5.4.3 Amend and Restore Disturbed Soils

Description

Soils are an important component of effective stormwater management. A healthy soil (defined as a living natural system consisting of a mixture of weathered minerals, decomposing organic matter, and biological organisms, that contains adequate air and water for the support of plants) permits water infiltration for groundwater recharge and provides water-holding capacity to support vegetation, both contributing to reduction in stormwater runoff.

This BMP provides guidance for the amendment and restoration of project site soils to improve their performance as a stormwater volume management media. This is also important for the effective performance of the engineered BMPs described in Section 5.3.

Disturbed soils may have been degraded by a number of factors, both natural and manmade. These factors include:

- Contamination and/or soil mixed with trash and construction debris.
- Mixed/imported fill soils with intermingled soil layers.
- Soil that has been compacted by foot traffic, vehicles, or equipment, and the pore spaces necessary to a healthy, functioning soil have been compressed. Silts and clays (with finer grain sizes) are more prone to compaction.
- Erosion has reduced soil to a thin covering, lacking nutrients, microorganisms, organic matter, soil depth, and water-holding capacity.

Indicators of disturbed soils may include one or more of the following:

- Soil horizons that differ significantly in depth, texture, or physical or chemical properties from a healthy reference soil in a neighboring undisturbed area.
- High bulk density readings by soil type at which growth limitations can be expected.
- Organic matter content lower than that of the reference soil.
- Soil chemical characteristics (parameters such as pH, salinity, cation exchange capacity, and nutrient profiles) different from that of healthy reference soil in a neighboring undisturbed area.
- Presence of toxic compounds.
- Presence of weedy, opportunistic, or invasive plant species.
- Presence of construction debris.

Restoring degraded soil involves de-compaction; restoration of soil porosity; reintroduction (amendment) of soil microorganisms, organic matter, and nutrients to support healthy rooting environments for plants; and reestablishment of the soil's long-term capacity for infiltration, storage, and pollutant removal.

BMP Functions Table

BMP	Applicability	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden	Cost
Amend and Restore Disturbed Soils	U/S/R	H	H	M	H	M	M	H	L	L*

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

*Initial cost may be high, but low in the long term.

Key Design Guidelines

- If possible, avoid importing topsoil from another location.
- Existing soil conditions should be evaluated before creating a restoration strategy.
- Test for bulk density, organic matter, soil texture, nutrient deficiencies, and the presence/absence of microorganisms, fungi, and bacteria.
- Where necessary, recreate an ideal soil profile.
- Physical loosening of the soils can mitigate compaction.
- Compost amendments and teas can increase biological communities and water-holding capacities and mitigate compaction over time.

Applications

Soil restoration is appropriate and useful where the soil has been badly damaged, especially where the soil's long-term capacity for infiltration, water storage, and pollutant removal is necessary for BMP function and for planting (either a vegetative cover or ornamentals).

Advantages

- Uses the landscape soils as a stormwater BMP, decreasing the need for structural measures to manage site stormwater.
- Healthy soils support healthy plant growth, providing cost savings on plant maintenance (labor, pesticides, fertilizers, and irrigation).

Disadvantages

- Initial upfront development costs.
- The value of soil improvement and/or repair is not well understood and often value engineered out of the project.
- A soil specialist is required to evaluate existing impaired soils and provide a formula for remediation.
- Careful oversight is required during the creation and installation of new soils. Contractors frequently do not study the specifications carefully or follow directions.

Applications

Soil restoration is appropriate and useful anywhere the soil has been degraded, especially where the soil's long-term capacity for infiltration, water storage, and pollutant removal is necessary for BMP function and for planting (either a vegetative cover or ornamentals).

Figure 5.4.3-1. Debris in wooded lot.

Figure 5.4.3-2. Highly compacted lawn.

