





Hastings District Council

Arboricultural review and tree survey for Keirunga Gardens

Arboricultural risk and condition assessment and management plan. Keirunga Gardens, Arthurs Path		
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1. Executive Summary

- 1.1. Hasting's District Council (HDC) has taken the proactive step of assessing the condition and risk posed by the trees alongside Arthur's Path in Keirunga Gardens, Havelock North. HDC has previously engaged a tree expert to assess the trees and create a draft tree management plan on which public consultation has been sought.
- 1.2. Arborlab have been engaged to peer review the draft tree management plan and assess the risk posed by the trees, assess their health and condition in order to comment on the draft management plan.
- 1.3. The trees have been assessed and an annual risk of harm provided for each tree in accordance with the Quantified Tree Risk Assessment (QTRA) model. Based on the risk posed and the condition of the trees, management recommendations have been proposed. The highest annual risk of harm was found to be broadly acceptable.
- 1.4. The management of trees in urban areas is often difficult with many influencing factors, all of which require attention and thought when developing tree management plans. Urban forestry, as this is known, is the care and management of single trees and tree populations in urban settings for the purpose of improving the urban environment. Urban forestry advocates the role of trees as a critical part of the urban infrastructure. In particular they often form the framework of urban parks, reserves and streets.
- 1.5. The above concepts have been considered and remedial pruning and proposed removal recommendations have been made to provide proactive tree management solutions. In addition, the management of the woodland group has been considered, rather than just tree by tree actions. This is to ensure the amenity and woodland feel of this portion of Keirunga Gardens is not adversely affected and can continue to be enjoyed while the tree asset is proactively managed and enhanced.
- 1.6. These proposed pruning and removal recommendations have been used to create a longer-term tree management plan over 10 years, with suitable review periods to ensure the effectiveness of the proposal and make any necessary changes. These new recommendations include crown reduction pruning specifications to allow the retention of the majority of the mature oak trees.

2. Introduction

- 2.1. Arborlab Consultancy Services Ltd has been engaged by Hasting District Council to undertake an independent arboricultural risk assessment of the trees alongside Arthur's Path, Keirunga Gardens, Havelock North.
- 2.2. In addition, a review of the proposed draft tree management plan was requested to be carried out to inform the draft tree management plans recommendations. The long term management of the Woodland Walk has been considered with a particular focus on increasing species diversity. A framework of large trees needs to be retained when diversifying the species. This will ensure the amenity provided by the trees is retained for people to enjoy this section of the reserve while new planting is established.

- 2.3. When managing a large tree stock it is important to consider the resilience of the overall stock as well as the individual tree. A key way to provide a resilient tree stock is to encourage a diverse array of species and age classes. The general rule when considering diversity of an urban forest is to aim for no more than 30% of a single family, no more than 20% of a genus and no more than 10% of a species (Frank S. Santamour. Jr, 2002).
- 2.4. Following the risk assessment, review and public feedback a draft tree management plan is to be presented to Council for consideration, for the woodland area alongside Arthur's Path.
- 2.5. The findings and recommendations contained herein are based on a visual ground based assessment of the trees undertaken during site visits by Mr David Spencer of Arborlab, following a briefing with Mr Leslie of Hastings District Council.

3. Site details and background

- 3.1. The trees are located within Keirunga Gardens alongside Arthur's Path, which is also known as the Woodland Walk. The below map shows the location of the site within Keirunga Gardens.



Figure 1: The Woodland Walk is marked as area 4 within Keirunga Gardens

- 3.2. Keirunga Gardens was gifted to the people of Hastings and contains heritage buildings, a play area, miniature railway and numerous tree and garden areas. It has been described as a parkland, with many mature exotic trees, in a woodland setting with paths winding around the hillside.
- 3.3. The Woodland Walk or Arthur's Path form a prominent portion of the gardens, which is enjoyed by walkers and people exercising their dogs for the most part. It is considered to be impressive and unique and should be retained and enhanced.

- 3.4. Arthur's Path is a woodland walk and has been typically maintained as such. This is not considered a formal area of the gardens and as such does not require high levels of formative pruning. The tree maintenance carried out to date seems to have been to clear fallen trees and keep paths and boundaries clear.
- 3.5. The Keirunga Gardens Management Plan states "*Keirunga Gardens contains a wide range and large number of trees, which form an important part of the environment, by contributing to its recreation, landscape, heritage and amenity value.*" The trees in the gully were planted by Mr and Mrs Reginald Gardiner. These plantings have matured and make up the framework of this portion of the reserve.

4. Scope and limitations

- 4.1. All observations were made from ground level only. Tree heights and canopy spreads were recorded using a digital laser range finder (Nikon Forestry Pro). Trunk girth measurements were estimated using the surveyors experience.
- 4.2. No decay detecting equipment was used as part of the inspection process. All comments and recommendations that have been discussed and provided are based on the visual observations recorded during the site visit.
- 4.3. Where appropriate, the lower parts of stems were tested with a sounding hammer. This is done to help the surveyor detect acoustic anomalies which are indicative of modification to the wood's properties either caused by decay or the production of dense wood in response to localised stresses. This technique can be limited by loose or soft bark.
- 4.4. Whilst this assessment is thorough it should be noted that trees are dynamic organisms exposed to varying weather conditions, which on occasion can be severe. This is taken into account by assessing the most likely events and not those which could or might occur.

5. Quantified Tree Risk Assessment

- 5.1. Quantified Tree Risk Assessment (QTRA) is an internationally recognised model, which enables accredited users to determine the annual risk of harm (ARoH) from tree and branch failure. The assessment process involves:
- An analysis of the land use adjacent to the tree in terms of its vulnerability to an impact and its likely occupation
 - A consideration of the likely consequences of an impact based on the size of the tree/branch
 - An estimate of the probability that the tree or branch will fail within the coming 12 months (based on prevailing weather conditions for the geographical location)
- 5.2. QTRA expresses the annual risk of harm from tree or branch failure as a probability. Advisory thresholds contained within the QTRA model enable tree owners to determine their 'tolerability' of a given risk and decide what, if any, action is needed to manage the risk.

- 5.3. QTRA's advisory thresholds are based on the Tolerability of Risk Framework (ToR). ToR is a conceptual model developed by the UK's Health and Safety Executive. By considering the magnitude of a risk and the level of societal concern it is likely to engender, ToR enables risks to be categorised into one of three defined 'tolerability regions'
- 5.4. Some risks will be of such magnitude they are simply unacceptable to society regardless of the benefits that might be derived. Others risks are considered to be so insignificant they are regarded as being broadly acceptable in the context of daily life. Other risks will generally be tolerated by society so that the associated benefits can be secured as long as the risk is managed in a way that it is as low as reasonably practical (a concept referred to as ALARP).

Table 1 is an abridged version of the 'tolerability regions' incorporated into QTRA's advisory thresholds. The full version of this information is included as appendix 2.

Tolerability region	Annual of risk of harm	Action
Unacceptable risk	Risks >1/10,000	Works must be undertaken to reduce the risk of harm.
Tolerable risk	Risks between 1/10,000 and 1/1,000,000	Practical steps may be taken to reduce the risk of harm.
Broadly acceptable risk	Risks <1/1,000,000	Risk of harm is already broadly acceptable. No further works required.

- 5.5. Even though QTRA's advisory thresholds provide a robust, proportionate and defensible framework for managing the risk of harm from tree and branch failure the factors and processes which ultimately determine the tolerability of a given risk are dynamic in nature, and can vary, depending on a multitude of factors. This makes it important that tree owners ultimately decide, based on their local circumstances, objectives and priorities what constitutes an acceptable, tolerable and unacceptable level of risk.

6. Visual Tree Assessment

- 6.1. Visual Tree Assessment is used internationally to evaluate the structural integrity and stability of trees.
- 6.2. The model is derived from the principles of biomechanics and uses the tree's growth response and form as a way of detecting and if necessary, investigating potential issues that can increase the likelihood of tree failure or branch failure.
- 6.3. VTA involves observing all parts of the tree visually a looking for signs of structural weakness and assessing any response growth.

7. Duty of Care

- 7.1. The owner of the land on which a tree stands, together with any party who has control over the tree(s) owes a duty of care to ensure:
- That insofar is reasonably practical that people and property are not exposed to unreasonable levels of risk from tree failure.
 - Reasonable care is taken to avoid acts or omissions that cause a reasonably foreseeable risk of injury/harm to persons or property.
- 7.2. The concept of 'a reasonably foreseeable risk of harm' reflects the potential for healthy and structurally sound trees to occasionally fail and the practical limitations associated with identifying any asymptomatic degradation of the wood properties in roots, stems and branches.

8. Main findings

- 8.1. An inventory of the trees at the site is included in table 4 on the following pages. Each tree has been assigned a number which corresponds to the numbered tree plots depicted on the drawing TC-31238-01 to 03 included as Appendix 1.
- 8.2. The following charts 1 and 2 summarise the data obtained through the survey and show the current diversity of the tree asset.

