearance of dust has occurred.

- Depending on type of dust control my require daily application and constant maintenance.
- Can be costly if not done properly.
- Contractor can reduce the pervious characteristics of the soil if some types of dust control are applied to heavily.

REFERENCE

- Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas
- Virginia Erosion and Sediment Control Handbook.
- Stormwater Manager's Resource Center (SMRC) Website www.stormwatercenter.net
- US EPA National Menu of Best Management Practices

2.9. Construction Safety Fence

DESCRIPTION

The purpose of safety fence around a site and within a site is to protect the general public and also the workers on site from entering an area with an apparent danger. The safety for the general public and workers must be considered at both the planning and implementation phases of any and all land disturbing activities. Generally speaking safety fence shall be placed around the entire site to control access by not allowing the public into the area. In addition safety fence should also be considered around large trenching operations, overhead dangers and any other danger that poses a threat to workers on site. In general there are two type of construction fence, chain link fencing and plastic (Polyethylene) fence.

DESIGN CONSIDERATIONS

- Safety fences should be placed at locations so that a formidable barrier is created to prevent undesirable access, while allowing for construction activities to continue.
- The height of fencing should be 5 feet for plastic fence and 8 feet for all metal (chain link) fencing. A fence should be tall enough to prevent children from climbing over it.
- Signs shall be posted every 50 feet along the fence line warning anyone approaching the area that a danger lies ahead. Signs can read “DANGER-KEEP OUT”, “HAZARDOUS AREA”, or any other warning.
- Plastic fencing may be used as a safety fence, primarily in temporary situation. The fencing should be meet the physical requirements in the table below:
- Plastic fencing shall be secured to a metal “T” or “U” post driven into the ground to a minimum depth of 18”. Post shall be placed 6 feet on center.
- Metal fencing should be placed when a hazard will be created for an extend period of time, i.e. site work for a construction project last more than 3 months, when the general public is exposed to a risk and unwanted entry is undesired. The metal fencing should be the requirements in the table below.
- Metal safety fence posts shall be installed at 10 feet on

Source:
www.shawnee.edu/off/com/uc/TL%20Photos

TARGETED CONSTITUENTS

- Bacteria (NR)
- Metals (NR)
- Nutrients (NR)
- Oil and Grease (NR)
- Organics (NR)
- Oxygen Demand (NR)
- Sediment (NR)
- Trash (NR)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

OBJECTIVES

- Access Control

APPLICABILITY

- Typically installed around all construction site and in areas of danger.

ADVANTAGES

- Can improve both the appearance and the public perception of the construction project.
- Help keep out unwanted persons from entering the construction site and rick being injured.
- Help works onsite from entering any areas that may be deemed a hazard within the projects limits.

LIMITATIONS

center. When determining spacing, the measurement will be made parallel with the ground surface.

- Post shall be set in concrete, backfilled or anchored by other acceptable means. When set in concrete the post shall be placed at least 18" below the surface with 6" of concrete on all sides. When backfilled the post shall be placed at least 24" below grade and the area backfilled with common burrow and compacted to at least 95%. Any other acceptable methods of anchoring shall be constructed so the fence does not fall during wind events.
- Wind screen shall not be placed on a fence until at least 7 days has passed from the time of installation. Wind screen shall be securely fastened by means of clips at the post intervals every 15" and at least every 2 feet on the top on bottom rails. Wind holes shall be placed in the screen as deemed necessary by the contractor or resident engineer.

MAINTENANCE CONSIDERATIONS

Maintain safety fences until the construction site has been fully stabilized. Safety fences shall be checked regularly for any weather or other type of damage. Sections should be replaced within 24 hours once damage is discovered. Care and maintenance attention should be given to all access points (gates) at the end of the work day. All locking devices shall be repaired if broken and be in working order throughout the life of the fence.

INSPECTION CONSIDERATIONS

Inspections should be performed in accordance with Section 4 of the Cambridge Stormwater Management Guidelines. Inspect fence for tears, rips or any other structural abnormality. Repairs should be made with 24 hours.

- Design of safety fence is often looked past due diligence must be placed on the contractor to ensure proper site safety.
- High winds can blow fences over possible injuring those near the fence, extreme care must be used to ensure the fence is properly anchored.

REFERENCE

- Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas
- Virginia Erosion and Sediment Control Handbook.
- Stormwater Manager's Resource Center (SMRC) Website www.stormwatercenter.net
- US EPA National Menu of Best Management Practices

2.10. Construction Entrance Stabilization

DESCRIPTION

The purpose of stabilizing entrances to a construction site is to minimize the amount of sediment leaving the area as mud and sediment attached to vehicles. Installing a pad of gravel over filter cloth where construction traffic leaves a site can help stabilize a construction entrance. As a vehicle drives over the pad, the pad removes mud and sediment from the wheels and reduces soil transport off the site. The filter cloth separates the gravel from the soil below, keeping the gravel from being ground into the soil. The fabric also reduces the amount of rutting caused by vehicle tires. It spreads the vehicle's weight over a soil area larger than the tire width. In addition to using a gravel pad, a vehicle washing station can be established at the site entrance. Using wash stations routinely can remove a lot of sediment from vehicles before they leave the site. Diverting runoff from vehicle washing stations into a sediment trap helps to make sure the sediment from vehicles stays onsite and is handled properly. Stabilized construction entrances should be used in conjunction with stabilized construction roads to reduce the amount of mud picked up by vehicles.

DESIGN CONSIDERATIONS

Entrance Design

- Stabilize all entrances to a site before construction and further site disturbance begin. Make sure the stabilized site entrances are long and wide enough to allow the largest construction vehicle that will enter the site to fit through with room to spare.
- If many vehicles are expected to use an entrance in any one day, make the site entrance wide enough for two vehicles to pass at the same time with room on either side of each vehicle.
- If a site entrance leads to a paved road, make the end of the entrance flared so that long vehicles do not leave the stabilized area when they turn onto or off the paved roadway.
- If a construction site entrance crosses a stream, swale, or other depression, provide a bridge or culvert to prevent erosion from unprotected banks.
- Avoid locating at curves in public roads or on steep slopes.

Preparation

- A filter fabric should be installed down-gradient from the construction entrance in order to contain any sediment-laden

Source: The Northern Virginia Soil and Water Conservation District - Fairfax County, Virginia.

TARGETED CONSTITUENTS

- Bacteria (NR)
- Metals (NR)
- Nutrients (NR)
- Oil and Grease (NR)
- Organics (NR)
- Oxygen Demand (NR)
- Sediment (H)
- Trash (NR)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

OBJECTIVES

- Sediment Control

APPLICABILITY

- Typically installed where construction traffic leaves or enters an existing paved road.
- Should be extended to any roadway or entrance where vehicles enter or leave the site.

ADVANTAGES

- Can improve both the appearance and the public perception of the construction project.
- Mud on vehicle tires is significantly reduced which avoids hazards caused by

runoff from the entrance.

- Remove all vegetation and other objectionable material from foundation area. Grade and crown foundation for positive drainage.
- A geotextile filter fabric should be placed between the stone fill and the earth surface below the pad to reduce the migration of soil particles from the underlying soil into the stone and vice versa. Filter cloth is not required for a single family residence lot.
- If the slope toward the road exceeds 2%, construct a ridge 6 to 8 in. high with 3:1 side slopes, across the foundation approximately 15 ft from the entrance to divert runoff away from the public road.
- All surface water that is flowing to or diverted toward the construction entrance should be piped beneath the entrance. If piping is impractical, a berm with 5:1 slopes that can be crossed by vehicles may be substituted for the pipe.

Gravel Pad

- Stone for a stabilized construction entrance must be 3 to 6 in. diameter stone, reclaimed stone, or recycled concrete equivalent placed on a stable foundation as specified in the approved Erosion and Sediment Control Plan.
- Make sure stone and gravel used to stabilize the construction site entrance area large enough so that they are not carried offsite by vehicles.
- Avoid sharp-edged stone to reduce the possibility of puncturing tires.
- Minimum length of the gravel pad should be 50 ft, except for a single residential lot where a 30 ft minimum length may be used. Longer entrances will provide better cleaning action. The pad should extend the full width of the construction access road or 10 ft whichever is greater. The aggregate should be placed at least 6 in. thick.
- Install stone or gravel at a depth of at least 6 in. for the entire length and width of the stabilized construction entrance.

Washing

- If gravel pad is not sufficient to remove majority of mud from vehicle tires, tires must be washed before vehicle enters public road.
- The wash area should be a level area with 3 in. washed stone

depositing sediments on public roadways.

- Sediment, which is otherwise contained on site, does not enter stormwater runoff elsewhere.

LIMITATIONS

- Some soil might still be deposited from vehicle tires onto paved surfaces.
- A reliable water source to wash vehicles before leaving the site might not be initially available. Trucking water to the site creates an additional cost.
- This practice will only be effective if sediment controls are used throughout the rest of the construction site.
- Effective only if installed at every entrance/exit.

REFERENCE

- Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas
- Stormwater Manager's Resource Center (SMRC) Website www.stormwatercenter.net
- US EPA National Menu of Best Management Practices

minimum, or a commercial rack. Wash water should be directed into a sediment trap, vegetated filter strip, or other approved sediment trapping device. Sediment should be prevented from entering any watercourses.

MAINTENANCE CONSIDERATIONS

Maintain stabilization of the site entrance(s) until the rest of the construction site has been fully stabilized. All temporary erosion and sediment control measures should be removed within 30 days after final site stabilization is achieved or after the temporary practices are no longer needed. Addition of stone and gravel periodically to each stabilized construction site entrance might be necessary to keep the entrance effective. If entrance becomes clogged with mud, stones should be replaced. Sweep up soil tracked offsite immediately for proper disposal. For sites with wash racks at each site entrance, construct sediment traps and maintain them for the life of the project. Periodically remove sediment from the traps to make sure they keep working. To further reduce the chance of sediments polluting stormwater runoff, sweep the paved area adjacent to the stabilized site entrance.

INSPECTION CONSIDERATIONS

Inspections should be performed in accordance with Section 4 of the Cambridge Stormwater Management Guidelines. Inspect gravel for clogging and the pad for bare spots. Inspect roadways and adjacent paved areas for tracked sediments.

Revised 02/12

2.11. Filter Berm

DESCRIPTION

A gravel or stone filter berm is a temporary ridge made up of loose gravel, stone, or crushed rock. It slows and filters flow and diverts it from an open traffic area. It acts as an efficient form of sediment control. One type of filter berm is the continuous berm, a geosynthetic fabric berm that captures sand, rock, and soil.

DESIGN CONSIDERATIONS

- Use well-graded gravel or crushed rock to build the berm, with rock size ranging from ¾ in. to 3 in. in diameter and containing less than 5 percent fines.
- Space berms according to the steepness of the slope. Space them closer together as the slope increases.

Berm dimensions:

- 1 ft high
- 3:1 side slopes
- 8 linear ft per 1 cfs of runoff based on the 10 yr 24 hr design storm.

Spacing of berms:

- Every 300 ft on slopes less than 5%.
- Every 200 ft. on slopes between 5% and 10%.
- Every 100 ft. on slopes greater than 10%.

MAINTENANCE CONSIDERATIONS

It is important to make repairs at the first sign of deterioration to keep the berm functioning properly. Accumulated sediment should be removed and properly disposed of and the filter material replaced as necessary. Regular inspection should indicate how often sediment needs to be removed.

INSPECTION CONSIDERATIONS

Inspections should be performed in accordance with Section 4 of the Cambridge Stormwater Management Guidelines. Inspect for accumulated sediments and deterioration of the berm. Inspect and repair immediately if damaged by construction traffic.

Source: US EPA website.

TARGETED CONSTITUENTS

- Bacteria (NR)
- Metals (NR)
- Nutrients (NR)
- Oil and Grease (NR)
- Organics (NR)
- Oxygen Demand (NR)
- Sediment (H)
- Trash (M)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

OBJECTIVES

- Sediment Control
- Runoff Control

APPLICABILITY

- Where a temporary measure is needed to retain sediment from the right-of-way or in traffic areas on construction sites.
- Intended to be used only in gently sloping areas (less than 10 percent).

ADVANTAGES

- Reduces speed of runoff.
- Efficient method of sediment control.

LIMITATIONS

- Do not last very long unless they are maintained regularly because they are prone to clogging with mud and soil.

- Can be difficult to maintain because of clogging from mud and soil on vehicle tires.
- Gravel filter berm is more expensive to install than other practices which use materials found on-site.

REFERENCE

- Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas
- US EPA National Menu of Best Management Practices

2.12. Silt Fence

DESCRIPTION

Silt fences remove sediment partially by filtering runoff and partially by slowing it down, providing opportunity for settling. Silt fences are geotextile, semi-permeable sheets supported by posts and anchored in the ground to intercept sediment-laden runoff. Silt fences are used as temporary perimeter controls around sites where construction activities will disturb the soil. They can also be used around the interior of the site. When installed correctly and inspected frequently, silt fences can be an effective barrier to sediment leaving the site in stormwater runoff.

DESIGN CONSIDERATIONS

- The material for silt fences should be a pervious sheet of synthetic fabric such as polypropylene, nylon, polyester, or polyethylene yarn. Choose the material based on the minimum synthetic fabric requirements shown in the table below.

Minimum Requirements for Silt Fence Construction:

Physical property	Requirements
Filtering efficiency	75%-85% (minimum): highly dependent on local conditions
Tensile strength at 20% (maximum) Elongation	Standard strength: 30 lb/linear in. (minimum) Extra strength: 50 lb/linear in. (minimum)
Ultraviolet radiation	90% (minimum)
Slurry flow rate	0.3 gal/ft^2/min (minimum)
Tensile Strength	124 LBS
Elongation	15%
Puncture	65 LBS
Mullen Burst	300 PSI
Trapezodail Tear	65 LBS
UV Resistance	70%
Apperent Opening Size	30 US sieve
Water Flow Rate	10 GPM/FT^2

Source: US EPA National Menu of Best Management Practices

- If a standard-strength fabric is used, it can be reinforced with wire mesh behind the filter fabric. This increases the effective life of the fence. The maximum life expectancy for synthetic fabric silt fences is about 6 months, depending on the amount of rainfall and runoff. Burlap fences have a much shorter

Source: Lake County Ohio Stormwater Management Department.

TARGETED CONSTITUENTS

- Bacteria (NR)
- Metals (NR)
- Nutrients (NR)
- Oil and Grease (NR)
- Organics (NR)
- Oxygen Demand (NR)
- Sediment (H)
- Trash (H)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

OBJECTIVES

- Sediment Control

APPLICABILITY

- Construction sites with relatively small drainage areas. Drainage area for silt fences should not exceed 0.25 acre per 100 ft. fence length.
- Appropriate for areas where runoff will occur as low-level flow, not exceeding 0.5 cfs.
- The slope length above the fence should not exceed 100 ft.
- Do not install across streams, ditches or waterways.
- Where there is no concentration of water in a channel or other drainage above the fence, and drainage

useful life span, usually up to 2 months.

- The stakes used to anchor the filter fabric should be wood or metal. Wooden stakes should be at least 5 ft. long and have a minimum diameter of 2 in. if a hardwood like oak is ued. Stakes from soft woods like pine should be at least 4 in. in diameter. When using metal posts in place of wooden stakes, they should weigh at least 1.00 to 1.33 lb/linear ft. If metal posts are used, attachment points are needed for fastening the filter fabric with wire ties.

- Erect silt fence in a continuous fashion from a single roll of fabric to eliminate gaps in the fence. If a continuous roll of fabric is not available, overlap the fabric from both directions only at stakes or posts. Overlap at least 6 in. Excavate a trench to bury the bottom of the fabric fence at least 6 in. below the ground surface. This helps to prevent gaps from forming near the ground surface. Gaps would make the fencing useless as a sediment barrier.

- Consider installing an orange mesh fence adjacent to the silt fence to alert construction equipment and other vehicles of the location.

- The height of the fence posts should be 30 to 36 in. above the original ground surface. If standard-strength fabric is used with wire mesh, space the posts no more than 10 ft. apart. If extra-strength fabric is used without wire mesh reinforcement, space the posts no more than 6 ft. apart.

- The fence should be designed to withstand the runoff from a 10-year peak storm event. Once installed, it should remain in place until all areas upslope have been permanently stabilized by vegetation or other means.

- The fence should be located where it will trap sediment; that is, where there will be contributing runoff. A silt fence located along the top of a ridge or at the upper end of a drainage area serves no useful purpose, except as it may be used to mark the limits of a construction area.

- Silt fences have a low permeability to enhance sediment trapping. This will create ponding conditions behind the fences, so they should not be located where ponding will cause property damage or a safety hazard. The sedimentation pool behind the fence is very effective and may reduce the need for sediment basins and traps.

- May be designed to store all the runoff from the design storm, or located to allow bypass flow when temporary sedimentation area is usually not more than 1.5 acres.

- Flow should not be concentrated, it should be spread out over many linear ft. of silt fence.

- Mainly used as a perimeter control.

ADVANTAGES

- Reduces the speed of runoff flow.
- Removes sediments and prevents downstream damage from sediment deposits.
- Minimal clearing and grubbing required for installation.
- Trap a much higher percentage of suspended sediments than straw bales.

LIMITATIONS

- Problems may arise from incorrect selection of filter fabric or from improper installation.
- Not an adequate method of runoff control for anything deeper than sheet or overland flow.

REFERENCE

- Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas
- Stormwater Manager's Resource Center (SMRC) Website www.stormwatercenter.net
- US EPA National Menu of Best Management Practices

pool reaches a predetermined level.

- Fence should be located so that water depth does not exceed one half of the silt fence height above the surface.
- Provide access to the location where sediment accumulates and provide reinforced, stabilized outlets for emergency overflow.
- Silt fence is most effective when used in conjunction with other practices such as perimeter dikes or diversions.
- Silt fence may be attached to permanent construction fencing as long as the post are metal with a weight at least 1.00 to 1.33 lb/linear ft. and are set 18” below grade and anchored by concrete.
- It is not necessary to used straw or hay bales together with silt fence.

MAINTENANCE CONSIDERATIONS

A silt fence requires a great deal of maintenance. Remove sediment deposits promptly to provide adequate storage volume for the next rain and to reduce pressure on the fence. Take care to avoid undermining fence during cleanout. If fabric tears, decomposes, or in any way becomes ineffective, replace it immediately. Replace burlap used in sediment fences after no more than 60 days. Remove all fencing materials after the contributing drainage area has been properly stabilized. Sediment deposits remaining after the fabric has been removed should be graded to conform with the existing topography and vegetated.

INSPECTION CONSIDERATIONS

Inspections should be performed in accordance with Section 4 of the Cambridge Stormwater Management Guidelines. Inspect fence for gaps, tears in fabric, and broken posts.

2.13.Inlet Protection Interior Devices

DESCRIPTION

Inlet protection systems are structures designed to filter sediment from runoff as it flows into an inlet device such as a catchbasin. Inlet protection is often a filtering device that is constructed on, around or near an inlet device. Inlet protection is used as a temporary filter for sediment laden runoff entering the storm drain system. Inlet protection should be located on all existing and proposed drainage structures. Additional protection will be need if the catchbasin has a curb inlet as well as a grate. When installed correctly and inspected frequently inlet protection can be an effective filter for removing sediment before it enters the storm drain system.

DESIGN CONSIDERATIONS

- Inlet protection that is placed within a catchbasin shall be used for all roadways and areas associate with bikes, pedestrians and automobile use.
- The material for Inlet Protection should be a pervious material of synthetic fabric such as polypropylene, nylon, polyester, or polyethylene yarn. Choose the material based on the minimum synthetic fabric requirements shown in the table below.
- The Inlet Protection for roadways and traffic areas should be selected based on flow entering the catchbasin structure.
- Inlet Protection that is placed inside of a catchbasin or drop inlet shall meet the following requirements;
    - Dump Straps at bottom of device
    - Lifting loops at the top of the device
    - A restrain cord/rebar located half way up the device
    - Sewn edges using high strength nylon thread.

Source: http://www.acfenvironmental.com/images/SiltSack.jpg

TARGETED CONSTITUENTS

- Bacteria (NR)
- Metals (NR)
- Nutrients (NR)
- Oil and Grease (NR)
- Organics (NR)
- Oxygen Demand (NR)
- Sediment (H)
- Trash (H)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

OBJECTIVES

- Sediment Control

APPLICABILITY

- Construction areas with relatively small drainage areas. Drainage area shall not exceed 1 acre without additional protection
- Should be sized according to flow
- Install in all catchbasins unless otherwise noted.
- Mainly used on all downstream catchbasins and selected upstream catchbasins.

Minimum Requirements for catch basin protection:

Regular Flow Inlet Protection	
Physical property	**Requirements**
Filtering efficiency	75%-85% (minimum): highly dependent on local conditions
Grab Tensile	390 LBS
Grab Elongation	30% (minimum)
Puncture	120 LBS
Mullen Burst	600 PSI
Trapezoid Tear	120 LBS
UV Resistance	90%
Apparent Opening	40 US Sieve
Flow Rate	40 Gal/Min/ft^2
Permittivity	0.55 Sec^-1

High Flow Inlet Protection	
Physical property	**Requirements**
Filtering efficiency	75%-85% (minimum): highly dependent on local conditions
Grab Tensile	390 LBS
Grab Elongation	30% (minimum)
Puncture	140 LBS
Mullen Burst	400 PSI
Trapezoid Tear	120 LBS
UV Resistance	90%
Apparent Opening	40 US Sieve
Flow Rate	175 Gal/Min/ft^2
Permittivity	1.5 Sec^-1

- The inlet protection device should be designed to withstand the runoff from a 10-year peak storm event. Once installed, it should remain in place until all areas upslope have been permanently stabilized by vegetation or other means.
- Inlet protection should be located in areas that receive runoff from any disturbed area including any catchbasin

ADVANTAGES

- Removes sediments and prevents downstream damage from sediment deposits.
- Minimal clearing and grubbing required for installation.

LIMITATIONS

- Problems may arise from incorrect selection of filter fabric or from improper installation.
- Not installing over a curb inlet will greatly reduce the amount of TSS removed.

REFERENCE

- Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas
- Stormwater Manager's Resource Center (SMRC) Website www.stormwatercenter.net
- US EPA National Menu of Best Management Practices

that collect runoff from truck traffic associated with construction.

- The inlet protection shall have an interior overflow in the material to allow for high flow events to by-pass device and enter the catchbasin without the device being removed.
- If a curb inlet is present then a sediment filtering/blocking fabric or material shall be placed in front of the inlet so that runoff is treated or blocked before entering the catchbasin.
- Provide access to the location where inlet protection has been placed. Do not place trailers, storage containers of stockpiles over the catchbasin.

MAINTENANCE CONSIDERATIONS

An inlet protection requires a great deal of maintenance. Remove sediment deposits promptly to ensure that runoff will flow through the catchbasin. If inlet protection device tears, decomposes, or in any way becomes ineffective, replace it immediately. Remove all inlet protection devices after the contributing drainage area has been properly stabilized.

INSPECTION CONSIDERATIONS

Inspections should be performed in accordance with Section 4 of the Cambridge Stormwater Management Guidelines. Inspect inlet protection devices for gaps, tears in fabric, and excessive debris build-up.

DESCRIPTION

Inlet protection systems are structures designed to filter sediment from runoff as it flows into an inlet device such as a catchbasin. Inlet protection is often a filtering device that is constructed on, around or near an inlet device. Inlet protection is used as a temporary filter for sediment laden runoff entering the storm drain system. Inlet protection should be located on all existing and proposed drainage structures. When installed correctly and inspected frequently inlet protection can be an effective filter for removing sediment before it enters the storm drain system.

DESIGN CONSIDERATIONS

- Inlet devices that are placed on the exterior of a catchbasin should be designed to maximize longevity, maintenance and inlet protections.
- There are several different methods to protect inlets with exterior controls. These controls include but are not limited to; silt fence placed on the outside edges, block and gravel, filter fabric and gravel, etc….
- The exterior Inlet Protection shall be placed around a catchbasin that is not located in a roadway or an area that receive bicycle, pedestrian or any other traffic of that nature.
- The inlet protection device should be designed to withstand the runoff from a 10-year peak storm event. Once installed, it should remain in place until all areas upslope have been permanently stabilized by vegetation or other means.
- Inlet protection should be located in areas that receive runoff from any disturbed area including any catchbasin that collect runoff from truck traffic associated with construction.
- An exterior device can allow for some ponding to occur as long as there is no damage to surrounding properties and no pedestrian, bicycle or automobile traffic is affected.
- If a curb inlet is present then a sediment filtering/blocking fabric or material shall be placed in front of the inlet so that runoff is treated or blocked before entering the catchbasin.
- Provide access to the location where inlet protection has been placed. Do not place trailers, storage containers of stockpiles over the catchbasin.

MAINTENANCE CONSIDERATIONS

An inlet protection requires a great deal of maintenance. Remove sediment deposits promptly to ensure that runoff will flow through

Source: Lake County Ohio Stormwater Management Department.

TARGETED CONSTITUENTS

- Bacteria (NR)
- Metals (NR)
- Nutrients (NR)
- Oil and Grease (NR)
- Organics (NR)
- Oxygen Demand (NR)
- Sediment (H)
- Trash (H)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

OBJECTIVES

- Sediment Control

APPLICABILITY

- Construction areas with small or large drainage areas. Drainage area shall not exceed 2 acres without additional protection
- Should be sized according to flow
- Install in all catchbasins unless otherwise noted.
- Mainly used on all downstream catchbasins and selected upstream catchbasins.

ADVANTAGES

- Removes sediments and prevents downstream damage from the catchbasin. If inlet protection device tears, decomposes, or in any way becomes ineffective, replace it immediately. Remove all inlet protection devices after the contributing drainage area has been properly stabilized.

INSPECTION CONSIDERATIONS

Inspections should be performed in accordance with Section 4 of the Cambridge Stormwater Management Guidelines. Inspect inlet protection devices for gaps, tears in fabric, and excessive debris build-up.

sediment deposits.

- Minimal clearing and grubbing required for installation.

LIMITATIONS

- Problems may arise from incorrect selection of material or from improper installation.

REFERENCE

- Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas
- Stormwater Manager's Resource Center (SMRC) Website www.stormwatercenter.net
- US EPA National Menu of Best Management Practices

2.15. Culvert Inlet Protection

DESCRIPTION

The purpose of Culvert Inlet Protection is to reduce the amount of sediment that can be transported directly in to a drainage system. Though there are few Culvert Inlets in Cambridge it is imperative that these structures be protected properly so that sediment does not flow into the City's drainage system. Culvert Inlet Protection is used as either a temporary or permanent solution to remove sediment and other debris before it enters the drainage system. There are several ways that culverts can be protected to reduce sediment load to the City's system.

DESIGN CONSIDERATIONS

- There are two types of culver inlet protection that the City approves of, Silt Fence, Culvert Inlet Sediment Traps.
- The general design for both shall be constructed so that the clean out and disposal of trapped sediment minimizes interference with construction activities.
- The inlet protection be constructed so that any resulting ponding of stormwater will not cause excessive inconvenience or damage to adjacent areas or structures.
- Each culvert protection shall be designed for that specific inlet.

Silt Fence Culvert Inlet protection

- Silt fence shall be placed so that no runoff can enter the culvert untreated and is at least 6 feet away from the culvert opening,
- Silt fence shall be wire supported to promote strength of the material.
- The silt fence shall be place per the silt fence detail.
- The silt fence should be placed so that no concentrated flow is directed towards the fence, a level spreader should be used to promote sheet flow if necessary. If concentrated flow is anticipated than a Culvert Inlet Sediment Trap should be used.

Culvert Inlet Sediment Trap

- Rip-rap shall be placed and sized so that erosion does not occur around the area. The minimum mean size of the rip-rap should be no smaller than 6".
- An energy diffuser should be constructed no greater than

Source: USDA-Natural Resources Conservation Service - Illinois

TARGETED CONSTITUENTS

- Bacteria (NR)
- Metals (NR)
- Nutrients (NR)
- Oil and Grease (NR)
- Organics (NR)
- Oxygen Demand (NR)
- Sediment (H)
- Trash (H)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

OBJECTIVES

- Sediment Control

APPLICABILITY

- Should be used on all culver inlets located near a construction site
- Should be sized correctly to reduce the amount of total suspended solids in the runoff.

ADVANTAGES

- Able to handle large amounts of flow when constructed correctly
- If maintained properly the culvert inlet protection should have a fairly long life span 1-2 years.
- Removes sediments and prevents downstream damage from sediment deposits.

LIMITATIONS

6 feet away from the from the culvert opening.

MAINTENANCE CONSIDERATIONS

A Culvert inlet protection requires a great deal of maintenance. Remove sediment deposits promptly to ensure that runoff will flow to the culvert. If inlet protection device tears, decomposes, or in any way becomes ineffective, replace it immediately. Remove all inlet protection devices after the contributing drainage area has been properly stabilized.

INSPECTION CONSIDERATIONS

Inspections should be performed in accordance with Section 4 of the Cambridge Stormwater Management Guidelines. Inspect silt fence for tears, rips or any other structural abnormality. Inspect Rip-rap for excess sediment build-up and any rocks that are out of place. Repairs should be made with 24 hours.

- Significant ponding can occur around the culvert
- A large amount of clearing and grading maybe needed to be done to install proper inlet protection
- Problems may arise from incorrect selection of material or from improper installation.

REFERENCE

- Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas
- Virginia Erosion and Sediment Control Handbook.
- Stormwater Manager's Resource Center (SMRC) Website www.stormwatercenter.net
- US EPA National Menu of Best Management Practices

2.16. Culvert Outlet Protection (Rip-Rap Protection)

DESCRIPTION

The purpose of culvert outlet protection is to prevent erosion and scour occurring downstream from an outlet point. Culvert outlet protection also prevents scour and erosion to occur further downstream by reducing velocity levels, energy levels and stabilizing the flow from a concentrated flow. The outlet of pipes and structurally lined channels are critical erosion points. Stormwater that is transported through a conveyance system usually has a high velocity and a large energy capacity that needs to be reduced before the flow can be introduced into the receiving channel or body. Most culvert outlet protection has an energy dissipater at the end to absorb the impact and reduce the energy and velocity from stormwater discharge.

The most common form of culvert outlet protection is rip-rap, however concrete, asphalt and grass can also be used in limited areas. Culvert outlet protection is related to the outlet flow and the tail water level. In some cases where outlet protection is not feasible due to space, flows or financial reasons a stilling basin can be used. Acceptable designs can be found:

Hydraulic Design of Energy Dissipaters for Culvert and Channels, Hydraulic Engineering Circular No. 14, U.S. Dept. of Transportation, Federal Highway Administration, (83).

Hydraulic Design of Stilling Basins and Energy Dissipaters, Engineering Monograph NO. 25, U.S. Dept. of the Interior – Bureau of Reclamation, (74).

DESIGN CONSIDERATIONS

- All culvert outlet protections should be set at a zero grade for the entire distance of the outlet protection. The protection should be design to withstand all flow, velocity and energy associated with a 25-year storm event.
- Culvert outlet protection is directly associated with the tail water depth immediately below the pipe outlet. A manning equation may be used to determine tail water depth.
  - If the tail water is less than half the diameter of the outlet pipe, it shall be classified as a **Minimum Tail Water Condition.** If the tail water is greater than half the pipe diameter is shall be classified as a **Maximum Tail Water Condition.**
- Apron Length shall be determined from the curves according to

Source: USDA-Natural Resources Conservation Service - Illinois

TARGETED CONSTITUENTS

- Bacteria (NR)
- Metals (NR)
- Nutrients (NR)
- Oil and Grease (NR)
- Organics (NR)
- Oxygen Demand (NR)
- Sediment (M)
- Trash (M)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

OBJECTIVES

- Sediment Control
- Erosion Control

APPLICABILITY

- At all downstream culverts that are directly affected by construction run off from the site-this will be at the discretion of the City Engineer.
- At any downstream culvert where erosion can take place.

