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Corrective Measures Study Technical Memorandum

Evaluation of Tree Preservation Measures for Suspected Air Deposition and Culvert 105 Study Areas

February 2010

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Acronyms

AOC	Administrative Order on Consent
CAOs	Corrective Action Objectives
CMS	Corrective Measures Study
DBH	Diameter at breast height
FMC	FMC Corporation
ICM	Interim corrective measure
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
RCRA	Resource Conservation and Recovery Act
USEPA	United States Environmental Protection Agency

Executive Summary

FMC Corporation (FMC) has completed an evaluation of potential tree preservation measures that might be employed in the course of remediation of potential FMC-related constituents (primarily arsenic) in soil located within the protected root zones of trees found within the off-site Suspected Air Deposition and Culvert 105 Study Areas (Study Areas) in Middleport, New York. This evaluation was implemented consistent with the *Corrective Measures Study Work Plan for Suspected Air Deposition and Culvert 105 Study Areas* dated August 2009 (CMS Work Plan) (AMEC Geomatrix 2009), which was approved by the New York State Department of Environmental Conservation (NYSDEC) and the United States Environmental Protection Agency (USEPA) (the latter two entities are referred to together as "the Agencies"), in consultation with the New York State Department of Health (NYSDOH). This evaluation is also consistent with the Agencies' Final Corrective Action Objectives Applicable to Off-Site Soil and Sediment ("CAOs"), which specifically state that one of the goals of corrective measures is to "[m]inimize disturbance and disruption of the community so that the character of the neighborhoods can be maintained." The preservation of trees is understood to be an important element in maintaining the character of the Middleport community and/or an affected property, and therefore a study of potential tree preservation measures was included as a task in the CMS Work Plan. The conclusions of this evaluation will be considered in the development and analysis of corrective measure alternatives in the Corrective Measures Study (CMS).

The feasibility of tree preservation during implementation of corrective measures (e.g., soil removal, soil tilling or blending) within the protected root zones of trees is dependent on a variety of factors, including distribution of FMC-related constituents; tree species; tree age, health and condition; and soil type. Due to the wide range of factors that must be considered, no single measure will apply to all situations within the Study Areas. This study provides an evaluation of nine identified potential tree preservation measures based on the following factors: the effectiveness of soil removal; maintenance of aesthetic character of the property or neighborhood; relative ease of implementation; minimizing inconvenience to property owners (i.e., noise and length of construction); tree structural stability; tree survival probability ; post-remediation maintenance requirements; short- and long-term safety of workers, property owners and the community; and cost effectiveness.

The evaluation concludes as follows:

- Any disturbance (e.g., soil removal, soil tilling, soil compaction) within the protected root zone could jeopardize the health or stability of an otherwise healthy tree. Measures implemented to attempt to preserve a tree offer varying likelihoods for success. For this reason, the most common approach in soil remediation projects is to remove the tree and replant with a new tree.

- Removal of larger trees and replanting with smaller trees would have an effect on the aesthetic character of an affected property and neighborhood. Based upon two recent inventories of trees located in right-of-ways in the Village of Middleport, approximately 80% of the trees have a trunk diameter (measured at breast height) of greater than 10 inches. The information from these inventories provides an indication of tree species and tree sizes found in a portion of the Study Area. Decades of growth time would likely be needed to fully replace the size of these trees.

- Not all trees can or should be preserved. The determination of whether a tree can or cannot be preserved is dependent on a number of property-specific or tree-specific factors. For example, an older tree with dwindling health would have a low probability of long-term survival if any soil removal was attempted within the protected root zone.

- No single tree preservation measure will apply to all situations within the Study Area. A final remedial design plan would likely include removal of numerous trees (e.g., those that are unhealthy, have been pruned, are over-mature, are poorly located, etc.) and preservation of other trees using selected measures identified in this Technical Memorandum.

- If a tree is to be preserved, limited depth excavation, using either mechanical or pneumatic pressure, would appear to present the best opportunity to preserve the tree and warrants further consideration as part of the CMS. The depth of excavation would be limited to approximately 6 inches below the soil surface, and would be completed in one continuous effort. Precedent was identified for limited depth manual excavation at four similar remediation projects within residential neighborhoods.

- Other identified measures to excavate soils within the protected root zones of trees were not recommended for further evaluation based upon practicability of implementation, lower probabilities for tree survivability, tree structural stability concerns, and safety concerns for workers, residents, and the community.

- Long term maintenance or monitoring of the preserved tree (i.e., watering, fertilizing) and/or subsequent removal of the tree would be the responsibility of the property owner.

1. Introduction

This *Corrective Measures Study Technical Memorandum – Evaluation of Tree Preservation Measures for Suspected Air Deposition and Culvert 105 Study Areas* ("Technical Memorandum") has been prepared by ARCADIS on behalf of FMC Corporation (FMC) for off-site properties in Middleport, New York. This Technical Memorandum identifies and evaluates the effectiveness and ability to implement potential tree preservation measures in the course of remediation of potentially FMC-related constituents (predominantly arsenic) in soil in off-site properties. The evaluation of tree preservation measures is being performed because corrective measures alternatives that include tree preservation measures will be evaluated in the Corrective Measures Study (CMS) for the Suspected Air Deposition and Culvert 105 Study Areas (collectively referenced hereinafter as "Study Area") (properties shaded green on Figure 1-1). FMC is performing the CMS in accordance with the terms and conditions of an Administrative Order on Consent (AOC), Docket No. II RCRA-90-3008(h)-0209, entered into by FMC and by the New York State Department of Environmental Conservation (NYSDEC) and the United States Environmental Protection Agency (USEPA) (the latter two entities are referred to jointly as "the Agencies").

1.1 Background

FMC is currently implementing tasks described in the *Corrective Measures Study Work Plan for Suspected Air Deposition and Culvert 105 Study Areas* dated August 2009 (CMS Work Plan) (AMEC Geomatrix 2009), which was approved by the Agencies in consultation with the New York State Department of Health (NYSDOH). One of the tasks detailed in the CMS Work Plan is the identification and evaluation of tree preservation measures. This task is consistent with the Agencies' Final Corrective Action Objectives Applicable to Off-Site Soil and Sediment (dated March 26, 2009 and included in Appendix A of the CMS Work Plan) ("CAOs"), which specifically states that one of the goals of corrective measures is to "[m]inimize disturbance and disruption of the community so that the character of the neighborhoods can be maintained."

The Study Area consists of approximately 230 off-site properties that are not owned by FMC. Most of the properties, which are located in the Village of Middleport, are occupied by single and multi-family homes (approximately 200 properties). The other properties within the Study Area consist of commercial businesses, agricultural or undeveloped land, Village of Middleport land (e.g., right-of-ways), and the Royalton-Hartland Central School District property. Interim corrective measures (ICMs) conducted previously at 26 residential properties in the Study Area south of the Erie Canal (i.e., at residential properties in the Suspected Air Deposition Area) have required removal of nearly all trees within the remediated areas to effectively remove soil with elevated arsenic levels. Based on observations and experience from the ICMs, the Middleport residents are cognizant of the potential impact remediation and removal of trees can have on the aesthetic character of the Middleport neighborhoods. Concerns raised by the community about the potential loss of more trees due to remediation has led to this evaluation of potential preservation measures for trees in the Study Area as part of the CMS process.

1.2 Objectives

The primary objectives of this Technical Memorandum are to identify potential tree preservation measures and evaluate the relative effectiveness and ability to implement these measures. The evaluation included the following considerations as identified in the Agency approved CMS Work Plan (AMEC Geomatrix 2009):

- Ability to perform the work without causing permanent damage to the tree.
- The level of effort and type of equipment required.
- The safety of workers, residents and neighbors during implementation.
- The potential for the tree to fall down or die during or after completion of the work.
- The degree to which the soil removal and replacement can be accomplished.
- The effectiveness of the method to reduce soil arsenic levels and/or human health risk levels associated with remaining soil arsenic concentrations.
- Costs for performance of the work and potential future costs/liabilities.
- The time of year during which soil removal in the root zone will have the least effect on the tree.
- The ability of partial soil removal within the root zone over multiple years to avoid damaging an otherwise healthy tree.
- The soil replacement type and any additives that may serve to enhance tree preservation.
- How far into the tree root zone (typically approximated by the tree’s drip line) can excavation be performed without expected damage to an otherwise healthy tree?
- How deep can soil be removed within the root zone without expected damage an otherwise healthy tree?

Site-specific information and data on tree abundance, species diversity, and tree health are presented in subsequent sections of this Technical Memorandum, along with information on factors that may result in tree damage and steps that can be taken to minimize or prevent damage to trees that are impacted by remediation activities (referred to herein as “Best Management Practices”) (Sections 2 through 4).

Discussions on the identification and evaluation of potential tree preservation measures are provided in Sections 5 and 6, respectively. Conclusions and recommendations relative to particular tree preservation measures that would be evaluated in the CMS are presented in Section 7. Reference materials are listed in Section 8.

2. Tree Abundance, Diversity and Conditions in Middleport

Although a comprehensive inventory of the abundance, diversity and size of trees within the Study Area does not exist, two recent inventories of trees located in right-of-ways in the Village of Middleport are available. The inventories were commissioned by the Village of Middleport and were conducted by Micha Tree and Landscape Consultants in 2003 and Cutting Edge Tree Service and Consulting in 2007. Results of these inventories are included as Appendix A. The information from these inventories will be used herein to provide an overall indication of tree species and tree sizes (based on diameter at breast height [DBH]) found in a portion of the Study Area. Only trees with a DBH greater than 2 inches were inventoried. DBH is a commonly used measure or convention for rapidly describing the size of a tree. However, a similar DBH can reflect very different tree sizes (i.e., heights) between individual trees or across different species of trees due to different growth habits between species, or the potential effects of site specific conditions (i.e., water and nutrient availability) on a tree's development.

Both inventories provide information on the types of trees present in the Study Area (see a complete listing of trees in Table 2-1, attached). The 2007 inventory identified 664 trees across 25 species within Village street right-of-ways. Approximately 80% of the trees identified in the 2007 inventory were silver maple (*Acer saccharinum*), Norway maple (*Acer platinoides*), or sugar maple (*Acer saccharum*). Table 2-2 provides a summary of the range of sizes of the seven most common trees (comprising 91% of trees) identified in the 2007 inventory. Of these most common tree species, 80% of the identified trees had a DBH greater than or equal to 10 inches.

The 2007 tree inventory, and a one-day site reconnaissance conducted by ARCADIS in the fall of 2009, identified a range of conditions in the trees throughout the Study Area. Tree conditions ranged from "good" to "fair-poor" condition. In 2009, it was observed that most of the right-of-way trees have been significantly pruned due to their proximity to overhead utility lines. This observation is noteworthy because stresses on a tree caused by past pruning could exacerbate the adverse effects on a tree if soil excavation is attempted within its protected root zone. The health/condition of a tree has direct implications on the uses of and/or applicability of tree preservation measures (as discussed in Section 3). Appendix B includes photographs of some of the trees in the Study Area (including some of the pruned trees) that were observed during the 2009 site reconnaissance.

Table 2-2. Common Tree Species Identified in 2007 Inventory

Species Name (Common)	Percentage of Trees in Study Area Right-of-Ways	Summary Statistics of Tree Sizes (DBH in Inches)		Number of Trees By Size Class (DBH in Inches)			
		Range	Mean	2 – 5	5 – 10	10 – 15	> 15
Silver maple	36.6	2.5 to 42	20	8	13	2	216
Norway maple	35.7	2.5 to 22	12.5	13	51	114	55
Sugar maple	7.2	12 to 28	20	0	0	5	43
Locust	4.5	12 to 20	18	0	0	3	26
Spruce	2.6	~8	8	0	17	0	0
Littleleaf linden tree	2.4	2.5 to 16	10	3	7	4	2
Oak	2.0	6 to 14	10	0	7	6	0
Summary (total)[1]	91.0	-	-	24	95	134	342

[1] The total number of trees only reflects a subset (or most common) tree species identified in the tree inventories. A complete listing of identified trees is included in Table 2-1.