Chart 1: Diversity by genus

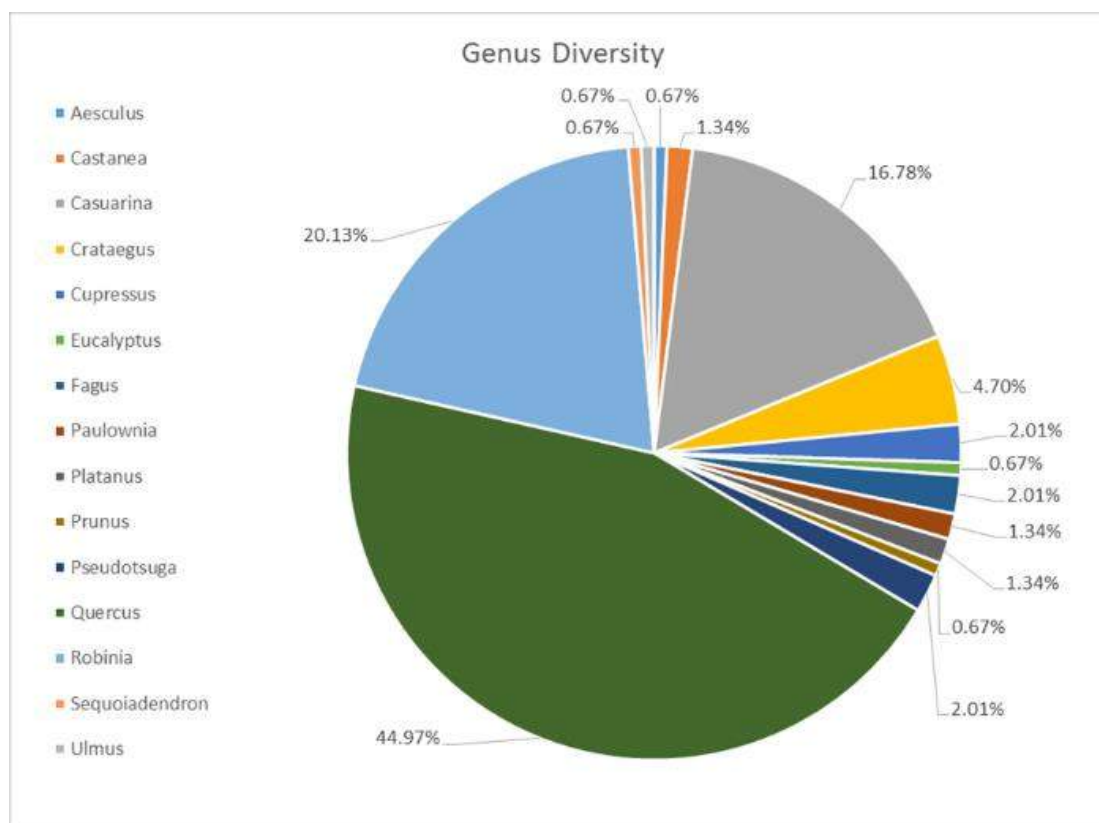
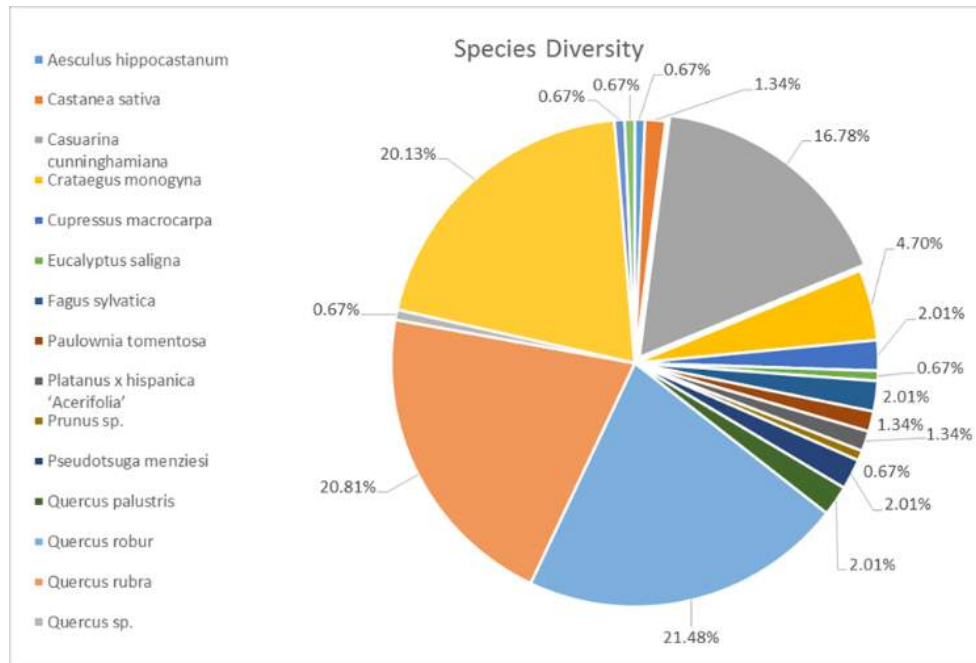


Chart 2: Diversity by species



- 8.3. The graphs show that *Quercus sp.* (Oaks) and *Robinia sp.* (False Acacia) dominate the genus diversity, with *Quercus robur* (English Oak), *Quercus rubra* (Red Oak) and *Quercus palustris* (Pin Oak) all making up over 20% each of the species diversity. The Robinia are weedy throughout the reserve and a removal program has been carried out in part.
- 8.4. There is a recent history of failure of some large oak trees within the reserve alongside Arthur's Path. These failures have occurred in a localised area, approximately half way along the path near trees 22 to 29 and tree 57.
- 8.5. Several areas have been 'opened up' by these failures and therefore provide opportunities for replanting. There are a number of smaller, weedy trees and some semi mature trees alongside the path that would not be considered high value, so could also be removed to create opportunities for new trees to be planted and species diversity increased.
- 8.6. The following Table 2 outlines the proposed work in terms of the pruning and removal work proposed.

Table 2: Proposed removal and pruning outline.

Age Class	Number of Trees	No work required	Crown Reduction	Maintenance Pruning	Removals
Mature	53	28	11	7	7
Semi Mature	24	2	0	5	16
Groups (4)	72	0	0	0	72
Totals	149	30	11	12	95

*There are 4 groups of trees consisting of a total of 72 trees

- 8.7. Included in Table 4 is the year in which any works are proposed to be carried out. If no work is required then this is not applicable.
- 8.8. The pruning and removal works have generally been proposed in four phases.
- Year 1 – The reduction work and maintenance work, with removals of semi mature individual trees and groups of trees to create planting opportunities. No removals of mature trees proposed in year 1.
 - Year 3 – Removal of semi mature individual trees and groups of trees to create planting opportunities.
 - Year 6 – Removal of semi mature trees to create planting opportunities. Removal of 2 mature trees.
 - Year 9 – Removal of semi mature trees to create planting opportunities. Removal of 5 mature trees.
- 8.9. The groups of trees contain weed trees which are in the most part, self sown poorly formed trees or less desirable semi mature trees. They mostly consist of Robinia, Casuarina, Hawthorn and English Oak.
- 8.10. These years could be changed to increase the timespan over which the work is completed. In addition, smaller amounts of work could be carried out each time, with reviews in between, to allow more time for new plantings to establish and the effect of any pruning or removals to be determined.
- 8.11. This can also be adjusted to fit within existing budget proposals or used to create an entirely new budget.
- 8.12. It is however important that the crown reduction work be carried out as part of the first phase in year 1. This is likely to be one of the more expensive operations, but will have the greatest benefit by significantly reducing the likelihood that these trees will fail onto the path or any new plantings.
- 8.13. An engineer's estimate has been provided in Table 3 following for each of the phases;

Table 3: Engineers cost estimate for phased works;

Phases	Year	Cost**
1	1	\$50,000
2	3	\$15,000
3	6	\$20,000
4	9	\$45,000

**Remove all mulch and log wood. No stump grinding.

Table 4: Tree Inventory;

Tree #	Nº trees	Botanical name	Common name	Height (m)	No. stems at 1.4m	Aggregate girth at 1.4m (mm)	CSR (m)	Form	Structure	Health	Age class	Risk of Harm	Proposal	Year
1	1	<i>Quercus robur</i>	English oak / Pedunculate oak	17	1	3800	10	Good	Good	Good	Mature	Broadly Acceptable	NWR	N/A
2	1	<i>Quercus robur</i>	English oak / Pedunculate oak	18	1	3800	10	Good	Good	Good	Mature	Broadly Acceptable	NWR	N/A
3	1	<i>Quercus palustris</i>	Pin oak	20	1	1700	8	Good	Good	Good	Semi-mature	Broadly Acceptable	Remove	3
4	1	<i>Quercus palustris</i>	Pin oak	15	1	1300	6	Fair	Good	Good	Semi-mature	Broadly Acceptable	Remove	3
5	10	<i>Quercus robur</i>	English oak / Pedunculate oak	15	1	1300	6	Fair	Good	Good	Semi-mature	Broadly Acceptable	Remove	3
6	1	<i>Quercus robur</i>	English oak / Pedunculate oak	20	1	3600	10	Good	Good	Good	Mature	Broadly Acceptable	NWR	N/A
7	1	<i>Paulownia tomentosa</i>	Foxglove tree	12	1	1400	5	Poor	Fair	Fair	Semi-mature	Broadly Acceptable	Remove	3
8	1	<i>Paulownia tomentosa</i>	Foxglove tree	11	1	700	3	Poor	Fair	Good	Semi-mature	Broadly Acceptable	Remove	3
9	1	<i>Aesculus hippocastanum</i>	Horse Chestnut	14	1	1300	5	Fair	Good	Good	Semi-mature	Broadly Acceptable	NWR	N/A
10	7	<i>Crataegus monogyna</i>	Hawthorn	9	3	1000	2	Poor	Good	Good	Semi-mature	Broadly Acceptable	Remove	3