ADVANTAGES

- Able to handle extremely small and large flows.
- Reduce the amount of scour and erosion that can occur downstream of the culvert.
- Once constructed can be left

tail water conditions

1. Minimum Tail Water – Use Plate 3.18-3
2. Maximum Tail Water – Use Plate 3.18-4

- The width of the apron shall extend along the bottom of the existing channel is one exists. The apron should extend up the channel banks to an elevation one foot above the maximum tail water depth of the top of bank, whichever is less.
- For outlets that do not flow into an existing channel, a channel should be constructed with a width that is at least equal to the pipe diameter plus 0.40 times the length of the apron.
- The side slopes for all types of outlet protections should be no steeper than 2:1 (horizontal: vertical)
- Culvert outlet protection should contain no bends, however if bends are necessary proper rip-rap sizing should be done around the edges of the corner to prevent scour from velocity changes. The bends should be design to have a Froude number of 1.0 or less.
- Rip-rap gradation should be done for all channels by calculating the D 50 stone size. The rip rap shall be composed of a well graded mixture down to one-inch size particles such that 50% of the mixture by weight shall be larger than the D 50 size as determined by the design procedure. The design mixture should be design primarily of larger stones but with a sufficient amount of smaller stones to fill voids and “lock” the rip-rap together. The largest diameter stone size should be no greater than 1 ½ times the size of the D 50 size. Refer to the chart for rip-rap weights and sizing.

in place for many years with limited maintenance

LIMITATIONS

- Can require a large footprint to be properly constructed.
- If the rip-rap is sized incorrectly it can wash out and significant damage to the channel and outlet can occur.
- Velocities need to be small enough so a hydraulic jump is not created.

REFERENCE

- Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas
- Virginia Erosion and Sediment Control Handbook.
- Stormwater Manager's Resource Center (SMRC) Website www.stormwatercenter.net
- US EPA National Menu of Best Management Practices
- USDA-SCS

Size of Rip-Rap

Weight (lbs)	Mean Spherical Diameter (D 50) (feet)
50	0.80
100	1.10
150	1.30
300	1.60
500	1.90
1,000	2.20
1,500	2.60
2,000	2.75
4,000	3.60
6,000	4.00
8,000	4.5
20,000	6.1

Source: VDOT Drainage Manual

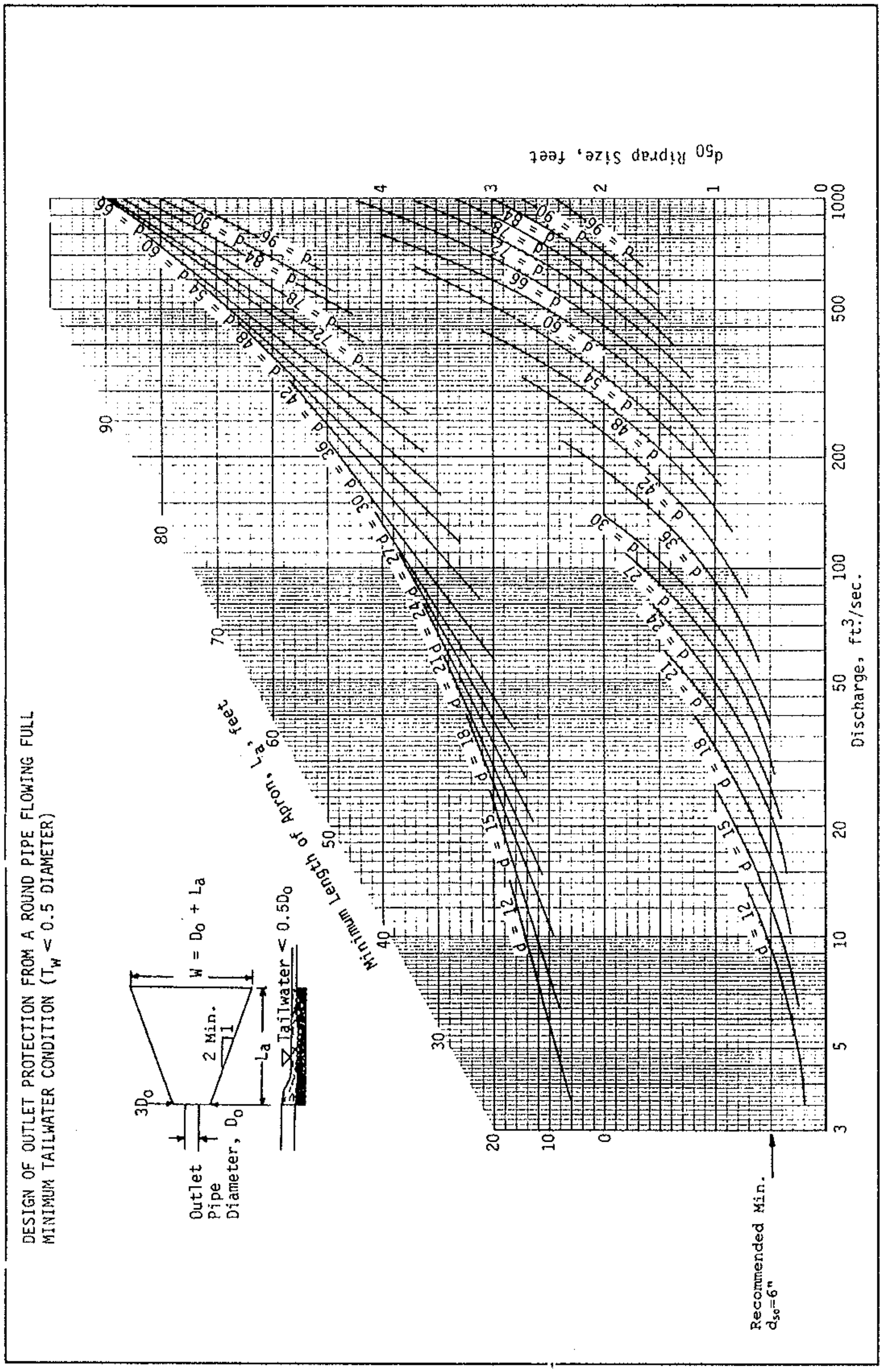
- The depth of the rip-rap shall be at least 2 times the maximum stone diameter but not less than 6 inches.
- The stone should be roughed quarried and approximately rectangular. No stone shall appear smooth. The stone shall be hard and angular and should not weather or degrade over time. The stone should have a specific gravity of at least 2.5. Concrete rubble maybe used provided it has a density of at least 150 pounds per cubic foot and meets the above mentions conditions.
- Filter fabric or a granular filter should used to reduce the possibility of soil movement beneath the rip-rap lining.
- The end of the channel should have an energy dissipater to reduce the velocity and energy of the runoff before it enters the receiving channel. The flow out of the energy dissipater should be calculated so that it is below the permissible velocity of the receiving waters.

MAINTENANCE CONSIDERATIONS

Once installed completely there should be very little maintenance to the rip-rap. Rip-rap should be replaced once it appears that the stones have moved or area starting to become dislodged. Maintenance at the end of the rip-rap may need to occur if evidence of erosion of scour has appears.

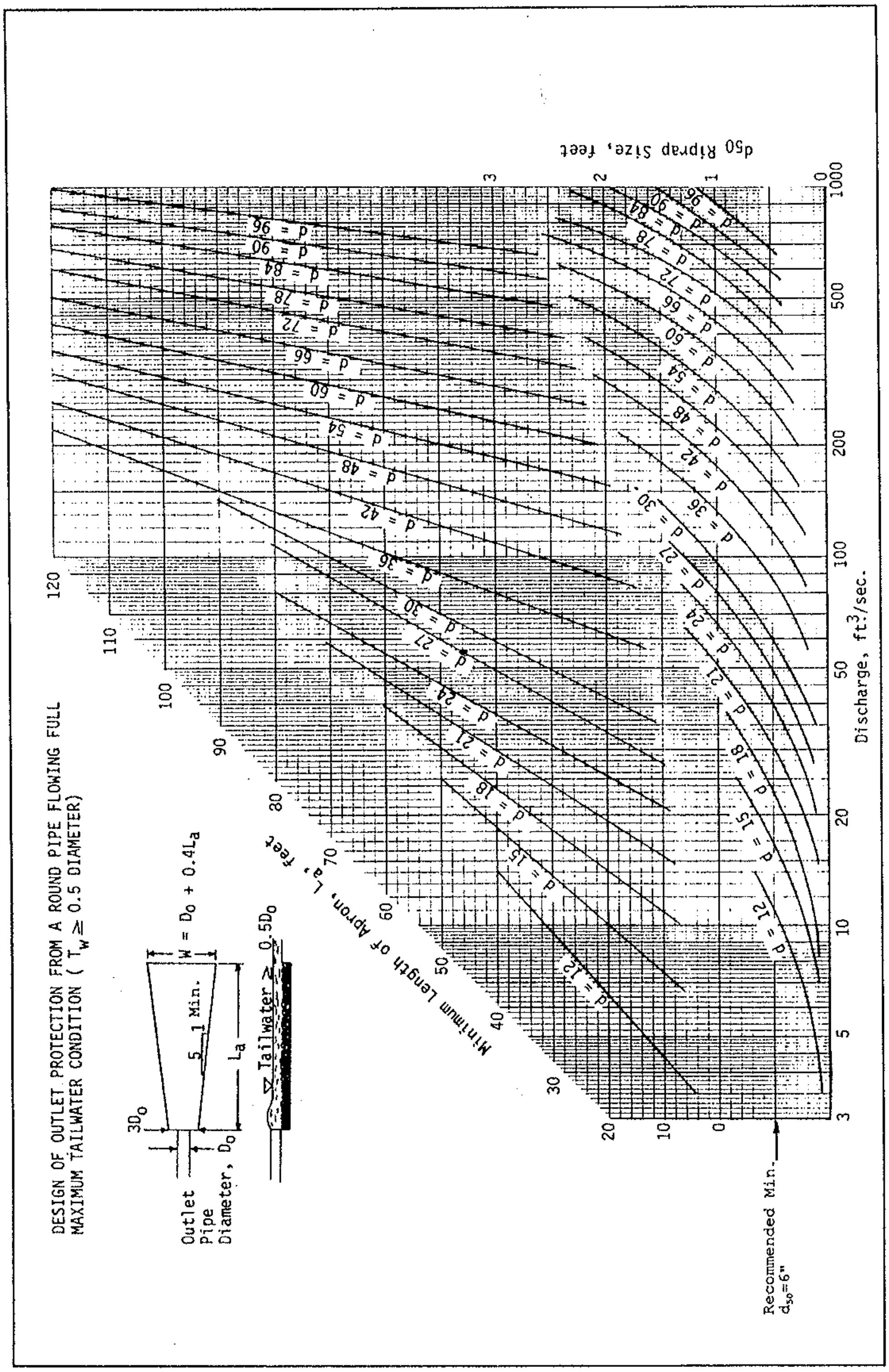
INSPECTION CONSIDERATIONS

The rip-rap culvert protection should be inspected after all storm events that are greater than the 25-year design storm. Attention should be placed on the side of the channel and also the bed to see if scour of erosion has taken place. Inspections should be performed in accordance with Section 4 of the Cambridge Stormwater Management Guidelines. Inspect Rip-rap for excess sediment build-up and any rocks that are out of place. Repairs should be made with 24 hours.



Source: USDA-SCS

Plate 3.18-3



Source: USDA-SCS

Plate 3.18-4

2.17. Dewatering Devices

DESCRIPTION

There are several different types of dewatering practices that can be used for construction sites depending on the amount of groundwater, the size of your site and also the size available for dewater devices. Dewatering the act of removing water from an area and treating the water to remove a certain amount of sediment before discharging it back into the ground or the stormwater system. Most projects located within the limit of the City will need to do some dewatering due to high groundwater levels and rainfall and runoff entering a trench or work zone.

DESIGN CONSIDERATIONS

- A dewatering device should be sized appropriately so that the water does not overtop the structure.
- A dewatering device must be designed so that it removes at least 80% of all sediment in the water before it is discharged into the ground or a storm water collection system.
- At no time shall water from a dewatering device enter a body of water directly unless at least a 75 foot wide buffer zone is provided between the device and body of water.
- There are several types of dewater devices
- Dewatering bags are an allowable method of dewatering provided that the bag is properly designed and the sediment laden runoff is being treated.
- Chemical dewatering is acceptable provided the water is treated with an environmentally friendly, non-toxic, flocculation agent.
- Pump discharge can also be discharge through drilled holes or other methods of release.

Portable Sediment Tank (large sediment amounts)

- A portable sediment tank also known as a frac tank should be movable.
- The tank should be at least two feet deep and have at least two baffles within the tank. The baffles should be evenly spaced apart and be constructed out of metal, plastic or a geo-textile fabric that filters sediment.
- The tank shall be located in a location where it can be cleaned and maintained easily and also collect the most amount of sediment laden water.

Source: www.syntexgeo.com/dewater.html

TARGETED CONSTITUENTS

- Bacteria (NR)
- Metals (NR)
- Nutrients (NR)
- Oil and Grease (NR)
- Organics (NR)
- Oxygen Demand (NR)
- Sediment (H)
- Trash (NR)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

OBJECTIVES

- Sediment Removal

APPLICABILITY

- For sites that have sediment laden discharge from dewatering activities

ADVANTAGES

- Can be small foot print depending on the type of unit selected.
- Removes a large amount of TSS from sediment laden runoff.
- Depending on the application can be relatively inexpensive.

LIMITATIONS

- May need a large foot print depending on the application

- The tank should be sized accordingly:

  Pump Discharge (gpm) x 16 = cubic feet of storage required

- If the outfall is still sediment laden the size of the tank, the number of baffles, or the settling time should be increased to achieve the proper amount or sediment removal.
- The tank should be cleaned once sediment reaches a quarter of the way up the tank or blocks any outlets.

Silt Fence Pit (medium sediment amounts)

- A silt fence pit is a de-watering device that allows sediment laden runoff to be filtered through silt fence and allowed to discharge onto the surrounding vegetated ground.
- The tank should be sized accordingly:

  Pump Discharge (gpm) x 16 = cubic feet of storage required

- A pervious filter fabric can be placed on the bottom of the storage area so water can be infiltrated back into the ground.
- The storage area can be excavated up to three feet below the toe of the silt fence provides the area is excavated at least 1 foot away from the silt fence.
- The storage area should not exceed 10 feet by feet.
- Pumps should be shut off once the water level has reached three fourths the way up on the silt fence.
- Sediment should be removed when it reaches a quarter the way up the silt fence or when the capacity of the area is less than 50% the designed amount.

Filter Box (small sediment amounts)

- A filter box should be made up of a sturdy material such as wood, metal or plastic.
- The filter box should be able to hold no more than 200 gpm.
- The tank should be sized accordingly:

  Pump Discharge (gpm) x 16 = cubic feet of storage required

- The Box should be lined with a geo-textile fabric similar to silt fence and also filled with clean crushed stone.
- The sediment laden runoff should not overtop the structure.
- The treated runoff can spill onto a vegetative surface, recharge into the ground or be pumped into the storm drainage system.

- Can be maintenance intensive is runoff is laden with high amounts of sediment.

REFERENCE

- Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas
- Virginia Erosion and Sediment Control Handbook.
- Stormwater Manager's Resource Center (SMRC) Website www.stormwatercenter.net
- US EPA National Menu of Best Management Practices

MAINTENANCE CONSIDERATIONS

Maintenance of these dewater devices should occur every time sediment laden runoff is entering the devices. The devices should be cleaned and maintained on a regular basis. If any damage occurs to the systems the dewatering devices should be taken off line immediately and all dewatering activities should stop until they are repaired or replaces. When draining a dewatering device the water should be removed from the top water surface elevation to the bottom to ensure that the sediment has been left undisturbed.

INSPECTION CONSIDERATIONS
Inspections should be performed in accordance with Section 4 of the Cambridge Stormwater Management Guidelines. Inspect the dewatering devices at every use. Dewatering devices should be cleaned once sediment reaches manufacturer, engineered, or required amounts. Repairs should be made immediately and all dewatering activities to the devices should be stopped while repair is being made.

2.18. Runoff Diversion

DESCRIPTION

Runoff diversion is meant to transport runoff to a catch basin, dewatering device, around a site and many other reasons. There are several types of diversion devices that can be used in coordination with other erosion and sediment control measures. A contractor should always keep sediment laden runoff on site to be treated, this may require a diversion structure to be built along the property line so that runoff can flow to a treatment area (dewatering, catchbasin that is protected, etc.). Diversion structures are often dug into the existing soil or a berm constructed on top the existing surface that allows runoff to be directed into another structure. A diversion structure can also be used to keep offsite watering from entering by diverting it around the site into a drainage structure, permanent or temporary.

DESIGN CONSIDERATIONS

- Diversion structures should be stabilized immediately with temporary or permanent vegetation to prevent erosion.
- Diversion structures should be one of the first erosion and sediment control devices put in on site to unsure once the area is disturbed no sediment laden runoff leaves the site view over land relief.
- The diversion structure should have a positive pitch from bottom to top to ensure that the area will properly drain to the drainage structure.
- A diversion structure can be constructed as a berm that is 18 inches high and a minimum of 4.5 feet wide with slopes no greater than 1 ½:1.
- A diversion structure can also have a ditch associated with it that is the shape of a trapezoid or smoothed channel. The excess fill can be used as berm.
- The diversion structure should have a channel slope that is less than or equal to 2% for the entire length. For slopes greater than 2% stabilization methods should be used.
- All diversion structures placed at the top of a slope shall be placed at least 2 feet from the top of the slope.
- The design channel should be able to pass the 10-year storm without over topping or erosion taking place.

Source: The Northern Virginia Soil and Water Conservation District - Fairfax County, Virginia.

TARGETED CONSTITUENTS

- Bacteria (NR)
- Metals (NR)
- Nutrients (NR)
- Oil and Grease (NR)
- Organics (NR)
- Oxygen Demand (NR)
- Sediment (L)
- Trash (NR)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

OBJECTIVES

- Sediment Control
- Runoff Control

APPLICABILITY

- Should be placed in areas where runoff needs to be diverted to a dewatering structure.

ADVANTAGES

- Relatively easy to install, can be constructed using stabilized fill from site work
- Effective way to convey runoff to dewater structures.

MAINTENANCE CONSIDERATIONS

It is important to make repairs at the first sign of deterioration to keep the berm and channel functioning properly. At the first sign of the erosion the area should be removed and new material should be placed and compacted properly. Accumulated sediment should be removed and properly disposed of. Regular inspection should indicate how often sediment needs to be removed.

INSPECTION CONSIDERATIONS

Inspections should be performed in accordance with Section 4 of the Cambridge Stormwater Management Guidelines. The berm and channel should be inspected after every ½ inch rain event with in any given 24 hour period. Inspect for accumulated sediments and deterioration of the berm and channel. Inspect and repair immediately if damaged has occurred.

- Ensures that no runoff will leave the site and enter other properties.

LIMITATIONS

- Need to be properly stabilized before runoff conveyance is introduced.
- Maintenance can be extensive depending on the type of stabilization.

REFERENCE

- Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas
- Virginia Erosion and Sediment Control Handbook.
- Stormwater Manager's Resource Center (SMRC) Website www.stormwatercenter.net
- US EPA National Menu of Best Management Practices

2.19. Stream Bank Stabilization

DESCRIPTION

There are two types of stream bank stabilization that can be utilized, one being structural stream bank stabilization and the other being vegetative stream bank stabilization. Structural stream bank stabilization should consist of placed rip-rap, gabions or other means of a structural device such as a grid paver. Vegetative stabilization should utilize living plants to stabilize the stream banks. The vegetative stabilization methods should be used in areas where a natural looking design is needed and can also be used with bio-degradable mats to protect the areas from being eroded prematurely.

DESIGN CONSIDERATIONS

- Since each stream bank is different and sometimes sections of stream banks are different the engineer should review each section and place the appropriate stabilization method.
- Bottom scour should be controlled, by either structural stabilization or vegetative stabilization before any type of bank stabilization is constructed.
- Stabilization should be started and ended at stabilized or controlled points
- Special attention should be given to maintaining and improving habitat for fish, wild life, and other aquatic life.
- The design of stabilization should be based off the 10-year event for the body of water and the stabilization should withstands the velocities from these events with minimum damage,.
- All requirements to state, local and federal laws and permit should be met.
- Stabilize all areas as soon as the structural measures are complete.

Structural Stream Bank Stabilization

- Used when velocities along the stream bank exceed 5 ft/s or when substantial erosion and sediment control is needed.
- **Rip-rap**-heavy angular stone placed or dumped onto the stream bank to provide protection form erosive forces. Rip-rap sizing should be based on the velocity that is being exerted on the rip-rap. The
- **Gabions**-rectangular rock-filler wire baskets that are pervious, semi-flexible building blocks that can be connected to each other to for an armored wall for the stream bank.
- Gabions should be at a minimum designed with a hexagonal

Source: The Northern Virginia Soil and Water Conservation District - Fairfax County, Virginia.

TARGETED CONSTITUENTS

- Bacteria (NR)
- Metals (NR)
- Nutrients (NR)
- Oil and Grease (NR)
- Organics (NR)
- Oxygen Demand (NR)
- Sediment (M)
- Trash (L)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

OBJECTIVES

- Sediment Removal
- Erosion Control
- Site Planning and Management

APPLICABILITY

- For all stream, culvert, or water conveyance channels where erosion has been significant and needs to be addressed to reduce the loss of property, wildlife or other natural resources.

ADVANTAGES

- Depending on the type of application can be made to mimic the natural triple twist mesh of heavy galvanized wire that can be poly coated.

- The design of gabions should follow the below chart.

Gabion Thickness (inches)	Maximum Velocity(fps)
6”	6 fps
8”	11 fps
12”	14 fps

- **Reinforced Concrete-**maybe used when velocities are to erosive for other methods. Reinforced Concrete is very esthetically unappealing and should be considered a final option.
- **Grid Pavers-**modular concrete or plastic units that have spaced voids to allow for vegetative growth to take root. For use in areas that have high velocities and need a vegetative appearance.
- **Rolled Mats-**fiber rolled mats that staked into the current stream bank. Rolled mats should be made out off biodegradable material and should be used in correspondence with vegetative stabilization.

Vegetative Stream Bank Stabilization

- Used when velocities along the stream bank are below 5 ft/s and when a vegetative stream bank is desired.
- The following items should be considered when utilizing a vegetative stream bank stabilization approach.
  - The frequency of bank full flow based on anticipated watershed development.
  - The channels slope and flow velocity.
  - The antecedent soil conditions
  - Present and anticipated channel roughness
  - The location of bends along with current condition
  - The location of unstable terrain upslope from the stream bank.
  - Pollutants currently found in the water, a high pollutant load my inhibit plant growth
  - The presence of brackish water.
- The following items should be considered when utilizing a vegetative stream bank stabilization approach.

MAINTENANCE CONSIDERATIONS

environment and create a channel that is environmentally friendly.

- Once a system is installed maintenance can be limited
- Helps protect the natural environment while limiting the amount of damage to the channel and any aquatic life.

LIMITATIONS

- Can be expensive depending on the length and size of the project.
- Special designs need to be considered for each application to ensure it is the most environmentally sound practice.

REFERENCE

- Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas
- Virginia Erosion and Sediment Control Handbook.
- Stormwater Manager's Resource Center (SMRC) Website www.stormwatercenter.net
- US EPA National Menu of Best Management Practices

Maintenance of a stabilized stream bank varies with each application depending on amount of vegetation, steam velocity and any storm intensity and frequency. At a minimum all newly stabilized stream banks showed be carefully maintained for at least two years past installation. The banks should be examined for any erosion, ripping, tearing or deformation. Repairs should be made immediately and the area should be properly marked as an area of concern. For any stabilization method that does not call for vegetation, any vegetation should be removed and the area should be inspected for damage and repairs should be made immediately.

INSPECTION CONSIDERATIONS

Inspections should be performed in accordance with Section 4 of the Cambridge Stormwater Management Guidelines. Steam bank stabilization should be checked after all rainfall events of ½ inch of rain within any given 24 hour period. Stream bank stabilization should be inspected for at least two years to ensure proper stabilization. Stream bank stabilization devices should be cleaned once sediment reaches manufacturer, engineered, or required amounts. Repairs should be made immediately and all dewatering activities to the devices should be stopped while repair is being made.

2.20. Turbidity Curtain

DESCRIPTION

A turbidity curtain is designed to greatly reduce the flow of sediment into a waterway by trapping the sediment and allowing it to settle to the bottom of the waterway in a controlled area. There are few locations within the City of Cambridge that would require a Turbidity Curtain to be placed when doing work, near the Charles River, Little River, Alewife Brook or Fresh Pond. A turbidity Curtain is placed when sediment is forced to enter a waterway due to shore bank work, dredging or filling near the area. A turbidity Curtain may also be placed at the discretion of the engineer/owner if sediment is entering a waterway.

DESIGN CONSIDERATIONS

- A turbidity curtain should be designed to withstand all current in the waterway. The curtain should also be designed to withstand all tidal action and wave action in the water caused by natural forces and human forces.
- Turbidity curtains should extend the entire depth of the waterway whenever the waterway is not subject to tidal action and/or significant wind and wave forces.
- In tidal and/or wind and wave action situations, the curtain should never be so long as to touch the bottom. A minimum 1-foot space should exist between the ballast and the bottom of the skirt at calculated mean low water mark.
- Turbidity curtains should be located parallel to the direction of flow of a moving body of water. Turbidity curtains should not be placed across the main flow of a significantly moving body of water.
- When sizing the length of the floating curtain, allow an additional 25% variance in the straight-line measurements. This will allow for measuring errors, reduce stress from potential wave action during high winds and ease of installation.
- When determining the length of a curtain the design should have a minimum amount of joints. Joints should be no closer than 50 feet apart and no further away than 100 feet apart. This should provide maximum stability for the curtain.
- The ends of the curtain, both floating upper and weighted lower, should extend well up into the shoreline, especially if high water conditions are expected. The ends should be secured firmly to the shoreline (preferably to rigid bodies such piles or other weighted structures) to enclose the area fully where sediment

Source: bmpinstalls.com

TARGETED CONSTITUENTS

- Bacteria (NR)
- Metals (NR)
- Nutrients (NR)
- Oil and Grease (H)
- Organics (NR)
- Oxygen Demand (NR)
- Sediment (H)
- Trash (H)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

OBJECTIVES

- Sediment Control

APPLICABILITY

- For all work that is being done on a shore line of a lake, river or stream.
- Also for work that may directly discharge into a lake, river Reduce the amount of TSS that can directly enter a waterway due to construction activities.

ADVANTAGES

- Greatly reduce the amount of TSS that can enter a waterway by creating a nearly impervious barrier between clean water and soil laden water.
- Relatively inexpensive to

may enter the water.

- When there is a specific need to extend the curtain to the bottom of the watercourse in tidal or moving water conditions, a heavy woven pervious filter fabric may be substituted for the normally recommended impervious geotextile. This creates a by-pass for water that will reduces the pressure on the curtain and keep it in the same relative location and shape during the rise and fall of tidal waters. The engineer should monitor the curtain during high flow events to ensure enough water is passing through the curtain so that excess pressure does not develop.
- Barriers should be bright yellow or international orange so that they stand out in contrast with the water.
- The seams of the fabric should be vulcanized, welded or sewn and should develop full strength of the fabric.
- Floatation devices should be buoyant units contained in an individual sleeve or collar that is attached to the curtain. The floatation device should be buoyant enough to hold the weight of the curtain and any sediment that has a force on the curtain.

MAINTENANCE CONSIDERATIONS

A turbidity curtain requires a great deal of maintenance. The curtain should be checked delay to ensure it is still in working order and has not been dislodged. Joints should be checked for weakness, rips, tears or other defects. Sediment levels should be checked after all storms greater than a half inch in any given 24 hour period. Sediment levels should also be checked twice a week to ensure no excessive buildup has occurred. Sediment should be removed once it is half way to the mean water surface elevation. While removing sediment extreme care must be used to ensure no sediment enters the unprotected waterway.

INSPECTION CONSIDERATIONS

Inspections should be performed in accordance with Section 4 of the Cambridge Stormwater Management Guidelines. Inspect the turbidity curtain for tears, rips or any other structural abnormality. Repairs should be made with 24 hours.

install.

LIMITATIONS

- Required maintenance daily to ensure it is still properly placed.
- Removal sediment behind the turbidity curtain can be difficult to complete.

REFERENCE

- Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas
- Virginia Erosion and Sediment Control Handbook.
- Stormwater Manager's Resource Center (SMRC) Website www.stormwatercenter.net
- US EPA National Menu of Best Management Practices

2.21. Fiber Logs

DESCRIPTION

Fiber logs (also called fiber rolls or straw wattles) are tube-shaped erosion control devices filled with straw, flax, rice, coconut fiber material, or composted material. Each roll is wrapped with UV-degradable polypropylene netting for longevity or with 100 percent biodegradable materials like burlap, jute, or coir. Fiber rolls compliment permanent best management practices used for source control and revegetation. When installed in combination with straw mulch, erosion control blankets, hydraulic mulches, or bounded fiber matrices for slope stabilization, these devices reduce the effects of long or steep slopes. Fiber rolls also help to sow, filter, and spread overland flows. This helps to prevent erosion and minimizes rill and gully development. Fiber rolls help reduce sediment loads to receiving waters by filtering runoff and capturing sediments. They can provide protection for 3 to 5 years, slowly decomposing into mulch with the netting breaking down into small pieces.

DESIGN CONSIDERATIONS

- Should be prefabricated rolls or rolled tubes of geotextile fabric. When rolling the tubes, make sure each tube is at least 8 inches in diameter. Bind the rolls at each end and every 4 feet along the length of the roll with jute-type twine.
- On slopes, install fiber rolls along the contour with a slight downward angle at the end of each row to prevent ponding at the midsection. Turn the ends of each fiber roll upslope to prevent runoff from flowing around the roll. Install fiber rolls in shallow trenches dug 3 to 5 inches deep for soft loamy soils, and 2 to 3 inches deep for hard, rocky soils. Determine the vertical spacing for slope installations on the basis of the slope gradient and soil type. A good rule of thumb is:

Slopes	Feet Apart
1:1	10
2:1	20
3:1	30
4:1	40

- Fiber rolls at the toe of slopes greater than 5:1 should be a minimum of 20 inches in diameter or installations achieving the same protection (i.e. stacked smaller diameter fiber rolls, etc.).
- For soft, loamy soils, place the rows closer together. For hard, rocky soils, place the rolls further apart. Stake fiber rolls securely into the ground and orient them perpendicular to the slope.

Source: US EPA National Menu of Best Management Practices.

TARGETED CONSTITUENTS

- Bacteria (NR)
- Metals (NR)
- Nutrients (NR)
- Oil and Grease (NR)
- Organics (NR)
- Oxygen Demand (NR)
- Sediment (H)
- Trash (L)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

OBJECTIVES

- Sediment Control

APPLICABILITY

- Fiber rolls placed along the shorelines of lakes and ponds provide immediate protection by dissipating the erosive force of small waves.
- Not to be used on slopes that are subject to creep, slumping, or landslide.
- Avoid using in channels that are actively incising or in reaches with large debris loads or potential for significant ice buildup.
- Can be used in areas of low shear stress.

