Chapter 7

Long-term Operation and Maintenance of Stormwater Control Measures

What's in this Chapter?

Section 7.1 provides an overview of why it is important to inspect and maintain the SCMs that have been designed and installed as part of an overall stormwater management control plan.

Section 7.2 reviews the legal and financial issues associated with implementing an inspection and maintenance program at the community level and site level.

Section 7.3 provides an overview of basic maintenance tasks to be performed by an SCM owner or operator

Section 7.4 discusses examples of inspection and maintenance check lists for many of the SCMs found in this manual.

7.1 Importance of Maintaining Stormwater Control Measures (SCMs)

Most of this manual is devoted to proper design and construction of stormwater control measures, tasks that require significant investment and expense. Once they are constructed, SCMs are crucial in protecting water quality from impacts of development projects. However, no matter how well they are designed and constructed, SCMs will not function correctly nor look attractive unless they are properly maintained. Failure to provide effective maintenance can reduce the hydraulic capacity and pollutant removal efficiency of SCMs and conveyance systems. ***SCM maintenance is the purposeful management of an SCM to maintain a desired level of performance and efficiency.***

We need of think of SCMs as key element of a community's stormwater infrastructure. As with any infrastructure, deferred maintenance can increase costs and negatively affect receiving waters. Unmaintained SCMs will ultimately fail to perform their design functions and might become a nuisance or pose safety problems. Local governments inherit problems arising from deferred maintenance. Most maintenance problems with SCMs are less costly to correct when they are caught early – as the old adage goes, "an ounce of prevention is worth a pound of cure." Therefore, developing and implementing an effective maintenance program is essential. As well, designers should give considerable thought to future long-term maintenance during the design of site plans and stormwater control measures.

Regular inspection and maintenance is an ongoing legal requirement after the SCM is constructed – in order to ensure that all SCMs are operating correctly and are properly maintained". Documentation of these inspections must be maintained and made available upon request. An appropriate professional should conduct the SCM inspections. The Tennessee Stormwater Training and Certification Program will begin offering a Tennessee SCM Inspection and Maintenance Certification course in spring of 2015; more information is available at their website:

www.tnstormwatertraining.org

This chapter will discuss the logistical issues associated with SCM inspection and maintenance as well as provide an overview of the tasks associated with maintaining SCMs. This chapter also discusses SCM design and construction considerations that affect maintenances and provides tips and sample checklists for conducting inspections. Each SCM section in this manual includes a table explaining the specific inspection and maintenance activities required to ensure proper functioning of the SCM.

7.2 Legal and Financial Issues

7.2.1 SCM Maintenance Agreements

All stormwater SCMs must be maintained in perpetuity, as required by local ordinance or other enforceable policy. Owners or operators of any SCM must develop and implement a maintenance agreement (or an equivalent document) addressing maintenance requirements. The agreement should allow the local authority, or its designee, to conduct inspections of the SCMs and also account for transfer of responsibility in leases and/or deeds. When inadequacies are discovered, the owner must initiate corrective action within 30 days of notification.

The agreement should also allow the local stormwater management authority, or its designee, to perform necessary maintenance or corrective actions neglected by the property owner/operator, and bill or recoup costs from the property owner/operator when the owner/operator has not performed the necessary maintenance within 30 days of notification. The local stormwater authority must conduct subsequent inspection (or obtain sufficient written and photographic evidence) to ensure completion of all required repairs.

7.2.2 Verification of Maintenance Responsibilities

Owners or operators of any SCM must provide verification of maintenance to the local authority. Verification of maintenance by SCM owners is typically required either by ordinance regulation or contractual agreement, or should include one or more of the following as applicable:

1. The owner/operator's signed statement accepting responsibility for maintenance with a provision for transferring maintenance responsibility if the property is legally transferred to another party; and/or
2. Written conditions in the sales or lease agreement that require the recipient to assume responsibility for maintenance; and/or
3. Written project conditions, covenants and restrictions for residential properties assigning maintenance responsibilities to a home owner's association, or other appropriate group, for maintenance of runoff reduction and pollutant reduction stormwater SCMs; and/or
4. Any other legally enforceable agreement that assigns permanent responsibility for maintenance of runoff reduction and pollutant reduction stormwater SCMs, including, but not limited to a SCM permit tracking system developed by the local authority.

The signed and notarized Inspection and Maintenance Agreement should be filed with the appropriate Register of Deeds. The responsible party should keep a copy of the Inspection and Maintenance Agreement along with a current set of SCM plans at a known set location.

