GUIDELINES FOR THE PROTECTION OF TREES ON CONSTRUCTION SITES

FOR THE SYDNEY OLYMPIC PARK AUTHORITY
PREPARED BY THE TREE SCHOOL
REVISED OCTOBER 2004

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

Established trees of good health and vigour represent an asset to any development site, particularly if landscaping is a significant component of the proposed development. Trees are retained because of their aesthetic features, for shade, for the scale that they will give to new buildings or for their historical value.

Trees are living organisms that require certain environmental conditions in order to maintain their value as an asset. As remediation of badly stressed or damaged trees is rarely successful, it is essential to avoid or minimise damage during the construction phase. Hence, to retain trees and meet their requirements, procedures that ensure the protection of trees must be in place at all stages of the development.

Successful and long-term preservation of trees on development sites depends on understanding the constraints of the tree and the site and achieving a workable compromise. The protection of trees on development sites, as detailed in this document, will marginally increase construction costs and should thus be included in relevant budgets or contracts. Long-term savings in landscape installation and maintenance will occur by adhering to quality protection measures.

The document “Guidelines for the Protection of Trees on Construction Sites” – prepared by The Tree School for the Sydney Olympic Park Authority forms the basis of these guidelines.

2.0 SCOPE

This document describes and substantiates the best practices for the protection and preservation of trees on construction sites. Plant biology and current best practices as covered in recently published literature form the basis of the procedures described. These Guidelines also refer to the British Standard, BS 5837: 1991*Guide for Trees in Relation to Construction*.

This document considers procedures at each stage of a development. The guidelines cover three periods:

i) pre-development planning and site evaluation;,
ii) construction; and
iii) post-development mitigation, maintenance and monitoring.

Pre-development issues include site selection, project planning and tree surveys. Construction focuses on site layout, tree protection zones and site damage control. Post-development issues concentrate on restoring and maintaining good growing conditions. The overall aim of all stages should be to minimise development problems whilst protecting tree quality. (5)

Note that construction not only refers to buildings, services and infrastructure but to any **landscape** construction as well.

3.0 APPLICATION

The Sydney Olympic Park Authority (SOPA) developed these guidelines to provide builders, developers, landscape contractors, project managers and others involved with site works at Sydney Olympic Park with information and procedures relating to the protection and preservation of trees on development sites. It also covers maintenance procedures once construction is complete.

4.0 BACKGROUND TREE BIOLOGY

4.1 The tree

All plants consist of three main sections: a crown (leaves), a stem or trunk and a root system (Figure 1). Each one of these sections carries out specific functions necessary for the survival of the tree as all of the parts interact. As a tree is in a state of physiological equilibrium between the above ground and below ground sections, damaging any one of these sections will cause the entire tree to suffer, with symptoms that may appear in any part of the tree.

Thus, it is necessary to carry out any construction operations that occur in or around trees in ways that minimise the impact on the health of the tree.

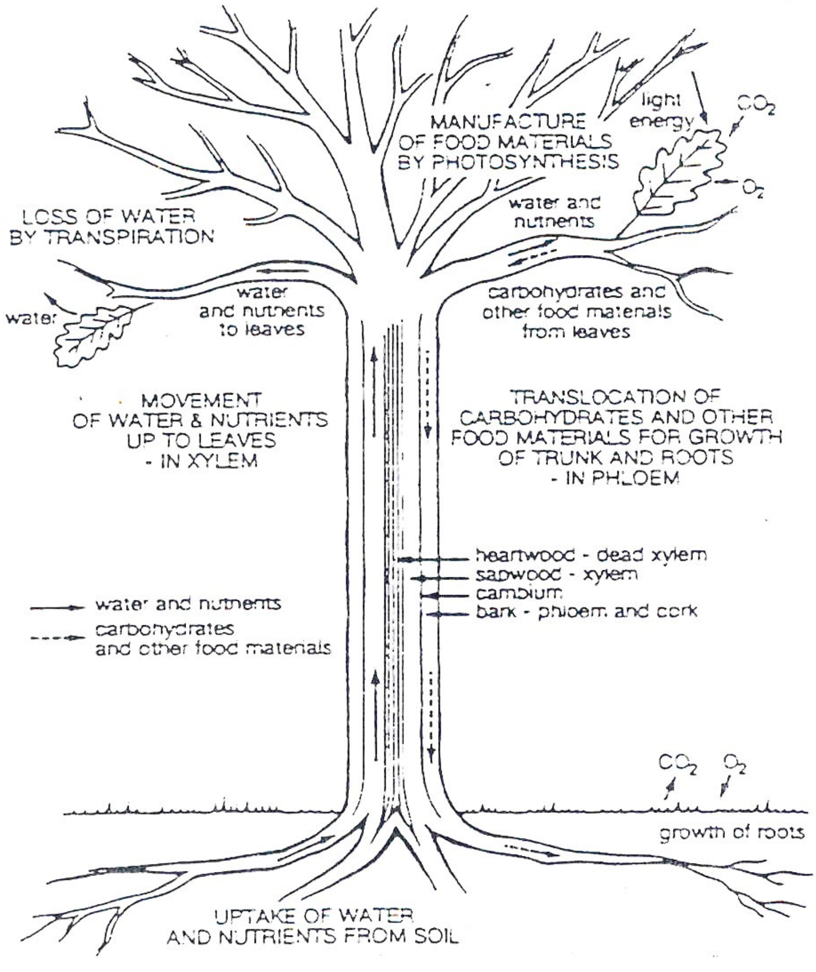


Figure 1: The structure and functions of the main parts of a tree (after Bradshaw *et al*, 1995).

4.2 The leaves

The main function of leaves is photosynthesis, that is, the production of sugars and oxygen. The sugars produced by the leaves (and any other green tissue) are the source of chemical energy for all living cells in the entire plant and as such are essential for the normal functioning and survival of the tree. Anything that directly or indirectly damages the leaves will interfere with photosynthesis.

Leaves also produce hormones that are required by other parts of the tree including the roots.

4.3 The branches and trunk

Branches and trunks are composed of many tissues with specialised functions (Figure 2). The main functions of these tissues are as follows:

- Bark: protects tissues beneath it from attack by insects and disease organisms; prevents water loss; trees with thick persistent bark may be more resistant to mechanical damage;

- Phloem: found just beneath the outer bark; transports sugars throughout the plant;

- Cambium: growth of new phloem, xylem and ray cells (i.e. new transport cells);

- Sapwood: transports water and nutrients up from the roots; storage of sugars;

- Heartwood: old sapwood; strength and support;

- Rays: internal transport of sugars, gases and water; major site of sugar storage

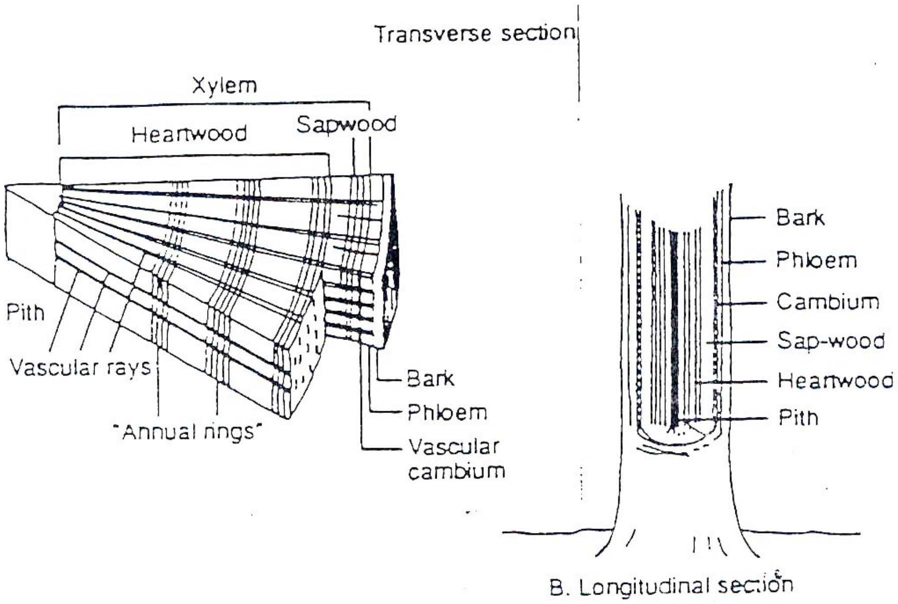


Figure 2: The internal structure of a tree.

