Trees and Construction

Is This Tree Likely to Survive Construction? One Method to Consider

By Ryan Gilpin

In the December 2023 issue of *Arborist News*, we discussed which trees we should focus on preserving during construction projects (Gilpin 2023). In that article I focused on suitability for preservation in the planning phase of development. This article starts where that article ended. However, it is not necessary to have read that article to follow along with this one.

The 3rd edition of the *Best Management Practices: Managing Trees During Site Development and Construction* (referred to here as the 3rd edition) was published by the ISA early in 2023 (Matheny et al. 2023a). This was a major BMP update, and significant changes were made throughout the document. Many communities are asking for more and larger trees to be preserved on construction sites. These communities establish permitting agencies to approve construction plans and often require arborists to be on the design team. The 3rd edition of the BMP was revised and expanded to provide better guidance during the design phase of development. The Introduction and Design Phase sections of the 3rd edition were published in their entirety in the April 2023 issue of *Arborist News* (Matheny et al. 2023b).

While Best Management Practices are not "how-to" guides, I hope that the 3rd edition provides a good framework for arborists who play key roles on design and construction teams. Ultimately, arborists need to use their experience and expertise if they are going to offer the best recommendations possible for their projects. Many readers will have their own practices that they have found effective. If you have a method or system that works for you, use that.

Plan Review and Tree Impact Assessment

An important change from the 2nd edition of *Managing Trees During Site Development and Construction* is a new section of the Design Phase titled **Plan Review and Tree Impact Assessment**. The 3rd edition of the BMP also defines responsibilities for the arborist as follows:

> *Using the site plans and knowledge of the tree resource, the arborist evaluates which trees can be preserved and which should be removed or transplanted.*
>
> *The arborist should evaluate how the trees near the limits of construction will respond as the site is graded, utilities are installed, foundations are excavated, and buildings are constructed.*

When I am involved in construction projects, I am often asked whether trees are going to survive construction and what design changes are needed to preserve them. While this can (and does) happen at every phase of construction, it most often occurs during the design phase. To do this assessment, I typically use data that I collected in the field coupled with construction plans created by an engineer or architect.

When trying to decide whether a tree is likely to survive construction, I learned from my mentors a method that works for me. I can't teach anyone that method in an article (we say that it takes about a year to learn), but I want to offer arborists who don't have experience or experienced mentors some idea about how they might approach this question.

This method involves:

1. interpreting construction plans to understand the big picture;
2. reviewing tree data collected during the planning phase;
3. estimating how far from the trees the greatest impacts from construction will be;
4. using tree data to estimate a Calculated Tree Protection Zone; and,
5. deciding whether planned construction will impact the Critical Root Zone.

Interpreting Construction Plans

I find that the skills involved in reviewing construction plans are acquired by arborists through training and practice. I learned to review construction plans by having experienced arborists show me what they see on the plans and then going to the site and watching that construction take place.

I have seen trees damaged in many ways, but on my projects, I am most focused on root loss from excavation. I spend much of my time figuring out what will be happening underground, which typically involves flipping back and forth between grading plans, utility plans, and tree protection plans.

When I am reviewing plans, I try to get the big picture and make the easy decisions first. The first question is: what are they building?

For this example, a new house with a new porch, driveway, and underground utilities will be installed (Figure 1). Next, I try to answer three questions:

1. Where is construction planned in relation to existing trees, buildings, hardscape, etc.?
2. Are there any trees that absolutely cannot be preserved?
3. Are there trees outside the construction area that will not be affected?

The existing site contains a house with utilities surrounded by sidewalks and planting strips (Figure 2); two street trees near the north property line (#1 and #2) are growing in the public planting area, and two trees are growing on private property (#3 and #4). Tree #3 is in the middle of the planned house, so it would be removed to complete this construction. Tree #4 in the southeast corner has no construction within twice the crown radius, so it should be easy to preserve. It is not immediately clear whether trees #1 and #2 (Figures 3 and 4) are likely to survive construction, so I will look at inventory data for these trees to help me decide.