7.2.3 Owner or Operator Inspections

In order to ensure that all SCMs are operating correctly and are properly maintained, owners or operators of SCMS are required, at a minimum, to:

1. Perform routine inspections to ensure that the SCMs are properly functioning. These inspections shall be conducted on an annual basis, at a minimum. These inspections shall be conducted by a person familiar with control measures implemented at a site. Owners or operators shall maintain documentation of these inspections.
2. Perform comprehensive inspections of all stormwater management facilities and practices. These inspections shall be conducted once every five years, at a minimum. Such inspections must be conducted by either a professional engineer or landscape architect. Complete inspection reports for these five year inspections shall include:

a. Facility type,

b. Inspection date,

c. Latitude and longitude and nearest street address,

d. SCM owner information (e.g. name, address, phone number, fax, and email),

e. A description of SCM condition including: vegetation and soils; inlet and outlet channels and structures; embankments, slopes, and safety benches; spillways, weirs, and other control structures; and any sediment and debris accumulation,

f. Photographic documentation of SCMs, and

g. Specific maintenance items or violations that need to be corrected by the BMP owner along with deadlines and re-inspection dates.

Sample inspection and maintenance provisions are included at the end of each SCM section. The most effective maintenance agreements are site-specific for the particular SCM components that are used on the site as well as any conditions that are unique to the site. Owners or operators must maintain documentation of these inspections, and make them available upon request.

Table 7.1: Recommended Inspection Frequency for SCMs.

Inspection Frequency	SCMs
Monthly and within 24 hours after every storm event greater than 1.0 inch.	Stormwater wetlands Wet detention basins Bioretention cells
Quarterly and within 24 hours after every storm event greater than 1.0 inch.	Level spreaders Infiltration devices Sand filters Extended dry detention basins Permeable pavement Rooftop runoff management Filter strips* Grassed swales* Restored riparian buffers*

** Although it is recommended that these devices be inspected quarterly, mowing will usually be done at more frequent intervals during the growing season.*

To summarize Table 7.1, practices that include vegetation in a highly engineered system are recommended to be inspected monthly and after large storm events to catch any problems with flow conveyance or vegetative health before they become serious. It is recommended that all other SCMs be inspected quarterly and after large storm events.

7.2.4 Maintenance Responsibilities

As stated in the previous section, maintenance is usually the responsibility of the owner, which in most cases is a private individual, corporation, or homeowners association. Simple maintenance items such as minor landscaping tasks, litter removal, and mowing can be done by the owner, or can be incorporated in conventional grounds maintenance contracts for the overall property.

Although a nonprofessional can undertake many maintenance tasks effectively, a professional (professional engineer or registered landscape architect) must be consulted once every five years, at a minimum, to ensure that all needs of the SCM facility are met. Some elements that can need professional review and consultation include structure, outlets, and embankments/dams, as well as plant health. Some developing problems may not be obvious to the untrained eye.

In addition, it is advisable to have professionals do the more difficult or specialized work. Filling eroded areas and soil-disturbing activities, such as re-sodding or replanting vegetation, are tasks that are best assigned to a professional landscaping firm. If the work is not done properly the first time, not only will the effort have been wasted, but also the facility may have been damaged by excessive erosion. Grading and sediment removal are best left to professional contractors.

7.2.5 Providing for Maintenance Expenses

The expenses associated with maintaining a SCM are highly dependent on the SCM type and design. However, the most important factor that determines the cost of SCM maintenance is the condition of the drainage area upstream of the SCM. If a drainage area conveys a high load of sediment and other pollutants to a SCM, the costs of maintaining the SCM will increase dramatically. Preventing pollution in the drainage area as much as possible will reduce the costs of SCM maintenance.

A funding mechanism should be created and regularly funded with an amount that provides enough money to pay for the maintenance expenses over the lifetime of the SCM. One option is to establish an escrow account, which can be spent solely for sediment removal, structural, biological or vegetative replacement, major repair, or reconstruction of the SCMs. In the case of a residential subdivision, the escrow account could be funded by a combination of an initial payment by the developer and regular contributions by the homeowners' association.

