- installing one or more syphon based diverters such as Gutter Pumper®, and

- installing overflow spouts that allow for the discharge of water in the event of a blockage taking place. (Spouts prevent damage to the building and make it clear that there is a blockage),

Root systems

The critical issue when developing adjacent to trees is the impact of that excavation on the root system. To understand this impact, it is important that we understand how the root system functions.

- All roots start as '**pioneer roots**', pushing their way through the soil in order to take advantage of newly available soil moisture and solutes that are in the zone that they have entered (hence the term pioneer). Cell division at the tip of the root and cell elongation behind this tip creates this push by the roots. This '**zone of elongation**' is typically a few millimetres to less than 100 mm in length.

Cell elongation uses water, and the presence or readily available water, solutes (soluble nutrients), and soil temperature (generally around 16^{O}C for most temperate trees) stimulates root growth. Whilst cells absorb some water in the zone of elongation, at best they seldom meet their needs.

- Once the roots have fully elongated single-celled hairs develop on the surface of the root and these roots with '**root hairs**' to form '**absorbing roots**'.

  The absorbing roots are responsible for the uptake of nearly all the water and the majority of solutes used by the tree. They are highly ephemeral, often lasting only a few weeks. However, in association with beneficial fungi, they can last a year or more.

  Where trees are already growing well, we can typically assume that soluble nutrients are present at satisfactory levels. Likewise, we can assume that the soil surface temperature often exceeds16 degrees Celsius most of the year and that at depth, the soil temperature does not vary significantly throughout the year. The biggest limiting factor, therefore, is usually the ready availability of water.

  A percentage of these pioneer/absorbing root structures survive the various environmental stresses and within a few weeks to a few months become woody.

- '**Woody roots**' are effectively underground branches. These roots can be a little under a millimetre in diameter and can grow to be hundreds of millimetres in diameter over time. Their thick bark prevents them from drying out, but as a result, they are not able to absorb water and nutrients from the soil to any great extent.

Whilst many young woody roots die as a result of disease, environmental damage or competition; they have the potential to be long-lived, sometimes lasting for hundreds of years. Woody roots act as the connection between the absorbing roots and the rest of the tree

- A small portion of the woody roots, closest to the stem, provide physical support for the tree. These **'structural roots'** grow directly from the trunk (first-order lateral roots) or are roots that branch close to the trunk. These roots provide support in compression and tension. They have a greater wood content and, as a result, tend to be much thicker to allow for strength, as well as transport.

In response to the forces of compression and/or tension, these structural roots develop an asymmetric shape rather than the normal circular shape. As the roots grow further from the trunk, they get rapidly thinner (zone of rapid taper) and more circular in shape.

In fast draining sandy loams, such as is the case on this site, the majority of roots are likely to be deeper than 600 mm, except where there is a sand interface or a permanent water table.

Damage to roots

Damage to larger roots inside the zone of rapid taper is extremely undesirable and, in most circumstances, should be avoided. These are woody roots, and therefore, excavation is more significant in its impact than careful construction over the top of these roots.

Depending on the amount of root division, the cutting of a woody root with a diameter of 25mm could conceivably result in the death of many millions of root hairs. This loss of absorbing roots has a direct impact on a tree's ability to absorb water and solutes. Also, it can affect hormone production, resulting in reduced growth above ground until the root/foliage ratio is restored to its ideal levels.

The loss of roots can result in wilting or thinning of the foliage, the loss of foliage and death of smaller branchlets and sometimes the death of specific larger branches. The ready availability of soil moisture is important in minimising this impact.

Not only do higher soil moisture levels, reduce the energy expended to absorb water, it also stimulates new root development. The faster that sufficient new roots are developed, the less the impact on normal function

Roots are often close to the surface, and therefore construction activity can indirectly impact on the health of roots through direct damage or soil compaction. Even regular pedestrian activity has an effect on the roots close to the surface. In addition, altering of levels by adding fill has the potential to change the movement of water into the soil and in some circumstances can cause the soil to become anoxic, in turn causing the death of the roots and potentially the death of the tree.

By far the easiest and most efficient way of limiting construction damage to trees is to establish and enclose a Root Protection Area (RPA) using a rigid fence. The function of this fence is to eliminate all construction activity in this area.

Methods of Tree Protection

It is important that we understand the processes and methods of tree protection. For that reason, some images have been included in Appendix 5 along with the information in this section to assist in ensuring that appropriate implementation of tree protection.

Protect the roots

As already explained the purpose of establishing a Tree Protection Zone is more than concerned with protecting the trunk of the tree. A Tree Protection Zone's primary function is the protection of the roots of the tree.