Biodegradable wood stakes or willow cuttings are recommended. Drive the stakes through the middle of the fiber roll and deep enough into the ground to anchor the roll in place. About 3 to 5 inches of the stake should stick out above the roll, and the stakes should be spaced 3 to 4 feet apart. A 24-inch stake is recommended for use on soft, loamy soils. An 18-inch stake is recommended for use on hard, rocky soils. Note that installation techniques will vary by manufacturer.

- Fiber rolls can also be used at projects with minimal slopes. Typically, the rolls are installed along sidewalks, on the bare lot side, to keep sediment from washing onto sidewalks and streets and into gutters and storm drains. For installations along sidewalks and behind street curbs, it might not be necessary to stake the fiber rolls, but trenches must still be dug. Fiber rolls placed around storm drains and inlets must be staked into the ground. These rolls should direct the flow of runoff toward a designated drainage area. Place them 1 to 1 ½ feet back from the storm drain or inlet.

MAINTENANCE CONSIDERATIONS:

Repair or replace split, torn, unraveled, or slumping fiber rolls. Fiber rolls are typically left in place on slopes. If they are removed, collect and dispose of the accumulated sediment. Fill and compact holes, trenches, depressions, or any other ground disturbance to blend with the surrounding landscape.

INSPECTION CONSIDERATIONS: Inspections should be performed in accordance with Section 4 of the Cambridge Stormwater Management Guidelines. Monitor fiber rolls daily during prolonged rain events. The inspection requirements of fiber rolls are minimal, but short term inspection is recommended to ensure that the rolls remain firmly anchored in place and are not crushed or damaged by equipment traffic.

- Have been used in a variety of areas: along highways and at construction sites, golf courses, ski areas, vineyards, and reclaimed mines.
- Suitable along the toe, top, face, and at grade breaks of exposed and erodible slopes to shorten slope length and spread runoff as sheet flow.
- Suitable at the end of downward slope where it transitions to a steeper slope, along the perimeter of a project, down slope of exposed soil areas, as check dams in unlined ditches, or around temporary stockpiles.

ADVANTAGES

- Installation is easy, particularly in shallow soils and rocky material.
- Readily molded to fit the bank line.
- Do not obstruct hydraulic mulch and seed applications.
- Can be removed or left in place after vegetation has established.
- More adaptable to slope applications and contour installations than other erosion and sediment control practices.
- Blend in with the landscape and are less obtrusive than other erosion and sediment control practices.

LIMITATIONS

- Not effective unless they are trenched.
- Can be difficult to move once they are saturated.
- Have a very limited sediment capture zone.
- If not properly staked and entrenched, fiber rolls can be

transported by high flows.

REFERENCES

- Massachusetts Stormwater Handbook
- US EPA National Menu of Best Management Practices
- California Stormwater BMP Handbook for Construction

2.22. Concrete Washout

DESCRIPTION

Concrete Washouts are used to contain standard concrete and also other types of concrete such as flow fill, grout etc...The washout area concentrates the concrete into a large single area or several smaller areas that will help ease in maintenance and cleanup of the site. The washout areas shall also prevent contrite spoils from spilling into stormwater catchbasin and polluting the downstream environment. It will also reduce the possibility of concrete spoils from clogging catchbasins or drainage pipes which can be costly to repair.

Source: www.cfpub.epa.gov

DESIGN CONSIDERATIONS

- Concrete washout areas must be located at least 50’ from all catchbasins, open channels or any other structure that receives drainage runoff.
- A washout area can be either man made or prefabricated.
- Prefabricated structures shall be leak free and be designed to be able to handle the amount of anticipated volume. Secondary controls such as hay bales or fiver rolled socks shall also be placed around the perimeter of the structure to ensure that no concrete spoils can enter the drainage system.
- A man made structure can be design numerous ways. The designer shall take into consideration ground topography, location of drainage structures, and ease of use. These structures should be placed below grade when possible to help reduce the amount of spillage that can occur. Manmade structures shall also be leak proof.
- When designing a prefabricated or manmade structure it can be assumed that 7 gallons of wash water (Concrete Washout Systems, Inc., (2006)) will be used to clean the chute and equipment.
- The washout structure should provide at least 12” of free board to also reduce the chance of spillage.
- For sidewalk work the contractor may clean concrete trucks in an area of sidewalk that has all ready been removed. The contractor shall ensure that no spoilage enters the drainage system and that they are 50’ away from the nearest catchbasin.

TARGETED CONSTITUENTS

- Bacteria (NR)
- Metals (NR)
- Nutrients (NR)
- Oil and Grease (NR)
- Organics (NR)
- Oxygen Demand (NR)
- Sediment (NR)
- Trash (NR)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

OBJECTIVES

- Concrete Control

APPLICABILITY

- On all sites where concrete placement will occur.

ADVANTAGES

- Reduce the amount of concrete washout that can enter the storm drain system
- Concentrate concrete spoils to a single/multiple locations for easier site cleanup
- Prevents runoff of concrete spoils that may contaminate the site.

REFERENCE

MAINTENANCE CONSIDERATIONS

The contractor should decide on a practice that is best suited for the project whether it is a manmade or prefabricated structures. The structures should be cleaned and concrete washout should be removed once it reaches at least 12” from the top. If concrete is spilled outside of the washout structure it should be cleaned immediately and the area should be adjusted to properly contain the concrete washout.

INSPECTION CONSIDERATIONS

Inspections should be performed in accordance with Section 4 of the Cambridge Stormwater Management Guidelines.

- Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas
- Virginia Erosion and Sediment Control Handbook.
- Stormwater Manager's Resource Center (SMRC) Website www.stormwatercenter.net
- US EPA National Menu of Best Management Practices

City of Cambridge, Massachusetts

Department of Public Works

147 Hampshire Street • Cambridge, MA 02139

APPENDIX A DRAFT Best Management Practices

Sections 3 - 5

Version 3/12/08

Report Prepared By:

Cambridge Department of Public Works and

Malcolm Pirnie, Inc.
601 Edgewater Drive
Suite 360

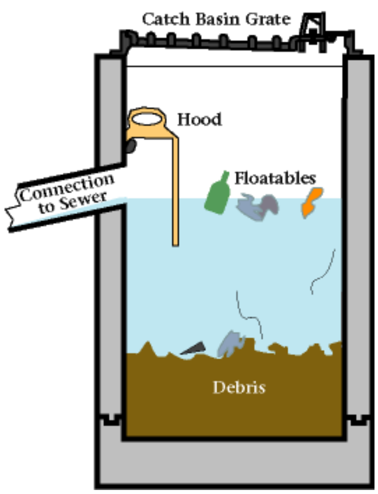
Wakefield, MA 01880
781-224-4488
5400001

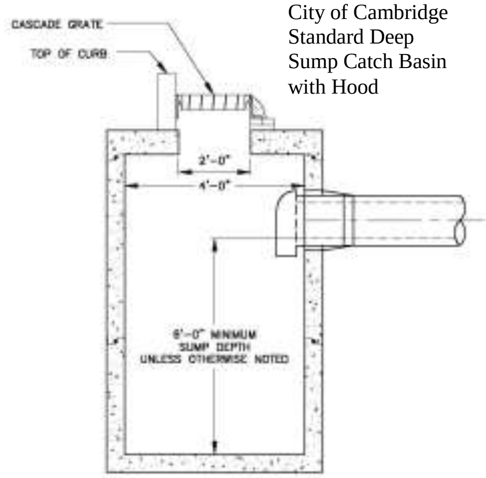
Contents

This is nonprinting text.
DO NOT DELETE THIS TEXT OR THE SECTION BREAK THAT FOLLOWS
(Click ¶ button on Formatting toolbar to display section breaks)

3. PRETREATMENT CONTROLS

3.1. Deep Sump Catch Basin (with Hood)





City of Cambridge Standard Deep Sump Catch Basin with Hood

TARGETED CONSTITUENTS

- Bacteria (L)
- Metals (L)
- Nutrients (L)
- Oil and Grease (H)
- Organics (L)
- Oxygen Demand (NR)
- Sediment (M)
- Trash (H)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

APPLICABILITY

- Impervious areas that are expected to receive high sediment and hydrocarbon loadings.
- Parking lots
- Other areas with substantial vehicular traffic
- Recommended as pretreatment device only
- Cannot be used for the removal of dissolved/emulsified oils such as coolants, soluble lubricants, glycols, and alcohols.

ADVANTAGES

- Usually located underground, so limited lot size is not a deterrent.
- Compatible with storm drain systems.

DESCRIPTION

Deep sump catch basins are underground retention systems designed to remove trash, debris, and some amount of sediment and oil and grease from stormwater runoff. The deep sump catch basin operates in a similar manner to the water quality inlet. Functioning as a modified catch basin, the deep sump design has the stormwater runoff inflow at the top of the basin. Stormwater flows through screened orifices to the chamber, which may contain a permanent pool of water. The stormwater must pass through the bottom opening of an inverted pipe. Oil and grease float on the permanent pool water, and are trapped in the chamber. Eventually, the oil and grease will attach to sediment and settle out.

DESIGN CONSIDERATIONS

- Contributing drainage area should be 0.25 to 0.5 acres (impervious).
- Should be designed as off-line system to prevent resuspension of sediments.
- Inflow pipe sized to pass the design storm volume into the catch basin and excess flows should be directed to another BMP.
- The discharge point should be located at least 4 ft. below the

inflow point. Generally the volume rule is to size the sump four times the diameter of the inflow pipe. In Cambridge, a 6 ft. sump is required.

- Trash rack or screen should cover discharge outlets

MAINTENANCE CONSIDERATIONS

Typical maintenance of deep sump catch basins includes trash removal if a screen or other debris capturing device is used, and removal of sediment using a vactor truck. Operators need to be properly trained in catch basin maintenance. Maintenance should include keeping a log of the amount of sediment collected and the date of removal. At a minimum, these structures should be cleaned once per year or when the sump accumulations reach a depth of 50 percent, whichever is sooner. Studies suggest that increasing the frequency of maintenance can improve the performance of catch basins, particularly in industrial or commercial areas. All sediments and hydrocarbons should be properly handled and disposed, in accordance with local, state and federal guidelines and regulations. BMPs designed with permanent water sumps, vaults, and/or catch basins (frequently installed below-ground) can become a nuisance due to mosquito and other vector breeding. Preventing mosquito access to standing water sources in BMPs is the best prevention plan. Bacterial mosquito prevention tablets should be installed in all catch basins during the month of July.

INSPECTION CONSIDERATIONS

An inspection schedule should be established and followed. Routine inspections and treatments by local mosquito and vector control agencies may be required. At a minimum, inspections should occur monthly and after every storm event to be sure unit is operating properly. Inspection and maintenance procedures may require Confined Space Entry training and certification.

DEEP SUMP CATCH BASINS IN CAMBRIDGE

The City of Cambridge standard BMP catch basin is a deep sump catch basin that includes a 6 ft. sump, floatables and oil and grease hood, and a 12 in. leader pipe connecting to a manhole on the local storm drain or another BMP. All existing catch basins not satisfying the City of Cambridge standards will be replaced. Catch basin density will not be less than one basin per 0.50 acre catchment. Deep sump catch basins will be required for all paved areas upstream of any storage facility intended to meet stormwater quality requirements.

- Can be used for retrofitting small urban lots where larger BMPs are not feasible.
- Provides pretreatment of runoff.
- Easily accessed for maintenance.
- Longevity is high, with proper maintenance.

LIMITATIONS

- Limited pollutant removal.
- Expensive to install and maintain.
- Frequent maintenance necessary.
- No volume control.
- Proper disposal of trapped sediment and oil and grease.
- Standing water can provide breeding ground for mosquitoes.

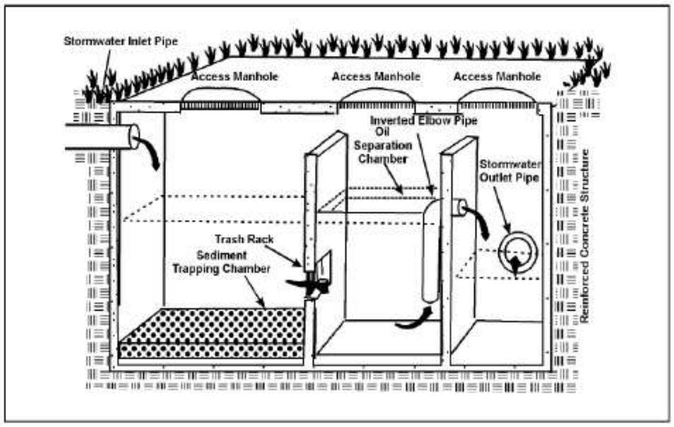
♦ LID ALTERNATIVES

- Reduce impervious surfaces.
- Disconnect runoff from non-metal roofs, roadways, and driveways.
- Vegetated Filter Strip

REFERENCES

- California Stormwater BMP Handbook for New Development and Redevelopment
- Massachusetts Stormwater Handbook
- Minnesota Urban Small Sites BMP Manual

3.2. Oil Grit Separator



Source: California Stormwater BMP Handbook, January 2003.

DESCRIPTION

Oil/grit separators, also commonly called trapping catch basins, water quality inlets or oil/water separators, consist of one or more chambers that promote sedimentation of coarse materials and separation of free oil (as opposed to emulsified or dissolved oil) from stormwater. Some oil/grit separators also contain screens to help retain larger or floating debris, and many of the newer designs also include a coalescing unit that helps promote oil/water separation. A typical oil/grit separator, as shown in the schematic, consists of a sedimentation chamber, an oil separation chamber, and a discharge chamber. These devices are appropriate for capturing hydrocarbon spills, but provide very marginal sediment removal and are not very effective for treatment of stormwater runoff. Oil/grit separators typically capture only the first portion of runoff for treatment and are generally used for pretreatment before discharging to other best management practices. In addition, pollutants are not actually removed from the oil/grit separator until the unit is cleaned out.

DESIGN CONSIDERATIONS

- Contributing drainage area should be 0.25 to 0.5 acres (impervious).
- Should be designed as off-line system to prevent resuspension of sediments.
- Typically designed with three chambers.
- To trap hydrocarbons, an inverted elbow pipe should be located between the second and third chambers and the bottom of the pipe should be at least 3 ft. below the second chamber permanent pool.

TARGETED CONSTITUENTS

- Bacteria (L)
- Metals (L)
- Nutrients (L)
- Oil and Grease (M)
- Organics (L)
- Oxygen Demand (NR)
- Sediment (M)
- Trash (M)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

APPLICABILITY

- Impervious areas that are expected to receive high sediment and hydrocarbon loadings.
- Parking lots
- Other areas with substantial vehicular traffic
- Recommended as pretreatment device only
- Cannot be used for the removal of dissolved/emulsified oils such as coolants, soluble lubricants, glycols, and alcohols.

ADVANTAGES

- Usually located underground, so limited lot size is not a deterrent.
- Compatible with storm drain systems.
- Can be used for retrofitting small urban lots where larger BMPs are not feasible.
- Provides pretreatment of runoff.
- Easily accessed for maintenance.

- Maximize the volume of the permanent pools within each chamber – minimum depth of 4 ft. Combined volume of these pools should equal at least 400 cubic ft. per acre of contributing impervious area. Where possible, the third chamber should also be used as a permanent pool. Vertical baffles at the bottom of the permanent pools can help to minimize resuspension of sediment.
- Inflow pipe sized to pass the design storm volume into the oil/grit separator and excess flows should be directed to another BMP.
- Trash rack or screen should cover discharge outlets
- Access holes should be included for each chamber to provide access for cleaning.

MAINTENANCE CONSIDERATIONS

Typical maintenance of oil/grit separators includes trash removal if a screen or other debris capturing device is use, and removal of sediment using a vactor truck. Operators need to be properly trained in oil/grit separator maintenance. Maintenance should include keeping a log of the amount of sediment collected from each chamber and the date of removal. At a minimum, these inlets should be cleaned out four times per year. Oil/water separator tank units can be fitted with sensing units that will indicate when they need to be cleaned. Ordinary catch basin cleaning equipment (vaccum pumps) can be used to clean oil/grit separators. Manual removal of sediment may also be necessary. Studies suggest that increasing the frequency of maintenance can improve the performance of oil/grit separators, particularly in industrial or commercial areas. All sediments and hydrocarbons should be properly handled and disposed, in accordance with local, state and federal guidelines and regulations. BMPs designed with permanent water sumps, vaults, and/or catch basins (frequently installed below-ground) can become a nuisance due to mosquito and other vector breeding. Preventing mosquito access to standing water sources in BMPs is the best prevention plan.

INSPECTION CONSIDERATIONS

An inspection schedule should be established and followed. Routine inspections and treatments by local mosquito and vector control agencies may be required. At a minimum, inspections should occur monthly and after every storm event to be sure unit is operating properly. Inspection and maintenance procedures may require Confined Space Entry training and certification.

OIL/GRIT SEPARATORS IN CAMBRIDGE

-

- Longevity is high, with proper maintenance.
- Can provide spill control.

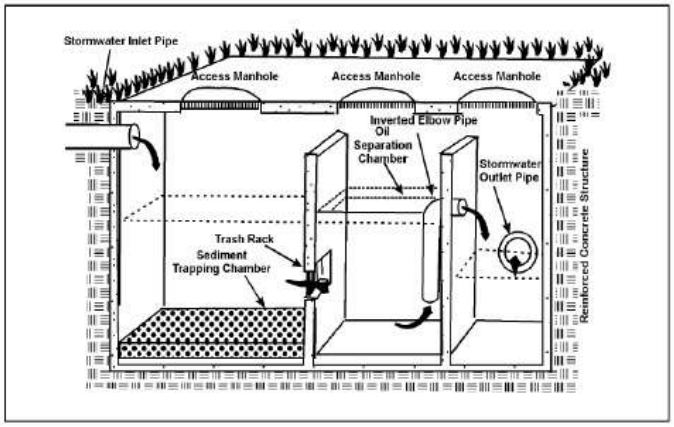
LIMITATIONS

- Limited pollutant removal.
- Expensive to install and maintain.
- Frequent maintenance necessary.
- No volume control.
- Proper disposal of trapped sediment and oil and grease required.
- Standing water can provide breeding ground for mosquitoes.

REFERENCES

- California Stormwater BMP Handbook for New Development and Redevelopment
- EPA Stormwater Technology Fact Sheets www.epa.gov
- Massachusetts Stormwater Handbook
- Minnesota Urban Small Sites BMP Manual

3.3. Proprietary Separators



Source: California Stormwater BMP Handbook, January 2003.

DESCRIPTION

A proprietary separator is a flow-through structure with a setlling or separation unit to remove sediments and other pollutants. They typically use the power of swirling or flowing water to separate floatables and coarser sediments, are typically designed and manufactured by private businesses, and come in different sizes to accommodate different design storms and flow conditions. Some rely solely on gravity separation and contain no swirl chamber. Since proprietary separators can be placed in almost any location on a site, they are particularly useful when either site constraints prevent the use of other stormwater techniques or as part of a larger treatment train. The effectiveness of proprietary separators varies greatly by size and design, so make sure that the units are sized correctly for the site's soil conditions and flow profiles, otherwise the unit will not work as designed.

DESIGN CONSIDERATIONS

- Can be configured either in-line or if subject to higher flows, off-line to reduce scouring.
- Must be sized in accordance with the manufacturer's specifications and the specifications of these Guidelines.
- When used as spill control devices, may have to be sized differently than for TSS removal.
- Design varies by manufacturer. Units are typically precast concrete, but larger systems may be cast in place. Units may have baffles or other devices to direct incoming water into and through a series of chambers, slowing the water down to allow sediment to drop out into internal storage areas, then directing this pre-treated water to exit to other treatment or infiltration devices.

TARGETED CONSTITUENTS

- Bacteria (L)
- Metals (L)
- Nutrients (L)
- Oil and Grease (M)
- Organics (L)
- Oxygen Demand (NR)
- Sediment (M)
- Trash (M)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

APPLICABILITY

- Must be used for pretreatment only because they have limited pollutant removal and storage capacity.
- May be the only structural pretreatment BMPs feasible on certain constrained redevelopment sites where space and storage is not available for more effective BMPs.
- May be especially useful in ultra-urban settings.
- Some may be used for spill control.

ADVANTAGES

- Removes coarser sediment.
- Useful on constrained sites.
- Can be custom-designed to fit specific needs of a specific site.

LIMITATIONS

- Needs frequent maintenance. Can become a source of pollutants via resuspension if not properly maintained.
- Generally ineffective at removing soluble pollutants,

- In some cases, flow will be introduced tangentially, to induce swirl or vortex.
- Units may include skirts or weirs, to keep trapped sediments from becoming re-entrained. Some units combine a catch basin with the treatment function, providing off-line rather than in-line treatment.
- Generally they are placed below ground on a gravel or stone base.
- Make sure all units contain inspection and access ports so that they may be inspected and cleaned. During design, take care to place the inspection and access ports where they will be accessible. Do not place the ports in locations such as travel lanes of roadways/highways or parking stalls.

MAINTENANCE CONSIDERATIONS

Clean devices in strict accordance with manufacturers' recommendations and requirements. Clean the units using the method specified by the manufacturer. Vactor trucks are typically used to clean these units. Clamshell buckets typically used for cleaning catch basins are almost never allowed by manufacturers. Sometimes it will be necessary to remove sediment manually. Note that if no sediment exists, the unit is failing due to scouring, and the unit needs to be adjusted.

INSPECTION CONSIDERATIONS

Inspect devices in strict accordance with manufacturers' recommendations and requirements, but no less than twice a year following installation, and no less than once a year thereafter.

PROPRIETARY SEPARATORS IN CAMBRIDGE

- Can be custom-designed to fit specific needs at a specific site.

fine particles or other particles.

LID ALTERNATIVES

- Reduce impervious surfaces.
- Disconnect runoff from non-metal roofs, roadways, and driveways.

REFERENCES

- Massachusetts Stormwater Handbook

3.4. Sediment Forebay

DESCRIPTION

A sediment trap or forebay is an excavated pit or cast structure designed to slow incoming stormwater runoff and settle suspended solids. Stormwater is routed through the sediment trap before continuing to the primary water quality and quantity control BMP. Typically, sediment forebays are components of effective stormwater pond and wetland designs. Cast sediment traps may also be used in connection with water quality swales. Designs incorporate simple access and other features for ease of accumulated sediment removal.

Source: County of San Diego, Public Works Department, Flood Control Grant Project.

TARGETED CONSTITUENTS

- Bacteria (L)
- Metals (L)
- Nutrients (L)
- Oil and Grease (L)
- Organics (L)
- Oxygen Demand (NR)
- Sediment (M)
- Trash (M)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

DESIGN CONSIDERATIONS

- Volume of the forebay is generally a minimum of 0.1 in. per contributing acre.
- Typically designed as on-line unit.
- Size for the prescribed water quality volume but can accommodate the 2 and 10 year storms.
- Incorporate design features to make maintenance easy/accessible. Direct maintenance access for appropriate equipment should be provided to the forebay. A fixed vertical sediment depth marker should be installed in the forebay to measure sediment deposition over time. The bottom of the forebay may be hardened to make sediment removal easier. Concrete floors/pads make shoveling sediment easy but may not be appropriate if forebay requires excavation.
- Generally no deeper than 3 to 6 ft.
- Side slopes should not be steeper than 3:1. Channel geometry should prevent erosion from the 2-year peak discharge. Exit velocities from the forebay should be non-erosive.

MAINTENANCE CONSIDERATIONS

Typical maintenance of a sediment forebay includes removal of trash and sediment. Operators need to be properly trained in forebay maintenance. Maintenance should include keeping a log of the amount of sediment collected and the date of removal. Direct maintenance access for appropriate equipment should be provided to the forebay. A fixed vertical sediment depth marker should be installed in the forebay to measure sediment deposition over time. The bottom of the forebay may be hardened to make sediment removal easier. At a minimum, these structures should be cleaned four times per year. Frequent removal of sediment will make it less

APPLICABILITY

- Most often used prior to pond and wetland designs. Forebays are important for the longevity and maintenance of these BMPs.
- Can be used in connection with most other BMP technologies.
- Use as pretreatment device only.

ADVANTAGES

- Compatible with a wide array of BMPs.
- Can be used to expand existing BMPs, especially pond and wetland systems.
- Provide pretreatment of runoff before delivery to other BMPs.

likely that sediments will be resuspended. All sediments and hydrocarbons should be properly handled and disposed, in accordance with local, state and federal guidelines and regulations.

INSPECTION CONSIDERATIONS

An inspection schedule should be established and followed. Forebays should be inspected monthly and after rain events.

SEDIMENT FOREBAYS IN CAMBRIDGE

- Slows velocities of incoming stormwater.
- Easily accessed for sediment removal.
- Longevity is high, with proper maintenance.
- Inexpensive relative to other BMPs.

LIMITATIONS

- Limited pollutant removal.
- No removal of soluble pollutants.
- No volume control.
- More space required than water quality inlets and deep sumps.
- Frequent maintenance necessary.
- Proper disposal of trapped sediment and oil and grease.

REFERENCES

- California Stormwater BMP Handbook for New Development and Redevelopment
- Massachusetts Stormwater Handbook
- Stormwater Manager's Resource Center (SMRC) Website www.stormwatercenter.net

3.5. Vegetated Filter Strip

Source: California Stormwater BMP Handbook, January 2003.

DESCRIPTION

Grassed buffer strips (vegetated filter strips, filter strips, and grassed filters) are vegetated surfaces that are designed to treat sheet flow from adjacent surfaces. Filter strips function by slowing runoff velocities and allowing sediment and other pollutants to settle and by providing some infiltration into underlying soils. Filter strips were originally used as an agricultural treatment practice and have more recently evolved into an urban practice. Filter strips are frequently planted with turf grass or native vegetation. With proper design and maintenance, filter strips can provide relatively high pollutant removal. In addition, the public views them as landscaped amenities and not as stormwater infrastructure. Consequently, there is little resistance to their use.

DESIGN CONSIDERATIONS

- Maximum length (in the direction of flow towards the buffer) of the tributary area should be 60 ft.
- Minimum length (in direction of flow) is 15 ft.
- Slopes should not exceed 15% or be less than 1%. (between 2% and 6% in Alewife document)
- Width should be the same as the contributing area - maximum of 75 ft. for impervious drainage; 150 ft. for pervious drainage.
- Upstream boundary of the filter should be located contiguous to the developed area.
- Either grass or a diverse selection of other low growing, drought

TARGETED CONSTITUENTS

- Bacteria (L)
- Metals (H)
- Nutrients (L)
- Oil and Grease (H)
- Organics (M)
- Oxygen Demand (NR)
- Sediment (H)
- Trash (M)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

APPLICABILITY

- Best suited to treating runoff from roads and highways, roof downspouts, small parking lots or portions of larger lots, and pervious surfaces.
- Gently sloping areas where vegetative cover is robust and diffuse.
- Where shallow flow characteristics are possible.
- Work well in residential areas.
- Ideal component of "outer zone" of a stream buffer or as pretreatment to structural practice.
- Good for protection of coldwater streams.
- Can provide benefits at construction sites.

ADVANTAGES

- Require less maintenance than other pretreatment BMPs.
- Reliable water quality benefits in conjunction with high aesthetic appeal.
- Flow characteristics and vegetation type/density can be

tolerant, native vegetation should be specified. Trees and shrubs may be incorporated into portions of the strip to create visual screening as well as a physical barrier. Vegetation whose growing season corresponds to the wet season is preferred.

- Runoff flow velocities should not exceed 1 fps.
- Sized to temporarily pond the 2-year 6-hour storm.
- Sheet flow must be maintained. Can incorporate a level spreader to distribute concentrated flows along the strip.
- Accurate grading of site during construction is essential.

MAINTENANCE CONSIDERATIONS

Filter strips require mainly vegetation management. Little special training is needed for maintenance crews. Maintenance includes normal grass or shrub-growing activities such as mowing, trimming, removal of invasive species, and replanting when necessary. Recent research indicates that grass height and mowing frequency have little impact on pollutant removal, therefore mowing may only be necessary once or twice a year for safety and aesthetics or to suppress weeds and woody vegetation. Trash tends to accumulate in strip areas, particularly along highways. The need for litter removal should be determined through periodic inspection but litter should always be removed prior to mowing. Filter strips require more tending as the volume of sediment increases. Periodically, strips used for sediment removal may require regrading and reseeding of their upslope edge. When used during construction activities, and if a high volume of sediment builds up, the strip may need to be reworked and replanted. The same would be necessary if concentrated flow erodes a channel through the strip.

INSPECTION CONSIDERATIONS

Inspect strips at least twice annually for erosion or damage to vegetation, preferably at the end of the wet season to schedule summer maintenance and before major fall runoff to be sure the strip is ready for winter. However, additional inspection after periods of heavy runoff is recommended. The strip should be checked for debris, litter, and areas of sediment accumulation. Regularly inspect strips for pools of standing water. Vegetated buffer strips can become a nuisance due to mosquito breeding.

VEGETATED FILTER STRIPS IN CAMBRIDGE

Encouraged as an LID technique.

This is nonprinting text.
DO NOT DELETE THIS TEXT OR THE SECTION BREAK THAT FOLLOWS
(Click ¶ button on Formatting toolbar to display section breaks)

controlled to maximize performance.

- Roadside shoulders act as effective buffer strips when meeting slope and length design criteria.
- Provide a convenient area for snow storage and treatment. Vegetation should be salt-tolerant.
- Since water does not pond for long periods, filter strips help maintain normal temperatures of the water – protecting aquatic habitat.
- Relatively simple/inexpensive to install.

LIMITATIONS

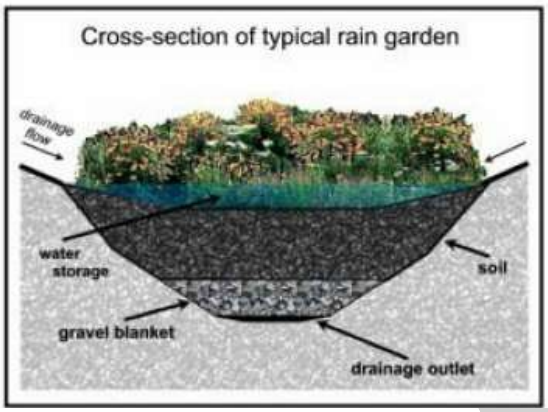
- May not be appropriate for industrial sites or locations where spills may occur.
- Cannot treat a very large drainage area.
- Thick vegetative cover needed for proper functionality.
- Buffer length and flow characteristics important to performance.
- May not provide treatment for dissolved constituents except to the extent that flows across the vegetated surface are infiltrated into the soil profile.
- Does not provide significant attenuation of the increased volume/flow rate of runoff during intense rain events.

REFERENCES

- California Stormwater BMP Handbook for New Development and Redevelopment
- Minnesota Urban Small Sites BMP Manual

4. TREATMENT CONTROLS

4.1. ♦ Bioretention Areas (including Rain Gardens)



Source: Massachusetts Riverways Program, Building a Rain Garden Fact Sheet.