Routine Maintenance costs are relatively easy to estimate, and include the expenses associated with the following activities and tasks:

- Conducting SCM inspections at the one and five year required minimums as detailed in Section 4.2.5.7 of the MS4 Permit and as recommended in Table 7.1.
- Maintaining site safety, including any perimeter fences and other access inhibitors (trash racks or pipe grates).
- Removing trash.
- Removing sediment that has accumulated in any components of the SCM.
- For infiltration-type systems, maintaining the filtering media and cleaning or replacing it when necessary.
- Restoring soils to assure performance.
- Pruning woody vegetation.
- Replacing dead vegetation.
- Stabilizing any eroding side slopes.
- Repairing damaged or eroded outlet devices and conveyance systems.
- Repairing embankments, dams, and channels due to erosion or rodents.

Emergency maintenance costs are more difficult to estimate. They depend on the frequency of occurrence and the nature of the problem, which could vary from erosion problems to complete failure of a structure.

7.3 Summary of SCM Maintenance Tasks

7.3.1 Emergency Maintenance

Maintenance after floods and other emergencies requires immediate mobilization. It can include replanting and repairs to structures. Living systems are likely to need at least minor repairs after emergencies. Following an emergency such as a flood, standing water may pose health risks because of mosquitoes. Mosquito control should be considered if it becomes a problem.

For all installations obstructions and debris deposited during storm events should be removed immediately. Exceptions include debris removal that provides habitat and does not damage vegetation or divert currents to, from, or in the SCM. In fact, because of the high quality of habitat that can be found in woody debris, careful re-positioning rather that complete removal may be desirable. Educating adjacent property owners about the habitat benefits of debris and vegetation can decrease requests for removal.

Formations of sinkholes or other evidence of subsidence within an SCM footprint or its drainage pathways indicates failure of the SCM. The practice should be repaired as soon as feasible after the first observation, using appropriate engineering techniques. (e.g., VDOT IIM228 – *Sinkholes: Guidelines for the Discharge of Stormwater at Sinkholes; WVDEP, 2004; MDE, 2000; etc.).*

Figure: 7.1 Sinkhole Collapse in SCM.

7.3.2 Routine Debris and Litter Removal

Trash removal is an integral part of SCM maintenance. Generally, a "spring cleanup" is needed to remove trash from all surface SCMs. Subsequently, trash removal is to be performed as required, based on observations during regular inspections. Special attention should be given to removing floating debris, which can clog the outlet device or riser. Regularly removing debris and litter is well worth the effort and can be expected to help in the following ways:

- Reduces the chance of clogging outlet structures, trash racks, and other facility components.
- Prevents damage to vegetated areas.
- Reduces mosquito breeding areas.
- Maintains facility aesthetics.
- Reduces conditions for excessive surface algae.
- Reduces the likelihood of stagnant pool formations.

7.3.3 Stability and Erosion Control

The best way to promote soil stability and erosion control is to maintain a healthy ground cover in and around the SCMs. Areas of bare soil quickly erode, potentially clogging the facility with sediment and threatening its integrity. Therefore, bare areas must be stabilized as quickly as possible. Newly seeded areas should be protected with mulch and/or an erosion control blanket is securely staked. For SCMs that rely on filtration, such as bioretention facilities, it is critical that adjacent soils do not contaminate the selected filter media during or after construction. If the site is not permanently stabilized with vegetation when the filter media is installed, the best design practice is to specify sod or other robust erosion control practices for all slopes in and immediately around the SCM.

Erosion is quite common in or around the inlets and outlets of SCM facilities and should be repaired as soon as possible. Erosion control efforts should also extend to areas immediately downstream of the SCM.

The roots of woody vegetation (e.g. young trees and shrubs) can cause embankments to be unstable. Consistent mowing of the embankment controls stray seedlings that take root. Growth of trees and shrubs further away

from the embankment should not pose a threat to the stability of the embankment and can provide important runoff filtering benefits. Trees and shrubs should not be planted within maintenance and access areas.

Animal burrows also diminish the structural integrity of an embankment. Muskrats, in particular, burrow tunnels up to 6 inches in diameter. Efforts should be made to control animal burrowing. Burrows should be filled as soon as possible.

Finally, subsidence can result in sinkholes on embankments or basin and channel bottoms. Subsidence is not solely related to karst areas. The presence of subsidence or sinkholes anywhere within the SCM perimeter or along the treatment train can short-circuit the stormwater management system, and it should always be considered a criterion for SCM failure that must be addressed and corrected as soon as possible.