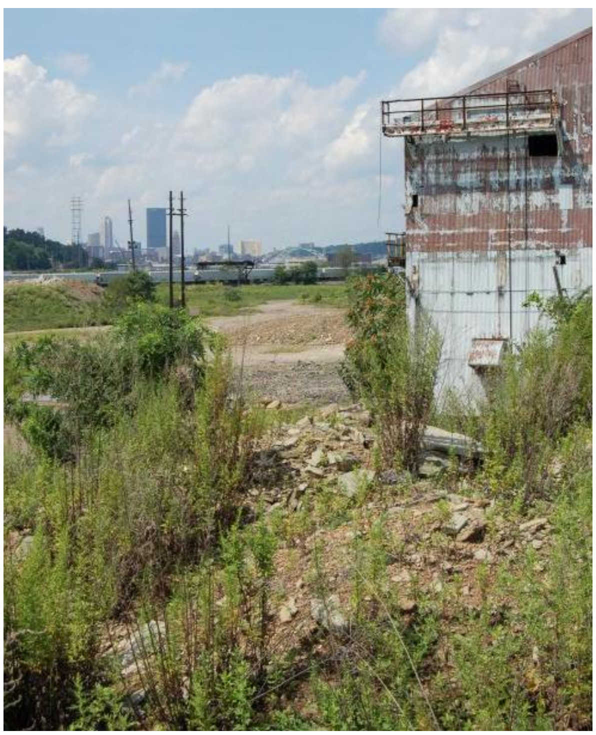

Figure 5.4.3-3. Brownfield.

Applicable Protocols and Specifications

Protocol 3 Soil Testing

Design Considerations

This BMP is eligible for SOV credits as defined in Chapter 7. A Criteria Checklist is provided at the end of this section as a summary of design and establishment considerations.

<u>Soil Design Options</u>

Three options are typically available when designing soil restoration or amendment strategies. Note that material availability must be taken into consideration.

- Import topsoil from another location.
  - Topsoil should not be stripped from agricultural fields, swamps, or bogs. The soil must be analyzed to make sure it meets the necessities of the site, specifications, and the plant palette.
- Modify existing soil material with amendments.
- Design the topsoil or an entire soil profile.
  - It is strongly recommended that the soil be designed for the Chattanooga climatic zone along with the corresponding plant palette.
  - Create specifications for the following soil horizon layers: O, A, B, and C. See Section 5.2.1, Protect Undisturbed and Healthy Soils, in this manual for a discussion of soil horizons. Other horizons omitted from the above list are generally not necessary and site design factors may limit their inclusion.

Figure 5.4.3-4. Soil being delivered to an elevated planting site.

Figure 5.4.3-5. Applying liquid biological amendment (compost tea) in situ.

- The primary function of each of these layers is as follows:
    - Compost imitates the organic horizons in the "O" layer.
    - Horizon "A" is the primary rooting medium.
    - A subsoil (B layer) provides added volume for rooting, plant stability, and nutrient and water storage.
    - In deeper urban profiles, a drainage layer serves in place of the parent material (C layer).

Figure 5.4.3-6. Designed soil layers being installed.

Figure 5.4.3-7. Close-up of designed soil layers.

Restoring Soil Structure

When natural soil is disturbed, it loses its structure. Loss of healthy soil structure affects the soil's ability to support plant life, move water, support microorganisms, etc. Soil horizons altered by compaction, grading, or other disturbances can lead to unhealthy vegetation, unstable soils, and poor stormwater management capacity.

Spreading topsoil or any material as a layer over an unknown sub-base material is **not** an effective strategy. Rather, a disturbed soil profile should be redesigned to reflect healthy existing conditions and the BMPs chosen for the site. The possibility of reusing existing site materials as components of the new soils and/or of using recycled materials should be explored.

Most natural soils have gradual transitions between layers that are important to the movement of water, roots, and nutrients. In contrast, sharp interfaces between horizons can impede or even stop water movement.

Figure 5.4.3-8. Urban soils being salvaged/sorted and debris being removed.

Figure 5.4.3-9. Urban soils being salvaged and mixed onsite.

