MA Healthy Soils Guide for Site Design + Construction
Best Design + Construction Practices

Site Analysis + Planning: Soil Smart Designs

Timeline Phases: 1

Audiences:

Previous:

Next: 3.2 Specifying Soils: Amendments + Blended Soil Specs

In This Section

Why Do This Step?

Pre-development analysis and assessment are foundational steps in ensuring soil health and ecological integrity during the design and construction process. Practices for assessing site conditions include observation, mapping, and soil testing. A comprehensive understanding of existing site conditions greatly informs the strategies that will best protect or enhance soil health during and after construction, ensuring better outcomes for vegetation, water management, and carbon storage.

> Goal: Develop a soil protection and management plan using information gathered from a comprehensive site assessment to achieve a healthy landscape with high-functioning soils

Find this and other resources at the MA Healthy Soils Guide website: https://masshealthysoils.org/guide

1. Site Analysis & Assessment

Typically, there are two phases to site analysis and assessment. The first phase involves learning about the site remotely using pre-existing information that is available online or in existing records. The second phase involves a site visit armed with the knowledge gained from remote analysis, along with any maps, materials, and equipment needed for in-field assessments.

The information gathered will be used to:

- Create a **Soil Preservation and Management Plan** (see p. ##)
- Provide a baseline for restoring the soil to pre-development conditions (or better)
- Determine appropriate remediation strategies during or after the project is complete
- Groundtruth SSURGO information with actual soil conditions on site
- Detect any soil deficiencies or contamination from past use (see p. ##)

a. Remote Soil Analysis

SSURGO Soils Data and Mapping

The USDA's Natural Resources Conservation Service (NRCS) Soil Survey Geographic Database (SSURGO) and associated soils mapping provide crucial data for understanding the current soil conditions across a site, including characteristics like texture, structure, and drainage capabilities. SSURGO data and mapping are available on the **NRCS Soil Survey website** *(NRCS, 2019)*

By leveraging SSURGO data and mapping, design teams can assess the suitability of soils for various development activities, identify areas of high soil function, and locate regions where soil regeneration practices may be necessary. The database and mapping can highlight soils that are vulnerable to compaction, erosion, or other forms of degradation, guiding the development of tailored management strategies. If the site has already been disturbed by previous activities, SSURGO data can also provide a baseline soil profile as a reference point for rehabilitation post-construction.

Review of Mapping

Review other types of mapping for the site in question, such as USGS topographic mapping, National Wetlands Inventory mapping, MassGIS datalayers, including MassGIS wetland data layer, FEMA floodplain mapping and data, Natural Heritage & Endangered Species Program mapping, aerial photography/imagery, and any existing site plans or surveys. In some instances, such as for highly disturbed sites, historic maps and aerial photographs can be useful in understanding the site's history.

While remote site analysis is an important initial source of information, the specifics of a site may not be well represented beyond a certain scale. Mapping accuracy varies widely from region to region. Some soils data is more reliable in agricultural areas than in urban or forested areas. Other maps may be derived from modeling more than actual surveys. Either way, the more reliable information will always be what is observed and gathered directly on-site.

b. Onsite Soil Analysis

Walk the Site

Before conducting any specific tests, walk around the site to get an overall understanding of the site's characteristics, such as landscape position relative to adjacent land, water features and wetlands, vegetative cover types, slopes, presence of unusual features, areas of existing disturbance, and presence of invasive species or rare species. In addition to understanding specific characteristics of the site, you will also gain a feel for the land that can be helpful as you engage in more specific soils-related assessments. A common phrase among soil scientists is, "Get your head out of the hole!" as often, a full understanding of soils on a site is not possible without also understanding the larger context and landscape.

Identify High-Functioning Soils & Regeneration Potential

Look for soils that have not previously been disturbed (i.e., for construction or agriculture) and prioritize for protection. Additional testing may reveal other soils that may have a high regenerative potential due to their organic matter content, nutrient-holding capacity, or proximity to undisturbed sites. Areas with high regeneration potential can be managed in ways that enhance soil health, reduce compaction, and encourage biodiversity. Recognizing these soils early in the planning process ensures that they are preserved and fully leveraged for their carbon storage and ecological benefits.