3. Impacts of Tree Health and Condition on Tree Preservation

The identification of trees potentially suitable for tree preservation and the identification and evaluation of appropriate tree preservation methods must take into consideration the overall health and condition of a tree. A tree's health is dependent upon the proper functioning of foundational physiological processes.[2] This section reviews the functions of the tree structure and factors, including physiological processes, potentially affecting tree health/survival, while the next section (Section 4) discusses Best Management Practices for tree preservation during construction activities.

3.1 Tree Structure and Function

A critical part of a tree's health is one that cannot be seen - the roots. Approximately 90 to 95% of the roots of trees present in the northeast U.S. are found within 36 inches below ground surface, with more than 50% within 12 inches of grade (Shigo 1989; Miller et al. 1993; Fite and Smiley 2008). The larger perennial roots of a tree and their primary branches characteristically grow horizontally between 6 to 24 inches below the soil surface. The finer roots (which average only 1/16 inch in diameter) which grow outward and upward from the larger woody roots are predominantly found within the top 6 inches of soil. The lateral extent of the roots typically includes at least the area within the "drip line" of the leaves as discussed further in Section 4.3. The roots of the tree provide three critical functions:

- <u>Provide Structural Support</u>: The roots provide the structural support of a tree. Literature suggests that the principal structural support of a tree is provided by the larger, coarse roots close to the base of the tree (Roberts et al. 2006), and that very little structural support is offered by the deeper roots or those further laterally from the base of the tree (Mattheck and Breloer 1994). These larger roots are believed to be long-lived (i.e., entire life of the tree), in contrast to the short-lived, fine roots.

[2] Photosynthesis allows a tree to capture energy from sunlight and convert it into chemical forms of energy that are used to support biological systems within the tree. The photosynthetic process begins with sun light striking chlorophyll within a tree's leaf. Through a series of reactions the energy in sunlight is converted into carbohydrates. Carbohydrates are then used by a tree to fuel all biological activities which include leaf development, growth, defense, and reproduction. Water and nutrient uptake occurs in the fine roots and epidermal cells of larger roots. Trees absorb water within their roots by osmosis, a process where water with a low concentration of minerals and nutrients passes through the root membrane towards an area that has a higher concentration of mineral and nutrients. Water is then transported from the roots to the leaves. This process is facilitated by water being lost within the leaves of a tree during transpiration (a process which supplies photosynthesis with carbon dioxide), and this loss of pressure within the leaves allows the tree to draw water and nutrients from its roots.

- Collect/Absorb Water and Nutrients: The major function of the fine roots is to absorb water and nutrients from the surrounding soil. The fine roots constitute a major portion of the total surface area of the root system, and grow outward and upward from the larger woody roots near the soil surface (i.e., top 6 inches of soil), where nutrients, water, and oxygen are characteristically available and abundant. They are commonly short-lived so that a tree is able to continually seek out un-tapped sources of water and nutrients within the soil.

- Store Water, Energy and Nutrients: The larger roots of trees conduct and store water, energy and nutrients essential to the survival of a tree. A tree characteristically stores excess energy produced during the growing season to support growth following dormancy. Existing stresses within an individual tree, whether they are caused by health, disease, or past management, cause a deficit of stored resources necessary to survival and increases the susceptibility of a tree to disease, pests, and/or general decline in health.

3.2 Factors Limiting Work in the Protected Root Zone

Disruptions within the protected root zone of a tree should be controlled and evaluated on a tree-by-tree basis. The likelihood that a tree will survive disruptions to the root system is dependent on a number of factors, as listed below.

- Tree Species: The ability of a tree to tolerate construction-related disturbance or damage is known to vary greatly by tree species (Matheny and Clark 1998). Different species have varying levels of tolerance to root severance, soil compaction and other common construction impacts. For example, silver maples have a poor-to-moderate tolerance in comparison to Norway maples, which have a moderate-to-good tolerance. Appendix C lists the relative tolerance of common tree species to the region. In addition, different species have varying susceptibilities to disease or pests. Thus, the species of a tree will have implications on the methods potentially appropriate to address soil within its protected root zone.

- Age and Health/Condition: The response of a tree to construction-related disturbance or damage, and its probability of survival, will vary greatly based upon its age and health/condition. For instance, an older tree with dwindling health will be less likely to survive potential stresses caused by the excavation/disturbance of soil from around the roots than a healthy younger tree. More specifically, a deficit of stored energy and/or nutrients can have amplified adverse consequences to a tree.

- Soil Type: The soil type within the protected root zone of a tree will directly affect the effectiveness and feasibility of any tree preservation measure that includes excavation. For example, a sandy soil can more easily be excavated than a compacted silty clay soil. Based on soil boring logs conducted in the Study Area, the soil types predominantly consist of silty loams, but are greatly variable due to the development that has occurred over the past 100 plus years. Hence, the soil type that exists around a specific tree will vary on a case-by-case basis.

- Climate/Weather: The local climate will have implications on the implementation of remediation affecting the protected root zones of trees and tree preservation measures. In the Middleport area, such work will likely be implemented within the regional growing season, to avoid excavating in frozen soils and to prevent exposure of exposed roots to freezing conditions. It is estimated that frozen ground days occur from mid-December through early March. In addition, remedial design will also need to account for other climate factors. For example, a severe storm during or subsequent to excavation within the protected root zone of a tree could potentially threaten the structural stability of that tree or amplify existing stresses caused by the excavation.

3.3 Physiological Concerns for Excavation within the Protected Root Zone

Even with the implementation of precautions, any disruption to the root system decreases the probability of the long-term survival of the tree (Pirone et al. 1988; Urban 2008). Therefore, when evaluating whether soil excavation in the protected root zone is feasible for a particular tree, the following considerations should be evaluated with respect to the three principal functions of the roots:

- Structural Stability Considerations: Complete removal of soil within the protected root zone (e.g., to a depth of approximately 24 inches) would likely cause significant structural weaknesses, if not complete failure (i.e., tree falling down), of the root system of the tree. Application of structural supports would be extremely difficult or infeasible for a tree within an existing excavation area. ARCADIS is not aware of and did not identify any precedent for such an application.

  ARCADIS researched previously approved and implemented approaches of shallow soil remediation projects in residential neighborhoods where soil excavation was necessary around trees. The most common approach was removal of the tree. However, a few examples of mechanical or hand removal of soil within the protected root zone of a healthy tree are available. Those projects that did excavate soil within the protected root zone of a tree only did so to an approximate depth of 6 inches below the soil surface and were based upon field direction provided by a certified arborist (USEPA 2008, 2009; CH2M Hill 2009; ARCADIS pers. comm. 2009). These projects included (1) Myers Property Superfund Site, Franklin Township, Hunterdon County, New Jersey; (2) South Minneapolis Residential Soil Contamination Site, Minneapolis, Minnesota; and

(3) two projects completed by ARCADIS for confidential clients in South Carolina and Indiana.

Urban (2008) suggests that phased excavation by removing soil in small sections (zones or area sectors) at a time is possible when using pneumatic pressure (such as the Air Spade®) or potentially hydraulic pressure. The protected root zone could be divided into a minimum of two to three zones or area sectors and phasing excavation at a rate of one zone per year. This could maintain the structural stability as well as minimize adverse affects to the tree's health and/or condition of a tree while attempting complete replacement of soil within the protected root zone. However, no examples involving a phased excavation approach were found relative to a soil remediation project within residential neighborhoods.

- Water / Nutrient Uptake Considerations: Any selected soil excavation method will likely cause a physical disturbance of the fine root biomass and the ability of the tree to uptake water and nutrients. If the roots become too dry, then root hairs wither and the tree is no longer able to absorb water and nutrients. Root hairs dry out quickly when exposed to situations where there is no moisture. Conversely, if the soil is too wet or compacted, roots suffocate and lose their absorbing capacity. If the soil around a tree is compacted or permanently wet, then air is unable to penetrate the soil and the root system can suffocate.

  The few identified cases of implementation of shallow soil remediation projects in residential neighborhoods only attempted manual (i.e., by hand) excavation to depths up to approximately 6-inches within the protected root zone. Manual excavation was selected due to the difficulties of implementation and inconvenience to residents associated with other methods, such as pneumatic excavation. Tree survival rate after one year is high (i.e., approximately 90%) and commonly shows a direct correlation to the health of the tree prior to excavation.

- Energy / Nutrient Storage Considerations: The stress to a tree caused by excavating soil from within the protected root zone will adversely affect the storage and distribution of energy and nutrients, and hence, will decrease the ability of the tree to defend against pests and/or diseases. For example, bark boring beetles are known to be attracted to weakened and/or dying trees (Sinclair and Lyon 2005). Another example is that many fungi normally do little damage to trees growing under proper conditions, but can readily destroy trees when growing under adverse conditions (Pirone et al. 1988).

4. Best Management Practices for Tree Preservation

Considerable information and technical guidance are available on protecting, preserving, maintaining and/or removing trees within or near a construction site. While the Best Management Practices from the various information sources do not describe the selection of a remedial strategy and are not specific to environmental remediation projects, they provide the basis for planning a remediation/construction project with emphasis on tree preservation. Best Management Practices would be implemented, as appropriate, along with each tree preservation measure identified in Section 5. The framework for Best Management Practices includes the following activities:

- Coordination of tree preservation activities before/during/after construction
- Identification of trees to be preserved during construction
- Establishment of protected root zones
- Avoidance of unacceptable soil compaction
- Appropriate soil replacement

4.1 Coordination of Tree Preservation Activities before/during/after Construction

*Best Management Practices: Managing Trees During Construction (*Fite and Smiley 2008) recommends dividing a construction project into five phases, noting that the fate of a tree can be affected during each of these phases. The five recommended phases of tree preservation activities are as follows:

- <u>Planning</u>: The planning phase includes a full inventory of trees within a project site. The trees are characterized in terms of maturity, size, condition and other factors that determine whether the tree could/should be preserved.
- <u>Design</u>: During the design phase, trees are identified either for preservation or removal, based on the site-specific conditions, remediation needs, susceptibility to construction damage and/or the location within a project site. This phase includes developing design drawings and associated construction details and specifications for recommended Best Management Practices.
- <u>Pre-Construction</u>: During the pre-construction phase, Best Management Practices are selected for those trees identified for preservation (e.g., delineating the protected root zone of a tree). This phase also includes removing those trees not selected for preservation.

- Construction: The goal of the construction phase is to maintain the integrity of the protected root zone, while being consistent with the design drawings and maintaining effective communication within the project team to allow for adaptive management if necessary.
- Post-Construction: The post-construction phase would involve monitoring the health/condition of the tree following construction activities. The landowner would be responsible for this phase of the project, which would primarily focus on appropriate watering and fertilizing of a tree.

4.2 Identification of Trees to be Preserved During Construction

The planning and design phases of the project will evaluate the inventory of trees within the project site, and in cooperation with the landowner(s), make the critical decision of which trees to preserve. It must be recognized that some trees cannot be preserved regardless of the preservation measures that might be implemented. Trees in poor health/condition, structurally unstable or otherwise determined to be unable to survive excavation/disturbance of soil within the protected root zone should not be selected for preservation. As noted in Section 3, the probability of survival of older, unhealthy trees significantly decreases when attempting excavation within the protected root zone. Any subsequent need to remove a tree after completion of the remedial activities by FMC would not be within the scope of FMC's corrective measures. Therefore, identification of trees that will be preserved within the Study Area should be conducted in consultation with the property owner based on 1) owners desire to preserve a tree; 2) physiological considerations of the tree(s); 3) consideration of the aesthetic effect of the tree(s) on a property and/or neighborhood; and 4) the extent of soil removal/disturbance required for completion of the corrective measure.

