AIRSPADE®

PNEUMATIC SOIL EXCAVATION

Technical Applications Bulletin

Use of Compressed Air-powered Excavation for Arboricultural Site Works

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research funded by
Guardair Corporation

prepared by
Stephen Stimson Associates | Landscape Architects
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September, 2016

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With construction master specifications by Vincent P. Rico, of Rico Associates, and standard construction detail drawings by Stephen Stimson Associates available online through Guardair Corporation at www.airspade.com/guide

Prepared by Stephen Stimson Associates | Landscape Architects, Cambridge, MA and Princeton, MA; and in collaboration with Bartlett Tree Research Laboratories, Charlotte, NC.
Research and publication funded by Guardair Corporation.

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Heritage tree preservation at the Massachusetts Institute of Technology: Successful tree preserva-tion requires collaboration with landscape architects, arborists, consultants, utilities, and contractors. The work shown here at M.I.T. utilized air-spading techniques and placed the project arborist from Bartlett Tree Experts in an integral role in the design process and throughout construction. (Image courtesy of Stephen Stimson Associates.)

Introduction by Terence J. Fitzpatrick, ASLA

It's fair to say that we value our trees a little more than we used to.

Nowhere is this more true than in cities where the desire for human comfort and enjoyment align with the imperatives of economic, environmental, and social sustainability. Increasingly, people are turning to cities as places to live and interact, grow, learn, and find inspiration. We now have many examples of cities progressing beyond single-minded zoning policies or car-centric urban planning, in favor of more inclusive, human-scale landscapes.

Trees are increasingly recognized as vital elements in our cities and cultural landscapes. Urban forestry programs have provided enormous benefits, including the ability to moderate a city's microclimate and to reduce energy usage associated with the heating and cooling of buildings. The cultural benefits of trees is even wider reaching than these significant, quantifiable examples. Trees appeal to an undeniable desire of human nature. Simply put, places with healthy trees provide comfort, enjoyment and stimulation. This translates into neighborhoods that gain the affection and fulfillment of their inhabitants, young and old. This sociological impact of the built environment is no small claim. Enduring and diverse communities are necessary to support access to economic and educational opportunities and are increasingly cited by sustainability experts for their positive impacts ranging from health care and well-being, to energy consumption, efficiency in allocating public funds, and improved land use practices. Trees play more than a superficial role in this equation. In the construction and tree care industry, we're seeing growing investment by clients and decision makers — public and private — who are demanding health and longevity from their trees. As a result, designers, arborists, and contractors are becoming more accustomed to close collaboration, and new techniques and technologies are being employed to promote the long-term success of the urban canopy.

In the practice of landscape architecture, there is overwhelming evidence of the rising cultural value of trees. For example, the funding and application of scientific research in arboriculture and soil science has grown rapidly in recent years. Both of these professions have become indispensable components of design and implementation teams, validated by clients and general contractors who increasingly recognize their contributions to projects with successful tree preservation, health, and longevity.

Excavation with tools using compressed air, or air-spading, has been developed as a technique in the tree-care industry since the mid-1990's. These methods allow tree roots to be excavated efficiently and without damage. This makes it possible to care for a tree's soil and root system, for example, in highly trafficked landscapes where soil becomes compacted or otherwise unsuited to natural tree growth or to accommodate construction projects (underground utilities, pavements, or building foundations), in which trees would otherwise be severely damaged or removed.

ABOUT THIS BOOK

This publication is aimed not just at tree-care professionals performing air-spading procedures, but also to the landscape architects, urban designers, engineers, contractors, consultants and decision makers involved in any project involving tree health care and preservation. It brings together the leading experts in arboricultural research and practice, landscape architecture, and innovators in tree-care technologies to illustrate common applications of air-spading and discuss the process and techniques necessary for success.

The detailed drawings and descriptions throughout the book have been prepared by Stephen Stimson Associates (SSA), a landscape architecture studio with decades of experience advocating for the stewardship of mature trees and a record of collaboration with some of the finest arborists and consultants available.

These drawings and accompanying text are intended to be used as a standard reference for understanding a wide range of possible applications and aid in communication between designers, consultants, and contractors. Additionally, these standard details will be made available digitally through the AirSpade website (in .pdf and .dwg file formats). As standard details, these drawings should be carefully considered and modified to meet the specific conditions and goals of individual projects.

In addition to thoroughly reviewing this publication for technical accuracy and clarity, diverse experts have contributed short essays that illuminate unique perspectives on the development, future, and practical application of the tree-care industry.

In their essay, Dr. Tom Smiley and Kelby Fite, Ph.D., provide insight into their research and development of practical applications using the AirSpade for over two decades at Bartlett Tree Research Laboratories. This work has contributed immensely to the industry at large and continues through arboricultural education programs and in supporting the growth of air-spading as it continues to become more readily available and acknowledged as a valuable professional service.

Next, Thomas C. Tremblay and Richard N. Sweet, both of AirSpade (division of Guardair Corporation in Chicopee, Massachusetts), discuss air excavation technology and product innovation. Today more than ever, air excavation technology is available and well suited to arboricultural applications. This is thanks, in large part, to Guardair's commitment to research and development and long-term partnership and collaboration with top people in the tree-care and horticultural industries.

Joe Wahler contributes a third essay in which he discusses the specified use of an AirSpade on several projects at Stephen Stimson Associates. These examples highlight the role of a landscape architect in driving the application of best-practices and orchestrating interdisciplinary consultants and contractors. Construction projects are especially challenging when dealing with highly variable site conditions and living trees. Joe is a master at orchestrating the details of the construction process to achieve a larger vision with flexibility and creativity and describes a process of collaborative feedback with project arborists in particular.

Vince Rico, a landscape architect and construction specification specialist, has prepared a master specification in conjunction with the collaborative effort in assembling this publication. Like the detailed drawings, these specifications should be considered and modified based on an individual project's requirements and are available digitally for use by landscape architects.

CONCLUSION

Given the rising cultural value of large trees, and the relative under-utilization of arboricultural techniques using the AirSpade, we believe this publication to be especially timely. The practical viability of air-spading services has increased dramatically in recent years, while evidence of its benefits and overwhelming acknowledgment of its value by clients and industry professionals alike has driven a growing demand. Still, these applications remain underutilized on most construction and tree-care projects. With this publication, we hope to share this growing body of knowledge and inspire more innovative project collaborations, and more widely improved stewardship of our precious trees.

This small streetscape project in Michigan's Upper Peninsula serves as a demonstration project, where the construction team successfully collaborated with the project arborist and employed new techniques including air-spading and structural soil replacement.

At the Radcliffe Institute in Cambridge, MA, SSA and Bartlett Tree collaborated to save several large, sensitive specimens. Increasingly, this type of stewardship is sought after by clients who recognize the significant value of their trees.

(Images courtesy of Stephen Stimson Associates.)

Arboricultural Research and Practice

Key findings, techniques, and practical application developed from Bartlett Tree Research Laboratories

by Dr. Tom Smiley and Kelby Fite

The AirSpade is a unique tool in the arboriculture industry. Shortly after its introduction to the industry in the 1990's, we started using it here at the Bartlett Tree Research Laboratories to address a number of issues that affect tree health. It was a decade prior to the introduction of the AirSpade that we first realized the negative impact of soil against tree trunks. We found that soil in this inappropriate location resulted in a deterioration of bark and infections of pathogenic fungi and some insect pests. These pests could weaken or kill trees.

We addressed the root collar burial problem by recommending manual root collar excavation using shovels, trowels, and other tools. We were able to move the soil, but in the process, trunk and roots were often wounded. By replacing steel tools with high-pressure air, we could quickly remove soil without creating additional problems.

The second issue we were working with was soil compaction. Compacted soil can lead to reduced root growth, tree decline, and eventual mortality. We experimented with a number of tools that injected air deeply into the soil and found that, while these tools produced an impressive lifting of a soil plate, they made little change in the overall density of the soil where roots develop. The AirSpade, allowed us to till the soil and incorporate organic matter, fertilizers, and other materials while not damaging tree roots. Years of research revealed significant improvement in soil quality and root health with the Root Invigoration process.

At the F.A. Bartlett Tree Expert Company, we continue to treat buried root collars and soil compaction problems using the AirSpade. We see positive responses from thousands of trees that receive these treatments every year. On the research side, we are continually striving to find improved techniques to make these treatments more effective, faster, and safer.

Bartlett Research Lab has been a leading voice in arboriculture since its founding in 1926. Today the laboratory, located in Charlotte, North Carolina, includes a 350-acre arboretum, several working test plots, and a fully equipped modern laboratory. The lab continually contributes research and publications, offers a wide range of professional services such as soil testing and plant diagnostics, offers training programs for professional arborists, and houses an extensive library and education center.

Root Collar Excavation: At Williams College in Massacusetts, a certified arborist prunes girdling roots while performing root collar excavation on a specimen oak tree. (Image courtesy of Stephen Stimson Associates.)

Air Excavation Technologies

Research and Development in an Emerging Industry

by Thomas C. Tremblay and Richard N. Sweet

A BRIEF HISTORY OF AIR EXCAVATION

The use of compressed air for excavation, as an alternative to mechanical or manual methods, began in the 1960's among utility companies interested in reducing costs associated with underground pipe repair. Pneumatic excavation proved to be a reliable way to safely uncover utility lines without damage.

In addition to uncovering utility lines, pneumatic excavation was tested in a number of applications during the 1970's and 1980's. This included work with the Department of Defense to safely excavate around land-mines and unexploded ordnance, as well as "soft digging" applications in other industries. Improvements in equipment included advancements in nozzle technology that provided faster excavation. During this period, the AirSpade tool was first developed and became commercially available.

In the mid-1990's, air excavation technology became widely utilized within the arboriculture and site construction industries. Clearly, the same technology used to uncover underground utility lines could also be used as a diagnostic tool for uncovering tree roots without harm. As tree-service companies began to recognize the advantages of air excavation, many new, low-impact arboricultural applications were developed. F.A. Bartlett Tree Expert Company, the largest and most recognized tree-service company in the U.S., became an early adopter, and additional techniques followed.

Consequently, over the past several decades, the use of air excavation tools for tree health management has grown enormously. Today, use of the AirSpade within the highly sensitive tree root-zone is a well-proven practice in a wide range of arborist projects.

ARBORICULTURAL RESEARCH AND PRACTICE

The positive benefits of air excavation for tree-care are widely recognized within the arboricultural community. To analyze these benefits, several research studies have been conducted. Among them is the following study on urban trees and an excerpt from the conclusions. (Note: The authors refer to root invigoration via air excavation as "air tillage";

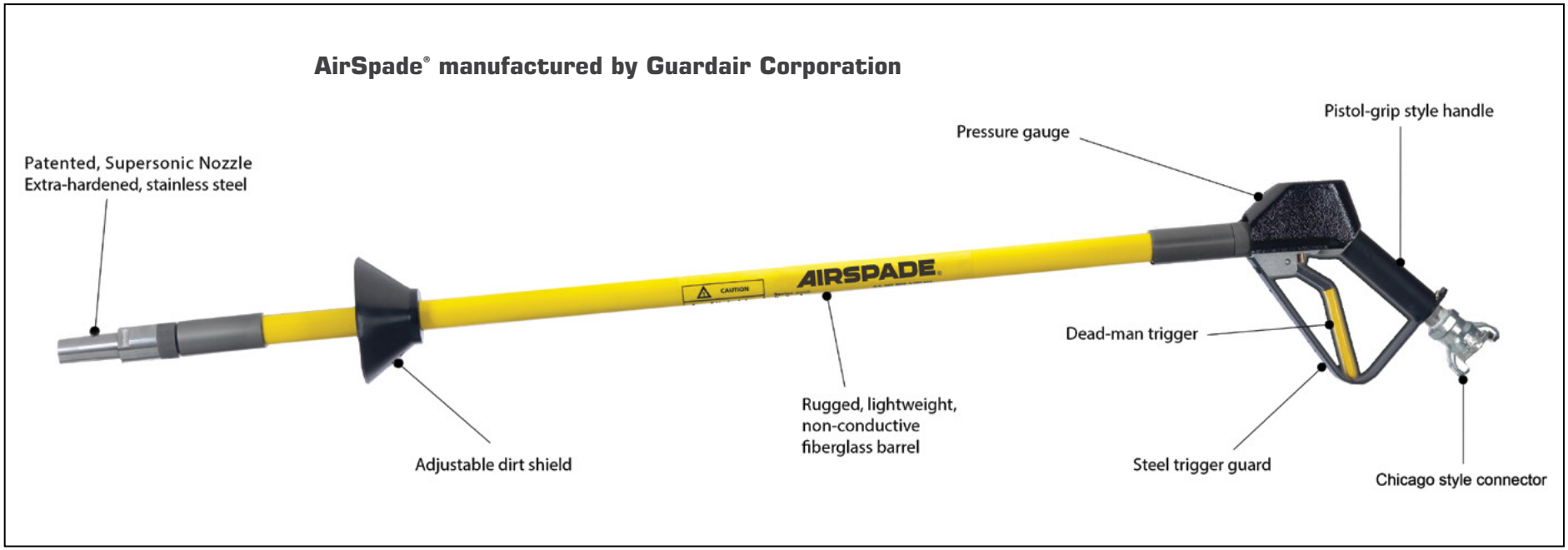
AirSpade being utilized for root collar excavation: Product development has gone hand-in hand with scientific research and the growth of practical applications in professional tree care services.

"AFM" refers to the process of air excavation, fertilization, and mulching.)

"A program of air tillage, prescription fertilization, and mulch improved a suite of physical and chemical properties in urban soils. Mulch was the most effective of the individual treatments, increasing soil organic matter and water content as effectively as the full AFM treatment and providing short-term decreases in soil strength. The specific benefits of the AFM treatment differed by site. In the field, practitioners should experiment with specific materials, techniques, and treatment frequencies to best address the needs of individual sites. Nonetheless, it is clear that a multi-pronged approach to soil remediation gives arborists an effective means to improve compacted soils beneath established urban trees."

(Excerpt from "Evaluation of a Soil Decompaction and Amendment Process for Urban Trees"by Kelby Fite, E. Thomas Smiley, John McIntyre, and Christina E. Wells. Arboriculture & Urban Forestry 37(6): November 2011, ©International Society of Arboriculture.)

This study concluded that those urban trees subjected to the full benefits of AFM treatment responded most positively. AirSpade played



an integral role in developing this research in collaboration with F.A. Bartlett Tree Expert Company. This type of collaborative research has advanced air-spading techniques and applications, and has also influenced the design of the AirSpade tool.

TECHNOLOGICAL RESEARCH AND DEVELOPMENT

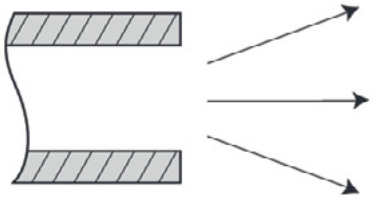
The keys to effective and safe air excavation are (1) the design of the air output nozzle, (2) human factors, and (3) safety features that must be incorporated into the tool.

Engineering of air excavation tools starts with an in-depth understanding of the effects of directing compressed air into soils. Soil is an unconsolidated assemblage of solid particles including clay, sand, silt, rock, and sometimes organic matter. Voids between the particles are occupied by air and/or water. When compressed air is directed into soil at close range, it enters the voids, expands, and fractures the soil in a fraction of a second. Non-porous materials such as metal or plastic pipes, cables, or even tree roots are unaffected.

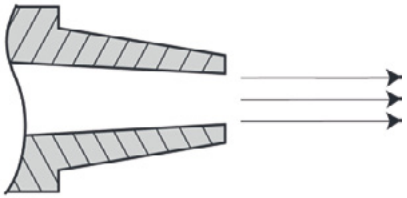
NOZZLE DESIGN

To optimize the performance of compressed air applied to soils, AirSpade recognized the importance of maximizing the exiting air speed (and subsequently the force) and to tightly focus the exiting air jet. This led to the development of the patented Supersonic Nozzle that converts compressed air into a high-speed, highly focused air jet moving at twice the speed of sound — Mach 2. Equipped with the Supersonic Nozzle, the AirSpade performs better in compact soils, provides faster excavation rates, and operates more efficiently by consuming less (expensive to produce) compressed air, thus saving time on the jobsite compared to other air excavation tools equipped with conventional nozzles. With a documented excavation rate of 1.0 to 1.5 cubic feet per minute (depending upon soil strength), the AirSpade is 2 to 3 times faster than hand digging and is highly effective in time-sensitive projects while still protecting sensitive root systems.

Supersonic Nozzle: Soil fractures from stress (force per unit area) applied to its surface. Focusing this force on a small unit area results in faster, and more efficient soil excavation. As shown in the diagrams above, air exiting from an open pipe, or from a conventional nozzle, expands rapidly outward, across 3 to 4 times the unit area, versus the focused output of the AirSpade Supersonic Nozzle. In addition, open pipes or conventional nozzles operate at speeds below Mach 2. Thus, the Supersonic Nozzle outperforms other air-jets by a wide margin.



Unfocused Air Flow from Pipe or Improperly Designed Nozzle



Focused Air Flow from Airspade Supersonic Nozzle

HUMAN FACTORS AND SAFETY

In addition to the Supersonic Nozzle, a properly designed air excavation tool must incorporate ergonomic features, be easy to use, and, above all, safe. Compressed air is a powerful and potentially dangerous utility, so the tool must be properly engineered to handle air flow at Mach 2 as well as air pressures as high as 200 psi. Also, air excavation is often performed in close proximity to underground electric utility lines, so protection from high voltages is essential.