Comprehensive Soil Testing and Assessment

Performing a standard soil chemistry test is not enough to fully evaluate soil health. Conduct a comprehensive soil assessment (see p. ##, **Soil Assessment Toolkit**) to gather necessary additional information about the functional capacity of the soils. Sampling areas should include average representations of the site prior to disturbance as well as key deviations, such as low areas, areas with notably different vegetation, or areas with particular land use histories. If the site is already disturbed, include samples from edges or fencerows where disturbance is minimal.

A comprehensive soil assessment goes beyond the standard soil test to evaluate the physical, chemical, and biological properties of the soil.

Most physical soil characteristics can be assessed onsite with a few simple tools. A lab analysis will reveal areas with imbalanced or excess nutrients that may pollute local waterways, and can verify the presence or absence of heavy metal contamination. Samples may be sent to the **UMass Soil and Plant Nutrient Testing Lab**. Currently, biological assessments are only available through private soil labs; however, the presence of healthy living soils can still be inferred from physical characteristics and organic matter content.

Contaminated Sites

Many of the soils in and around existing impervious surfaces have been both changed structurally and contaminated by historic land uses. Persistent lead contamination in roadside soils generated from historic vehicle emissions is an example of widespread but low-level contamination. In urban and industrial areas, testing is necessary to determine the best course of action on a case-by-case basis.

MassDEP is the lead agency that manages guidelines and regulations around contaminated soils. Contamination is a systemic problem in Eastern Massachusetts. When contamination is detected, a site must be certified to be below a certain level of risk, also called "No Significant Risk." If it is above this level, remediation must follow. Commercial and industrial sites have a different threshold than residential areas. For more information, see **Urban Soil Management for Climate Resilience, TreePeople, pp. 22-23**.

Interpreting Results

Soil test results must be interpreted with a clearly articulated goal for the final use of the landscape or site. Before altering soil texture with imported soils, for instance, consider whether the natural soils on site can already support a more ecologically or geologically diverse landscape with more adaptable plant species. Natural soils may have a higher SOC content than an imported soil and should be preserved if possible (see p. ##, **Soil Specifications: Blended + Amended**). This step alone can considerably reduce the carbon footprint of a development. Moreover, while results from a chemical analysis will typically include fertilizer and amendment recommendations, there are many different ways to approach soil health that may not require inputs at all—a potential cost-savings. Long-term management strategies that reduce compaction and prioritize a healthy soil microbiome are the most effective ways to ensure optimally functioning soils for carbon sequestration, productivity, ecosystem services, and long-term sustainability.

c. Hydrological Assessment

Stormwater can have significant impacts on soil and soil health. Stormwater can recharge groundwater, support soil moisture, and maintain wetlands and waterways. However, heavy storms and expansive impervious surfaces can lead to high velocity overland stormwater flows that can erode and damage soils as well as negatively impact downstream wetlands and water bodies. Understanding current surface and groundwater dynamics is essential for effective stormwater management. A hydrological assessment involves mapping water flow patterns, watershed areas, and identifying potential wetland areas and other sensitive receptors. By evaluating these dynamics, design teams can create stormwater solutions that maximize infiltration, reduce runoff, and protect water quality. Green infrastructure, such as bioswales, rain gardens, and permeable pavements, manages stormwater in a sustainable, ecologically responsible manner while also providing additional benefits such as heat island reduction. Green strategies are often easier and less costly to maintain than traditional grey infrastructure.

The key components of a hydrological assessment are:

- Mapping surface water flow, watershed areas, and wetland and other sensitive receptor locations to assess potential water-related impacts.
- Mapping depth to water table, depth to restrictive layer, and likely seasonal fluctuations of wet areas.
- Assessing infiltration rates to determine where green infrastructure, such as permeable pavements or rain gardens, can be integrated.

d. Vegetation & Biodiversity

Mapping existing vegetation and biodiversity on the site provides critical insights into the ecological health of the area and its relationship with soil. Understanding the flora and fauna of a site helps inform design decisions that aim to preserve or enhance biodiversity through plant selection, habitat creation, and minimizing ecological disturbance. This mapping process should include an inventory of plant species, identification of native and invasive species, and assessment of how these plants interact with soil health.