Damage to branches or trunks may allow infection by plant pathogens (disease-causing organisms), disrupt the movement of vital materials and or structurally weaken the tree.

As branches develop, branch and trunk tissues overlap at the base of the branch. This results in two discernible anatomical features - the branch collar and the branch bark ridge (see Figure 3). The branch collar is the area at the base of all branches and branchlets, the design of which is to deal with decay physically and chemically. The branch collar produces chemicals that protect the branch from decay in the event of its natural decline. The branch collar is the point to which branches naturally die (30).

In some trees, the branch collar is easily recognised as a distinct swelling and change in diameter of branch thickness. Collar angles and length are variable between species and individuals. Ideally, only prune to the branch collar and without damaging the branch bark ridge.

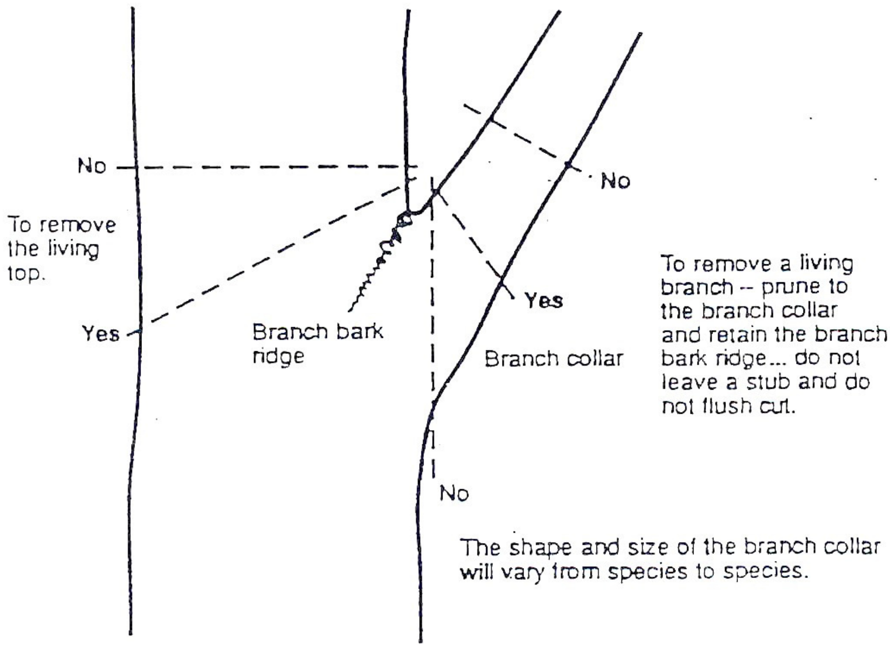


Figure 3: The branch collar and branch bark ridge .

4.4 The roots

The main functions of roots include the uptake of water and nutrients, anchorage, storage of sugar reserves and the production of some plant hormones required by the shoots. In order for roots to function, they must obtain oxygen from the soil. The root system of trees consists of several ‘types’ of roots found in different parts of the soil and is generally much more extensive than most people think. The importance of roots is easily overlooked because they are not visible, that is “out of sight, out of mind”. Damage to the root system is a common cause of tree decline and death and is the most common form of damage associated with construction sites.

Root growth is opportunistic and takes place wherever the soil environment is favourable. The most limiting factor for root growth is air. A number of studies have indicated that roots are much more extensive than most people believe. In general, roots extend outward from the trunk and occupy irregularly shaped areas 4-7 times larger than the projected crown area with an average diameter of one to two or more times the height of the tree (25,26). Gilman, (11) studied the root spread of a number of species and found that the mean maximum root spread was 2.9 times the dripline. Schnell *et al*, (29) report on a number of studies of several species where between 52% and 77% of roots were beyond the drip zone. Hence, the common belief that tree roots only extend to the dripline (or edge of the canopy) is a fallacy.

Root systems consist of three main parts- the primary woody root system (anchorage, storage and transport), secondary woody roots (anchorage, exploration, storage and transport) and non-woody roots (absorption of water and nutrients, storage, synthesis of amino acids and growth regulators) (9,16,32). Hand digging a number of test trenches is the only way to confirm the location of major woody roots.

In addition to underestimating lateral root spread, root depth in trees is also grossly exaggerated. Deep root systems are the exception rather than the rule (29). Perry (25) states that most roots of most trees are found in the top metre of soil. The vast majority of these roots are small non-woody absorbing roots that grow upward into the surface layers of the soil and leaf litter (26). This delicate, non-woody system, because of its proximity to the surface, is very vulnerable to injury.

It is important to note that most trees do not produce deep taproots (9,25).

4.5 Buds

Buds are tightly packed, undeveloped new shoots or flowers. They form at the tips of branches, in the forks of branches and at the base of leaves. The “strongest” bud or apical bud is located at the tip of the tallest stem or branch. It produces hormones (auxins) that control the development of buds below. An understanding of buds and how they work is necessary in understanding what happens when pruning trees.

Most trees (except most conifers) produce epicormic buds along the trunk and main branches. These buds are dormant or the tree produces them in response to stress or injury. For example, the ‘injury’ may be pruning or fire and the stress may be root damage. The production of epicormic shoots is a survival mechanism and indicates stress.

Epicormic shoots produced from large diameter branches, such as those produced after lopping, are always more weakly attached than natural branches.

4.6 Growth

A number of factors influence tree growth:

- the genetic programme of the particular species,
- the influence of hormones within the plant,
- the physical environment in which it is growing and its effect on the basic requirements of light, water, air, nutrients, temperature and support, and human practices that may have an impact on the tree.

As trees mature, the rate of growth decreases and in some species, the growth habit changes. Damage to roots and or shoots may alter the hormonal balance within the tree. Mature and senescent trees may be less able to cope with radical changes to their environment.

5.0 EFFECTS OF CONSTRUCTION ON TREES

5.1 General

Construction may damage all parts of the tree. Damage to any one part of the tree will affect its functioning as a whole. This section considers the possible impact of injury on the functioning of each main section of the tree and highlights necessary, specific protective measures.

5.2 Crown damage

Crown damage can be direct or indirect. Although not discussed here, trunk and or root damage will result in indirect crown damage.

Usually, foliage is lost or damaged on construction sites by pruning or mechanical injury. Leaf removal reduces the level of photosynthesis and thus the production of sugars. This in turn reduces its capacity to function normally and to withstand stresses imposed by a change in its environment.

Incorrect techniques of pruning such as lopping or flush cutting may produce wounds that are potentially susceptible to infection by wood decay organisms. Similarly, mechanical damage to branches by machinery etc will also create wounds. Trees automatically respond to wounding and in doing so use stored sugars. Any wound places an additional load on inevitably stressed trees during construction.

5.3 Trunk damage

Construction work activity may wound tree trunks mechanically. This not only predisposes a tree to potential decay but it also interferes with the transport of water, nutrients and sugars throughout the tree. Serious impacts may structurally weaken the tree.