The AirSpade is designed to meet these requirements and includes the following features:

- Lightweight, ergonomic cast aluminum handle with soft rubber grip
- Padded, full-length trigger with dead-man feature
- Steel trigger guard prevents accidental activation
- Integral air pressure gauge ensures optimal operating performance
- Rugged, lightweight, insulated fiberglass barrel
- Adjustable, dirt shield protects the operator from dislodged soil
- Extra-hardened, stainless steel Supersonic Nozzle
- ¾"FNPT air inlet accommodates standard Chicago-style swivel fitting

CONCLUSION

Over the past 30+ years, the AirSpade has become a must-have tool for tree-service companies providing tree health management and site construction services. Applications using the AirSpade are safe for both trees and personnel on site. When paired with a standard 185 cfm tow-behind air compressor, the AirSpade delivers exceptional performance for a range of applications at remote locations. Through ongoing engineering, research, and experimentation, AirSpade continues to develop new options, nozzle sizes, and accessories in response to demand from arborists and other end-users.

Anticipate and React

Landscape Architectural Practice and New Opportunities for Tree Preservation

by Joe Wahler,
Landscape Architect, RLA, ASLA
Principal, Stephen Stimson Associates

Our goal for every project is to anticipate potential issues and establish procedures with our collaborators (client, contractor, consulting professionals, plant nursery, and maintenance) that result in long-term success. Plant protection and establishment is a complex and dynamic endeavor that requires a good plan but also tools to react and remedy unintended poor growing conditions, which, unfortunately, happen more often than we would like. This is the reality of landscape design and construction that requires myriad tools and operations.

The importance and value of trees in our urban environments and private landscapes is well documented and espoused by landscape professionals. Chief among these are trees' social and environmental benefits. The livability and quality of our urban environments depend on the cultivation and preservation of our urban forests. Trees play a vital role through carbon sequestration, production of oxygen, heat island reduction, and storm water management. All of these benefits are of utmost importance as global population centers densify.

Preserving existing trees and cultivating the urban canopy are important missions of the landscape profession that have local and global impacts. The science of preserving and nurturing our trees is rapidly evolving and an area of focus for us as landscape professionals. We have increasingly specified the use of air-spading for the preservation and protection of existing heritage trees, conditioning of nursery-grown material, and to remedy post-completion challenges.

PRESERVING HERITAGE TREES

We have been working with the Parks and People Foundation since 2006 on their new headquarters in Baltimore's Druid Hill Park. The park, originally part of Dr. George Buchanan's Auchentoroly estate, was purchased by the City of Baltimore in 1860. The urban park, designed by Howard Daniels and John Latrobe, includes some of the oldest growth forest in the state. Within the construction limits

Site Plan: The Center for Parks and People at Archentoroly Terrace in Baltimore, designed by Stephen Stimson Associates.

of our project alone are many old growth heritage trees, including a seventy-two-inch caliper yellow poplar (Liriodendron tulipifera), which anchors the site's main pedestrian arrival point adjacent to the city's Mondawmin Metro Station.

The location of every tree was included on the survey, but a lack of management of the parcel for over twenty years resulted in an overgrown, nearly impenetrable wild. After clearing of the site's understory by a herd of goats, the Parks and People's staff arborist led a group of community children in the identification, assessment, and measurement of the trees' diameters and canopies. The use of goats was the idea of the client and their representative in response to our tree protection plan, which limited the use of machinery within all critical root zones (CRZ).

We specified that all work within CRZs was to be supervised by a certified arborist and any excavation be done by AirSpade only. The site design we developed was sensitive to the existing trees and minimized disturbance to the greatest extent possible. Where construction

Goat Clearing: At Parks and People, goats were brought to clear the overgrown site without causing damage to the numerous large specimen trees throughout the wooded lot. (Photo by Meredith Cohn from the Baltimore Sun, copyright, 2009.)

Tree Survey: Parks and People's arborist worked with local youths to survey the overgrown forest, including many of the largest trees in the area, and to help develop a vision for the design and protection of the site and its existing resources.

within the CRZs was necessary, strict procedures were developed and implemented. One aspect of construction was directly adjacent to the yellow poplar where the main pedestrian path extended the project's geometries to create a connection to the subway station and community.

Excavation for the path subbase and step foundation was done by air-spading. This allowed the tree roots to be exposed and properly protected or avoided in the construction of these elements. Through this process, an encounter with this enormous specimen tree was made possible, providing visitors with a consciousness of the site's history and longevity.

CONDITIONING NURSERY MATERIAL

Nurseries tend to exist in rich alluvial soils that have a high percentage of fine-grained silts and clay. These soils are generally slow draining, which keeps moisture near the plants' roots and thus reduces the need for irrigation by the grower. When these nursery plants are transplanted, their root systems are significantly reduced as a result. The trees are then planted in site soils (whether amended existing soils or engineered soils), that are typically more coarse and well-draining. This can result in dissimilar water retention between the root ball and the site soil and difficulty in managing irrigation and nutrients. Blending of the nursery and site soil profile is critical for the management and long-term success of the plant.

We are working with F.A. Bartlett Tree Expert Company to precondition in ground, and container-grown plant material prior to planting a five (5) acre intensive green roof at Harvard University. Pine & Swallow Environmental, the project soil scientist, is designing engineered soil mixes that are well draining with high sand percentages. Based on our collective experience, we are developing a procedure to remove the plants' nursery soil using an AirSpade. The plants will be transported to a holding yard at the site, the root balls will be bare rooted by AirSpade to remove a significant amount of the nursery or container soil to expose the root systems and allow for blending of the root ball soil and engineered site soil.

This will be done just prior to planting by F.A. Bartlett Tree Expert Company and the installing contractor. The goal is to minimize the dissimilar watering requirements of the nursery soil and site soil. It will also allow for the establishment of a healthy root system through the correction with any problematic crossing or girdling roots.

Parks and People, Baltimore: The site seen here, still in construction, has many large trees that define the experience of the site and its value to the community (photo courtesy of Ziger/Snead, LLC., architects).

POST–COMPLETION REMEDY

The built landscape is never perfect, and avoidable problems have a way of compounding when they evade detection. We've been reminded of this reality from time to time through valuable although difficult learning experiences. This was the case on a private residence we designed in Cambridge, Massachusetts.

We had specified an American beech (Fagus grandiflora) hedge along the street side of this double lot urban residence. We tagged the plants at the nursery with the contractor, checking for good branch structure and shape. The plants were beautifully full to the ground, which was perfect for the intended use, but we failed to notice that the trees' crowns were buried by an average of six inches of soil from years of field tilling.

All provisions were made on site for a successful planting. The site soil was evaluated and infiltration tests were done prior to planting. The site soil was an urban fill soil that was finely graded with low but acceptable infiltration rates.

The trees were planted with the root ball slightly high of the finish grade per our details and created a beautiful twelve-foot hedge at the completion of construction. The plants were fine for the first season, as

Yellow poplar (Liriodendron tulipifera): The Parks and People site included several massive specimen trees, including this one, which without proper consideration could easily have been severely damaged or destroyed in the construction process.

Harvard Divinity School, Rockefeller Hall: Clients and decision makers are increasingly aware of the social and economic benefits of mature trees in their landscape. This combined with advanced techniques involving air-spading allow the tools to preserve trees that, in the past, would have been considered economically infeasible or impossible to integrate into the constraints of a construction project.
(Image courtesy of Stephen Stimson Associates.)

Cambridge Residence: The beech hedge shown prior to initial planting. Despite proper planting, the plants subsided, resulting in their root crown being too low, and the hedgerow soil poorly drained. Root crown excavation and drainage cores were the remedy implemented by the project arborist, and the trees have done very well ever since.

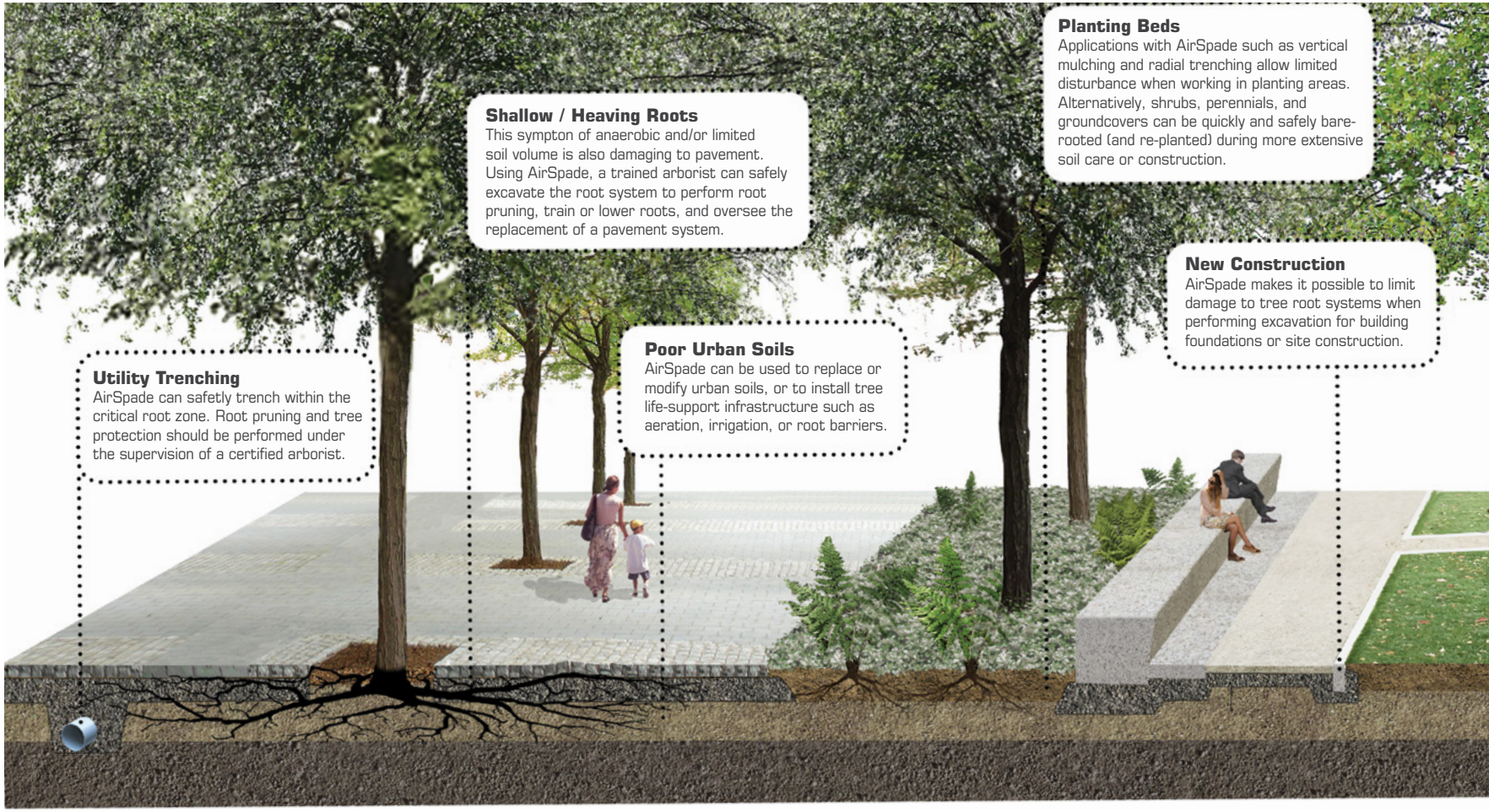
Cambridge Residence: The beech hedge was planted to enclose a generous lawn and private garden space.

is the case with most nursery material, but they slowly started showing signs of stress and decline during the second season.

We asked F.A. Bartlett Tree Expert Company to investigate the plants and determine the cause of decline. They determined that the soil profile was over-saturated from too much irrigation and slow infiltratio but, more importantly, that the trees' crowns were too low, which was limiting air exchange. They recommended an extensive removal of the mulch and topsoil to expose the plants' crowns and drainage cores (also known as vertical mulching) through the planting soil and into the subsoil to increase water infiltration. The soil removal and drainage cores were done by air-spading to minimize the impact on the plants. A continuing care program was implemented following the remediation, and now, eight years later, the plants are thriving.

CONCLUSION

Air excavation has allowed us to design landscapes in close proximity to heritage trees and for problems to be resolved with minimal disturbance and maximum effect. We have been fortunate to collaborate with leading landscape professionals in the development, preservation, and remediation phases of our projects. The preservation and expansion of our collective tree canopy is of great importance to us and our work. These ambitions have benefited greatly from air excavation techniques and technologies as well as from the ongoing scientific research and first-hand experience of our allied professionals.



The Critical Root Zone: Issues & Applications

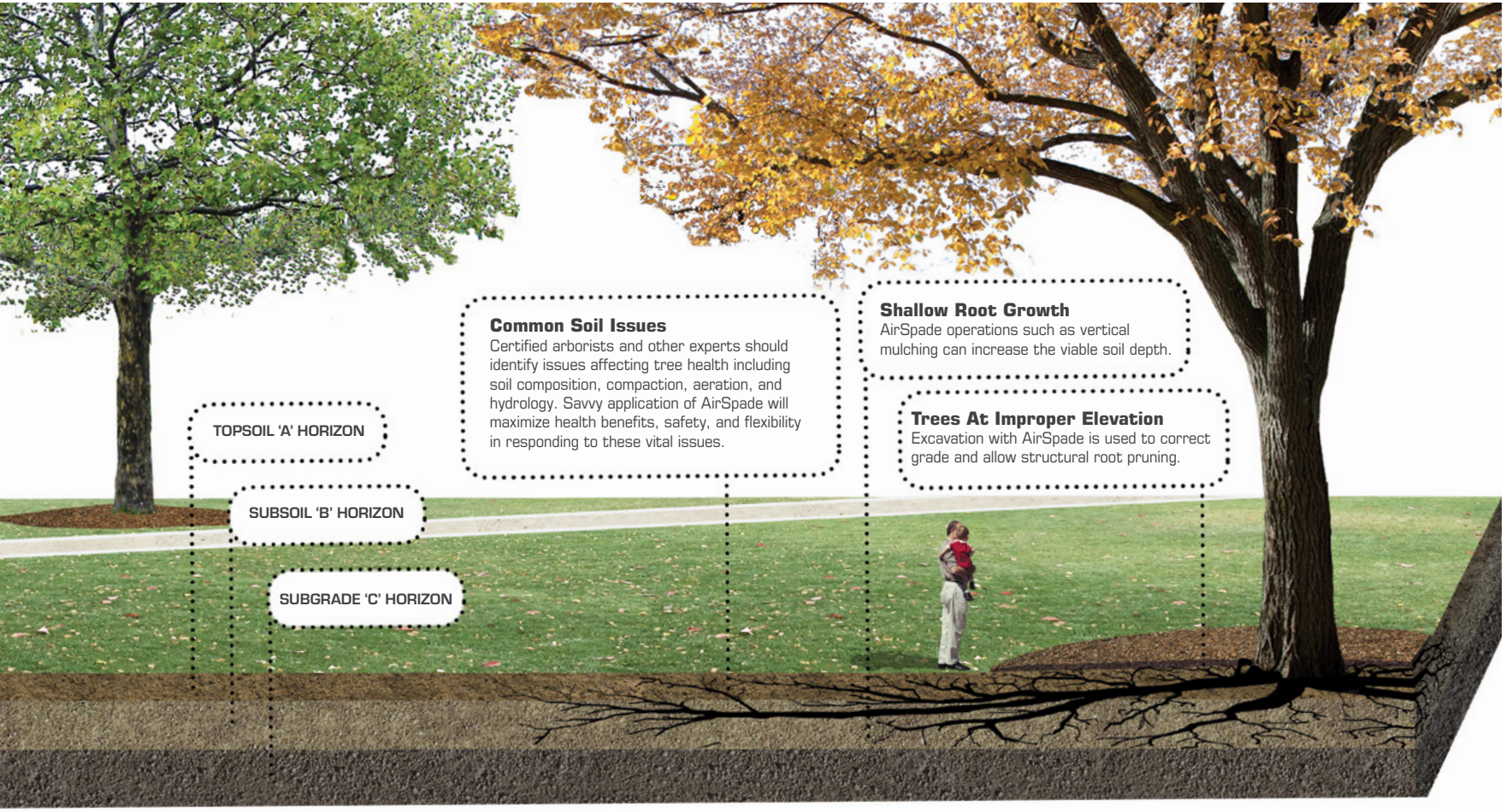
The use of a compressed air-powered tool, or AirSpade, facilitates excavation, soil management, and tree health-care within a tree's critical root zone (CRZ). In fact, the proven benefits to tree health from air-spading has made it a preferred means for professional arborists. Unlike mechanical excavation techniques, air-spading efficiently removes or loosens soil without damaging a tree's delicate root system. There are several common reasons for requiring the use of an AirSpade, all of which open new possibilities for landscape stewardship and construction involving valuable, established trees.

Root Zone Soil Management

The AirSpade can be used to mitigate many soil conditions that are unfavorable to a tree's health, including soil that is overly compacted, poorly drained, anaerobic, or imbalanced in its physical or chemical composition. Depending on specific site conditions and proper evaluation by a certified arborist, an appropriate intervention can be chosen from a range of air-spading applications. Air tilling, radial trenching, and vertical mulching are examples of operations commonly used for soil management. Each can serve simply as a method of decompaction, which yields considerable health benefits to the tree, or used as an implementation method for soil augmentation.

Soil Replacement

Soil replacement is sometimes desirable for trees which have very poor soil, or where new landscape construction occurs around the



existing tree. Examples may include urban trees with poor soils or the installation of sand-based or reinforced topsoils for high-use lawn areas. Air-tilling, full or partial bare-rooting, and soil blending are ideal applications for this type of work.

Corrections to Root Structure

Corrections to a tree's root system is another important operation involving the use of an AirSpade. Common issues include girdling roots caused by trees that are planted too low, have settled, or have soil built up at their base, heaving roots due to shallow depth of viable soil, or constricted growing space. These issues are often amplified in urban conditions with poor soils and tree pits that limit growth and pavements, which limit soil aeration and can be heaved by roots if a proper planting system is not provided. Air tilling can be useful to detect root defects and improper planting. Root collar excavation, root pruning, and bare rooting are applications that most commonly involve corrections to root structure.