The most appropriate method of protecting a tree is to establish an exclusion zone using some form of rigid temporary fence (a Tree Protection Zone or TPZ). While it may seem easier to use flexible fabric barrier fence, these products tend to fail over time and is easily pushed out of the way or damaged. In comparison, damaging rigid fence requires more of a hit, can damage machinery and involves the cost of repair or replacement of the damaged fence.

Sometimes, however, it may become necessary to work within or to gain access through a Tree Protection Zone. To do this, we need to develop a method to stop soil compaction and prevent direct physical damage to roots. A simple action such as walking on the same spot half a dozen times or more can lead to soil compaction. Pushing a full wheelbarrow will cause compaction on the first instance. It does not take long for that damage to accumulate and harm the roots of a tree.

There are some ways to protect roots against compaction and physical damage. We can divide these into two simple groups;

- Systems that share the load and
- Systems that are fully load bearing.

Load-sharing surfaces are temporary lightweight systems. Load-sharing surfaces sometimes can be as simple as mulch beneath plywood or planks or the use of scaffolding, to heavier duty systems such as the use of plastic or metal road plates. Photographs in Appendix 4 show that these can be enough to protect a delicate egg from breaking.

Fully load-bearing structures include finished structures such as the slab of a building, a driveway or a pathway. Obviously, each of these has a limit to the weight that it can bear and if this is exceeded the structure and things beneath it can be damaged. Load bearing systems can also include scaffolding and temporary bridging structures.

Protect the trunk

In most instances, enclosing of the Tree Protection Zone ensures that the trunk of a tree cannot be damaged. Sometimes, however, work needs to take place within the Tree Protection Zone and, as a result, there is a risk of impact to the trunk. Damage to the trunk is extremely undesirable. Where it is possible to treat the wound treatment is time critical and is very expensive. When treatment is not possible or is ineffective, a trunk injury can lead to long-term structural and physiological problems.

Where machinery or performing activities that may result in an impact to the trunk of the tree, such activities should be avoided where possible. Where this is not feasible, it is important to protect the trunk. Strapping pieces of timber to the trunk of the tree has been the traditional method of achieving this task.

As any high school science student will recall Conservation of Momentum (as demonstrated by Newtons cradle) tells us that this force is transferred through the pieces of timber to the trunk of the tree often providing little to no protection and in some circumstances resulting in increased damage.

In response to the failure of wood to absorb impact, hessian or carpet underlay were used and while these improved the situation the timber still lacked the ability to absorb any of the energy. The use of fabric wraps also carried new problems; in particular, they often held moisture and this moist material was in constant contact with the trunk.

A more appropriate system needs a hard, but flexible outer surface bonded to a soft impact absorbing material that has a low water holding capacity. This system is better at absorbing the energy of an impact … just think about a bicycle helmet. Just as with a bicycle helmet, if the impact damages a board it needs to be replaced and at the same time the trunk of the tree needs inspecting.

Lastly, prevention is the best process. When machinery is operating near the trunk of a tree using, an observer can significantly reduce the likelihood of impact. To be effective, the observer should maintain direct visual contact with the tree and the machine and should have direct audio contact with the operator. (Two-way earmuff systems are useful for this task).

Protection of the canopy

The canopy of the tree is often the part of the tree that is least harmed in the construction process. Even so, there are two ways that the construction process can harm the canopy. The first is by direct impact between equipment and the branches of the tree, and the second is from incorrect or excessive tree pruning.

Avoiding potential impact between machinery and branches simply requires care. When machinery needs to operate near branches, an independent observer should be used. The observer should maintain direct visual contact with the machine and the branches of the tree and should have direct audio contact with the operator.

All pruning work should be performed in accordance with the Australian Standard AS 4373-2007 "Pruning of Amenity Trees." Any person who does not fully understand this standard or who has not had the proper training to perform pruning should not attempt this work. The site arborist may provide instructions to workers on the site on making temporary cuts for later rectification by an arborist. These instructions should be carefully followed.

Post Construction

33	At practical completion, the project arborist **should** "assess tree condition and provide certification" on their condition	This certification completes to the document trail for the certifier and or the consent authority.
34	"Certification **should** include details of the deviations from the approved tree protection measures and their impacts on [the] trees" and provide specifications for any remedial or rectification works required.	This complies with AS 4970-2009 (5.5.2). It provides a documented record of the final condition of the tree. It audits and certifies the correction of any problems.
35	The project arborist **should** continue to perform quarterly inspects, maintenance and reporting for whichever is greater: • For 12 months after the completion of construction activities or • For 12 months after achieving stable growth of the tree	To ensure the long-term recovery of the tree is certain.

Should you require any further information, please call our office for assistance.