5.4 Root damage

Root damage is the most common cause of damage to trees on construction sites. As already mentioned in Section 4.4, roots are far more extensive and closer to the surface that commonly thought. Figure 4 illustrates the approximate percentage and type of roots damaged by locating trenches at varying distances from the trunk.

Common root damage causes include:

- removal during grading, excavation and trenching for foundations, services etc;
- mechanically wounded, crushed or torn;
- compaction by machinery, storage of materials, and installation of work sheds;
- soil build-up;
- laying of pavements;
- chemical contamination of the soil by solvents, paints, fuel, oil, diesel, herbicides, cement waste, herbicides etc;
- changes in air levels through changes in drainage patterns.

Apart from the actual removal or roots during excavation or trenching, soil compaction is one of the major causes of root damage on construction sites (7,9,10,15,16,17,27). The definition of compaction is the loss of large pore spaces (macropores) within the soil with a net loss of total pore space (7,8). Macropores are essential for the exchange of gases between the soil air and the atmosphere (aeration) and the removal of excess water from the soil (drainage).

Compaction results from loads or stress forces applied to the soil as well as shearing forces. Both foot traffic and vehicle traffic exert both forces on soils. Vehicle traffic may cause significant compaction at depths of 150-200mm (the area in which most feeder roots are located). The degree of compaction will depend on weight of vehicles, number of movements, soil moisture levels and clay content. Soil handling, stockpiling and transporting also tends to lead to the breakdown of soil structure and thus to compaction. Vibration from frequent traffic or adjacent construction activities also compacts soils (7).

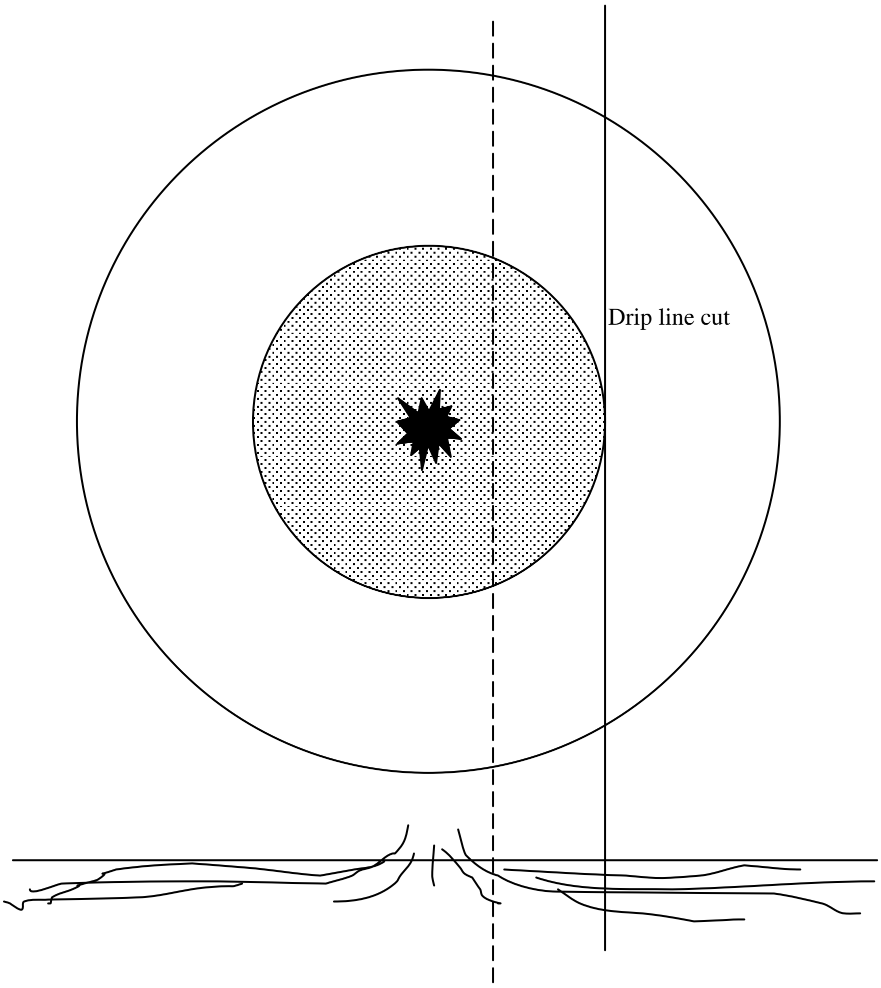
The effects of compaction include:

- reduced aeration (oxygen levels decrease and carbon dioxide concentration increases to perhaps toxic levels);
- low oxygen levels discourage root growth and thus the uptake of water and nutrients;
- reduced infiltration of water into the soil and more run-off;
- increased run-off increases soil losses by erosion;
- low oxygen levels also lead to chemical changes in the soil which can reduce the availability of some plant nutrients; and
- reduced number and diversity of beneficial soil organisms (including mycorrhizal fungi).

In summary, the effects of root loss or damage by any means could include:

- loss of stability if primary or even secondary woody roots are cut;
- reduced water and nutrient uptake;
- an eventual loss of leaves, reduced photosynthesis and thus sugar production;
- decay as a result of wounding;
- predisposition to soil borne pathogens.

Trees commonly take many years to decline and eventually die from root damage.



Removing the roots in one area back to the drip line would cut off about 20% of the feeding roots; cutting a trench about 1m from a mature tree would remove about 45% of the roots including major woody roots

Figure 4: Root damage from trenching, excavation, sealing or soil build-up. Note the relative types of roots and the percentage of the root system damaged when trenches are located at varying distances from the trunk. This assumes that the tree is growing in an originally unrestricted area. The percentage of roots damaged would increase if pavements etc already constricted the root system (after Harris, 1992).

6.0 PROCEDURES TO MINIMISE THE IMPACT OF CONSTRUCTION ON TREES

6.1 Pre-development planning and site evaluation stage

Perhaps the most important stage in the protection of trees on construction sites is at the pre-development planning stage (1,2,4,13,14,23). Building and infrastructure designs should consider the retention and preservation of trees on site. The pre-planning phase covers a number of stages, which should involve a team of people including the client, engineers, architects, landscape architects, project managers and an arborist. Each team member's role in the project should be clearly defined. Before any work commences, it is essential to determine the characteristics of the site, which trees should remain, which to remove, and then determine the design potential of the site.

6.1.1 Tree surveys

A suitably qualified and experienced consulting arborist should survey all existing vegetation on the site. A plant ecologist should be involved if natural or remnant vegetation is included. The planning authority should engage the arborist, not the construction contractor (13). Appendix 1 contains the survey details.

Pre-development tree assessments are a means of establishing the relative usefulness of existing trees on potential development sites. They involve allocating trees to categories of importance in order to identify the most sensitive areas of the site (2). Apart from retention or removal, the arborist would note any trees that require pruning or other work before construction. It is essential to establish the information required by the design team before any fieldwork and data collection. This may be quantitative (dimensions, location, defects) and qualitative (more subjective assessments based on experience, aesthetic qualities etc) (1). The more comprehensive the survey, the more use it can be in establishing necessary precautions for successful tree preservation.

At the planning stage, the arborist should have two stages of involvement:

- i) to collect information and present it in such a way that it can be interpreted by designers (architects, engineers, landscape architects etc); and
- ii) to later interpret this information in relation to the various proposed layouts (1)

A very important concept for all people concerned with the retention of trees on development sites is that of *Safe Useful Life Expectancy* (SULE). SULE is the length of time that the arborist assesses an individual tree can be retained with an acceptable level of risk based on the information available at the time of the inspection (1,2).