Planning Phase Tree Data

For many of my projects, I visit the site and collect data on the trees months before I receive construction plans and evaluate impacts to trees. I have been contacted for projects in every phase of construction, but for this project I had data well before these plans were ready. The most important data that I collect will eventually help me decide whether trees are likely to survive construction and how to best protect them. I typically use species, size (DBH), condition, suitability for preservation, and existing growing spaces in my evaluation. Photographs of the trees from various angles are often helpful. As I discussed in my previous article, the biggest factor in my suitability for preservation ratings is a species' tolerance to root loss.

This site has four trees mostly growing as individuals rather than a stand of interdependent trees or forest. Here are photos and data of the two trees that I am exploring more deeply. The previous article described my process for assessing suitability for preservation of these trees.

Estimating Distance from the Most Impactful Construction

Most of the jurisdictions in which I work require topographic surveys where civil engineers or surveyors accurately locate the trunk and base elevation of the trees on the construction plans. Not every project has or requires this level of detail, but knowing how far the actual trunk of the tree will be from the planned construction and its elevation relative to new construction is central to my

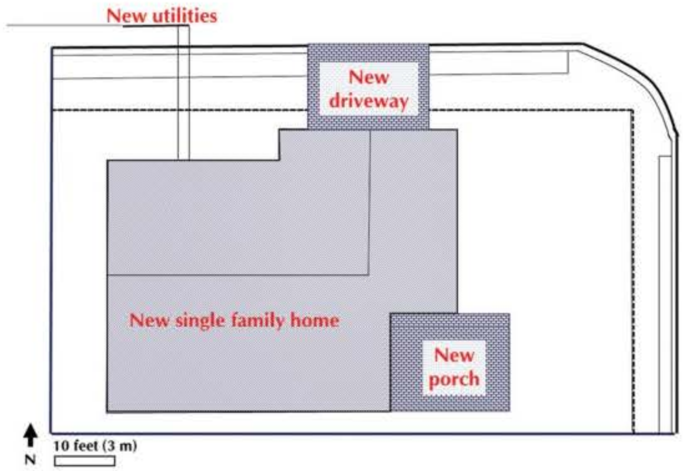

Figure 1. An example site plan showing the location of a planned single-family home.

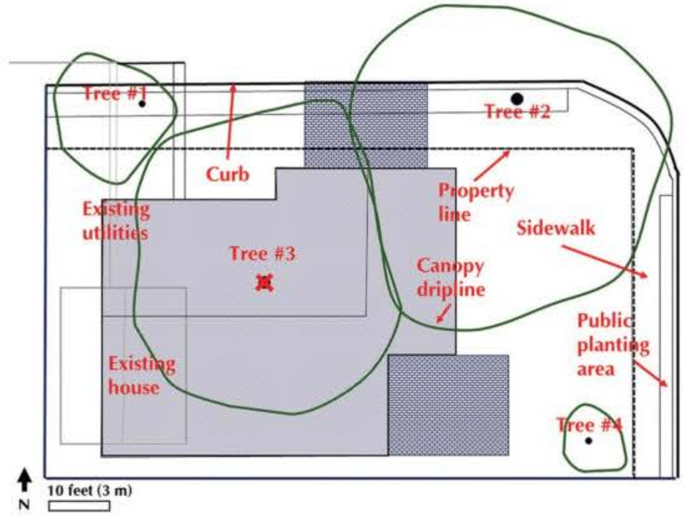

Figure 2. An example site plan overlayed with existing trees, structures, and hardscape.

ability to give good recommendations. For this project, tree trunks and crown dimensions were accurately plotted on the construction plans. I measured the distances from the trees to the new structures on the plans (Figure 5).

Tree #1 is approximately 15 feet (4.5 m) north of the planned house and 8 feet (2.4 m) west of new underground utilities. It may require some minor crown pruning for clearance to build the house, but my primary concern is root loss to install the utilities.