Specialized Excavation for Construction

Lacking proper consideration, excavation to build foundations, install pavements, or install or maintain utilities can cause excessive damage to a tree's critical root zone. Once necessary excavation is completed using an AirSpade, an arborist can prune and train roots as necessary and oversee care and protection of the tree during and after construction.

General Site Provisions

Proper site preparation, tree protection, and safety procedures are vital to the success of any project using an AirSpade.

Overall tree health is crucial prior to the use of an AirSpade. The project team, including a certified arborist, should evaluate trees to be impacted and ensure proper watering and health-care well in advance of the scheduled work. Tree health-care should also be scheduled for the period following the procedure, when trees can be especially susceptible to cold, injury, drought, and pests.

When using an AirSpade, it is important to perform a field moisture test to ensure that the soil is near field capacity but not saturated. If the soil is too dry, excess dust will be generated, and if too wet, the use of an AirSpade will spray mud and can destroy soil structure. Some AirSpade applications require the removal of turf or other plant material first. Turf within the work area should be treated with herbicide well in advance of air-spading, or it can be removed just prior to the operation. Shrubs and ground-covers can be either left in place or temporarily relocated.

Site protection plans should be developed with the landscape architect prior to the start of work. When working on a construction site, it is advisable to install tree protection fencing to restrict traffic within the critical root zone. Airborne stones or other particles can cause risk to nearby people and property within 25 feet (7.5 m) or more. Protective barriers (made from plywood or fabric) may be moved during the operation or fixed throughout the site as necessary.

The safety of the operator, and nearby people and property is of paramount importance when using compressed air powered tools such as an AirSpade. The use of these tools requires training and education beyond what is covered in this book. Always be sure to reference the tool manufacturer for their most updated safety procedures and operational materials.

top photo: Tree protection is a basic and vital provision for any construction site. Many projects have well-defined protection areas, including critical root zones (CRZ), and even pre-defined damage-penalties based on established tree valuation standards. All of these things provide insurance and help contractors deliver on the project goals. (Image courtesy of SSA.)

bottom photo: Use of the AirSpade can send soil particles airborne at a very high rate. Operators should wear proper clothing and barriers should be used to protect pedestrians and adjacent property from damage.

NOTES:

1. THE CRITICAL ROOT ZONE (CRZ) SHALL BE ESTABLISHED BY THE ARBORIST AND LANDSCAPE ARCHITECT. THE CRZ MAY BE WITHIN OR OUTSIDE OF THE TREE'S DRIPLINE DEPENDING ON THE PROJECT GOALS, CURRENT AND FUTURE PROJECTION OF THE TREE'S ROOT PROLIFERATION, AND OTHER SITE CONDITIONS. THE CRZ SHALL BE PROTECTED AND MAINTAINED BY ALL CONTRACTORS THROUGHOUT CONSTRUCTION. ANY WORK WITHIN THE CRITICAL ROOT ZONE SHALL BE OVERSEEN BY THE ARBORIST.

2. UNLESS OTHERWISE SPECIFIED, TREE PROTECTION FENCE SHALL BE 6' HT. STEEL CHAIN LINK FENCE, POSTS DRIVEN INTO GRADE. DO NOT HARM TREE ROOTS; SURFACE MOUNTED POST ANCHORS MAY BE ACCEPTABLE IF FENCE IS REQUIRED WITHIN TREE ROOT ZONE.

3. CERTAIN PROCEDURES REQUIRE ALL TURF WITHIN AREA TO BE AIR-SPADED SHOULD BE REMOVED IN ADVANCE USING AN HERBICIDAL TREATMENT. OTHER PLANT MATERIAL SHALL REMAIN IN PLACE, OR BE TEMPORARILY RELOCATED AND PROTECTED AS SPECIFIED BY THE L.A.

4. ARBORIST AND/OR CONTRACTOR TO DETERMINE, FURNISH AND MAINTAIN ALL NECESSARY PROTECTION BARRIERS, AND ENSURE SAFETY TO PEOPLE AND PROPERTY WITHIN AND OUTSIDE OF THE LIMIT OF WORK.

5. ALL WORK TO BE DONE UNDER THE SUPERVISION OF CERTIFIED ARBORIST OR APPROVED CONTRACTOR. ENSURE THAT TREES ARE IN GOOD HEALTH AND NOT EXPERIENCING UNUSUAL STRESS PRIOR TO COMMENCING WORK.

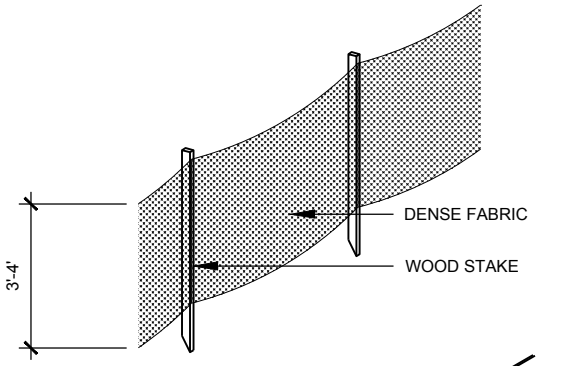
6. PROTECT TREE AND TREE ROOTS THROUGHOUT CONSTRUCTION. AIRSPADE OR HAND DIG ONLY WITHIN THE CRITICAL ROOT ZONE. DOCUMENT AND ASSESS ALL DAMAGES TO TREES AT COMMENCEMENT AND THROUGH COMPLETION OF WORK. DAMAGES TO BE COMPENSATED BASED ON PRE-AGREED TERMS. SEE SPECIFICATIONS.

7. ENSURE PROPER SOIL MOISTURE LEVELS THROUGH DURATION OF WORK. SOIL MUST BE NEAR FIELD CAPACITY, BUT NOT SATURATED, AND PASS A FIELD MOISTURE TEST PRIOR TO USE OF AN AIRSPADE. HAND WATER TREES AS NECESSARY BEFORE COMMENCEMENT OF WORK AND WITHIN 24 HOURS OF COMPLETION. COVER BARE ROOTS AND WATER AS NECESSARY DURING WORK.

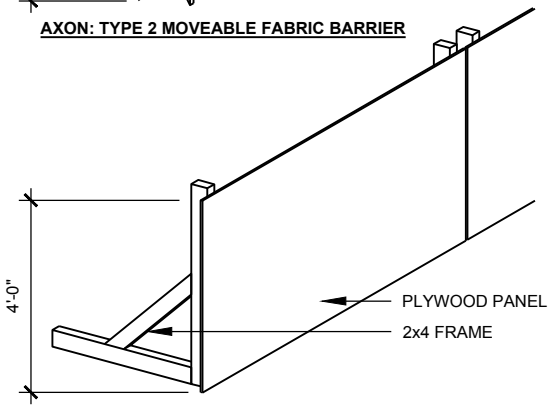
8. CERTIFIED ARBORIST TO EVALUATE THE OVERALL HEALTH OF TREES, AND TO MAKE A REPORT AND RECOMMENDATIONS FOR ADDITIONAL TREE CARE BEFORE, DURING, AND AFTER THE COMPLETION OF WORK.

9. CALL 811 OR CONTACT THE APPROPRIATE LOCAL AGENCIES TO LOCATE EXISTING UTILITIES PRIOR TO ANY EXCAVATION. PROTECT EXISTING UTILITIES THROUGHOUT THE CONSTRUCTION PROCESS AND REPAIR ANY DAMAGE TO THESE AT NO COST TO THE OWNER.

10. SEE SPECIFICATIONS FOR ADDITIONAL INFORMATION. ALSO SEE MANUFACTURER'S GUIDE FOR PROPER SAFETY AND OPERATION.

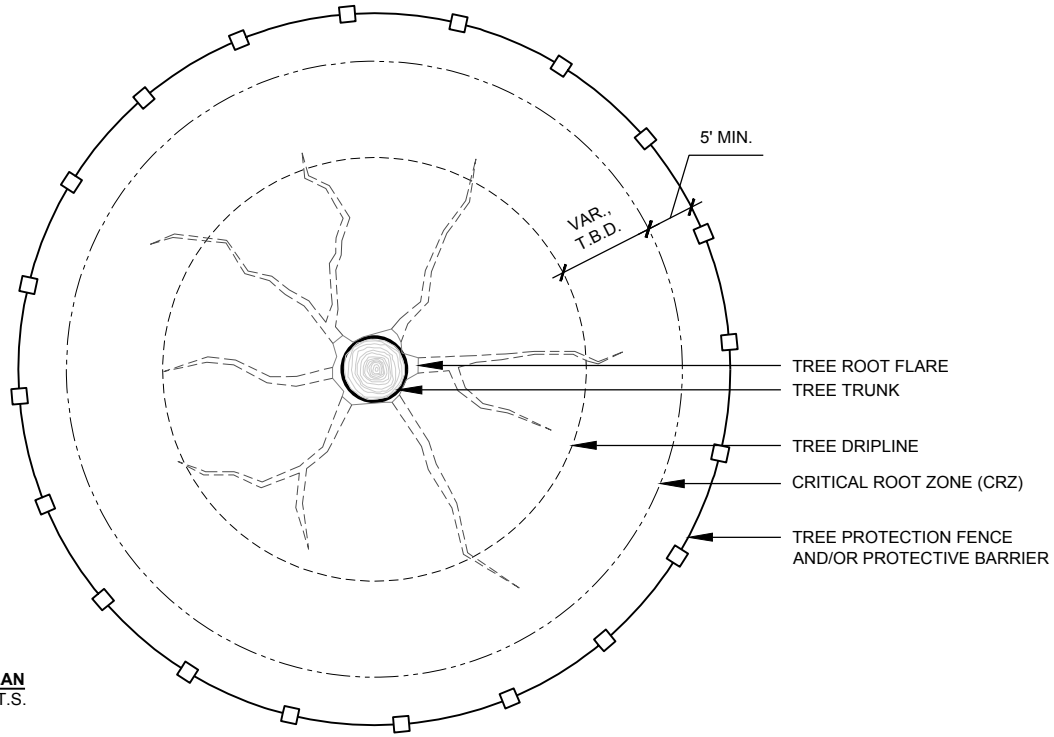


AXON: TYPE 2 MOVEABLE FABRIC BARRIER

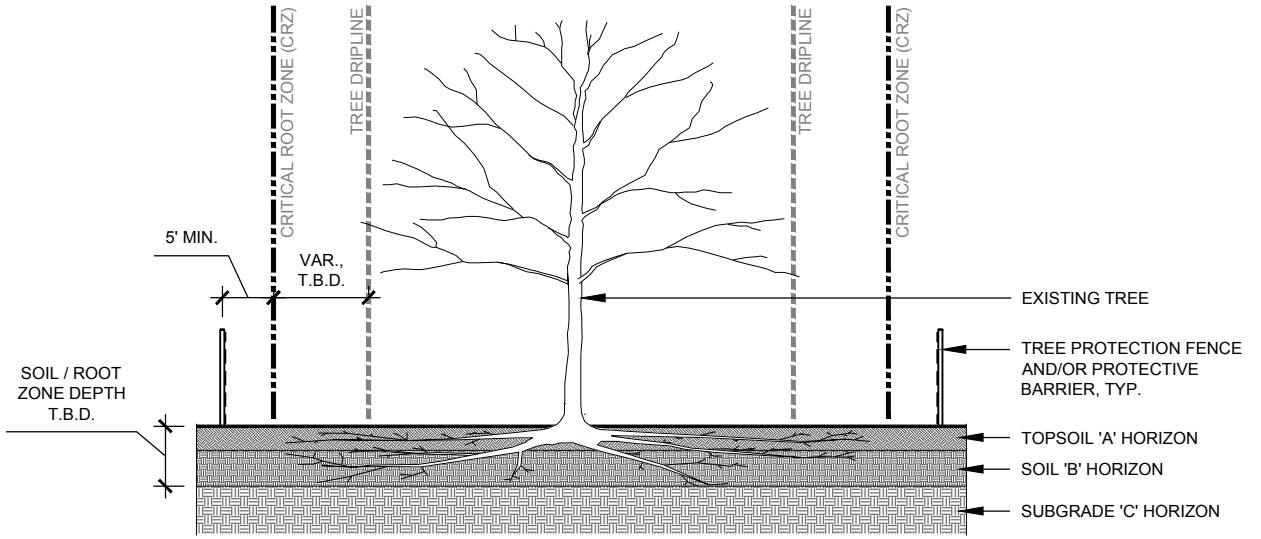


AXON: TYPE 1: PLYWOOD BARRIER

1.1 PROTECTIVE BARRIER
1/4" = 1'-0"



PLAN
N.T.S.



SECTION
N.T.S.

1.0 SITE PREP AND PROTECTION W/ AIRSPADE
1/4" = 1'-0"

Air Tilling (Root Invigoration)

Trees and shrubs suffering from shallow soil compaction (typically due to pedestrian use or vibrations caused by vehicular traffic,) or lacking vigorous root growth due to poor topsoil quality (lack of organic matter, nutrients, beneficial organisms, or aeration) are ideal candidates for air tilling. Since most of a tree's roots proliferate near the surface where they have the best access to oxygen and nutrients, air tilling is excellent at promoting robust and uniform root growth. If it's necessary to affect soil to a depth greater than 6-8 inches (15-20 cm), then it's possible to combine air tilling with other methods such as radial trenching or vertical mulching.

While the tree health benefits of air tilling alone (decompaction and aeration) are significant, this method is often used for soil augmentation as well. Air tilling is a preferred method to make organic topsoil amendments, including nutrients and beneficial organisms, due to the uniformity of treatment. Often referred to in the industry as root invigoration, this type of soil enhancement has been proven to increase root development and lead to overall improvements in tree health. As with all tree health-care applications, one size does not fit all. Collaboration between the landscape architect and certified arborist, as well as other professionals such as soil scientists, is vital to determine the best course of action.

Air tilling is typically applied around tree trunks in a radius ranging from five feet to near or well beyond the dripline. The larger the area, generally, the more effective the treatment. The process starts with the removal of any turf or mulch within the specified treatment area. The soil is then tilled using an AirSpade. The operator can work in circular or linear patterns, moving the AirSpade at one to two feet (0.3- 0.6 m) per second until the soil is visibly loosened. Several passes may be required if the soil is heavily or deeply compacted. The tool is held vertically, directing the airflow straight down. If the tip of the tool is kept beneath the soil surface, noise can be greatly reduced. After the initial tilling, the specified soil amendments can be applied evenly over the decompacted soil. The amendment is then blended into existing soil using an AirSpade in the same way and to the same depth that the soil was originally tilled. Finally, organic mulch (often wood chips are preferable) is applied to the surface in a layer 2-4 inches (5-10 cm) thick. After air tilling, continued monitoring and irrigation may be required since the soil is very porous and can dry out quickly.

above: A trained operator using an AirSpade to till the root zone of a large canopy. Air tilling is useful for arborists to investigate tree soil and root conditions, as well as for extensive tree root health-care applications.

below: After air tilling, specified soil augmentation (such as the organic leaf compost shown in this photo) is spread evenly over the loosened soil. The soil is then blended using an AirSpade in the same manner as the initial tilling.

NOTES:

1. PROPOSED DEPTH OF AERATION AND OPTIONAL SOIL AMENDMENTS TO BE DETERMINED BY LANDSCAPE ARCHITECT, CERTIFIED ARBORIST, AND SOIL SCIENTIST BASED ON INITIAL SITE INVESTIGATION AND BASED ON INDIVIDUAL SITE CONDITIONS AND TREE HEALTH CARE NEEDS.

2. ALL TURF WITHIN AREA TO BE AIR-SPADED SHOULD BE REMOVED IN ADVANCE USING AN HERBICIDAL TREATMENT. USE AIRSPADE TO BARE-ROOT IMPACTED PLANTINGS DURING SOIL AERATION. STOCKPILE, PROTECT, AND WATER PLANTS AS NECESSARY, AND ENSURE PROPER REPLANTING OR REPLACEMENT AT COMPLETION OF WORK.

3. ALL WORK TO BE DONE UNDER THE SUPERVISION OF CERTIFIED ARBORIST OR APPROVED CONTRACTOR. ENSURE THAT TREES ARE IN GOOD HEALTH AND NOT EXPERIENCING UNUSUAL STRESS PRIOR TO COMMENCING WORK.