As SULE relates to tree health and the surrounding environment, it is not static. Changes in these factors will result in a change to the SULE assessment.

Appendix 1 includes the details of a Safe Useful Life Expectancy assessment and SULE categories for retention or removal.

It is essential to survey trees and locate them accurately on the site plan, measuring and showing branch spread as it actually is (not as perfect circles) (4). The site survey should map and include all trees and vegetation, noting and drawing the canopy spread then shading an area 1.5 times the canopy spread to represents a guide to the amount of root space which will need protecting. This area constitutes the *protection zone*. As this method may underestimate actual root spread, Appendix 2 notes other methods for determining the protection zone.

Photograph trees noted for retention as part of the survey process. This serves as a record of their success or failure in the long term.

6.1.2 Site Survey

The site survey should include all relevant site features including existing trees as described in 6.1.1. Overlaying existing development plans with the site survey will clearly identify the likely impact of the development on the existing vegetation. The development plans should include all service easements (above and below ground), buildings, roadways, and any level changes. If retaining certain vegetation nominated as important, it is necessary to alter the design at this stage and or put measures in place to protect the trees.

If additional landscaping of the site is to occur, thought should also be given to identifying areas to be landscaped (where no trees to be retained exist) and protecting them from construction activities. It can be very difficult to remediate sites that are extremely compacted or contaminated during construction.

If the development plans have not yet been finalised, relocating buildings, services, etc may enable the retention of desirable vegetation.

6.1.3 Trees to be retained or removed

The tree survey and the constraints of the proposed development form the basis for sorting the trees on site into categories relating to their potential for retention or removal. Use colour coding on plans as well as on site to indicate these trees. See Appendix 1 for the categories.

Decisions at this stage are critical for the long-term survival of the tree. Where it is not possible to sensibly alter the plan to protect the minimum required root space for a tree considered worthy of retention, then tree removal should occur.

Particular attention should be paid to the safe, useful life expectancy of the trees on the site. Whilst it may be tempting to attempt to retain large, over-mature trees for historical reasons, they may not have the reserves or vigour to withstand the changes in their environment. Similarly, consider removing small trees that are replaceable or transplantable which, if retained, could lead to expensive design or site layout compromises.

Use an acceptable valuation method to value retained trees so that, should damage occur during construction, the relevant contractor can be penalised (see 6.1.5).

6.1.4 Site Planning

Upon identifying the trees for retention in the field and on the plan and siting the location of buildings, services, roads and other infrastructure on the plan, designation of construction and protection areas is necessary. Apart from buildings, services, roads, etc, construction plans should clearly indicate the following:

- location of protective fencing around trees (this should also include trees on adjacent properties whose roots or crowns will be within the construction area);
- location of future landscaping sites with the possible designation of "no go" areas;
- location of site sheds;
- materials storage areas;
- areas for stockpiling of excavated soil;
- designated transport routes and parking areas;
- designated areas for the disposal of materials such as fuels, oils, concrete waste etc; and
- refuelling areas

Section 6.2A covers specifications for these activities.

6.1.5 <u>On-site personnel</u>

Apart from the design and project management team, **all** construction personnel (supervisors, contractors, sub-contractors, labourers, machinery operators, truck drivers etc) must be made aware of the importance of the trees remaining on site and the need to protect them. Consider the following points to ensure this:

- include all penalties for damage to nominated or protected vegetation in all contracts;
- include clauses that state the actions that constitute a breach of the conditions of protection in contracts;
- issue all personnel with a modified version of this document detailing the importance of trees, the methods of protection in place and precautions to be taken when working near trees;
- place large signs at all vehicular entry points and site offices warning of the need to protect the trees on site and noting the penalties that apply; and
- place signs on the fencing around protected trees; these should state that this is a restricted area, no entry unless in the company of the arborist...

An arborist should therefore be on site to monitor works and supervise the protected areas. The establishment of fines is an important deterrent to violations of the protected areas (13,14). Without the fines and the supervision, there is often nothing to prevent construction personnel from moving fence limits or temporarily removing the fence and working around the tree.

6.2 Construction stage

A: Prior to building and road works

6.2.1 Remedial works, tree removal

Remove trees nominated for removal and their stumps before any other site activities commence. When removing a single tree from a group of trees, grind the stump, as mechanical removal could damage remaining root systems.

Engage a suitably qualified and experienced arborist to undertake any specified pruning work including removal of dead wood and branches at risk of damage by construction work or vehicle access, pruning branches to the branch collar. Specify and carry out all pruning works according to AS 4373-1996 Australian Standard *Pruning of Amenity Trees*.

6.2.2 Installation of protection devices.

Determine and mark the protection zone for each tree (see Appendix 2), and survey and mark building, road and service easements on site. Survey and peg proposed changes of levels. Once this has occurred, proceed with protective devices and measures under the direct supervision of an arborist.

In general, site sheds, car parks, soil and materials storage areas, cement wash-out areas, refuelling areas and chemical holding and disposal areas should all be located well beyond the protection zone of any tree, even if the tree is fenced.

6.2.2.1 *Fencing*

Fence off all trees noted for retention (and if possible, any future landscaping sites) with 1.8m steel mesh fencing at the perimeter of the designated protection zone. Authorised access to the protected zone could be through a locked gate or via ladders. Take care not to damage woody roots and branches during the erection of the fence.

Attach signs relating to the importance of tree protection and penalties for breaching tree protection orders to the fencing. If the area is large, install multiple signs.

6.2.2.2 *Irrigation*

Provide for irrigating the protection zone. If it is possible to supply mains water from hoses or fixed pipes, engage a licensed irrigator to install a drip irrigation system under the supervision of the arborist. Lay the irrigation lines on the soil surface and cover them with mulch. No trenching should occur. Mark the position of the drippers with a short stake to enable checking of the system.

If it is impossible to use hoses or fixed pipes on site, provide irrigation by water tanker. Reference (6) is a useful guide to the quantities of water that trees may require.

6.2.2.3 *Mulching*

Mulch the area within the fence to 100mm depth of with a non-toxic organic material such as wood chips.

Also mulch future planting areas outside of fenced areas that may be subject to construction traffic, storage of materials or parking to 150 mm with woodchips (14, 17,18)

6.2.2.4 *Boarding of temporary roadways etc*

If vehicle access is necessary adjacent to a fenced protection zone, and where the protection zone has had to be reduced to accommodate a temporary road, the road surface should be boarded to a distance agreed to by the arborist and the project manager. Boarding intends to minimise the impact of compaction. Lay timber boards or interlocked steel plates on 100 - 150 mm of mulch or gravel on a geotextile base to allow easier clean up. An alternative to boards would be 150mm of mulch or 100mm of gravel on a geotextile base (17,18).

If scaffolding is necessary close to or within a protection zone, erect additional fencing to provide sufficient space for the scaffolding. Leave the ground between the fence and the building works undisturbed and protected by boarding. Cover the ground first with geotextile fabric and then a layer of sand (50mm plus) to allow levelling of the boards. Leave the boards in place until the building works are completed (4).

6.2.2.5 *Root pruning*

(i) *Tree to remain at same grade*. If excavations are to take place adjacent to the fenced protection zone, then roots should be pruned at least 300mm inside the fence (this may have to be done before the fence is erected). Trenching and excavation by conventional means tends to crush and tear roots. Root pruning with a concrete cutter or specialised root-pruner cuts roots cleanly. As roots regenerate from the severed end, selective root pruning and suitable maintenance will allow some regeneration of roots during the construction process (13). Engage an arborist to carry out or supervise all root pruning.