NWR – No work required

CSR – Crown Spread Radius

Table 4: Tree Inventory continued

Tree #	N° trees	Botanical name	Common name	Height (m)	No. stems at 1.4m	Aggregate girth at 1.4m (mm)	CSR (m)	Form	Structure	Health	Age class	Risk of Harm	Proposal	Year
11	1	<i>Quercus robur</i>	English oak / Pedunculate oak	16	1	1500	7	Fair	Poor	Good	Semi-mature	Broadly Acceptable	Remove	3
12	1	<i>Quercus robur</i>	English oak / Pedunculate oak	17	1	1300	8	Fair	Fair	Good	Semi-mature	Broadly Acceptable	Remove	3
13	1	<i>Quercus robur</i>	English oak / Pedunculate oak	17	1	1400	6	Poor	Fair	Good	Semi-mature	Broadly Acceptable	Remove	3
14	1	<i>Quercus robur</i>	English oak / Pedunculate oak	20	1	3000	8	Good	Fair	Good	Mature	Broadly Acceptable	NWR	N/A
15	1	<i>Quercus robur</i>	English oak / Pedunculate oak	16	1	1400	7	Poor	Fair	Good	Semi-mature	Broadly Acceptable	Remove	3
16	1	<i>Quercus robur</i>	English oak / Pedunculate oak	18	1	2200	7	Poor	Fair	Good	Mature	Broadly Acceptable	Remove	9
17	1	<i>Castanea sativa</i>	Spanish / Sweet chestnut	18	1	2200	8	Good	Fair	Good	Semi-mature	Broadly Acceptable	NWR	N/A
18	1	<i>Ulmus minor</i>	English elm	7	1	900	3	Good	Fair	Good	Semi-mature	Broadly Acceptable	Crown lift and formative prune	1
19	1	<i>Quercus robur</i>	English oak / Pedunculate oak	10	1	1000	4	Good	Fair	Good	Semi-mature	Broadly Acceptable	Remove	1
20	1	<i>Castanea sativa</i>	Spanish / Sweet chestnut	13	1	2200	6	Good	Fair	Good	Semi-mature	Broadly Acceptable	Crown lift and formative prune	1

NWR – No work required

CSR – Crown Spread Radius

Table 4: Tree Inventory continued

Tree #	N° trees	Botanical name	Common name	Height (m)	No. stems at 1.4m	Aggregate girth at 1.4m (mm)	CSR (m)	Form	Structure	Health	Age class	Risk of Harm	Proposal	Year
21	1	<i>Quercus sp.</i>	Oak	13	1	1800	4.5	Good	Fair	Good	Semi-mature	Broadly Acceptable	Crown lift and formative prune	1
22	1	<i>Quercus rubra</i>	Red oak	27	2	4400	10	Good	Fair	Good	Mature	Broadly Acceptable	Reduce height by 20%	1
23	1	<i>Quercus rubra</i>	Red oak	27	3	5400	10	Good	Fair	Good	Mature	Broadly Acceptable	Reduce height by 20%	1
24	1	<i>Quercus rubra</i>	Red oak	26	1	3000	6	Fair	Fair	Good	Mature	Broadly Acceptable	Reduce height by 20%	1
25	1	<i>Quercus rubra</i>	Red oak	26	2	5000	8	Poor	Fair	Good	Mature	Broadly Acceptable	Reduce height by 20%	1
26	1	<i>Quercus rubra</i>	Red oak	27	4	5600	10	Fair	Fair	Good	Mature	Broadly Acceptable	Reduce height by 20%	1
27	1	<i>Quercus rubra</i>	Red oak	29	1	3800	8	Good	Fair	Fair	Mature	Broadly Acceptable	Reduce height by 20%	1
28	1	<i>Quercus rubra</i>	Red oak	29	1	3000	8	Good	Fair	Fair	Mature	Broadly Acceptable	Reduce height by 20%	1
29	1	<i>Quercus rubra</i>	Red oak	28	1	5200	12	Good	Fair	Good	Mature	Broadly Acceptable	Reduce height by 20%	1
30	1	<i>Quercus rubra</i>	Red oak	28	1	4000	7	Fair	Fair	Good	Mature	Broadly Acceptable	Reduce height by 20%	1

NWR – No work required
 CSR – Crown Spread Radius

Table 4: Tree Inventory continued

Tree #	N° trees	Botanical name	Common name	Height (m)	No. stems at 1.4m	Aggregate girth at 1.4m (mm)	CSR (m)	Form	Structure	Health	Age class	Risk of Harm	Proposal	Year
31	1	<i>Quercus rubra</i>	Red oak	28	1	2800	8	Poor	Fair	Good	Mature	Broadly Acceptable	Reduce height by 20%	1
32	1	<i>Quercus rubra</i>	Red oak	28	1	4200	10	Poor	Fair	Good	Mature	Broadly Acceptable	NWR	N/A
33	1	<i>Quercus rubra</i>	Red oak	28	1	2300	10	Fair	Fair	Good	Mature	Broadly Acceptable	NWR	N/A
34	1	<i>Quercus rubra</i>	Red oak	28	1	4800	10	Poor	Fair	Good	Mature	Broadly Acceptable	NWR	N/A
35	1	<i>Quercus rubra</i>	Red oak	30	1	3200	10	Fair	Fair	Good	Mature	Broadly Acceptable	NWR	N/A
36	1	<i>Quercus rubra</i>	Red oak	28	1	4200	10	Poor	Fair	Good	Mature	Broadly Acceptable	NWR	N/A
37	1	<i>Quercus rubra</i>	Red oak	28	1	4000	12	Fair	Fair	Good	Mature	Broadly Acceptable	NWR	N/A
38	1	<i>Quercus rubra</i>	Red oak	28	2	3600	10	Fair	Fair	Good	Mature	Broadly Acceptable	NWR	N/A
39	1	<i>Quercus rubra</i>	Red oak	28	4	8200	14	Good	Fair	Good	Mature	Broadly Acceptable	NWR	N/A
40	1	<i>Quercus rubra</i>	Red oak	32	1	3800	10	Good	Fair	Good	Mature	Broadly Acceptable	NWR	N/A

NWR – No work required
 CSR – Crown Spread Radius

Table 4: Tree Inventory continued

Tree #	N° trees	Botanical name	Common name	Height (m)	No. stems at 1.4m	Aggregate girth at 1.4m (mm)	CSR (m)	Form	Structure	Health	Age class	Risk of Harm	Proposal	Year
41	1	<i>Quercus rubra</i>	Red oak	30	2	6000	14	Good	Fair	Good	Mature	Broadly Acceptable	Deadwood only	1
42	1	<i>Quercus rubra</i>	Red oak	28	1	4800	13	Poor	Fair	Good	Mature	Broadly Acceptable	Deadwood only	1
43	1	<i>Quercus rubra</i>	Red oak	30	1	2800	10	Good	Fair	Good	Mature	Broadly Acceptable	Deadwood only	1
44	1	<i>Quercus rubra</i>	Red oak	28	1	5500	14	Good	Fair	Good	Mature	Broadly Acceptable	Deadwood only	1
45	1	<i>Quercus robur</i>	English oak / Pedunculate oak	10	1	500	4.5	Poor	Fair	Good	Semi-mature	Broadly Acceptable	Remove	9
46	1	<i>Quercus robur</i>	English oak / Pedunculate oak	13	1	750	4	Fair	Fair	Good	Semi-mature	Broadly Acceptable	Remove	9
47	1	<i>Quercus rubra</i>	Red oak	23	1	3200	10	Good	Fair	Good	Mature	Broadly Acceptable	NWR	N/A
48	1	<i>Quercus robur</i>	English oak / Pedunculate oak	16	1	900	5	Fair	Fair	Good	Semi-mature	Broadly Acceptable	Remove	9
49	1	<i>Prunus sp.</i>	Flowering cherry	10	1	750	4	Poor	Fair	Good	Semi-mature	Broadly Acceptable	Remove	9
50	1	<i>Quercus rubra</i>	Red oak	16	1	900	4	Poor	Fair	Good	Semi-mature	Broadly Acceptable	Remove	9