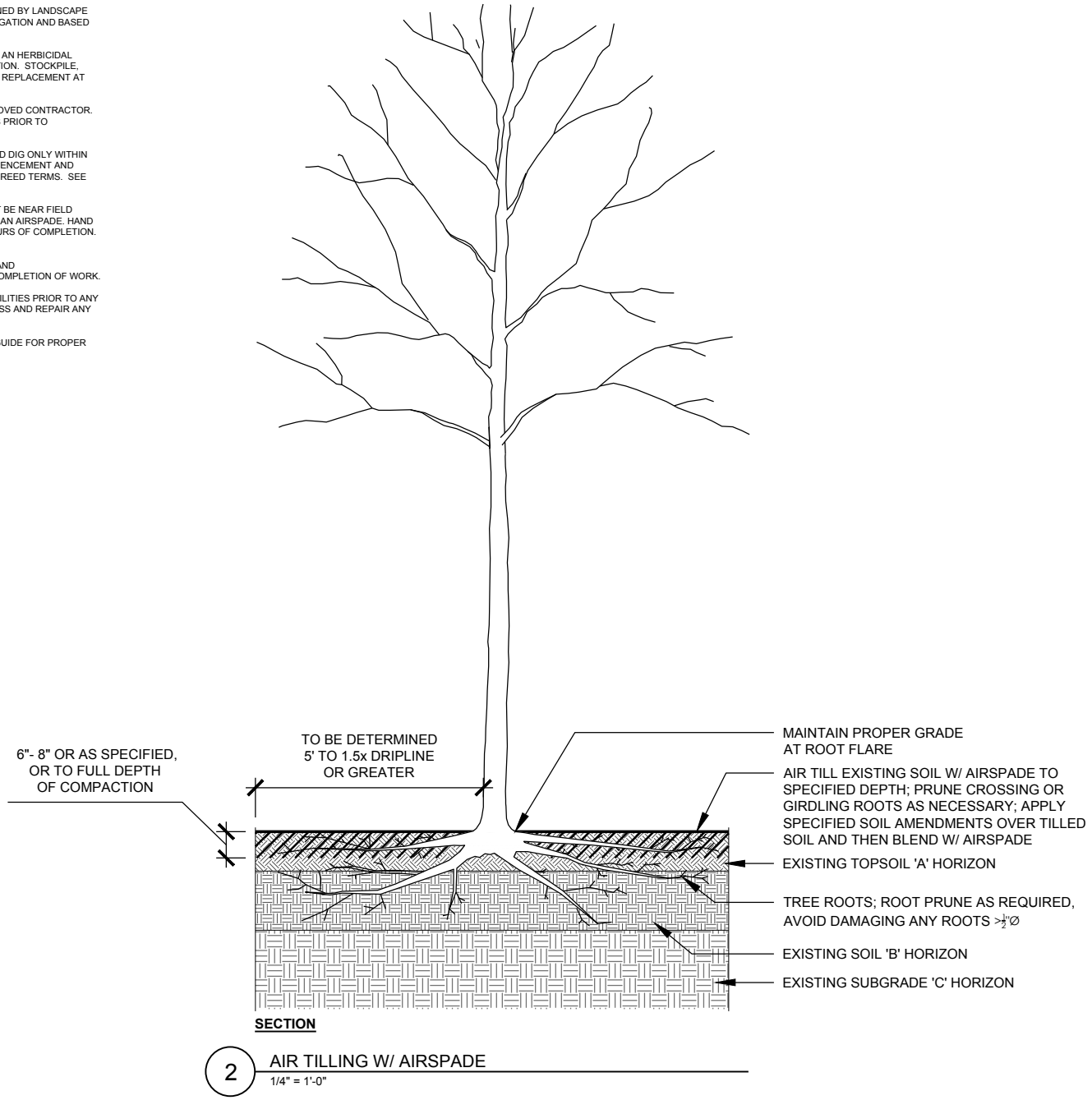
4. PROTECT TREE AND TREE ROOTS THROUGHOUT CONSTRUCTION. AIRSPADE OR HAND DIG ONLY WITHIN THE CRITICAL ROOT ZONE. DOCUMENT AND ASSESS ALL DAMAGES TO TREES AT COMMENCEMENT AND THROUGH COMPLETION OF WORK. DAMAGES TO BE COMPENSATED BASED ON PRE-AGREED TERMS. SEE SPECIFICATIONS.

5. ENSURE PROPER SOIL MOISTURE LEVELS THROUGH DURATION OF WORK. SOIL MUST BE NEAR FIELD CAPACITY, BUT NOT SATURATED, AND PASS A FIELD MOISTURE TEST PRIOR TO USE OF AN AIRSPADE. HAND WATER TREES AS NECESSARY BEFORE COMMENCEMENT OF WORK AND WITHIN 24 HOURS OF COMPLETION. COVER BARE ROOTS AND WATER AS NECESSARY DURING WORK.

6. ARBORIST TO EVALUATE THE OVERALL HEALTH OF TREES, AND TO MAKE A REPORT AND RECOMMENDATIONS FOR ADDITIONAL TREE CARE BEFORE, DURING, AND AFTER THE COMPLETION OF WORK.

7. CALL 811 OR CONTACT THE APPROPRIATE LOCAL AGENCIES TO LOCATE EXISTING UTILITIES PRIOR TO ANY EXCAVATION. PROTECT EXISTING UTILITIES THROUGHOUT THE CONSTRUCTION PROCESS AND REPAIR ANY DAMAGE TO THESE AT NO COST TO THE OWNER.

8. SEE SPECIFICATIONS FOR ADDITIONAL INFORMATION. ALSO SEE MANUFACTURER'S GUIDE FOR PROPER SAFETY AND OPERATION.



SECTION

2 AIR TILLING W/ AIRSPADE

1/4" = 1'-0"

Radial Trenching

Radial trenching with AirSpade is done to modify soil composition, improve aeration, and encourage root growth to moderate depths (typically 10"-12" or more), and is especially effective when trees have highly stratified or shallow depth of viable soil or anaerobic conditions. Additionally, this application can be useful in planting areas where minimal disturbance is desired.

Radial trenching is shown to encourage deep root growth far reaching from the trunk and between structural root leaders. An appropriate soil augmentation strategy is vital to each individual project. Because radial trenching is not as uniform as air tilling for soil augmentation, it can produce undesirable concentrations of nutrients if not properly considered. It's therefore important to carefully select amendments that are compatible with existing soils, and it can be beneficial to perform air tilling in combination with radial trenching. For example, it may be preferable to augment soil within radial trenches with a higher percentage of porous inorganic materials (such as sand) to improve aeration and to then amend the top soil with a higher percentage of organic nutrients using the more uniform air tilling (or root invigoration) procedure. Alternatively, established trees that are struggling to survive in poor soils may benefit from a long-term strategy in which radial trenching is performed several times and over the course of several years to make more extensive improvements to a tree's soil.

Radial trenching is preferably done throughout the dripline or beyond. Once the removal of turf and plant material is complete and the trench pattern is laid out (it may be helpful to paint guides on the ground), the operator can begin excavation. The operator will continuously move the AirSpade while holding the tool at a 30° to 45° angle to achieve the specified depth and working side to side to control the trench width. While digging a trench, plywood sheets are recommended to cover adjacent trenches to prevent refilling. The soil can then be collected to be replaced or amended, or it may be augmented in place. An AirSpade can be used in the soil replacement process to help blend the new and existing soil, and to fill pockets around tree roots.

Linear trenching is a variation of radial trenching in which an area is trenched in parallel rows rather than in a radial pattern. This is useful for working in planted beds or in areas with trees planted closely together. Another technique similar to radial trenching is called root trenching, in which select primary root leaders are deliberately uncovered rather than avoided. Root trenching is often used to train roots deep into the soil, under a paved surface, and into adjacent planting soils or to install a root barrier.

Radial trenching was combined with root collar excavation around this street tree to prune girdling roots and encourage deeper root growth.

Radial trenching with an AirSpade encourages root growth by breaking through compacted and highly stratified soil layers.

Once air-spaded, radial trenches can be filled with new or augmented soil.

NOTES:

1. SPACING, WIDTH AND DEPTH OF RADIAL TRENCHING TO BE DETERMINED BY L.A. AND/OR CERTIFIED ARBORIST BASED ON INITIAL SITE INVESTIGATION. SPECIFIED TRENCHING AND SOIL AUGMENTATION SHOULD BE BASED ON INDIVIDUAL SITE CONDITIONS AND TREE HEALTH CARE NEEDS. ACTUAL LOCATION OF TRENCHING MAY BE ADJUSTED SLIGHTLY BASED ON FIELD CONDITIONS. TRENCHES SHOULD OCCUR BETWEEN ROOTS AND AVOID FOLLOWING PRIMARY LEADERS.

2. ALL WORK TO BE DONE UNDER THE SUPERVISION OF CERTIFIED ARBORIST OR APPROVED CONTRACTOR. ENSURE THAT TREES ARE IN GOOD HEALTH AND NOT EXPERIENCING UNUSUAL STRESS PRIOR TO COMMENCING WORK.

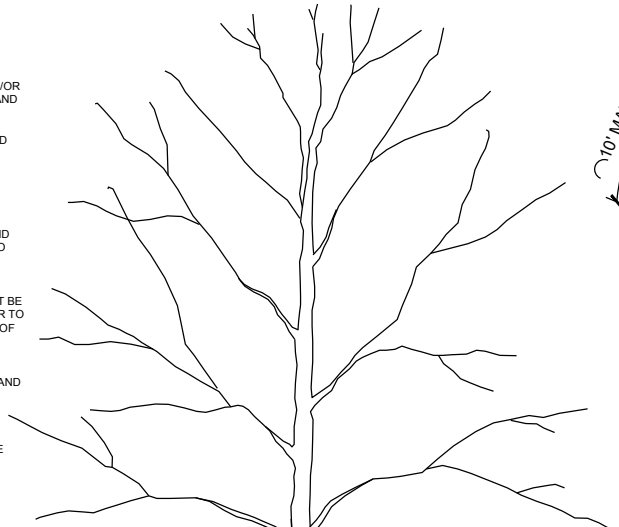
3. PROTECT TREE AND TREE ROOTS THROUGHOUT CONSTRUCTION. AIRSPADE OR HAND DIG ONLY WITHIN THE CRITICAL ROOT ZONE. DOCUMENT AND ASSESS ALL DAMAGES TO TREES AT COMMENCEMENT AND THROUGH COMPLETION OF WORK. DAMAGES TO BE COMPENSATED BASED ON PRE-AGREED TERMS. SEE SPECIFICATIONS.

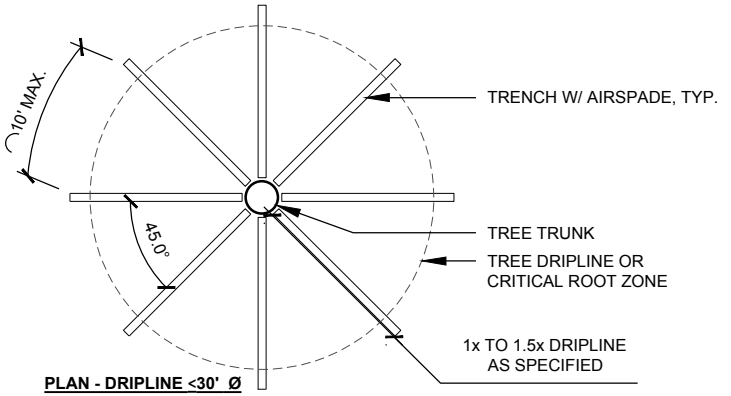
4. ENSURE PROPER SOIL MOISTURE LEVELS THROUGH DURATION OF WORK. SOIL MUST BE NEAR FIELD CAPACITY, BUT NOT SATURATED, AND PASS A FIELD MOISTURE TEST PRIOR TO USE OF AN AIRSPADE. HAND WATER TREES AS NECESSARY BEFORE COMMENCEMENT OF WORK AND WITHIN 24 HOURS OF COMPLETION. COVER BARE ROOTS AND WATER AS NECESSARY DURING WORK.

5. ARBORIST TO EVALUATE THE OVERALL HEALTH OF TREES, AND TO MAKE A REPORT AND RECOMMENDATIONS FOR ADDITIONAL TREE CARE BEFORE, DURING, AND AFTER THE COMPLETION OF WORK.

6 CALL 811 OR CONTACT THE APPROPRIATE LOCAL AGENCIES TO LOCATE EXISTING UTILITIES PRIOR TO ANY EXCAVATION. PROTECT EXISTING UTILITIES THROUGHOUT THE CONSTRUCTION PROCESS AND REPAIR ANY DAMAGE TO THESE AT NO COST TO THE OWNER.

7. SEE SPECIFICATIONS FOR ADDITIONAL INFORMATION. ALSO SEE MANUFACTURER'S GUIDE FOR PROPER SAFETY AND OPERATION.





PLAN - DRIPLINE <30' Ø
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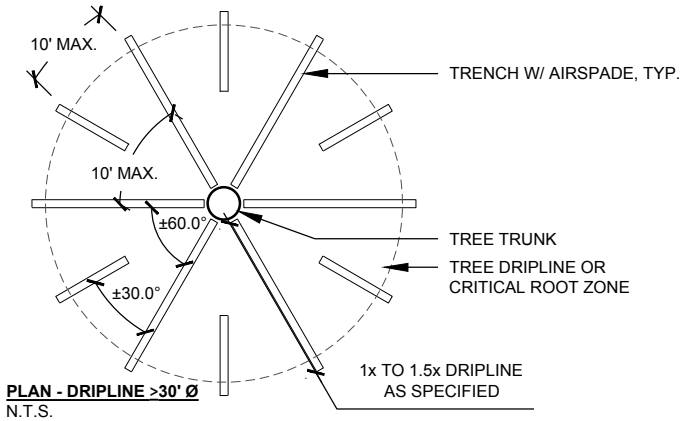

PLAN - DRIPLINE >30' Ø
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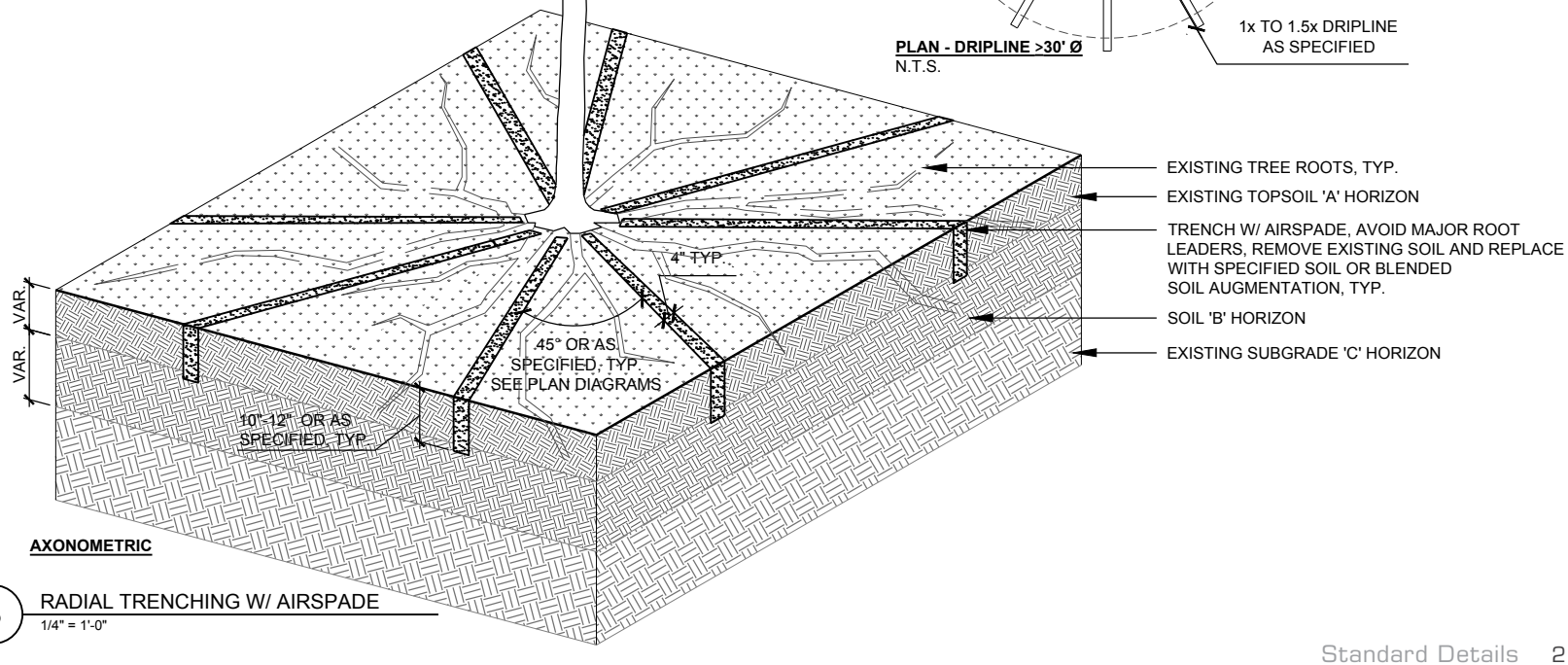


AXONOMETRIC

3 RADIAL TRENCHING W/ AIRSPADE
1/4" = 1'-0"

Vertical Mulching

Vertical mulching with AirSpade is done to de-compact and augment soil deep into the tree root zone. This application is especially useful in areas with poor drainage, with shallow or impervious soils, or shared by perennial or ground-cover plantings, where minimal disturbance is desired.

Aeration and soil amendments from vertical mulching can encourage roots to grow deep into the soil profile, thereby improving the tree's stability and volume of viable growing medium. Because vertical mulching affects the deepest soil profile, it is recommended for sites with shallow soil depth, hard-pan, anaerobic conditions, or other types of poor growing soils.

An appropriate soil augmentation strategy is vital and should be developed on a case-by-case basis. Vertical mulching can produce undesirable concentrations, or hotspots, of nutrients or organic matter, which can counter healthy, uniform root growth. For this reason, it's advisable to use amendments that are compatible or blended with existing soils. For more extensive results, it is possible to perform vertical mulching over the course of several growing seasons.

Like other root zone soil treatments, vertical mulching is preferably done throughout the trees dripline or beyond. Once the layout, target depth, and size of holes has been determined, the operator can proceed with air-spading. Positioning the AirSpade perpendicular to the ground with the nozzle near the surface, the operator depresses the trigger and slowly pushes the tool into the soil. When resistance is met, the operator slowly withdraws the tool, clears the hole of loosened soil, and then reinserts. Excavated soil can be collected to be removed or augmented before the bore holes are refilled.

top and middle: Vertical cores being excavated by an arborist.

bottom: Large campus trees are good candidates for vertical mulching, where decades of pedestrian use causes deep soil compaction. The procedure has been shown to be effective for soil and root zone invigoration and can help stabilize overall tree health by encouraging deep root growth by boosting soil ecology through improved aeration and nutrients.

NOTES:

1. DEPTH AND SPACING OF BORE HOLES TO BE DETERMINED BY LANDSCAPE ARCHITECT AND/OR CERTIFIED ARBORIST BASED ON INITIAL SITE INVESTIGATION. SPECIFIED BORE HOLE DEPTH MAY RANGE FROM 18" TO 36" AND SHOULD BE SPECIFIED BASED ON INDIVIDUAL SITE CONDITIONS AND TREE HEALTH CARE NEEDS.