(ii) *Tree to be substantially above grade during or after site works.* In this instance, consider the stability and integrity of the protection zone. In cohesive (clay-based) soils, it may be possible to excavate the soil first, cut the roots cleanly and then shore up the cutting with timber or similar. If there is a risk of the soil collapsing and thus damaging more of the root system, then sheet-piling may have to be considered. Care should be taken to ensure that the installation (and later the removal) of the sheet-piling does not damage the crown.

B: During construction

6.2.3 Monitoring, maintenance and notification

Depending on the number and location of trees to be protected and the stage of the construction, the arborist may need to be on site on a daily basis or less frequently but regularly. The arborist should be readily contactable should access be required to particular trees or there is a tree-related problem. A schedule of trees should be produced and records of inspection kept for each tree on each visit. Systematically record any damage or necessary treatments and attach relevant photographs.

The arborist should be on site during critical phases such as any excavation, trenching or boring works carried out near or within protection zones.

The arborist should notify the project manager or site supervisor should there be a breach of the tree protection conditions. Should damage occur, impose the pre-determined fine on the responsible contractor.

Maintain mulch levels to a depth of 100mm. Inspect irrigation systems and maintain moist soil conditions at all times.

6.2.4 Trenching, boring and root pruning

Trenching for underground services, especially if carried out close to the trunk can cause major damage to root systems. In some instances, underground services may have to pass through the protection zone around a tree. The closer the trench is to the tree the greater the impact on the tree. Table 1 gives the minimum distances from the trunk for the location of trenches, based on tree trunk diameter at breast height (dbh).

Under-boring (also known as directional boring, or augering) can be used instead of or in conjunction with trenching and causes minimum damage to roots if the minimum distances in Table 1 are adhered to. This technology is now widely available.

Tree diameter (dbh) mm	Auger distance from trunk mm or metres
0-50	300mm
50-100	600mm
100-250	1.5m
250-400	3.0m
400-500	3.6m
over 500	4.5m

Table 1: The distance from the trunk (in any direction) at which trenching should cease and under-boring should commence. The depth should be at least 500mm. (After Morell (21) and Watson (34).

Note: Should the arborist consider that trenching could damage roots of more than 75 mm diameter at the limits suggested by Table 1, dig trenches by to locate the limits of trenching.

Apart from trenching, the arborist must supervise any excavation close to or within the protection zone of the tree. Cut all roots cleanly. As cutting any roots will lead to temporary and or permanent loss of vigour, investigate the size and position of the targeted roots by hand digging before using any machinery. Note that the rate and longevity of root regeneration from the severed ends depends on many factors including temperature, moisture and aeration. In some cases, the fate of generated roots depends on the age and diameter of the severed root. Large roots, when severed, may produce no roots from near the injured surface for five years. In contrast, small roots, when severed can produce (depending on what media they grow into) dominant new roots that can grow vigorously, thus forming a new root system (33).

After trenching or augering, install the services as soon as possible and backfill the hole. Replace the excavated material in its original order, that is, subsoil first and then topsoil. Take care not to mix soil horizons. It is acceptable to mix 50mm of organic matter such as cow manure into the top 100mm of backfill. Place no organic matter below this level. Treat the severed roots with a liquid rooting hormone at the manufacturer's recommended rate.

6.2.5 Remedial works

Remove any damaged or dangerous branches to the branch collar as per AS 4373-1996.

6.3 Post-development

Upon completing construction activities and subsequent landscaping works, the ideal situation is that the trees retained on the site will continue to grow and perform the functions for which they were retained. In order for this to occur, the root environment must be favourable for growth.

6.3.1 Removal of protective fencing etc.

Once construction works are completed, and before final soft landscaping works, remove protective fencing, sheet piling and or boarding from the trees, taking care to avoid mechanical injury or compaction. Engage the arborist to supervise this work.

6.3.2 Tree inspection

The arborist should conduct a final construction stage inspection to note any damage to trees and or breach of contract. If this has occurred, photograph the tree and notify the project supervisor and relevant contractor. Note any remedial actions required.

6.3.3 Mitigation of any damage

(i) Pruning:

Carry out all pruning according to the arborist's specifications and in compliance with the Australian Standard: *Pruning of Amenity Trees* AS 4373-1996.

(ii) Decompaction:

Soil compaction due to grading, vehicle movements and construction activities is a common cause of tree decline post-construction. Decompact the soil beyond the protected area to encourage healthy tree growth. This also applies to areas that may have been set aside for future landscape works.

Appendix 3 details a number of decompaction methods.

6.3.4 Landscape works

Any soft landscaping works necessary within the protection zone should be minimal, as the installation of other plants will damage tree roots. Similarly, the use of skid-steer vehicles or other machinery to spread mulch etc could also compact the previously protected soil and root zone.

6.3.5 Maintenance

Where possible, extend mulching and irrigation beyond the protection zone to encourage the development of new roots. Maintain mulch to 75-100mm. Depth. Monitor irrigation and maintain the soil in a moist condition.

6.3.6 Monitoring

For the first year post completion of the project, inspect the trees on a monthly basis by the arborist, note any necessary actions and refer them to the site manager. Depending on the performance of the trees in their new environment, the inspection period can be extended to every three months in the second year and then every six months for ever after.

7.0 SUMMARY.

Apply the following if retaining trees on development sites:

1. Engage a suitably qualified and experienced consulting arborist to conduct a pre-development tree survey to determine the existing condition of the trees and their worthiness for retention. Note hazardous or moribund trees for removal and requirements for remedial treatments to retained trees. Estimate the safe useful life expectancy of each tree.

2. The arborist must present the arborist's report to the design team. If tree preservation is an important component of the development, then compromises in design may be necessary with regard to the long-term viability of trees noted for retention.

3. After agreement between all relevant parties (including the arborist), survey and locate tree protection zones, construction, storage, transport easements etc areas on site.

4. Put tree protection measures in place before any other site works commence.

5. Make all on-site personnel aware of their responsibility to protect trees and to observe the protection measures. Penalty clauses and monetary fines may be a component of any contracts.

6. The arborist is to be on site for any critical construction activities that may take place near the protection zones.

7. The arborist should regularly inspect and monitor the condition of the trees and the observation by others of the protection zones. Maintain trees and protective measures throughout the entire length of the project.

8. Before the final soft landscaping of the site, remove the protective fences and undertake any remedial works such as decompaction.

9. The arborist must inspect the trees with the project manager for damage when all works are completed and before handing over the site.

10. The arborist must regularly inspect all retained trees on site and carry out any necessary remedial works post completion, and for a pre-determined period.

Figure 5 is a flow chart from BS 5837: 1991 which summarizes planning for trees on development sites.

8.0 CONCLUSION

To successfully retain trees for the long term on development sites, it is essential for the process start at the pre-development stage. Failure to plan, cost and implement realistic protective measures usually results in irreparably damaged trees. Such damage usually results in hazardous, declining trees that are impossible to treat and which become costly liabilities.

The effectiveness of measures to protect trees and ensure their healthy survival through development ultimately depends on co-operation between site owners, managers, and the design and construction teams.