Strategies for Soil De-compaction

What is soil compaction?

Soil compaction reduces porosity. Soils become compacted by the simple application of pressure from foot traffic, vehicles, settling, and even rain on unprotected or fragile soils. As soil particles are compacted, their pore space shrinks, creating soils that are largely impervious. Plant roots and soil organisms are negatively impacted by compaction. Biological activity is greatly reduced, decreasing the ability of living organisms to breathe, eat, and move. Compaction of soil can occur naturally and is called a "hard pan." In nature, hard pans usually result from special chemical or physical properties of the soil, which cement the particles together and create a barrier layer that is generally impenetrable.

There are two notable types of mechanical compaction:

- Minor Compaction – surface compaction within 8 to 12 inches
  - An axle load greater than 10 tons can compact through the root zone, up to 1 foot deep.
- Major Compaction – deep compaction, 1 foot or greater
  - An axle load greater than 20 tons can compact up to 2 feet deep.
  - Large areas are usually compacted to increase strength and stability for paving and foundations. As a result, lawns adjacent to these areas often have major compaction issues.

Compacted soil is determined in part by its bulk density, which is calculated as the dry weight of soil divided by its volume. Bulk density reflects the soil's ability to function as structural support, and to allow water and nutrient movement and the exchange of atmospheric gases. In general, the higher the bulk density of a soil, the lower the infiltration rate and the higher the stormwater runoff volume.

<u>Remediation</u>

Once the bulk density and depth of compaction have been determined for the soils, there are several possible strategies that can be used to mitigate the effects of soil compaction.

- Potential strategies for minor soil compaction (compaction that occurs in the top 8 to 12 inches of soil):
  - Core aeration.

Figure 5.4.3-10. Core aerator.

  - The effect of core aeration is temporary, requiring at least annual treatment depending on the use of the site.
  - Organic matter amendment.

Figure 5.4.3-11. Top dressing with compost.

- Native planting.
- Tilling/scarifying is an option as long as it is done deep enough (at least 12 inches) and the right equipment is used. Other site work, such as utility installation and paving, should be completed before commencing preparation of soils.

• Potential strategies for major soil compaction (compaction that extends to 20 inches or more):
  - Ripping/Sub-soiling: Sub-soiling chisels (a type of plow) can be pulled through the soil to break up deep compacted layers. The preferred depth is 24 to 30 inches. A series of passes in two perpendicular directions will improve effectiveness.

Figure 5.4.3-12. Chisel plow.

  - Some variations of these plows should not be allowed because they are too shallow (e.g., various disks, chisel plows), can compact the soil just beneath the depth of tillage (e.g., disks), or are not built to pull through densely compacted layers (e.g., spring-loaded equipment).

- If deep sub-soiling is planned, consider the location of utility lines, tree roots, and potential archaeological artifacts. Utility conflicts are the most common reason why sub-soiling may not be appropriate.

- Mitigating compaction in areas with existing vegetation:
  - For soil amendment within 3 feet of the drip zone of trees, compost should be worked into the upper 3- to 4-inch depth of the soils, just short of the transport roots, with a hand-tiller or similar tool. Because of the reduced depth of incorporation, amendment quantity will need to be reduced proportionately.

Figure 5.4.3-13. Hand tiller.

  - Restoration of appropriate soil chemical characteristics for plant growth requires matching the pH, cation exchange capacity, and nutrient profiles of the original undisturbed soil or the site's reference soil. Choose soil amendments (and fertilizers if needed) that minimize nutrient loading to waterways or groundwater.
  - Amendments to the soil should extend to a minimum depth of 12 inches.

Figure 5.4.3-14. Tree being injected with compost tea.

- De-compacting soils around trees:
  - Air Spading: First delineate the major framework roots. When roots are located, push the air into the ground to a depth of 1 foot. Ensure that the soil moisture is between 5 and 15 percent.

Figure 5.4.3-15. Air spading.