Factors limiting the effectiveness of work within the protected root zone of a tree include tree species, location, structural stability, health/condition and age, soil characteristics within the protected root zone, as well as weather conditions during the construction activities, as discussed in Section 3.2. The ability of a tree to tolerate construction-related disturbance or damage is known to vary greatly by tree species. While construction tolerance is an important trait in the evaluation of whether to preserve an individual tree, the response of a particular tree also depends upon a tree's age, health, previous injuries, soil conditions, susceptibility to pests, and the time of year of proposed construction.

The aesthetics of a tree or trees on a property and/or neighborhood will also be considered in the design phase. Some trees provide greater aesthetic benefits (e.g., shade, property character) than others. While evaluating aesthetic benefits is often subjective, this will be included in the planning and design phases of the project.

The extent of soil removal/disturbance required for completion of the corrective measure also needs to be considered when identifying which trees to preserve. This would be likely based on levels of constituents found in the soil within the protected root zone of the tree and the actual excavation depths required for the Agencies to determine that FMC has completed the corrective measures for the affected area/property.

4.3 Establishment of Protected Root Zones

One of the most effective Best Management Practices to preserve a tree is to delineate and protect (from construction activities) the protected root zone of a tree. As Urban (2008) notes, "[w]henever natural soil is disturbed, it loses some of its ability to support plant life by losing its structure."

There are several methods used by arborists to identify the protected root zone. One of the most common methods of such identification is based on the "drip line" of a tree. The "drip line" is defined as all areas directly below the branches of a tree. However, varying site or environmental conditions can lead to the "drip line" not including a sufficient area of the critical root zone for successful preservation. For example, trees growing in close proximity to existing structures or other trees may have a narrow growth habit. In these circumstances, the protected root zone may be calculated by an arborist based upon the diameter of the tree and the species' tolerance to construction damage. The DBH (in inches) of the tree is multiplied by a factor ranging from 6 to 18, depending upon the tolerance factor of the tree species (Appendix C) to obtain the radius of the protected root zone (in feet). Table 4-1 (attached) provides guidelines that are used by arborists for determining the protected root zone of healthy, structurally sound trees. Figure 4-1 illustrates the potential difference of delineating the protected root zone based upon the "drip line" method in comparison to the tree diameter method.

Construction planning should also involve an arborist to evaluate the chance of survival of a given tree if soils need to be removed from within the protected root zone of a tree. A publication entitled *Preserving Trees in Construction Sites* (Dicke and Raymond 2004) notes that the reduction of the protected area around a tree significantly reduces the likelihood of survival and recommends protecting a minimum of 70% of the protected root zone from construction activities. The publication qualifies this recommendation by excluding unhealthy trees or species susceptible to damage from construction.

4.4 Avoidance of Unacceptable Soil Compaction

Soil compaction is often the greatest threat to an individual tree within a typical construction site (Fite and Smiley 2008; Miller et al. 1993; Dicke and Raymond 2004).

Stockpiling of building materials, heavy machinery traffic, and even excessive foot traffic can all result in soil compaction and damage to soil structure. The compaction of soils reduces pore space, and thus can lead to lack of aeration, lack of water penetration below ground surface, lack of root growth and root suffocation and thus a disruption in basic physiological processes (i.e., photosynthesis, transpiration) critical to tree survival. Best Management Practices must ensure that any traffic or activities that result in compaction be avoided in the protected root zone. Further, any backfilled material within the protected root zone should not be compacted to an extent that prevents aeration and adversely affects the ability of the tree to uptake water and nutrients. Best Management Practices may include prohibiting or minimizing access to certain areas, using equipment with proper flotation to minimize compaction, and/or temporarily mulching the protected root zone with wood chips or gravel.

4.5 Appropriate Soil Replacement

Any excavation within the protected root zone of a tree would require the replacement of the contaminated soil that was removed. A soil replacement plan would be developed to identify the proper soil characteristics for backfill and topsoil and to identify the soil compaction necessary to ensure structural stability of the tree, while not compacting to an extent that would adversely impact the soil aeration around the existing roots. The method for soil replacement would depend upon the depth of excavation. Shallow excavation (e.g., depths up to 6 inches) would be addressed by filling with compaction-resistant soils and then light compaction with water and/or low impact tools. A deeper excavation would likely require multiple phases of compaction to maintain structural stability of the tree while not deterring future root growth within the disturbed areas.

In addition, the soil replacement plan would evaluate any potential soil amendments required to promote the long-term survival of the affected tree. For example, many trees rely on a fungus called mycorrhizae to maximize their mineral absorption capacities. These microrrhizae colonize the roots of a host plant and are able to establish a symbiotic (commonly mutualistic) association where the fungus receives carbohydrates in return for water and minerals. Excavation of soil from within the protected root zone could adversely affect these fungi, and have detrimental impacts on a tree’s water and nutrient uptake capacities. The soil replacement plan should evaluate the need for including microrrhizae amendments or inoculations based upon the species of tree.

5. Identification of Potential Tree Preservation Measures

Table 5-1 (below) lists the potential tree preservation measures that have been identified to address impacted soil within the protected root zone of trees identified for preservation, as discussed in Section 4.2. Included in this list are two measures (i.e., Measures 2a and 2b) which would remove trees and replace them with nursery stock trees. While these measures are not specifically tree preservation measures, they have been included as part of this evaluation because (1) a tree removal and replacement plan was previously approved and implemented for ICMs within the Study Area, and/or (2) in at least the long term, replacement would contribute to maintenance of the aesthetic character of a property and neighborhood. All identified measures would be implemented along with the various Best Management Practices identified in Section 4.

Table 5-1 - Identification of Potential Tree Preservation Measures

Measure Number	Description
1	No Soil Removal within the Protected Root Zone
2a	Tree Removal and Replacement with Nursery Stock Trees
2b	Phased (Extended Time) Tree Removal and Replacement With Nursery Stock Trees
3a	Limited Depth Manual Excavation within the Protected Root Zone
3b	Phased Sector Manual Excavation within the Protected Root Zone
4a	Limited Depth Pneumatic Excavation within the Protected Root Zone
4b	Phased Sector Pneumatic Excavation within the Protected Root Zone
5a	Limited Depth Hydraulic Excavation within the Protected Root Zone
5b	Phased Sector Hydraulic Excavation within the Protected Root Zone

A description of each potential measure is provided below. A summary of the evaluation of these measures is provided in Section 6. It is important to note that no single tree preservation measure will apply to all situations within the Study Area. Each property will have to be evaluated on an individual and neighborhood-wide basis. Remedial design will require planning to evaluate the potential to maintain the existing aesthetic character of an individual property and neighborhood while also attempting to minimize potential exposure to impacted soils within the protected root zones of these trees.

5.1 Measure 1: No Soil Removal within the Protected Root Zone

This measure would involve no excavation within the protected root zones of trees in the Study Area. This approach relies on the presence of the tree and tree roots to serve as a binding mechanism to limit exposure and mitigate contaminant migration via soil erosion and leaching. This measure could allow higher soil arsenic concentrations within the protected root zone of a tree in comparison to the remaining portions of a property. Implementation of this measure may require risk evaluation and/or establishment of institutional controls or management practices to minimize potential human exposures to unacceptable levels of constituents in soil located within the protected root zones of these trees.

5.2 Measure 2: Tree Removal and Replacement

The removal and replacement measures would consist of the complete removal of trees to facilitate soil removal within the protected root zones and replacement with nursery stock trees. For the purposes of this Technical Memorandum, standard nursery stock trees are assumed to be equal to or less than 2-inch DBH and in the first third of their characteristic life span. Use of nursery stock trees as a restoration measure is consistent with the previously approved and implemented ICMs within the Study Area. For this evaluation, two potential approaches for excavation and replacement of trees are identified and are discussed below.

- **Measure 2a – Tree Removal and Replacement with Nursery Stock Trees:** This measure would include the removal of trees to facilitate soil excavation and restoration with standard nursery stock trees. This approach provides flexibility to the property owner in deciding type, placement and timing for trees planted on their property. Although this approach would effectively remove all impacted soil, it has the potential to impact the aesthetic character of a property and neighborhood. Trees can take many years to mature and develop the canopy characteristics that bring much of the existing character to the affected neighborhood and properties. A conceptual illustration of the potential growth of a planted nursery stock sugar maple over an interval of 40 years is provided as Figure 5-1.

- **Measure 2b – Phased (Extended Time) Tree Removal and Replacement with Nursery Stock Trees:** This approach consists of the completion of remedial activities within the Study Area phased over time to maintain the current aesthetic character of Middleport to the extent practicable. For example, remediation activities within the active right-of-ways could be delayed for a pre-determined time period to maintain some of the character of Middleport while the small replacement trees on adjoining properties are provided time to mature. This approach would require completion of the soil removal activities over many years and would significantly extend the time required to complete the corrective measures for the Study Area. The interval of time between phases could depend upon anticipated growth rates of planted nursery stock trees (as illustrated in Figure 5-1), which characteristically take many years to mature and develop the canopy characteristics that bring much of the existing character to the affected neighborhood and properties.

5.3 Measure 3: Manual Excavation within the Protected Root Zone

Manual excavation is the most common method used when remediating soils within the protected root zones of trees at other sites around the United States (USEPA 2008 and 2009; CH2M Hill 2009; ARCADIS pers. comm. 2009). Previous projects which have attempted manual excavation used shovels, trowels, picks, and “micro-excavators,” depending on the specific conditions of the tree being preserved. This measure was evaluated based on using a limited depth approach and a phased sector approach, as described below.

- **Measure 3a – Limited Depth Manual Excavation (for soil removal depths up to 6 inches):** This measure would consist of manually excavating soil within the protected root zone to a maximum depth of 6 inches below ground surface in one continuous effort. A maximum of six inches below ground surface was selected based upon (1) precedent established at four other identified similar remedial projects within the U.S. (USEPA 2008, 2009; CH2M Hill 2009; ARCADIS pers. comm. 2009); and (2) the larger perennial roots of a tree characteristically grow horizontally at depths from approximately 6 to 24 inches below the soil surface.

  Following removal of this surface soil, the excavation would be backfilled with clean compaction-resistant soil. If impacted soil remains at depth, this backfill would serve as a soil cover and would prevent exposure. Appropriate Best Management Practices and/or institutional controls would be applied to minimize potential exposure to impacted soils remaining beneath a depth of six inches. Long term maintenance or monitoring of the preserved tree (i.e., watering, fertilizing) and/or subsequent removal of the tree would be the responsibility of the property owner.

- **Measure 3b – Phased Sector Manual Excavation (for soil removal depths greater than 6 inches):** This measure would involve manually excavating soil within the protected root zone using a phased sector approach. This approach would divide the protected root zone into a minimum of three area sectors, with excavation spanning over a minimum of three years (i.e., one zone per year). This would enable excavation deeper than 6 inches below ground surface in a manner that attempts to maintain the structural stability of a tree while limiting adverse effects on the health or condition of a tree.

This measure would allow removal of soil containing unacceptable levels of potential FMC-related constituents within the protected root zone to depths greater than 6 inches below the soil surface. Long term maintenance or monitoring of the preserved tree (i.e., watering, fertilizing) and/or subsequent removal of the tree would be the responsibility of the property owner.

5.4 Measure 4: Pneumatic Excavation within the Protected Root Zone

Pneumatic excavation involves the use of high pressure air to excavate soils within the protected root zone of a tree. Common arborist tools, such as the Air Spade®, focus compressed air into a high speed jet stream of air, which is able to dislodge and break apart soils from around tree roots without unduly damaging the roots. After loosening, the dislodged soil can be removed by a commercial vacuum truck. Based upon factory specifications, the Air Spade® can excavate several feet in depth in medium to stiff soil at a rate of about 1 to 2 inches per second.