7.3.4 Sediment Removal and Disposal

Sediment gradually accumulates in SCMs and must eventually be removed. However, removal intervals vary so dramatically among facilities that no "rules of thumb" are applicable. The required frequency of sediment removal is dependent on many factors, including the following:

- The type of SCM;
- The design storage volume (e.g. if the active and permanent pool storage is oversized for sediment storage);
- The characteristics of the upstream catchment area (e.g. land use; level of imperviousness; upstream construction activities and effectiveness of sediment and erosion control activities);
- Municipal practices (e.g. winter weather roadway sanding and salting etc.) in the contributing drainage area.

Before installing a SCM, the designers should estimate the lifetime sediment accumulation that the SCM will have to accommodate. Several time periods may be considered, representing expected changes in land use in the watershed. To estimate sediment accumulation, an estimate of the long term sediment load from upstream must be calculated. Then an estimate of the SCM's sediment removal efficiency must be determined. The analysis of watershed sediment loss and SCM efficiency can be expedited by using a sediment delivery computer model.

The frequency of sediment removal is then based on the sediment accumulation rate versus the amount of sediment storage volume that is inherently provided in the SCM without affecting treatment efficiency or stormwater storage volume. Again, the frequency of sediment removal is SCM site-specific. It could be as often as every 2 years, or as long as 15-25 years. The volume of sediment that must be removed and disposed of each dredging cycle is the volume calculated above multiplied by any density or dewatering factors, as appropriate.

Sediment removal is usually the largest single cost of maintaining a SCM facility, so the necessary funds should be allocated in advance. Since sediment removal costs are so site specific and dependent on disposal plans, it is difficult to provide good estimates. Actual estimates should be obtained during the design phase of the SCM. The estimates should include: mobilization expenses, sediment removal expenses, material transport expenses (if applicable), and disposal expenses (if applicable).

Wet sediment is more difficult and expensive to remove than dry sediment. Ideally, the entire facility can be drained and allowed to dry sufficiently so that appropriate equipment can operate on the bottom. Provisions for draining permanent pools should be incorporated in the design of water impoundments, where feasible. Also, low-flow channels and outlets should be included in all SCMs in order to bypass stormwater flow during maintenance. However, in many impoundments periodic rainfall keeps the sediment soft, preventing access by equipment. In these cases, sediment may have to be removed from the perimeter by using backhoes, grade-alls or similar equipment.

Underground or proprietary SCMs – such as vaults, chambers, and other structures that require accumulated material to be pumped out – require special consideration. For such facilities, inspection and maintenance staff may be required to have confined-space training to satisfy OSHA safety requirements. Also, some types of proprietary devices require more frequent maintenance in order to perform as designed. Maintenance contracts are essential when such SCMs are specified on plans.

At sites where sediment loads are expected to be high, designers should designate a dewatering and storage area on the site. This area must be located outside of the floodplain. If such a disposal area is not set aside, transportation and landfill tipping fees can greatly increase cost of the SCM maintenance, espically if disposal of wet sediment is not allowed in the local landfill. If on-site storage is not feasible, sediment can be used elsewhere after dewatering, unless the material was generated from a stormwater hot spot (e.g. a gasoline station). In this case, a Toxicity Characteristic Leachate Procedure (TCLP) or other analysis should be performed on the removed sediment to determine if it meets the criteria of a hazardous waste, which requires special handling and disposal. If the waste is not hazardous waste and is going to be managed as a solid waste, other testing may be required by a receiving facility.

Sediment removed from an SCM requires proper disposal, which must be carefully planned. Some pump-outs result in waste material that is composed of both liquids and solids. Wastewater plants usually will do not accept wastewater with solids, and landfills usually do not accept any liquids or saturated sediments. Therefore, sediment removal activities must result in a waste material that meets the various disposal requirements. State and local waste disposal requirements should be consulted for information pertaining to the exact parameters and acceptable levels for different disposal options. Generally, sediment removal from SCMs will not be contaminated to the point that it should be classified as a hazardous waste. However, all sediment removed from SCMs should be tested to determine the proper disposal option. Most private laboratories are familiar with waste disposal regulations and can test sediment samples with these in mind. Generally, there are three sediment disposal options:

- **On-Site Disposal.** On-site disposal allows the sediment to be disposed of on any land area that is not regulated (i.e., land other than floodplain, buffer zone, etc.) During the site planning process, when determining land requirements for stormwater control measures, land can be set aside for on-site disposal of sediment removed from the various SCMs during maintenance. The areas that are used for sediment disposal should be landscaped after each sediment removal operation, in order to stabilize the soil and provide a natural appearance.
- **Off-Site Disposal.** Off-site disposal is often preferred by developers and local governments. Off-site disposal does not reduce the developable area, landscaping/grading does not have to be performed, and there are no perceived liability/health concerns with respect to the surrounding landowners. Off-site disposal can mean disposal at a landfill or disposal at another area undergoing filling. The decision of where the material is deposited depends on the quality of the sediments and the availability of and distance to the alternative fill areas.
- **Hazardous Waste Disposal.** Although sediment removed from SCMs is expected to contain some contaminant's (metals, bacteria, nutrients), the levels of pollutants involved are typically not sufficient for it to be classified as hazardous waste. Hazardous waste must be deposited at a hazardous waste facility. Transportation costs and disposal fees are expensive for hazardous waste, since licensed hauler must be used to transport the material and the number of accessible hazardous waste receiving facilities may be limited in number and distance.

7.3.5 Maintenance of Mechanical Components

Each type of SCM may have mechanical components that need periodic attention. For example, valves, sluice gates, fence gates, locks, and access hatches should be functional at all times. The routine inspection, exercising, and preventive maintenance for each mechanical component should be included on a routine inspection/maintenance checklist.

7.3.6 Vegetation Maintenance

Vegetation maintenance is an important component of any stormwater maintenance program. The grasses and plants in all SCMs, but particularly in vegetative SCMs such as filter strips, grass swales, restored riparian buffers, bioretention facilities, and constructed stormwater wetlands, require regular attention. The development of distressed vegetation, bare spots and rills, indicate that a SCM is not functioning properly. Problems can have many sources, such as:

- Excessive sediment accumulation, which clogs the soil pores and produces anaerobic conditions.
- Nutrient deficiencies or imbalances, including pH and potassium.

- Water-logged conditions caused by reduced soil drainage or high seasonal water table.
- Invasive species.

The soil in vegetated areas should be tested every other year and adjustments made to sustain vigorous plant growth with deep, well-developed root systems. Aeration of soils is recommended for filter strips and grassed swales where sediment accumulation rates are high. Ideally, vegetative covers should be mown infrequently, allowing them to develop thick stands of tall grass and other plant vegetation. Also trampling from pedestrian traffic should be prevented.

Areas immediately up and downstream of some SCM plantings often experience increased erosion. Although properly designed, located, and transitioned installations experience this effect to only a minor degree, all erosion should be repaired immediately to prevent spreading. Live stakes, live fascines and other soil bioengineering techniques, possibly in combination with geotextiles, can be applied to eroded areas in natural drainage ways with minor grading.

Table 7.2 describes some specific vegetation maintenance activities at various types of SCMs. It is important to note that there are specific requirements related to certain management practices that must be followed, such as those preformed in buffers. In addition, any vegetation that poses threats to human safety, buildings, fences, and other important structures should be removed. Finally, vegetation maintenance activities naturally change as the vegetation matures after construction.

Table 7.2: Vegetation Maintenance for SCMs.

Maintenance Activity	Instructions
Replacement of Dead Plants	All dead plants should be removed and disposed of in an environmentally friendly manner. Before vegetation that has failed on a large scale is replaced, the cause of such failure should be investigated. If the cause can be determined, it should be eliminated before any replanting.
Fertilization	The objective of fertilizing at a SCM is to secure optimum vegetative growth rather than yield (often the objective with other activities such as farming). Infertile soils should be amended before installation and then fertilized periodically thereafter. Fertilizer can be composed of minerals, organic matter (manure), compost, green crops, or other materials.
Irrigation/ Watering	Watering of the vegetation can often be required during the germination and establishment of the vegetation, as well as occasionally to preserve the vegetation through drought conditions. This can typically be accomplished by pumping water retained in the SCM or from the stream, installing a permanent irrigation system or frost-proof hose bib, or using portable water trucks.
Mulching	Mulching should be used to maintain soil temperature and moisture, as well as site aesthetics. A half-inch layer is typically adequate. Ideally, mulch should be removed before winter to prevent an infestation of rodents.
Weeding	Weeding is often necessary in the first growing season, particularly if herbaceous grasses are out-competing the young woody vegetation growth. The need for weeding may be largely eliminated by minimizing the amount of seed used for temporary erosion control. Weeding may also be required if, over time, invasive or undesirable species are entering the site and outcompeting plants that are specifically involved in the treatment of the stormwater.
Cultivating/ Hoeing	Hoeing is often required to loosen overly compacted soil and eliminate weeds that compete with the desirable vegetation.
Pruning	Pruning is used to trim to shape and remove dead wood. It can force single shoot shrubs and trees to assume a bushier configuration.

