ARBORICULTURAL ASSESSMENT

For

ESKDALE PARK

PREPARED BY

PAPER STREET TREE COMPANY

TREE MANAGEMENT
RECOMMENDATIONS

REPORT COMMISSIONED BY: Hastings District Council

REPORT DATED: 24.08.21

PROPOSAL: To provide arboricultural management recommendations

EST. PS 2013

ARBORICULTURE CONSULTANCY

Contents

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EXECUTIVE SUMMARY

The site survey recorded 1239 items. These trees are estimated to have stored 2,543t of carbon, which would be worth $230,22, and are estimated to have intercepted (prevented runoff into streams and rivers) 2,182m^3 of stormwater annually.

The main Park area has 52% of canopy coverage, with tree health being good overall. The majority of canopy coverage (50%) is poplar, with one cultivar providing the majority of canopy coverage.

The site survey shows the poplar that provides the most canopy cover is a cultivar with a high propensity for limb failure. The majority of these trees are either mature or fully mature specimens. Overall the structure of the trees shows emerging mechanical weaknesses or a mechanical weakness.

The current risks of harm is low due to site low site occupancy levels and Council's current proactive management approach in response to the increased limb failure. But the risks (loss of environmental, amenity, increased maintenance cost and duty of care towards public safety) is rising. In addition, certain trees are reaching a point where the costs to maintain these trees are beginning to outweigh the benefits received.

Therefore, recommendations are made to support current Council strategies for planting but to also suggest proactive replacement and removal of trees that are becoming impractical to maintain. Part of this plan is to replace the relatively short-lived failure-prone cultivar with long-lived specimens. Initially 4 polar trees are proposed for removal in the first 3yrs and another 7 poplar trees in the next 3-6yrs. Additionally, another 13 trees are proposed for removal for general management purposes (compromised structures).

Modelling 14 replacement trees at maturity shows the replacement trees could have a 114% increase in carbon stored and a 1,175% increase in rainwater intercepted over trees proposed for removal. The replacement trees are longer-lived trees, and will provide benefits over a longer period than the trees they would replace.

There will be temporary losses to amenity and the environment during the replacement removal works. But the strategy is staged and flexible to ensure existing values can be maintained whilst successive trees can establish. This will involve retaining trees until they become impractical to retain.

Opportunities exist for community engagement and continued partnerships for connection to place through planting, to ensure long-term landscape values are sustainable.

Richie HIll

1 INTRODUCTION

1.1 I have been engaged by Hastings District Council to provide arboricultural management recommendations for Eskdale Park in Eskdale.

1.2 The recommendations are based on; site observations and survey details carried out between April and May of 2021.

1.3 The purpose of this report is to summarise those findings, build on existing strategies and provide recommendations to support sustainable outcomes for the Park.

1.4 ***Layout of the assessment***

The report is set out as follows:

2. Performance summary of trees captured

Summarises the survey information

3. Risks and management options

Processes the site information and identifies risks and management options.

4. Recommendations

Provide recommendation options based on the analysis

5 Sustainable Development Goals (SDGs)

Assessing the recommendations against the relevant SDGs

1.5 ***Assessing information to achieve objectives***

Street Tree Company Ltd (PS) supports the Sustainability Development Goals (SDGs). The Sustainable Development Goals provide a framework to build greener, stronger and more resilient societies.

1.5.1 There is a growing body of research documenting the benefits of the close integration of trees with society. These include buffering heat extremes, slowing rainwater runoff, reducing air pollution, sequestering carbon, and improving human health and wellbeing.

1.5.2 Competing land needs, management activities, development intensities, and climate change place increasing stresses on trees being able to deliver these benefits. This is at a time when public aspirations for more trees is increasing. Therefore, adaptation, collaboration and partnerships across external and internal disciplines are essential to improve the sustainable management of the urban tree resource.