Utilizing pneumatic pressure can potentially minimize impacts to roots, reduce the time necessary to excavate a large area within the protected root zone, and minimize impacts to surrounding infrastructure. By minimizing the impacts to fine root biomass, this measure would aid in recovery time by providing greater levels of water and nutrient uptake immediately after excavation. In addition, the reduced time needed for excavation decreases the time that roots are exposed and helps prevent them from drying out. Both a phased area sector approach and a limited depth approach identified in this measure are described below.

- **Measure 4a – Limited Depth Pneumatic Excavation:** This measure is the same as Measure 3a, except that the soil would be removed by using compressed air (i.e., Air Spade®).

- **Measure 4b –Phased Sector Pneumatic Excavation:** This measure is the same as Measure 3b, except that the soil would be removed by using compressed air (i.e., Air Spade®).

5.5 Measure 5: Hydraulic Excavation within the Protected Root Zone

Hydraulic excavation involves the use of water pressure to excavate soil from within the protected root zone of a tree. Similar to pneumatic excavation, hydraulic power can be used to free compacted and immobilized soil from within roots. Excavated soil would be removed from the work area in the form of a slurry (i.e., a thick suspension of solids in a liquid), which would be pumped to a truck and subsequently dewatered for proper disposal. Both a phased area sector approach and a limited depth approach were identified for this measure, as described below.

- **Measure 5a – Limited Depth Hydraulic Excavation:** This measure is the same as Measure 3a, except that the soil would be removed by using high pressure water.

- **Measure 5b – Phased Sector Hydraulic Excavation:** This measure is the same as Measure 3b, except that the soil would be removed by using high pressure water.

6. Evaluation of Potential Tree Preservation Measures for Middleport

The potential tree preservation measures identified in Section 5 are assessed based on nine factors listed below. These nine factors were selected to best represent the evaluation criteria identified in the CMS Work Plan (AMEC Geomatrix 2009) and the objectives set forth in Section 1.2 of this report. The first two factors specifically address the effectiveness of the potential measure, while the remaining seven factors address various aspects of the implementability of the potential measure.

- Effectiveness of soil removal
- Maintenance of character of property and neighborhood
- Relative ease of implementation
- Minimizing inconvenience to property owners (i.e., noise and length of construction)
- Tree structural stability
- Tree survival probability
- Post-restoration maintenance
- Short- and long-term safety
- Cost effectiveness

The evaluation of tree preservation measures was performed based upon a review of published literature, a review of similar soil remediation projects within other residential neighborhoods, consultations with local arborists and regional tree specialists, and best professional judgment. Results of the evaluation are provided below, organized according to each evaluation factor, and summarized in Table 6-1.

As noted in Section 5, no single tree preservation measure would apply to all situations within the Study Area. However, to evaluate the effectiveness of each measure, it is assumed below that each measure would be applied across an entire affected property.

6.1 Effectiveness of Soil Removal

The potential measures were evaluated relative to the degree to which soils containing unacceptable levels of FMC-related constituents (i.e., arsenic) within the protected root zone of trees would be removed. This evaluation assumes that construction would be completed during the growing season of the tree as discussed in Section 3.2. A low rating for this factor means the measure would provide a low level of effectiveness relative to soil removal within the protected root zone of a tree, while a high rating means this measure would be very effective.

- **Measure 1 – Not Applicable**. This measure is not applicable, as no excavation would occur within the protected root zone of identified trees.

- **Measures 2a and 2b – High**. The two tree removal and replacement measures scored a high rating as these approaches provide an effective and practicable approach to soil removal by removing trees from within the Study Area. This approach is the one most commonly implemented in soil remediation projects across the U.S., and Measure 2a has been previously implemented successfully during the ICMs that have been conducted in Middleport (e.g., for the Western Residential Properties and the 2007 Early Action work).

- **Measures 3a, 4a, and 5a – Low-to-High.** The limited depth excavation measures scored a rating of low-to-high for effectiveness of soil removal, depending on the extent of impacted soils left below 6 inches of the ground surface and the identified soil textures (to be determined during the planning phase of this project) within the protected root zone. Using any of the three excavation methods, soil could likely be effectively removed to 6 inches below ground surface across the entire protected root zone of a tree in one phase of excavation. Presence of heavily compacted or clayey soils within the protected root zone could affect the time requirements and/or effectiveness of soil excavation.

  Impacted areas would be replaced with clean soil cover, which would reduce the potential for direct human exposure to deeper soils. This approach has been implemented using manual excavation (Measure 3a) in similar residential remedial projects (USEPA 2008, 2009; CH2M Hill 2009; ARCADIS pers. comm. 2009), and could be completed within a single mobilization and construction season.

  These measures would potentially leave soil containing higher levels of arsenic within protected root zones of trees below 6 inches. However, removal of the surface soil containing unacceptable levels of arsenic and replacement with clean soil containing lower arsenic concentrations would reduce human health risks and would reduce the overall average soil arsenic level of the soil within the protected root zone. If the Agencies determine that the remaining soil arsenic levels beneath the 6-inch thick clean surface soil require further controls, these might take the form of institutional controls and/or management practices to minimize potential future human exposures.

  Under these measures, individual property owners would be responsible for each tree preserved on their property. In addition, each individual property owner would be responsible for maintaining (or even monitoring) the soil cover and preventing erosion around the base of the tree or preventing the digging to a depth greater than 6 inches that may result in human exposure of unexcavated subsurface soil within the protected root zone.

- **Measures 3b, 4b, and 5b – Low-to-Moderate**. The phased zone excavation measures scored a low-to-moderate rating for effectiveness of soil removal. First, ARCADIS was unable to identify any precedent for a phased excavation deeper than approximately 6 inches within the protected root zone in similar residential remediation projects. Second, such excavation presents significant issues, including (1) difficulties in maintaining the structural integrity of the tree when excavating around structurally important roots, and (2) difficulties removing soil below 6 inches where the complexity of root systems typically increase. Due to the latter, some soil may not be accessible or may need to remain to preserve the long-term health of the tree as well as maintain structural integrity of the tree during excavation. However, this approach would reduce the average soil arsenic levels within the protected root zone and provide cover with clean soil, thereby reducing human health risks associated with impacted soils within the protected root zone. Potential differences between the excavation methods (e.g., pneumatic, hydraulic) are not significant enough to warrant different ratings for this factor.

6.2 Maintenance of Character of Property and Neighborhood

The evaluation of this factor addresses the ability of a measure to maintain the aesthetic character and other benefits to the property owner (such as shade) that are provided by existing trees. The planning and design phase will evaluate which trees are suitable for preservation in attempt to maintain the aesthetic character of a property, as well as the expanded effects across the community. To effectively evaluate the difference between each measure relative to this criterion, it is assumed that each measure is applied across an entire affected property. This approach differentiates which measures have a positive effect on maintenance of the aesthetic character of a property and those which will have a negative effect. A low rating indicates that the measure would result in removal of mature trees and replacement with typical nursery stock trees (equal to or less than 2-inch DBH). A high rating indicates that implementation of the measure would maintain mature, healthy trees within the Study Area to the extent that the aesthetic character of the property is not significantly changed.

- **Measure 1 – High.** This measure would involve no tree removal. Therefore, this measure was assessed a high rating.

- **Measure 2a – Low.** This measure was given a low rating as it would involve the removal of trees to facilitate the remedial process. The planting of nursery stock trees to replace the removed larger trees would have a negative effect, at least in the short term, on the aesthetic character of an affected property and neighborhood. As discussed in Section 2, approximately 80% of the trees within Village right-of-ways have a DBH greater than 10 inches. Replacement with nursery stock trees of the same species would require decades of growth to replace the size of these trees.

- **Measure 2b – Low-to-Moderate.** This measure was given a low-to-moderate rating as it would include multiple phases of remedial excavation to allow a greater number of existing mature trees to remain in a property and neighborhood for a longer period of time in order to maintain the aesthetic character of the affected property and neighborhood. This measure could include delaying remediation activities within the Village right-of-ways for a pre-determined period to maintain some of the aesthetic character while the smaller replacement trees on adjoining properties are provided time to grow. In theory, this measure allows planted trees a period of several years to develop aesthetic characteristics important to a property and neighborhood. However, given the years of growth required, and the species of trees that grow in this climate, there may be little advantage to including multiple phases of remedial excavation over an interval of several years (e.g., less than five years). It should also be noted that many of the trees within Village right-of-ways have been significantly affected by pruning due to their proximity to aboveground utility lines. Therefore, delaying the remediation/removal of trees from the right-of-ways may not significantly improve the post-remediation aesthetic character of some neighborhoods.

- **Measures 3a, 4a, and 5a– High**. A high rating was given to the three limited depth excavation measures, as they would attempt to preserve mature, healthy trees within the Study Area by excavating impacted soils within the protected root zone. If successful, implementation of any of these three approaches would avoid or minimize direct effects to the aesthetic character of a property and neighborhood.

  As noted in Section 4.2, certain mature trees may not be able to be saved using these measures based on various tree- and site-specific factors (i.e.; size, location, age, health and condition of the tree). The planning and design phases of this project would identify and exclude such trees from preservation measures as appropriate.

- **Measures 3b, and 4b – Moderate.** A moderate rating was given to the manual and pneumatic phased sector excavation measures, as the probability of long-term tree survival is less than a limited depth excavation approach. A lower survival rate would have an adverse affect on the aesthetic character of a property and neighborhood.

- **Measures 5b – Low.** A low rating was given to the hydraulic phased sector excavation measure due to the very low probability for long-term tree survival. This approach significantly increases the risk to the tree's roots as hydraulic pressure can sever and/or injure both fine and coarse roots.

6.3 Relative Ease of Implementation

This factor considered the ease of implementing each measure from a construction perspective. A low rating indicates that implementation of the measure would be difficult, while a high rating means the measure could be readily implemented.

- **Measure 1 – High**. The ease and practicability of implementing Measure 1 was assessed as high because it would not involve implementation of any further remedial actions within the protected root zone of a tree within the Study Area.
- **Measure 2a – High**. The ease and practicability of implementing Measure 2a was also assessed as high because this approach was previously implemented during earlier phases of this project. It is the most commonly used remedial approach across the U.S.
- **Measure 2b – Moderate**. The ease and practicability of implementing Measure 2b is similar to that of Measure 2a, except that additional time and mobilizations are needed to complete the corrective measures. Therefore, Measure 2b was given a moderate rating.
- **Measure 3a – Moderate**. A moderate rating was given to the limited depth manual excavation measure (Measure 3a). Similar remedial projects have demonstrated that a limited depth manual excavation to approximately 6 inches below ground surface can be successfully implemented. This measure attempts to maintain the structural integrity of the tree while also avoiding detrimental impacts by confining excavation within the top 6 inches from the ground surface to avoid excavation around and disturbance of structurally important perennial roots. However, excavation within the protected root zone using any method will always increase the complexity and difficulty of implementation in comparison to the tree removal and soil excavation measures (Measures 2a and 2b). Previous projects which have attempted manual excavation used shovels, trowels, picks, and "micro-excavators," depending on the specific conditions of the tree being preserved. This measure would require full-time construction oversight by a professional arborist to address any issues that may arise and to monitor potential exposure of the tree's roots to ensure that appropriate moisture levels are maintained.
- **Measure 3b – Low.** A low rating was given to the phased sector manual excavation measure (Measure 3b). Excavation within the protected root zone using this method increases the complexity and difficulty of implementation with (1) an increasing depth from the ground surface, and (2) possibly extending multiple phases of excavation over several years (i.e., minimum of 2 to 3 years).

Implementation of this measure would require full-time construction oversight by a professional arborist to address issues as they arise and to monitor the tree roots so they maintain appropriate moisture levels.