Tree #2 is approximately 15 feet (4.5 m) northeast of the corner of the house and 15 feet (4.5 m) east of the new driveway. Approximately 20% of the crown may be removed to install scaffolding and build the house on the southwest (blue hashed area). I am also concerned about root loss to build the house foundation and driveway. I have learned from monitoring the construction of similar

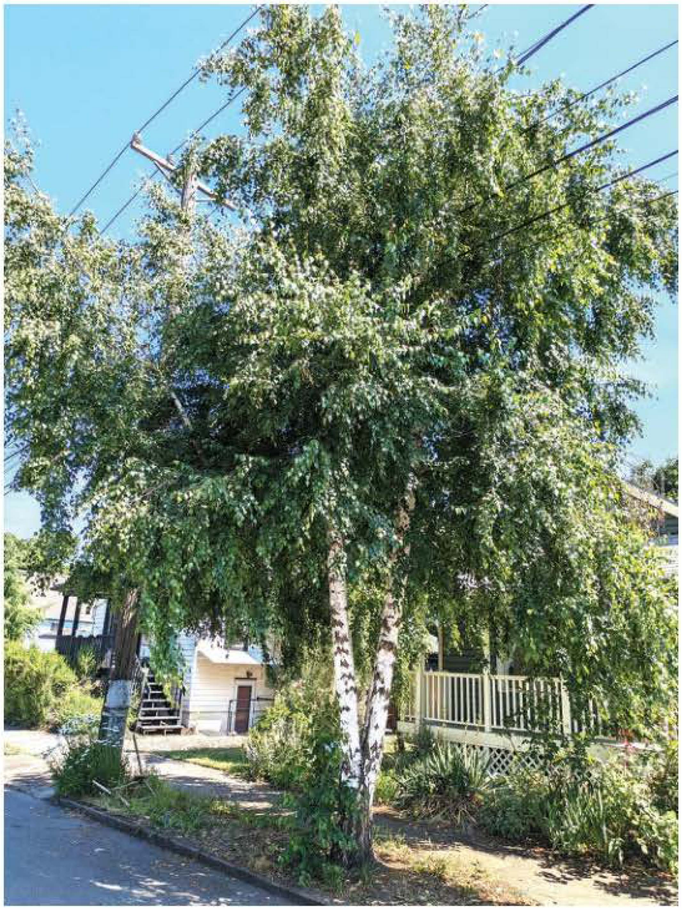

Figure 3. Tree #1. European white birch (*Betula pendula*); DBH: 9,8 in (23,20 cm); Condition: Fair; Suitability for preservation: Low (see Gilpin 2023 for explanation).

Figure 4. Tree #2. London plane (*Platanus × hispanica*); DBH: 21 in (53 cm); Condition: Good; Suitability for preservation: High (see Gilpin 2023 for explanation).

homes in my area that excavation will extend beyond where the house is shown on the plans (often referred to as over-build or over-excavation). It is important to know about typical construction techniques in your area.

I now have all of the information that I need to decide whether these trees are likely to survive construction. Before we dive into methods, a few definitions.

Definitions

While I would like us to all use terms like Tree Protection Zone (TPZ) and Critical Root Zone (CRZ) in the same ways, arborists seem to vary widely in how they define these terms. For a deeper dive into this topic, see Clark et al. (2021)(Figure 6). In my work, I use the definitions from the 3rd edition of the BMP:

> ***tree protection zone (TPZ)*** *– area within which certain activities are prohibited or restricted to prevent or minimize potential injury to designated trees, especially during construction or development. The TPZ should encompass the Critical Root Zone based on the judgment of the arborist.*

> ***critical root zone (CRZ)*** *– area of soil around a tree where the minimum amount of roots considered critical to the health of the tree or structural stability are located. There are no universally accepted methods to calculate the CRZ.*

Before deciding how to protect a tree, I try to first figure out if a tree is likely to survive construction, which to me is the same question as: what is the CRZ for that tree? We don't know exactly how close we can get to a tree without killing it. Trees are complicated biological organisms that act in surprising ways sometimes. For the above definition of CRZ, there is no one calculation or formula for estimating the exact critical area of a given tree. Each tree has a unique root area. If we can preserve enough of it, we can preserve the tree. Unfortunately, the minimum dimensions are a bit of a mystery to us.