1.5.3 Therefore, the SDGs provide a measure to ensure recommendations allow pathways to meet that end, to build greater resilience within the urban ngahere

SUSTAINABLE DEVELOPMENT GOALS

"Sustainable development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

2.1 *Site summary*

The site contains large mature trees and a paddock with restricted access used for casual grazing. The planting within site has been structured to create open spaces and closed canopy shaded areas. The majority of the trees are located at the northern reaches of the site adjacent to a stream. The site is a quiet space, regularly used by locals with occasional use by groups (e.g. schools). The site is of high use during the summer months due to access to the river. Continual planting is evident with native species primarily planted along the margins and amongst existing trees and other exotic tree species. Part of the land forming Eskdale Park was gifted to the community by Thomas Clark in the 1920s.

2.1.1 <u>Values</u>

High local community value, space for reflection, and as a summer destination due to river access.

2.2 *Site survey methods*

The purpose of the inspection was to check all trees within the designated areas (section 1.1) and provide management recommendations. Risk management (ISO31000) and asset management principles (ISO55002) underline PS management recommendations set against the SDGs. A total of 1,229 items were recorded during the survey.

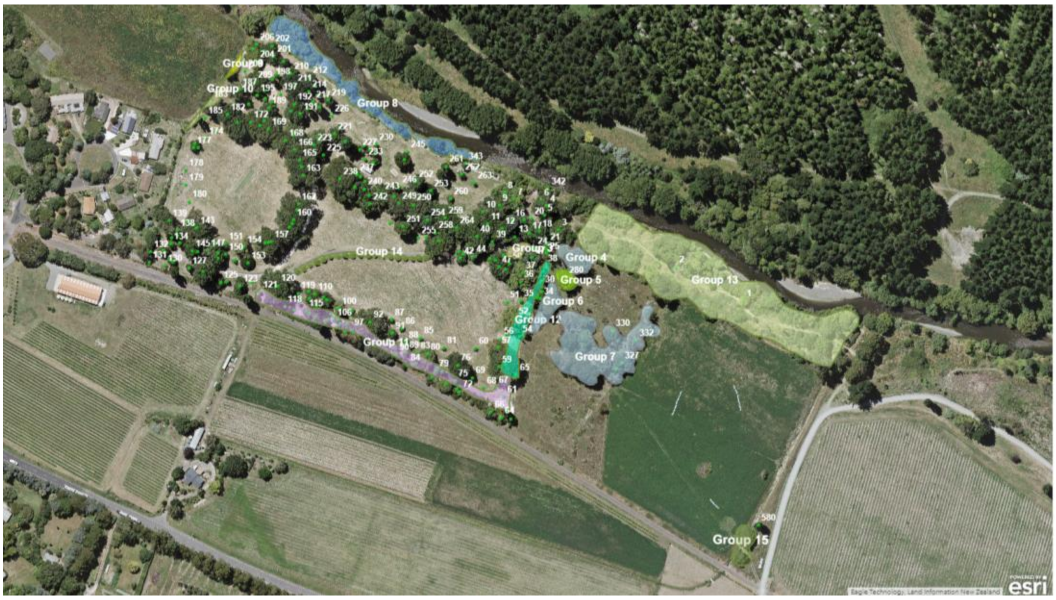


Fig.1 Showing trees captured.