DESCRIPTION

Bioretention is a technique that uses soils, plants and microbes to treat stormwater before it is infiltrated and/or discharged. Bioretention cells (also called rain gardens in residential applications) are shallow depressions filled with sandy soil topped with a thick layer of mulch and planted with dense native vegetation. Stormwater runoff is directed into the cell via piped or sheet flow. The runoff percolates through the soil media that acts as a filter. There are two types of bioretention cells: Filtering bioretention areas are designed solely as an organic filter, and exfiltrating bioretention areas are configured to recharge groundwater in addition to acting as a filter. A filtering bioretention area includes an impermeable liner and underdrain that intercepts the runoff before it reaches the water table so that it may be conveyed to a discharge outlet, other BMPs, or the municipal storm drain system. An exfiltrating bioretention area has an underdrain that is designed to enhance exfiltration of runoff into the groundwater.

DESIGN CONSIDERATIONS

- **Construction and Sizing:** Surface area of the bioretention area to be 5% to 7% of the area draining to it. Construct bioretention cells so they are at least 4 ft. deep, depending on local conditions.

TARGETED CONSTITUENTS

- Bacteria (L)
- Metals (H)
- Nutrients (M)
- Oil and Grease (H)
- Organics (M)
- Oxygen Demand (L)
- Sediment (H)
- Trash (M)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

APPLICABILITY

- Can provide excellent pollutant removal for the "first flush" of stormwater runoff. Properly designed/maintained cells can infiltrate an inch or more of rainfall.
- Can be applied to a wide range of commercial, residential, and industrial developments in many geologic conditions.
- Work well on small sites with space constraints, and on large sites divided into multiple drainage areas.
- Often well suited for ultra-urban settings where little pervious area exists.
- Although they require approximately 5% to 7% of the area that drains to them, they can be integrated into parking lots, parking lot islands, median strips, and

Size the cells (based on void space and ponding area) at a minimum to capture and treat the required water quality volume the required recharge volume, or the larger of the two volumes if used to achieve compliance with both water quality and recharge standards. Cover the bottom of the excavation with coarse gravel, over pea gravel, over sand. Do not use fabric filters or sand curtains because they are prone to clogging. During construction, avoid excessively compacting soils around the bioretention areas and accumulating silt around the drain field

- **Pretreatment:** A pretreatment BMP, such as a vegetated filter strip, is required. A stone or pea gravel diaphragm or, even better, a concrete level spreader upstream of a filter strip will enhance sheet flow and sediment removal. Bioretention cells can be dosed with sheet flow, a surface inlet, or pipe flow. When using a surface inlet, first direct the flow to a sediment forebay. Alternatively, piped flow may be introduced to the bioretention system via an underdrain.
- **Ponding Area:** For bioretention cells dosed via sheet flow or surface inlets, include a ponding area to allow water to pond and be stored temporarily while stormwater is exfiltrating through the cell. Grade the area to allow a ponding depth of 6 to 8 in. Where bioretention areas are adjacent to parking areas, allow 3 in. of freeboard above the ponding depth to prevent flooding.
- **Mulch Layer:** Cover the soil with 2 to 3 in. of fine-shredded hardwood mulch.
- **Planting Soil Bed:** A range of different soils may be used for Filtering Bioretention Systems, but for Exfiltrating Bioretention Systems, the state of Massachusetts recommends the following Engineered Soil Mix for Bioretention Systems Designed to Exfiltrate – 40% sand (gravelly sand), 20-30% topsoil (sandy loam, loamy sand or loam texture), and 30-40% compost (processed from yard waste and must not contain biosolids). The soil mix must be uniform, free of stones, stumps, roots, or similar objects larger than 2 in. Clay content should not exceed 5%. The pH should generally be between 5.5 and 6.5. Use soils with 1.5 to 3% organic content and maximum 500 ppm soluble salts. On-site soil mixing or placement is not allowed if soil is saturated or subject to water within 48 hours. Cover and store soil to prevent wetting or saturation. Test soil for fertility and micro-nutrients and, only if necessary, amend mixture to create optimum conditions for plant establishment and early growth. Determine the infiltrative capacity of the underlying native soil through an infiltration test that uses a double-ring infiltrometer. Do not use a standard septic system (i.e., Title 5) percolation test to determine

traffic islands.

- Sites can be retrofitted with bioretention areas by replacing existing parking lot islands or by reconfiguring a parking lot during resurfacing.
- On residential sites, they are commonly used for rooftop and driveway runoff.
- Can be applied to drainage areas of 2 acres or less and shallow slopes of less than 20%.
- Both types of bioretention areas may be used to treat runoff from hot spots.

ADVANTAGES

- Can be designed to provide ground water recharge and preserves the natural water balance of the site.
- Can be designed to prevent recharge where appropriate.
- Enhance the landscape, provide habitat, supply shade (reducing the urban heat island effect), absorb noise, and provide windbreaks.
- Can remove other pollutants besides TSS including phosphorus, nitrogen and metals.
- Help reduce stress in watersheds that experience severe low flows due to excessive impervious cover.
- Low-tech, decentralized bioretention areas are also less costly to install and maintain than conventional stormwater technologies that treat runoff at the end of the pipe.
- Decentralized bioretention cells can also reduce the size of storm drain pipes, a major component of stormwater treatment costs.
- Small rain gardens are

soil permeability.

- **Underdrain (if runoff is to be collected rather than infiltrated):** An impermeable liner and an underdrain must be installed in Filtering Bioretention Systems.
- **Overflow Drain:** Most bioretention cells have an overflow drain that allows ponded water above the selected ponding depth to be dosed to an underdrain. If the bioretention system is designed to exfiltrate, the underdrain is not connected to an outlet, but instead terminates in the bioretention cell. If the bioretention area is not designed to exfiltrate, the underdrain is connected to an outlet for discharge or conveyance to additional BMPs.
- **Plants:** The planting plan should include a mix of herbaceous perennials, shrubs, and (if conditions permit) understory trees that can tolerate intermittent ponding, occasionally saline conditions due to road salt, and extended dry periods. To avoid a monoculture, the planting plan should include one tree or shrub per 50 square ft. of bioretention area, and at least 3 species each of herbaceous perennials and shrubs.
- For residential rain gardens, pick a low spot on the property, and route water from a downspout or sump pump into it. It is best to choose a location with full sun, but if that is not possible, make sure it gets at least a half-day of sunlight.
- Do not excavate an extensive rain garden under large trees. Digging up shallow feeder roots can weaken or kill a tree. If the tree is not a species that prefers moisture, the additional groundwater could damage it.
- Exfiltrating bioretention designs must ensure vertical separation of at least 2 ft. from the seasonal high water table to the bottom of the bioretention cell.
- Exfiltrating bioretention systems must be designed to drain within 72 hours. However, rain gardens are typically designed to drain water within a day and are thus unlikely to breed mosquitoes.
- Ensure that bioretention areas are easily accessible for maintenance.

MAINTENANCE CONSIDERATIONS

Inspect and remove trash monthly. Mulch 1-2 times in the spring each year. Fertilize initially in the spring. Prune and remove dead vegetation in the fall and spring of each year, and replace dead vegetation each spring. Water plants as necessary during the first growing season and during dry periods after the first growing season. Every 3-5 years, replace all media and all vegetation in the late spring

mosquito death traps.

- Little or no hazard for amphibians or other small animals.

LIMITATIONS

- Not suitable where groundwater table is within 6 ft. of the ground surface.
- May reduce the number of parking spaces if incorporated into parking area design.
- Not suitable where mature tree removal is required.
- Not suitable for large drainage areas.

REFERENCES

- Massachusetts Stormwater Handbook
- Minnesota Urban Small Sites BMP Manual

or early summer. Never store snow in bioretention areas. The Operation and Maintenance Plan must specify where on-site snow will be stored. When bioretention areas are located along roads, care must be taken during plowing operations to prevent snow from being plowed into the bioretention areas. If snow is plowed into the cells, runoff may bypass the cell and drain into down gradient wetlands or surface waters without treatment.

INSPECTION CONSIDERATIONS
Inspect bioretention areas and pretreatment devices monthly for sediment build-up, structural damage, and standing water.

BIORETENTION AREAS IN CAMBRIDGE
Encouraged as an LID technique.

4.2. Constructed Stormwater Wetlands

DESCRIPTION

Constructed stormwater wetlands are stormwater wetland systems designed to maximize the removal of pollutants from stormwater runoff through wetland vegetation uptake, retention and settling. Constructed stormwater wetlands temporarily store runoff in shallow pools that support conditions suitable for the growth of wetland plants. Like extended dry detention basins and wet basins, constructed stormwater wetlands must be used with other BMPs, such as sediment forebays. There is also an innovative constructed wetland – the gravel wetland – that acts more like a filter. Information on the gravel wetland is presented in Section 4.4.

DESIGN CONSIDERATIONS

The four basic constructed wetland designs are:

- **Shallow Marsh Systems:** Most shallow marsh systems consist of pools ranging from 6 to 18 in. deep during normal conditions. Shallow marshes may be configured with different low marsh and high marsh areas, which are referred to as cells. Shallow marshes are designed with sinuous pathways to increase retention time and contact area. They may require larger contributing drainage areas than other systems, as runoff volumes are stored primarily within the marshes, not in deeper pools where flow may be regulated and controlled over longer periods of time.
- **Basin/Wetland Systems:** Multiple cell systems, such as basin/wetland systems, use at least one basin along with a shallow marsh component. The first cell is typically the wet basin, which removes particulate pollutants. Wet basins also reduce the velocity of the runoff entering the system. Shallow marshes provide additional treatment of runoff, particularly for dissolved pollutants. These systems require less space than the shallow marsh systems and generally achieve a higher pollutant removal rate than other stormwater wetland systems.
- **Extended Detention Wetlands:** Extended detention wetlands provide a greater degree of downstream channel protection. These systems require less space than shallow marsh systems, because temporary vertical storage substitutes for shallow marsh storage. The additional vertical storage area also provides extra runoff detention above normal elevations. Water levels in the extended detention wetlands may increase by as much as 3 ft. after a storm, and return gradually to normal within 24 hours of the rain event. The growing area in extended detention wetlands expands from the normal pool elevation to the maximum surface water elevation. Wetlands plants that tolerate intermittent flooding and dry periods should be selected for the extended detention area above the shallow marsh elevations.
- **Pocket Wetlands:** Use these systems for smaller sites of one to ten acres. To maintain adequate water levels, excavate pocket wetlands to the groundwater table. Pocket wetlands that are supported exclusively by stormwater runoff

Source: Buzzards Bay Nationa
Program.

TARGETED CONSTITUENTS

- Bacteria (H)
- Metals (H)
- Nutrients (M)
- Oil and Grease (H)
- Organics (H)
- Oxygen Demand (M
- Sediment (H)
- Trash (H)

Estimated Removal Efficiencie	
(H) High	(L) Low
(M) Moderate	(NR) Not R

APPLICABILITY

- Site constraints inclu types, depth to groundwater, contrib drainage area, and av land area. Consider wetlands where land limited.
- Do not locate within natural wetland areas Typically, constructe stormwater wetlands not have the full rang ecological functions natural wetlands.
- Do not use near cold fisheries. Highly recommended for us other critical areas.
- Require relatively lar contributing drainage

generally will have difficulty maintaining marsh vegetation due to extended periods of drought.

- Use the table below to determine the design criteria for a specific type of stormwater wetland.

Recommended Design Criteria for Stormwater Wetlands Designs

Design Criteria	Shallow Marsh	Basin/Wetland	ED Wetland	Pocket Wetland	Gravel Wetland (Surface)
Minimum Drainage Area (acres)	≥ 25	≥ 25	≥ 10	≥ 1 to 10	SEE SPECIFICATIONS
Constructed Wetland Surface Area/Watershed Area Ratio[1]	≥ 0.02	≥ 0.01	≥ 0.01	≥ 0.01	
Length to Width Ratio (minimum)	≥ 2:1	≥ 2:1	≥ 2:1	≥ 2:1	
Extended Detention (ED)[2]	NOT ALLOWED	OPTIONAL	YES	OPTIONAL	
Allocation of WQv Volume (wet pools[3]/low and high marsh/ED) in %	30/70/0	70/30/02	20/30/50	20/80/02	
Allocation of Surface Area (wet pools[3]/low marsh/ high marsh/semi-wet) in %	15/40/40/5	45/25/25/5	10/40/40/10	10/45/40/5	
Sediment Forebay[4]	REQUIRED	REQUIRED	REQUIRED	REQUIRED	
Micropool	REQUIRED	REQUIRED	REQUIRED	REQUIRED	
Outlet Configuration	Reverse slope pipe or hooded broad crested weir	Reverse slope pipe or hooded broad crested weir	Reverse slope pipe or hooded broad crested weir	Hooded broad-creasted weir	
Target Allocations	Shallow Marsh	Basin/Wetland	ED Wetland	Pocket Wetland	
	% Surface Area				
Sediment Forebay[4]	5%	0%5	5%	5%	
Micropool	5%	5%	5%	5%	
Deep Water Channel	5%	40%	0%	0%	
Lo Marsh	40%	25%	40%	45%	
High Marsh	40%	25%	40%	40%	
Semi-Wet	5%	5%	10%	5%	
	% WQv Volume				
Sediment Forebay[4]	10%	0%5	10%	10%	
Micropool	10%	10%	10%	10%	
Deep Water Channel6	10%	60%	0%	0%	
Lo Marsh	45%	20%	20%	55%	
High Marsh	25%	10%	10%	25%	
Semi-Wet	0%	0%	50% (ED)	0%	

[1]Constructed Wetland Surface Area includes wet pool, deep water channel, marshes, and semi-wet zone.
[2]ED volume shall be an additional volume above the WQv (except for the ED Wetland)
[3]Wet Pool = Forebay+Micropool+Deep Water
[4]Sediment Forebay for 1/2-inch WQv is 20% of WQv. Only 10% of that Volume may be included in the Constructed Wetland.
[5]Basin Wetland Forebay: Forebay sizing must not be counted as part of WQv. Sediment Forebay Volume = 0.1-inch x Impervious area
[6]Includes "basin" volume in Basin/Wetland Design

Source: Massachusetts Stormwater Handbook.

and dry weather base flows. 10 acres is th minimum contributin drainage area, althou pocket type wetlands be appropriate for sm sites.

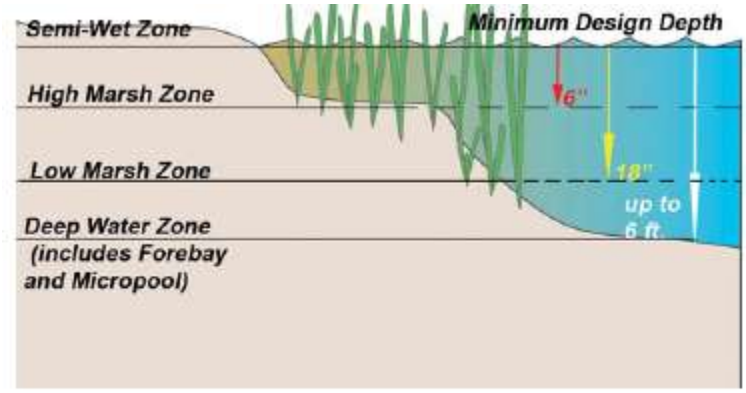
ADVANTAGES

- Relatively low maint costs.
- High pollutant remov efficiencies for both soluble pollutants an particulates.
- Removes nitrogen, phosphorus, oil and g
- Enhances aesthetics site and provides recreational benefits.
- Provides wildlife hab

LIMITATIONS

- Depending on design land requirements th other BMPs.
- Until vegetation is w established, pollutan removal efficiencies be lower than anticip
- Relatively high construction costs compared to other B
- May be difficult to maintain during exte dry periods.
- Does not provide rec
- Creates potential bre habitat for mosquitoe
- May present a safety for nearby pedestrian
- Can serve as decoy wetlands, interceptin breeding amphibians moving toward verna pools.

- Design the constructed stormwater wetlands with the recommended proportion of "depth zones." Each of the four constructed wetlands designs has depth zone locations, which are given as a percentage of the stormwater wetland surface area.



Source: Massachusetts Stormwater Handbook.

- **Deepwater Zone:** From 1.5 to 6 ft. deep. This zone supports little emergent vegetation, but may support submerged or floating vegetation. This zone can be further broken down into forebay, micropool and deepwater channels.
- **Low Marsh Zone:** Ranges from 18 to 6 in. below the pool up to the normal pool. This area is suitable for growing several emergent wetland plant species.
- **High Marsh Zone:** Ranges from 6 in. below the pool up to the normal pool. This zone will support a greater density and diversity of emergent wetland species than the low marsh zone. The high marsh zone should have a higher surface area to volume ratio than the low marsh zone.
- **Semi-wet Zone:** This zone includes those areas above the permanent pool that are intermittently inundated that can be expected to support wetland plants.
- Design each constructed stormwater wetland with the recommended proportion of treatment volumes, which have been represented as a percentage of the three basic depth zones (pool, marsh, extended detention). The Design Criteria table specifies the allocations of treatment volume per zone.
- The wetland should be designed to achieve a dry weather flow path of 2:1 (length:width) or greater. A shorter flow path may be allowable for pocket wetlands.
- Prepare a water budget to demonstrate that the water supply to the wetland is greater than the expected loss rate.
- Provide extended detention (ED) for smaller storms. The volume of the ED should be no more than 50% of the total treatment volume. The target ED detention time for this volume should be 12 to 24 hours. Use V-shaped or proportional weirs to ensure constant detention time for all storm events. For ED wetlands less than 100 acres, the ED volume can be assumed to fill

REFERENCES

- California Stormwate BMP Handbook for I Development and Redevelopment
- Massachusetts Storm Handbook

instantaneously. When using a reverse slope pipe, increase the actual diameter of the orifice to the next greatest diameter on the standard pipe schedule, because the pipe will be equipped with a gate valve. Protect the ED orifice from clogging. Make the maximum ED water surface eleation no grater than 3 ft. above the normal pool.

- Design each constructed stormwater wetland with a separate cell near the inlet to act as a sediment forebay. Design the forebay with a capacity of at least 10% of the total treatment volume, normally 4 to 6 ft. deep. Provide a direct and convenient access for cleanout.
- Surround all deep-water cells with a safety bench that is at least 10 ft. wide, and 0 to 18 in. below the normal water depth of the pool.
- Place above-ground berms or high marsh wedges at approximately 50 ft. intervals, and at right angles to the direction of the flow to increase the dry weather flow path within the wetland.
- Include a 4 to 6 ft. deep micropool before the outlet to prevent the outlet from clogging. Provide a micropool capacity of at least 10% of the total treatment volume. Use a reverse slope pipe or a hooded, broad-crested weir for outlet control. Locate the outlet from the micropool at least 1 ft. below the normal pool surface.
- To prevent clogging, install trash racks or hoods on the riser. To facilitate access for maintenance, install the riser within the embankment. Install anti-seep collars on the outlet barrel to prevent seeping losses and pipe failures. Install a bottom drainpipe with an inverted elbow to prevent clogging and to facilitate complete draining of the wetland for emergency purposes or routine maintenance. Fit both the outlet pipe and the bottom drainpipe with adjustable valves at the outlet ends to regulate flows. Design embankments and spillways in accordance with the state regulations and criteria for dam safety.
- All constructed stormwater wetlands must have an emergency spillway capable of bypassing runoff from large storms without damage to the impounding structure.
- Provide an access for maintenance, with a minimum width of 15 ft. and a maximum slope of 15%, through public or private rights-of-way. Make sure this access extends to the forebay, safety bench and outflow structure and never crosses the emergency spillway, unless the spillway has been designed and constructed for this purpose.
- Locate vegetative buffers around the perimeter of the constructed stormwater wetland to control erosion and provide additional sediment and nutrient removal.
- Establishing and maintaining wetland vegetation is important. In selecting plants, consider the prospects for success over the specific pollutant removal capabilities. Plant uptake is an important removal mechanism for nutrients, but not for other pollutants. The most versatile genera for pollutant removal area

Carex, Scirpus, Juncus, Lemna, and *Typha*. Select native species, avoiding those that are invasive. Because diversification will occur naturally, use a minimum of species adaptable to the various elevation zones within the wetland. Give priority to perennial species that establish themselves rapidly. Select species adaptable to the broadest ranges of depth, frequency and duration of inundation (hydroperiod). Match site conditions to the environmental requirements of plant selections. Take into account hydroperiod and light conditions. Give priority to species that have already been used successfully in constructed stormwater wetlands and that are commercially available. Avoid using only species that are foraged by the wildlife expected on site. Establish woody species after herbaceous species. Where applicable, add vegetation that will achieve other objectives, in addition to pollution control. Plants will develop best when soils are enriched with plant roots, rhizomes, and seed banks. Use "wetlands mulch" to enhance the diversity of the plant community and speed its establishment. Wetlands mulch is hydric soil. This mulch is available where wetland soils are removed during cleaning and dredging of drainage channels, swales, sedimentation basins, dry detention basins, infiltration basins, and natural wetlands that are scheduled to be filled under permit. Wetland soils are also available commercially. The upper 5.9 in. of donor soil should be obtained at the end of the growing season, and kept moist until installation. Drawbacks to using wetlands mulch are the unpredictable content, limited donor sites, and the potential for the introduction of exotic, opportunistic species. Enhance the development of wetland vegetation by transposing natural species from nearby wetlands. Transplanting wetland vegetation is the most reliable method of propagating wetland vegetation because it provides cover quickly. Plants are also commercially available through wetland plant nurseries.

MAINTENANCE CONSIDERATIONS

Constructed stormwater wetlands require small-scale maintenance at regular intervals to evaluate the health and composition of the plant species. Proponents must carefully observe the constructed stormwater wetland system over time.

INSPECTION CONSIDERATIONS

- In the first 3 years after construction, inspect the wetlands twice a year during both the growing and non-growing seasons. During these inspections, record and map the following information:
- The types and distribution of the dominant wetland plants in the marsh.
- The presence and distribution of planted wetland species.
- The presence and distribution of invasive wetland species.
- Indications that other species are replacing the planted wetland species.
- Percentage of standing water that is unvegetated (excluding the deep water cells which are not suitable for emergent plant growth)
- The maximum elevation and the vegetative condition in this zone, if the design

elevation of the normal pool is being maintained for wetlands with extended zones.

- Stability of the original depth zones and the micro-topographic features.
- Accumulation of sediment in the forebay and micropool and survival rate of plants in the wetland buffer.

CONSTRUCTED STORMWATER WETLANDS IN CAMBRIDGE

4.3. Extended Dry Detention Basins

DESCRIPTION

Extended dry detention basins are modified conventional dry detention basins, designed to hold stormwater for at least 24 hours to allow solids to settle and to reduce local and downstream flooding. Extended dry detention basins may be designed with either a fixed or adjustable outflow device. Pretreatment is a fundamental design component of an extended dry detention basin to reduce the potential for clogging. Other components such as a micropool or shallow marsh may be added to enhance pollutant removal.

DESIGN CONSIDERATIONS

- Maximum depth of the extended dry detention basins may range from 3 to 12 ft. The depth of the basin may be limited by groundwater conditions or by soils.
- Construct extended dry detention basins above the normal groundwater elevation (i.e. the bottom of the basin should not intercept groundwater). If runoff is from a hot spot, provide adequate pretreatment and a greater separation between the bottom of the basin and the seasonal high groundwater table. Consider whether a pervious or impervious channel lining is most appropriate.
- To be effective in reducing peak runoff rates, basin is usually located where it can intercept most of the runoff from the site, (i.e. at the lowest elevation of the site where freshwater wetlands are frequently found). Do not construct basins in wetland resource areas. Select a location that will not adversely affect wetland resource areas but will still provide the peak rate attenuation. Embankments or dams that are created to store more than 15 acre-ft. or that are more than 6 ft. high are under the jurisdiction of the state Office of Dam Safety and are subject to regulation.
- The critical parameters in sizing an extended dry detention basin are storage capacity and the maximum rate of runoff released from the basin.
- Design the extended dry detention basin to maximize the detention time for the most frequent storms. Routing calculations for a range of storms should provide the designer with the optimal basin size.
- The minimum detention time for the Water Quality Volume is 24 hours. The most traditional and easiest method for Extended Detention routing is the 24 hour brimfull drawdown (Required Water Quality Volume /24 hours = Qavg). This sets the average discharge rate, then an orifice is sized based on a max Q = 2*Qavg, using the brimfull head (Qmax = (CA(2gh)1/2) where h is the head when the

Source: US EPA National Menu of Best Management Practices

TARGETED CONSTITUENTS

- Bacteria (M)
- Metals (M)
- Nutrients (L)
- Oil and Grease (M)
- Organics (M)
- Oxygen Demand (L)
- Sediment (M)
- Trash (H)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

APPLICABILITY

- Generally not practical if contributing watershed area is less than 10 acres.
- Can be used at residential, commercial, and industrial sites.
- May be used as a treatment BMP hot spots provided bottom is lined and sealed.
- More suitable for commercial applications where there are high loadings of sediment, metals, and hydrocarbons because they have a limited capability for removing soluble pollutants.
- Not feasible for sites where land cost or space is at a premium.

basin is full to the Required Water Quality Volume (WQv) elevation, g is acceleration due to gravity, A is the net opening area, and C is the orifice coefficient. The orifice coefficient is determined by consulting tables in standard references.

- Pond side slopes should be 3% or flatter for grass stabilized slopes. Slopes steeper than 3:1 must be stabilized with an appropriate stabilization practice.
- To maximize sedimentation, design the extended dry detention basin to lengthen the flow path, thereby increasing detention time. To maximize the detention time, locate the inflow points as far from the outlet structure as possible. Long, narrow configurations with length to width ratios of 2:1 provide better removal efficiencies than small deep basins. Consider using internal berms and other baffles to minimize short-circuiting of flows and increase detention times.
- Design all inflow points with riprap or other energy dissipators, such as a baffle below the inflow structure to lengthen detention times and minimize resuspension of solids.
- A low flow channel routes the last remaining runoff, dry weather flow, and groundwater to the outlet, which should be installed in the upper stage of the basin to ensure that the extended dry detention basin dries out completely.
- Make design velocities in pervious low flow channels high enough to prevent sedimentation but low enough to prevent scouring and erosion. The maximum flow velocity (which should be set at the 2-year peak discharge rate) depends on the nature of the material used to line the channel.
- Locate the top of the impervious channel lining at or below the level of the adjacent grassed areas to ensure thorough drainage of these areas. When designing impervious channels, take into account settlement of the lining and the adjacent areas as well as the potential for frost impacts on the lining.
- Safety should be provided either by fencing of the facility or by managing the contours of the pond to eliminate dropoffs and other hazards. Earthen side slopes should not exceed 3:1 and should terminate on a flat safety bench area. Landscaping can be used to impede access to the facility. The primary spillway opening must not permit access by small children. Outfall pipes above 48 in. in diameter should be fenced.

MAINTENANCE CONSIDERATIONS

Make any necessary repairs immediately after inspections or upon general observation of problems. Mow the upper-stage, side slopes, embankment

- Sites where bedrock is close to th surface can significantly increase excavation costs and make extend dry detention basins infeasible.
- Feasibility depends on soils, deptl to bedrock, depth to water table, a space constraints.
- Existing dry detention basins can retrofitted as extended dry detenti basins.

ADVANTAGES

- Least costly BMP that controls bo stormwater quantity and quality. Relatively easy and inexpensive t construct and operate.
- Good retrofitting option for existi basins.
- Can remove significant levels of sediment and sorbed pollutants.
- Potential for beneficial terrestrial and aquatic habitat.
- Less potential for hazards than deeper permanent pools.

LIMITATIONS

- Infiltration and groundwater recharge is negligible, resulting in minimal runoff volume reduction.
- Removal of soluble pollutants is minimal.
- Requires relatively large land area
- Moderate to high maintenance requirements.
- Potential contributor to downstrea warming.
- Sediment can be resuspended afte large storms if not removed.
- Adverse aesthetics of the dry bare areas and the inlet/outlet structure can detract from the value of a property.

and emergency spillway at least twice per year. Also remove trash and debris at this time. Remove sediment from the extended dry detention basin as necessary, but at least once every 5 years. Providing on-site sediment disposal area will reduce the overall sediment removal costs.

INSPECTION CONSIDERATIONS

Inspect extended dry detention basins at least once per year to ensure that the basins are operating as intended. Inspect basins during and after major storms to determine if basin is meeting the expected detention times. Examine the outlet structure for evidence of clogging or outflow release velocities that are grater than design flow. Potential problems that should be checked include: subsidence, erosion, cracking or tree growth on the embankment, damage to the emergency spillway, sediment accumulation around the outlet, inadequacy of inlet/outlet channel erosion control measures, changes in the condition of the pilot channel, and erosion within the basin and banks. During inspections, note any changes to the extended dry detention basin or the contributing watershed, because these could affect basin performance.

EXTENDED DRY DETENTION BASINS IN CAMBRIDGE

LID ALTERNATIVES

- Bioretention Areas
- Decentralized stormwater management system that directs stormwater runoff from different sections of the site to small bioretention areas distributed throughout the site.

REFERENCES

- California Stormwater BMP Handbook for New Development and Redevelopment
- Massachusetts Stormwater Handbook
- Minnesota Urban Small Sites BM Manual

4.4. Gravel Wetlands

Source: Georgia Stormwater Management Manual.

DESCRIPTION

The gravel wetland consists of a 3-cell open flow-through treatment system consisting of a sediment forebay and two treatment cells. Gravity separation of suspended solids occurs in the sediment forebay cell. Stormwater then passes through gravel substrate through a perforated underdrain to the second cell. The gravel substrate filters suspended sediments and other constituents. Biological and physical-chemical treatment (plant uptake and soil microorganisms) occurs in the second and third cells.

DESIGN CONSIDERATIONS

- The device is designed to retain and filter the entire water quality volume (WQV)—10 percent in the forebay and 45 percent in each treatment cell.
- For small, frequent storms, each treatment cell filters 100 percent of its water quality volume. Additionally, the wetland can detain a channel protection volume of 4600 cubic ft., and release it over 24 to 48 hours.
- Water Quality volume is filtered and drains offsite. Any storm volume exceeding WQV overflows into the adjacent swale. Since standing water of significant depth is not expected (except during heavy rains, swale side slopes are graded at 3:1 or flatter for maintenance.
- The wetland is designed to continuously saturate at a depth that begins 4 in. beneath the treatment's surface. This promotes water quality treatment and vegetation growth.
- Should be designed as off-line systems designed to handle only

TARGETED CONSTITUENTS

- Bacteria (H)
- Metals (H)
- Nutrients (M)
- Oil and Grease (H)
- Organics (H)
- Oxygen Demand (M)
- Sediment (H)
- Trash (H)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

APPLICABILITY

- Intended for space-limited applications.
- Can be located in low permeability soils with high water table.

ADVANTAGES

- Generally requires low land consumption and can fit within an area typically devoted to landscaping.
- High pollutant removal capabilities expected; however, limited performance data exist.

LIMITATIONS

- High maintenance needs.

REFERENCES

- Georgia Stormwater Management Manual
- Massachusetts Stormwater Handbook
- UNH Stormwater Center

water quality volume.

- Need sufficient drainage area to maintain vegetation.
- The local slope should be relatively flat (<2%). While there is no minimum slope requirement, there does need to be enough elevation drop from the inlet to the outlet to ensure that hydraulic conveyance by gravity is feasible (generally about 3 to 5 feet).
- All gravel wetland designs should include a sediment forebay or other equivalent pretreatment measures to prevent sediment or debris from entering and clogging the gravel bed.
- Unless they receive hotspot runoff, gravel wetland systems can be allowed to intersect the groundwater table.