Estimating a Calculated Tree Protection Zone

The 3rd edition of the BMP introduces a new term—Calculated Tree Protection Zone (Calculated TPZ). This is a new definition for an old idea. The idea is that in some situations, we need something more concrete, something we can calculate, something we can have some confidence in. I don't typically use Calculated TPZ very often in my work, but it can be a useful tool to gain insight not only into what the TPZ should be, but also what the CRZ may be. The definition provided in the 3rd edition is:

> ***calculated tree protection zone*** *– a TPZ that is calculated using the trunk diameter and a multiplication factor based on the species tolerance to construction and age of the tree.*

In our example, for the two trees that I need to explore in more detail (#1 and #2), I will estimate the Calculated TPZ using Table 2 from the 3rd edition of the BMP. This table has been in use for over 30 years, with only minor updates. Many people point out that this is not a scientifically rigorous method because it has not been experimentally proven, and that is 100% true. But it does provide reasonable guidance based on its successful use for several decades.

I consider tree #1 to be a mature tree with low tolerance to construction damage. If European white birch isn't commonly planted in your area, consider another tree that in your experience does not tolerate root loss as effectively as other species. Table 2 tells us that 15× may be a good multiplication factor to use for a Calculated TPZ.

For multi-stemmed trees, a single value for DBH should be calculated before the table can be used. Magarik et al. (2020) suggest that measuring below the multi-stem attachment or using quadratic sum (such as iTree uses) gives good results. I prefer to measure multiple stems and add them together using the quadratic sum formula, where the diameter of the multi-stemmed tree (D_{MS}) is equal to the square root of the sum of the squares of the individual stem diameters (D_1, D_2, etc.):

$$D_{MS} = \sqrt{(D_1^2 + D_2^2 \ldots)}$$

$$D_{MS} = \sqrt{(9^2 + 8^2 \ \ldots)}$$

DBH = 12 in (30 cm)

So an estimate of tree #1's Calculated TPZ:

12 in DBH × 15 = 180 in = 15 feet
(30 cm DBH × 15 = 450 cm = 4.5 m)

I consider tree #2 to be mature with a high tolerance to construction damage. If London plane isn't common in your area, consider another tree that tolerates root loss better than other species in your area. Table 2 tells us that 8× may be a good multiplication factor. So, an estimate of tree #2's Calculated TPZ:

21 in DBH × 8 = 168 in = 14 feet
(53 cm DBH × 8 = 425 cm = 4.25 m)

The Calculated TPZ is not a perfect system but can be a useful tool. I think it may be less appropriate for very large trees, very small trees, or if it is clear that the root system is asymmetrical. More important is what arborists are doing with this number once they have it. In this

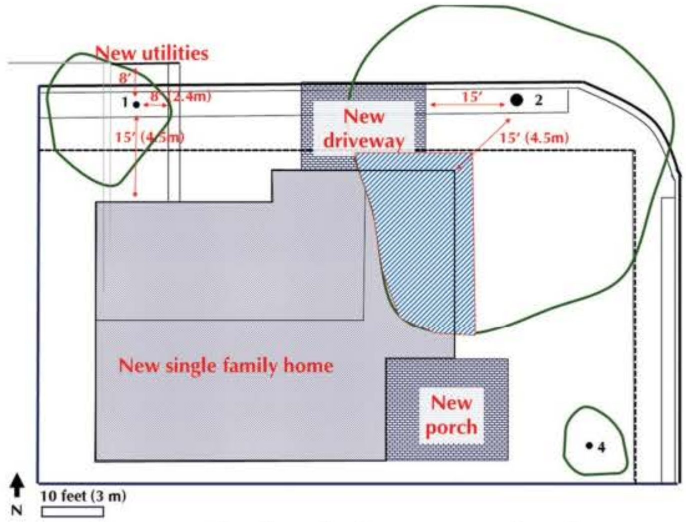

Figure 5. Measurements from the trunks of existing trees to planned construction. Blue hashing represents potential canopy requiring clearance pruning.