BS 5837:1991

BRITISH STANDARD
GUIDE FOR TREES IN RELATION TO
CONSTRUCTION

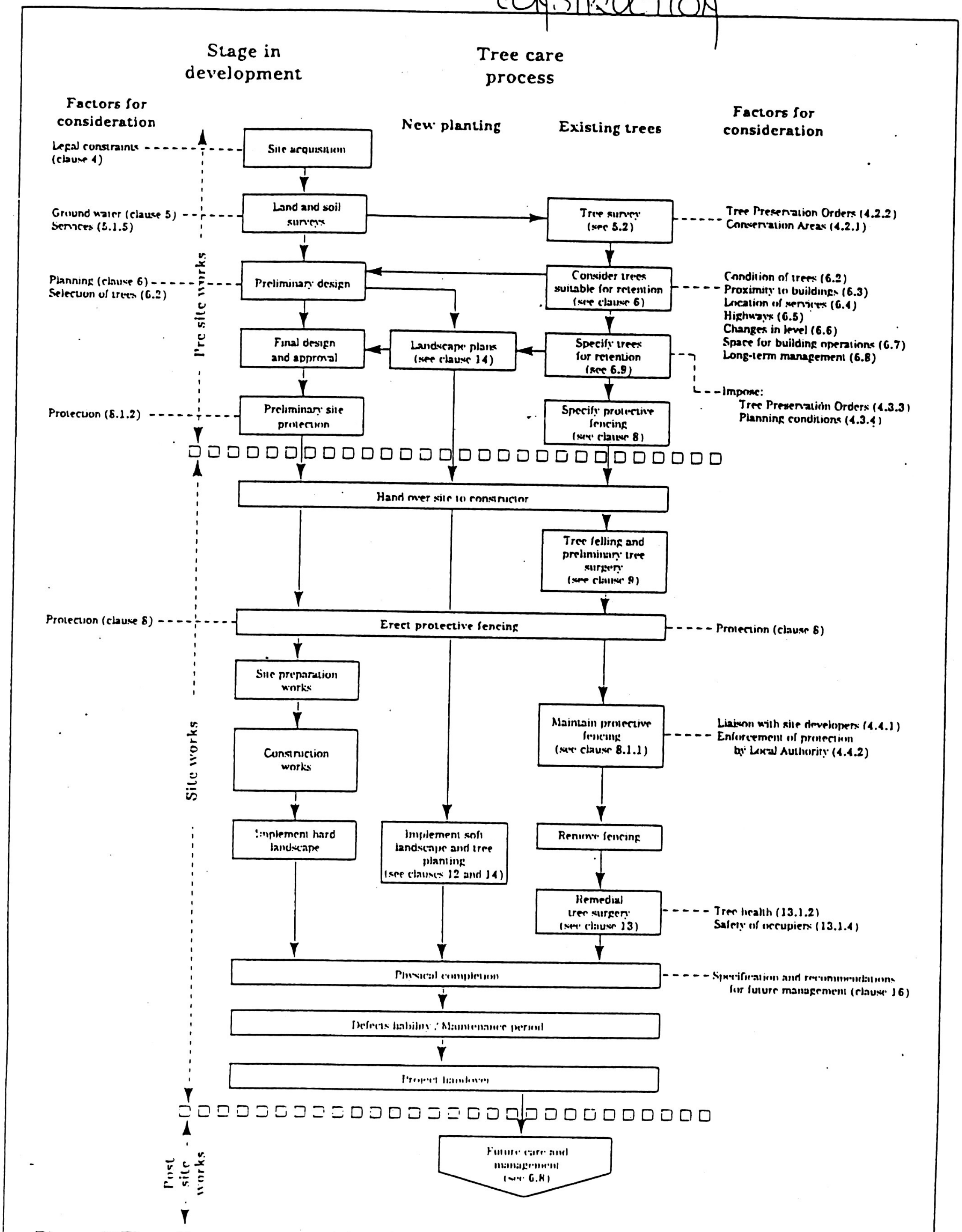


Figure 5 Flow diagram, summarizing planning for trees on development sites

9.0 REFERENCES

1. Barrell, J. (1993) "Pre-planning tree surveys: Safe Useful Life Expectancy (SULE) is the natural progression", *Arboricultural Journal:* 17: pp33-46

2. ________ (1995) "Pre development Tree Assessment" in Trees and Building Sites, Ed. G.W. Watson and D. Neely, International Society of Arboriculture, Savoy, Illinois.

3. Bernstsky, A. (1878) Tree Ecology and Preservation. Elselvier Publishing, New York.

4. British Standards BS 5837 (1991) Guide for Trees in Relation to Construction. BSI

5. Coder, K.D. (1995) "Tree quality BMPs for developing wooded areas and protecting residual trees", in Trees and Building Sites, Eds. Watson and Neely, International Society of Arboriculture, Savoy, Illinois.

6. Connellan, G. (1991) "Tree irrigation - a logical approach", in Trees: Management Issues for Urban Australia, Proceedings of the 1991 National Tree Seminar, Royal Australian Institute of Parks and Recreation, Canberra.

7. Craul, P.J. (1992) Urban Soil in Landscape Design, John Wiley and Sons, New York.

8. ________ (1994) "Soil compaction on heavily used sites", Arboricultural Journal 20(2): 69-74.

9. Culter, D.F. (1993) "Interactions between tree roots and construction work", Arboricultural Journal 17: 47-55.

10. Day, S.D. and Bassuk, N.L. (1994) "A review of the effects of soil compaction and amelioration treatments on landscape trees", Journal of Arboriculture, 20(1): 9-17.

11. Gilman, E.F, 1989 "Predicting root spread from trunk diameter and branch spread", Arboricultural Journal, Vol 13, pp 25-32.

12. Grabosky, J and Bassuk, N (1995) "A new urban soil to safely increase rooting volumes under sidewalks", Arboricultural Journal: 21(4): 187-201.

13. Green, T.L. and Young, P (1995)"Parkway tree protection program", in Trees and Building Sites, Eds. Watson and Neely, International Society of Arboriculture, Savoy Illinois.

14. Harris, R.W. (1992) Arboriculture: Integrated management of landscape trees, shrubs and vines. Second Edition.
Prentice Hall, New Jersey.

15. Kalisz, P.J, Stringer, J.W and Wells, R.J (1994) "Vertical mulching of trees: effects on roots and water status",
Arboricultural Journal: 20(3): 141-145.

16. Kozlowski, T.T (1992) "Growth of tree roots in urban environments", in Scientific Management of Plant in the Urban Environment, Proceedings of the Burnley Centenary Conference.
The Centre for Urban Horticulture, Melbourne.

17. Lichter, J.M and Lindsey, P.A (1994a) "The use of surface treatments for the prevention of soil compaction during site construction",
Arboricultural Journal: 20(4): 205-209.

18. ________________________ (1994b) "Soil compaction and site construction: Assessment and Case Studies', in The Landscape Below Ground, Eds. Watson and Neely,
International Society of Arboriculture, Savoy, Illinois.

19. Matheny, N.P. and Clark, J.R. (1994) A Photographic Guide to the Evaluation of Hazard Trees in Urban Areas, Second Edition,
International Society of Arboriculture, Savoy, Illinois.

20. Miller, F.D (1994) "The effect of trenching on growth and overall plant health of selected species of shade trees". In The Landscape Below Ground, Eds. Watson and Neely,
International Society of Arboriculture, Savoy, Illinois.

21. Morell, J.D. (1984) "Parkway Tree Augering Specifications",
Arboricultural Journal, 10 (5): 129-132.

22. O'Callaghan, D (1989) "Remedial tree work- a long term investment",
Arboricultural Journal 13: 303-311.

23. O'Callaghan, D and Lawson, M (1995) "Trees and Development Conflicts: The importance of advance planning and site control in tree preservation plans" in Trees and Building Sites, Eds. Watson and Neely,
International Society of Arboriculture, Savoy, Illinois.

24. Patterson, J.C and Bates, C.J (1994) "Long term, light-weight aggregate performance as soil amendments", in The Landscape Below Ground, Eds. Watson and Neely,
International Society of Arboriculture, Savoy, Illinois.

25. Perry, T.O (1982) "The ecology of tree roots and the practical significance there-of",
Arboricultural Journal: 8: 197-211.