The key components of a biodiversity assessment are:

- Mapping the location of key vegetation that characterizes main features of the sites (e.g., mature trees, established plant communities, socially significant plantings)
- Mapping native species and the presence of any rare or endangered plant species or animal habitats
- Assessing the presence and aggressiveness of invasive species

e. Slope Stability & Erosion Risks

Mapping slope stability and erosion risks is necessary for preventing soil loss and ensuring the structural integrity of the development. Areas with steep slopes and fine-grained, sandy, or fragile soils are particularly vulnerable to erosion, especially after disturbance during construction.

> **Disturbed land may have an erosion rate 1,000 times greater than the pre-construction rate.**

Understanding the site's topography and erosion-prone areas allows for the strategic placement of retention systems and erosion control measures. Evaluating slope stability and minimizing steep slopes and slope lengths can help mitigate long-term soil erosion risks.

2. Design & Planning

Projects will realize the greatest benefits of soil function when construction activities and interventions are well-planned during the design phase. Establishing the condition of the soils on site early in the process (see p. ##, **Soil Assessment Toolkit**) will help determine the most appropriate soil management strategies (see below) and specifications (see p. ##, **Soil Specifications: Blended + Amended**).

To the extent possible, the site assessment should inform the design based on the limitations of the existing soil. This way, limited amendments can be used along with minimal soil disturbance to enhance soil functions over time. Where that is not feasible, and the necessary functions of the site exceed the capacities of the existing soils, more extensive interventions can be planned to ensure healthy soil functions while still accomplishing the goals of the design. In both cases, having a Soil Protection and Management Plan in place will facilitate a “soil smart” development.

a. Developing a Soil Protection and Management Plan

A Soil Protection and Management Plan consolidates the findings of the site analysis and assessment phase to create a map and accompanying plan. Creating a Soil Protection and Management Plan enables designers and contractors to observe, assess, and protect soils and vegetation well in advance of site preparation. Including this plan in construction documents, along with detailed drawings of best management practices and sections showing final grading specifications, creates a legally binding contract that clearly communicates the goal of maximizing soil health to the general contractor, excavators, landscape designers, and the client(s).

The Soil Protection and Management Plan will at a minimum:

- Include a scale drawing of the construction site that illustrates where Vegetation and Soil Preservation Zones and Critical Root Zones will be retained undisturbed
- Locate disturbed soils and detail with drawings and sections how soil management strategies will be applied during excavation, stockpiling, backfilling, and final grading
- Identify Soil Restoration Treatment Zones and determine which amendments will be used to restore/enhance soil function
- Specify any soil blends that will be used to replace disturbed soils
- Contain volume calculations of imported soils, compost, and mulch
- Include copies of laboratory analyses for any imported soils to be used that meet established topsoil or fill quality standards

Key Definitions

Vegetation and Soils Protection Zones

A vegetation and soils protection zone (VSPZ) specifies an area with high-functioning, fertile, and/or ecologically sensitive soil, unique features, or intact diverse vegetation of ecological importance. Not all sites will have a VSPZ. VSPZs can consist of one plant or can include several plants in a group, making sure that the zone encompasses all of the critical root zones of the desired vegetation to be protected (see CRZs below).

Soils and vegetation within VSPZs must not be disturbed or compacted during construction. Construction activities outside of a VSPZ should also not change drainage patterns and microclimate effects within the VSPZ. VSPZs should be protected from equipment parking and traffic, storage of materials, and other construction activities with a fence or other physical barrier that cannot be easily moved. The location of VSPZs should be clearly marked on the development plan AND on the site, with clear communication to contractors to respect VSPZ boundaries.