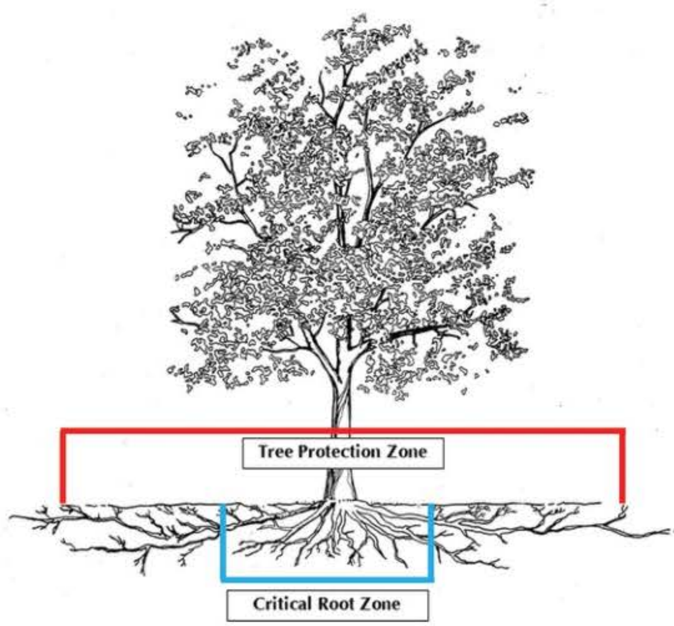

Figure 6. Conceptual illustration of the Tree Protection Zone (red) and Critical Root Zone (blue)(Clark et al. 2021).

example, I am using it to help me decide if a tree is likely to survive construction. In practice, roots don't grow in perfect circles, and it is worth thinking about where roots are more likely to be based on site conditions and tree characteristics.

Now that I have a number, I can compare the Calculated TPZ with the planned changes and consider if I think the trees can tolerate the root loss that will occur. In my experience, some root loss within the Calculated TPZ is tolerated by most trees, but how much is too much?

Table 2. Guidelines for calculating tree protection zone radius for trees in good condition (adapted from Matheny and Clark 1998). To use this table, determine the TPZ multiplication factor based on the species tolerance to construction damage and relative tree age. That number (TPZ multiplication factor) is then multiplied by the tree trunk diameter (DBH). The result is the radius of the TPZ in the same units used to measure DBH. That number is usually converted to feet or meters.

Species tolerance to construction damage	Relative tree age*	Multiplication factor
High	Young or semimature	6
	Mature	8
	Old	12
Medium	Young or semimature	8
	Mature	12
	Old	15
Low	Young or semimature	12
	Mature	15
	Old	18

* Young to semimature = less than 40 percent life expectancy; Mature = 40 to 80 percent life expectancy; Old = greater than 80 percent life expectancy

Will the Critical Root Zone Be Impacted?

In my experience, there is no bright line where trees will tolerate root loss and where trees will die from root loss. As impacts get closer and closer to trees, the trees become more likely to be affected, decline, and/or become structurally unstable. The closer that distance, the less comfortable I become. I particularly like the graphic from Benson et al. (2019), which summarizes root pruning research performed on young *Quercus virginiana* trees.

The science studying root loss is super interesting; the Benson paper gives us insight into water stress after root loss, which is relevant to our project. Other research tries to get at this question in other ways. Hopefully more research occurs in this area. As of 2023, I am not aware of peer reviewed research that has studied the likelihood of survival of a 12-inch (30-cm) DBH *Betula pendula* street tree when a trench is excavated 8 feet (2.4 m) away. I have to combine the available science with my experience and expertise to make this decision.