2 USE AIRSPADE TO BARE-ROOT IMPACTED PLANTINGS DURING SOIL AERATION. STOCKPILE, PROTECT, AND WATER PLANTS AS NECESSARY, AND ENSURE PROPER REPLANTING OR REPLACEMENT AT COMPLETION OF WORK.

3. ALL WORK TO BE DONE UNDER THE SUPERVISION OF CERTIFIED ARBORIST OR APPROVED CONTRACTOR. ENSURE THAT TREES ARE IN GOOD HEALTH AND NOT EXPERIENCING UNUSUAL STRESS PRIOR TO COMMENCING WORK.

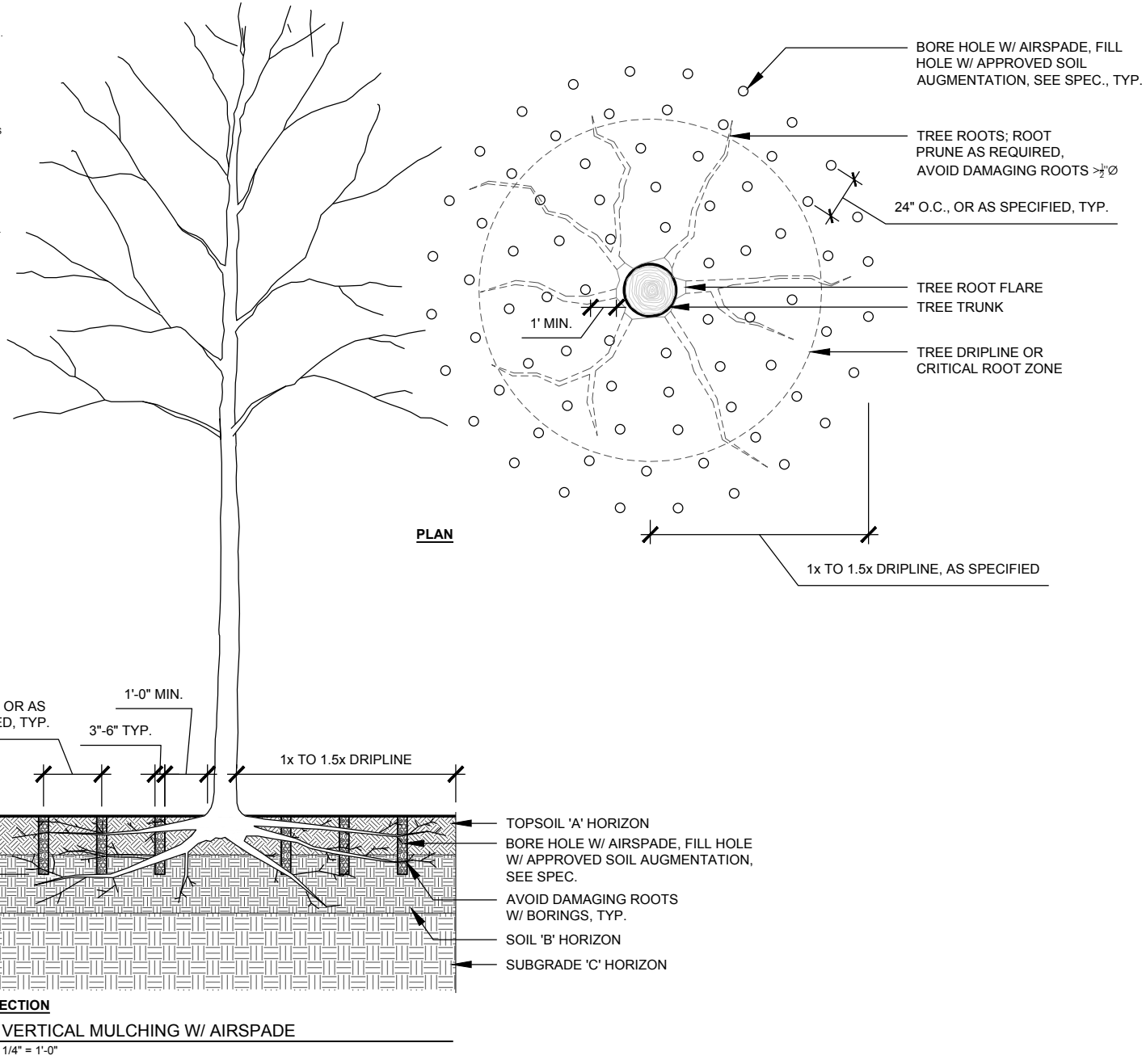
4. PROTECT TREE AND TREE ROOTS THROUGHOUT CONSTRUCTION. AIRSPADE OR HAND DIG ONLY WITHIN THE CRITICAL ROOT ZONE. DOCUMENT AND ASSESS ALL DAMAGES TO TREES AT COMMENCEMENT AND THROUGH COMPLETION OF WORK. DAMAGES TO BE COMPENSATED BASED ON PRE-AGREED TERMS. SEE SPECIFICATIONS.

5. ENSURE PROPER SOIL MOISTURE LEVELS THROUGH DURATION OF WORK. SOIL MUST BE NEAR FIELD CAPACITY, BUT NOT SATURATED, AND PASS A FIELD MOISTURE TEST PRIOR TO USE OF AN AIRSPADE. HAND WATER TREES AS NECESSARY BEFORE COMMENCEMENT OF WORK AND WITHIN 24 HOURS OF COMPLETION. COVER BARE ROOTS AND WATER AS NECESSARY DURING WORK.

6. ARBORIST TO EVALUATE THE OVERALL HEALTH OF TREES, AND TO MAKE A REPORT AND RECOMMENDATIONS FOR ADDITIONAL TREE CARE BEFORE, DURING, AND AFTER THE COMPLETION OF WORK.

7. CALL 811 OR CONTACT THE APPROPRIATE LOCAL AGENCIES TO LOCATE EXISTING UTILITIES PRIOR TO ANY EXCAVATION. PROTECT EXISTING UTILITIES THROUGHOUT THE CONSTRUCTION PROCESS AND REPAIR ANY DAMAGE TO THESE AT NO COST TO THE OWNER.

8. SEE SPECIFICATIONS FOR ADDITIONAL INFORMATION. ALSO SEE MANUFACTURER'S GUIDE FOR PROPER SAFETY AND OPERATION.



4 VERTICAL MULCHING W/ AIRSPADE

1/4" = 1'-0"

Root Collar Excavation

Trees commonly suffer when the grade is set too high against their root flare or root collar. This can occur when trees are planted at the wrong elevation or when trees subside due to improper compaction below the root ball when they are planted. Alternatively, root collars can be buried over time due to the accumulation of mulch or soil around the tree.

Whatever the cause, harm to the tree from grade set above the root collar can be long lasting and should be remediated through root collar excavation (RCX) with an AirSpade. Symptoms of this condition include rot or infection of bark at the base of the trunk, growth of roots that are too high relative to the natural root flare, and girdling roots, which constrict the root flare and tree trunk. Girdling can also occur on urban sites, where roots have limited room to grow or have encountered compacted or anaerobic soil conditions, causing roots to heave around the collar. Use of an AirSpade allows tree root collars and girdling roots to be excavated with minimal damage to the tree. Once uncovered, a certified arborist can easily identify roots that need to be removed or trained.

RCX often impacts a relatively small area of disturbance around the root flare. If grade is being removed, the limit of disturbance must extend far enough to allow appropriate drainage away from the tree. Once turf and other plant material are removed from the work area, the arborist can begin excavation, holding the AirSpade at a 45° angle, continuously working the tool back and forth at 1 to 2 feet per second, until the natural root flare is exposed. The arborist can then perform root pruning, removing any roots that are wrapping the tree or have grown too high in elevation. Sometimes it's possible to excavate under roots that are grown too high, and train them down into the new finished grade. Soil is then returned to the excavated roots and grade is re-established at the appropriate elevation. RCX is not typically considered a method for soil augmentation; however, like other AirSpade applications, it can be combined with other techniques depending on the project goals and tree health-care needs. Finally, organic mulch (often wood chips are preferable) is applied to the surface in a layer 2-4 inches (5-10 cm) thick.

top: This young tree was planted several inches too low and shows significant rot to the bark at the base of the trunk. (Images courtesy of Guardair Corporation.)

middle: Girdling roots can strangle a tree's water and nutrient flow, severely inhibiting tree health and survival, and is frequently caused by improper planting.

bottom: Use of an AirSpade is the fastest and safest method to excavate a tree's natural root collar. The entangled roots in this photo are characteristic of roots pushing up and doubling back to reach the more arable soil near the surface.

NOTES:

1. PROPOSED FINISHED GRADE TO BE DETERMINED BY LANDSCAPE ARCHITECT AND/OR CERTIFIED ARBORIST BASED ON INITIAL SITE INVESTIGATION AND BASED ON INDIVIDUAL SITE CONDITIONS AND TREE HEALTH CARE NEEDS.

2. ROOT PRUNING TO BE DONE BY HAND ONLY AND BY CERTIFIED ARBORIST.

3. ALL WORK TO BE DONE UNDER THE SUPERVISION OF CERTIFIED ARBORIST OR APPROVED CONTRACTOR. ENSURE THAT TREES ARE IN GOOD HEALTH AND NOT EXPERIENCING UNUSUAL STRESS PRIOR TO COMMENCING WORK.

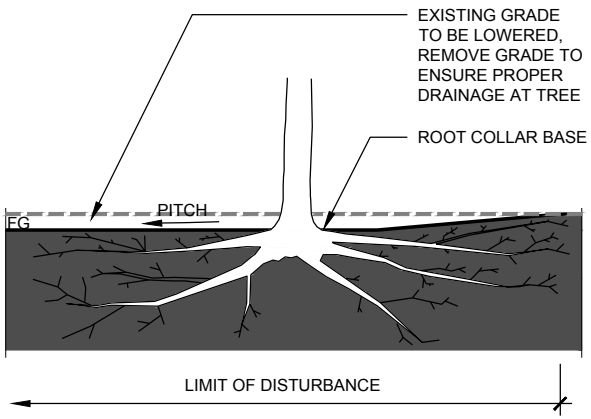
4. PROTECT TREE AND TREE ROOTS THROUGHOUT CONSTRUCTION. AIRSPADE OR HAND DIG ONLY WITHIN THE CRITICAL ROOT ZONE. DOCUMENT AND ASSESS ALL DAMAGES TO TREES AT COMMENCEMENT AND THROUGH COMPLETION OF WORK. DAMAGES TO BE COMPENSATED BASED ON PRE-AGREED TERMS. SEE SPECIFICATIONS.

3. ENSURE PROPER SOIL MOISTURE LEVELS THROUGH DURATION OF WORK. SOIL MUST BE NEAR FIELD CAPACITY, BUT NOT SATURATED, AND PASS A FIELD MOISTURE TEST PRIOR TO USE OF AN AIRSPADE. HAND WATER TREES AS NECESSARY BEFORE COMMENCEMENT OF WORK AND WITHIN 24 HOURS OF COMPLETION. COVER BARE ROOTS AND WATER AS NECESSARY DURING WORK.

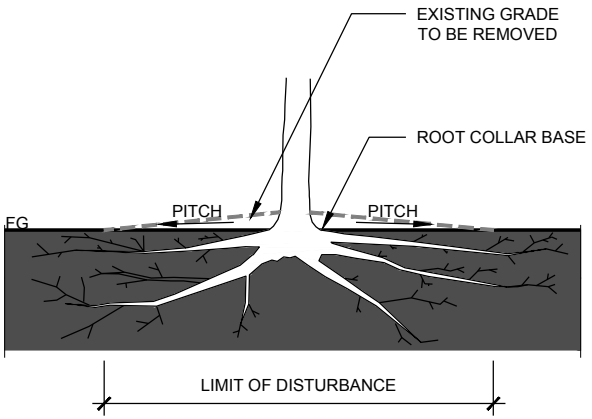
5. ARBORIST TO EVALUATE THE OVERALL HEALTH OF TREES, AND TO MAKE A REPORT AND RECOMMENDATIONS FOR ADDITIONAL TREE CARE BEFORE, DURING, AND AFTER THE COMPLETION OF WORK.

6. CALL 811 OR CONTACT THE APPROPRIATE LOCAL AGENCIES TO LOCATE EXISTING UTILITIES PRIOR TO ANY EXCAVATION. PROTECT EXISTING UTILITIES THROUGHOUT THE CONSTRUCTION PROCESS AND REPAIR ANY DAMAGE TO THESE AT NO COST TO THE OWNER.

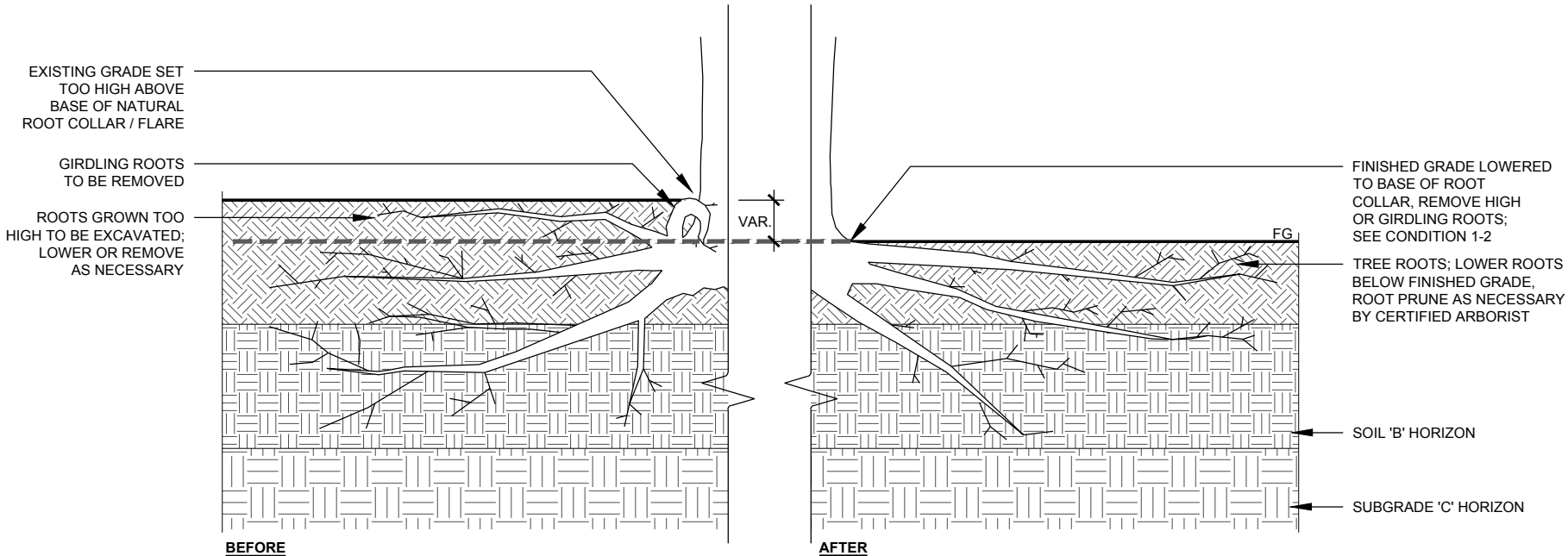
7. SEE SPECIFICATIONS FOR ADDITIONAL INFORMATION. ALSO SEE MANUFACTURER'S GUIDE FOR PROPER SAFETY AND OPERATION.



CONDITION 1: TREE SET TOO LOW
SCALE: $\frac{1}{4}$" = 1'-0"



CONDITION 2: GRADE BUILT UP AT TREE
SCALE: $\frac{1}{4}$" = 1'-0"



5 ROOT COLLAR EXCAVATION W/ AIRSPADE
1/2" = 1'-0"

Root Pruning

Construction or maintenance work that makes intrusions into a tree's root zone will benefit from use of an AirSpade. Air-spading is safe to the tree's roots and a highly efficient method to perform exploratory excavation to locate existing roots and utilities. Almost any site work operations — including the building of foundations, pavements, drainage infrastructure, and utilities — present ideal opportunities for air-spading and root pruning.

Proper root pruning will encourage future growth and minimize negative impacts to structures or utilities. Once the existing roots have been excavated, a certified arborist can easily determine the best places to make clean cuts using a hand pruner.

In all cases, an arborist should oversee care for the tree before, during, and after construction. In this type of application, the tree's excavated root zone may often remain exposed for several days or more. For this reason, it is important to protect and cover roots (for example with soil, mulch, or burlap cloth) and to provide supplemental water as required.

Of course, it is preferable to remove as little of a tree's root system as possible, and site planning of utilities or new structures should try to minimize impacts to established trees whenever possible. If large roots or a substantial percentage of a tree's roots need to be removed, then the tree will be under significant stress and may require special attention through an extended recovery period.

Root pruning for construction begins with preliminary site layout exploratory excavation by the arborist. Soil should be stockpiled and replaced as soon as possible to avoid undue stress to the tree. The arborist may advise the best location for utility placement to benefit the tree as well as the ongoing maintenance of the utilities. The arborist may excavate as much as necessary to properly locate and stagger pruning cuts and to allow roots to be trained around or away from the new construction. The arborist should provide oversight throughout construction to ensure tree protection and proper tree care and watering.

At the Radcliffe Institute, the foundation for a new path was excavated using an AirSpade. Irrigation lines were snaked through the exposed roots, and minimal root pruning was completed before installing a gravel root barrier and the top course of stone dust pavement. (Image courtesy of SSA.)

Trenches are being located around this existing tree to accommodate an electrical conduit.

To install this area-way at M.I.T. required diligent tree protection, and intensive excavation using an AirSpade and root pruning by a trained arborist. (Image courtesy of SSA.)

NOTES:
1. HAND PRUNE ROOTS ONLY BY CERTIFIED ARBORIST. DO NOT SHEAR ROOTS.

2. COVER ROOTS AND PROVIDE SUPPLEMENTAL WATER AS NECESSARY. IF LARGE ROOTS OR A LARGE PERCENTAGE OF ROOTS ARE REMOVED, EXTENDED RECOVERY PERIOD MAY BE NECESSARY.