NWR – No work required

CSR – Crown Spread Radius

Table 4: Tree Inventory continued

Tree #	N° trees	Botanical name	Common name	Height (m)	No. stems at 1.4m	Aggregate girth at 1.4m (mm)	CSR (m)	Form	Structure	Health	Age class	Risk of Harm	Proposal	Year
51	1	<i>Sequoiadendron giganteum</i>	Wellingtonia	28	1	1800	6	Fair	Fair	Good	Semi-mature	Broadly Acceptable	Remove	9
52	1	<i>Quercus rubra</i>	Red oak	23	1	4400	12	Good	Fair	Good	Mature	Broadly Acceptable	NWR	N/A
53	1	<i>Platanus x hispanica</i> 'Acerifolia'	London plane	19	1	2200	6.5	Good	Fair	Fair	Mature	Broadly Acceptable	NWR	N/A
54	1	<i>Platanus x hispanica</i> 'Acerifolia'	London plane	19	1	2000	6	Good	Fair	Fair	Mature	Broadly Acceptable	NWR	N/A
55	30	<i>Robinia pseudoacacia</i>	Black locust	12	1	500	3	Fair	Fair	Good	Semi-mature	Broadly Acceptable	Remove	1
56	1	<i>Quercus rubra</i>	Red oak	26	1	3800	14	Poor	Fair	Good	Mature	Broadly Acceptable	Remove	9
57	1	<i>Quercus rubra</i>	Red oak	30	1	4200	16	Poor	Fair	Good	Mature	Broadly Acceptable	Reduce height by 20%	1
58	25	<i>Casuarina cunninghamiana</i>	She oak	15	1	1000	4	Fair	Fair	Good	Semi-mature	Broadly Acceptable	Remove	1
59	1	<i>Quercus robur</i>	English oak / Pedunculate oak	20	1	2200	8	Good	Fair	Good	Mature	Broadly Acceptable	Deadwood and remove hanging branch	1
60	1	<i>Quercus robur</i>	English oak / Pedunculate oak	22	1	3200	10	Good	Fair	Good	Mature	Broadly Acceptable	NWR	N/A

NWR – No work required

CSR – Crown Spread Radius

Table 4: Tree Inventory continued

Tree #	N° trees	Botanical name	Common name	Height (m)	No. stems at 1.4m	Aggregate girth at 1.4m (mm)	CSR (m)	Form	Structure	Health	Age class	Risk of Harm	Proposal	Year
61	1	<i>Quercus rubra</i>	Red oak	29	1	3400	10	Good	Fair	Good	Mature	Broadly Acceptable	NWR	N/A
62	1	<i>Fagus sylvatica</i>	Common beech	20	1	3400	10	Good	Fair	Good	Mature	Broadly Acceptable	NWR	N/A
63	1	<i>Quercus robur</i>	English oak / Pedunculate oak	13	1	500	4	Good	Fair	Good	Semi-mature	Broadly Acceptable	Remove	6
64	1	<i>Quercus robur</i>	English oak / Pedunculate oak	17	1	900	5	Good	Fair	Good	Semi-mature	Broadly Acceptable	Remove	6
65	1	<i>Fagus sylvatica</i>	Common beech	19	1	2900	8	Good	Fair	Good	Mature	Broadly Acceptable	NWR	N/A
66	1	<i>Quercus robur</i>	English oak / Pedunculate oak	9	1	2000	3	Poor	Fair	Good	Mature	Broadly Acceptable	Remove	6
67	1	<i>Quercus robur</i>	English oak / Pedunculate oak	11	1	2300	3	Poor	Fair	Good	Mature	Broadly Acceptable	Remove	6
68	1	<i>Quercus rubra</i>	Red oak	33	1	3700	12	Good	Fair	Good	Mature	Broadly Acceptable	Deadwood only	1
69	1	<i>Quercus robur</i>	English oak / Pedunculate oak	15	1	1800	6	Fair	Fair	Good	Semi-mature	Broadly Acceptable	Deadwood only	1
70	1	<i>Quercus robur</i>	English oak / Pedunculate oak	17	1	1800	8	Fair	Fair	Good	Semi-mature	Broadly Acceptable	Deadwood only	1

NWR – No work required

CSR – Crown Spread Radius

Table 4: Tree Inventory continued

Tree #	N° trees	Botanical name	Common name	Height (m)	No. stems at 1.4m	Aggregate girth at 1.4m (mm)	CSR (m)	Form	Structure	Health	Age class	Risk of Harm	Proposal	Year
71	1	<i>Eucalyptus saligna</i>	Sydney Blue Gum	37	1	8500	14	Excellent	Fair	Good	Mature	Broadly Acceptable	NWR	N/A
72	1	<i>Pseudotsuga menziesi</i>	Douglas fir	30	1	2400	6	Good	Fair	Fair	Mature	Broadly Acceptable	NWR	N/A
73	1	<i>Pseudotsuga menziesi</i>	Douglas fir	30	1	2400	6	Good	Fair	Fair	Mature	Broadly Acceptable	NWR	N/A
74	1	<i>Pseudotsuga menziesi</i>	Douglas fir	30	1	2400	6	Good	Fair	Fair	Mature	Broadly Acceptable	NWR	N/A
75	1	<i>Quercus palustris</i>	Pin oak	27	1	2400	8	Fair	Fair	Good	Mature	Broadly Acceptable	Deadwood only	1
76	1	<i>Cupressus macrocarpa</i>	Monterey cypress	28	1	4200	10	Fair	Fair	Good	Mature	Broadly Acceptable	Remove	9
77	1	<i>Cupressus macrocarpa</i>	Monterey cypress	26	1	3800	10	Fair	Fair	Good	Mature	Broadly Acceptable	Remove	9
78	1	<i>Cupressus macrocarpa</i>	Monterey cypress	26	1	4000	10	Fair	Fair	Good	Mature	Broadly Acceptable	Remove	9
79	1	<i>Quercus rubra</i>	Red oak	23	1	2800	12	Fair	Fair	Good	Mature	Broadly Acceptable	NWR	N/A
80	1	<i>Quercus robur</i>	English oak / Pedunculate oak	23	1	3800	10	Fair	Fair	Good	Mature	Broadly Acceptable	NWR	N/A
81	1	<i>Fagus sylvatica</i>	Common beech	20	1	1800	6	Fair	Fair	Good	Mature	Broadly Acceptable	NWR	N/A

NWR – No work required

CSR – Crown Spread

9. QTRA Analysis

- 9.1. No data was provided for the number of people using Arthur's Path as there are no track counters and no user number surveys have been carried out. However, on site observations during the days of the survey put the target range for the path as Target 3. That means between 2 and 7 people per hour use the path over a 24 hour period. More information on the QTRA target ranges is included in the Practice Note, appendix 2.
- 9.2. The findings have been used to calculate the greatest annual risk of harm posed by each tree to users of Arthur's Path and neighbouring properties. Any lower risks to property or people have not been included, as any mitigation or remedial pruning will reduce the highest risk calculated to within broadly acceptable or tolerable limits.
- 9.3. For ease of interpretation the table has been colour coded using the colours in the QTRA Advisory Risk Thresholds.
- 9.4. As can be seen from Table 4 the risk of harm posed by the surveyed trees is Broadly Acceptable using the QTRA framework.

10. Discussion and Comments

- 10.1. The management of trees in a group can be extremely difficult. Maintaining the woodland effect, as desired here, when trees have been removed or failed proves problematic. Newly planted trees often struggle to compete for light and other resources when they are shaded out by large mature trees in close proximity. Establishing a mature group of trees in the first instance is difficult and can take a long time for their benefits to be fully developed.
- 10.2. Given the difficulty of establishing mature trees and the time required for them to reach an age and size where they are providing maximum benefits, every effort should be made to retain them when they are established. This may involve pruning and other maintenance actions, prior to any consideration to remove the trees. Proactively rejuvenating and diversifying your stock also needs to be considered. This can sometimes require the removal of healthy trees to provide the space for new ones to come through.
- 10.3. It is difficult to determine how much longer these trees will live and provide useful benefits, but currently the majority of the mature trees are in fair to good health and could possibly live on for another hundred years.
- 10.4. The trees alongside Arthur's Path have often been planted too closely given the ultimate dimension of the species if a full grown open canopied tree is the desired goal. Most of the species in the group have ultimate dimensions in excess of 30m canopy spread when at maturity, yet the planting spacing is less than 15m, in some cases as little as 5m.