- **Measures 4a and 4b - Low**. A low rating was given to both pneumatic excavation measures. The implementation of pneumatic excavation would be subject to several challenges, including difficulty in controlling fugitive dust and frequent clogging and repair of the vacuum line. ARCADIS has conducted a number of pilot studies on similar residential soil remediation sites to evaluate the effectiveness and efficiency of using pneumatic pressure to excavate soils from within the protected root zone of a tree. These pilot studies demonstrated that the potential advantages of this approach (i.e., time of excavation, minimized impacts to tree roots) do not outweigh the disadvantages (i.e., repair of equipment/unclogging of vacuum lines, noise and dust associated with excavation). In fact, ARCADIS has found better results with implementing manual excavation and incorporating full-time construction oversight by a licensed arborist. However, there may be locations within the Study Area where strategic excavations with pneumatic pressure may be effective and more appropriate than manual excavation.

- **Measures 5a and 5b – Low.** A low rating was given to the two hydraulic excavation measures. Implementing a hydraulic excavation approach would present many disadvantages such as increased safety concerns (discussed in Section 6.8), increased risk of damaging infrastructure (such as severing plastic pipes or cables), and increased risk to the tree's roots as hydraulic pressure can sever and/or injure both fine and coarse roots.

  In addition, controlling the excavation and containing impacted soils within the project site would be difficult as mud would quickly form within the work site and the depth of excavation would become uncontrollable. Removal of excavated soil in the form of a slurry would then require pumping from the work site and subsequent dewatering to facilitate appropriate disposal of excavated soils.

6.4 Minimizing Inconvenience to Property Owners

This factor focused on the degree to which each measure would impact the daily lives of the property owners. Primary considerations would be the amount of noise generated during remediation and the time/duration of construction activities. A low rating indicates a higher degree of inconvenience to the property owners. For example, multiple excavations spanning over multiple years with a high level of noise associated with the remediation activities would rate low. A high rating means property owners would experience little or no additional inconvenience due to factors such as brief construction intervals and minimal to no associated noise.

- **Measure 1 – High**. A high rating was given as it would not involve active remediation within the protected root zones of trees within the Study Area; therefore, the property owners and residents would not be inconvenienced as a result of measures to preserve trees within the Study Area.

- **Measure 2a – Moderate**. A moderate rating was given as this is a proven measure that can be implemented quickly (i.e., one phase), but would entail some level of additional inconvenience to the property owners.

- **Measure 2b – Low**. A low rating was given as remedial activities would take place over an interval of many years and would take multiple mobilization efforts to complete the work. Property owners and residents would be inconvenienced over several years and multiple mobilization efforts to complete the excavation. In addition, this approach would extend the overall restoration process and the time interval necessary to restore affected properties.

- **Measure 3a – Moderate and Measure 3b – Low**. A moderate rating was assigned for Measure 3a, while Measure 3b was given a low rating. There is limited noise associated with manual excavation (in comparison to the other identified excavation measures), and the limited depth approach (3a) allows all excavation to be completed in one phase. The phased manual excavation (3b) approach increases the time required for excavation (could extend up to a minimum of three years), and therefore as described with respect to Measure 2b, above, scored lower.

- **Measures 4a, 4b, 5a and 5b – Low**. A low rating was given to the two pneumatic and the two hydraulic measures. Property owners would be inconvenienced by the noise generated by the equipment, duration of construction activities, and, with Measures 4b and 5b, multiple mobilizations over a number of years and the increased truck traffic on Middleport streets. ARCADIS has found on similar residential remediation sites that communities were in favor of a manual excavation due to the noise level and duration associated with pneumatic (or comparably loud hydraulic) excavation.

6.5 Tree Structural Stability

This factor pertains to the ability of a measure to maintain and protect the structural stability of trees. A low rating indicates that the measure would be less effective in protecting the tree's structural stability, while a high rating means the measure would be more effective.

- **Measure 1 – High.** A high rating was given as no active soil removal activities would be performed within the protected root zone of a tree in the Study Area.

- **Measures 2a and 2b – Not Applicable**. The two tree removal and replacement measures do not attempt to preserve a tree. Therefore, this factor was judged to be not applicable for these measures.

- **Measures 3a and 4a – High**. A high rating was given to the manual and pneumatic limited depth excavation measures. As noted in Section 3.1, depending on the species of tree, the larger structurally important roots of a tree occur 6 to 24 inches below ground surface. By limiting the depth of excavation, and with full-time construction oversight by an arborist, these measures would not affect the structural stability of a tree and therefore mitigate any risks of a windfall during or after excavation.

- **Measures 3b and 4b – Moderate**. A moderate rating was given to the manual and pneumatic phased sector excavation measures. While a phased sector approach is specifically designed to address the structural stability of a tree, any excavating around the larger structurally important roots increases the risk that some potential damage may occur to the roots which are critical to a tree's structural stability.

- **Measures 5a and 5b – Low**. A low rating was given to both hydraulic measures based on the difficulty to control depth of excavation and the high risk for severing or injuring structurally important roots when using hydraulic pressure.

6.6 Tree Survival Probability

This factor assessed the probability of a tree's survival after implementing a particular measure. Measures were given a low rating if the likelihood of a tree's survival after implementation was judged to be low. A high rating was given to measures where the probability of tree survival would not be affected.

It is important to note that tree injuries and their effects may not be evident until after the completion of construction activities. Any subsequent need for long term maintenance or monitoring of a preserved tree (i.e., watering or fertilizing) and/or subsequent removal of the tree after completion of the corrective measures activities by FMC would not be within the scope of FMC's corrective measures.

- **Measure 1 – High**. A high rating was given as no active soil removal activities would be performed within the protected root zone of a tree in the Study Area.

- **Measures 2a and 2b – Not applicable**. The two tree removal and replacement measures do not attempt to preserve a tree. Therefore, this factor was judged to be not applicable for these measures.

- **Measure 3a – High and Measure 3b – Moderate**. A high rating was given to Measure 3a as manual excavation allows careful consideration of roots and root structures, and could be applied in a variety of soil types. With full-time construction oversight by a professional arborist, previously implemented ARCADIS remedial projects have documented high (i.e., approximately 90% or greater) survival rates of trees when excavation depths within the protected root zones are limited to approximately 6 inches below ground surface.

  Measure 3b received a moderate rating due to the complexity of roots below 6 inches of the ground surface and the increased likelihood for cutting, tearing, and abrasions to the coarse tree roots. Injuries to coarse roots could amplify the effects of the removal of a portion of fine root biomass, and a tree's overall ability to uptake water and nutrients and distribute throughout the tree. Adaptive management below 6 inches becomes more difficult for the arborist to effectively address damages (i.e., provide preventative care) caused to coarse tree roots.

- **Measure 4a – High and Measure 4b – Moderate**. A high rating was given to Measure 4a and a moderate rating was given to Measure 4b. An assessment of both pneumatic excavation measures reflect those of the manual excavation measures discussed above for Measures 3a and 3b. It was judged that the long-term benefits of using the Air-Spade® instead of manual excavation are comparable in terms of the probability of a tree's long-term survival.

- **Measures 5a and 5b – Low**. A low rating was given to both hydraulic measures as it is difficult to control the depth of hydraulic excavation which increases the risk of cutting or tearing both coarse and fine roots.

6.7 Post-Restoration Maintenance

This evaluation factor considered the need for tree maintenance activities after a measure is implemented. The level of required "after care" or post-restoration maintenance normally will be minimal and could be easily accomplished by the property owner. The primary maintenance activities to support an affected tree will focus on watering and potentially fertilizing over time. A low rating for this factor indicates a higher level of required maintenance activities. A high rating indicates minimal or no maintenance activities would be needed.

- **Measure 1 – Not Applicable**. This factor is not applicable for Measure 1 because no active soil removal activities would be performed within the protected root zone of a tree in the Study Area. Therefore, no trees would be affected and post-restoration maintenance would not be required.

- **Measures 2a and 2b – High**. Measures including tree removal and subsequent planting of nursery stock trees were both given a high rating relative to the level of required post-restoration maintenance. Smaller nursery stock trees often have high growth rates, higher survival rates, and are less susceptible to initial decline of health/condition (in comparison to larger transplanted trees). This is primarily the result of a smaller percentage of roots being removed during transplanting, in comparison to larger transplanted trees. The level of maintenance following planting would include watering and fertilizing.

- **Measures 3a and 4a – Moderate**. A moderate rating was given to both the manual and pneumatic limited depth excavation measures. While shallow excavation increases the probability for long-term survival of a tree, any excavation within the protected root zone causes a threat to a tree's health. Post-restoration maintenance for these two measures would include watering and fertilizing, but could also include monitoring for general decline of health/condition in the tree due to possible damage during excavation. As noted above, tree injuries and their effects may not be evident until after the completion of construction activities.

- **Measures 3b and 4b – Low.** A low rating was given to both the manual and pneumatic phased excavation measures. Excavation within the protected root zone at depths greater than 6 inches increases the likelihood for cutting, tearing, and abrasions to the coarse tree roots. The presence of a full-time arborist during construction would allow issues to be immediately addressed as they arise. Post-restoration maintenance for these two measures would include watering and fertilizing. Additional maintenance activities may include monitoring for general decline of health/condition of the tree due to the lower survival probabilities when excavating below 6 inches of the soils surface.

- **Measures 5a and 5b- Low.** A low rating was given to both hydraulic excavation measures as it is difficult to control the depth of hydraulic excavation, as well as the increased likelihood for cutting or tearing both coarse and fine roots. A higher level of post-restoration maintenance (i.e., monitoring of health/condition of tree) would likely be required due to the high likelihood for injuries to both coarse and fine roots which increases the susceptibility to disease or pest infestations.

6.8 Short- and Long-Term Safety

Both the short-term safety implications to workers, residents and the community during (or immediately after) implementation of the measure, and the long-term safety implications after construction to residents, their homes and other buildings (i.e., commercial or industrial), infrastructure (i.e., utility lines, sidewalks), and nearby trees, shrubs, or other landscaping were evaluated. Both considerations focus on the potential for the structural failure of a tree, either during construction or thereafter.

Among other conditions, a severe rainstorm possibly with accompanying high winds during or subsequent to excavation within the protected root zone of a tree could threaten the structural stability of a tree.

A low rating for this factor means implementation of the measure would pose a high level of safety risk. A high rating means little or no risk would be incurred during or after the measure's implementation.

- **Measure 1 – High**. A high rating was given as no active soil removal activities would be performed within the protected root zone of a tree within the Study Area. As no trees would be affected, there would be no additional risk during implementation.

- **Measures 2a and 2b – Moderate**. A moderate rating was given to both tree removal and replacement measures as safety concerns are greater than those compared to the no action alternative. While certain safety risks exist when removing a tree or remediating contaminated soils, these risks would be managed using appropriate health and safety practices.

- **Measure 3a – High.** A high rating was given as it specifically addresses structural stability of a tree (i.e., decreases likelihood for a windfall), while allowing time to carefully remove soil from around a tree's fine roots within the top six inches of soil.

- **Measure 3b – Moderate**. A moderate rating was given as it increases the safety concerns due to excavation deeper than 6 inches below ground surface, and around structurally important coarse roots. Excavating deeper than 6 inches below ground surface increases the risk that some potential damage may occur to the roots and adversely affect a tree's structural stability during or after the excavation. Also, excavating around roots deeper than 6 inches below ground surface increases the difficulty of excavation, and therefore increases risk to workers performing the excavation.

- **Measure 4a – Moderate and Measure 4b – Low**. A moderate rating was given to Measure 4a as the safety concerns (in comparison to manual excavation) increase due to the difficulty in controlling fugitive dust; frequent clogging/repair of the vacuum line; and increased noise associated with the excavating and vacuum equipment. These factors pose risks to workers performing the excavation and fugitive dust poses a risk to surrounding residents.

  A low rating was given to Measure 4b based on the complexity of excavation around structurally important coarse roots deeper than 6 inches below ground surface as well as the increased difficulties associated with implementing a pneumatic excavation approach within a residential neighborhood.