26. ________ (1994) "Site design and management of tree planting sites", in The Landscape Below Ground, Eds. Watson and Neely, International Society of Arboriculture, Savoy, Illinois.

27. Rolf, K (1994a) "A review of preventative and loosening measures to alleviate soil compaction in tree planting areas" Arboricultural Journal, 18: 431-448.

28. ______ (1994b) "Soil compaction and loosening effects on soil physics and tree growth', in The Landscape Below Ground, Eds. Watson and Neely, International Society of Arboriculture, Savoy, Illinois.

29. Schnelle, M.A, Feucht, J.R, Klett, J.E., 1989 "Root systems of trees-facts and fallacies", Arboricultural Journal 15(9): September, 1989.

30. Shigo, A.L (1986) A New Tree Biology, Shigo and Trees ,Associates, Durham, New Hampshire.

31. Smiley, E.T. (1994) "The effects of soil aeration equipment on tree growth", in The Landscape Below Ground, Eds. Watson and Neely, International Society of Arboriculture, Savoy, Illinois.

32. Wargo, P.M., 1983 "Effects and consequences of stress on root physiology", Journal of Arboriculture, 9(7): July, 1983.

33. Watson G.W (1994 "Root development after transplanting", in The Landscape Below Ground Eds. Watson and Neely, International Society of Arboriculture, Savoy, Illinios.

34. _________ (1995) "Tree root damage from utlility trenching", in Trees and Building Sites, Eds. Watson and Neely, International Society of Arboriculture, Savoy, Illinois.

APPENDIX 1:

TREE SURVEY
SAFE USEFUL LIFE EXPECTANCY
CATEGORIES FOR RETENTION OR REMOVAL

Note: A suitably qualified and experienced arborist should carry out these assessments.

This appendix has referred to references 1,2,4,12,19.

(i) Tree inspection schedule:

There are many methods and many criteria which could be assessed. This is an example of a comprehensive survey.

- *Inspected by:*
- *Date:*
- *Tree no. on site survey:*
- *Tree species:*
- *Diameter at breast height (dbh): / no. of trunks:*
- *Height:*
- *Canopy spread:*
- *Age class:* Young/ Semi-mature/Mature/ Overmature or senescent
- *Condition of foliage:* normal/ sparse/necrotic/ chlorotic
- *Extension growth:* poor/ average/ excellent
- *Deadwood:* %/ normal/ dieback/ large limbs/ extensive
- *Trunk condition:* poor/ average/ excellent; % damage
- *Root condition:* exposed/ soil build-up/ trenching/ paving/wounded/ no obvious problems.
- *Presence of defects:* decay/termites/cavities/fruiting bodies/ cracks or splits/ included bark/ previously lopped/ hanging branches/ previous failure.
- **Relevant site history:* level changes/ paving/ trenching/ buildings/ compaction.
- *% of rootzone affected by previous site works.*
- *% of rootzone likely to be affected by proposed works.*
- *Treatment required if tree were to be retained:*
- *Comments:*

(ii) Safe Useful Life Expectancy (SULE) (after Barrell (1,2)).

SULE is the length of time an arborist assesses an individual tree can be retained with an acceptable level of risk based on the information available at the time of inspection. SULE is not static and is closely related to tree health and the surrounding conditions. Alterations to the variables may result in changes in the SULE assessment. SULE may have to be reassessed if a significant amount of time passes from the initial inspection to the eventual development.

Once a tree survey has been carried out (as described above), the arborist would then estimate the remaining life expectancy. This can be difficult if it is not known how long a particular species may live for in a particular location, however, the exercise is very useful for categorising which trees have the best chance of long term survival once construction is completed.

(iii) Categories for retention or removal. (1,2,4)

The trees in each category could be colour coded both on site plans and on the ground. These categories are adapted and modified from BS 5837:1991 (4) and Barrell (1 and 2).

Category A: *Trees whose retention is most desirable; long safe useful life expectancy - retainable with an acceptable level of risk for more than 40 years. High category; long SULE*

i) structurally sound trees of good form in positions that are compatible with the proposed development and where future growth can be accommodated.

ii) trees for screening or softening the effect of existing structures in the near vicinity, or of particular visual importance to the locality.

iii) trees of special significance for historical, commemorative or rarity reasons that would warrant extraordinary efforts to secure their long term retention.

Category B: Trees whose retention is desirable or that would be retainable with an acceptable level of risk for 15-40 years. Moderate category; medium SULE.

i) trees that may only live for another 15-40 years.

ii) trees that might live for more than 40 years but which have defects which may lead to their removal within this period.

iii) trees which may live more than 40 years but which would be removed to allow the safe development of more suitable individuals.

iv) storm damaged or defective trees which can be made suitable for retention in the medium term by remedial treatment.

v) immature trees with potential to develop into the high category.

Category C: *Trees that could be retained or those with an acceptable level of risk for 5-15 years. Low category; short SULE.*

i) trees that may only live for 5-15 years

ii) trees that may live for more than 15 years but which have defects that would lead to their removal within this period

iii) trees that may live for more than 15 years but which would be removed to allow the safe development of more suitable individuals

iv) damaged or defective trees which warrant remedial work for their short term retention

v) immature trees of no particular merit

Category D: *Trees to be removed*

i) dead trees

ii) unstable or structurally defective trees with a high hazard rating

iii) trees which will be impossible to retain or irreparably damaged by construction activities where no realistic compromise is possible

Trees can be coded in reports and on site plans; eg. Tree 15, *Ficus rubiginosa* Category B (ii).

APPENDIX 2:

DETERMINING THE PROTECTION ZONE

The protection zone is the area around trees to be retained that is to be fenced or protected from all construction activities. The methods below are used to calculate the position of the fence.

Various authors give varying calculations for determining the protection zone around trees (3,4,5,14). All methods underestimate the actual root systems of trees but are guides to the **minimum** distances from the trunk that should be protected. It has been found that trees within 9-10 m of major constructions are seriously compromised in their long term survival.

Where as much of the root system beyond these measurements can be protected from construction activity, it should be. Compromises may have to be made on site. The minimum area to be protected should be the edge of the secondary root system. This can only be determined by hand digging or the use of hydraulic excavation techniques. If the areas specified below are encroached upon on one side by construction activities, an equivalent area should be protected on the remaining sides.

i) Diameter at breast height (dbh):

For every 25 mm of trunk diameter (measured at 1.5m high), allow 450 mm of space away from the trunk (radius distance). The minimum for any tree less than 100 mm dbh should be at least 1.8m. If this falls within the drip line (ie. outer edge of the canopy), additional protection to at least 2m beyond the drip line should be provided by mulching to 100-150 mm deep. Care must also be taken not to damage the foliage which may overhang the fence.

ii) Drip line:

Dripline in metres multiplied by 1.5 (radius distance). The protection of the dripline should at least protect the canopy of the tree.

APPENDIX 3

DECOMPACTION

Whilst compaction is always best avoided by adequately fencing and protecting trees and soils, it is not always possible on construction sites. Even if areas have been fenced off, decompaction is necessary to promote root growth beyond the protection zone once construction works have been completed. The following recommendations are based on current research (7,8,10,12,15,17,18,31). Figure A summarises the general effects of soil compaction.