MAINTENANCE CONSIDERATIONS

Maintenance involves periodic mowing and replacement of vegetation as necessary. If sediment buildup is preventing flow through the wetland, remove gravel and sediment from the cell. Replace with clean gravel and replant vegetation.

INSPECTION CONSIDERATIONS

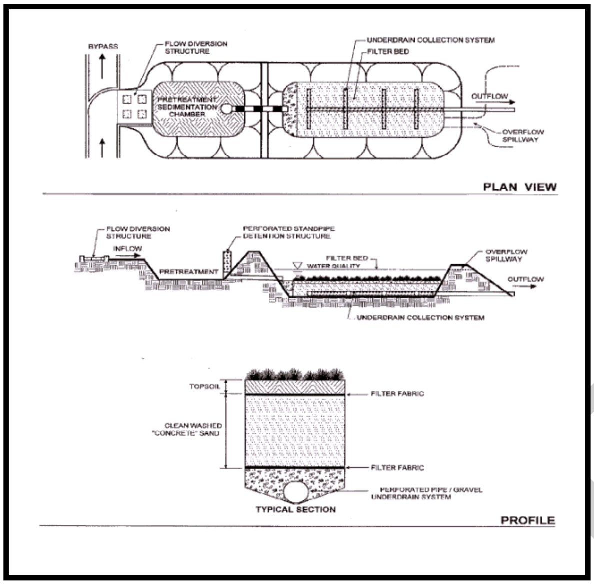
Inspect inlets and outlets to each gravel wetland cell monthly to be sure they are free from debris and not clogged. Annually, check the gravel bed for sediment buildup.

GRAVEL WETLANDS IN CAMBRIDGE

Encouraged as an LID technique.

4.5. Proprietary Media Filters

4.6. Sand/Organic Filters



Source: Stormwater Managers Resource Center, www.stormwatercenter.net

DESCRIPTION

Sand and organic filters (also known as filtration basins) are usually two-chambered including a pretreatment settling basin and a filter bed filled with sand or other absorptive filtering media. As stormwater flows into the first chamber, large particles settle out removing heavy sediment, floatable debris, and oil, before slowly filtering stormwater through self contained beds of sand or peat (or combinations of these and other materials) where finer particles and additional pollutants are removed when they become trapped between sand particles and other filter media. In some filters, microbes help remove metal and nutrient pollutants through biochemical conversion. Typically, the filters are either underlain with perforated underdrains or designed with cells and baffles with inlets/outlets. Runoff is discharged or conveyed to another BMP for further treatment. Where the potential for groundwater contamination is low and proper soils are present, the treated runoff may be allowed to infiltrate into the subsoil.

DESIGN CONSIDERATIONS

- Sand filters should be preceded by pretreatment to allow for the settling of coarse sediment that may clog the sand filter and reduce its effectiveness.
- Generally, sand filters are designed to function as stormwater quality controls, and not to provide detention for downstream

TARGETED CONSTITUENTS

- Bacteria (M)
- Metals (H)
- Nutrients (L)
- Oil and Grease (H)
- Organics (H)
- Oxygen Demand (NR)
- Sediment (H)
- Trash (H)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

APPLICABILITY

- Applicable in small drainage areas of 1 to 10 acres; although some designs may accept runoff of up to 50 acres.
- Can be applied in areas with thin soils, high evaporation rates, low soil infiltration rates and limited space.
- Can be used in ultra-urban sites with small drainage areas that are completely impervious (such as small parking lots and fast food restaurants).
- Can be applicable to many areas that are difficult to retrofit due to space limitations, such as highly developed and steeply sloped sites.
- Sand filters can be applied to areas with poor soil infiltration rates, where groundwater concerns restrict the use of infiltration, or for high pollutant loading areas.
- Should not be used in areas where heavy sediment loads are expected or on sites that

areas.

- If runoff is delivered by a storm pipe or is along the main conveyance system, filtering practice should be designed off-line.
- Most stormwater filters normally require 2 ft - 6 ft of head.
- A design filtration of 2 in./hour is recommended.
- The sand filters should be designed to completely drain in 24 hours or less.
- A minimum depth of eighteen in. of 0.02-0.04 in. diameter sand (smaller sand is acceptable) is recommended for the sand bed. Media used for organic filters may consist of peat/sand mix or leaf compost. Peat should be a reed-sedge hemic peat. 4 to 6 in. of gravel is recommended for the bed of the filter.
- The filter area should be sized based on Darcy's Law. The coefficient of permeability (k) should be used as follows:
  - Sand: 3.5 ft/day
  - Peat: 2 ft/day
  - Leaf Compost: 8.7 ft/day
- The required filter bed area is computed using the following equation

  $$\mathbf{A_f = (WQ_v)\,(d_f) \,/\, [\,(k)\,(h_f + d_f)\,(t_f)]}$$ where

  A_f = Surface area of filter bed (ft^2)

  d_f = filter bed depth (ft)

  k = coefficient of permeability of filter media (ft/day)

  h_f = average height of water above filter bed (ft)

  t_f = design filter bed drain time (days)

- An overflow should be provided within the filter to pass a percentage of the water quality volume to a stabilized water course. Additionally, overflow for the 10-year storm should be provided to a non-erosive outlet point (i.e. prevent downstream slope erosion).
- Filters should be equipped with a minimum 4" perforated pipe underdrain (6" preferred) in a gravel layer. A permeable filter fabric should be placed between the gravel layer and the filter media.
- Designs using a geotextile layer, surface screen, or a grating at the top are recommended to filter coarse sediment and debris, and for ease of maintenance.
- The careful selection of topsoil and sod for natural cover will help

have not been stabilized.

- Not applicable in areas of high water tables.

ADVANTAGES

- Have few constraints; therefore can be applied to most development sites.
- Good retrofit capability.
- Longevity of sand filters is high.
- Flexibility to provide groundwater recharge if conditions and situations allow.
- Requires a smaller area than other BMPs.
- There is no standing water in the unit between storms, minimizing opportunity for mosquito breeding.
- Media capable of removing dissolved pollutants can be selected.
- Modular concept allows the designer to more closely match the size of the facility to the design storm.
- High removal efficiencies for TSS.

LIMITATIONS

- Pretreatment required to prevent clogging.
- Frequent maintenance required.
- Relatively costly to build/install.
- An elevation difference of about 4 ft. between the inlet and outlet of the filter is usually needed.
- Without grass cover, the surface of sand filters can be extremely unattractive.

reduce the potential for failure; sod with fine silts and clays will clog the top of the sand filter.

- A dense and vigorous vegetative cover should be established over the contributing pervious areas before runoff can be accepted.
- The entire treatment system (including pretreatment) should temporarily hold at least 75% of the water quality volume prior to filtration.

MAINTENANCE CONSIDERATIONS

Sand filters require frequent manual maintenance. Raking of the sand and removal of surface sediment, trash and debris are the primary maintenance tasks. Sediment should be cleaned from the sedimentation chamber when it accumulates to a depth of more than 6 in. Vegetation within the sedimentation chamber should be limited to a height of 18 in. Sedimentation chamber outlet devices should be cleaned/repaired when drawdown times exceed 36 hours. Trash and debris should be removed as necessary. Eventually a layer of sediment will accumulate on the top of the sand. This sediment can be easily scraped off using rakes or other devices and should be removed when accumulation exceeds 1 in. Finer sediments will penetrate deeper into the sand over time, and replacement of some (several in.) or all of the sand will be necessary. Discolored sand is an indicator of the presence of fine sediments. The top few in. of discolored material should be removed and replaced with fresh material when the filtering capacity of the filter diminishes substantially (i.e. when water ponds on the surface of the filter bed for more than 48 hours). Sand removed from the filter component should be de-watered and then disposed properly. Filters with grass cover should be mowed at a minimum of 3 times per growing season to maintain grass heights of less than 12 in. Grass should be capable of withstanding frequent periods of inundation and drought. Direct maintenance access should be provided to the pretreatment area and the filter bed.

INSPECTION CONSIDERATIONS

Sand filters should be inspected after every major storm in the first few months after construction to ensure proper function. Thereafter, the sand filter should be inspected at least once every 6 months.

SAND FILTERS IN CAMBRIDGE

- May have odor problems, which can be overcome with design and maintenance.
- Generally do not provide quantity control.
- Performance reduced if underdrains or filter media freeze.

REFERENCES

- California Stormwater BMP Handbook for New Development and Redevelopment
- Massachusetts Stormwater Handbook
- Minnesota Urban Small Sites BMP Manual
- Northern Virginia Regional Commission – Maintaining Stormwater Systems Guidebook
- Stormwater Manager's Resource Center (SMRC) Website www.stormwatercenter.net

4.7. Treebox Filter

Source: Low Impact Development Center.

DESCRIPTION

The tree box filter consists of an open bottom concrete barrel filled with a porous soil media, an underdrain in crushed gravel, and a tree. Stormwater is directed from surrounding impervious surfaces through the top of the soil media. Stormwater percolates through the media to the underlying ground. Treated stormwater beyond the design capacity is directed to the underdrain where it may be directed to a storm drain, other device, or surface water discharge.

DESIGN CONSIDERATIONS

- Suggested 6 foot diameter concrete manhole riser filled with a 2 ft. thick sand-compost mix (76% sand / 24% compost). Mix should be designed to maximize permeability while providing a minimum organic matter of 10 percent to sustain tree health and adsorb pollutants.
- At the surface, install a 2 in. mulch layer and gravel pad where flow enters to dissipate energy.
- Plant a 2 in. caliper inundation-tolerant tree, hardy shrub or herbaceous vegetation in the center.
- Set an overflow approximately 6 in. above the sand-compost mix. Flows that pass through the filter media and into the overflow should be collected in the underdrain that eventually discharges onto a riprap pad and swale.
- Unit can be bottomless to allow for infiltration of water pooled in the 12 in. of high porosity crushed gravel below the underdrain. Sealed bottoms can also be used so infiltration and recharge do

TARGETED CONSTITUENTS

- Bacteria (Not reported)
- Metals (Not reported)
- Nutrients (Not reported)
- Oil and Grease (Not reported)
- Organics (Not reported)
- Oxygen Demand (Not reported)
- Sediment (H)
- Trash (H)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

APPLICABILITY

- May be used as a pretreatment device (must be lined if used in hot spot areas).
- Ideal for redevelopment or in the ultra-urban setting.
- Can be a good retrofit to existing catch basin inlets, especially in urban environments.
- Can receive runoff from both streets and parking lots, as long as a downstream inlet or outfall is present.

ADVANTAGES

- Provides decentralized stormwater treatment.
- Reduces volume and rate of runoff.

LIMITATIONS

- Treats small volumes.

not occur (hot spot locations or soils with low permeability).

MAINTENANCE CONSIDERATIONS
Occasional trash removal will be necessary. Rake media surface to maintain permeability twice per year. Replace media whenever tree is replaced.

INSPECTION CONSIDERATIONS
Inspect tree annually (expected life of tree is 5 to 10 years).

TREEBOX FILTERS IN CAMBRIDGE
Encouraged as an LID technique.

REFERENCES

- Massachusetts Stormwater Handbook
- UNH Stormwater Center

4.8. Wet Basin

Source: The Northern Virginia Soil and Water Conservation District - Fairfax County, Virginia.

DESCRIPTION

Wet basins use a permanent pool of water as the primary mechanism to treat stormwater. The pool allows sediments to settle (including fine sediments) and removes soluble pollutants. Wet basins must have additional dry storage capacity to control peak discharge rates. Wet basins have a moderate to high capacity to remove most urban pollutants, depending on how large the volume of the permanent pool is in relation to the runoff from the surrounding watershed.

DESIGN CONSIDERATIONS

- Evaluate soils and depth to bedrock before designing basin. Where bedrock is close to the surface, high excavation costs may make wet basin infeasible. IF soils on site are relatively permeable or well drained (Hydrologic Group A), it will be difficult to maintain a permanent pool. In this case, it may be necessary to line the bottom of the basin.
- Permanent pool volume should be equal to twice the water quality volume.
- Use an average pool depth of 3 to 6 ft. Water depth should not exceed 8 ft. If possible, vary depths throughout the basin.
- Use intermittent benches around the perimeter of the basin for safety and to promote vegetation. Design the safety bench to be at least 10 ft. wide and above normal pool elevations.
- Use a minimum pool surface area of 0.25 acres.

TARGETED CONSTITUENTS

- Bacteria (H)
- Metals (H)
- Nutrients (M)
- Oil and Grease (H)
- Organics (H)
- Oxygen Demand (H)
- Sediment (H)
- Trash (H)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

APPLICABILITY

- Contributing drainage area must be at least 20 acres, but not more than one square mile. Sites with less than 20 acres of contributing drainage area may be suitable only if sufficient groundwater flow is available.
- Can be used at residential, commercial, and industrial sites.
- Ideal for sites where nutrient loadings are expected to be high.
- Soils, depth to bedrock, and depth to water table are all factors for suitability of a site.
- Cannot be constructed in wetland resource areas.

ADVANTAGES

- Capable of removing both solid and soluble pollutants.
- Capable of removing nutrients and metals.
- Aesthetically pleasing.
- Can increase adjacent property values when properly planned

- The original design of wet basin depths and volumes should take into account the gradual accumulation of sediment.
- Pretreatment with a sediment forebay is required. Design sediment forebays for ease of maintenance.
- Locate the inflow points as far from the outlet structure as possible. Use a length to width ratio of at least 3:1.
- Set the invert elevation of the inlet pipe at or below the surface of the permanent pool, preferably within 1 foot of the pool.
- Establish wetland vegetation on the aquatic bench. 6 to 18 in. of water depth are needed for wetland vegetation growth.
- Make the slopes of the pools no steeper than 3:1. In addition, design the sides of the pool that extend below the safety/aquatic benches to the bottom of the pool at a slope that will remain stable, usually no steeper than 2:1.
- Design the invert of the wet basin outlet pipe to convey stormwater from approximately one foot below the pool surface and to discharge into the riser in the pond embankment. To prevent clogging, install trash racks or hoods on the riser. To facilitate maintenance, install the riser within the embankment. Place anti-seep collars or filter and drainage diaphragms on the outlet barrel to prevent seepage and pipe failure.
- Fit both the outlet pipe and the bottom drain pipe with adjustable valves at the outer end of the outlet to permit adjustment of the detention time, if necessary.
- Install a flow transition structure, such as a lined apron or plunge pad, to absorb the initial impact of the flow.
- All wet basins must have an emergency spillway capable of bypassing runoff from large storms without damaging the impounding structure. Design embankments and spillways to conform with DCR Dam Safety Regulations.
- Provide an access way for maintenance, with a minimum width of 15 ft. and a maximum slope of 15%, by public or private right-of-way. Equipment that will be used for maintenance must be capable of using this access way. This access should extend to the forebay, safety bench, and outflow structure and should never cross the emergency spillway, unless the spillway has been designed for that purpose.
- Place vegetative buffers around the perimeter of the wet basin to control erosion and remove additional sediment and nutrients. The vegetative buffer must be at least 33 feet (10 meters). Vegetation must be designed to prevent the introduction of

and sited.

- Sediment generally needs to be removed less frequently than for other BMPs.
- Can be used in retrofits.

LIMITATIONS

- More costly than extended dry detention basins.
- Larger storage volumes for the permanent pool and flood control require more land area.
- Infiltration and groundwater recharge is minimal, so runoff volume control is negligible.
- Moderate to high maintenance requirements.
- Can be used to treat runoff from hot spots if bottom is lined and sealed.
- Invasive species control required.

REFERENCES

- California Stormwater BMP Handbook for New Development and Redevelopment
- Massachusetts Stormwater Handbook

invasive species.

MAINTENANCE CONSIDERATIONS

Mow the upper-stage, side slopes, embankment and emergency spillway at least twice per year. Remove sediment, trash, and debris from the sediment forebay as necessary (at least twice per year). Remove sediment from the basin as necessary, and at least once every 10 years.

INSPECTION CONSIDERATIONS

Inspect basin to ensure it is operating as designed at least once per year. Check the sediment forebay for accumulated sediment, trash, and debris at least twice per year.

WET BASINS IN CAMBRIDGE

This is nonprinting text.
DO NOT DELETE THIS TEXT OR THE SECTION BREAK THAT FOLLOWS
(Click ¶ button on Formatting toolbar to display section breaks)

5. INFILTRATION CONTROLS

5.1. 💧 Dry Well

5.2. Infiltration Basin

Source: California Stormwater BMP Handbook, January 2003.

DESCRIPTION

Infiltration basins are shallow stormwater runoff impoundments that are constructed over permeable soils. Infiltration basins use the natural filtering ability of the soil to remove pollutants in stormwater runoff. These basins store runoff until it gradually exfiltrates through the basin floor into the soil, and eventually into the water table. Pretreatment is critical for effective performance of infiltration basins. Full exfiltration basin systems are sized to provide storage and exfiltration for the entire volume of runoff from the water quality design storm. An emergency overflow channel is used to discharge runoff volumes in excess of the design storm. Partial basin systems exfiltrate a portion of the runoff (usually the first flush or first half in.), while the remaining runoff is conveyed to other BMPs. The use of a flow splitter or weir diverts the first flush into the infiltration basin.

DESIGN CONSIDERATIONS

- The contributing drainage area to any individual infiltration basin should be restricted to 15 acres or less and base flow should not be present in the contributing watershed.
- If runoff is delivered by a storm drain pipe or along the main conveyance system, the basin must be designed off-line.
- The minimum acceptable soil infiltration rate should be 0.5 in. per hour. Maximum soil infiltration rates should not exceed 2.4 in. per hour to ensure adequate pollutant removal.
- One soil sample for every 5,000 ft of basin area is recommended, with a minimum of three samples for each infiltration basin.

TARGETED CONSTITUENTS

- Bacteria (H)
- Metals (H)
- Nutrients (H)
- Oil and Grease (H)
- Organics (H)
- Oxygen Demand (H)
- Sediment (H)
- Trash (H)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

APPLICABILITY

- Feasible at sites with gentle slopes, permeable soils, and bedrock and seasonal high groundwater levels are at least 2 ft below the surface.
- Not applicable for sites constructed of fill, having a base flow or a slope of 15% or greater.
- May not be appropriate for industrial sites or locations where spills may occur.
- Contributing drainage areas of approximately 2 to 15 acres.
- Not appropriate for areas which contribute high concentrations of sediment, or suspended solids, without adequate pretreatment.
- Should always be constructed with pretreatment. Can only be used in hot spot areas/critical areas with proper pretreatment/treatment train.
- Should not be used at sites where soils have 30% or greater clay content, or 40% or greater silt clay content.

Samples should be taken at the actual location of the proposed infiltration basin so that any localized soil conditions are detected. The design of the basin should be based on the slowest rates obtained from the infiltration tests performed at the site.

- Infiltration basins require pretreatment to remove coarse sediments and where necessary oil and grease. Exit velocities from pretreatment BMPs should be non-erosive (5 fps) during the 2-year design storm.
- Inlet channels to the basin should be stabilized to prevent incoming flow velocities from reaching erosive levels which can scour the basin floor. Riprap may be used for this purpose. The riprap should be designed to terminate in a broad apron, which spreads runoff more evenly over the basin surface to promote better infiltration.
- The depth of the infiltration basin should be adjusted so that maximum drain time is 72 hours for the total runoff volume, with a minimum retention time of 48 hours.
- The floor of the basin should be graded as flat as possible for uniform ponding and exfiltration of the runoff across the floor.
- The side slopes of the basin should be no steeper than 3:1 (horizontal:vertical)
- Embankments and spillways should be designed in conformance with the State Office of Dam Safety regulations. All infiltration basins must have an emergency spillway capable of bypassing runoff from large storms without damage to the impounding structure.
- The bottom and side slopes of the basin should be stabilized with a dense turf of water tolerant grass. In place of turf, a basin liner of 6 to 12 in. of fill material, such as coarse sand, may be used. Loose stone, riprap and other irregular materials requiring hand removal of debris and weeds should not be used.
- The site and contributing areas should be completely stabilized prior to construction of the basin and infiltration basins should not be used as temporary sediment traps during construction.
- Before the development site is graded, the area of infiltration basin should be roped off to prevent heavy equipment from compacting underlying soils.
- During and after excavation, all excavated materials should be placed downstream of the infiltration basin to prevent redeposition.
- Light-weight equipment should be used to excavate the basin.

ADVANTAGES

- Provides groundwater recharge and baseflow in nearby streams.
- Reduces the volume of runoff from a drainage area.
- Reduces local flooding.
- Preserves the natural water balance of the site.
- Reduces the size and cost of downstream stormwater control facilities and/or storm drain systems by infiltrating stormwater in upland areas.
- Provides 100% reduction in load discharges to surface waters.
- Can be used for small sites.

LIMITATIONS

- High failure rates due to improper siting, design, and lack of maintenance.
- Difficult to restore once clogged.
- Generally, use is restricted to small drainage areas.
- Depending on soil conditions, and aquifer susceptibility, a slight risk of groundwater contamination exists.
- Requires frequent maintenance.
- Not appropriate for treating significant loads of sediment and other pollutants.

SETBACK REQUIREMENTS

- Minimum of 50 ft from any slope greater than 15%.
- Minimum of 100 ft from any septic system component.
- Minimum of 100 ft from any private well and Zone I radius from any public groundwater

Since some compaction of soils will occur during construction, the basin floor should be deeply tilled with a rotary tiller or a disc harrow to restore infiltration rates after final grading.

- Design should include dewatering methods in the event of failure. This can be accomplished with underdrain systems that accommodate drawdown.

MAINTENANCE CONSIDERATIONS

Direct access to the basin for maintenance and rehabilitation should be provided. Vegetation should be managed carefully and should be trimmed at the beginning and end of the wet season. The grass in the basin, on the sideslopes and in the buffer areas should be mowed, and grass clippings, organic matter, and accumulated trash and debris removed. Eroded or barren spots should be reseeded immediately after inspection and stabilized with erosion control mulch or mat until new vegetation is established. To avoid reversing soil development, scarification or other disturbance should only be performed when there are actual signs of clogging, rather than on a routine basis. Always removed deposited sediments before scarification and use a hand-guided rotary tiller, if possible, or a disc harrow pulled by a very light tractor. Deep tilling can be used to break up a clogged surface area. Any tilled areas should be revegetated immediately. Accumulated sediment should be removed from the basin when the accumulated sediment volume exceeds 10% of the basin. The basin should be regraded at this time. Removal procedures should not take place until the floor of the basin is thoroughly dry.

INSPECTION CONSIDERATIONS

Infiltration basins should be inspected after every major storm for the first few months after construction to ensure proper stabilization and function. Thereafter, the basin should be inspected at least twice per year. Pretreatment BMPs should be inspected and the accumulated sediment removed at least twice a year, ideally after every major rainfall event or every other month.

INFILTRATION BASINS IN CAMBRIDGE

drinking supplies (additional setback distance may be required depending on hydrogeological conditions).

- Zone A from any surface water supply and its tributaries (400 ft. from surface supply and 100 ft. from its tributary).
- Minimum of 100 ft. from any surface water of the Commonwealth (other than drinking water supplies and their tributaries).
- Minimum of 10 ft. downslope and 100 ft. upslope from any building foundations.

REFERENCES

- California Stormwater BMP Handbook for New Development and Redevelopment
- Massachusetts Stormwater Handbook
- Minnesota Urban Small Sites BMP Manual
- Stormwater Manager's Resource Center (SMRC) Website www.stormwatercenter.net

5.3. Infiltration Trench

Source: California Stormwater BMP Handbook, January 2003.

DESCRIPTION

Infiltration trenches are shallow excavations with no outlet that are filled with stone to create underground reservoirs for stormwater runoff. Runoff is stored in the void spaces between the stone and then gradually exfiltrates through the bottom of the trench into the subsoil and eventually into the water table. Trench designs may be modified to include vegetative cover and other features, establishing a biofiltration area. Infiltration trenches may be designed for complete exfiltration or partial exfiltration where a portion of the runoff volume is routed to the trench and the remainder is conveyed to additional BMPs. Complete exfiltration is preferred.

DESIGN CONSIDERATIONS

- Soils should have a minimum percolation rate of 0.5 in. per hour. The final soil infiltration rate below the trench is determined by a geotechnical study. A minimum of 2 borings should be taken for each infiltration trench. Trenches over 100 ft in length should include at least one additional sample for each 50 ft increment. Borings should be taken at the actual location of the proposed trench to identify localized soil conditions. The design of the infiltration trench should be based on the slowest rate obtained from the infiltration tests performed at the site. Maximum infiltration rartes should not exceed 2.4 in. per hour.
- Pretreatment should be a fundamental component of any BMP system relying on infiltration. Additionally, a vegetated buffer (20 ft minimum) around surface trenches is recommended. Exit

TARGETED CONSTITUENTS

- Bacteria (H)
- Metals (H)
- Nutrients (H)
- Oil and Grease (H)
- Organics (H)
- Oxygen Demand (H)
- Sediment (H)
- Trash (H)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

APPLICABILITY

- Feasible at sites with gentle slopes, permeable soils, and where bedrock and seasonal high groundwater levels are at least 4 ft below the surface.
- Contributing drainage areas should not exceed 5 acres.
- Suitable for parking lots, rooftop areas and small residential developments.
- Should always be constructed with pretreatment. Can only be used in hot spot areas/critical areas with proper pretreatment/treatment train.
- Can be used in upland areas of larger sites to reduce the overall runoff and improve water quality.
- Adaptable to many sites because of thin profile and space requirements (small). Make good stormwater retrofits.
- Should not be used at sites where soils have 30% or greater clay content, 40% or greater silt clay content.
- Best used to infiltrate first

velocities from pretreatment BMPs should be non-erosive (5 fps) during the 2-year design storm.

- Slopes of the contributing drainage areas should not be steep, and generally should not exceed 5%. Infiltration trenches should not be located on slopes greater than 6% or within fill soils.
- Permeable filter fabric should be placed 6 to 12 in. below the surface of the trench, along the sides, and at the bottom of the trench. The cut width of the filter fabric must have sufficient material for a minimum 12 in. overlap (when overlaps are required between rolls, the upstream roll must lap a minimum of 2 ft over the downstream roll to provide a shingled effect). Using filter fabric, especially at the surface will help prevent clogging; if failure does occur, it can be alleviated without reconstruction of the trench. A 6 to 12 in. layer of sand (VDOT Fine Aggregate – Grading A or B) may be substituted or added to the bottom of the trench.
- Volume and surface area of an infiltration trench are related to the quantity of runoff entering from the contributing area. Depth of the infiltration trench should be adjusted so that the maximum drain time is 72 hours for the total runoff volume, with a minimum retention time of 48 hours.
- Trench should be filled with 1.5 – 3.0 in. diameter, clean washed stone. The stone should be placed in the trench in lifts and lightly compacted with plate compactor to form the base course. The surface of the trench should also be lined with permeable filter fabric and then capped with topsoil or more aggregate stone.
- The maximum depth of the trench must be at least 2 ft above seasonal high groundwater or bedrock, and below the frost line.
- An observation well should be installed at the center of the trench to monitor runoff clearance from the system. This well should consist of an anchored vertical 4”- 6” diameter perforated PVC pipe with a lockable aboveground cap installed flush with the ground surface.
- Heavy equipment should not operate on the surface location where the infiltration trench is planned. Soil compaction will adversely affect the performance of the trench. The site should be roped off and flagged. Manual excavation or light earth-moving equipment is recommended. All excavated material should be located downgradient of the trench site to prevent redeposition.
- The site and contributing areas should be stabilized prior to construction of the trench. Infiltration trenches should never be used as temporary sediment traps. Diversion berms or staked and

in./half inch of runoff from frequent small storms.

ADVANTAGES

- Promotes groundwater recharge.
- Reduces downstream flooding and protects streambank integrity.
- Preserves the natural water balance of the site.
- Provides a high degree of runoff pollution control when properly designed and maintained.
- Provides 100% reduction in load discharged to surface waters.
- Reduces the size and cost of downstream stormwater control facilities and/or storm drain systems by infiltrating stormwater in upland areas.
- Utilized where space is limited. As an underground BMP, they are unobtrusive and have little impact of site aesthetics.

LIMITATIONS

- High failure rates due to improper siting, design, construction and maintenance. Rehabilitation requires complete reconstruction.
- Generally, use is restricted to small drainage areas.
- Not suitable on fill sites or steep slopes (greater than 6%).
- May not be appropriate for industrial sites or locations where spills may occur.
- Depending on soil conditions, and aquifer susceptibility, a slight risk of groundwater contamination exists.
- Susceptible to clogging by sediment and requires frequent maintenance.

lined hay bales can be used around the perimeter of the trench during its construction.

- Design should include dewatering methods in the event of failure. This can be accomplished with underdrain systems that accommodate drawdown.

MAINTENANCE CONSIDERATIONS

Direct access should be provided to the infiltration trench for maintenance and rehabilitation. Because infiltration trenches are prone to failure due to the clogging of the porous soils, it is imperative that aggressive maintenance plans and schedules be developed and implemented. The use of pretreatment BMPs will significantly minimize maintenance requirements of the trench itself. Preventive maintenance should be performed at least twice a year. Ideally sediment and oil/grease should be removed from pretreatment BMPs after every major storm event and monthly. Grass clippings, leaves, and accumulated sediment should be removed monthly from the surface of the trench. When ponding occurs at the surface or in the trench, corrective maintenance is required immediately. If the clogging appears to be only at the surface, it may be necessary to remove and replace the topsoil or first layer of stone aggregate and the filter fabric. Ponding water in the trench indicates infiltration failure from the bottom. In this case, all of the stone aggregate and filter fabric or media must be removed. Accumulated sediment should be stripped from the trench bottom. At this point, the bottom may be scarified or tilled to help induce infiltration. Additionally, all dimensions of the trench should be increased by 2 in. to provide fresh surface for infiltration. New fabric and clean stone aggregate should be refilled.

INSPECTION CONSIDERATIONS

Infiltration trenches should be inspected after the first several rainfall events, after all major storms (2-year), and on regular bi-annual scheduled dates. Ponded water inside the trench (as visible from the observation well) after 24 hours or several days often indicates that the bottom of the trench is clogged. Water ponded at the surface of the trench may indicate only surface clogging. Pretreatment BMPs should be inspected during the regular biannual inspections.

INFILTRATION TRENCHES IN CAMBRIDGE

- Can be difficult to site in dense urban settings, due to the required separation from foundations and because urban soils often have poor infiltration capacity due to many years of compaction.
- Not effective for infiltrating runoff from large storms – overflow should be directed to a swale or other conveyance.

SETBACK REQUIREMENTS

- Minimum of 100 ft from any slope greater than 5% to any surface-exposed trench.
- Minimum of 100 ft from any slope greater than 20% to any underground trench.
- Minimum of 100 ft from any septic system component.
- Minimum of 100 ft from any private well and Zone I radius from any public groundwater drinking supplies (additional setback distance may be required depending on hydrogeological conditions.
- Zone A from any surface water supply and its tributaries (400 ft. from surface supply and 100 ft. from its tributary).
- 150 ft downslope and 100 ft upslope from any surface water of the Commonwealth (other than drinking water supplies and their tributaries).
- Minimum of 20 ft from any building foundations.
- Minimum 10 ft from paved areas to prevent frost heave (where possible).