- **Measures 5a and 5b – Low**. A low rating was given to both hydraulic excavation methods. Hydraulic excavation increases the risk of damage to a tree's roots which would adversely affect the tree's structural stability during or after the excavation. In addition, hydraulic pressure poses an increased risk to the workers performing the excavation as it can cut clothes or work boots, and sever underground pipes and cables. Control of mud and/or slurry would be more difficult than manual or pneumatic excavation approaches. While these safety concerns can be addressed by incorporating health and safety practices, the relative safety concerns would be significantly higher in comparison to other measures.

6.9 Cost Effectiveness

The cost of each potential tree preservation measure was also evaluated. For this factor, a high rating equates to a low cost, a moderate rating means a moderate cost, and a low rating means a high cost as compared to the other approaches.

- **Measure 1 – Moderate to high.** A moderate to high rating was given as there would be a need to implement Best Management Practices to preserve trees and protect the protected root zones, dependent upon site-specific conditions.

- **Measure 2a – Moderate**. A moderate rating was given as this measure could be implemented efficiently and effectively with relatively low overall cost.

- **Measures 2b – Moderate to low.** A moderate to low rating was given as the cost increases with multiple phases of remediation activities over multiple years.

- **Measure 3a – Moderate**. A moderate rating was given as work would be completed in one phase and would entail excavation of surface soils to about six inches, above the roots. This approach would likely include full-time construction oversight by an arborist.

- **Measure 3b – Low**. This approach would entail high costs, primarily due to the time required for mechanical excavation within the protected root zone, care required between phases and the likely requirement of multiple phases spanning years to complete the excavation. This approach would include full time construction oversight by an arborist.

- **Measures 4a, 4b, 5a and 5b – Low**. A low rating was given for the four pneumatic and hydraulic excavation measures as these measures are difficult to implement and entail increased costs. Past experience using a pneumatic approach has proven difficult due to frequent clogging of the vacuum line and frequent equipment repairs. The hydraulic approach would include similar concerns along with the necessity for management of the resulting slurry. This slurry would be of a significantly greater volume and weight than excavated soil, would require a dewatering step, and therefore incur higher costs.

7. Conclusions and Recommendations

This evaluation provides a basis for identifying measures for further evaluation in the CMS that could be implemented within the Study Area to address human health risk while maintaining the aesthetic character of Middleport and/or affected property. Table 7-1 is included as a summary of the evaluation for each tree preservation measure. Best Management Practices, including coordinating tree preservation activities, properly identifying the trees to be preserved, establishing protected root zones to promote the survivability of affected trees, avoiding unacceptable soil compaction during construction activities, and protecting trees from grade changes are recommended as part of any tree preservation measure, except Measures 1, 2a or 2b.

The following five measures for removing soil containing unacceptable levels of FMC-related constituents within the protected root zone of a tree are recommended to be further considered as part of the CMS based upon the evaluation of nine factors identified in Section 6. The five measures include:

- Measure 1. No Soil Removal within the Protected Root Zone
- Measure 2a. Tree Removal and Replacement with Nursery Stock Trees
- Measure 2b. Phased (Extended Time) Tree Removal and Replacement With Nursery Stock Trees
- Measure 3a. Limited Depth Manual Excavation within the Protected Root Zone
- Measure 4a. Limited Depth Pneumatic Excavation within the Protected Root Zone

The evaluation concludes as follows:

- Any disturbance (e.g., soil removal, soil tilling, soil compaction) within the protected root zone could jeopardize the health or stability of an otherwise healthy tree. Measures implemented to attempt to preserve a tree offer varying likelihoods for success. For this reason, the most common approach in soil remediation projects is to remove the tree and replant with a new tree.

- Removal of larger trees and replanting with smaller trees would have an effect on the aesthetic character of an affected property and neighborhood. Based upon two recent inventories of trees located in right-of-ways in the Village of Middleport, approximately 80% of the trees have a trunk diameter (measured at breast height) of greater than 10 inches. The information from these inventories provides an indication of tree species and tree sizes found in a portion of the Study Area. Decades of growth time would likely be needed to fully replace the size of these trees.

- Not all trees can or should be preserved. The determination of whether a tree can or cannot be preserved is dependent on a number of property-specific or tree-specific factors. For example, an older tree with dwindling health would have a low probability of long-term survival if any soil removal was attempted within the protected root zone.

- No single tree preservation measure will apply to all situations within the Study Area. A final remedial design plan would likely include removal of numerous trees (e.g., those that are unhealthy, have been pruned, are over-mature, are poorly located, etc.) and preservation of other trees using selected measures identified in this Technical Memorandum.

- If a tree is to be preserved, limited depth excavation, using either mechanical or pneumatic pressure, would appear to present the best opportunity to preserve the tree and warrants further consideration as part of the CMS. The depth of excavation would be limited to approximately 6 inches below the soil surface, and would be completed in one continuous effort. Precedent was identified for limited depth manual excavation at four similar remediation projects within residential neighborhoods.

- Other identified measures to excavate soils within the protected root zones of trees were not recommended for further evaluation based upon practicability of implementation, lower probabilities for tree survivability, tree structural stability concerns, and safety concerns for workers, residents, and the community.

- Long term maintenance or monitoring of the preserved tree (i.e., watering, fertilizing) and/or subsequent removal of the tree would be the responsibility of the property owner.

8. References

Agencies. 2009. Letter to Brian McGinnis of FMC from Matthew Mortefolio of the NYSDEC and Michael Infurna of the USEPA, providing final Corrective Action Objectives (CAOs) for the Off-Site Soil and Sediment Corrective Measure Studies. March 26. Included as appendix to CMS Work Plan.

AMEC Geomatrix. 2009. *Corrective Measures Study Work Plan for Suspected Air Deposition and Culvert 105 Study Areas*. Prepared for FMC Corporation, Middleport, NY. August.

ARCADIS. 2009. Personal communication between D.J. Partridge and ARCADIS colleagues regarding similar excavation projects in the United States. November 2009.

British Standards Institute. 2005. *British Standard – Trees in Relation to Construction – Recommendations.* Third Edition. BS 5837:2005. BSI, London, UK.

CH2M Hill. 2009. *Final Basis of Design Report: Remedial Design South Minneapolis Residential Soil Contamination Site, Minneapolis, Minnesota.*

Cutting Edge Tree Service and Consulting. 2007. *Storm Damage Evaluation Report/Tree Inventory.* Prepared for Village of Middleport, NY.

Dicke, S.G. and M.S. Raymond. 2004. *Preserving Trees in Construction Sites.* Mississippi State University, MS.

Fite, K. and E.T. Smiley. 2008. *Best Management Practices: Managing Trees During Construction.* International Society of Arboriculture, Champaign, IL.

Luzadis, V.A. and E.R. Gossett. 1996. Sugar Maple. Pages 157-166. *Forest Trees of the Northeast*, edited by James P. Lassoie, Valerie A. Luzadis, and Deborah W. Grover. Cooperative Extension Bulletin 235.

Matheny, N.P. and J.R. Clark. 1998. *Trees and Development: A Technical Guide to Preservation of Trees During Land Development*. International Society of Arboriculture, Champaign, IL.

Mattheck, C. and H. Breloer. 1994. *The Body Language of Trees: A handbook for failure analysis.* The Stationery Office, London, UK.

Micah Tree and Landscape Consultants. 2003. *Street Tree Survey and Individual Examination*. Prepared for Village of Middleport, NY. July 18.

Miller, N.L., D.M. Rathke, and G.R. Johnson, 1993. *Protecting Trees From Construction Damage: A Homeowners Guide.* NR-FO-6135-S. Minnesota Extension Service, St. Paul, MN.

Pirone, P.P., T.P. Pirone, J.R. Hartman, and M.A. Sall. 1988. *Tree Maintenance,* Sixth Edition. Oxford University Press, USA. November.

Roberts, J., N. Jackson, and M. Smith. 2006. *Tree Roots in the Built Environment*. The Stationary Office, London, UK.

Shigo, A.L. 1989. *A New Tree Biology: Facts, Photos, and Philosophies on Trees and Their Problems and Proper Care*, Second Edition. June.

Sinclair, W.A. and H.H. Lyon. 2005. *Diseases of Trees and Shrubs*. Second Edition. Cornell University Press, Ithaca, NY.

USEPA. 2008. *Five Year Review Report for the Myers Property Superfund Site, Franklin Township, Hunterdon County, New Jersey*. May.

USEPA. 2009. *Ecological Revitalization: Turning Contaminated Properties into Community Assets*. EPA 542-R-08-003. Prepared by Office of Solid Waste and Emergency Response. February.

Urban, J. 2008. *Up By the Roots--Healthy Soils and Trees in the Built Environment.* International Society of Arboriculture. Champaign, IL.

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Tables

Table 2-1 - Tree Species Identified in Surveys Conducted for the Village of Middleport within Right-of-Ways

CMS Technical Memorandum - Evaluation of Tree Preservation Measures
FMC Corporation, Middleport, New York

Tree Species		Year of Observation	
Scientific Name	**Common Name**	**2003 (X = Present)**	**2007 (% of total)**
Acer negundo	Box Elder	X	0.2
Acer platanoides	Norway Maple	X	35.7
Acer platanoides var Schwedleri	Schwedler Maple	X	
Acer platanoides var Crimson King	Crimson King Maple	X	
Acer psuedoplatanus	Wine Leafed Sycamore - Maple	X	
Acer rubrum	Red Maple	X	0.6
Acer saccharinum	Silver Maple	X	36.6
Acer saccharum	Sugar Maple	X	7.2
Acer saccharum	Hard Maple	X	
Aesculus hippocastanum	Horse Chestnut	X	1.1
Catalpa speciosa	Northern Catalpa	X	0.2
Crataegus laevigata	Paul's Scarlet Hawthorne	X	0.2
Forsythia spp.	Forsythia	X	
Fraxinus americana	White Ash	X	1.4
Fraxinus pennsylvanica	Green Ash	X	
Ginkgo biloba	Ginkgo	X	
Gleditsia spp.	Locust		4.5
Gleditsia triacanthos	Honey Locust (Morraine, Imperial)	X	
Hibiscus syriacus	Rose of Sharon	X	
Juglans nigra	Black Walnut	X	0.5
Juglans regia	English Walnut	X	0.2
Laburnum anagyroides	Golden Chain	X	
Malus spp.	Crab Apple		1.1
Malus spp.	Flowering Crabapple	X	
Picea glauca	White Spruce		0.2
Picea spp.	Spruce		2.6
Platanus occidentalis	American Sycamore	X	
Platanus spp.	Sycamore		0.2
Populus spp.	Cottonwood		0.5
Prunus spp.	Cherry		0.2
Pseudotsuga menziesii	Douglas Fir		0.2
Quercus palustris	Pin Oak	X	0.2
Quercus rubra	Red Oak	X	1.8
Quercus velutina	Black Oak	X	
Salix spp.	Willow	X	
Sorbus aucuparia	European Mountain Ash	X	0.2
Syringa reticulata	Japanese Tree Lilac	X	
Syringa spp.	Lilac		2.6
Syringa vulgaris	Common Lilac	X	
Tilia cordata	Little leaf Linden (Greenspire)		2.4
Tilia spp.	Basswood	X	
Ulmus americana	American Elm		0.2
Ulmus americana	Hybrid American Elm	X	
Ulmus spp.	Elm	X	
Ulmus spp.	Liberty Elm	X	

Notes:
* Tolerance from Matheny and Clark (1998) - P = poor, M = moderate, G = good
N/A - tolerance for species not available from Appendix A
2007 percentages do not sum to exactly 100% due to rounding to one decimal place

Table 4-1 - Guidelines for Determining Protected Root Zones of Healthy, Structurally Sound Trees

CMS Technical Memorandum - Evaluation of Tree Preservation Measures[1]
FMC Corporation, Middleport, New York

Tolerance to Construction Damage	Tree Age[4]	Distance from Tree Trunk to PRZ Boundary[2,3]	
		Distance in Multiples of Tree Trunk Diameter	Distance in Feet per Inch of Trunk Diameter
High	Young	6	0.50
	Mature	8	0.75
	Over Mature	12	1.00
Medium	Young	8	0.75
	Mature	12	1.00
	Over Mature	15	1.25
Low	Young	12	1.00
	Mature	15	1.25
	Over Mature	18	1.50

Notes:
1. Table adapted from Matheny and Clark (1998) and the British Standards Institute (2005).
2. PRZ = Protected Root Zone (see explanation of PRZ in Section 5)
3. Trunk diameter measured at "breast height," or approximately 4.5 feet above grade.
4. Maturity of tree species must be determined by a certified professional arborist. An "over mature tree" is defined by Fite and Smiley (2008) as being in the later one-third of its normal life expectancy, in comparison to a "young" tree, which is in the first one-third of its normal expectancy.