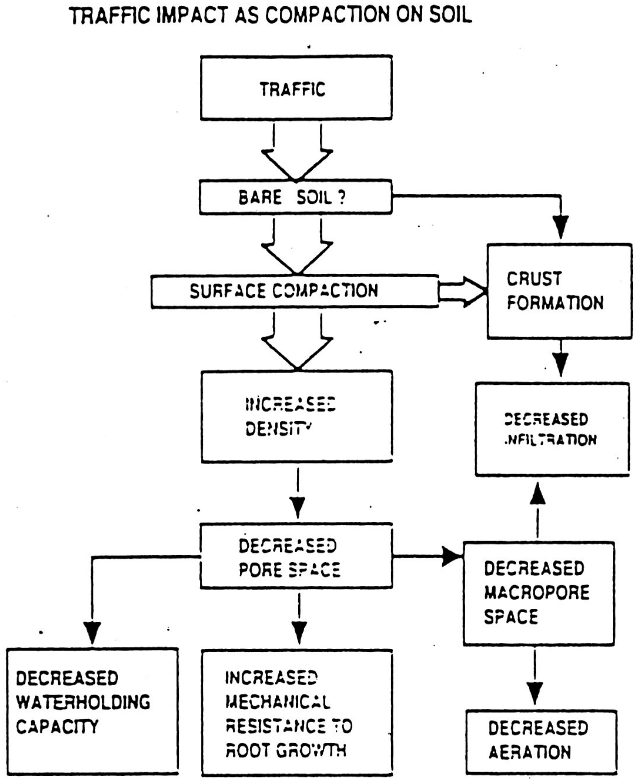


Figure A: The general effects of soil compaction (Craul, 1994)

i. Remedial techniques around existing trees.

The use of equipment to either inject air and or water into soils under pressure has been shown to be of little value in improving growth rates of trees in compacted soils. The most promising treatment appears to be the digging of radially arranged trenches back-filled with friable soil (see Figure B). The excavation must be carried out carefully to avoid woody roots. "Sand-slitting" would be an alternative in some instances but instead of sand being placed in the slits, the loosened soil should be replaced. Sand is not recommended as a back-fill as it can lead to water movement problems.

The back-fill could include rigid, highly porous, inert material such as sintered fly ash at up to 30% by volume. (Sintered fly ash is a manufactured by product of fly ash from coal burning power stations.) It has been shown to withstand compaction over a 22 year study period (24).

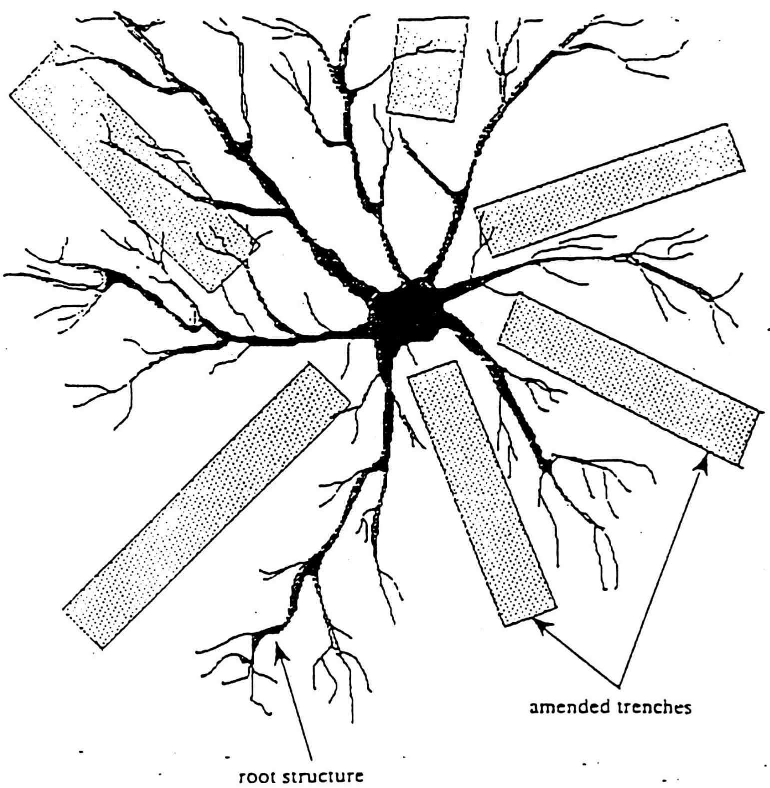


Figure B: Radial trenching (after Craul, 1994).

ii. Decompaction of future landscape sites where there are no trees or where root damage would be negligible.

Subsoiling (Figure C) using agricultural subsoilers or deep rippers is possible but the effects may be relatively short term depending on the subsequent use of the amended site. Soils should be ripped to at least a depth of 500mm.

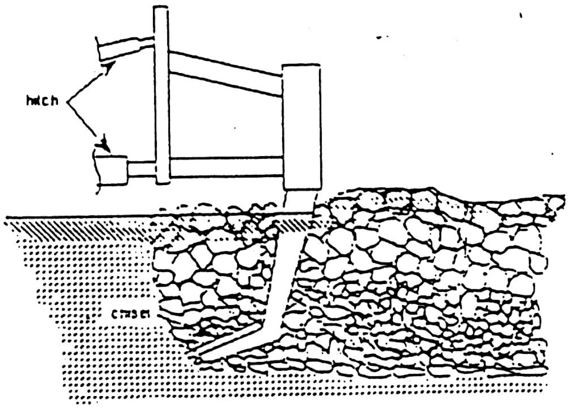


Figure C: Subsoiling or ripping (after Craul, 1994).

A more successful method has been the use of a backhoe or excavator to loosen and crack subsoils (27,28) (Figure D). Before replacing stock piled top soil, the bucket of a backhoe or excavator is lowered to the required depth, the bucket is lifted up and then shaken and then the soil is dropped back in the hole. The soil is not turned over in this process and significant cracking is created. When the top soil is replaced it fills some of the cracks and allows good root penetration. Once the excavator has replaced the soil it moves away from (and not over) the loosened soil. The replacement of the topsoil should occur with the minimum of traffic.

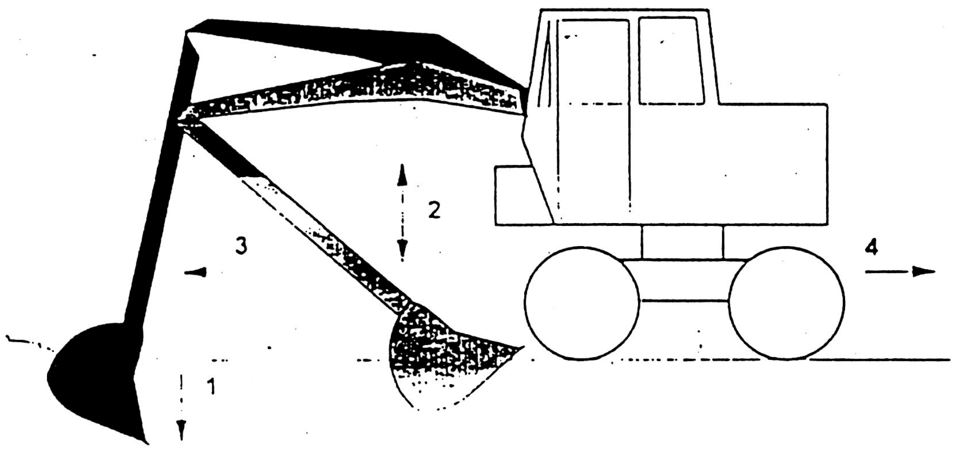


Figure D: The use of the excavator; the soil is dug shaken and then replaced (after Rolf, 1994).

iii. Preventative measures in areas where extensive foot or other traffic is expected.

The amendment of site soils with 20 - 33% by volume of sintered fly ash or very similar material is highly recommended. As already stated, this material has shown excellent results over long periods of use in trials in the USA in areas of high pedestrian traffic.

In conclusion it should be re-stated that prevention of compaction by adequate protection from heavy machinery is far more successful than remedial treatments, particularly in the case of existing trees.