Critical Root Zones

Critical root zones (CRZ) are the areas around trees or other vegetation where roots have the highest density and where soil disturbance must be minimized. This is the zone where the highest rates of infiltration, biological action, and carbon sequestration occur. Mapping and planning for CRZs ensures that critical vegetation is preserved during construction. This includes maintaining soil structure, avoiding compaction, and preventing direct construction activities near these zones. Protecting CRZs is vital for preserving plant health, improving carbon sequestration, and maintaining overall ecosystem functions on the site.

CRZs for trees can be identified as a circle with a radius no less than 1 foot for every inch of tree diameter, with a radius no less than 5 feet. Encircling trees at the outmost edge of canopy, also known as the dripline, provides adequate minimum protection, while an additional 3 feet beyond the dripline provides optimal protection. Perimeters around shrubs should be not less than twice the radius of the shrub. Boundaries for herbaceous vegetation should extend to encompass the diameter of the plant.

Soil Restoration Treatment Zones

Any area with low-functioning soils or soils that will be impacted by construction activities can be designated as a Soil Restoration Treatment Zone (SRTZ). The SRTZ is where specific management strategies and/or amendments will be implemented to restore or improve soil health and functionality post-construction.

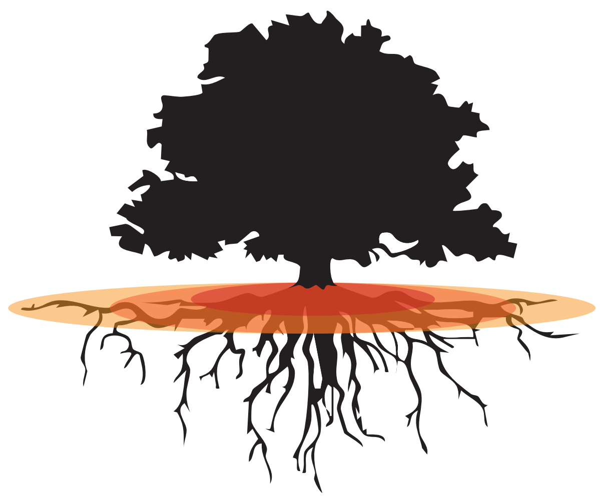


Figure 1: Critical root zone

b. Soil Management Strategies

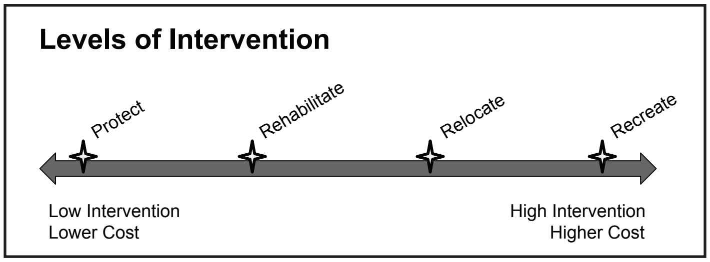
A key part of developing a Soil Protection and Management Plan is determining which soil management strategies to apply in different areas or stages of the construction process.

Key questions to consider during the design phase:

- What and where are the high-quality soils that need to be **protected**?
- Where are the soils that can be **rehabilitated** for greater ecological capacity?
- Which soils will need to be **relocated** during construction, and where will they move to?
- Which soils will need to be replaced or **recreated** to serve particular functional requirements?

A typical construction project may utilize several strategies on the same site to achieve the highest overall standards of soil health both during and after construction. These strategies can also be considered as varying levels of intervention, from low cost/low intervention (protect) to high cost/high intervention (recreate). The four main strategies are:

- **Protect** sensitive and valuable areas from impact
- **Rehabilitate** soils for better ecological function
- **Relocate** soils that will be disturbed by construction using best management practices
- **Recreate** soils using offsite mixes and amendments to add to, alter, or replace removed or compromised soils.



i. Protect

Identify **Vegetation and Soils Protection Zones (VSPZs)** and **Critical Root Zones (CRZs)**. Areas with high-quality soils *should not be disturbed or amended* in order to protect the diversity of soils on site.
Approaches may include:

- Fencing, signage, and access restrictions on design and construction plans. Show to scale and include appropriate details.
- Prohibiting the use of some or all heavy equipment in designated areas.
- Root and canopy projections for trees and shrubs on site preparation and design plans. Root and canopy projections, as well as protection measures, should show on all construction documents where work may impact VSPZs and/or CRZs.