3. ALL WORK TO BE DONE UNDER THE SUPERVISION OF CERTIFIED ARBORIST OR APPROVED CONTRACTOR. ENSURE THAT TREES ARE IN GOOD HEALTH AND NOT EXPERIENCING UNUSUAL STRESS PRIOR TO COMMENCING WORK.

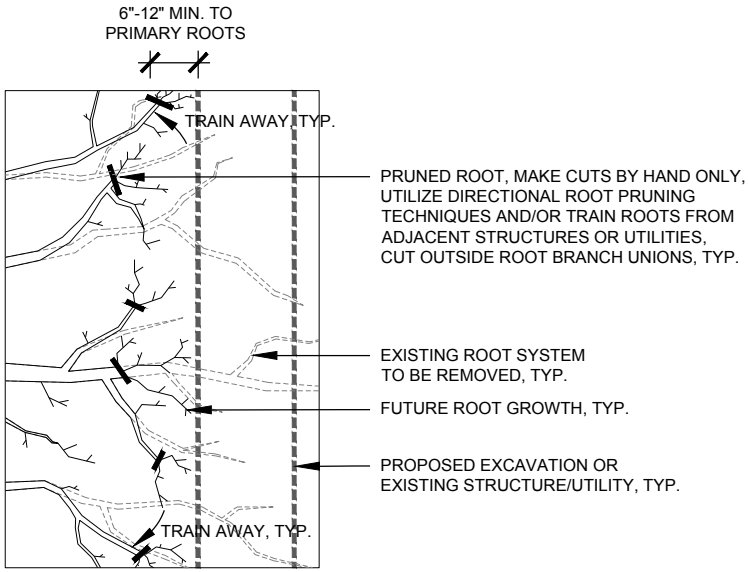
4. PROTECT TREE AND TREE ROOTS THROUGHOUT CONSTRUCTION. AIRSPADE OR HAND DIG ONLY WITHIN THE CRITICAL ROOT ZONE. DOCUMENT AND ASSESS ALL DAMAGES TO TREES AT COMMENCEMENT AND THROUGH COMPLETION OF WORK. DAMAGES TO BE COMPENSATED BASED ON PRE-AGREED TERMS. SEE SPECIFICATIONS.

3. ENSURE PROPER SOIL MOISTURE LEVELS THROUGH DURATION OF WORK. SOIL MUST BE NEAR FIELD CAPACITY, BUT NOT SATURATED, AND PASS A FIELD MOISTURE TEST PRIOR TO USE OF AN AIR SPADE. HAND WATER TREES AS NECESSARY BEFORE COMMENCEMENT OF WORK AND WITHIN 24 HOURS OF COMPLETION. COVER BARE ROOTS AND WATER AS NECESSARY DURING WORK.

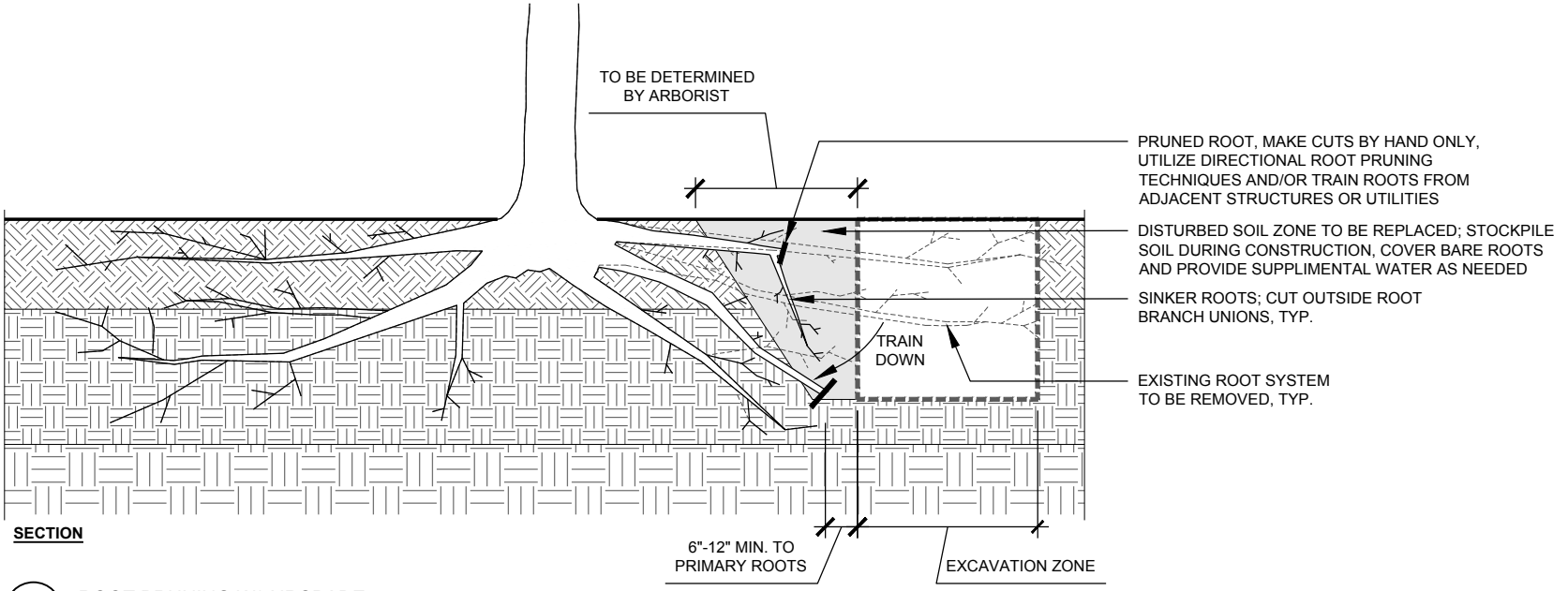
5. ARBORIST TO EVALUATE THE OVERALL HEALTH OF TREES, AND TO MAKE A REPORT AND RECOMMENDATIONS FOR ADDITIONAL TREE CARE BEFORE, DURING, AND AFTER THE COMPLETION OF WORK.

6. CALL 811 OR CONTACT THE APPROPRIATE LOCAL AGENCIES TO LOCATE EXISTING UTILITIES PRIOR TO ANY EXCAVATION. PROTECT EXISTING UTILITIES THROUGHOUT THE CONSTRUCTION PROCESS AND REPAIR ANY DAMAGE TO THESE AT NO COST TO THE OWNER.

7. SEE SPECIFICATIONS FOR ADDITIONAL INFORMATION. ALSO SEE MANUFACTURER'S GUIDE FOR PROPER SAFETY AND OPERATION.



PLAN
SCALE: $\frac{1}{4}$" = 1'-0"



SECTION

6 ROOT PRUNING W/ AIRSPADE
1/2" = 1'-0"

Bare Rooting and Transplanting

Bare rooting is a procedure used to relocate or remove soil around existing trees. Use of an AirSpade for bare rooting is the best way to minimize damage to the tree's root system and the most efficient technique available.

Bare rooting with an AirSpade can also be applied to perennial, shrub, and groundcover plantings. This is a preferred method of transplanting plant material because of its efficiency and ability to preserve fine root systems. Furthermore, bare rooting small plants is often required during more extensive root zone treatments (such as aeration and de-compaction) or other site work applications.

The oversight of a certified arborist is critical during bare rooting. While use of an AirSpade can significantly reduce trauma to the tree, it is important to monitor the tree's health and care before, during, and after the procedure. Supplemental watering is typically necessary and should be provided with direction and continued monitoring from the arborist.

Bare rooting trees and large shrubs to transplant can require root pruning if the root mass is too large to transplant. If possible, incremental root pruning can be done in months or years preceding transplanting to help reduce stress to the tree. Using an AirSpade, it's possible to remove almost all the soil from the tree root system or to leave excess soil to transplant with the tree. Once the root zone is excavated, the arborist can prune the root mass to the desired length. It is critical to keep bare roots protected from the sun and hydrated, and to minimize the time between excavation and transplanting.

Another application of growing popularity involves bare rooting of nursery stock prior to planting. Air-spading containerized plants or ball-and-burlap trees is the best technique to break up the root ball for new plantings. With any new planting, it is critical to break up the root ball to encourage root growth out into adjacent soils and to help blend dissimilar soils. While this adds some cost to planting, air-spading plants for new installation is becoming recognized as an increasingly viable method.

This tree at Williams College was bare rooted using an AirSpade and transplanted as part of a new quad construction project. (Image courtesy of SSA.)

Bare rooting allows large, established trees to be relocated with minimal trauma. Unlike ball-and-burlap or container-grown plants, bare rooted plant material maintains a nearly complete,and well-formed root system.

Bare rooting can allow for partial or complete soil replace-ment and facilitate new site construction and tree longevity.

NOTES:
1. HAND PRUNE ROOTS ONLY BY CERTIFIED ARBORIST. DO NOT SHEAR ROOTS.

2. COVER BARE ROOTS AND PROVIDE SUPPLEMENTAL WATER AS NECESSARY. IF LARGE ROOTS OR A LARGE PERCENTAGE OF ROOTS ARE REMOVED, EXTENDED RECOVERY PERIOD MAY BE NECESSARY.

3. ALL WORK TO BE DONE UNDER THE SUPERVISION OF CERTIFIED ARBORIST OR APPROVED CONTRACTOR. ENSURE THAT TREES ARE IN GOOD HEALTH AND NOT EXPERIENCING UNUSUAL STRESS PRIOR TO COMMENCING WORK.

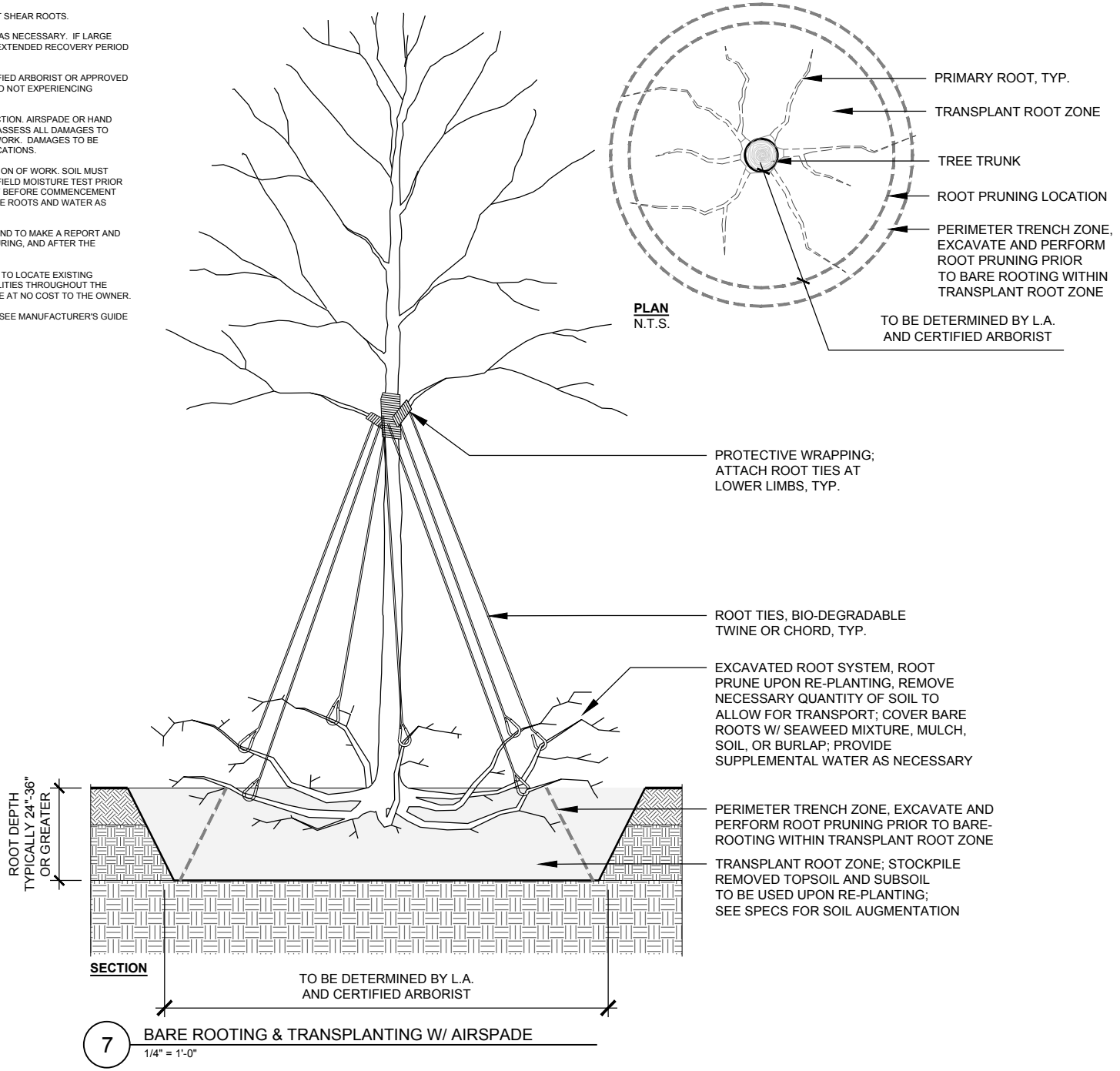
4. PROTECT TREE AND TREE ROOTS THROUGHOUT CONSTRUCTION. AIRSPADE OR HAND DIG ONLY WITHIN THE CRITICAL ROOT ZONE. DOCUMENT AND ASSESS ALL DAMAGES TO TREES AT COMMENCEMENT AND THROUGH COMPLETION OF WORK. DAMAGES TO BE COMPENSATED BASED ON PRE-AGREED TERMS. SEE SPECIFICATIONS.

5. ENSURE PROPER SOIL MOISTURE LEVELS THROUGH DURATION OF WORK. SOIL MUST BE NEAR FIELD CAPACITY, BUT NOT SATURATED, AND PASS A FIELD MOISTURE TEST PRIOR TO USE OF AN AIRSPADE. HAND WATER TREES AS NECESSARY BEFORE COMMENCEMENT OF WORK AND WITHIN 24 HOURS OF COMPLETION. COVER BARE ROOTS AND WATER AS NECESSARY DURING WORK.

6. ARBORIST TO EVALUATE THE OVERALL HEALTH OF TREES, AND TO MAKE A REPORT AND RECOMMENDATIONS FOR ADDITIONAL TREE CARE BEFORE, DURING, AND AFTER THE COMPLETION OF WORK.

7. CALL 811 OR CONTACT THE APPROPRIATE LOCAL AGENCIES TO LOCATE EXISTING UTILITIES PRIOR TO ANY EXCAVATION. PROTECT EXISTING UTILITIES THROUGHOUT THE CONSTRUCTION PROCESS AND REPAIR ANY DAMAGE TO THESE AT NO COST TO THE OWNER.

8. SEE SPECIFICATIONS FOR ADDITIONAL INFORMATION. ALSO SEE MANUFACTURER'S GUIDE FOR PROPER SAFETY AND OPERATION.



7 BARE ROOTING & TRANSPLANTING W/ AIRSPADE
1/4" = 1'-0"

Urban Tree Soil Replacement

Soil science and planting technologies for urban trees have undergone tremendous advancement in the last several years. For example, engineered structural soils can resist compaction from traffic or bear the weight of pavement or structures while also offering aeration and nutrients deep into the soil profile. Due to the overwhelming benefits of these planting systems, it may be desirable to partially replace the soil around a tree's root zone in an effort to enhance the tree's health and lifespan.

This application is ideal for tree plantings with root zones extending underneath pavement and those that have poorly suited or limited soil volume, or where pavement is proposed to be added or replaced within an existing root zone. Similarly, this may be applied to trees planted in high-use lawn areas (for example within parks or campus landscapes,) where soil replacement is desired to improve lawn durability and health.

Planting infrastructure elements shown in the drawing (such as aeration pipes, root barriers, feeding tubes, irrigation and moisture sensors) represent a sampling of many available technologies that can be selected, omitted, or combined based on the tree needs and project goals, and should be determined by a landscape architect.

Installation of a new paving system for ginko street trees. At the right of the photo, an arborist excavates highly compacted sandy loam soil that had supported brick pavement for over 20 years. At left, the contractor finishes installation of an engineered sand based structural soil, which is to bear the load of new pavement.

Partially bare rooted ginko street tree ready for new sand-based structural planting soil.
(Images courtesy of Stephen Stimson Associates.)

NOTES:

1. LIMIT DISTURBANCE OF EXISTING SOIL BASED ON EXISTING SOIL CONDITIONS AND FOUND DISPERSION OF TREE ROOTS. ALL DIGGING AND SOIL REPLACEMENT OR AUGMENTATION TO BE DONE UNDER THE SUPERVISION OF CERTIFIED ARBORIST.

2. ALL WORK TO BE DONE UNDER THE SUPERVISION OF CERTIFIED ARBORIST OR APPROVED CONTRACTOR. ENSURE THAT TREES ARE IN GOOD HEALTH AND NOT EXPERIENCING UNUSUAL STRESS PRIOR TO COMMENCING WORK.

3. PROTECT TREE AND TREE ROOTS THROUGHOUT CONSTRUCTION. AIRSPADE OR HAND DIG ONLY WITHIN THE CRITICAL ROOT ZONE. DOCUMENT AND ASSESS ALL DAMAGES TO TREES AT COMMENCEMENT AND THROUGH COMPLETION OF WORK. DAMAGES TO BE COMPENSATED BASED ON PRE-AGREED TERMS. SEE SPECIFICATIONS.

4. ENSURE PROPER SOIL MOISTURE LEVELS THROUGH DURATION OF WORK. SOIL MUST BE NEAR FIELD CAPACITY, BUT NOT SATURATED, AND PASS A FIELD MOISTURE TEST PRIOR TO USE OF AN AIR SPADE. HAND WATER TREES AS NECESSARY BEFORE COMMENCEMENT OF WORK AND WITHIN 24 HOURS OF COMPLETION. COVER BARE ROOTS AND WATER AS NECESSARY DURING WORK.