- Raised Root Soil Fill: Raised root systems above the soil surface need to be covered with soil to provide root plate weight and more accessible rooting volume. After the existing soil has been de-compacted, the filling soil should be placed no more than 3 inches thick per year. The soil used should be approved additional specified planting soil. Ensure that the soil moisture is between 5 and 15 percent before any soil remediation is performed.
- Vertical Mulching: Vertical mulching can be used in situations where there are several trees with overlapping roots that are difficult to identify and locate. Core the soil to a depth of 12 to 18 inches using a 4- to 6-inch-diameter auger in a grid pattern with holes approximately 3 feet apart on center. Take care to not excessively damage many large framework roots. The area to be cored shall be the entire area, excluding a 3- to 5-foot radius away from the tree trunk to the limits of the tree crown's drip edge. Scratch the walls of the core hole before filling the hole with a soil using approved additional planting soil. Ensure that the soil moisture is between 5 and 15 percent before any soil remediation is performed.

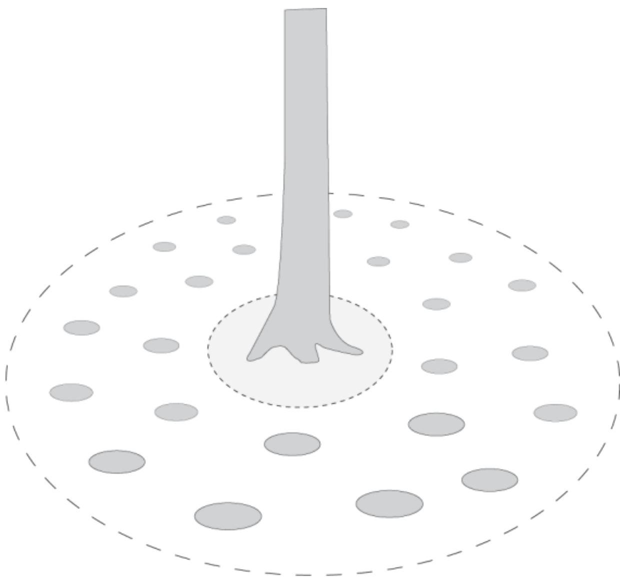

Figure 5.4.3-16. Vertical mulching.

- Radial Trenching: Radial trenching should be used when soil compaction is severe in and around single trees or when structural framework roots are easily identified and located. First delineate the major framework roots. Ensure that the soil moisture is between 5 and 15 percent prior to accomplishing any soil work. Starting 3 to 5 feet away from the trunk, dig a trench between the framework roots using a 10-inch-wide bucket or air spade down to a depth of 10 to 15 inches, just beyond the drip edge of the tree crown. Scarify the edges of the trench to remove any soil smearing. Fill the trench with soil using the approved additional planting soil.

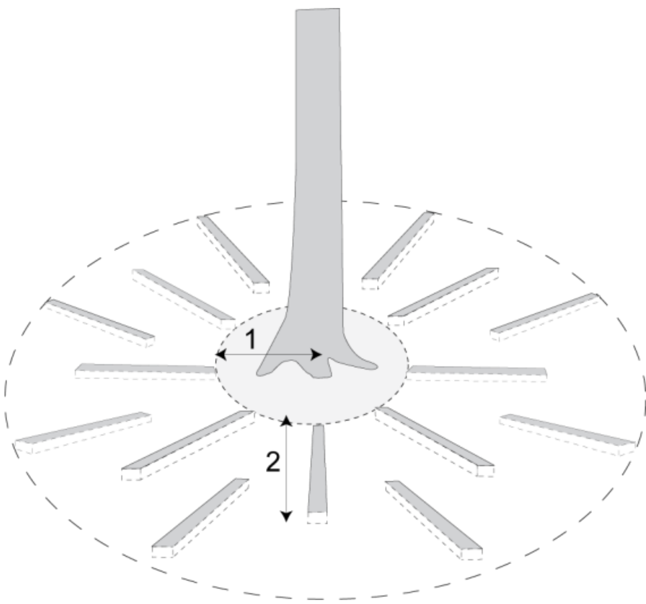

Figure 5.4.3-17. Radial trenching – 1) 3 to 5 feet away from the trunk, 2) trenches 10 inches wide, 10 to 15 inches deep to the edge of the drip line of the tree as indicated.