Criteria for mapping:

- Mature forests and woodlands with high Soil Organic Carbon (SOC)
- Wetlands and hydric soils with critical water retention functions
- Critical Root Zones (CRZs) around large trees and native plant communities
- Farmlands or areas with high regenerative potential
- High-quality habitat features or areas
- Buffer distances (e.g., 50–100 feet) around key ecological areas

ii. Rehabilitate

Identify **Soil Restoration Treatment Zones (SRTZs)** that do not fall under the criteria for prioritized protection, but where low-disturbance methods for soil regeneration would increase health and function.

Approaches may include:

- Scratch, Not Dig: Light aeration techniques to break up surface compaction while preserving existing soil horizons.
- Organic Amendments: Compost and biochar additions to enhance microbial activity and water retention.
- Cover Crops & Mulching: Using temporary vegetative cover to stabilize disturbed areas and build organic matter.
- Addressing erosion and sedimentation issues.

Criteria for mapping:

- Previously disturbed areas with moderate compaction or depleted organic matter
- Soil with some structure remaining but in need of improvement for water infiltration and plant establishment
- Areas where minor disturbance is necessary but can be mitigated through low-impact restoration techniques

iii. Relocate

Identify areas where soil must be temporarily moved for grading or construction, but where the soil profile can be rebuilt with on-site soils and improved with amendments.

Approaches may include:

- Strategic soil excavation and stockpiling with staged removal to preserve structure.
- Amending soil before relocation to improve organic matter, nutrient levels, and the soil's physical properties.

Criteria for Mapping:

- Areas where disturbance is unavoidable but soil is not contaminated or overly compacted

iv. Recreate

Identify soils that are severely compacted, eroded, or contaminated and cannot be rehabilitated that will be recreated and replaced by blended or engineered soils.

Approaches may include:

- Blending imported soil with organic amendments to match native soil profiles
- Importing engineered soil mixes for stormwater infiltration or structural support

Criteria for Mapping:

- Severely compacted or eroded soil areas
- Contaminated soil areas

c. Planning "Soil Smart" Construction Practices

Planning the following actions will improve the soil health outcomes of a typical construction project using "soil smart" design and planning. These practices not only protect and promote healthier soils, they also frequently provide cost savings through increased efficiency and reduced post-construction site repair. Detailed instructions for all best management practices (BMPs) can be found in [Managing Soils On-Site](#).

Reduce Construction Footprint

An early intervention into any project is to minimize the construction footprint to the greatest extent possible. If the site of the building itself is not already fixed, prioritize protecting high-functioning soils and locate construction activities on areas with the poorest, or most disturbed, soil. See p. ## 1a-i. Protect Healthy Soil and Vegetation BMP. Building footprints can also sometimes be reduced through the use of alternatives to standard concrete foundations and slabs, such as piers, cantilevers, towers, and metal screw piles (Mickelburgh, 2023). While these alternatives may require more engineering and therefore be a more expensive design solution, they can still be a cost-effective and innovative way to minimize soil compaction and disturbance.

Define the Area of Work to require as little clearing and disturbance to existing vegetation as possible and prohibit the stockpiling of materials, driving, or storing of vehicles outside of the area of work. If possible, specify this boundary and the appropriate access routes in advance on the construction documents.

This single strategy may have the greatest positive impact on the long-term health of the soil and soil organic carbon (SOC) accumulation over the life of the project (see p. ##). It also typically reduces construction costs by limiting the cost of site repair post-construction.

Prevent Compaction

Compaction is one of the most soil-damaging impacts of construction. Compression and shear forces squeeze air out of larger soil pores and, in moist soils, cause the pores to refill with water rather than air (*The Science of Soil Compaction | Agriculture and Food*, 2018). Compaction severely compromises rainwater retention and filtration, exacerbating issues with runoff and drainage on the site. It also reduces the number, activity, and biodiversity of soil microorganisms, preventing efficient nutrient cycling, reducing carbon storage and sequestration, and increasing nutrient leaching and the emission of greenhouse gases. The effects of compaction are difficult to overcome and may persist for decades. Natural decompaction processes such as freeze-thaw cycles, animal burrowing, and root growth only slowly diminish compaction, and are typically limited to the upper foot or two of soil. Even when bulk densities decrease, the original soil structure may not be achieved (Randrup, 1997).