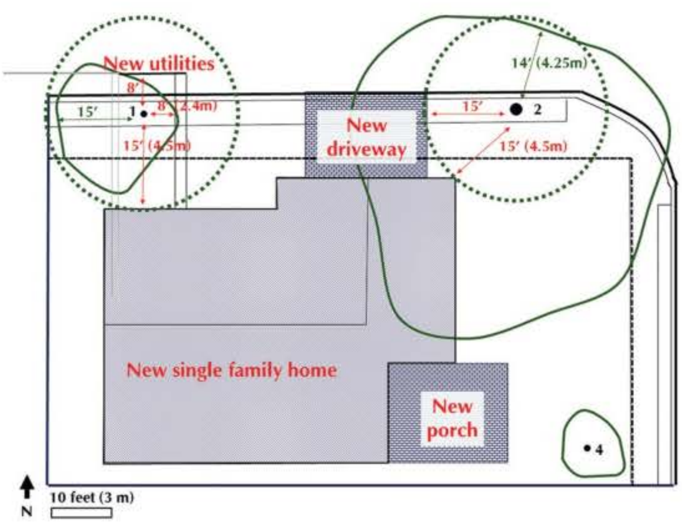

Figure 7. The Calculated Tree Protection Zone (dashed green) shown for trees #1 and #2.

The graphic from the Benson paper and Figure 8 show root loss impact on a tree's likelihood of survival. This matches well with how I think about tree survival. When construction is far from the tree, the tree's likelihood of survival is green, and I am feeling good. As construction gets closer to the tree, the tree's likelihood of survival becomes orange, and I am worried about the tree's survival. When we get very close to the tree, the tree's likelihood of survival is red, and I am not just worried about the tree dying; I am worried about the tree falling over.

Figure 8 doesn't account for variation in responses of trees of different species or ages. Benson et al. (2019), working with *Quercus virginiana*, concluded that, "tree protection zones should be prescribed by a radius of 15 times the trunk diameter…". My experience, and training from my mentors, say that tree species vary greatly in their ability to tolerate root loss. Table 2 is designed to account for this variation in tolerance and offers a range of starting points, including 15×.

Tree #1 will lose roots during excavation to install utilities. In my experience, this species doesn't tolerate root loss well. Table 2 offers a multiplication factor of 15× with a Calculated TPZ of 15 feet (4.6 m). The excavation will occur approximately 7× from the trunk, which is less than half of the Calculated TPZ (Figure 9). This is in the orange zone where I am getting concerned about the tree's ability to survive construction. Because tree #1 is in fair condition, I am even more concerned about its likelihood of survival and its ability to be an asset to the future project. On your projects, you need to use your experience to decide what to recommend. I am going to tell my client that I don't think that tree #1 will survive this construction.

Table 2 offers other multiplication factors besides 15×. It would be great to have very large Tree Protection Zones for every tree, but that is unrealistic for many of my projects. The question that I am currently trying to answer is: is the tree likely to survive construction? For more construction-tolerant and younger trees, this method proposes using the same color scale, but compressing it so that green is equal to the multiplication factors from Table 2 (Figure 10).

Tree #2 will lose roots and crown. In my experience London plane trees are tolerant of both of these impacts. Table 2 lists 8× as the multiplication factor, which equals a Calculated TPZ of 14 feet (4.25 m). There is construction planned near the edge of this zone, and excavation will probably occur approximately 7× DBH from the trunk (Figure 10). For me, this is within the green zone. I would prefer that we had more space, but I expect this tree, which is in good condition, to survive the planned construction.