Maintenance Activity	Instructions
Thinning	Thinning dense brush may be necessary for particular species to thrive, increase the vigor of individual specimens, to reduce flow obstructions, and to increase the ability of maintenance staff to access the entire SCM. Tall maturing trees, for the most part, have no place in a SCM (except for buffers) and should be removed as soon as possible.
Staking	Saplings of tall trees planted in or near the SCM may require staking. Care should be taken not to damage the tree's roots with stakes. Stakes should be kept in place for 6 to 18 months, and the condition of stakes and ties should be checked periodically.
Wound Dressing	The wounds on any trees found broken off or damaged should be dressed following recommendations from a trained arborist.
Disease Control	Based on monitoring observations, either insecticides or (preferably) organic means of pest and fungal control should be used.
Protection from Animals and Human Foot Traffic	Fencing and signage should be installed to warn pedestrians and to prevent damage due to trampling. These measures are often most necessary during the early phases of installation but may be required at any time. Measures for controlling human foot traffic include signs, fencing, floating log barriers, impenetrable bushes, ditches, paths, and piled brush. Wildlife damage is caused by the animals browsing, grazing, and rubbing the plants. The use of chemical wildlife repellents should be avoided. Fences and meshes can be used to deter entry to the SCM. Tree tubes can be used to prevent damage to individual specimens.
Mowing	Mowing of perennial herbaceous grasses and wildflowers, especially once seed heads have set, promotes redistribution of seed for this self-sustaining system. Mowing should be carefully controlled, however, especially when performed for aesthetics. As adjacent property owners and customers in general learn more about SCMs, their vision of what is aesthetically pleasing can change. Grasses, in healthy herbaceous stands, should never be mown more than once per year.

7.3.6.1 Grass Cutting

Generally, grass-cutting should be limited or eliminated around SCM facilities. Allowing grass to grow tends to enhance water quality and provides other benefits for wet facilities. Short grass around a wet stormwater facility provides ideal habitat for nuisance species such as geese. Allowing grass to grow is an effective means of discouraging geese. Grass cutting is one maintenance activity that is undertaken solely to enhance the perceived aesthetics of the facility. The frequency of grass cutting depends on surrounding land uses, local municipal or HOA by-laws, and public or peer pressure. In view of the various influences, grass cutting should be done as infrequently as possible but with sensitivity to the aesthetic concerns of nearby residents.

Grass around wet facilities should not be cut to the edge of the permanent pool. As a safety precaution, cutting should be done parallel to the shoreline with grass clippings being ejected upland, in order to avoid adding organic matter to the pond.

7.3.6.2 Weed Control

Weeds are generally defined as any kind of vegetation which is unwanted in a particular area. In terms of SCMs, weeds are generally invasive species which cannot provide the intended function of the planting strategy, or other non-invasive species such as purple loosestrife, the spread of which is undesirable. Local weed control rules should be consulted for local requirements. Weed control may be required annually or more frequent as determined by inspection of the SCMs.

Ideally, weeding should be done by hand to prevent the destruction of surrounding vegetation. The use of herbicides and insecticides, which cause water quality problems, should be prohibited near SCMs. The use of fertilizer should also be limited to minimize nutrient loading to the downstream receiving waters.

7.3.7 Plantings

Upland and flood fringe plantings are generally stable and should not need much maintenance or re-establishment. Shoreline fringe areas are subject to harsher conditions as a result of the frequent wetting and drying associated with this zone. Aquatic plantings are the hardest to establish initially. Typically, vegetation in the aquatic and shoreline fringe zones will require some replanting or enhancement during the first two years of SCM facility operation. Preliminary results of studies of stormwater plantings indicate that a healthy vegetative community will establish if proper conditions are created (although the final set of species may not be those that were originally planted).