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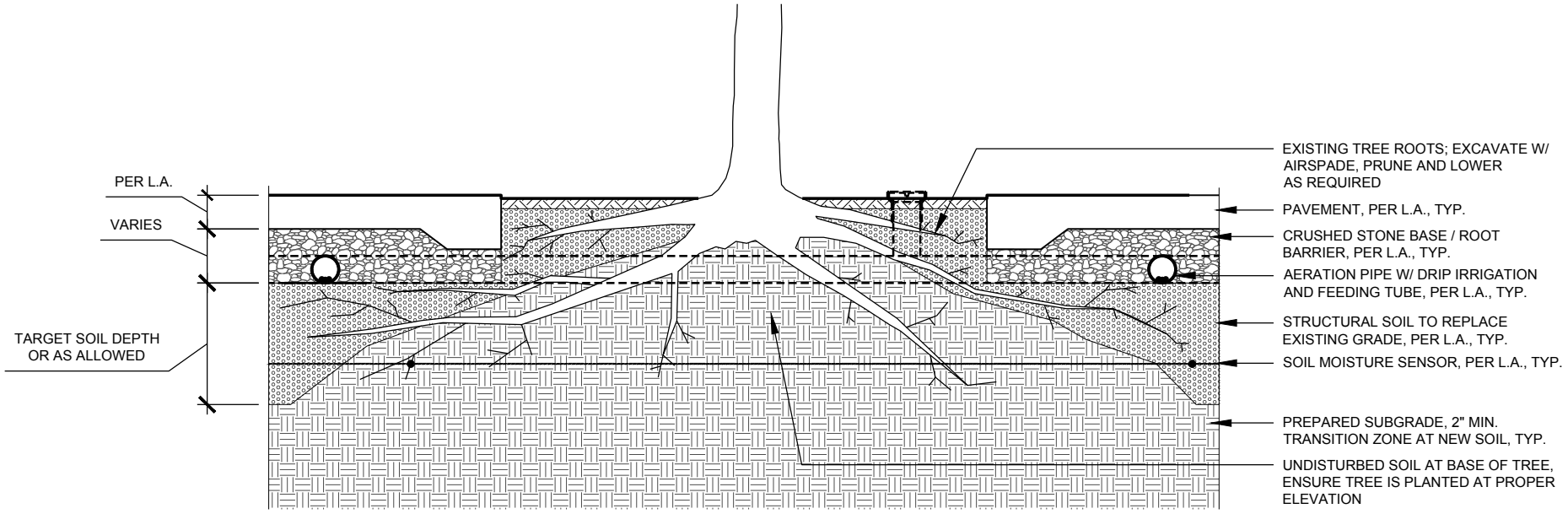
7. SEE SPECIFICATIONS FOR ADDITIONAL INFORMATION. ALSO SEE MANUFACTURER'S GUIDE FOR PROPER SAFETY AND OPERATION.



8 TREE SOIL REPLACEMENT FOR URBAN SITES

1/2" = 1'-0"

APPENDIX

Appendix A: Soil Amendments

Table 2. Potential uses and limitations of typical soil amendments for urban trees.

Amendment	Uses										Limitations							
	Modify texture	Increase water-holding	Increase drainage	Decrease density	Promote aggregation	Increase organic matter	Increase nutrients	Decrease pH	Increase pH	Decrease salinity	Expensive or limited availability	Excessive amounts required	Unstable	Odor	Salts	Contaminants	Popential N immobilization	Temporary or unknown efficacy
Compost[1]		●		●	●	●	●											
Leaves[2]				●	●	●								●				
Manure[2]					●	●								●	●	●	●	
Biosolids[2]					●	●								●	●	●	●	
Woody material[2]			●	●	●												●	
Bark[2]			●	●	●												●	
Biochar[2]		●	●	●	●				●							●	●	
Bio-stimulants					●	●	●											●
Compost tea					●	●	●											●
Sand			●															
Exp. shale/slate				●														
Perlite/vermic.				●														
Polystyrene				●														
Diatom. earth				●														
Polymer gels		●																
Lime									●						●			●
Gypsum					●						●					●		●
Sulfur and iron							●								●			●
Inorganic fert.						●	●								●			●

[1] Refers to any combination of organic materials (e.g., yard trimmings, feed waste, manure) that have undergone the composting process to produce mature, stable humus that is dark brown or black and has a soil-like consistency and an earthy smell.

[2] Refers to materials in non-composted form. However, these materials may also be composted prior to use as an amendment.

Table excerpted from ANSI A300 Support Systems Standard (Part 2), "Best Manangement Practices Soil Management for Urban Trees" (2014). Used with permission from the International Society of Arboriculture (ISA).

Appendix B: Construction Specifications

SECTION 312317

SPECIALIZED ROOT ZONE AND SOIL EXCAVATION

****
Intent of this document: In general, the intent of this specification section is to describe the desired soil excavation, aeration, and root zone modification results achieved through the use of a compressed air-powered tool referred to as an AirSpade. The use of this piece of equipment is focused on managing the physical properties of the soil and root zones to create and/or maintain favorable nutritional and soil conditions to meet an objective.

It shall be understood that, unless otherwise indicated, the use of this tool has already been predetermined to be the proper method to modify soil and/or root zone conditions in response to pre-construction on-site evaluations and previous diagnosis and recommendations by a certified testing laboratory and/or certified arborist.

Soil amendment procedures, including management of chemical and biological properties, as well as overall tree care practices and maintenance in accordance with ANSI A300 (all parts), are specified elsewhere. Coordinate with work of sections listed in paragraph 1.02, RELATED WORK.
****

PART 1 GENERAL

1.00 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.01 WORK INCLUDED

A. Provide all work equipment, labor, and supervision necessary to perform specialized root zone and soil excavation with a compressed air-powered tool also referred to as an AirSpade, within the limits indicated on the drawings and as specified herein. Work shall include, but not be limited, to the following:

1. Remove and break up soils around existing trees to conduct visual inspection and correction of specific plant health concerns.

****
Delete 2. below if diagnosis has already been performed and Contractor is conducting specialized excavation as a means to administer prescribed treatments.
****

2. Remove and break up soils around existing trees to conduct diagnosis of plant diseases.
3. Remove and break up soils around existing trees to facilitate application of blended soils or amended soils to promote root growth.
4. Remove and break up soils around existing trees to facilitate root pruning.
5. Remove and break up soils around existing trees to locate tree roots.
6. Remove and break up soils around existing trees to accommodate proposed site construction.
7. Root collar (crown) excavation (RCX) to expose the lower trunk and buttress roots of the designated trees and shrubs.
8. Soil replacement for the prevention or mitigation of soil compaction, poor drainage, soil structural issues, or new landscape construction.
9. Root pruning.
10. Removal of all rubbish, debris, and other materials to be disposed of as a result of the work of this section.

1.02 RELATED WORK

A. Examine Contract Documents for requirements that affect work of this Section. Other Specification Sections that directly relate to work of this Section include, but are not limited to:

1. Section 015639, TEMPORARY TREE PROTECTION.
2. Section 015640, TEMPORARY TREE AND SOIL PROTECTION.
3. Section 024113, SELECTIVE SITE DEMOLITION AND REMOVALS.
4 Section 311000, SITE CLEARING.
5. Section 311300, SELECTIVE TREE REMOVAL AND TRIMMING.
6. Section 311317, TREE PRUNING.
7. Section 312300, SITE EXCAVATING, BACKFILLING, AND COMPACTING; Excavation and backfill.
8 Section 312500, EROSION AND SEDIMENT CONTROLS.
9. Section 329115, PLANTING SOILS.
10. Section 329300, PLANTING.
11. Section 329600, TRANSPLANTING.

1.03 REFERENCED STANDARDS

A. Comply with applicable requirements of the following standards. Where these standards conflict with other specified requirements, the most restrictive requirements shall govern.

1. American National Standards Institute (ANSI):

   Z133.1 Safety Requirements for Pruning, Trimming, Repairing, Maintaining and Removing Trees, and for Cutting Brush.

   A300 Tree Care Operations – Tree, Shrub And Other Woody Plant Maintenance - Standard Practices (Parts 2, 5, and 8).

2. Council of Tree and Landscape Appraisers:

   Guide for Plant Appraisal - 9th Edition

3. TCIA – Tree Care Industry Association, Inc. (TCIA)

1.04 DEFINITIONS

A. Arborist: An individual engaged in the profession of arboriculture who, through experience, education, and related training, possesses the competence to provide for or supervise the management of trees and other woody ornamentals.

B. Dripline: An imaginary line defined by the branch spread.

C. Critical rootzone (CRZ): The minimum volume of roots necessary for the maintenance of tree health and stability, typically determined by measuring the tree diameter 4.5 ft. above grade and multiplying by 12 in., a minimum radius of 10' from the trunk, or at the tree's dripline, whichever is farthest from the trunk, or as otherwise indicated on the drawings, or established in the field. CRZ will be determined/established on a case by case basis by the arborist and approval by the landscape architect.

D. Finish grade: Elevation of finished surfaces.

E. Hand-digging: Careful soil excavation using hand-tools to expose roots for inspection or to determine where mechanical excavation can be done without causing significant root damage or loss.

F. Subgrade: Surface or elevation of subgrade soil remaining after completing excavation, or top surface of a fill or backfill immediately beneath planting soil.

G. Topsoil: Soil that is present at the top layer of the existing soil profile at the project site.

H. Loam: Soil that contains a combination of particles typically almost equal in parts sand, silt, and clay and including organic matter.

I. Mulch: A material placed on the soil surface composed of 100% fine-shredded pine bark or wood chips generated by sending tree parts through a wood chipping machine of uniform size and free from rot, leaves, twigs, debris, stones, or any material harmful to plant growth. No chunks 3 in. or more in size and thicker than 1/4 in. shall be left on site.

J. Leaf compost: Well-composted, stable, and weed-free organic matter, pH of 5.5 to 8; moisture content 35 to 55 percent by weight; 100 percent passing through a 1-inch (25-mm) sieve; soluble-salt content of 2 to 5 dS/m; not exceeding 0.5 percent inert contaminants and free of substances toxic to plantings.

K. Tree resource evaluation: A document or site plan describing the tree resources on the site, with information provided from an inventory or survey including: tree species, size (DBH), location, condition, and liklihood of failure.

1.05 SUBMITTALS

A. Prepare and submit a "Specialized Root Zone and Soil Excavation Plan," indicating the extent of soils to be air-spaded. Show all areas of proposed staging, vehicle or equipment access, trenching, excavating, or other disturbance to soils. Include:

1. Proposed plan will be reviewed and approval by the owner and landscape architect. No work of this Section shall commence prior to approval.

****

Delete B. below if diagnosis has already been performed and Contractor is conducting specialized excavation as a means to administer prescribed treatments.

****

B. Prepare and submit a "Tree Resource Evaluation" as defined herein.

C. Proposed methods, materials, and schedule for effecting soils and root zones, in accordance with ANSI A300 (all parts), shall be submitted by certified arborist for approval.

D. Submit schedule of existing trees to be air-spaded.

E. Submit a description of each type of proposed specialized root zone and soil excavation operation and the reason for and location of each type described. Specialized root zone and soil excavation operations shall include, but not be limited to:

1. Soil aeration and decompaction.
2. Radial trenching.
3. Vertical mulching.
4. Root collar excavation.
5. Root pruning.
6. Bare rooting.
7. Soil replacement.
8. Transplanting.
9. Root training.
10. Root trenching.
11. Excavation or trenching required for construction or utility work in CRZ.

****

Root zone investigations may be necessary for a wide range of reasons, including:
Root collar excavation to identify root damage or root disease
Root mapping on development sites to assist in installing footings and underground services:

- Root pruning
- Root structure analysis
- Root location identification in neighbor disputes
- Risk assessment and management
- Assessing tree stability

Delete F. below if diagnosis has already been performed and Contractor is conducting specialized excavation as a means to administer prescribed treatments.

****

F. Conduct a Tree Root Zone Investigation and evaluate the crown/foliage rating of each tree. Submit a health assessment for each tree to undergo specialized soil exacavation operations, prepared by a certified arborist, indicating that each tree is healthy enough to withstand the proposed AirSpade operation and anticipated soil and/or root system disturbance.

1. Submit digital photos documenting tree conditions and illustrating the findings of the Tree Root Zone Investigation. Refer to Paragraph 3.05.

1.04 PROPERTY PROTECTION

A. Prevent damage to and movement, settlement, or collapse of adjacent services, utilities, structures, and trees. Assume liability for such damage, movement, settlement, or collapse. Promptly repair damage at no cost to the owner.

1.05 TREE DAMAGE PENALTIES

****

Keep first Paragraph A if Section 015639 is part of Construction Documents. If not part of Construction Documents, then delete and keep second Paragraph A through E.

****

A. Refer to Section 015639, TEMPORARY TREE AND PLANT PROTECTION.

A. Certain specimen trees within the construction areas and in other key locations will be identified by the owner and the architect and marked with red tags. Loss of any of these trees will result in fines assessed at $10,000 per tree. Damage to all other trees on the property will be assessed at the rate of $200 per inch caliper of the tree.

1. If at any time during the operation, damage to the trunk or root bark is noticed, the operator shall move the tool further from the root or trunk, or stop the operation. Bark damage is not acceptable and will result in fines.

B. A fine of $1,000 will be levied against the contractor for incursion inside tree protection areas.

C. Damages to trees, shrubs, and other vegetation will be assessed by the architect and owner in accordance with the fine structure prescribed in Paragraphs A and B above.

D. Trees or roots visibly damaged will cause the owner to withold from the contractor an assessed amount conforming to the requirements stipulated above for a period of two years. After that period, the impact of the damage to any tree will be assessed accordingly.

E. If any trees or shrubs designated to be saved are damaged and replacement is required, a number and diameter of trees or shrubs of the same species and variety, as specified by the owner and architect, shall be furnished and planted by the contractor. The total inch diameter of the replacement trees or shrubs shall equal the diameter of the tree or shrub to be replaced.

1.06 EXISTING SERVICES

A. Existing structures and utilities shall be suitably protected from damage.

1.07 QUALITY ASSURANCE

****

Select A. below, first paragraph, for national certification. Second paragraph for Commonwealth of Massachusetts only.

****

A. Work of this section shall be completed by a professional ISA Certified Arborist with a minimum five years experience who has successfully completed the International Society of Arboriculture (ISA) Certification Program, sponsored by the International Society of Arboriculture, P.O. Box 3129, Champaign, IL 61826 (217) 355-9411; Email: isa@isa-arbor.com.

A. Work of this section shall be completed by a professional Certified Arborist with a minimum five years experience who has successfully completed the Massachussetts Certified Arborist (MCA) program/examination sponsored by the Massachusetts Arborists Association, 8-D Pleasant Street, South Natick, MA 01760; (508) 653-3320; FAX: (508) 653-4112; E-mail: MaarbAssn@aol.com.

B. Arborist shall have the following minimum qualifications:

1. Certification by:
   a. TCIA -- Tree Care Industry Association, Inc. acccredited company
   b. ISA — International Society of Arborists
2. Meet state requirements for insurance.
3. Licenses for the application and use of pesticides if pesticide application will be required.

C. Equipment utilized to complete the work of this Section shall be operated by experienced technicians, trained and certifed by equipment manufacturer to safely and properly operate the compressed air-powered tool in accordance with manufacturer's Operator's Manual and the "AirSpade Technical Applications Bulletin (2016)."

D. AirSpade operations shall not be performed in heavy rain or when soil is deemed too wet or too dry by certified arborist.

E. Tree trunks shall be suitably protected from damage by AirSpade operations during all activities specified.

1.08 SITE MONITORING

A. While use of an AirSpade can significantly reduce trauma to the tree, it is important to monitor the tree's health and care before, during, and after the procedure. Supplemental watering is typically necessary and should be provided with the direction and continued monitoring of a certified arborist.

B. Site monitoring shall be the responsibility of a Certifed Arborist. Any damage to existing trees shall be immediately reported to the architect. If any tree has been damaged, work shall be halted and reasons for damage assessed. No work shall commence until contractor has submitted a plan for prevention of further tree damage and plan has been approved in writing by landscape architect.

1.09 PRE-CONSTRUCTION CONFERENCE

A. Pre-Construction Conference: Prior to implementing specialized root zone and soil excavation measures, conduct meeting with landscape architect, certified arborist, [AirSpade manufacturer's rep], and owner to verify and review the following:

1. Project requirements for tree and soil protection measures as set out in Contract Documents.
2. AirSpade manufacturer's product data including application, operation, and safety instructions.
3. Limits where specialized root zone and soil excavation measures shall be implemented.
4. Areas of proposed staging, vehicle or equipment access, trenching, excavating, or other disturbance to soils.

****
Delete 5 below if diagnosis has already been performed and contractor is conducting specialized excavation as a means to administer prescribed treatments.
****

5. Health-care needs of individual trees, including specific site conditions, that may affect the project goals or construction implementation strategy.
6. Tree health-care implementation strategy before, during, and after construction.

****
Delete B below if covered in Division 01 GENERAL REQUIREMENTS.
****

B. If the operation is close to a residential area, hours of operation shall be limited to 8:00am to 6:00pm or as otherwise required by governing state or municipal authorities.

C. If air is drained from the hose and air tool, the tip of the tool shall be in contact or beneath the soil surface to avoid excessive noise.

PART 2 - PRODUCTS

2.01 EQUIPMENT

****
Select first Paragraph A if proprietary specification is permitted
****

A. Specialized root zone and soil excavation operations shall be performed using Guardair Corporation's AirSpade [Series 2000], a compressed air-powered tool consisting of an ergonomic pistol grip style handle, insulated fiberglass barrel, and patented supersonic nozzle, manufactured by AirSpade, a Division of GuardAir Corporation, 47 Veterans Drive, Chicopee, MA 01022; Tel. 1-800-482-7324; www.airspade.com, or approved equal.