- 10.5. This has led to a densely packed canopy with minimal light penetration to the ground for any newly planted trees. Oak trees are shade intolerant and therefore require an open area when planted in a group situation. Planting of other species has been attempted and some self-sown oaks have been left to grow into semi mature trees. This has produced a number of poorly formed trees underneath the larger and more dominant original oak tree plantings.
- 10.6. Any removal and replanting of trees should give consideration to the effect on the woodland group as a whole. The woodland look and feel should continue to be maintained. This can be done by having a variation in age of the group and taking the opportunity to rationalise tree locations and create useful planting space for trees where it is possible.
- 10.7. While individual trees within the stand are important it may often be prudent to proactively remove trees that have structural issues that are unlikely to improve or are poorly formed, thus creating planting opportunities or allow more light and resources to become available for neighbouring trees.
- 10.8. It should be noted that trees numbered 5, 10, 55 and 58 in the table are groups of trees, with approximately 10, 7, 30 and 25 trees within each group respectively. In general, they are either pest plant species, weedy or of poor form and little amenity value. Removal of these trees will create space for a more formal and thought out replacement planting plan to increase species diversity.
- 10.9. In addition to the trees recorded in table 4 there are self-sown juvenile weedy trees growing throughout the reserve. These should be removed with a view to creating further planting opportunities.
- 10.10. There have been some historic failures within the Arthur's Path area. These have typically been of the oak trees approximately half way along the path and in a relatively localised area. It is suspected that high rainfall and the subsequent change in soil elasticity and plasticity has resulted in soil that is not sufficient to support the tree, leading to whole tree failure at the root plate.
- 10.11. Concern has been raised about these failures and the subsequent risk posed by the remaining trees if additional failures were to occur. The trees have been inspected and while it is not possible to assess the soil and likelihood of tree failure during high rain events, the current risk posed is still within the broadly acceptable range using the QTRA framework.
- 10.12. However, concern still remains over tree failure onto any new planting and irrigation system, which would likely damage any new trees to the degree that they would require replacement. The public are unlikely to be in the reserve in adverse weather conditions, when we would expect tree failure (In this case through soil saturation and high winds). This means that the risk of injury to people remains broadly acceptable. However the irrigation and new planting are permanent fixtures, so the risk to them is not affected by the weather conditions, so collateral damage we may need to replant. We should accept the occasional replanting.
- 10.13. It is imperative that any new planting survives and is allowed to grow to maturity. It has therefore been proposed to crown reduce the trees around the historic failure area and proposed new planting site. This reduction work should remove no more than 20 percent of the foliage of any one tree. It should also take into account species characteristics and available growth points within the canopy.

10.14. A proposed species planting list has been provided in the earlier draft tree management plan. This list needs a brief review to ensure the proposed species are shade tolerant and that it contains a sufficient number of species that will attain large ultimate dimensions to ensure the continued woodland feel of Arthur's Path. There are some species within the existing proposed list that meet these requirements, including;

- *Tilia* – Lime
- *Ulmus* – Elm

10.15. To ensure the proposed pruning and removal work has been effective in creating the desired outcomes, a regular review should be carried out. This should occur every three years just prior to the next phase of proposed works. In particular the response of the trees to the crown reduction work should be assessed with recommendations made and carried out if required.

10.16. In addition to the regular reviews an annual maintenance program should be implemented to control self-sown trees, weed tree growth and ensure any poisoned stumps do not regrow. This will allow the spaces created for planted trees to remain open for new trees to aid their development.

11. Conclusion

11.1. The trees alongside Arthur's Path in Keirunga Gardens have been assessed and the level of risk posed by the trees determined. All the trees pose a broadly acceptable level of risk.

11.2. The original draft tree management plan has been reviewed and an alternative proposed, which retains most of the larger trees by carrying out remedial crown reduction pruning. The new proposal still creates new planting spaces and allows for the diversification of the tree asset within the woodland walk.

11.3. While the above removals are a large percentage of the total number of trees most are of semi mature or weed trees or those which currently have structural issues that are unlikely to improve over time.

11.4. The new proposal requires annual monitoring of newly planted trees and review of the removal and pruning program every three years.

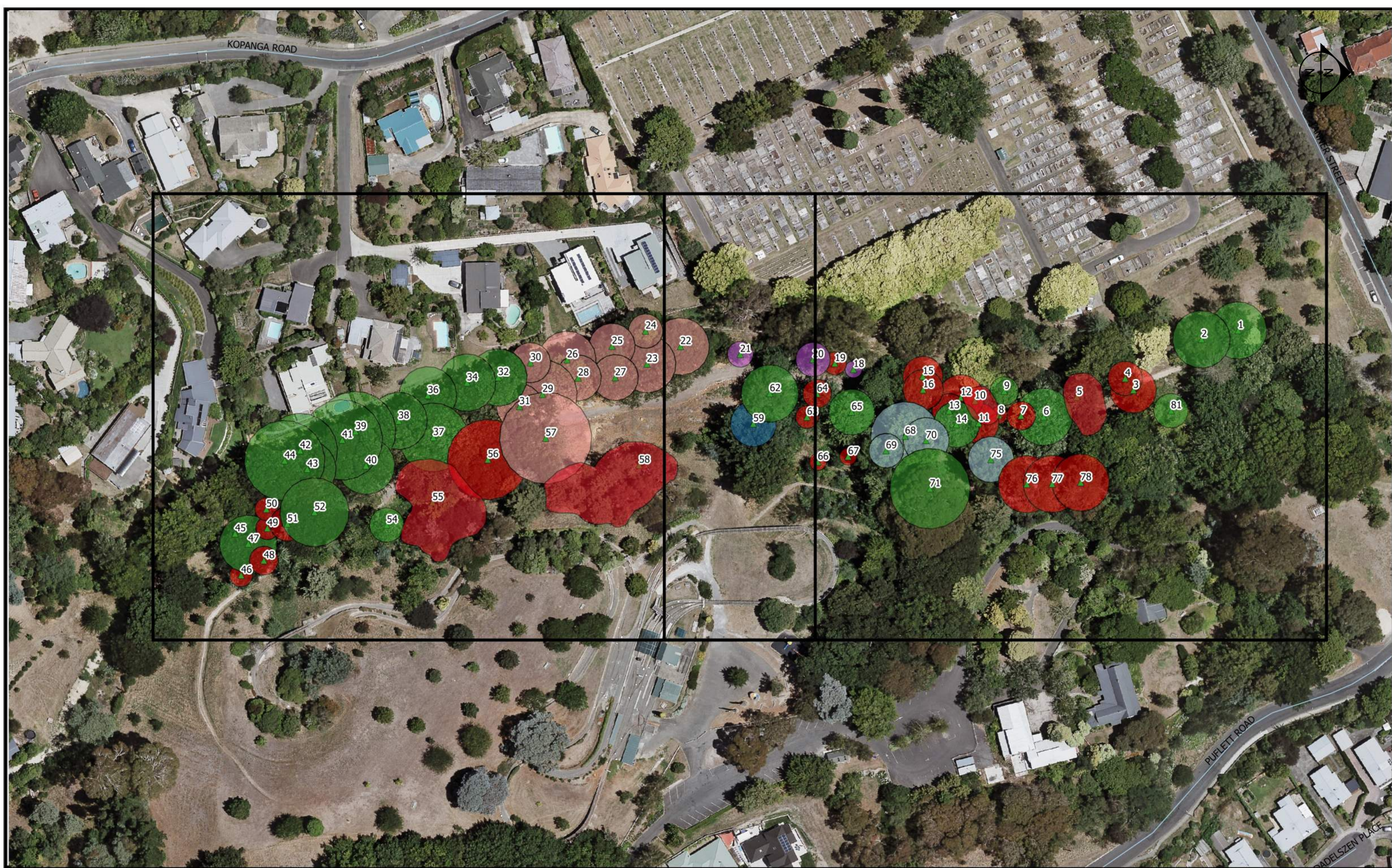
12. Recommendations and Management Options

12.1. Carry out the remedial tree works as described in Table 4 of this report.

12.2. The remaining trees should be re-inspected every three years by a suitably trained and qualified arborist. This inspection should include details of any change to the group dynamics and look for signs of failure subsequent to the remedial tree work recommended above and provide a risk analysis.

12.3. The newly planted trees should have irrigation installed and be inspected annually to ensure they are growing well. Any replacement planting should be carried out in the first planting season after remedial tree works are complete (typically April – September).

12.4. Any arboricultural work shall be undertaken by suitably trained and experienced individuals.



<p>Aerial images may not accurately reflect the actual vegetation cover. Vegetation is plotted as accurately as possible. Unless otherwise stated, project specific vegetation only has been plotted and captured.</p> <p>Vegetation alteration/removal may be subject to resource consent requirements/conditions. It shall be the client's responsibility to determine whether or not this is the case.</p> <p>Works within the root zone of trees should be supervised by an appointed works arborist.</p>		<p>Tree Plot</p> <p>▲ Broadly Acceptable</p> <p>Crown spread</p> <p>■ Crown lift and formative prune</p>		<p>■ Deadwood and remove hanging branch</p> <p>■ Deadwood only</p> <p>■ No Works Required</p> <p>■ Reduce height by 20%</p> <p>■ Remove</p>		<p>HASTINGS DISTRICT COUNCIL</p> <p>ARBORLAB CONSULTANCY SERVICES LIMITED</p> <p>09 379 3302 www.arborlab.co.nz</p>		<p>Arborlab Tree Assessment</p> <p>Keirunga Gardens Arthurs Pass</p>		<p>Requested by _____ Date _____</p> <p>Surveyed by _____</p> <p>Plotted by _____</p> <p>Checked by _____</p> <p>Drawing number TC-31238-01 Rev _____</p>	
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Works within the root zone of trees should be supervised by an appointed works arborist.