Planting methods can be separated into the following three main categories (from terrestrial to aquatic), based on the wetness level and types of vegetation that will grow in these conditions:

- **Upland/Flood Fringe.** The two types of plantings used are herbaceous (ground covers and grasses) and woody vegetation (shrubs and trees). Planting should occur in the spring after groundwater levels have normalized. Ground cover can be installed either by hydroseeding or using a custom seed mix in a nutrient rich medium impregnated in a biodegradable mesh-like blanket. Individual shrubs and trees can be planted manually, with openings made in the mesh blanket for each individual plant, if necessary.
- **Shoreline Fringe (Wet Riparian).** Shoreline fringe vegetation should be planted in mid-May to early June but after water levels have subsided to a stable level. Some form of protection of the seed mixture and soil nutrient medium (if required) should be provided in this dynamic zone of water level fluctuation. In order to establish ground cover in this zone, the biodegradable mesh-like blanket suggested for the upland zone is also highly recommended for this zone. Shrubs and trees can be planted through openings created in the mesh blanket.
- **Aquatic Fringe/Shallow Water.** The establishment of plantings in this zone will require greater material handling and growth monitoring, both in the short-term and over the long-term. Emergent vegetation is easily planted by hand if the substrate is suitable (e.g., ideally, a firm substrate with at least 10% organics by volume). Young shoots (rather than rhizomes or corms) are preferable for planting, since these plants are already growing with an established root structure (for early stability). The plants should be at least 10 cm tall, and planting should occur from late May to early June. Sprigs or plugs are preferable for planting emergent plants, since the root material is already contained in a suitable growth medium.

Mature growth should be planted to establish submerged rooted plants (including pondweeds), if planted in late spring to early summer when the mature plants can take advantage of warmer water and sunlight penetration. Plantings in early spring or fall should use vegetative propagules such as turions or rhizome plugs, which can germinate in the spring or over the winter and begin growing in the following growing season.

7.3.8 Maintenance of the Aquatic Environment

An important yet often overlooked aspect of non-routine maintenance of SCMs that maintain a permanent pool of water is the need to regularly monitor and manage conditions to promote a healthy aquatic environment. An indicator of excess nutrients (a common problem) is excessive algae growth in the permanent pool of water. In most cases, such problems can be addressed by encouraging the growth of more desirable aquatic and semi-aquatic vegetation in and around the permanent pool. The plants selected should be tolerant of varying water levels and have a high capacity to incorporate the specific nutrients associated with the problem. If algae proliferation is not addressed, algae-laden water will be washed downstream during rain events and may contribute to nuisance odors and pollution stresses in downstream aquatic habitat.

7.3.9 Insect Control

Ponded water can function as breeding grounds for mosquitoes and other insects. Mosquito problems can be minimized through proper design and maintenance. The most effective control technique for prevention of mosquito breeding is to ensure that permanent impoundments do not develop stagnant areas. SCMs with permanent pools should include a source of steady dry-weather flow. Promptly removing

floatable debris helps eliminate areas where water can collect and then stagnate. Fish that feed on mosquito larvae can be stocked in larger basins. Additionally, splash aerators can be employed to prevent stagnant water, however, this requires electricity at the site, increases maintenance costs, and must be properly designed so as to not decrease the settling efficiency of the SCM.

7.3.10 Winter Operation

Infiltration facilities are subject to reduction in capacity due to freezing or saturation of the soil. Surface filters and bioretention areas are generally subject to similar problems. Subsurface filters, while less susceptible that surface filters, may demonstrate poorer performance in the winter due to freezing in underdrain pipes or the filter medium. Filters which use organic media are particularly prone to freezing because they retain water.

There is also an increased likelihood of infiltration facilities and filters clogging during winter operation due to the high sediment loads resulting from road maintenance activities (e.g. sanding and salting). Furthermore, there is an increased risk of groundwater contamination from road salt associated with winter operation of infiltration facilities that receive road runoff.

7.3.11 Maintenance of Other Project Features

All other devices and features associated with the SCM should be monitored and maintained appropriately. These additional items could affect the safety or aesthetics of the facility, which can be as important if not more important than the operational efficiency of the facility. Such items include:

- Fences
- Access roads
- Trails
- Lighting
- Signage (e.g. no trespassing, emergency notification contact information, etc.)
- Nest boxes
- Platforms
- Watering systems

7.4 Inspection and Maintenance Checklist

Appendix F provides examples that may be part of a comprehensive SCM operation and maintenance program. Appendix F includes examples of operation and maintenance agreements; example operation and maintenance plans for select SCMs; an example of a Declaration of Restrictions and Covenants; and templates of SCM Inspection checklists. Examples of these documents were provided by Metro Nashville-Davidson County, City of Franklin, and the City of Murfreesboro.