1. The compressor shall be in good working condition and exhibit no signs of excessive discharge of oil in the air stream.
2. Tool shall be equipped with a "dead-man trigger."

A. Specialized root zone and soil excavation operations shall be performed using a compressed air-powered tool, also referred to as an AirSpade. High-pressure air will come from a compressor that is matched to the design flow of the tool, producing a focused jet air stream capable of penetrating and fracturing existing soil for a fast, efficient method of excavating.

1. The compressor shall be in good working condition and exhibit no signs of excessive discharge of oil in the air stream.
2. Tool shall be equipped with a "dead-man trigger."

PART 3 - EXECUTION

3.01 GENERAL

A. The site where air-spading is to be performed shall have access restricted. Only personnel that are involved in the operation shall be permitted within 25 feet of the operation. A temporary screen barrier shall be set up to prevent flying rocks and debris from leaving the immediate work area during the operation.

B. Personnel using the air tool or working in close proximity to the operation shall wear appropriate personal protective equipment, which includes at a minimum:

1. Hard hat with plastic face shield
2. Goggle-type eye protection
3. Ear plugs
4. Ear muffs
5. Long sleeved shirt and long pants
6. Work boots and socks

C. If the area has active fire ant activity, personnel shall take precautions including sealing of cuffs and the use of insect repellents to avoid fire ant attack.

D. Air hoses used in the operation shall have safety pins and whip guards installed at each hose junction.

E. The air flow heating valve (if present on the compressor) shall be turned off when working near trees so as not to damage bark.

3.02 SOIL PREPARATION

A. Trees proposed to undergo specialized root zone and soil excavation operations shall be adequately watered before start of operations. Amount and frequency of watering shall be determined by certified arborist. No operations shall commence prior to preparation approval in writing by certified arborist.

B. Soil shall be moist to the point of field capacity prior to and during the operation. If dust is generated during the operation, it shall be stopped and the soil should be wetted. If turf, large rock, or mulch is present in the area to be included in the excavation, it shall be removed prior to the start of the operation.

3.03 AIR TILLING

A. Contractor shall utilize the AirSpade tool to aerate and de-compact to the specified depth (typically 6-8 in.) of the topsoil layer. If modification to soil content and aeration is necessary to a greater depth, then this application can be combined with others such as radial trenching or vertical mulching. (Refer to Paragraphs 3.06 and 3.07.)

1. Place plywood sheets over adjacent trenches to prevent refilling.
2. Position the AirSpade at an angle of 30° to 45° (depending on target depth) and about 1 inch from the surface.
3. Move the nozzle from side to side to define the desired trench width.
4. Do not dwell on the same spot.
5. Width, depth, and length of trench, and soil augmentation to be determined based on tree needs and project goals.
6. The adjustable dirt shield should be positioned close to the ground to deflect airborne material away from the operator.
7. Refer to manufacturer's updated safety and operational guidelines.

3.04 SOIL AUGMENTATION

A. Soil augmentation: Fertilizers, composts, or other soil components shall be applied evenly and at rates determined by soil test results in accordance with Section 329115, PLANTING SOILS. Soil amendments shall be blended into existing soil using an AirSpade.

3.05 TREE ROOT ZONE INVESTIGATION

A. At a minimum, Tree Root Zone Investigation shall include the following:

1. Establishing the objective of the inspection, such as detecting cut or damaged roots, particularly where trees are located near to recent excavation works on building sites or where trenches for underground utilities have been dug, root disease or decay, drilling for decay, or collecting samples for submission to a lab.
2. The location of tree roots may also need to be determined, for example during an assessment to trees in relation to building subsidence or when planning construction works near to a tree.
3. Defining the area to be excavated — mark the soil surface of the area to be inspected and define the depth of inspection/soil removal.
4. After inspection, define how the space is treated; i.e., fill it in with the same soil, new soil, or leave open; mulch, sod, or seed on surface.
5. Define aftercare, e.g., soil moisture sensors, irrigation level, or frequency.

B. The assessment should also provide any recommendations for tree protection, health care before, during, and after the completion of site work, and any additional issues or constraints that should guide project goals and/or implementation strategies based on tree and field conditions.

C. Utilize AirSpade or hand dig to carry out subterranean investigations to ascertain the condition of structural roots to assess tree stability. AirSpade shall be used to investigate suspected tree root decay or damage.

3.06 VERTICAL MULCHING

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Utilize vertical mulching for sites with shallow soil depth, anaerobic conditions, or other types of poor growing soils. This application is especially useful in areas shared by perennial or ground-cover plantings, where minimal disturbance is desired.

****

A. Vertical mulching with AirSpade shall be used to de-compact and augment soil deep into the tree root zone.

B. Spray paint target marks on the ground to indicate hole locations.

C. Bore holes shall be to specified depth (typically 18 to 36 in. deep) depending on individual site needs and determined health of trees. When resistance is met, slowly withdraw the AirSpade and then reinsert, allowing loosened soil at the bottom of the hole to exit upwards.

D. Fill vertical holes with mature leaf compost or other augmentation material as recommended by arborist.

E. To avoid undesirable concentrations of augmented nutrients ("hotspots"), use amendments that are compatible or blended with existing soils. [Refer to Section 329115, PLANTING SOILS]. For more extensive results, it is possible to perform vertical mulching over the course of several growing seasons.

3.07 RADIAL TRENCHING

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Utilize radial trenching to de-compact and augment soil to moderate depths within a CRZ. This application is especially useful in areas shared by perennial or ground-cover plantings, where minimal disturbance is desired.

****

A. Radial trenching with AirSpade shall be used to de-compact and augment soil into the tree root zone.

B. Spray paint lines on the ground to indicate trench locations.

C. Create trenches to a specific depth (typically 10 to 12 in. deep) depending on individual site needs and determined health of trees.

D. To avoid undesirable concentrations of augmented nutrients ("hotspots"), use amendments that are compatible or blended with existing soils. [Refer to Section 329115, PLANTING SOILS].

3.08 ROOT COLLAR EXCAVATION

A. When grade is set too high against tree root flare or root collar, it shall be corrected through root collar excavation with an AirSpade. AirSpade must be kept moving back and forth. Do not dwell on same spot.

B. Fine roots should be cut and removed if they interfere with the excavation. qThe excavation shall be concluded when the upper portion of a majority of buttress roots are exposed. Once uncovered, certified arborist shall identify roots that need to be removed. Roots less than ¼ in. diameter may be lowered into the soil using an AirSpade. If the excavation depth exceeds one foot, consult with the certified arborist and landscape architect. If signs or symptoms of decay or disease are noticed, notify the certified arborist and landscape architect. If stem girdling roots less than 1/3 the diameter of the trunk are discovered during the operation, or if several small stem girdling roots are discovered, they should be removed. If stem girdling roots greater than 1/3 the diameter of the trunk or many smaller stem girdling roots are discovered, the certified arborist and landscape architect shall be notified.

C. Replace topsoil or augmented soil to cover roots to proper elevation. [Refer to Section 329115, PLANTING SOILS.]

D. After the excess soil is removed, the excavated area shall be filled with mulch or wood chips as directed by the arborist. The mulch or wood chips shall not be in contact with the tree trunk and shall not hide the buttress roots from inspection. Mulch or wood chip depth should be between 2 and 4 inches, based on the coarseness of the material and approved by the certified arborist and landscape architect.

3.09 ROOT PRUNING AND TRAINING

A. Trees subjected to soil cuts within the root zone shall be root pruned by a certified arborist utilizing an AirSpade, removing as little of the tree's root system as possible.

B. Once existing roots have been safely exposed, a certified arborist shall determine the best places to make clean cuts using a hand pruner. Smaller roots shall be lowered down into soil horizon to help train them to follow a future path of growth.

C. When the tree's excavated root zone will remain exposed for several days or more, protect and cover roots (for example with soil, mulch, or burlap cloth) and provide supplemental water as required.

3.10 BARE ROOTING AND TRANSPLANTING

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Bare rooting with an AirSpade can also be applied to perennial, shrub, and groundcover plantings. This method of transplanting offers the ability to preserve fine root systems. Furthermore, bare rooting small plants is often required during more extensive root zone treatments (such as aeration and de-compaction) or other site work applications. Another application of growing popularity involves bare rooting of nursery stock prior to planting.

****

A. When bare rooting is required to relocate or replace soil around existing trees, utilize an AirSpade to minimize damage to the tree's root system. Bare rooting operations shall expose existing tree roots as necessary to allow them to be pruned and turned down to accommodate new adjacent paving systems.

B. Using an AirSpade, remove almost all the soil from the tree root system, or leave excess soil to transplant with the tree. Once the root zone is excavated, the arborist can prune the root mass to the desired length. It is critical to keep bare roots protected from the sun and hydrated, and to minimize the time between excavation and transplanting.

3.11 SOIL REPLACEMENT

A. Refer to Section 329115, PLANTING SOILS.

3.12 DISPOSAL OF MATERIALS

A. Soil moved during the air-spading operations shall be collected and moved off-site or disposed of on-site if it not visually apparent.

B. Material resulting from the specialized root zone and soil excavation work and not scheduled to be salvaged and is unsuitable for reuse on the project, shall become the property of the contractor and shall be legally disposed of off-site.

C Debris, rubbish, and other material shall be disposed of promptly and shall not be left until final cleanup of site.

END OF SECTION

Glossary

Aeration. Describes the ability of air to transfer through the soil, and the availability of oxygen to a plant's root system. Also used to refer to several techniques used to loosen or penetrate compacted or poorly drained saturated soils.

Air-spading. Refers to any specialized soil excavation technique utilizing a supersonic compressed air-powered tool.

Amendment. Soil additives that can be added to existing site soil. These can include organic or inorganic soil matter, nutrients, bio-char, or beneficial organisms.

American Society of Landscape Architects (ASLA). National professional association for landscape architects.

Anaerobic. Soil conditions that lack oxygen, typically caused by saturation, over-compaction, or soil structure that is poor or incompatible with use of a landscape.

Approved contractor. Operators engaged in specialized soil excavation using an AirSpade should demonstrate minimum education, training, and experience to perform the required work.

Arborist. An individual engaged in the profession of arboriculture who, through experience, education, and related training, possesses the competence to provide for or supervise the management of trees and other woody ornamentals. Qualified arborists should possess certification through ISA. Arborist companies should also be accredited through the TCIA and meet state requirements for insurance.

Augmentation. The process of adding amendments to existing site soil.

Bare root. The removal of soil from a tree's root system.

Beneficial organisms/microbes. See Soil microbes.

Council of Tree and Landscape Appraisers. Publisher of "Guide for Plant Appraisal," a standard reference for tree valuation.

Critical Root Zone (CRZ). The volume of roots necessary for maintenance of tree health and stability, typically measured with a minimum radius of 10' from the trunk or as much as one and one-half times (1.5x) the tree's current dripline. CRZ will be determined/established on a case by case basis through input from the arborist and approval by the landscape architect.

Directional root pruning. Cutting root branches that are growing in the desired direction.

Dripline. The edge of a tree's leafing canopy as projected onto the ground.

Fibrous root. Fine root mass responsible for most of a tree's water and nutrient uptake.

Finish grade. Elevation of surfaces after completion of construction or tree maintenance work.

Girdling. Roots or materials that wrap or cross other roots, the root collar or the trunk of the tree. Girdling roots can weaken or kill a tree by constricting the circulatory system and causing structural issues.

Hand-digging. Careful soil excavation using handtools to expose roots for inspection or to determine where mechanical excavation can be done without causing significant root damage or loss.

Initial Site Investigation. Site visit, usually by the project arborist and landscape architect, to inventory and evaluate existing trees' health and treatment options, and to determine strategic design possibilities based on these opportunities and constraints.

Inorganic. Refering to soils low in carbon and nutrients; typically inert stone or sand. Inorganic soil amendments are often used to improve soil drainage and aeration.

International Society of Arboriculture (ISA). International professional association for arborists.

Landscape architect (L.A.).

Leaf compost. Well-composted, stable, and weed-free organic matter, pH of 5.5 to 8; moisture content 35 to 55 percent by weight; 100 percent passing through a 1-inch (25-mm) sieve; soluble-salt content of 2 to 5 dS/m; not exceeding 0.5 percent inert contaminants and free of substances toxic to plantings.

Loam. Soil that contains a combination of particles typically almost equal in parts sand, silt, and clay and including organic matter.

Mulch. A material placed on the soil surface often for the purpose of aiding soil moisture retention and preventing soil compaction. Wood chips are a specific type of mulch that is preferable for most arboricultural applications because it's readily available, compaction

resistant, and relatively low in nutrients. Other common mulches are made from composted organic matter such as leaves or pine bark.

Permeability. The ability of water to pass through soil. Permeability is commonly impacted by soil composition, gradation, and compaction.

Organic amendments. Refers to soil additives high in carbon or nutrients. Common organic amendments include manure, composts, and other fertilizers.

Root ball. The transplanted portion of a plant's root system, either from container growth or from being dug using a tree spade. A root ball includes transplanted soil, and can remain distinctive long after planting, causing issues with plant growth due to differential soils.

Root collar. The junction between a tree's root system and the trunk.

Root leader. Large roots that spread out from the center of a plant.

Root Zone Investigation. A diagnostic inventory or sampling of a tree's root zone, typically conducted using an AirSpade and always by a trained arborist.

Scarify. A process of loosening compacted soil either by use of mechanical or air excavation tools.

Sinker roots. Arise along lateral roots and generally occur within the drip line. They grow vertically downward, penetrating as much as several feet. Sinker roots play a key role in accessing water and minerals deeper in the soil profile. This function is especially important at times when surface soils become depleted of vital resources, principally water. Sinker roots also serve a role in anchoring the tree *(excerpted from ISA Root Management BMP).*

Soil horizon. One of several layers in a soil profile defined by physical makeup, color, and texture. The 'A' horizon refers to topsoil near the surface (up to 18"- 24" depth or more), and is usually defined by a composition of organic and inorganic matter important to plant growth. The 'B' horizon, or subsoil, is also important for deep root growth, and is typically more coarse and lower in organic content and nutrients than the topsoil. The 'C' horizon, or substratum, is typically inorganic and defines the limit of most vertical root penetration.

Soil microbes. A wide array of organisms that are necessary to maintain healthy soil ecology and sustained tree nutrient uptake and root growth.

Specialized Root Zone and Soil Excavation Plan. Indicating the extent of soils to be air-spaded. Show all areas of proposed staging, vehicle or equipment access, trenching, excavating, or other disturbance to soils.

Supplemental watering. Watering done outside of a normal regimen of tree care, typically required due to construction, transplanting, drought, or other tree care operations that would place abnormal stress on a tree. Supplemental watering often requires constant monitoring by a tree care professional.

Tap root. A large, typically single root that extends vertically from at tree's central leader, and deep into the soil profile.

Tilling. A process of loosening and turning soil, typically done within a shallow soil depth; tilling promotes root growth by improving aeration, opening pore space due to compaction.

Topsoil. Soil that is present at the top layer of the existing soil profile at the project site.

Tree Care Industry Association (TCIA). Trade association of tree care firms and affiliates.

Tree Damage Penalty. A penalty assessed to a contractor for damage to trees designated for construction. These penalties are typically based on industry standards for tree valuation or specially assigned to important specimen trees, and should be designated in construction specifications and bid as part of known construction contingencies.

Tree Resource Evaluation. A document or site plan describing the tree resources on the site, with information provided from an inventory or survey such as: tree species, size, location, condition, plant community, structure, health, and population estimate.

Tree Value Appraisal. A formal assessment of the value of trees based on an agreed standard, typically done by a certified arborist.

Wood-chip mulch. A material placed on the soil surface composed of ground wood, bark, and leaves, usually generated by sending tree parts through a wood chipping machine.

Further Reading

ANSI A300 Support Systems Standard (Part 2). "Best Manangement Practices Soil Management for Urban Trees." International Society of Arboriculture (ISA), 2014.

ANSI A300 Support Systems Standard (Part 3). "Tree, Shrub, and Other Woody Plant Maintenance – Standard Practices (Supplemental Support Systems)." International Society of Arboriculture (ISA), 2006.

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Kelby Fite and Dr. E. Thomas Smiley. "Best Management Practices (BMP) - Managing Trees During Construction, Second Edition." International Society of Arboriculture (ISA), 2016.

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Phelps, Johanna. "To preserve and protect: Working with arborists." Point of View. Metropolis Magazine, 7 Jan. 2016. Web. 19 May 2016.

Rick Sweet. "Ease Excavating Dangers with Compressed Air Tools," Damage Prevention Professional. Winter, 2016.

Online Resources

AirSpade "Applications: Arboriculture/Horticulture," including master specifications: https://www.airspade.com/applications/markets/arboriculture-horticulture

Bartlett Tree Resource Library: https://www.bartlett.com/resourceList.cfm

International Society of Arboriculture: http://www.isa-arbor.com/

This booklet is available to download as a PDF, along with master specifications and CAD details online at: www.airspade.com/guide

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Born and raised on a dairy farm, Stephen's agrarian heritage has inspired and shaped the landscapes he has created across New England and the country. He received his education from the University of Massachusetts and the Harvard Graduate School of Design and has been practicing landscape architecture for over twenty years, founding the firm in 1992. His work has been widely recognized with numerous awards from the Boston Society of Landscape Architects and the American Society of Landscape Architects. He has taught at the Harvard Graduate School of Design and lectured and served on design juries at the University of Massachusetts, Rhode Island School of Design, and Roger Williams University. Stephen was elected as a Fellow of the American Society of Landscape Architects in 2004 for his outstanding achievements in the field of landscape architecture. For the past five years, he has been cultivating Charbrook Nursery for project use and field research related to native plant propagation, collected species, planted forms, and soil specifications.

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AirSpade Technical Applications Bulletin

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This booklet is available to download as a PDF, along with CAD details online at:
www.airspade.com/guide

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