Tree Plot

▲ Broadly Acceptable

Crown spread

■ Crown lift and formative prune

■ Deadwood and remove hanging branch

■ Deadwood only

■ No Works Required

■ Reduce height by 20%

■ Remove



Arborlab Tree Assessment

Keirunga Gardens Arthurs Pass

Requested by		Date	
Surveyed by			
Plotted by			
Checked by			
Drawing number	TC-31238-02		Rev



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● Crown lift and formative prune

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Deadwood only

No Works Required

Reduce height by 20%

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HASTINGS
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Arborlab Tree Assessment

Keirunga Gardens Arthurs Pass

Requested by		Date	
Surveyed by			
Plotted by			
Checked by			
Drawing number	TC-31238-03		Rev



Quantified Tree Risk Assessment
Simply Balancing Risks With Benefits



Quantified Tree Risk Assessment **PRACTICE NOTE**

VERSION 5

Quantified Tree Risk Assessment Practice Note

"When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind"

William Thomson, Lord Kelvin, Popular Lectures and Addresses [1891-1894]

1. INTRODUCTION

Every day we encounter risks in all of our activities, and the way we manage those risks is to make choices. We weigh up the costs and benefits of the risk to determine whether it is acceptable, unacceptable, or tolerable. For example, if you want to travel by car you must accept that even with all the extensive risk control measures, such as seat-belts, speed limits, airbags, and crash barriers, there is still a significant risk of death. This is an everyday risk that is taken for granted and tolerated by millions of people in return for the benefits of convenient travel. Managing trees should take a similarly balanced approach.

A risk from falling trees exists only if there is both potential for tree failure and potential for harm to result. The job of the risk assessor is to consider the likelihood and consequences of tree failure. The outcome of this assessment can then inform consideration of the risk by the tree manager, who may also be the owner.

Using a comprehensive range of values¹, Quantified Tree Risk Assessment (QTRA) enables the tree assessor to identify and analyse the risk from tree failure in three key stages. 1) to consider land-use in terms of vulnerability to impact and likelihood of occupation, 2) to consider the consequences of an impact, taking account of the size of the tree or branch concerned, and 3) to estimate the probability that the tree or branch will fail onto the land-use in question. Estimating the values of these components, the assessor can use the QTRA manual calculator or software application to calculate an annual Risk of Harm from a particular tree. To inform management decisions, the risks from different hazards can then be both ranked and compared, and considered against broadly acceptable and tolerable levels of risk.

A Proportionate Approach to Risks from Trees

The risks from falling trees are usually very low and high risks will usually be encountered only in areas

with either high levels of human occupation or with valuable property. Where levels of human occupation and value of property are sufficiently low, the assessment of trees for structural weakness will not usually be necessary. Even when land-use indicates that the assessment of trees is appropriate, it is seldom proportionate to assess and evaluate the risk for each individual tree in a population. Often, all that is required is a brief consideration of the trees to identify gross signs of structural weakness or declining health. Doing all that is reasonably practicable does not mean that all trees have to be individually examined on a regular basis (HSE 2013).

The QTRA method enables a range of approaches from the broad assessment of large collections of trees to, where necessary, the detailed assessment of an individual tree.

Risk of Harm

The QTRA output is termed the Risk of Harm and is a combined measure of the likelihood and consequences of tree failure, considered against the baseline of a lost human life within the coming year.

ALARP (As Low As Reasonably Practicable)

Determining that risks have been reduced to As Low As Reasonably Practicable (HSE 2001) involves an evaluation of both the risk and the sacrifice or cost involved in reducing that risk. If it can be demonstrated that there is gross disproportion between them, the risk being insignificant in relation to the sacrifice or cost, then to reduce the risk further is not 'reasonably practicable'.

Costs and Benefits of Risk Control

Trees confer many benefits to people and the wider environment. When managing any risk, it is essential to maintain a balance between the costs and benefits of risk reduction, which should be considered in the determination of ALARP. It is not only the financial cost of controlling the risk that should be considered, but also the loss of tree-related benefits, and the risk to workers and the public from the risk control measure itself.

¹ See Tables 1, 2 & 3.

When considering risks from falling trees, the cost of risk control will usually be too high when it is clearly 'disproportionate' to the reduction in risk. In the context of QTRA, the issue of 'gross disproportion'², where decisions are heavily biased in favour of safety, is only likely to be considered where there are risks of 1/10 000 or greater.

Acceptable and Tolerable Risks

The Tolerability of Risk framework (ToR) (HSE 2001) is a widely accepted approach to reaching decisions on whether risks are broadly acceptable, unacceptable, or tolerable. Graphically represented in Figure 1, ToR can be summarised as having a Broadly Acceptable Region where the upper limit is an annual risk of death 1/1 000 000, an Unacceptable Region for which the lower limit is 1/1 000, and between these a Tolerable Region within which the tolerability of a risk will be dependent upon the costs and benefits of risk reduction. In the Tolerable Region, we must ask whether the benefits of risk control are sufficient to justify their cost.

In respect of trees, some risks cross the Broadly Acceptable 1/1 000 000 boundary, but remain tolerable. This is because any further reduction would involve a disproportionate cost in terms of the lost environmental, visual, and other benefits, in addition to the financial cost of controlling the risk.

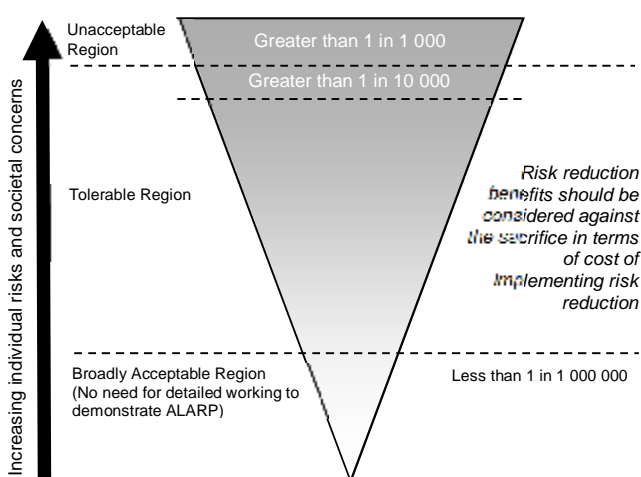


Figure 1. Adapted from the Tolerability of Risk framework (HSE 2001).

Value of Statistical Life

The Value of Statistical Life (VOSL), is a widely applied risk management device, which uses the value of a hypothetical life to guide the proportionate allocation of resources to risk reduction. In the UK, this value is currently in the region of £1 500 000

(\$2 900 000), and this is the value adopted in the QTRA method.

In QTRA, placing a statistical value on a human life has two particular uses. Firstly, QTRA uses VOSL to enable damage to property to be compared with the loss of life, allowing the comparison of risks to people and property. Secondly, the proportionate allocation of financial resources to risk reduction can be informed by VOSL. *"A value of statistical life of £1 000 000 is just another way of saying that a reduction in risk of death of 1/100 000 per year has a value of £10 per year"* (HSE 1996).

Internationally, there is variation in VOSL, but to provide consistency in QTRA outputs, it is suggested that VOSL of £1 500 000 (\$2 900 000) should be applied internationally. This is ultimately a decision for the tree manager.

2. OWNERSHIP OF RISK

Where many people are exposed to a risk, it is shared between them. Where only one person is exposed, that individual is the recipient of all of the risk and if they have control over it, they are also the owner of the risk. An individual may choose to accept or reject any particular risk to themselves, when that risk is under their control. When risks that are imposed upon others become elevated, societal concern will usually require risk controls, which ultimately are imposed by the courts or government regulators.

Although QTRA outputs might occasionally relate to an individual recipient, this is seldom the case. More often, calculation of the Risk of Harm is based on a cumulative occupation – i.e. the number of people per hour or vehicles per day, without attempting to identify the individuals who share the risk.

Where the risk of harm relates to a specific individual or a known group of people, the risk manager might consider the views of those who are exposed to the risk when making management decisions. Where a risk is imposed on the wider community, the principles set out in the ToR framework can be used as a reasonable approach to determine whether the risk is ALARP.

3. THE QTRA METHOD - VERSION 5

The input values for the three components of the QTRA calculation are set out in broad ranges³ of Target, Size, and Probability of Failure. The assessor

² Discussed further on page 5.

³ See Tables 1, 2 & 3.

estimates values for these three components and inputs them on either the manual calculator or software application to calculate the Risk of Harm.

Assessing Land-use (Targets)

The nature of the land-use beneath or adjacent to a tree will usually inform the level and extent of risk assessment to be carried out. In the assessment of Targets, six ranges of value are available. Table 2 sets out these ranges for vehicular frequency, human occupation and the monetary value of damage to property.

Human Occupation

The probability of pedestrian occupation at a particular location is calculated on the basis that an average pedestrian will spend five seconds walking beneath an average tree. For example, ten pedestrians per day, each occupying the Target for five seconds, is a daily occupation of fifty seconds. The total seconds in a day are divided to give a probability of Target occupation ($50/86\,400 = 1/1\,728$). Where a longer occupation is likely, as with a habitable building, outdoor café, or park bench, the period of occupation can be measured, or estimated as a proportion of a given unit of time, e.g. six hours per day ($1/4$). The Target is recorded as a range (Table 2).