REFERENCES

- California Stormwater BMP Handbook for New Development and Redevelopment
- Massachusetts Low Impact Development Toolkit

www.mapc.org/lid

- Massachusetts Stormwater Handbook
- Stormwater Manager's Resource Center (SMRC) Website www.stormwatercenter.net

5.4. Leaching Catch Basin

5.5. Subsurface Structure

City of Cambridge, Massachusetts

Department of Public Works

147 Hampshire Street • Cambridge, MA 02139

APPENDIX A DRAFT Best Management Practices

Sections 6 - 7

Version 4/23/08

Report Prepared By:

Cambridge Department of Public Works and

Malcolm Pirnie, Inc.
601 Edgewater Drive
Suite 360
Wakefield, MA 01880
781-224-4488

5400001

Contents

This is nonprinting text.
DO NOT DELETE THIS TEXT OR THE SECTION BREAK THAT FOLLOWS
(Click ¶ button on Formatting toolbar to display section breaks)

6. CONVEYANCE CONTROLS

6.1. Drainage Channel

DESCRIPTION

Drainage channels are open channel systems with vegetation that are designed to have sufficient capacity to safely convey runoff during large storm events without causing erosion. Drainage channels typically have a cross-section with sufficient hydraulic capacity to handle the peak discharge for the 10 year storm event. Channel dimensions (slope and bottom width) should not exceed a critical erosive velocity during the peak discharge. Drainage channels should maintain some type of grass or channel lining to maintain bank and slope integrity. Other than basic channel size and geometry, there are no other design modifications to enhance pollutant removal capabilities. Therefore, pollutant removal efficiency is typically very low for drainage channels, and drainage channels receive no infiltration or TSS removal credit. The distinction between drainage channels and water quality swales lies in the design and planned use of the open channel conveyance. Water quality swales and grass channels (formerly biofilter swales) incorporate specific features to enhance stormwater pollutant removal.

DESIGN CONSIDERATIONS

- The two primary design considerations are maximumizing channel capacity and minimizing erosion. Use the maximum expected retardance when checking drainage channel capacity. Usually the greatest flow retardance occurs when vegetation is at its maximum growth for the year. This usually occurs during the early growing season and dormant periods.
- Shape of the cross-sectional channel is important. The V-shaped or triangular cross-section can result in higher velocities than other shapes, so use this shape only if quantity of flow is relatively small. Parabolic cross-section results in a wide shallow channel that is suited to handling larger flows and blends in well with natural settings. Use trapezoidal channels when deeper channels are needed to carry larger flows and conditions require relatively high velocities.

Source: www.chesapeakebay.net, Stormwater Management webpage.

TARGETED CONSTITUENTS

- Bacteria (insufficient data)
- Metals (insufficient data)
- Nutrients (insufficient data)
- Oil and Grease (insufficient data)
- Organics (insufficient data)
- Oxygen Demand (insufficient data)
- Sediment (NR)
- Trash (L)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

APPLICABILITY

- Residential and institutional areas of low to moderate density.
- Where percentage of impervious cover in the contributing areas is relatively small.
- Can be used in parking lots to break up areas of impervious cover.
- Along the edge of roadways in place of curb and gutter

- Minimum channel length of 100 ft. is generally recommended for sufficient contact time and flow dissipation.
- Low velocity channels may act as sediment traps. If this is the case, extra capacity should be added for sediment accumulation without reducing design capacity. An extra 0.3 to 0.5 ft. of freeboard depth is recommended if sediment storage is expected.
- Side slopes of 3:1 or flatter are recommended for maintenance and to prevent side slope erosion. The longitudinal slope of the channel should be as close to zero as possible and not greater than five percent.
- Select a grass type for the channel lining that is appropriate for site conditions, including one that is able to resist shear from the design flow, is shade tolerant, is water tolerant, and has low maintenance requirements. Use vegetation that has a dense root system. Alternatively, drainage channel may be lined with stone.
- Generally the maximum design velocity for drainage channels should not exceed 5 ft. per second. The channel should be non-erosive for the 2-year storm. Check dams can be installed in channels when necessary to achieve 5 fps velocity. Do not use earthen check dams. The maximum ponding time behind the check dam should not exceed 24 hours.
- Outlet protection must be used at discharge points from a drainage channel to prevent scour at the outlet.
- Water quality volume should be retained or infiltrated in 24 hours.
- Pretreatment required is required. A small forebay or filter strip is recommended.
- Provided an underdrain and prepared soil bed if infiltration rate of underlying soil is less than 1 in. per hour to promote filtration.
- During construction, use temporary erosion and sediment controls. Soil amendments, such as aged compost that contains no biosolids, may be needed to encourage vegetation growth. Seeding will require mulching with appropriate materials, such as mulch matting, straw, wood chips, other natural blankets, or synthetic blankets. Provide new seedlings with adequate water until they are well established.
- The design must include access for maintenance. When drainage channels are located along a street, off-street parking can be doubled up as the access, provided signs are posted indicating no parking is allowed during maintenance periods.

systems, though the number of driveway culverts can reduce the effectiveness and they are generally not compatible with extensive sidewalk systems. When using in combination with roadways and sidewalks, it is most appropriate to place between two impervious covers (e.g. between sidewalk and roadway.

- May be used to achieve temperature reduction for runoff discharging to coldwater fisheries.

ADVANTAGES

- Conveys stormwater.
- Generally less expensive than curb and gutter systems.
- Roadside channels reduce driving hazards by keeping stormwater flows away from street surfaces during storms.
- Accent natural landscape.
- Compatible with LID design practices.

LIMITATIONS

- Higher degree of maintenance required than for curb and gutter systems.
- Roadside channels are subject to damage from off street parking and snow removal.
- Provides limited pollutant removal compared to water quality swales.
- May be impractical in areas with flat grades, steep topography, or poorly drained soils.
- Large area requirements for highly impervious sites.

REFERENCES

- California Stormwater BMP

When locating channels adjacent to pervious surfaces, include a 15 ft. wide grass strip to provide access for maintenance strips.

MAINTENANCE CONSIDERATIONS

Regular maintenance of drainage channels includes mowing, fertilizing, liming, watering, pruning, and weed and pest control. Channels should be mowed as necessary. The grass must not be cut shorter than 3 or 4 in. but should not exceed 6 in. Excessive mowing is discouraged. Sediment and debris should be removed manually, at least once per year, before the vegetation is impacted adversely. Sediment build-up within the bottom of the channel should be removed when 25% of the original water quality volume has been exceeded. Periodic reseeding may be necessary. Care should be taken to protect drainage channels from snow removal procedures and off street parking.

INSPECTION CONSIDERATIONS

Drainage channels should be inspected on a semi-annual basis; additional inspections should be scheduled during the first few months to make sure that the vegetation in the channels is established adequately and for signs of rilling and gullying. The drainage channels should be inspected for slope integrity, soil moisture, vegetative health, soil stability, soil compaction, soil erosion, ponding, and sedimentation.

DRAINAGE CHANNELS IN CAMBRIDGE

Encouraged as an LID technique. Drainage channels cannot be used to meet the stormwater management standards. They are a component of a larger stormwater management system and serve to convey runoff from impervious surfaces to or from stormwater treatment BMPs.

Handbook for New Development and Redevelopment

- Massachusetts Stormwater Handbook
- Stormwater Manager's Resource Center (SMRC) Website www.stormwatercenter.net

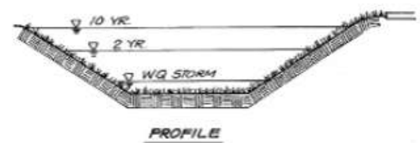
6.2. ♦ Grassed Channels/Biofilter Swales

DESCRIPTION

Grassed Channels (formerly known as Biofilter swales) are conveyance and treatment systems with a longer hydraulic residence time (HRT) than drainage channels. The removal mechanisms are sedimentation and gravity separation, rather than filtration. To receive TSS credit, a sediment forebay or equivalent must be provided for pretreatment. Note that the sediment forebay does not receive a separate TSS removal credit. Grassed channels differ from swale, bioretention, and drainage channels in various ways. Dry water quality swales contain a specific soil media mix and underdrain, providing greater treatment. Wet water quality swales are designed with a permanent wet channel, whereas grass channels must be designed to completely drain between storm events. Bioretention areas are designed solely for treatment and not for conveyance. Drainage channels act solely as conveyance, in contrast to properly designed grassed channels where runoff flow is deliberately lagged to provide some level of treatment.

DESIGN CONSIDERATIONS

- **Sizing (water quality volume):** Design grassed channels to maximize contact with vegetation and soil surface to promote greater gravity separation of solids during the storm associated with the water quality event (either ½ inch or 1-inch runoff). Design the channel such that the velocity does not exceed 1 fps during the 24-hour storm associated with the water quality event. For design purposes, do not allow the water depth during the storm event to exceed 2/3 the height of the grass or 4 inches, whichever is less. Make sure the selected design storm provides at least 9 minutes of HRT within the channel. Increasing the HRT beyond 9 minutes increases the likelihood of achieving the 50% TSS removal efficiency. Adding meanders to the swale increases its length and may increase the HRT.
- **Sizing (conveyance):** Design grassed channels to convey both the 2-year and 10-year 24-hour storms. Provide a minimum of 1 ft. freeboard above the 10-year storm. Make sure that the runoff velocities during the 2-year 24-hour storm do not cause erosion problems.
- **Sizing (other):** Channel length depends on design factors to achieve the minimum 9-minute residence time for the storm



Source: Massachusetts Stormwater Handbook, February 2008.

TARGETED CONSTITUENTS

- Bacteria (L)
- Metals (M)
- Nutrients (L)
- Oil and Grease (M)
- Organics (M)
- Oxygen Demand (M)
- Sediment (M)
- Trash (L)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

APPLICABILITY

- Ideal when used adjacent to roadways or parking lots, where runoff from the impervious surfaces can be directed to the channel via sheet flow.
- Roadside ditches should be regarded as significant potential grassed channel/swale/buffer strip sites and should be utilized for this purpose whenever possible.
- Not suitable for vernal pools or bathing beaches. At other critical

associated with the water quality event. The channel should be not less than 100 ft. in length. Channel width should be determined using Manning's Equation at the peak of the design storm, using a value of 0.25 for Manning's n. The maximum bottom width of the channel should not exceed 10 ft. unless a dividing berm is provided. The longitudinal slopes should not exceed 2.5%.

- **Shape:** Trapezoidal channels are normally recommended but other configurations, such as parabolic, can also provide water quality improvement and may be easier to mow than designs with sharp breaks in slope.
- **Channel Crossings:** In residential settings, driveways will cross over the channel, typically via culverts (pre-cast concrete, PVC, or corrugated metal pipe).
- **Soils:** Grassed channels may be constructed from most parent soils, unless the soils are highly impermeable. Soils must be able to support a dense grass growth. MassDEP recommends sandy loams with an organic content of 10 to 20%, and no more than 20% clay. Highly impermeable soils, such as clays, are not suitable for grass channels, because they do not support dense grass stands. Similarly, gravelly and coarse soils may not be suitable due to their lower moisture retention capability, leading to potential die-back of the grass lining during the summer when the inter-event period between storms is longer than during other times of the year.
- **Grasses:** The grasses serve to stabilize the channel, and promote conditions suitable for sedimentation, such as offering resistance to flow, which reduces water velocities and turbulence. Select a grass height of 6 inches or less. Grasses over that height tend to flatten when water flows over them, inhibiting sedimentation. Select grasses that produce a fine, uniform and dense cover that can withstand varying moisture conditions. Select grasses that are salt tolerant to withstand winter deicing of roadways. In the spring, replant any areas where grasses died off due to deicing.
- **Pea Gravel Diaphragm:** Use clean bank-run gravel, conforming to ASTM D 448, varying in size from 1/8 inch to 3/8 inch (No. 6 stone).
- **Inlet/Outlet:** If flow is to be introduced to the channel through curb cuts, place pavement slightly above the elevation of the vegetated areas. Curb cuts should be at least 12 in. wide to prevent clogging. Outlet protection must be

areas, may be used as a pretreatment device.

- Typically not suited for retrofits.
- No infiltration credit.
- Achieves 50% TSS removal with adequate pretreatment.

ADVANTAGES

- Provides pretreatment if used as the first part of a treatment train.
- Open drainage system aids maintenance.
- Accepts sheet or pipe flow.
- Compatible with LID design measures.
- Little or no entrapment hazard for amphibians or other small animals.

LIMITATIONS

- Short retention time does not allow for full gravity separation.
- Limited biofiltration provided by grass lining – cannot alone achieve 80% TSS removal.
- Must be designed carefully to achieve low flow rates for Water Quality Volume purposes (<1,0 fps).
- Mosquito control considerations.

REFERENCES

- California Stormwater BMP Handbook for New Development and Redevelopment
- Massachusetts Stormwater Handbook

used at discharge points to prevent scour downstream of the outlet.

- **Construction Considerations:** Stabilize the channel after it is shaped before permanent turf is established, using natural or synthetic blankets. Never allow grassed channels to receive construction period runoff.

MAINTENANCE CONSIDERATIONS

Maintenance access must be designed as part of the grass channel. If located adjacent to a roadway, make the maintenance access at least 15 feet wide, which can also be combined with a breakdown lane along a highway or on-street parking along a residential street. When combined with on-street parking, post signs prohibiting parking when the channel is to be inspected and cleaned. Do not use travel lanes along highways and streets as the required maintenance access. Mow the channel on an as-needed basis during the growing season so that the grass height does not exceed 6 inches. Set the mower blades no lower than 3 to 4 in. above the ground. Do not mow beneath the depth of the design flow during the storm associated with the water quality event (e.g., if the design flow is no more than 4 inches, do not cut the grass shorter than 4 inches). Cuttings should be removed from the channel and disposed of in a local composting facility. Other vegetation maintenance includes weed control, watering during drought conditions, and reseeding of bare areas. Minimize the use of fertilizers and pesticides. Repair damaged areas within the channel. For ruts or holes, repair with a suitable soil that is properly tamped and seeded. Grass cover should be thick. If it is not, reseed as necessary. Any standing water removed during maintenance must be disposed to a sanitary sewer at an approved location (permits may be required). Remove accumulated trash and debris prior to mowing. Monitor accumulated sediment on a yearly basis and clean as needed when sediment accumulation reaches 25% of the channel volume. Use hand methods (i.e., a person with a shovel) when cleaning to minimize disturbance to vegetation and underlying soils.

INSPECTION CONSIDERATIONS

Inspect semi-annually during the first year, and at least once a year thereafter. Inspect the grass for growth and the side slopes for signs of erosion and formation of rills and gullies. Plant an alternative grass species if the original grass cover is not successfully established. If grass growth is impaired by winter road salt or other deicer use, re-establish the grass in the spring. Regularly inspect for pools of standing water (during dry periods) and for trash and debris. Annually, monitor sediment accumulation.

GRASSED CHANNELS IN CAMBRIDGE

Encouraged as an LID technique. Recommended for use along roadways with available space.

6.3. Water Quality Swale (Wet & Dry)

Source: California Stormwater BMP Handbook, January 2003.

TARGETED CONSTITUENTS

- Bacteria (L)
- Metals (M)
- Nutrients (M)
- Oil and Grease (M)
- Organics (M)
- Oxygen Demand (M)
- Sediment (M)
- Trash (L)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

DESCRIPTION

Water quality swales are designed primarily for the prescribed stormwater water quality volume and have incorporated specific features to enhance their stormwater pollutant removal effectiveness. Pollutant removal rates are significantly higher for water quality swales than for drainage channels. Water quality swales include dry swales, wet swales, and grassed swales or "biofilters". Swales can slow runoff, filter it, and promote infiltration into the ground. As a result, runoff volumes are smaller, peak discharge rates are lower, and runoff is cleaner. Swales are not just ditches under another name – they must be carefully designed and maintained to function properly.

DESIGN CONSIDERATIONS

- During construction, it is important to stabilize the channel until vegetation is established.
- Pretreatment is typically a forebay behind a checkdam. Gentle slopes or pea gravel diaphragms for runoff entering the sides of the swale (lateral sheet flow) can be used.
- Check dams can be utilized to establish multiple cells. Check dams at 50-ft intervals (<2' drop) help to maximize retention time, increase infiltration, promote particulate settling, and decrease flow velocities.
- If flow is to be introduced to the channel through curb cuts, place pavement slightly above the elevation of the vegetated areas. Curb cuts should be at least 12 in. wide to prevent

APPLICABILITY

- Residential and institutional areas of low to moderate density.
- Where percentage of impervious cover in the contributing areas is relatively small – for larger areas, use multiple swales.
- Can be used in parking lots to break up areas of impervious cover.
- Along the edge of roadways in place of curb and gutter systems. Roadside ditches should be regarded as significant potential grass channel/swale/buffer strip sites and should be utilized for this purpose whenever possible.
- May not be applicable to sites with many driveway culverts or extensive sidewalk systems.
- Wet swales may not be desirable for some residential applications because standing/stagnant water may be present at times.
- Should not be used in areas

clogging.

- Should be designed to capture and treat the entire prescribed stormwater runoff water quality volume.
- The longitudinal slope in the water quality swale is generally between 1% and 2% and should not exceed 4%. Minimum slope of ½%.
- The flat bottom of the trench should be between 2 ft and 8 ft wide.
- Swales should follow natural topography and drainage patters to the extent possible.
- Side slopes of 3:1 or flatter are recommended for maintenance and to prevent side slope erosion. Runoff velocities should not cause erosion for the 2 year stormwater runoff event. The swale should be sized to convey the 10 year storm volume with a minimum of 6 in. of freeboard.
- Maximum allowable ponding time is 48 hours.
- Dense vegetative cover required for proper treatment.
- Dry swales require 30 in. deep bed of well drained soils, consisting of about 50% sand and 50% loam, and the bottom of the swale should be separated from groundwater by at least 2 ft. Onsite soils may be enhanced, and where well drained soils do not exist, a perforated underdrain should be utilized.
- Wet swales require saturated soil conditions to support wetland vegetation and intersection with groundwater helps. Check dams must be utilized to establish multiple cells.
- Grassed swales should be sandy loam or a similar soil type with no more than 20% clay. Soil augmentation may be necessary. Dense grass cover must be achieved. These swales should be designed to retain the water quality volume for a minimum of 10 minutes with no greater than a 1.0 fps velocity.
- Outlet protection must be used at any discharge point from a water quality swale to prevent scour.

MAINTENANCE CONSIDERATIONS

Regular maintenance of swales includes mowing, fertilizing, liming, watering, pruning, and weed and pest control. Swales should be mowed as needed to maintain a grass height of 4” – 6”. The grass must not be cut shorter than four in. in order to maintain the swale’s effectiveness in reducing flow velocity and pollutant removal. Grass cuttings should be removed from the swale and composted. Sediment and debris should be removed manually, at least once per year.

where pollutant spills are likely.

ADVANTAGES

- Controls peak discharges by reducing runoff velocity and promoting infiltration (especially for dry swales)
- Provides pretreatment by trapping, filtering and infiltrating particulate and associated pollutants.
- Generally less expensive than curb and gutter systems.
- Roadside swales provide water quality and quantity control benefits, while reducing driving hazards by keeping stormwater flows away from street surfaces.
- Can act as a snow storage/treatment area as long as salt tolerant plants are used, such as creeping bentgrass.
- Accent natural landscape – can increase the value and attractiveness of a site as well as appeal to neighbors and regulatory boards.

LIMITATIONS

- Higher degree of maintenance required than for curb and gutter systems.
- Roadside swales are subject to damage from off street parking and snow removal.
- Cannot treat a very large drainage area.
- Standing water in wet swales may create a mosquito-breeding situation.
- Must be designed and maintained correctly for pollutant removal.

Sediment buildup within the bottom of the channel should be removed when 25% of the original water quality volume is exceeded. Periodic reseeding may be required to maintain the dense growth of vegetation. Care should be taken to protect water quality swales from snow removal and disposal practices and off street parking that can cause rutting or soil compaction. Irrigate only as necessary to prevent vegetation from dying and minimize application of fertilizers and pesticides. Regularly remove trash and/or obstructions that cause standing water. At least annually, remove sediment from pea gravel diaphragm and correct associated problems.

INSPECTION CONSIDERATIONS

Swales should be inspected on a semi-annual basis and after storm events; additional inspections should be scheduled during the first few months to make sure that the vegetation in the swale is established adequately. Swales should be inspected for slope integrity, soil moisture, vegetative health, soil stability, soil compaction, soil erosion, ponding and sedimentation. Inspect pea gravel diaphragm at least annually for clogging from excess sediment.

DRAINAGE CHANNELS IN CAMBRIDGE

Encouraged as an LID technique. ADD items from Concord-Alewife LID Appendix here.

This is nonprinting text.
DO NOT DELETE THIS TEXT OR THE SECTION BREAK THAT FOLLOWS
(Click ¶ button on Formatting toolbar to display section breaks)

REFERENCES

- California Stormwater BMP Handbook for New Development and Redevelopment
- Massachusetts Low Impact Development Toolkit www.mapc.org/lid
- Massachusetts Stormwater Handbook
- Minnesota Urban Small Sites BMP Manual
- Site Owners' Guide to Stormwater - BMPs in a Flash www.stormwaterauthority.org
- Stormwater Manager's Resource Center (SMRC) Website www.stormwatercenter.net

7. OTHER CONTROLS

7.1. Dry Detention Basin

DESCRIPTION

A dry detention basin is an impoundment or excavated basin for the short-term detention of stormwater runoff from a completed development that allows a controlled release from the structure at downstream, pre-development flow rates. Conventional dry detention basins typically control peak runoff for 2-year and 10-year 24-hour storms. They are not specifically designed to provide extended dewatering times, wet pools, or groundwater recharge. Sometimes flows can be controlled using an outlet pipe of the appropriate size but this approach typically cannot control multiple design storms. Compared to extended dry detention basins or wet basins, dry detention basins have an extremely limited ability to remove TSS. A dry detention basin is designed to empty out completely in less than 24 hours, resulting in limited settling of sediments and the potential for resuspension. Dry detntion basins have traditionally been one of the most widely used stormwater best management practices. In some instances, these basins may be the most appropriate BMP. However, they should not be used as a one size fits all solution. In many cases, smaller-sized BMPs are most appropriate.

DESIGN CONSIDERATIONS

- Investigate soils. If soils are impermeable (Soil Group D), a dry detention basin may experience problems with standing water. If soils are highly permeable (Soil Group A), it will be difficult to establish a shallow marsh component in the basin.
- Recommend at least 4 acres of drainage area for each acre-ft. of storage in the basin.
- Maximum depth of basins typically ranges from 3 to 12 ft. Depth of the basin may be limited by groundwater conditions or by soils. Locate basin above the normal groundwater elevation (basin bottom should not intercept groundwater).
- Design dry detention basins to store the volume required to meet the peak rate attenuation requirements of the standards

Source: Massachusetts Stormwater Handbook, February 2008.

TARGETED CONSTITUENTS

- Bacteria (L)
- Metals (L)
- Nutrients (L)
- Oil and Grease (L)
- Organics (L)
- Oxygen Demand (L)
- Sediment (NR)
- Trash (M)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

APPLICABILITY

- Used solely for water quantity control to attenuate peak flows and limit downstream flooding.
- May be used as part of a treatment train (in addition to required water quality BMPs). Size of basin can be substantially decreased if placed at the end of the treatment train.
- Generally not practical if the contributing drainage area is less than 10 acres.

listed in Section 3 of the Stormwater Management Guidelines. In some cases, compliance with the standards may require flood storage volume to prevent an increase in off-site flooding from the 100-year 24-hour storm.

- Stormwater should be conveyed to and from the basin safely in a manner that minimizes the erosion potential. Low flows should be conveyed through the system by a pilot channel (surface channel).
- Design a multiple stage outlet structure to control peak discharges for the 2-year and 10-year 24-hour storms. Provide an emergency spillway. Build the spillway in the existing ground—not in the embankment. Make the interior embankment slopes no greater than 3:1. To provide drainage, make the minimum slope of the bottom 2%. Provide access for maintenance. Design embankments to meet safety standards. Stabilize the earthen slopes and the bottom of the basins using seed mixes recommended by National Resources Conservation Service. Embankments or dams that store greater than 15 acre-ft. or that are greater than 6 ft. high are regulated by the Office of Dam Safety.
- Impervious channels are recommended because they are simple to construct and easy to maintain. They can be designed to empty completely after a storm. Locate the top of the impervious channel lining at or below the level of the adjacent grassed areas to ensure thorough drainage of these areas. When designing the channels, consider settlement of the lining and the adjacent areas, the potential for frost impacts on the lining and to potential for erosion or scour along the edges of the lining cause by bank-full velocities. Provide impervious linings with broken stone foundations and weep holes. Design the channel to maintain a low outflow discharge rate at the downstream end. Use low-flow underdrains, connected to the principal outlet structure or other downstream discharge point. Consider the depth of the low flow channel when preparing the final bottom-grading plan.
- Design the outlet to control the outflow rate without clogging. Locate the outlet in the embankment for maintenance, access, safety and aesthetics. Make sure the vital outlet parts are accessible for maintenance. Include a draw-down valve to allow the dry detention basin to completely drain within 24 hours. To prevent scour at the outlet, include a flow transition structure, such as a lined apron or plunge pad, to absorb the initial impact of the flow and reduce the velocity to a level that will not erode the receiving channel or area. Provide shade

- Can be used on sites with slopes of 15% or flatter.
- Can receive hot spot runoff if bottom is lined and sealed.
- Do not use for discharges near to critical areas.
- Not usually suitable for redevelopment; however existing detention basins may be retrofitted.
- May not be constructed in wetland resource areas.

ADVANTAGES

- Controls peak runoff flows for 2-year and 10-year storms.
- Relatively low cost BMP.

LIMITATIONS

- Provides negligible removal of TSS compared to extended dry detention basins and wet basins.
- Provides negligible groundwater recharge.
- Frequently clogs at inlets and outlets, dramatically affecting retention times and pollutant removal efficiency.
- Cannot be used to control multiple storm events.
- Susceptible to resuspension of settled materials by subsequent storms.
- Requires large land area.
- Cannot be used in watersheds with coldwater fisheries.

SETBACK REQUIREMENTS

- Minimum of 50 ft from any septic system leach field.
- Minimum of 25 ft from any septic system tank.
- Minimum of 50 ft from any private well.
- Minimum of 10 ft from property line.

around the pond at the outlet to keep the stormwater temperature low at the discharge point.

- Provide an access for maintenance by public or private right-of-way, using a minimum width of 15 feet and a maximum slope of 5:1.
- In some cases, dry basins may be an option for snow storage to promote treatment of plowed snow. If this practice is planned, incorporate salt tolerant plants. Sediment may need to be removed more frequently to account for deposits as a result of road sanding.

MAINTENANCE CONSIDERATIONS

It is critical to provide access for maintenance, especially to the interior of the basin. After inspections, make any necessary repairs immediately. Ongoing maintenance includes repair of undercut or eroded areas, and mowing the side slopes, embankment, and emergency spillway at least twice per year. Remove trash and debris at this time. Remove sediment from the basin as necessary, and at least once every 10 years or when the basin is 25% full. Provide for an on-site sediment disposal area to reduce the overall sediment removal costs. Annually, seed and sod to restore dead and damaged ground cover.

INSPECTION CONSIDERATIONS

Inspect dry detention basins at least once per year to ensure that they are operating as intended. Inspect basins during and after storms to determine if the basin is meeting the expected detention times. Inspect the outlet structure for evidence of clogging or outflow release velocities that are greater than design flow. Potential problems that should be checked included: subsidence, erosion, cracking or tree growth on the embankment; damage to the emergency spillway; sediment accumulation around the outlet; inadequacy of the inlet/outlet channel erosion control measures; changes in the condition of the pilot channel; and erosion within the basin and banks. During inspections, note changes to the detention basin or the contributing watershed because these changes could affect basin performance.

DRY DETENTION BASINS IN CAMBRIDGE

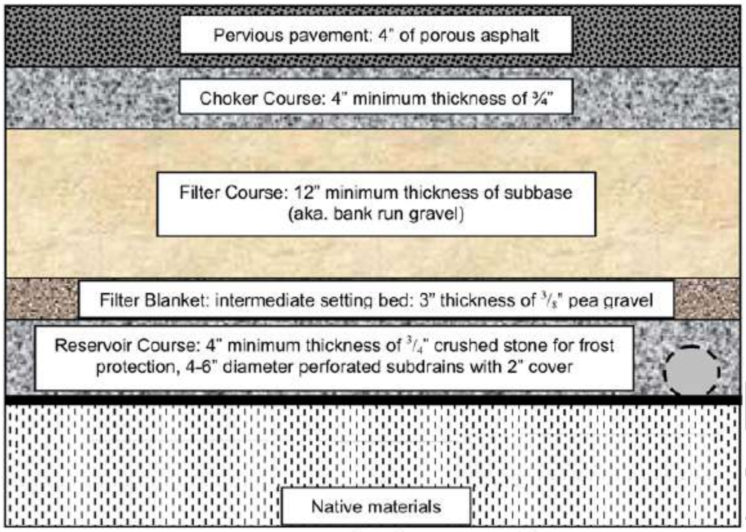
LID ALTERNATIVES

- Consider treatment trains including vegetated filter strips or dry water quality swales and bioretention areas.

REFERENCES

- Massachusetts Stormwater Handbook
- Minnesota Urban Small Sites BMP Manual
- US EPA National Menu of Best Management Practices

7.2. Porous Pavement



adapted from the University of New Hampshire

Source: Massachusetts Stormwater Handbook, February 2008.

DESCRIPTION

Porous pavement is a paved surface with a higher than normal percentage of air voids to allow water to pass through it and infiltrate into the subsoil. This porous surface replaces traditional pavement, allowing parking lot, driveway, roadway runoff to infiltrate directly into the soil and receive water quality treatment. All permeable paving systems consist of a durable, load bearing, pervious surface overlying a stone bed that stores rainwater before it infiltrates into the underlying soil. Permeable paving techniques include porous asphalt, pervious concrete, paving stones, and manufactured "grass pavers" made of concrete or plastic. Permeable paving may be used for walkways, patios, plazas, driveways, parking stalls, and overflow parking areas.

DESIGN CONSIDERATIONS

There are three major types of permeable paving, each of which is constructed over a storage bed.

- <u>Porous asphalt and pervious concrete.</u> Although it appears to be the same as traditional asphalt or concrete pavement, it is mixed with a very low content of fine sand, so that it has from 10%-25% void space.
- <u>Paving Stones – (also known as unit pavers) are impermeable blocks made of brick, stone or concrete, set on a prepared sand base. The joints between the blocks are filled with sand or stone dust to allow water to percolate to the subsurface. Some concrete</u>

TARGETED CONSTITUENTS

- Bacteria (insufficient data)
- Metals (insufficient data)
- Nutrients (insufficient data)
- Oil and Grease (insufficient data)
- Organics (insufficient data)
- Oxygen Demand (insufficient data)
- Sediment (H)
- Trash (M)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

APPLICABILITY

- Porous paving is appropriate for pedestrian-only areas and for low-volume, low speed areas such as overflow parking areas, bikeways, walkways, and patios.
- It can be constructed where the underlying soils have a permeability of at least 0.17 inches per hour.
- Porous pavement should not be used in high traffic/high speed areas because it has a lower load-bearing capacity than conventional pavement.
- Cannot receive runoff from hotspot locations.
- Not suitable in critical areas, especially within Zone II's or Zone A's of public water supplies.
- Suitable for redevelopment.
- Excellent technique in ultra-urban areas because it does not require additional land area.
- Must not receive stormwater from other drainage areas,

paving stones have an open cell design to increase permeability.