Mark Hartley
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Dip Arboriculture, Dip Horticulture
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Registered Consulting Arborist™ #0001
ISA Tree Risk Assessment Qualified
Registered QTRA user (No. 807)
Member - Society of Risk Analysis Australia & New Zealand

Appendix 1:

Tree Schedule

Client Name: Matt Campbell, Helm PTY LTD **Site Address:** 177 Russell Ave, Dolls Point

No	Scientific Name	Health	Height (m)	Spread (m)	DBH (cm)	ITPZ (m)	MTPZ (m)	TI/ME (m)	Retention Value	Comments	Retain / remove
1.	*Robinia pseudoacacia*	Fair	9	6	40	4.8	2.0	3.4	Low	Possum damage	Remove
2.	*Robinia pseudoacacia*	Fair	7	5	30	3.6	1.5	2.5	Low		Retain and protect
3.	*Magnolia grandiflora*	Good	14	14	100	12.0	5.0	8.4	Low	Lopped at some stage in the past	Remove for construction
4.	*Magnolia grandiflora*	Good	14	14	110	13.2	5.5	9.2	Low	Lopped at some stage in the past	Remove for construction
5.	*Quercus robur*	Good	18	18	100	12.0	5.0	8.4	Essential		Retain and protect
6.	*Agonis flexuosa*	Fair	5	10	E100	12.0	5.0	8.4	Low		Remove
7.	*Cotoneaster glaucophyllus*	Fair	6	7	E35	4.2	1.8	2.9	Nil	Undesirable species with a weed-like behaviour	Remove
8.	*Archontophoenix cunninghamiana*	Good	2	-	-	2.0	0.6	-	Moderate		Retain and protect
9.	*Archontophoenix cunninghamiana*	Good	1.5	-	-	2.0	0.6	-	Moderate		Retain and protect
10.	*Brachychiton acerifolia*	Good	12	8	35/20	4.8	2.0	3.4	Low	DBH calculated as 40cm	Remove
11.	*Thuja plicata*	Fair	8	3	10/10	2.0	0.7	1.2	Low	Variegated, DBH calculated as 14cm	Remove
12.	*Archontophoenix cunninghamiana*	Good	4	-	-	2.0	0.6	-	High		Retain and protect
13.	*Archontophoenix atropurpurea*	Good	5	-	-	2.0	0.6	-	High	An uncommon species	Retain and protect
14.	*Phoenix roebelenii*	Good	2	-	-	2.0	0.6	-	Low		Retain and protect
Trees on neighbouring properties											
N1	*Lophostemon confertus*	Good	9	5	50	6.0	2.5	4.2	Essential		Retain and Protect
N2	*Lophostemon confertus*	Good	5	5	40	4.8	2.0	3.4	Essential		Retain and protect
N3	*Tristaniopsis laurina*	Fair - Good	5	5	E40	4.8	2.0	3.4	Essential		Retain and protect

Notes on Tree Schedule

Number (No)	N – Neighbours tree within proximity of the development
Scientific Name	Identification was made using visual features visible from ground level at the time of inspection
Health	**Good** – In good health with no significant faults or defects **Fair** – Some faults or health problems not likely to cause short-term problems, generally able to be managed. **Poor** – Significant health or structural defects with management likely to be inadequate or inappropriate
Height (m)*	Palm heights given for trunk only and does not include the height of the fronds.
Spread (m)*	The average diameter of the canopy unless the asymmetry of the canopy is noted or is critical to the design process
DBH (cm)*	Trunk diameter - measured or approximated at 1.4m above ground as outlined in "Appendix A" AS 4970 – 2009 E – Estimated equivalent trunk diameter where multiple trunks and branching exist.
ITPZ	The Indicative Tree Protection Zone radius specified by section 3.2 of AS 4970 -2009and rounded up to one decimal place
TI/ME	The minimum radius for a Tangential Incursion into the TPZ yet still be a Minor Encroachment using AS 4970 - 2009
TPZM	The suggested minimum Tree Protection Zone radius determined following the process for reducing the TPZ outlined in AS 4970 – 2009. The TPZM usually requires moderate to extensive arboricultural input along with ongoing maintenance
Retention Value	**E = Essential** - Site suitability 40 plus years, good condition, able to be retained without design changes **H = High** - Site suitability 40 plus years, fair condition or better able to be retained with minor design changes **M = Moderate** - Site suitability 20 - 40 years, or only retainable with moderate impact on the development of the site **L = Low** - Site suitability less than 20 years, or retention impacts significantly on development of the site **N = Nil** - Site suitability less than five years or retention sterilises development of site **Note:** Site suitability considers health, life expectancy, risk of harm, desirability of species, and impacts on current and proposed land use. Impact on development needs to be considered throughout the planning stage
Recommendations	Unless otherwise stated trees are to be retained.

* All dimensions are approximate.