Table 6-1 - Evaluation of the Effectiveness and Implementability of Tree Preservation Measures

CMS Technical Memorandum - Evaluation of Tree Preservation Measures
FMC Corporation, Middleport, New York

Potential Tree Preservation Measure [1]	Evaluation Criteria								
	Effectiveness		Implementability						
	Effectiveness of Soil Removal	Maintenance of Aesthetic Character of Property and Neighborhood	Relative Ease of Implementation	Minimizing Inconvenience to Property Owners (i.e., noise and length of construction)	Tree Structural Stability	Tree Survival Probability	Post-Restoration Maintenance Requirements	Short- and Long-term Safety of Workers, Residents, and the Community	Cost Effectiveness
1. No Soil Removal within the Protected Root Zone	Not applicable	●	●	●	●	●	Not applicable	●	◐ to ●
2a. Tree Removal and Replacement with Nursery Stock Trees	●	○	●	◐	Not applicable	Not applicable	●	◐	◐
2b. Phased (Extended Time) Tree Removal and Replacement with Nursery Stock Trees	●	○ to ◐	◐	○	Not applicable	Not applicable	●	◐	○ to ◐
3a. Limited Depth Manual Excavation within the Protected Root Zone	○ to ●*	●	◐	◐	●	●	◐	●	◐
3b. Phased Sector Manual Excavation within the Protected Root Zone	○ to ◐	◐	○	○	◐	◐	○	◐	○
4a. Limited Depth Pneumatic Excavation within the Protected Root Zone	○ to ●*	●	○	○	●	●	◐	◐	○
4b. Phased Sector Pneumatic Excavation within the Protected Root Zone	○ to ◐	◐	○	○	◐	◐	○	○	○
5a. Limited Depth Hydraulic Excavation within the Protected Root Zone	○ to ●*	●	○	○	○	○	○	○	○
5b. Phased Sector Hydraulic Excavation within the Protected Root Zone	○ to ◐	○	○	○	○	○	○	○	○

Notes:

1. All measures will be implemented in conjunction with a selected set of Best Management Practices; the selection of these practices will vary on a case-by-case basis.
2. * = Depends upon extent of impacted soils below 6 inches (i.e., maximum depth of excavation)
3. Symbols:

● = High (most desired outcome)

◐ = Moderate

○ = Low (least desired outcome)

Potential Tree Preservation Measure		Recommended for Further Consideration in CMS Report?	Basis for Recommendation
1	No Soil Removal from the Protected Root Zone	**Yes**	• This approach relies on the presence of the tree roots to serve as a binding mechanism to limit exposure and prevent contaminant migration via soil erosion and leaching, and would involve no excavation of soils within the protected root zone. • This measure would allow for higher soil arsenic levels within the protected root zone of a tree in comparison to the remaining portions of a property. • Implementation of this measure may require further risk evaluation, establishment of institutional controls or management practices to minimize potential human exposures to constituents in soil located within the protected root zones of these trees. • Recommended for further consideration in the CMS because there may be situations where this approach would be suitable for tree preservation.
2a	Tree Removal and Replacement with Nursery Stock Trees	**Yes**	• This measure, which was implemented successfully during the Interim Corrective Measures in the Study Area, would involve the removal of select trees to facilitate soil excavation and restoration with standard nursery stock trees. • While this approach would effectively remove all impacted soil and could be easily implemented, it has the potential to impact the aesthetic character of a property and the surrounding neighborhood. Trees can take many years to mature and develop the canopy characteristics that bring much of the existing character to the affected properties and neighborhoods. • This approach provides flexibility to the property owner in deciding replacement tree species, location and timing. • Recommended for further consideration in the CMS based on precedence and flexibility.
2b	Phased (Extended Time) Tree Removal and Replacement with Nursery Stock Trees	**Yes**	• This approach would phase remedial activities within the Study Area to maintain some of the current aesthetic character of impacted properties and neighborhoods. • This approach would require completion of the soil removal activities over several years and would significantly extend the time required to complete the corrective measures for the Study Area. • Due to this extended time frame, this measure has a higher level of inconvenience to property owners and is more expensive to implement. Regardless, there may be little advantage to including multiple phases of remedial excavation over an interval of several years (i.e., less than 5 years) due to the slow growth rates of common tree species found in Middleport. • Many of the trees within Village right-of-ways have been significantly affected by pruning due to their proximity to aboveground utility lines. Therefore, delaying the remediation/removal of trees from the Village right-of-ways may not significantly improve the post-remediation aesthetic character of some neighborhoods. • Recommended for further consideration in the CMS because there may be locations within the Study Area where strategic phased excavations may be an effective approach to maintaining the aesthetic character of a property or neighborhood depending on the final remedial strategy.
3a	Limited Depth Manual Excavation within the Protected Root Zone	**Yes**	• This measure would limit the depth of excavation within the protected root zone to a maximum depth of 6 inches below ground surface independent of the soil concentrations below this depth, and could be completed in one excavation phase. • This approach has been successfully implemented at other similar residential remediation projects throughout North America (USEPA 2008, 2009; CH2M Hill 2009; ARCADIS pers. comm. 2009) with minimal relative inconvenience to property owners, and has maintained the aesthetic character of affected neighborhoods. • Previously implemented ARCADIS remedial projects have documented high (i.e., approximately 90% or greater) survival rates of trees when excavation depths within the protected root zones are limited to approximately 6 inches below ground surface of healthy trees. • Removal of the surface soil containing unacceptable levels of arsenic and replacement with clean soil containing lower arsenic concentrations would reduce human health risks and would reduce the overall average soil arsenic level of the soil within the protected root zone. If the Agencies determine that the remaining soil arsenic levels beneath the 6-inch thick clean surface soil require further controls, these may take the form of institutional controls or management practices to minimize potential future human exposures. • Recommended for further consideration in the CMS based on successful prior applications in other projects.
3b	Phased Manual Excavation within the Protected Root Zone	**No**	• This approach would potentially allow excavation deeper than 6 inches below ground surface by separating the necessary excavation within the protected root zone into a minimum of 3 excavation zones, with excavation spanning over a minimum of three years (i.e., one zone per year). • This phasing over an extended period of time decreases the effectiveness of remediation, while increasing the difficulty to implement and inconvenience to land owner as well as overall costs. • Given the lack of precedent for this approach, the identified disadvantages of this approach (i.e., inconvenience to land owner, ease of implementation) outweigh the potentially questionable advantages (i.e., effectiveness to remove soil). • Not recommended for further consideration in the CMS based on the above findings.

Potential Tree Preservation Measure		Recommended for Further Consideration in CMS Report?	Basis for Recommendation
4a	Limited Depth Pneumatic Excavation within the Protected Root Zone	**Yes**	• This approach would utilize common arborist tools such as the Air Spade® to potentially minimize impacts to roots, reduce the time necessary to excavate a large area within the protected root zone and minimize impacts to surrounding infrastructure such as pipes or cables. • Based on professional experience, ARCADIS has found the implementation of pneumatic excavation would be subject to several challenges, such as: difficulty in controlling fugitive dust; frequent clogging of the vacuum line and need for repair; and increased noise associated with the excavating and vacuum equipment. • Pilot studies conducted by ARCADIS on similar projects have demonstrated that the potential advantages of this approach (i.e., time of excavation, minimized impacts to tree roots) do not outweigh the disadvantages (i.e., repair of equipment, unclogging of vacuum lines, noise associated with excavation). • ARCADIS has found better results with implementing manual excavation and incorporating full-time construction oversight by a licensed arborist. • Recommended for further consideration in the CMS because there may be locations within the Study Area where strategic excavations with pneumatic pressure may be effective and more appropriate than manual excavation.
4b	Phased Pneumatic Excavation within the Protected Root Zone	**No**	• Similar to the discussion for Measure 3b, the phasing over an extended period of time decreases the effectiveness of remediation, while increasing the difficulty to implement and inconvenience to the land owner. • Given the lack of precedent for this approach, the identified disadvantages of this approach (i.e., inconvenience to land owner, ease of implementation) outweigh the potentially questionable advantages (i.e., effectiveness to remove soil). • Not recommended for further consideration in the CMS based on the above findings.
5a	Limited Depth Hydraulic Excavation within the Protected Root Zone	**No**	• There are few advantages when comparing hydraulic excavation to manual or pneumatic methods. • Implementing a hydraulic excavation approach would present many disadvantages such as increased safety concerns, increased risk of damaging infrastructure (such as severing plastic pipes or cables), and increased risk to the tree's roots as hydraulic pressure can sever both fine and coarse roots. In addition, controlling the excavation and containing impacted soils would be difficult as mud would quickly form within the work site and the depth of excavation would become uncontrollable. • Removal of excavated soil in the form of a slurry would then require pumping from the work site and subsequent dewatering to facilitate appropriate disposal of excavated soils. • Not recommended for further consideration in the CMS based on the above findings.
5b	Phased Hydraulic Excavation within the Protected Root Zone	**No**	• Not recommended for further consideration in the CMS based on a similar basis for recommendation that was provided above for Measure 4b and Measure 5a.