<u>Soil Amendments</u>

Soils should be amended, as suggested by the soil test analysis.

There are several possible organic amendments:

- Compost: Composted leaves, sewage sludge, and animal waste, if permitted.
  - Compost should be well-decomposed so as not to "burn" the plants with heavy doses of raw nutrients.
  - Well-decomposed compost is an excellent source of slow-release nutrients, promoting plant growth, feeding beneficial soil microorganisms, and reducing water stress.
  - Wood derivatives: Shredded and composted, nitrogen-treated sawdust, ground bark, or woodchips.
  - Manure: Well-rotted, stable cattle manure.
- Fertilizers: Use organic compost or slow-release fertilizers. Base rates on recommendations provided by the soil test report. (Note: Fertilizers may not be needed for meadow conditions because meadows thrive in poor mineral soils and disturbed richer soils can encourage the growth of weeds and invasive plants.)

- Biological Amendments: Mycorrhizal inoculants and compost teas (a dissolved solution of compost made by steeping compost in water for three to seven days) are the most recently recommended amendments.
- Mulch and erosion control materials (type depends on vegetative cover):
  - Straw mulch with tackifier
  - Compost mulch
  - Woodchip mulch
  - Fiber mulch

Figure 5.4.3-18. Soil injected with mycorrhizal inoculants before planting.

<u>Decontamination</u>

Contaminated sites are often extremely complex and primarily the result of former and present land use. Land development at brownfield sites normally occurs in three phases:

1. Site assessment
2. Site remediation
3. Redevelopment

Mapping contaminated soils and the resulting cleanup can be time consuming and expensive. An expert team of contamination specialists (geologists, hydrologists, industrial chemists), as well as special geographic information system (GIS) and computer modeling skills, may be required if the problem is extensive and if the proposed redevelopment covers most of the site.

Management of stormwater on brownfield sites depends largely on the remediation strategies. Imaginative remediation schemes can be integrated with site development plans to reduce costs.

Figure 5.4.3-19. Compost tea brewer.

On contaminated sites, the aim of soil remediation is to reduce contaminants to a level suitable for the use proposed, allowing the site to be developed with minimal environmental risks.

Bioremediation is the most economical remedial technique available for severely contaminated sites. This technique uses specific plants with their associated microorganisms to treat organic fuel-based contaminants such as hydrocarbons. The microorganisms living on the plants, including bacteria and fungi, use the pollutants as food, transforming them into more benign chemical compounds. This method of treating severe contamination is not fully explored herein. It is akin to the removal of pollutants and sediments by vegetation discussed in other protective and restorative BMPs.

For more information on soil remediation, see TDEC Division of Remediation online at http://www.tn.gov/environment/dor/.

Urban Soils

Urban soils are those soils that are disturbed in profile (one or more layers) and may consist primarily of fill materials or construction debris. In natural soils, wind, water, ice, gravity, and heat are the active agents in soil-forming processes. Mixing, filling, and contamination create a soil very different in characteristic and function from a similar healthy natural soil.
General characteristics of urban soils are:

- Horizon layers mixed
- Compaction
- Presence of a surface crust on bare soil; usually hydrophobic
- Restricted aeration and water drainage
- Interrupted nutrient cycling and modified soil organism activity
- Presence of manmade materials and other contaminants
- Extreme soil temperature regimes (hot/cold)

Figure 5.4.3-20. Urban soils.