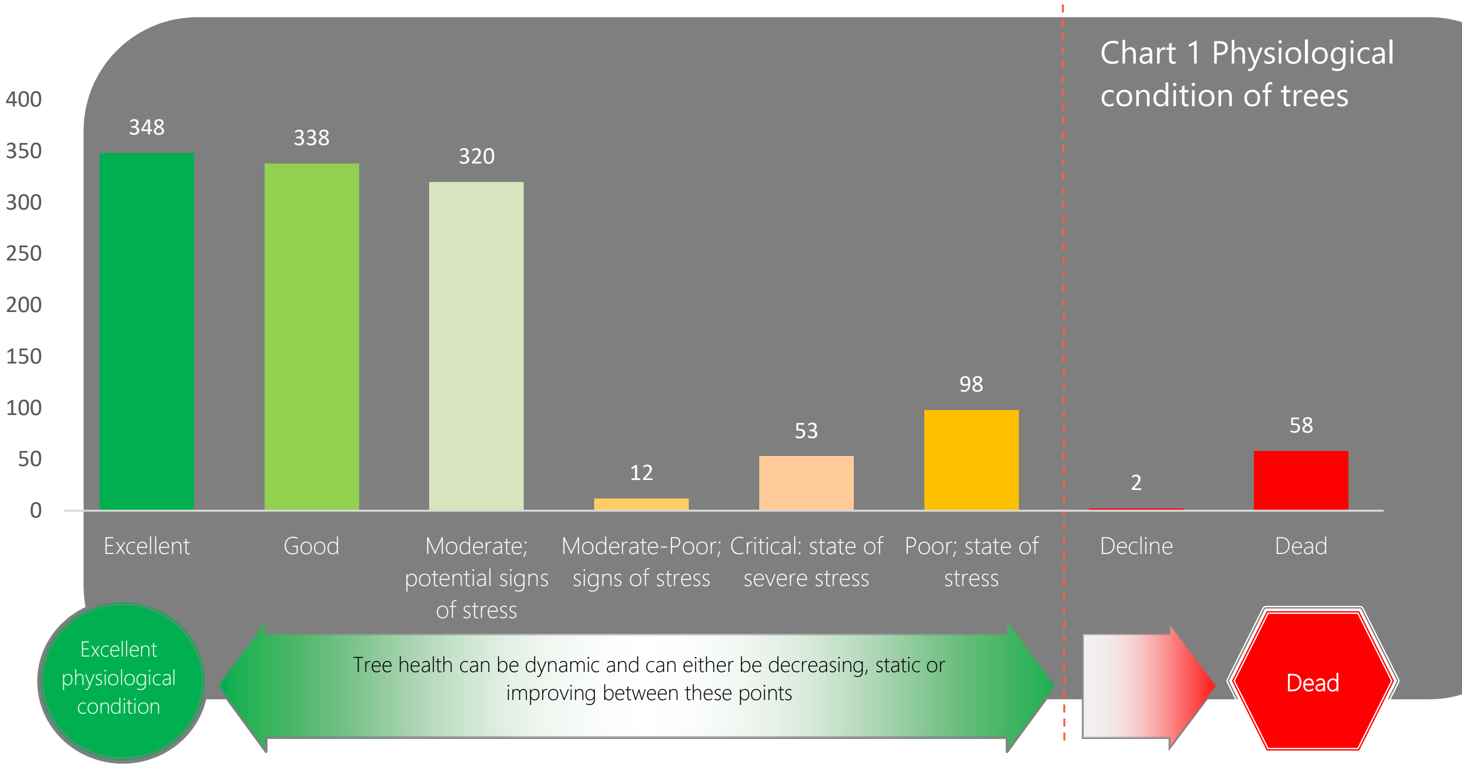
2.1.1 Specific site survey details can be viewed in the PS Excel spreadsheet titled:

- PS Site Survey Eskdale Park 2021

A tree location plan with management works overlaid is included within the spreadsheet.