- Grass Pavers – (also known as turf blocks) are a type of open-cell unit paver in which the cells are filled with soil and planted with turf. The pavers, made of concrete or synthetic material, distribute the weight of traffic and prevent compression of the underlying soil.

The University of New Hampshire has developed specifications for storage beds used in connection with porous asphalt or pervious concrete. According to UNH, the storage bed should be constructed with the following components from top to bottom:

- 4 in. choker course comprised of uniformly graded crushed stone.
- A filter course, at least 12 in. thick, of poorly graded sand or bankrun gravel to provide enhanced filtration and delayed infiltration.
- A filter blanket, at least 3 in. thick, of pea stone gravel to prevent material from entering the reservoir course.
- A reservoir course of uniformly graded crushed stone with a high void content to maximize the storage of infiltrated water and to create a capillary barrier to winter freeze thaw. The bottom of the stone reservoir must be completely flat so that runoff can infiltrate through the entire surface.
- The size of the storage bed may have to be increased to accommodate the larger of the required WQV and the require recharge volume.
- If paving stones or grass pavers are used, a top course of sand that is 1 in. thick should be placed above the choker course.

Overflow Edge

- Some designs incorporate an "overflow edge." An overflow edge is a trench surrounding the edge of the pavement. The trench connects to the stone reservoir below the surface of the pavement and acts as a backup in case the surface clogs.

Preparation of Porous Asphalt

- Care must be taken in batching and placing porous asphalt. It is critical to minimize the amount of asphalt binder. Using greater amounts of asphalt binder could lead to a greater likelihood of "binder" or asphalt drawdown and clogging of voids. Sun light heating can liquefy the asphalt. The liquefied asphalt then drains into the voids, clogging them. Such clogging is not remedied by power washing and vacuuming. The topcoat in such instances needs to be scarified and resurfaced.

especially any areas not fully stabilized.

- Use only on gentle slopes (5% or flatter).

ADVANTAGES

- Reduces stormwater runoff volume from paved surfaces.
- Reduces peak discharge rates.
- Increases recharge through infiltration.
- Reduces pollutant transport through direct infiltration.
- Can last for decades in cold climates if properly designed, installed, and maintained.
- Improved site landscaping benefits (grass pavers only).
- Can be used as a retrofit when parking lots are replaced.
- Reduces need for other stormwater conveyances and treatment structures, resulting in cost savings.
- Reduces the amount of land needed for stormwater management.

LIMITATIONS

- Prone to clogging so aggressive maintenance with jet washing and vacuum street sweepers is required.
- No winter sanding is allowed
- Winter road salt and deicer runoff concern near drinking water supplies for both porous pavements and impervious pavements.
- Soils need to have a permeability of at least 0.17 inches per hour
- Special care is needed to avoid compacting underlying parent soils.

SETBACK REQUIREMENTS

- Minimum of 50 ft from any

Additional Design Considerations

- Provide an open-graded subbase with minimum 40% void space.
- Use surface and stone beds to accommodate design traffic loads.
- Generally, do not use porous pavement for slopes greater than 5%.
- Do not place bottom on compacted fill.
- Provide perforated pipe network along bed bottoms for distribution.
- Provide a 3 ft. buffer between the bed bottom and the seasonal high groundwater elevation, and a 2 ft. buffer for bedrock.

Cold Weather Design Considerations

- Porous pavement performs well in cold climates. Porous pavement can reduce meltwater runoff and avoid excessive water on the road during the snowmelt period.
- In cold climates, the major concern is the potential for frost heaving. The storage bed specifications prepared by the University of New Hampshire address this concern.
- Do not apply sand to porous pavements because it will cause clogging. Care also needs to be taken when applying salt to porous pavement since chlorides can potentially migrate to the groundwater. Plow blades can catch the edges of block pavers damaging the surface.

MAINTENANCE CONSIDERATIONS

- Post signs identifying porous pavement areas.
- Minimize salt use during winter months. If drinking water sources are located nearby (see setbacks), porous pavements may not be allowed.
- No winter sanding is allowed.
- Keep landscaped areas well maintained to prevent soil from being transported onto the pavement.
- For porous asphalts and concretes, clean the surface using a power washer to dislodge trapped particles and then vacuum sweep the area. Do this monthly. For paving stones, periodically add joint material (sand) to replace material that has been transported.
- Regularly monitor the paving surface to make sure it drains properly after storms.

septic system soil absorption system.

- Minimum of 100 ft from any private well.
- Outside of the Zone I of a public well.
- Outside of the Zone A of a public reservoir.
- Minimum of 100 ft from surface waters.
- Minimum of 20 ft from cellar foundations.
- Minimum of 10 ft from slab foundations.
- Minimum of 10 ft from properly lines.
- Minimum of 2 ft vertical separation above seasonal high groundwater from bottom of storage layer.

REFERENCES

- Massachusetts Stormwater Handbook
- Stormwater Manager's Resource Center (SMRC) Website www.stormwatercenter.net
- University of New Hampshire Stormwater Center

- Never reseal or repave with impermeable materials.
- Periodically reseed grass pavers to fill in bare spots.
- Attach rollers to the bottoms of snowplows to prevent them from catching on the edges of grass pavers and some paving stones.

INSPECTION CONSIDERATIONS

Inspect the surface annually for deterioration. Assess exfiltration capability at least once a year.

POROUS PAVEMENTS IN CAMBRIDGE

Encouraged as an LID technique. Porous pavement should only be used in pedestrian areas and low-volume/low speed areas such as sidewalks, walkways, bike paths, patios, and overflow parking.

7.3. Rain Barrels and Cisterns

DESCRIPTION

Cisterns and rain barrels are structures that store rooftop runoff and reuse it for landscaping and other non-potable uses. Instead of a nuisance to get rid of, consider rooftop runoff as a resource that can be reused or infiltrated. In contrast, conventional stormwater management strategies take rooftop runoff, which is often relatively free of pollutants, and direct it into the stormwater treatment system along with runoff from paved areas. Cisterns are partially or fully buried tanks with a secure cover and a discharge pump. They provide considerably more storage than barrels, as well as pressurized distribution. Cisterns can collect water from multiple downspouts or even multiple roofs and then distribute this water. Rain barrels are covered plastic tanks that can hold from 50 to 100 gal. with a hole in the top for downspout discharge, an overflow outlet, and a valve and hose adapter at the bottom. They are typically installed above ground and must be disconnected prior to the winter and drained completely to prevent cracking.

DESIGN CONSIDERATIONS

General

- For cisterns and rain barrels to be effective, building owners need to have a use for the water collected (non-potable).
- Most common approach to roof runoff storage is to direct each downspout to a 55 gal. rain barrel. A hose is attached to a facuet at the bottom of the barrel and water is distributed by gravity pressure. A more sophisticated and effective technique is to route multiple downspouts to a partilally or fully buried cistern with an electric pump for distribution.
- The roof surface can be deducted from the impervious area used to calculate the Required Water Quality Volume for sizing other structural treatments BMP's a.) when rain barrel or cistern is sized to store the Required Water Quality Volume for the roof surface (0.5 inch or 1.0 inch), b.) stored water is used within 72-hours or discharged to an infiltration BMP, and c.) the system is designed to operate all year round.
- Hide rain barrels and cisterns with shrubs or other landscaped features.
- Each house should have the appropriate number of rain barrels or an appropriately sized cistern. A 1-in. storm produces over 620 gallons of water from a 1,000 square ft. roof.

Source: Massachusetts Stormwater Handbook, February 2008.

TARGETED CONSTITUENTS

- Bacteria (NR)
- Metals (NR)
- Nutrients (NR)
- Oil and Grease (NR)
- Organics (NR)
- Oxygen Demand (NR)
- Sediment (NR)
- Trash (NR)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

APPLICABILITY

- Applicable to most commercial and residential properties where there is a gutter and downspout system to direct roof runoff to the storage tank.
- Take up little room and can be used in dense urban areas.
- Rain barrels are used almost exclusively on residential properties.
- Suitable for redevelopment.
- Generally not applicable to very small lots or lots with no landscaping.

ADVANTAGES

- Can reduce water demand for

- Direct overflow from rain barrels and cisterns to a dry well, infiltration trench, rain garden, bioretention area, or other infiltration BMP sized to recharge the overflow volume. Use pond routing methods to design cisterns or rain barrels to account for retention of early runoff in the storage tank.

Cisterns

- If present, place the cistern's continuous discharge outlet so that the tank does not empty completely. This ensures water availability at all times, and provides some storage capacity for every storm. A diverter at the cistern inlet can redirect the "first flush" of runoff, which is more likely to have particulates, leaves, and air deposited contaminants washed of the roof. Keep leaves and debris out of the storage tank by placing a screen at the top of the downspout.
- Include access ports for any subsurface cisterns. Confined space entry training may be needed to enter large cisterns. MassDEP does not require treatment of runoff from non-metal roofs prior to infiltration.

Rain Barrels

- Because rain barrels rely on gravity flow, place them near, and slightly higher than, the point of use (garden, flower bed, lawn, etc.).
- Because of the low pressure of the discharge, rain barrels are most effectively used with a drip irrigation system.
- Secure rain barrels against disturbance by children or animals. Seal any openings with mosquito netting.

MAINTENANCE CONSIDERATIONS

<u>The following components should be routinely inspected and either repaired or replaced as needed:</u>

- Roof catchment, to ensure that trash and particulate matter are not entering the gutter and downspout to the rain barrel.
- Gutters, to ensure that no leaks or obstructions are occurring.
- Downspouts, to assure that no leaks or obstructions are occurring.
- Entrance at rain barrel, to ensure that there are no obstructions and/or leaks occurring.
- Rain barrel, to check for potential leaks, including barrel top and seal.
- Runoff/overflow pipe, to check that overflow is draining in non-erosive manner.

irrigation or other non-potable uses.

- Property owners save money on water bills by using stored water for landscape purposes.
- Public water systems may experience lower peak demand in summer.
- When properly installed, rain barrels and cisterns reduce stormwater runoff volume for small storms.

LIMITATIONS

- Provides mosquito-breeding habitat unless properly sealed.
- May need to be disconnected and drained in winter to avoid cracking of storage structure.

REFERENCES

- Massachusetts Stormwater Handbook
- US EPA National Menu of Best Management Practices

- Spigot, to ensure that it is functioning correctly.
- Any accessories, such as rain diverter, soaker hose linking kit, and additional guttering.
- Apply larvicides in strict accordance with all Mass. Department of Agricultural Resources Pesticide Bureau regulations to prevent mosquitoes from reaching adulthood.
- Add bleach or other chemicals annually to kill bacteria present in the system. A qualified professional should determine appropriate treatment.
- Drain system before winter if it is located above ground or partially exposed, to prevent cracking.
- Disconnect the system from roof leaders in the fall, if water is not intended to be used during the winter, unless the runoff is directed to a qualifying stormwater infiltration practice.
- When the cistern or barrel is connected to a stormwater recharge system, remove particulates trapped in the cistern or rain barrel annually to limit clogging of the stormwater infiltration system.

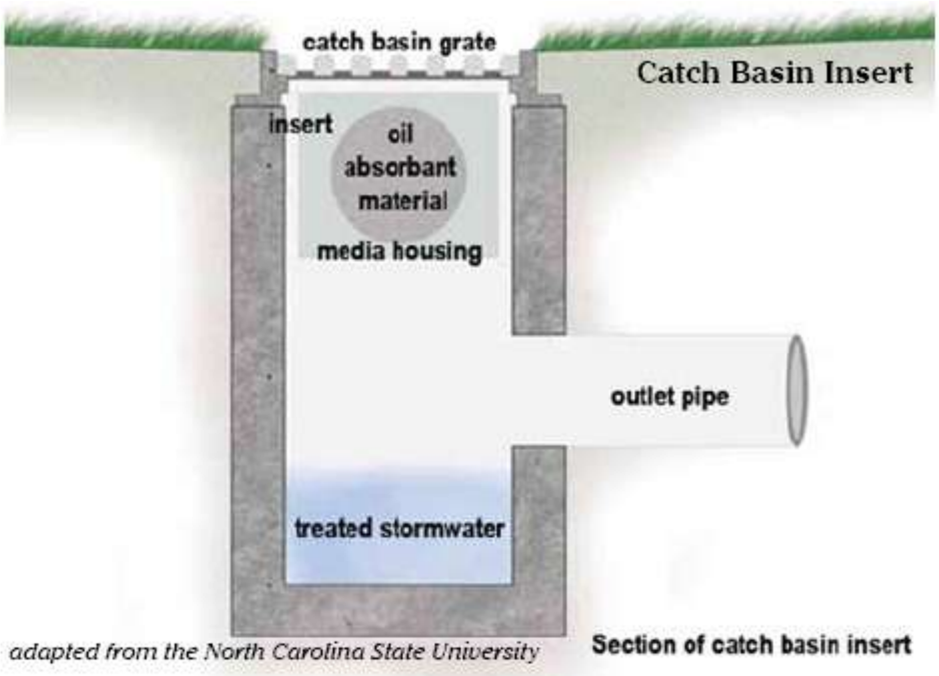
INSPECTION CONSIDERATIONS

Inspect the unit twice a year.

RAIN BARRELS/CISTERNS IN CAMBRIDGE

The Cambridge DPW sponsors rain barrel sales events. Contact the DPW to inquire about the next scheduled event.

7.4. Catch Basin Inserts



Source: Massachusetts Stormwater Handbook, February 2008.

DESCRIPTION

Catch Basin Inserts are a BMP accessory recently developed to add filtering efficiency to traditional catch basins. These proprietary BMP's are capable of removing a range of pollutants, from trash and debris to fine sediments and oil/grease and metals depending upon the filtering medium used. They typically have three components: an insert that fits into the catch basin, absorbent material (can be a single unit or series of filters), and a housing to hold the absorbent material.

DESIGN CONSIDERATIONS

- Manufacturer's specifications must be followed, which may include modifications to the catch basin. Such modifications may include a high flow bypass or other feature to handle clogging or larger storm events.
- Since Catch Basin Inserts are usually proprietary devices, the manufacturer should be asked to ensure that the device will work in the type of catch basin in which it is installed.
- Flow characteristics and sediment loading should be evaluated and any resulting modifications to the catch basin made before installation of the insert.

MAINTENANCE CONSIDERATIONS:

TARGETED CONSTITUENTS

- Bacteria (Varies)
- Metals (Varies)
- Nutrients (Varies)
- Oil and Grease (Varies)
- Organics (Varies)
- Oxygen Demand (Varies)
- Sediment (Varies)
- Trash (Varies)

Estimated Removal Efficiencies Key	
(H) High	(L) Low
(M) Moderate	(NR) Not Removed

APPLICABILITY

- Can be useful for specialized applications such as targeting specific pollutants other than TSS, at hot spot locations, or for oil control at small sites.
- Can be used to add TSS removal capability to areas with higher sediment loading.
- To improve existing conditions at size-constrained sites (e.g., catch basins near bathing beaches).

ADVANTAGES

- Can be used to retrofit existing catch basins with undersized sumps.

LIMITATIONS

- Typically designed for and used for smaller volume applications.
- Larger sized sediment can clog and significantly reduce the effectiveness of

Whoever is responsible for maintenance should explicitly agree to conduct the maintenance per the manufacturer's recommendations and to lawfully dispose of the cleanings or used filtration media.

INSPECTION CONSIDERATIONS

Inspect per the manufacturer's schedule, and especially after large rainfall events.

CATCH BASIN INSERTS IN CAMBRIDGE

Catch basin inserts should be considered in hot spot locations and at high vehicle traffic locations.

some catch basin insert filtering media.

REFERENCES

- Massachusetts Stormwater Handbook

City of Cambridge, Massachusetts

Department of Public Works

147 Hampshire Street • Cambridge, MA 02139

APPENDIX A DRAFT Best Management Practices

Sections 8 - 10

Version 4/23/08

Report Prepared By:

Cambridge Department of Public Works and

Malcolm Pirnie, Inc.
601 Edgewater Drive
Suite 360

Wakefield, MA 01880
781-224-4488

5400001

Contents

This is nonprinting text.
DO NOT DELETE THIS TEXT OR THE SECTION BREAK THAT FOLLOWS
(Click ¶ button on Formatting toolbar to display section breaks)

8. LOW IMPACT DEVELOPMENT

8.1. Introduction

Low Impact Development (LID) is an innovative stormwater management approach that is modeled after nature: manage rainfall at the source using uniformly distributed decentralized micro-scale controls. LID employs small, cost-effective natural and built landscape features that reduce the rate of runoff, filters out pollutants and increases groundwater recharge. In urban environments these measures help to improve the water quality of receiving streams/rivers, protect threatened aquatic resources, reduce the potential for flooding by stabilizing the flow rates of nearby rivers, improve project aesthetics, and reduce the size and cost of traditional BMPs and end-of-pipe (EOP) treatments.

LID techniques have gained popularity in recent years. These techniques have been shown to decrease surface runoff from urban areas and decrease the flooding and water quality impacts of urbanization on receiving water bodies.

LID methods integrate stormwater management early in site planning activities with an emphasis on prevention and minimization rather than mitigation. The basic design objectives are:

- Develop a site plan that reflects natural hydrology or recreates natural landscape features.
- Reduce impervious areas.
- Treat stormwater in numerous small, decentralized systems.
- Use natural topography for drainageways and storage areas.
- Facilitate detention opportunities.
- Preserve portions of the site in undisturbed, natural conditions.
- Increase drainage flow paths to increase time of concentration and attenuate peak rates.
- Use "end of pipe" structures only for quantity/rate controls of large storms.

LID features not only include open space, but also rooftops, streetscapes, parking lots, sidewalks, and medians. Rather than collecting runoff in piped drainage systems and controlling flow downstream in large stormwater management facilities, LID's decentralized approach disperses flows and manages runoff closer to where it originates. Because LID embraces a variety of useful techniques for controlling runoff, designs can be customized according to resource protection requirements as well as site constraints. New projects, redevelopment projects, and capital improvement projects can all be viewed as candidates for implementation of LID techniques.

The LID site design process involves identifying important natural features, locating buildings and roadways in areas less sensitive to disturbance, and designing a stormwater management system that balances the relationship between development and natural hydrology.

Site Analysis: The site planning phase begins with an evaluation of existing conditions, including identification of important natural features such as streams, drainageways, floodplains, wetlands, recharge areas, high-permeability soils, steep slopes, etc. This analysis allows for determination of areas to be protected from development and natural areas that can be utilized or enhanced as part of the LID stormwater system. This process will outline a "development envelope" that protects the sensitive areas identified. The development envelope generally includes upland areas, ridge lines and gently sloping hillsides, and slowly permeable soils outside of wetlands. Only areas that will be permanently altered should be designated for construction activity, including stockpiles and storage areas. The remainder of the site should be left in undisturbed condition.

Locate Development and Roadways: Based on the existing conditions and specified development envelope, potential site development layouts can be prepared. The layout should meet the basic design objectives and minimize the amount of runoff that must be treated. Techniques for reducing site coverage but not square footage include clustering buildings together, using parking structures instead of lots, or creating taller buildings with smaller footprint relative to floor area. Additional techniques include reduced road widths, smaller parking areas, porous pavement, and roof gardens. Once building locations have been identified, roads can be prepared. Roads should not cross steep slopes; instead, roadways should follow existing grades and run along existing ridge lines or high points. They should run parallel to contours on gentle slopes and perpendicular to contours on steeper slopes. Multiple smaller parking lots should be used instead of one large parking lot.

Create a Decentralized Stormwater System: Actual location of buildings and alignment of roadways should be developed in conjunction with the design of the stormwater management system. The goal is to minimize directly connected impervious area – impervious areas that drain directly into a pipe conveyance system. This method involves maintaining or creating small sub-watersheds on the site to micromanage the runoff in small decentralized structures such as swales, bioretention areas, filter strips, etc. Paved surfaces are graded and crowned so that they form multiple sub watersheds. The runoff from each small drainage area is directed to a swale, bioretention area, filter strip, etc. or a treatment train of BMPs to maximize filtration and recharge. Roof runoff is generally sent to rain barrels, cisterns, dry wells, or vegetated areas. Techniques to maximize travel time of the runoff should also be incorporated. These may include retaining stormwater in small structures close to the source, providing as much overland or sheet flow as possible, using open drainage systems, and using vegetation to increase surface roughness. Wherever possible, site design should utilize BMPs which function as landscaping or green space areas, wildlife habitats, and snow storage areas in addition to stormwater treatment.

8.2. LID in Cambridge

Studies have found that, in an urban environment, it is not practical to attempt reaching a 100 percent (%) natural hydrologic regime even with widespread use of LID techniques. Many LID techniques rely on infiltration practices, which are not effective during the winter season and have decreased efficiency during snowmelt or rain-on-snow events.

The effectiveness of LID's as "stand-alone" stormwater volume controls for a watershed is strongly dependent on the infiltration nature of local soils and average groundwater levels. Groundwater levels and infiltration capabilities of the soils in Cambridge vary and therefore, the ability to employ LID techniques will be different for each site. For example, because of the poorly draining soils and high groundwater levels in the Alewife sub-watershed area the successful application of a number of highly efficient LID technologies such as deep bed biofilters, infiltration basins, infiltration trenches and porous pavement will be limited. However, other LID applications can be used in the Alewife sub-watershed such as grass channels, roof gardens, reduction in impervious areas, etc. Since LID applications emulate the natural hydrologic regime more effectively than current piped stormwater conveyances and EOP structures, use of both conventional technology and LIDs are envisioned for the City of Cambridge.

In general, the best applications for LID techniques in the City of Cambridge include:

- Parking lot retrofits – particularly where runoff is diverted to porous landscaping and where parking lot sizes are reduced.
- Use of grass channels in place of curb and gutter to increase detention storage and to reduce the size or extent of piped stormwater systems.
- Use of vegetated areas to reduce impervious areas and to disconnect paved areas.
- Utilization of roof garden technology to dampen peak flows from roof areas.

The Comparative Assessment of Select LID Techniques Table compares various LID techniques and indicates their applicability within the City. BMPs are identified by their BMP Fact Sheet number. BMPs 8.3 through 8.5 can be found within this section.

Comparative Assessment of Select LID Techniques Table

BMP	Treatment Focus	Longevity	Potential Effectiveness for LID	Cambridge Applicability
1.5 Roof Gardens	Stormwater retention and flow management	20+ years	High (infiltration and storage potential)	Moderate
3.5 Vegetated Filter Strips	Pretreatment for stormwater infiltration or retention	Unknown, but may be limited	Low Best for pretreatment for other LID	Moderate
4.1 Bioretention Areas (including Rain Gardens)	Reduction in Impervious Area / Stormwater Infiltration	Varies	High (minimizes overall impervious area)	Moderate High
4.7 Treebox Filter	Reduction in Impervious Area / Stormwater Infiltration	Unknown, but may be limited	High (minimizes overall impervious area)	Moderate High
5.1 Dry Well	Stormwater Infiltration	Varies	Moderate	Applicable only in Charles River Watershed and only for roof runoff.
5.2 Infiltration Basins	Stormwater infiltration	60 to 100% failure rate within 5 years	Moderate (infiltrates but high failure rate)	Applicable only in Charles River Watershed
5.3 Infiltration Trenches	Stormwater infiltration	50% failure rate within 5 years	Moderate (infiltrates but high failure rate)	Applicable only in Charles River Watershed
6.1 Drainage Channels	Stormwater Conveyance	20+ years	Low (conveyance only)	Low Moderate
6.2 Grass Channel/Biofilter Swale	Stormwater Conveyance	20+ years	High (infiltration and storage potential)	Low Moderate
7.2 Porous Pavement	Stormwater Infiltration	Unknown, but may be limited	High (maximizes infiltration)	Applicable only in Charles River Watershed
7.3 Rain Barrels and Cisterns	Disconnect Impervious Area	Varies	Low (storage only)	High
8.3 Revegetation of Paved Areas	Reduction in Impervious Area	50+ years	Very High (preserves the most natural hydrology)	Moderate High
8.4 Reduction in Parking Lot Size	Reduction in Impervious Area	50+ years	High (minimizes overall impervious area)	Moderate
8.5 Disconnection of Roof Area	Reduction in Impervious Area	50+ years	High (maximizes infiltration potential)	Moderate

Reduction in impervious area is the first and most important step in reducing runoff peaks and volumes in urban and suburban areas. Related to this, is minimizing directly connected impervious areas, so that runoff from impervious surfaces is not discharging into the storm drain system which leads to surface water bodies. The benefits of reducing impervious area include the following:

- Creation of open space.
- Increased infiltration and decreased runoff rate and volume.
- Decreased volume of water to be treated for water quality improvements before discharge.
- Decreased peak runoff rates and volumes on downstream conveyances and detention facilities.
- Decreased extent of curb and gutter.
- Smaller stormwater drainage systems.
- Decreased pavement for street cleaning and on-going maintenance.

Several approaches for reducing or disconnecting impervious area are recommended for Cambridge.

8.3. Environmentally Sensitive Landscaping and Revegetation

Environmentally sensitive landscaping involves the revegetation or landscaping of a site using trees, shrubs, grasses, or other groundcover. This provides an opportunity to reintroduce native vegetation, which may be more disease-resistant and require less maintenance than non-native species. Benefits of environmentally sensitive landscaping include:

- Erosion control and soil stabilization.
- Runoff volume reduction.
- Water quality treatment (especially for sediment and nutrients).
- Creation or extension of wildlife habitat and corridors and local greenways.
- Aesthetic enhancements.
- Reduction of water demands for landscaping.

Revegetating a portion of the drainage area will reduce the runoff volume and peak discharge rate for the drainage area by lowering its runoff potential. Individual plantings scattered across the drainage area will not appreciably reduce these parameters. Vegetation should be planted contiguously, where possible, in order to influence the runoff potential for the drainage area.

Some basic Environmentally Sensitive Landscaping principles are:

- Revegetated a site within 30 days after creating the final grade unless temporary stabilization is used.

- Interseeding (seeding among existing plant growth, especially grasses) is a sound initial approach to plant establishment. Interseeding should be performed in the fall or early spring.
- Take care not to compact the soil in areas to be revegetated. Surface roughening may improve seed establishment and moisture retention.
- Use mulch to increase water retention, decrease erosion and improve soil stability, and insulate seeds and stock from temperature extremes. Mulching or the use of matting is especially critical on steep slopes.
- If an area is being planted for the specific purpose of providing a water quality management area, clearly post signs indicating so.
- Watering of vegetation may be necessary during dry periods and occasional replanting may be necessary. Reseed or replant any areas where vegetation did not become established. "Established" means that the soil cover has been maintained for at least one year since replanting.

Another revegetation technique, though not widely applicable for urban areas such as Cambridge, is reforestation/afforestation. Reforestation is the planting of trees in an area that was forested in the recent past (e.g. an area that was cleared for residential development). Afforestation is planting trees in an area where they were absent for a significant period of time (e.g. an old farm field or a riparian buffer). Plantings may be seeds, seedlings, or semi-mature trees. Trees reduce runoff volume through evapotranspiration and interception and improve the infiltration capacity of the soil, thereby reducing runoff potential. Trees may be placed strategically as a buffer, or in flow paths and depressions to absorb runoff.

8.4. Reduce Parking Lot Size

Many parking lots are designed with far more spaces than are actually required. A common practice is setting parking ratios to accommodate the highest hourly parking during the peak season. By determining actual average parking demand instead, a maximum number of spaces can be determined. Developers can also reduce paved parking by looking for opportunities to share parking with other facilities that may have different peak parking needs. Employers can incorporate facilities and programs to encourage alternative means of transportation to reduce the need for parking. Where flexibility allows, specific parking lot design considerations include:

- Use a parking structure rather than a parking lot.
- Consider one-way traffic flow, rather than two-way flow through parking lots.
- Reduce stall width to minimum allowed by zoning.
- Shorten stall lengths to minimum allowed by zoning allowing vehicles to overhang pervious areas.
- Size more of the required stalls, at least 30 percent, for compact cars.

- Reduce the number of stalls by careful consideration of required parking lot size.
- Use 90-degree stall angle; it has the least pavement per vehicle as compared to 30-degree, 45-degree, or 60-degree stall angles.
- Reduce paved areas that do not contribute to parking lot functions.
- Consider the use of porous pavement in overflow parking lot design and for sidewalks.

8.5. Disconnect Impervious Areas

Runoff from connected impervious surfaces commonly flows directly to a stormwater collection system with no possibility for infiltration into the soil. For example, roofs and sidewalks commonly drain onto roads, and the runoff is conveyed by the roadway to the nearest catch basin. Runoff from numerous impervious drainage areas may converge, combining runoff volumes, peak runoff rates, and pollutant loads. Disconnection decouples roof leaders, parking lots, roadways, and other impervious areas from stormwater conveyance systems, allowing runoff to be collected and managed on site or dispersed into the landscape. Runoff is redirected onto pervious surfaces such as vegetated areas, reducing the amount of directly connected impervious area and potentially reducing the runoff volume and filtering out pollutants. Disconnection practices may be applied in almost any location, but impervious surfaces must discharge into a suitable receiving area for the practices to be effective. Runoff must not flow toward building foundations or onto adjacent private property.

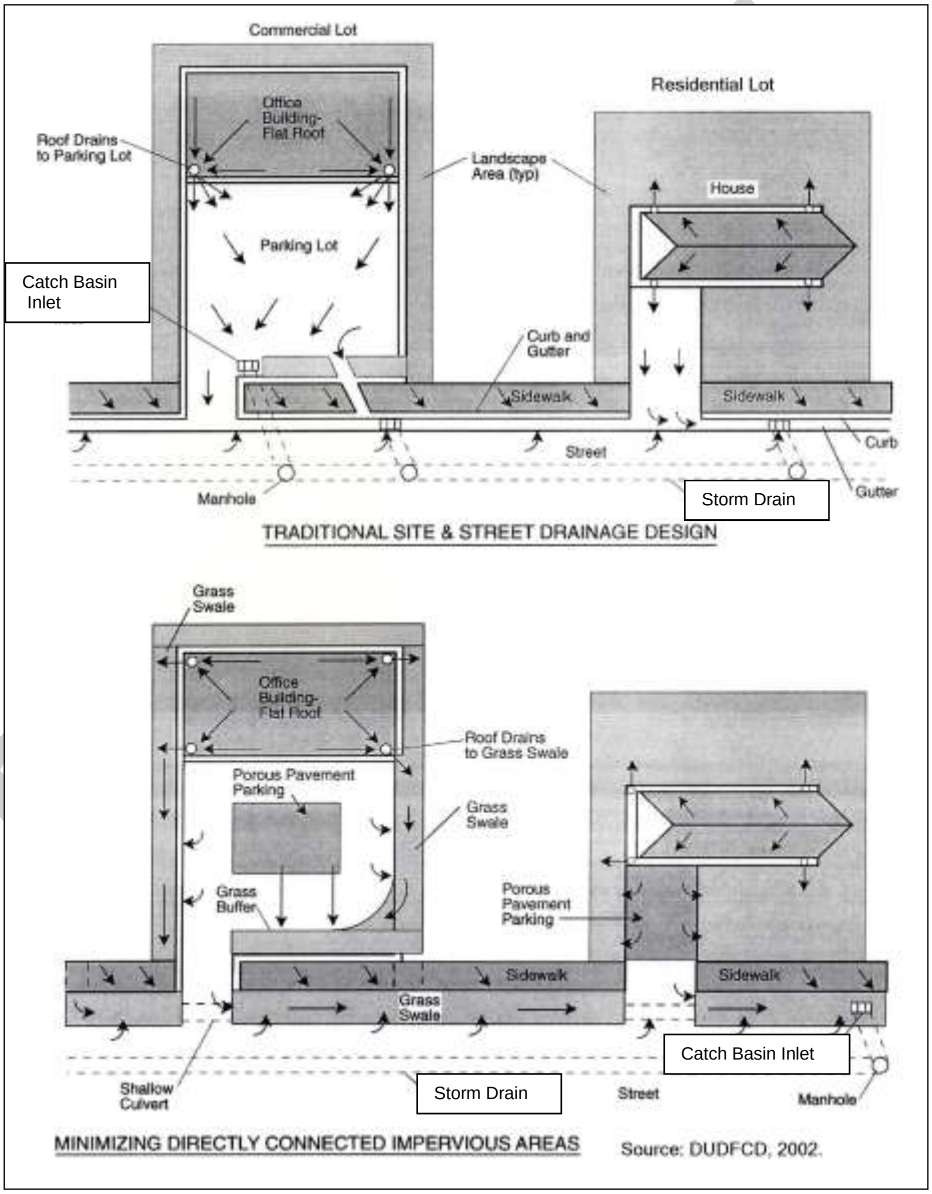
Disconnecting impervious areas requires little construction and few materials. Rooftop disconnection will require minimal modifications to the downspouts to redirect runoff away from the collection system or other impervious areas. Various other methods are available to disconnect impervious areas, but typical procedures may include curb cuts to encourage stormwater flows away from inlets and open area modifications to enhance the infiltration characteristics of receiving areas. Other modifications include flow spreading and leveling devices, which may be used to encourage shallow sheet flow through vegetated areas. Soil amendments to increase soil permeability (discussed in more detail in Section 8.X) are also a possible design option.