Mixed Soils

Mixed soils may change abruptly at one or more levels within the profile, meaning the rooting environment may be drastically different from one area to the next or the whole profile may be homogenized, with elements from previously distinct profiles intermixing in a variety of proportions throughout the site. This all depends on the type and extent of the processes having previously affected the soil on the site (stripping, filling, mixing, compaction, addition, etc.). Thorough analysis of the entire soil profile and its properties is needed to ensure proper design and planning for landscape, hardscape, and architectural elements on the site.

Construction Considerations

Preconstruction Soil Testing: See Protocol 3 – Soil Testing

Soils should be amended, based on information on texture, organic matter content, nutrient deficiencies, and pH, as determined by recommended USDA Extension Service soil tests.

Management of Disturbance and Soil Erosion

Minimize the length of time that soil is left bare and unprotected. Avoid leaving soil bare during rainy or windy periods. Provide special protections for critical areas, such as steep slopes and the borders of streams. Note: Chattanooga requires a Land Disturbing Permit for most land disturbing activity. Please refer to Chapter 3 for applicability.

- Clear only those areas where construction is to begin and avoid creating large expanses of cleared areas.
- Plant temporary vegetation or cover crops to hold soil in place.
- Use compost berms and erosion blankets to prevent soil movement. Use silt fences to mitigate overland flow of stormwater.
- Use mulch for temporary erosion control and as part of the final landscaping plan.

Soil Characteristics: The following soil characteristics are difficult or generally unsuitable for reuse in Chattanooga (USDA Forest Service 1979):

- Salinity (millimoles per cubic meter): greater than 6
- Alkalinity (exchangeable sodium percentage [ESP]): greater than 8
- Concentration of toxic or undesirable elements: Moderate and higher
- Soil pH: less than 5 and greater than 8

Infiltration Rates: See Protocol 3, Soil Testing, in this manual.

Amendments: The addition of organic compost is probably the most critical amendment for soil deficiencies on most sites to prepare the site for planting. To apply amendments, loosen the soil to a depth of 3 inches and incorporate the organic materials by rototilling or disk harrowing to mix the soil and compost again to a depth of at least 3 inches. Inoculate the site with compost tea (commercially available). Fertilization with nutrients the soil needs in the recommended quantities will make up for inherent nutrient deficiencies.

Placing Soils on Steep Slopes

On steep slopes, increasing soil moisture can potentially cause soil instability. Soil should be placed in these areas during dry weather and in early fall to allow the roots of the plants to establish before the onset of frost. On slopes steeper than 4:1, protect seeded areas with erosion-control blankets and/or erosion-control fiber mulch.

Designed Soils

- The various components of a designed soil must be mixed. A variety of methods exist for mixing.
- The soil profile is best installed by layers (soil horizons) to ensure horizontal continuity of the material. Use natural soil profiles typical of the area to suggest appropriate thickness of each layer. Wide variations in thickness within a layer are not acceptable.
- Place soil in 4- to 6-inch “lifts” to ensure uniform thickness. Mix each lift between horizons.
- Conduct recommended tests; see Protocol 3, Soil Testing, in this manual.

Stockpiling Topsoil

- Stockpiles must be protected from wind and water erosion. Cover with an impermeable material to slow down drying, reduce dust, and exclude windblown weed seeds. On large projects, piles can be planted with a fast-growing cover crop to provide protection.
- Keep piles moderately damp to avoid drying out, blowing away, and creating dust.
- Where possible, create several smaller piles, rather than one large pile, to keep the soil from compacting under its own weight. The depth of each pile should be no more than 6 feet for sandy soils and 4 feet for clay soils.
- Living organisms in stockpiles will die from lack of oxygen, excessive drying, or other factors. It is difficult to prevent this loss during storage. Remediate soil, when replaced, with compost teas and living organisms to restore the biotic component.
- Handle the soil in these stockpiles as little as possible to prevent compaction.
- Store soil for as short a time period as possible.
- If stockpiling areas are to be counted as permeable, when the soil pile has been removed and the project is complete, reinvigoration of soil remaining under the pile location (with compost teas and other amendments) will be required.