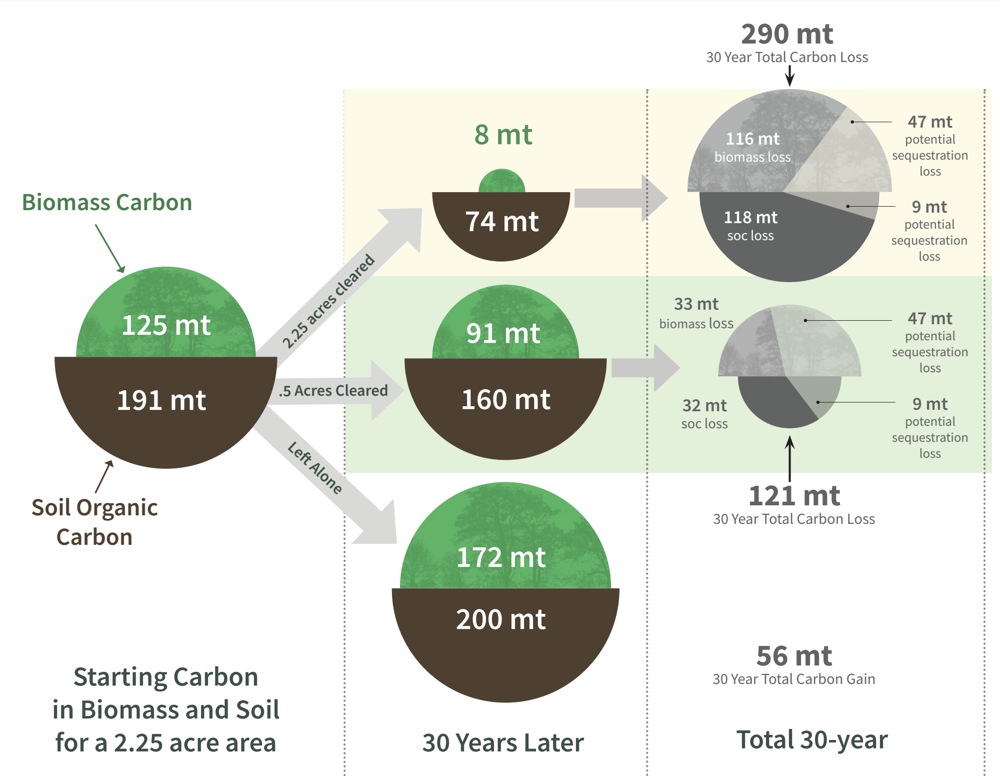


Figure 2: Comparison of total 30-year biomass by acreage of clearing

Construction documents can specify access paths to and from stockpiles and materials drop-off zones. On loose soil, the first vehicle pass causes the most subsoil compaction. Subsequent passes increase the area and severity of compaction. In most soils, there is little increase in subsoil compaction after four to five passes (*The Science of Soil Compaction | Agriculture and Food*, 2018). Using narrow and well-defined access roads will limit the compaction caused by construction vehicles to a smaller area and protect more soils on site. Other ways to prevent and limit compaction include using smaller equipment and prohibiting construction activities when soils are wet. For additional BMPs, see **p. ##: 1b.1 Compaction.**

Prevent Erosion

Soil and sediment runoff during typical construction projects can top 100-200 tons per acre, or more. Erosion reduces the productive capacity of soils and negatively impacts local water quality. The primary culprit in construction settings is exposed ground that has been cleared or stripped of topsoil, or mounded in poorly-managed stockpiles. Bare ground leaves dirt particles vulnerable to high winds and heavy downpours, both of which are becoming more prevalent with higher intensity storm systems in the northeastern United States.