Weather Affected Targets

Often the nature of a structural weakness in a tree is such that the probability of failure is greatest during windy weather, while the probability of the site being occupied by people during such weather is often low. This applies particularly to outdoor recreational areas. When estimating human Targets, the risk assessor must answer the question 'in the weather conditions that I expect the likelihood of failure of the tree to be initiated, what is my estimate of human occupation?' Taking this approach, rather than using the average occupation, ensures that the assessor considers the relationship between weather, people, and trees, along with the nature of the average person with their ability to recognise and avoid unnecessary risks.

Vehicles on the Highway

In the case of vehicles, likelihood of occupation may relate to either the falling tree or branch striking the vehicle or the vehicle striking the fallen tree. Both types of impact are influenced by vehicle speed; the faster the vehicle travels the less likely it is to be struck by the falling tree, but the more likely it is to strike a fallen tree. The probability of a vehicle

occupying any particular point in the road is the ratio of the time it is occupied - including a safe stopping distance - to the total time. The average vehicle on a UK road is occupied by 1.6 people (DfT 2010). To account for the substantial protection that the average vehicle provides against most tree impacts and in particular, frontal collisions, QTRA values the substantially protected 1.6 occupants in addition to the value of the vehicle as equivalent to one exposed human life.

Property

Property can be anything that could be damaged by a falling tree, from a dwelling, to livestock, parked car, or fence. When evaluating the exposure of property to tree failure, the QTRA assessment considers the cost of repair or replacement that might result from failure of the tree. Ranges of value are presented in Table 2 and the assessor's estimate need only be sufficient to determine which of the six ranges the cost to select.

In Table 2, the ranges of property value are based on a VOSL of \$2 900 000, e.g. where a building with a replacement cost of \$29 000 would be valued at 0.01 ($1/100$) of a life (Target Range 2).

When assessing risks in relation to buildings, the Target to be considered might be the building, the occupants, or both. Occupants of a building could be protected from harm by the structure or substantially exposed to the impact from a falling tree if the structure is not sufficiently robust, and this will determine how the assessor categorises the Target.

Multiple Targets

A Target might be constantly occupied by more than one person and QTRA can account for this. For example, if it is projected that the average occupation will be constant by 10 people, the Risk of Harm is calculated in relation to one person constantly occupying the Target before going on to identify that the average occupation is 10 people. This is expressed as Target $1(10T)/1$, where 10T represents the Multiple Targets. In respect of property, a Risk of Harm $1(10T)/1$ would be equivalent to a risk of losing \$29 000 000 as opposed to \$2 900 000.

Tree or Branch Size

A small dead branch of less than 25mm diameter is not likely to cause significant harm even in the case of direct contact with a Target, while a falling branch with a diameter greater than 450mm is likely to cause some harm in the event of contact with all but the most robust Target. The QTRA method categorises

Size by the diameter of tree stems and branches (measured beyond any basal taper). An equation derived from weight measurements of trees of different stem diameters is used to produce a data set of comparative weights of trees and branches ranging from 25mm to 600mm diameter, from which Table 1 is compiled. The size of dead branches might be discounted where they have undergone a significant reduction in weight because of degradation and shedding of subordinate branches. This discounting, referred to as 'Reduced Mass',

reflects an estimated reduction in the mass of a dead branch.

Table 1. Size

Size Range	Size of tree or branch	Range of Probability
1	> 450mm (>18") dia.	1/1 - >1/2
2	260mm (10 ¹ / ₂ ") dia. - 450mm (18") dia.	1/2 - >1/8.6
3	110mm (4 ¹ / ₂ ") dia. - 250mm (10") dia.	1/8.6 - >1/82
4	25mm (1") dia. - 100mm (4") dia.	1/82 - 1/2 500

* Range 1 is based on a diameter of 600mm.

Table 2. Targets

Target Range	Property (repair or replacement cost)	Human (not in vehicles)	Vehicle Traffic (number per day)	Ranges of Value (probability of occupation or fraction of \$2 900 000)
1	\$2 900 000 – >\$290 000 (£1 500 000 – >£150 000)	Occupation: Constant – 2.5 hours/day Pedestrians 720/hour – 73/hour & cyclists:	26 000 – 2 700 @ 110kph (68mph) 32 000 – 3 300 @ 80kph (50mph) 47 000 – 4 800 @ 50kph (32mph)	1/1 – >1/10
2	\$290 000 – >\$29 000	Occupation: 2.4 hours/day – 15 min/day Pedestrians 72/hour – 8/hour & cyclists:	2 600 – 270 @ 110kph (68mph) 3 200 – 330 @ 80kph (50mph) 4 700 – 480 @ 50kph (32mph)	1/10 – >1/100
3	\$29 000 – >\$2 900	Occupation: 14 min/day – 2 min/day Pedestrians 7/hour – 2/hour & cyclists:	260 – 27 @ 110kph (68mph) 320 – 33 @ 80kph (50mph) 470 – 48 @ 50kph (32mph)	1/100 – >1/1 000
4	\$2 900 – >\$290	Occupation: 1 min/day – 2 min/week Pedestrians 1/hour – 3/day & cyclists:	26 – 4 @ 110kph (68mph) 32 – 4 @ 80kph (50mph) 47 – 6 @ 50kph (32mph)	1/1 000 – >1/10 000
5	\$290 – >\$29	Occupation: 1 min/week – 1 min/month Pedestrians 2/day – 2/week & cyclists:	3 – 1 @ 110kph (68mph) 3 – 1 @ 80kph (50mph) 5 – 1 @ 50kph (32mph)	1/10 000 – >1/100 000
6	\$29 – \$2	Occupation: <1 min/month – 0.5 min/year Pedestrians 1/week – 6/year & cyclists:	None	1/100 000 – 1/1 000 000

Vehicle, pedestrian and property Targets are categorised by their frequency of use or their monetary value. The probability of a vehicle or pedestrian occupying a Target area in Target Range 4 is between the upper and lower limits of 1/1 000 and >1/10 000 (column 5). Using the VOSL \$2 900 000, the property repair or replacement value for Target Range 4 is \$2 900 - >\$290.

Probability of Failure

In the QTRA assessment, the probability of tree or branch failure within the coming year is estimated and recorded as a range of value (Ranges 1 – 7, Table 3).

Selecting a Probability of Failure (PoF) Range requires the assessor to compare their assessment of the tree or branch against a benchmark of either a non-compromised tree at Probability of Failure Range 7, or a tree or branch that we expect to fail within the year, which can be described as having a 1/1 probability of failure.

During QTRA training, Registered Users go through a number of field exercises in order to calibrate their estimates of Probability of Failure.

Table 3. Probability of Failure

Probability of Failure Range	Probability
1	1/1 - >1/10
2	1/10 - >1/100
3	1/100 - >1/1 000
4	1/1 000 - >1/10 000
5	1/10 000 - >1/100 000
6	1/100 000 - >1/1 000 000
7	1/1 000 000 - 1/10 000 000

The probability that the tree or branch will fail within the coming year.

The QTRA Calculation

The assessor selects a Range of values for each of the three input components of Target, Size and Probability of Failure. The Ranges are entered on either the manual calculator or software application to calculate a Risk of Harm.

The Risk of Harm is expressed as a probability and is rounded, to one significant figure. Any Risk of Harm that is lower than $1/1\,000\,000$ is represented as $<1/1\,000\,000$. As a visual aid, the Risk of Harm is colour coded using the traffic light system illustrated in Table 4 (page 7).

Risk of Harm - Monte Carlo Simulations

The Risk of Harm for all combinations of Target, Size and Probability of Failure Ranges has been calculated using Monte Carlo simulations⁴. The QTRA Risk of Harm is the mean value from each set of Monte Carlo results.

In QTRA Version 5, the Risk of Harm should not be calculated without the manual calculator or software application.

Assessing Groups and Populations of Trees

When assessing populations or groups of trees, the highest risk in the group is quantified and if that risk is tolerable, it follows that risks from the remaining trees will also be tolerable, and further calculations are unnecessary. Where the risk is intolerable, the next highest risk will be quantified, and so on until a tolerable risk is established. This process requires prior knowledge of the tree manager's risk tolerance.

Accuracy of Outputs

The purpose of QTRA is not necessarily to provide high degrees of accuracy, but to provide for the quantification of risks from falling trees in a way that risks are categorised within broad ranges (Table 4).

4. INFORMING MANAGEMENT DECISIONS

Balancing Costs and Benefits of Risk Control

When controlling risks from falling trees, the benefit of reduced risk is obvious, but the costs of risk control are all too often neglected. For every risk reduced there will be costs, and the most obvious of these is the financial cost of implementing the control measure. Frequently overlooked is the transfer of risks to workers and the public who might be directly affected by the removal or pruning of trees. Perhaps

more importantly, most trees confer benefits, the loss of which should be considered as a cost when balancing the costs and benefits of risk control.

When balancing risk management decisions using QTRA, consideration of the benefits from trees will usually be of a very general nature and not require detailed consideration. The tree manager can consider, in simple terms, whether the overall cost of risk control is a proportionate one. Where risks are approaching $1/10\,000$, this may be a straightforward balancing of cost and benefits. Where risks are $1/10\,000$ or greater, it will usually be appropriate to implement risk controls unless the costs are grossly disproportionate to the benefits rather than simply disproportionate. In other words, the balance being weighted more on the side of risk control with higher associated costs.