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Figures

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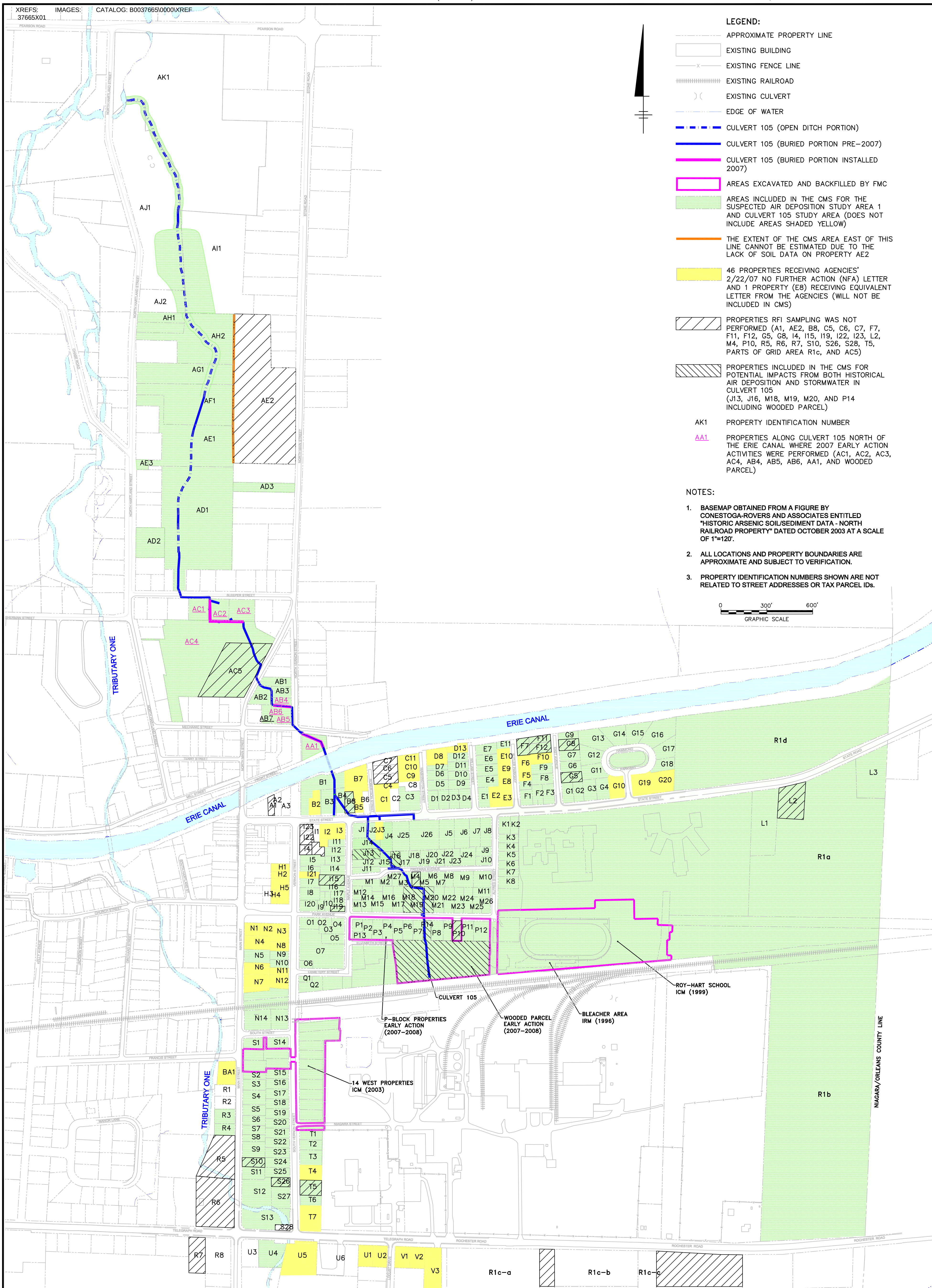

FMC CORPORATION - MIDDLEPORT, NEW YORK
CMS TECHNICAL MEMORANDUM
EVALUATION OF TREE PRESERVATION MEASURES

CORRECTIVE MEASURES STUDY AREA

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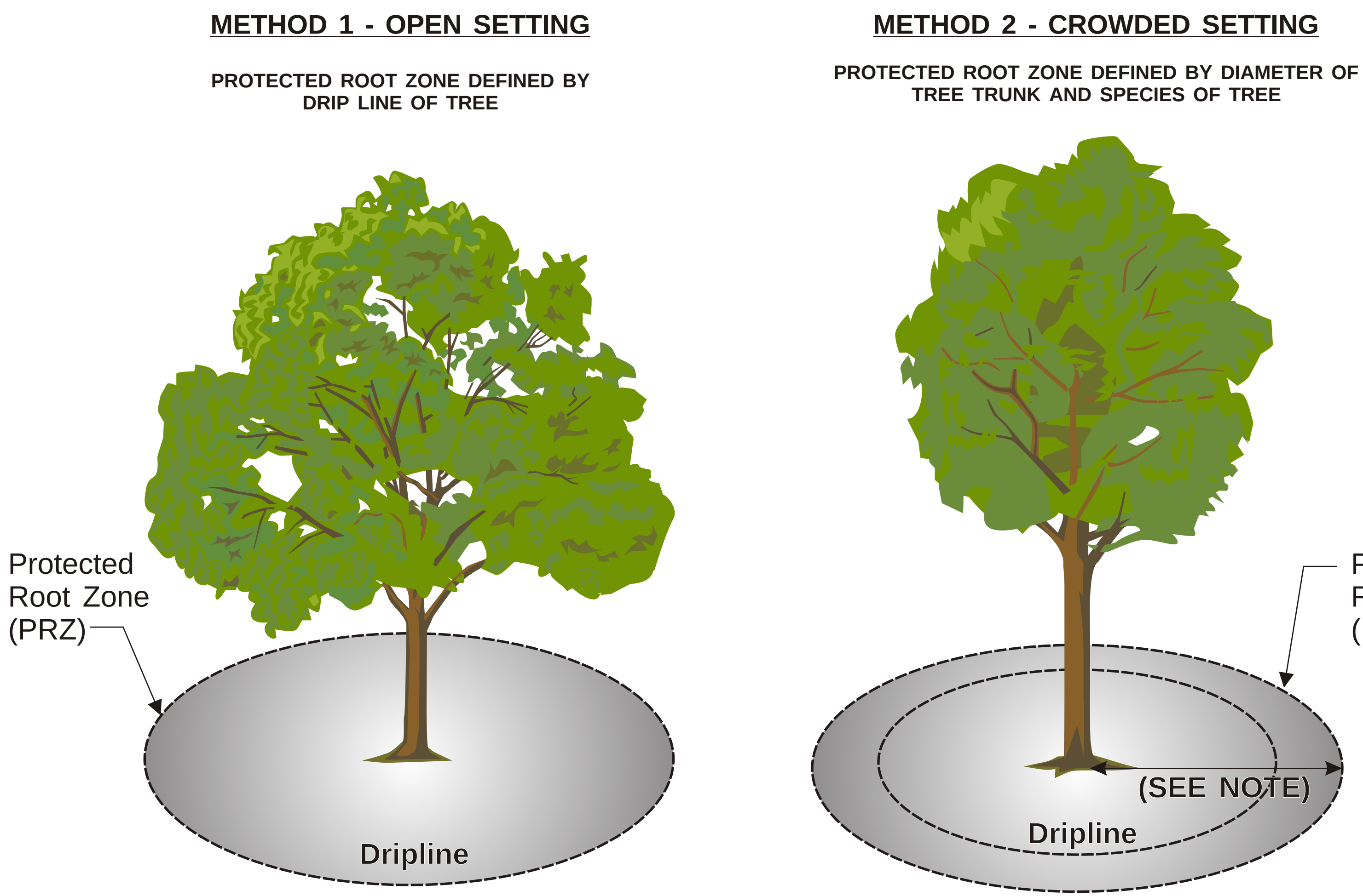
FIGURE
1-1



Note:
The protected root zone is defined by the trees diameter (i.e., diameter at breast height) multiplied by a factor of 6 to 18. This factor is dependent upon the species of tree and its tolerance to construction impacts.

FMC CORPORATION, MIDDLEPORT, NEW YORK

CMS TECHNICAL MEMORANDUM
EVALUATION OF TREE PRESERVATION MEASURES

METHODS OF DETERMINING PROTECTED ROOT ZONE

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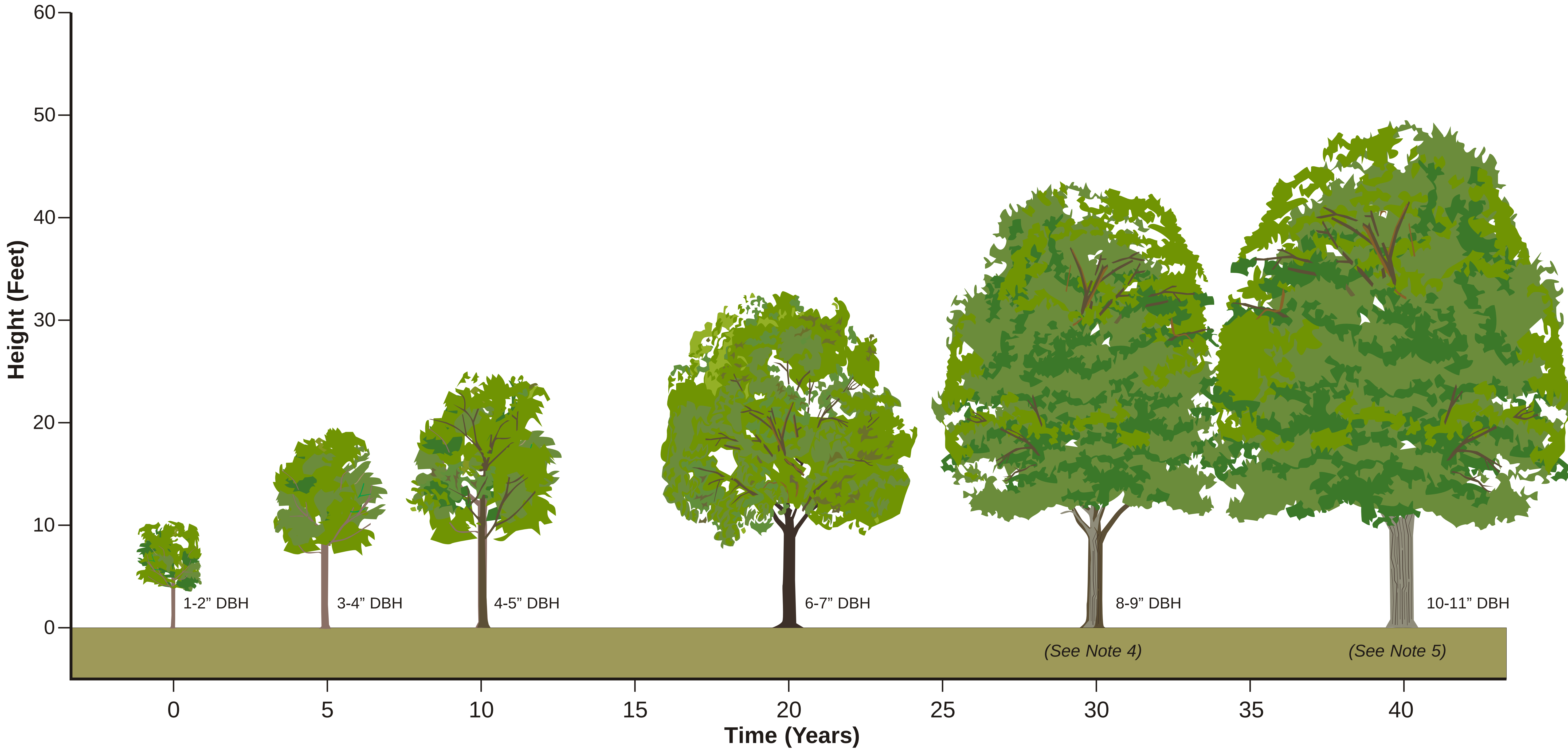
FIGURE
4-1



Notes/Assumptions:

1. DBH = diameter of the tree trunk at approximately 4.5 feet from the ground surface.
2. Assumes planting of a standard nursery stock sugar maple tree (i.e., DBH of 1 to 2 inches)
3. Assumes a growth rate of approximately 1 vertical foot per year and 1 inch DBH every 4 to 5 years under optimal conditions.
4. Minimum reproductive age (i.e., stage where tree has reached full maturity) of sugar maple is approximately 30 years (Luzadis and Gossett 1996).
5. Mature tree reaches approximate height of 50 to 80 feet with a canopy width of 35 to 50 feet.

FMC CORPORATION, MIDDLEPORT, NEW YORK

CMS TECHNICAL MEMORANDUM
EVALUATION OF TREE PRESERVATION MEASURES

CONCEPTUAL ILLUSTRATION OF THE DEVELOPMENT OF A PLANTED NURSERY STOCK TREE (SUGAR MAPLE)

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FIGURE
5-1

02/08/2010 SYRACUSE, NY-ENV/CAD-DJHOWES
B0037736/0000/00002/CDR/37736G04.CDR

Appendices

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Appendix A

Historic Middleport Tree Inventories

1. 2007. Storm Damage Evaluation Report/Tree Inventory. Cutting Edge Tree Service & Consulting, Inc.

2. 2003. Micah Tree and Landscape Consultants, Inc.

Storm Damage Evaluation Report / Tree Inventory

Prepared For:

Village of Middleport

Prepared By:

Cutting Edge Tree Service & Consulting, Inc.

2007

Table of Contents

Species Composition – Chart

Diversity of Species