Eroded landscapes are costly to repair. They cause short-term changes in water quality, such as restricted recreational activities, stressed aquatic organisms, and damaged shellfish beds. Long-term accumulation of sediment and pollutants into receiving waters can create problems that are particularly difficult to correct, such as eutrophication, polluted groundwater, and contaminated sediments (*Erosion and Sediment Control Guidelines for Urban and Suburban Areas*, 2003).

Erosion can be controlled using physical barriers such as silt fences, sediment traps, erosion control matting, vegetative cover, or terraces. See p. ##: **2c-iv. Soil Maintenance BMPs #1 and #2**. Incorporating slope stability and minimizing steep slopes and slope lengths into the design phase can mitigate long-term soil degradation, save money, and protect valuable ecosystems.

Planned Soil Movement

The only thing worse than moving soil once is moving it twice! In the design phase, consider how and where soil movement will occur throughout the construction timeline. This will protect healthy soils from being buried under stockpiles, reduce further mixing of soil horizons, and minimize the compaction caused by large equipment accessing piles from multiple angles.

Determine an appropriate area for stockpiling that avoids critical root zones, natural hydrological pathways, and sensitive ecosystems. It is essential to select stockpile locations that do not interfere with existing vegetation and biodiversity. Areas that are already disturbed or have low-functioning soils are less likely to be harmed by temporary soil storage. Additionally, areas should be well-drained to prevent erosion and sedimentation issues while ensuring minimal soil disturbance. See p. ##: **3c-i. How You Stockpile Matters**.

Final Landscape Design

Instead of engaging landscaping as an afterthought in the construction process, consider planning future plantings during the design phase. Decide whether the final landscaping will work with existing conditions, or whether the soil conditions need to change in order to achieve particular design goals (i.e., stormwater management, heat island reduction, etc.) Knowing the location of future planting beds, trees, rain gardens, etc., can help contractors to protect and preserve soil functions in productive areas, prevent subsoil compaction in areas requiring good drainage, and save money with reduced need for soil inputs and amendments post-construction.

Consider as well the impact of landscaping on the site's long-term ability to capture and store carbon.

> **Imported sandy loam soils are the most frequently specified soils for lawns and ornamental landscapes, yet they also have a low carbon storage potential.**

They tend to require annual applications of fertilizer that can negatively impact both soil biology and local water quality. Instead, work with the soils already on site as much as possible by designing geodiverse landscapes with adaptable species and utilizing locally sourced amendments. This will help to increase soil organic carbon and reduce the costs of landscape installation and long-term maintenance. Strategies may include establishing meadow instead of lawn, reforesting edges, planting pocket forests, installing rain gardens, restoring wetlands, or reintroducing native wetland vegetation. In general, the sooner vegetation is established post-construction, the less prone the site will be to erosion and the sooner disturbed soils can rebuild healthy functions.

Wherever possible, these five key practices should be noted on the construction documents with as many detailed drawings as needed to communicate to contractors the importance of protecting soil resources.

Next Steps

[Conclusion or teaser for next section, explanation of why these sections happen in sequence.]

Resources + Tools

Case Studies + Applications

The nutrient cycling model: lessons learned (NuCM, weekly or monthly time scales)

Soil Health Resources

Massachusetts Healthy Soils Action Plan (HSAP)

Soil Health Soil Testing and Soil Amending - Maine Organic Farmers and Gardeners
Paradigm shifts in understanding soil health

Cornell Soil Health Manual Fact Sheets

Comprehensive Assessment of Soil Health (CASH) Manual

New York Soil Health Initiative videos

NRCS Soil Health Assessment guides

Soil Quality: Indicators
Soil Quality for Environmental Health

Tools, apps, and guidelines for assessing soil health on construction sites

Carbon Conscious

NRCS Cropland In-Field Soil Health Assessment

Credentialing Programs

SITES

Living Building Challenge

Endangered Species Resources

MESA Massachusetts Endangered Species Act

MassWildlife's Natural Heritage & Endangered Species Program

Mass.gov Regulatory Maps: Priority & Estimated Habitats

MassGIS Maps

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