Considering the Value of Trees

It is necessary to consider the benefits provided by trees, but they cannot easily be monetised and it is often difficult to place a value on those attributes such as habitat, shading and visual amenity that might be lost to risk control.

A simple approach to considering the value of a tree asset is suggested here, using the concept of 'average benefits'. When considered against other similar trees, a tree providing 'average benefits' will usually present a range of benefits that are typical for the species, age and situation. Viewed in this way, a tree providing 'average benefits' might appear to be low when compared with particularly important trees – such as in Figure 2, but should nonetheless be sufficient to offset a Risk of Harm of less than $1/10\,000$. Without having to consider the benefits of risk controls, we might reasonably assume that below $1/10\,000$, the risk from a tree that provides 'average benefits' is ALARP.

In contrast, if it can be said that the tree provides lower than average benefits because, for example, it is declining and in poor physiological condition, it may be necessary to consider two further elements. Firstly, is the Risk of Harm in the upper part of the Tolerable Region, and secondly, is the Risk of Harm likely to increase before the next review because of an increased Probability of Failure. If both these conditions apply then it might be appropriate to consider the balance of costs and benefits of risk reduction in order to determine whether the risk is ALARP. This balance requires the tree manager to take a view of both the reduction in risk and the costs of that reduction.

⁴ For further information on the Monte Carlo simulation method, refer to http://en.wikipedia.org/wiki/Monte_Carlo_method



Fig. 2

Lower Than Average Benefits from Trees

Usually, the benefits provided by a tree will only be significantly reduced below the 'average benefits' that are typical for the species, age and situation, if the life of the benefits is likely to be shortened, perhaps because the tree is declining or dead. That is not to say that a disbenefit, such as undesirable shading, lifting of a footpath, or restricting the growth of other trees, should not also be considered in the balance of costs and benefits.

The horse chestnut tree in Figure 3 has recently died, and over the next few years, may provide valuable habitats. However, for this tree species and the relatively fast rate at which its wood decays, the lifetime of these benefits is likely to be limited to only a few years. This tree has an already reduced value that will continue to reduce rapidly over the coming five to ten years at the same time as the Risk of Harm is expected to increase. There will be changes in the benefits provided by the tree as it degrades. Visual qualities are likely to reduce while the decaying wood provides habitats for a range of species, for a short while at least. There are no hard and fast measures of these benefits and it is for the tree manager to decide what is locally important and how it might be balanced with the risks.

Where a risk is within the Tolerable Region and the tree confers lower than average benefits, it might be appropriate to consider implementing risk control while taking account of the financial cost. Here, VOSL can be used to inform a decision on whether the cost of risk control is proportionate. Example 3 below puts this evaluation into a tree management context.

There will be occasions when a tree is of such minimal value and the monetary cost of risk reduction so low that it might be reasonable to

further reduce an already relatively low risk. Conversely, a tree might be of such considerable value that an annual risk of death greater than 1/10 000 would be deemed tolerable.

Occasionally, decisions will be made to retain elevated risks because the benefits from the tree are particularly high or important to stakeholders, and in these situations, it might be appropriate to assess and document the benefits in some detail. If detailed assessment of benefits is required, there are several methodologies and sources of information (Forest Research 2010).



Fig. 3

Delegating Risk Management Decisions

Understanding of the costs with which risk reduction is balanced can be informed by the risk assessor's knowledge, experience and on-site observations, but the risk management decisions should be made by the tree manager. That is not to say that the tree manager should review and agree every risk control measure, but when delegating decisions to surveyors and other staff or advisors, tree managers should set out in a policy, statement or contract, the principles and perhaps thresholds to which trees and their associated risks will ordinarily be managed.

Based on the tree manager accepting the principles set out in the QTRA Practice Note and or any other specific instructions, the risk assessor can take account of the cost/benefit balance and for most

situations will be able to determine whether the risk is ALARP when providing management recommendations.

Table 4. QTRA Advisory Risk Thresholds

Thresholds	Description	Action
1/1 000	Unacceptable Risks will not ordinarily be tolerated	<ul style="list-style-type: none"> Control the risk
	Unacceptable (where imposed on others) Risks will not ordinarily be tolerated	<ul style="list-style-type: none"> Control the risk Review the risk
	Tolerable (by agreement) Risks may be tolerated if those exposed to the risk accept it, or the tree has exceptional value	<ul style="list-style-type: none"> Control the risk unless there is broad stakeholder agreement to tolerate it, or the tree has exceptional value Review the risk
1/10 000	Tolerable (where imposed on others) Risks are tolerable if ALARP	<ul style="list-style-type: none"> Assess costs and benefits of risk control Control the risk only where a significant benefit might be achieved at reasonable cost Review the risk
1/1 000 000	Broadly Acceptable Risk is already ALARP	<ul style="list-style-type: none"> No action currently required Review the risk

QTRA Informative Risk Thresholds

The QTRA advisory thresholds in Table 4 are proposed as a reasonable approach to balancing safety from falling trees with the costs of risk reduction. This approach takes account of the widely applied principles of ALARP and ToR, but does not dictate how these principles should be applied. While the thresholds can be the foundation of a robust policy for tree risk management, tree managers should make decisions based on their own situation, values and resources. Importantly, to enable tree assessors to provide appropriate management guidance, it is helpful for them to have some understanding of the tree owner's management preferences prior to assessing the trees.

A Risk of Harm that is less than 1/1 000 000 is Broadly Acceptable and is already ALARP. A Risk of Harm 1/1 000 or greater is unacceptable and will not ordinarily be tolerated. Between these two values, the Risk of Harm is in the Tolerable Region of ToR and will be tolerable if it is ALARP. In the Tolerable

Region, management decisions are informed by consideration of the costs and benefits of risk control, including the nature and extent of those benefits provided by trees, which would be lost to risk control measures.

For the purpose of managing risks from falling trees, the Tolerable Region can be further broken down into two sections. From 1/1 000 000 to less than 1/10 000, the Risk of Harm will usually be tolerable providing that the tree confers 'average benefits' as discussed above. As the Risk of Harm approaches 1/10 000 it will be necessary for the tree manager to consider in more detail the benefits provided by the tree and the overall cost of mitigating the risk.

A Risk of Harm in the Tolerable Region but 1/10 000 or greater will not usually be tolerable where it is imposed on others, such as the public, and if retained, will require a more detailed consideration of ALARP. In exceptional circumstances a tree owner might choose to retain a Risk of Harm that is 1/10 000 or greater. Such a decision might be based on the agreement of those who are exposed to the risk, or perhaps that the tree is of great importance. In these circumstances, the prudent tree manager will consult with the appropriate stakeholders whenever possible.

5. EXAMPLE QTRA CALCULATIONS AND RISK MANAGEMENT DECISIONS

Below are three examples of QTRA calculations and application of the QTRA Advisory Thresholds.

Example 1.

	Target	Size	Probability of Failure	Risk of Harm
Range	6	x 1	x 3	= <1/1 000 000

Example 1 is the assessment of a large (Size 1), unstable tree with a probability of failure of between 1/100 and >1/1 000 (PoF 3). The Target is a footpath with less than one pedestrian passing the tree each week (Target 6). The Risk of Harm is calculated as less than 1/1 000 000 (green). This is an example of where the Target is so low consideration of the structural condition of even a large tree would not usually be necessary.

Example 2.

	Target	Size	Probability of Failure	Risk of Harm
Range	1	x	4	x
			3	=
				1(2T)/50 000

In Example 2, a recently dead branch (Size 4) overhangs a busy urban high street that is on average occupied constantly by two people, and here Multiple Target occupation is considered.

Having an average occupancy of two people, the Risk of Harm 1(2T)/50 000 (yellow) represents a twofold increase in the magnitude of the consequence and is therefore equivalent to a Risk of Harm 1/20 000 (yellow). This risk does not exceed 1/10 000, but being a dead branch at the upper end of the Tolerable Region it is appropriate to consider the balance of costs and benefits of risk control. Dead branches can be expected to degrade over time with the probability of failure increasing as a result. Because it is dead, some of the usual benefits from the branch have been lost and it will be appropriate to consider whether the financial cost of risk control would be proportionate.

Example 3.

	Target	Size	Probability of Failure	Risk of Harm
Range	3	x	3	x
			3	=
				1/500 000

In Example 3, a 200mm diameter defective branch overhangs a country road along which travel between 470 and 48 vehicles each day at an average speed of 50kph (32mph) (Target Range 3). The branch is split and is assessed as having a probability of failure for the coming year of between 1/100 and 1/1 000 (PoF Range 3). The Risk of Harm is calculated as 1/500 000 (yellow) and it needs to be considered whether the risk is ALARP. The cost of removing the branch and reducing the risk to Broadly Acceptable (1/1 000 000) is estimated at \$670. To establish whether this is a proportionate cost of risk control, the following equation is applied. \$2 900 000 (VOSL) x 1/500 000 = \$5.8 indicating that the projected cost of \$670 would be disproportionate to the benefit. Taking account of the financial cost, risk transfer to arborists and passers-by, the cost could be described as being grossly disproportionate, even if accrued benefits over say ten years were taken into account.

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