Typical receiving areas in Cambridge for disconnected runoff include:

- Vegetative buffers (highly recommended, details described in Section 8.5.1)
- Planter boxes (highly recommended, details described in Section 8.5.2)
- Filter strips (BMP 3.5)
- Bioretention areas (BMP 4.1)
- Treebox filters (BMP 4.7)
- Other landscape features or vegetated BMPs

Areas of pavement can be disconnected to reduce the volume of water discharging to a single point. Paved areas that can be interrupted include parking lots, traffic lanes (by medians), and paved walkways. An example of an integrated design for reducing connected impervious areas is shown the figure below. This figure shows use of grassed swales and vegetative buffers. Vegetative buffers and porous landscaping are ideal for providing breaks in paving. Site and design considerations for vegetative buffers can be found in Section 8.5.1.

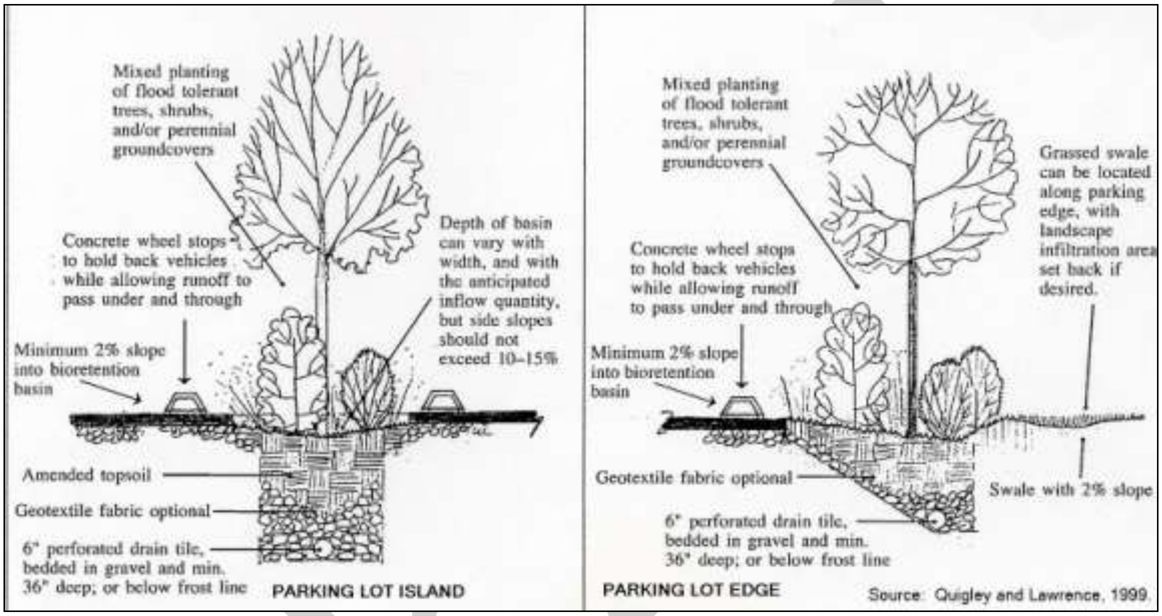
Examples of Minimizing Directly Connected Impervious Areas Figure



8.5.1. Vegetative Buffers

The Examples of Vegetative Buffers in Parking Lot Setting Figure shows a parking lot island planting incorporating vegetative buffer concepts. Recessed vegetative buffers can be used in place of the typical landscaped islands that are curbed and set higher than the paved parking lot grade. Pavement is graded so that the surface flow is towards rather than away from the islands. A bypass should be included in the design that can handle runoff in excess of the design flow and direct it towards an overflow structure.

Examples of Vegetative Buffers in Parking Lot Setting



The success of vegetative buffers is extremely dependent on both a designer developing proper installation specifications and a contractor properly implementing them. Poor construction techniques can cause the best-designed facility to fail prematurely. Construction technique and inspection are critical to ensure proper landscaping, soil mixtures, and grading around the facility, as well as the use of approved materials. Keep in mind that the plant and soil components are crucial elements of the facility and are the key to the vegetative buffer's basic function. Considerations for vegetative buffers and porous landscaping are provided below (source: LID Center, 2003).

Drainage Area:

- Limit drainage area to less than 2 to 3 acres; preferably less than 1 acre.

Ponding Depth:

- Maximum 3 to 4 inches recommended for soils with low infiltration rates, or high hydraulic loadings (combine with a smaller drainage area).

- Ponding depth may be increased if using sandy soils and underdrains to increase filtration.
- If space is limited, depth may be increased up to 1-foot, as long as the drainage area is ¼-acre or less.
- Any pooled water should be drawn down within 4 to 6 hours after a storm event.

Plants:

- Use species able to tolerate expected pollutant loadings, highly variable soil moisture conditions, and ponding water fluctuations.
- Use a minimum of three species of shrubs to ensure diversity.
- Avoid species that require regular maintenance.
- Do not plant shrubs within 15 feet of perforated pipes.
- Check water tolerances of existing plant materials prior to inundation of area.
- Do not block maintenance access to structures with trees or shrubs.
- Decrease the areas where turf is used. Use low maintenance ground cover to absorb run-off.
- Select plants that can thrive in on-site soil with no additional amendments, or a minimum of amendments.
- When planting a mix of plant species, plant individuals of same species in clumps (e.g., groups of three to five) rather than alternating species on a plant-by-plant basis.
- Maintain and frame desirable views. Be careful not to block views at entrances, exits, or difficult road curves. Screen or buffer unattractive views into the site.
- Use plants to direct pedestrians and to prohibit pedestrian access to pools or slopes that might be unsafe.
- Carefully consider the long-term vegetation management strategy of the planting, keeping in mind the maintenance requirements for future owners. Provide a planting surface that can withstand the compaction of vehicles using maintenance access roads.
- Select salt tolerant plant material in areas that might receive wintertime salt applications (roads and parking lots).

Soil:

- Homogeneous mix of 50% construction sand, 20% to 30% topsoil with less than 5% maximum clay content, and 20% to 30% organic leaf compost.
- PH between 5.5 and 6.5.
- Minimum depth of 2 to 2.5 feet, without large tree plantings.
- If shallow rooted plants are used, soil depth may be reduced to 1.5 feet.

- Soil infiltration rate should exceed 1.5 inches/hour.
- Have soil tested to determine if there is a need for amendments. It is often necessary to test the soil in order to determine the following:
- PH – whether acid, neutral, or alkali
- Major soil nutrients – nitrogen, phosphorus, potassium
- Minerals – such as chelated iron, lime
- Areas that have recently been involved in construction can become compacted. If compaction has occurred, soils should be loosened to a minimum depth of 2 inches, preferably to a 4-inch depth. Hard soils might require disking to a deeper depth. The soil should be loosened regardless of the ground cover. This will improve seed contact with the soil, providing greater germination rates, allowing the roots to penetrate into the soil. If the area is to be sodded; disking will allow the roots to penetrate into the soil. Providing good growing conditions can prevent weak or patchy plantings.
- Whenever possible, topsoil should be spread to a depth of 4 inches (2 inch minimum) over the entire area to be planted. This provides organic matter and important nutrients for the plant material and allows the stabilizing materials to become established faster, while the roots are able to penetrate deeper and stabilize the soil, making it less likely that the plants will wash out during a heavy storm.
- If topsoil has been stockpiled in deep mounds for a long period, test the soil for pH and microbial activity. If the microbial activity has been destroyed, it will be necessary to inoculate the soil after application.

Mulch:

- Maximum 2 to 3 inches deep.
- Should be fresh, not aged.
- Apply uniformly; do not pile around the base of trees.

Groundwater:

- Water table depth at least 2 feet below the lowest part of the facility (or an underdrain may be used).

Pollutant Concerns:

- Primary pollutant concerns in ultra-urban areas are metals from traffic, buildings, and rooftops, oils from automobiles, and sediment from street and lot sanding.

Underdrain:

- Recommended where the in-situ soil infiltration rate is less than 1-inch per hour (if an underdrain is not being used, soils investigation/geotechnical reports are required).

- Build with an accessible cleanout well.
- Do not locate within the groundwater zone of saturation.
- Must have a hydraulic capacity greater than the planting soil infiltration rate.

Inflow and Overflow:

- Design for overflow is necessary, since drainage areas in commercial and institutional settings are highly impervious
- Special design considerations are necessary to direct the impervious drainage area's runoff to the vegetative buffer.
- Water may be diverted into the vegetative buffer through the use of an inlet deflector block, which has ridges to channel the runoff into the landscaped area.
- In a paved area with no curb, pre-cast car stops can be installed along the pavement perimeter to protect the vegetative buffer.
- Parking lot runoff may be captured through the use of vegetated soil/gravel trenches integrated into the parking area at strategic locations.
- When inflow exceeds 3 cubic feet per second, the designer should evaluate the potential for erosion.

Location:

- Avoid locating the vegetative buffer near building areas.
- Locate away from travelled areas, such as public pathways, to avoid compaction.
- For parking lot islands, a buffer (2 feet recommended) may be used to minimize the possibility of drainage seeping under the pavement section and creating frost heave during winter (alternatively, a geotextile filter fabric curtain wall along the perimeter of the vegetated island may be used).

8.5.2. Planter Boxes

Planter boxes are similar to treebox filters, but are elevated structures containing plants or trees that may be used as stormwater control devices in urban environments, such as Cambridge. As part of a disconnection strategy, roof downspouts may be directed to vegetated planter boxes to store and filter stormwater. Trees in planter boxes intercept rainfall before it can be converted to stormwater. Planter boxes offer “green space” in tightly confined urban areas that provide soil/plant mixture suitable for stormwater capture and treatment.

Source: LID Center

Considerations for planter boxes are:

- Planter boxes are most commonly used in urban areas adjacent to buildings and along sidewalks. Locations close to roof downspouts are preferable when used as part of a disconnection program.
- May be constructed of any durable material. When built adjacent to buildings as a receptacle for downspout runoff, they are often constructed of the same material as the building. Otherwise, they may be constructed of concrete to blend in with the sidewalk or metal when they are stand-alone units.
- An appropriate soil mix is also necessary to ensure plant growth and vitality.
- Indigenous plants and vegetation are preferable for ease of maintenance.
- Underdrains can be installed to connect planter boxes to an adequate conveyance system. Observation/cleanout wells should be installed if underdrains are used.

8.6. Create New Vegetation

Vegetation helps prevent erosion, filters runoff, and allows stormwater to filter into the ground, which ultimately results in lower stormwater management costs. New vegetation can be created as part of a environmentally sensitive landscape design and/or disconnection program.

In addition to general landscaping, techniques for creating new vegetation on site include installation of the following BMPs:

- Roof Garden (BMP 1.5)
- Vegetated Filter Strip (BMP 3.5)
- Bioretention Areas/Rain Gardens (BMP 4.1)
- Treebox Filters (BMP 4.7)
- Grass Channels (BMP 6.2)

- Swales (BMP 6.3)

8.6.1. Soil Amendments

For existing pervious areas, soil amendments can increase the soil's infiltration capacity and help reduce runoff from the site. 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. Soil amendments increase the spacing between soil particles so that the soil can absorb and hold more moisture. Amended soils have the ability to remove pollutants through sorption, precipitation, filtering, and bacterial and chemical degradation. Soil amendments are valuable in areas with poor soils because they can help add available plant nutrients and sustain vegetative cover, reduce long-term erosion, and help reduce runoff peak volumes and discharges by absorption of rainfall and runoff.

Considerations for Soil Amendments include:

- Soil amendments can improve the water retention capacity and properties of almost any soil but have the greatest impact in areas with poorly draining native soils.
- Soil amendments may be used during construction and/opr maintenance of BMPs to increase soil permeability and the BMP's effectiveness.
- A variety of techniques are included as potential soil amendments including aerating, fertilizing, and adding compost or other organic matter or lime to the soil.

Low Impact Development References:

- Low Impact Development Center, Inc.
- Massachusetts Low Impact Development Toolkit
- Stormwater Manager's Resource Center (SMRC)

9. PLANT LISTS

9.1. Introduction

Vegetation protects the soil surface from rain, a major force in displacing soil particles and causing erosion. It also reduces the velocity of overland flow, decreasing the erosive capacity of runoff and preventing scouring. Vegetative cover is generally inexpensive and is often the only feasible, long-term solution to stabilization and erosion control on most disturbed sites in Cambridge. Additional benefits included providing an established land surface that absorbs rain, reducing heat reflectance and dust, restricting weed growth, and increasing property value by complementing architectural features.

Initial planning that includes vegetative cover generally reduces cost, minimizes maintenance and repair, and allows for more effective erosion and sediment control. Additionally, when soils have not been eroded during construction, final landscaping is less costly.

9.1.1. Plant Selection and Planting Seasons

Post-construction land use, general site management, and level of maintenance should be considered when selecting plant species for site stabilization. For example, plants that respond well to frequent mowing and intensive maintenance should be used on sites where a “neat appearance” is desired. Where low maintenance and longevity are desired, native species should be used.

The most effective times for planting perennials (permanent cover) generally extend from April through May and from August through September. The probability of failure is higher when planting occurs outside these dates. The best time to establish grasses and legumes is late summer (August 15 through September 30). Grasses and legumes are usually classified as “warm” or “cool” season plants in reference to their growth season. Late summer into the early fall is the most effective time to plant cool season plants because they produce most of their growth during the spring and fall and are relatively dormant during summer months. Warm season plants appear in late spring, grow most actively during the summer and go dormant at the first frost in fall. Spring and early summer are preferred planting times for warm season plants.

Temporary cover of annual species (small grains, Sudangrass, or German millet) should be planted if the time of year is not suitable for permanent cover. Dormant seeding can be conducted from the end of November through March. Use mulch or erosion control fabric (preferred) to adequately protect dormant seeding. The City of Cambridge has developed an approved seed mix for construction site stabilization.

The plant lists that follow contain suggested native species for Middlesex County, salt-resistant plants, and selected invasive species. For more information on plants in Cambridge, please contact the City Arborist or the National Resources Conservation Service.

- Native Species: Where possible, native species should be used because they evolved under local soil and climate conditions, and are best adapted to sites similar to those on which they grow naturally. They are easier to maintain and have a lower failure rate.
- Salt-Resistant Plants: If a site's planned Source Controls and O&M Plan include salting as part of winter maintenance, these plants should be considered.
- Invasive Species: A selective list of invasive, likely invasive, and potentially invasive plants is provided. Invasive and likely invasive plants should not be used and potentially invasive plants should be avoided. For more information on invasive species, contact the City Arborist or the Natural Resources Conservation Service.

Plant List References:

- Massachusetts Erosion and Sediment Control Guidelines for Urban & Suburban Areas
- Massachusetts Highway Department Project Development & Design Guide
- Natural Resources Conservation Services

9.2. Native Grasses, Groundcovers, and Legumes

Common Name	Scientific Name	Comments
Dry Sites		
Ticklegrass	Agrostis hyemalis	no seed source, cool season
Upland Bentgrass	Agrostis prennans	no seed source, cool season
Beachgrass	Ammophila brevigulata	cool season
Big Bluestem	Andropogon gerardii	warm season
Broomsedge	Andropogon virginicus	warm season, suitable for use in bioretention, wetland plant
Common Hairgrass	Deschampsia flexuosa	no seed source, warm season
Deertongue grass	Dichanthehum clandestinum	warm season, suitable for use in bioretention
Canada Wild Rye	Elymus Canadensis	cool season
Tumble Lovegrass	Eragostis spectabilis	warm season
Red Fescue	Festuca rubra	cool season
Nimblewill	Muhlenbergia schreberi	no seed source
Switchgrass	Panicum virgatum	warm season, suitable for use in bioretention
Little Bluestem	Schizachyrium scoparium	warm season, suitable for use in bioretention
Dropseed	Sporabolus cryptandrus	warm season
Poverty Dropseed	Sporobolus vaginiflorus	Annual, warm season
Indiangrass	Sorghastrum nutans	warm season, suitable for use in bioretention
Purple Sandgrass	Triplasis purpurea	Annual, cool season
Wild Indigo	Baptisia tinctoria	
Showy Tick-Trefoil	Desmodium canadense	
Beach Pea	Lathyrus japonicus var. glaber	
Round Head Bush Clover	Lespideza capitata	
Moist Sites		
Creeping/Marsh Bentgrass	Agrostis stolonifera var. palustris	cool season
Canada Anemone	Anemone canadensis	warm season
Wild Ginger	Asarum canadense	warm season
Fringed Bromegrass	Bromus ciliatus	cool season, wetland plant
Virgin's Bower	Clematis virginiana	well drained soil
Deertongue Grass	Dichanthelium clandestinum	warm season, suitable for use in bioretention
Canada Wild Rye	Elymus canadensis	cool season
Virginia Wild Rye	Elymus virginicus	cool season
Purple Lovegrass	Eragrostis pectinacea	warm season
Virginia Creeper	Parthenocissus quinquefolia	well drained soil
Switchgrass	Panicum virgatum	warm season, suitable for use in bioretention
Fowl Meadow Grass	Poa palustris	cool season
Salt Meadow Cordgrass	Spartina patens	tidal
Giant Cordgrass	Spartina cynocuroides	brackish
Foam Flower	Tiarella cordifolia	warm season
Eastern Gammagrass	Tripsacum dactyloides	warm season
Labrador Violet	Viola labradorica	warm season, well drained soil
Ground Nut	Apios americana	
Showy Tick-Trefoil	Desmodium canadense	
Wet Sites		
Creeping Bentgrass	Agrostis stolonifera var. palustris	cool season, wetland plant
Fringed Bromegrass	Bromus ciliatus	cool season, wetland plant
Blue Joint Reed Grass	Calamagrostis canadensis	cool season, wetland plant

Stout Wood Reed	Cinna arundinacea	cool season, wetland plant
Wild Rye	Elymus riparius	cool season, wetland plant
Canada Manna Grass	Glyceria canadensis	cool season, wetland plant
Fowl Meadow Grass	Glyceria striata	cool season, suitable for use in bioretention, wetland plant
Rice Cut Grass	Leersia oryzoides	cool season, wetland plant
Marsh Mully	Muhlenbergia glomerata	
Smooth Cordgrass	Spartina altiniflora	tidal
Freshwater Cordgrass	Spartina pectinata	wetland plant

9.3. Native Wildflowers

Common Name	Scientific Name	Comments
Dry Sites		
American Columbine	Aguilegia canadensis	warm season, sandy soil
Butterfly Weed	Asclepias tuberose	warm season
Lanceleaf Coreopsis	Coreopsis lanceolata	warm season
Spotted Geranium	Geranium maculatum	warm season
Moist Sites		
New England Aster	Aster novae-angliae	warm season
Lanceleaf Coreopsis	Coreopsis lanceolata	warm season
Spotted Geranium	Geranium maculatum	warm season
Blue Flag	Iris versicolor	warm season
Spike Gayfeather	Liatris spicata	warm season
Cardinal Flower	Lobelia cardinalis	warm season, mulched in winter
Obedient Plant	Physostegia virginiana	warm season
Cutleaf Coneflower	Rudbeckia laciniata	warm season

9.4. Native Tree and Shrub Plantings

Common Name	Scientific Name	Mature Height (ft)	Comments
Trees For Dry Soils			
Box Elder	Acer Negundo	60	
Gray Birch	Betula populifolia	30	suitable for use in bioretention
Red Pine	Pinus resinosa	80	
Eastern White Pine	Pinus strobus	90	
Scotch Pine	Pinus sylvestris	60	
Quaking Aspen	Populus tremuloides	50	
Shrubs For Dry Soils			
Amur Maple	Acer ginnala	20	
New Jersey Tea	Ceanothus americanus	2	
Sweet Fern	Comptonia peregrina	3	
American Hazelnut	Corylus americana	6	
Black Huckleberry	Gaylussacia baccata	3	
Common Juniper	Juniperus communis	3-30	suitable for use in bioretention
Red-cedar	Juniperus virginiana	10-90	suitable for use in bioretention
Bayberry	Myrica pennsylvanica	5	suitable for use in bioretention
Fragrant Sumac	Rhus aromatica	3	
Shining Sumac	Rhus copallina	30	
Smooth Sumac	Rhus glabra	9-15	
Stagborn Sumac	Rhus typhina	30	
Rugosa Rose	Rosa rugosa	6	
Virginia Rose	Rosa virginiana	3	
Lowbush Blueberry	Vaccinium angustifolium	2	
Nannyberry	Viburnum lentago	15	suitable for use in bioretention
Trees For Moderately Moist Soils			
Flowering Dogwood	Cornus florida	15-40	
American Beech	Fagus grandifolia	90	
Green Ash	Faxinus pennsylvanica	50	suitable for use in bioretention
Norway Spruce	Picea abies	150	
Colorado Spruce	Picea pungens	100	
Eastern White Pine	Pinus strobus	100-150	
Lombardy Poplar	Populus nigra 'Italica'	90	
Douglas-fir	Pseudotsuga menziesii	100-300	
Black Willow	Salix nigra	40	
American Mountain Ash	Sorbus americana	25	
American Arbor-vitae	Thuja occidentalis	60	suitable for use in bioretention
Basswood	Tilia americana	60-80	
Canada Hemlock	Tsuga canadensis	90	
Shrubs For Moderately Moist Soils			
Silky Dogwood	Cornus amomum	6-10	suitable for use in bioretention
Gray-stemmed Dogwood	Cornus racemosa	6	
American Hazelnut	Corylus americana	6	
Beaked Hazelnut	Corylus cornuta	12	
Border Forsythia	Forsythia Z intermedia	9	

Common Witchhazel	Hamemelis virginiana	15	suitable for use in bioretention
Inkberry	Ilex glabra	5	suitable for use in bioretention
Bayberry	Myrica pennsylvanica	5	suitable for use in bioretention
Rhododendron	Rhododendron maximum	20	
Trees For Very Moist Soils			
Box Elder	Acer negunda	60	
Red Maple	Acer rubrum	60	suitable for use in bioretention
Silver Maple	Acer saccharinum	70	
Green Ash	Fraxinus pennsylvanica	40	Suitable for use in bioretention
Black Ash	Fraxinus nigra	45	
American Larch	Larix laricina	60	
Sycamore	Platanus occidentalis	100	suitable for use in bioretention
Eastern Cottonwood	Populus deltoides	70	suitable for use in bioretention
Black Willow	Salix nigra	40	
Bebb Willow	Salix bebbiana	25	
White Cedar	Thuja occidentalis	60	suitable for use in bioretention
Shrubs For Very Moist Soils			
Speckled Alder	*Alnus rugosa*	*20*	
Smooth Alder	Alnus serulata	20	
Red Chokeberry	Aronia arbutifolia	20	suitable for use in bioretention
Sweetpepper Bush	Clethra alnifolia	10	suitable for use in bioretention
Silky Dogwood	Cornus amomum	8	suitable for use in bioretention
Red Osier Dogwood	Cornus stolonifera	8	suitable for use in bioretention
Winterberry	Ilex verticillata	10	suitabe for use in bioretention
Canada Honeysuckle	Lonicera canadensis	15	
Maleberry	Lyonia ligustrium	8	
Rhodora	Rhododendrum canadensis	12	
Purple Flowering Raspberry	Rubus odoratus	8	
Pussy Willow	Salix discolor	10	
Shining Willow	Salix lucida	8	
Elderberry	Sambucus canadensis	10	
Highbush Blueberry	Vaccinium corymbosum	10	
Wild Raisin	Viburnum cassinoides	12	suitable for use in bioretention
Mapleleaf Viburnum	Viburnum acerifolium	6	
Arrowwood	Viburnum dentatium/recognitum	8	suitable for use in bioretention
Highbush Cranberry	Viburnum trilobum	15	

9.5. Salt-Resistant Trees and Shrubs

Deciduous Shrubs	**Comments**
Alpine Currant	
Arrowwood	suitable for use in bioretention
Black Jetbead	
Broom	
Chokeberry	
Cinquefoil	
European Fly Honeysuckle	
Fivestamen Tamarisk	
Glossy Buckthorn	
Rose of Sharon	
Hydrangea	
Mock Orange	
Northern Bayberry	suitable for use in bioretention
Sea Buckthorn	
Serviceberry	
Shrubby roses (e.g., Rosa rugosa)	
Siberian Pea Shrub	
Silver Buffalo Berry	
Snowberry	
St. John's Wort	suitable for use in bioretention
Sumac	
Winterberry	suitable for use in bioretention
Witch Hazel	suitable for use in bioretention
Zabel's Honeysuckle	
Broadleaf Evergreens	
Adam's Needle	
Spreading Cotoneaster	
Groundcovers	
Bearberry	
Blueberry	
Cranberry	
Edging Candytuff	
Shrubby Cinquefoil	
Snowberry	
Spring Heath	
Deciduous Trees	
Birch	
Black Locust	
Blackgum	
Common Horse Chestnut	
European Ash	
Green Ash	suitable for use in bioretention
Hedge Maple	
Honey Locust	suitable for use in bioretention
Japanese Pagoda	suitable for use in bioretention
Kentucky Coffee Tree	
Magnolia (most)	
Maidenhair Tree	
Mountain Ash	
Poplar	
Red Oak	suitable for use in bioretention
Russian olive	

Sand Cherry	
Sycamore Maple	
Tree-of-Heaven	
White Ash	suitable for use in bioretention
White Oak	
Willow	
Conifers	
Austrian Pine	
Bald Cypress	suitable for use in bioretention
Colorado Blue Spruce	
European Larch	
Jack Pine	
Japanese Black Pine	
Japanese Larch	
Japanese White Pine	
Mountain Pine	
Oriental Arborvitae	
Ponderosa Pine	
White Spruce	

9.6. Invasive Species

Common Name	Scientific Name
Invasive	
Norway Maple	Acer platanoides
Sycamore Maple	Acer pseudoplatanus
Tree-of-Heaven	Ailanthus altissima
Japanese Barberry	Berberis thunbergii
Oriental Bittersweet; Asian or Asiatic Bittersweet	Celastrus orbiculatus
Autumn Olive	Elaeagnus umbellata
Winged Euonymus, Burning Bush	Euonymus alatus
European Buckthorn, Glossy Buckthorn	Frangula alnus
Dame's Rocket	Hesperis matronalis
Yellow Iris	Iris pseudacorus
Japanese Honeysuckle	Lonicera japonica
Morrow's Honeysuckle	Lonicera morrowii
Bell's Honeysuckle	Lonicera x bella (morrowii xtatarica)
Purple Loosestrife	Lythrum salicaria
Reed Canary-Grass	Phalaris arundinacea
Common Reed	Phragmites australis
Common Buckthorn	Rhamnus cathartica
Black Locust	Robinia pseudoacacia
Multiflora Rose	Rosa multiflora
Likely Invasive	
Common Bayberry; European Bayberry	Berberis vulgaris
Cypress Spurge	Euphorbia cyparissias
Border Privet	Ligustrum obtusifolium
Tatarian Honeysuckle	Lonicera tatarica
Plume Grass; Amur Silvergrass	Miscanthus sacchariflorus
Potentially Invasive	
Amur Honeysuckle	Lonicera maackii

10. BMP REFERENCE GUIDE

This section contains additional reference information for the BMPs provided in this Appendix.

References:

- *Connecticut Stormwater Quality Manual*, Connecticut Department of Environmental Protection, 2004. http://ct.gov/dep/cwp/view.asp?a=2721&q=325704&depNav_GID=1654
- *Georgia Stormwater Management Manual*, Atlanta Regional Commission and Georgia Department of Natural Resources, 2001. http://www.georgiastormwater.com/
- Low Impact Development Center, Inc. website, 2008. http://www.lowimpactdevelopment.org/
- *Low Impact Design Strategies – An Integrated Approach*, Prince George's County Maryland Department of Environmental Resources, 1999. http://www.epa.gov/owow/nps/lid/lidnatl.pdf
- *Maryland Stormwater Design Manual*, Maryland Department of the Environment, 2000. http://www.mde.state.md.us/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.asp
- *Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas*, Massachusetts Department of Environmental Protection, 2003. http://www.mass.gov/dep/water/esfull.pdf
- Massachusetts Low Impact Development Toolkit, Metropolitan Area Planning Council, 2008. http://www.mapc.org/LID.html
- *Massachusetts Stormwater Handbook*, Massachusetts Department of Environmental Protection, 2008. http://www.mass.gov/dep/water/laws/policies.htm#storm
- *Minnesota Urban Small Sites Best Management Practice Manual – Stormwater Best Management Practices for Cold Climates*, Metropolitan Council, 2001. http://www.metrocouncil.org/environment/Watershed/BMP/manual.htm
- National Menu of Stormwater Best Management Practices, United States Environmental Protection Agency, 2008. http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm
- *New Jersey Stormwater Best Management Practices Manual*, New Jersey Department of Environmental Protection, 2004. http://www.njstormwater.org/bmp_manual2.htm

- *Northern Virginia BMP Handbook*, Northern Virginia Planning District Commission, 1992. http://www.novaregion.org/index.asp?NID=250
- *Pennsylvania Stormwater Best Management Practices Manual (Draft)*, Pennsylvania Department of Environmental Protection, 2005. www.dep.state.pa.us/dep/subject/advcoun/stormwater/Manual_DraftJan05/cover-toc-jan-rev.pdf
- *Project Development and Design Guide*, Massachusetts Highway Department, 2006. http://www.mhd.state.ma.us/default.asp?pgid=content/designGuide&sid=aboutSite Owners Guide to Stormwater, StormwaterAuthority.org, 2008. http://www.stormwaterauthority.org/site_owners/
- *Stormwater Best Management Practices Handbooks*, California Stormwater Quality Association, 2003. http://www.cabmphandbooks.com/
- Stormwater Manager's Resource Center, Center for Watershed Protection, 2008. http://www.stormwatercenter.net/
- University of New Hampshire Stormwater Center website, University of New Hampshire, 2008. http://www.unh.edu/erg/cstev/