Placing Stockpiled or Imported Topsoil

- Test the topsoil before placing on prepared subsoil to identify deficient or missing nutrients, organic matter, texture, etc. as noted above.
- Amend soil with missing components. Note plant requirements for an adequate depth of topsoil:
  - A minimum of 4 inches for turf, no mow mix, and ornamental herbaceous plants.
  - 6 to 8 inches for woody vegetation.
  - 5 percent minimum organic content.
  - Compact each lift to 75 to 82 percent of maximum Standard Proctor density according to ASTM D 698 or a maximum of 100 pounds per square inch within the top 6 inches of the soil profile, measured using a cone penetrometer with a ¾-inch diameter head.
  - Note: Topsoil may not be required where planting meadow vegetation.
- To allow water to pass from one layer to the other, topsoil must be "bonded" to the subsoil when it is reapplied to disturbed areas. This bonding can be accomplished by applying 2 to 3 inches of topsoil, tilling it into the underlying soil, and then applying the remaining topsoil.

Operations and Maintenance

- After the restoration and amendment process, soil may settle. In these instances, the area(s) in question should be backfilled with additional approved material and compacted to specified rates. Any newly disturbed areas should be restored to an acceptable condition.
- Planting areas should be amended for any critical deficiencies as shown by the soil tests.
- Drainage swales and other BMPs with vegetation must be periodically cleared of sediment to ensure that soil layers drain properly and do not get clogged. Maintain a buffer of vegetation at the edges of each vegetated BMP to reduce erosion and sediment deposition.
- To ensure the long-term health of designed soil and BMP vegetation:
  - Collect initial soil samples in each soil area after construction is complete and submit them for laboratory testing for additional amendments needed.
  - Each "type" of soil must be sampled separately and not mixed together. Tailor amendments to each area to reduce the possibility of over-fertilization and contamination of groundwater.
  - Repeat soil sampling every two years after the initial sampling and amend soils to follow test recommendations.

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Criteria Checklist BMP 5.4.3

ITEM DESCRIPTION	YES	N/A
The following checklist provides a summary of design guidance for the owner/applicant for successful implementation.		
• Evaluate existing soil conditions, including bulk density, organic matter, soil texture, and existing vegetation, before forming a restoration strategy.	☐	☐
• Perform soil restoration where appropriate and useful, anywhere the soil has been disturbed or badly damaged, especially where there will be new planting.	☐	☐
• Determine which of the following options for amending or restoring soil is appropriate: importing topsoil from another location; modifying existing soil with amendments; designing the topsoil or soil profile.	☐	☐
• Do not spread topsoil or any material as a layer over unknown sub-base material.	☐	☐
• Utilize the appropriate soil de-compaction strategy depending on depth of compaction and proximity to areas of existing vegetation.	☐	☐
• Utilize the appropriate soil de-compaction strategy for soil around trees. Strategies include air spading, raised root soil fill, vertical mulching, and radial trenching.	☐	☐
• Amend soil, based on the deficiencies made apparent by soil test analysis.	☐	☐
• For mixed or urban soils, thoroughly analyze the entire soil profile and its properties to ensure proper design and planning for landscape, hardscape, and architectural elements on the site.	☐	☐
• Minimize the length of time that soil is left bare and unprotected.	☐	☐
• Provide special protection to critical areas such as steep slopes and stream borders.	☐	☐
• Control soil moisture on steep slopes to prevent soil instability. Installation should be performed during dry weather, and early enough in the year to permit the establishment of vegetation before the onset of winter.	☐	☐
• Utilize the appropriate soil stockpiling strategies.	☐	☐
• Provide language in specifications for imported topsoil to be "bonded" to the subsoil when it is reapplied to disturbed areas.	☐	☐
• Provide language in specifications if soil settling occurs, the area(s) in question should be backfilled with additional approved material, compacted to specified rates.	☐	☐