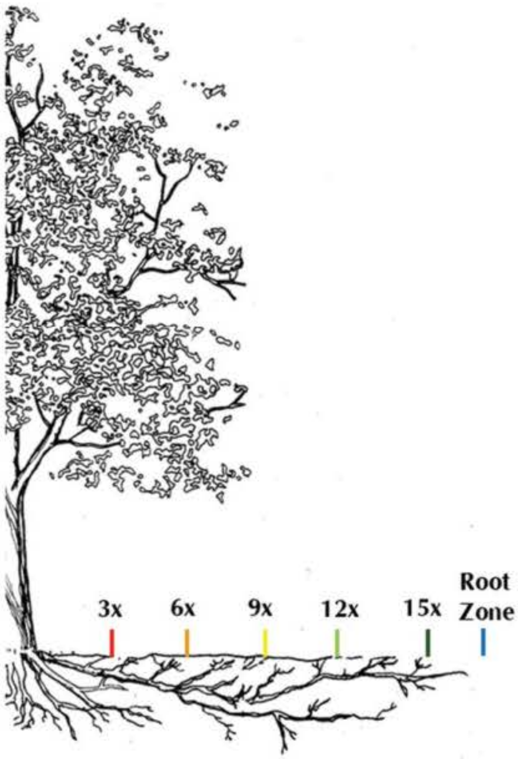

Figure 8. Tree Protection Zone radius depicted as multiples of the trunk diameter. At 3×, noted in red, most of the roots are removed and the tree will likely die. At 15×, noted in green, most of the root system would be left intact. As the TPZ increases from the red zone to the green zone, the likelihood that the tree will survive increases (after Benson et al. 2019).

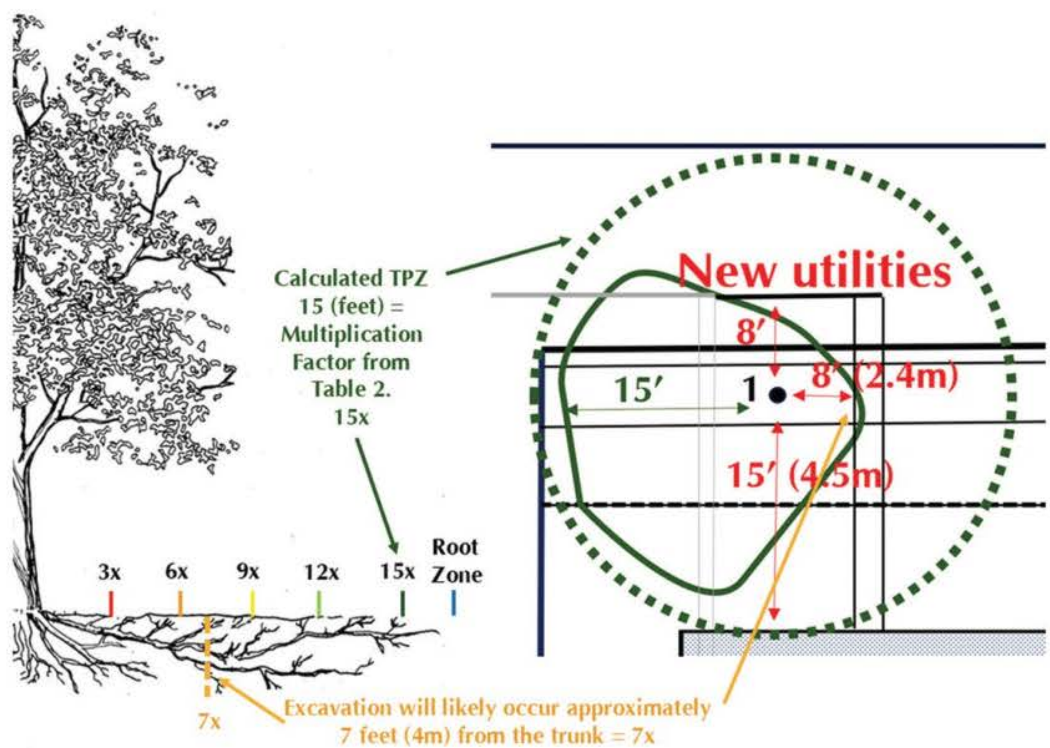

Figure 9. European white birch #1 has construction planned closer than half the distance of the Calculated TPZ.

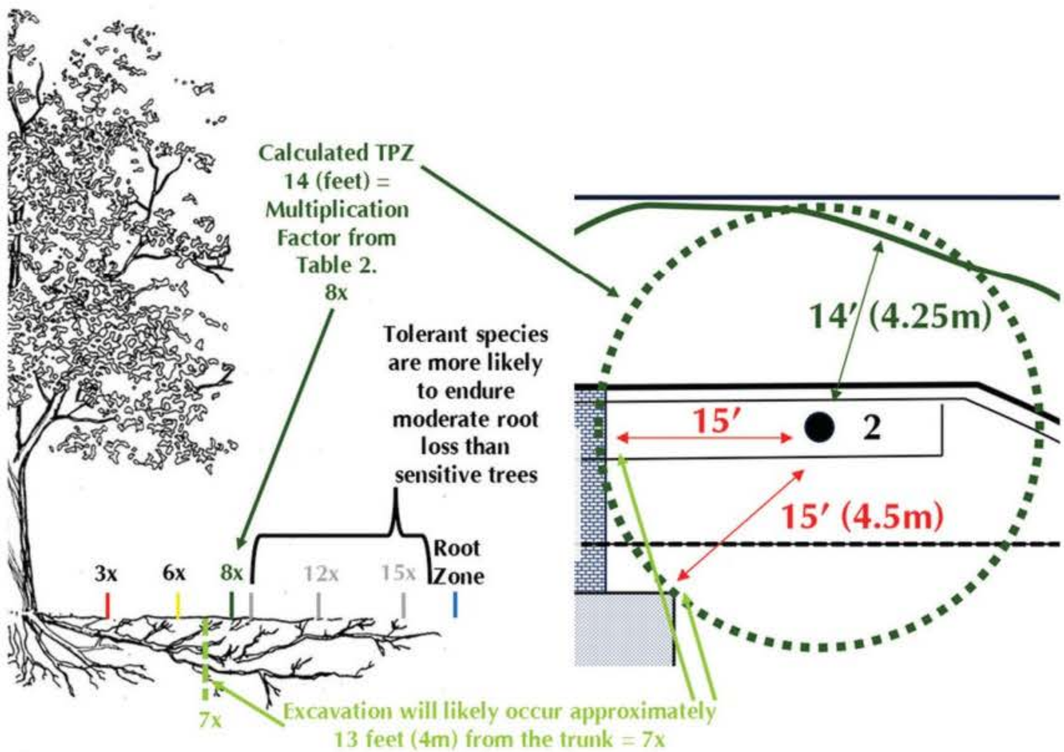

Figure 10. London plane #2 has construction planned near the edge of the Calculated TPZ.

Summary

I have outlined one way in which arborists could try to answer the question: is this tree likely to survive construction? This method combines the available science with elements from the 3rd edition of the BMP to compare the size of the Calculated TPZ to where construction is planned. An important element of this method is the observation that most trees seem to tolerate excavation near the edge of their Calculated TPZ, and that as construction gets closer to the tree, the likelihood of survival goes down.

Instead of trying to quantify this change in probability, I have shown some color-coded graphics where I feel good when the ratio is green, am worried when in the orange zone, and am alarmed when in the red zone. I encourage all arborists working on construction sites to review the science studying this topic, read the 3rd edition of the BMP, and use your experience and expertise to make the best predictions that you can about whether trees are likely to survive the planned construction.

Next Steps

Once we decide whether we expect trees to survive the planned construction, there are several options for how to proceed:

1. ***Further investigation.*** When construction is near trees, and we are not sure of the intensity of root impacts, further investigation may be appropriate. Techniques could include localized soil excavation to expose roots, ground penetrating radar, and viewing root loss during excavations. If roots aren't present in the area being constructed, the tree is likely to survive. Some arborists rely on exploratory methods to assess where roots are more than I do and seem to have good success.
2. ***Redesign.*** Depending on where the project is in the construction process, it may be possible to adjust the plans to reduce tree impacts. Some aspects of the project are easier to change than others. For example, on this project, asking if utilities can be rerouted is an option.
3. ***Remove, protect, monitor, and replant.*** Most likely on this project, we would discuss the following scenario:
   - Trees #2 and #4 will be preserved.
   - Trees #1 and #3 will be removed.
   - The arborist works with the design team to create a Tree Protection Plan for trees #2 and #4.
   - The arborist monitors the excavation in the root zone and prunes the crown for clearance following the ISA *Pruning* BMP (Lilly et al. 2019).
   - After construction is complete, the landscaper plants trees to mitigate the loss of trees #1 and #3.

Good luck with your construction projects. I look forward to hearing what challenges you are having and how you are overcoming them.

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