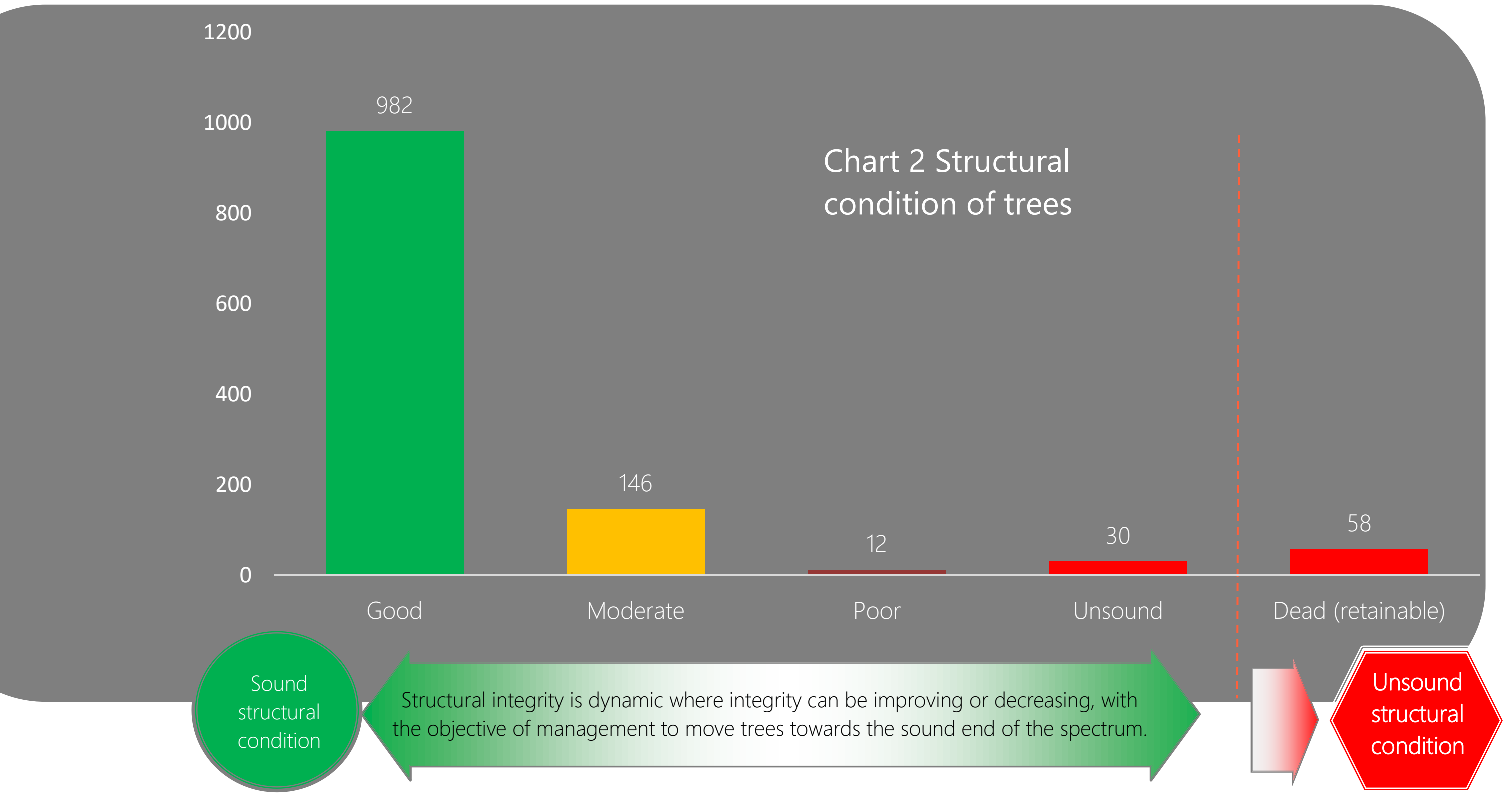
2.3. <u>Tree physiological function (tree health)</u>

Tree health is essential for tree function, reaction to stress, and for the delivery of ecosystem services. Below is a summary of the current health of the 1,229 trees assessed.



2.4 ***Tree structure***

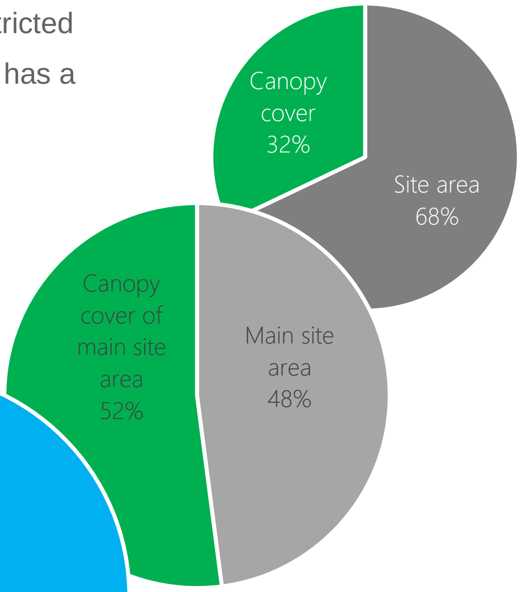
Summary of the overall tree structure of the 1,228 trees assessed.

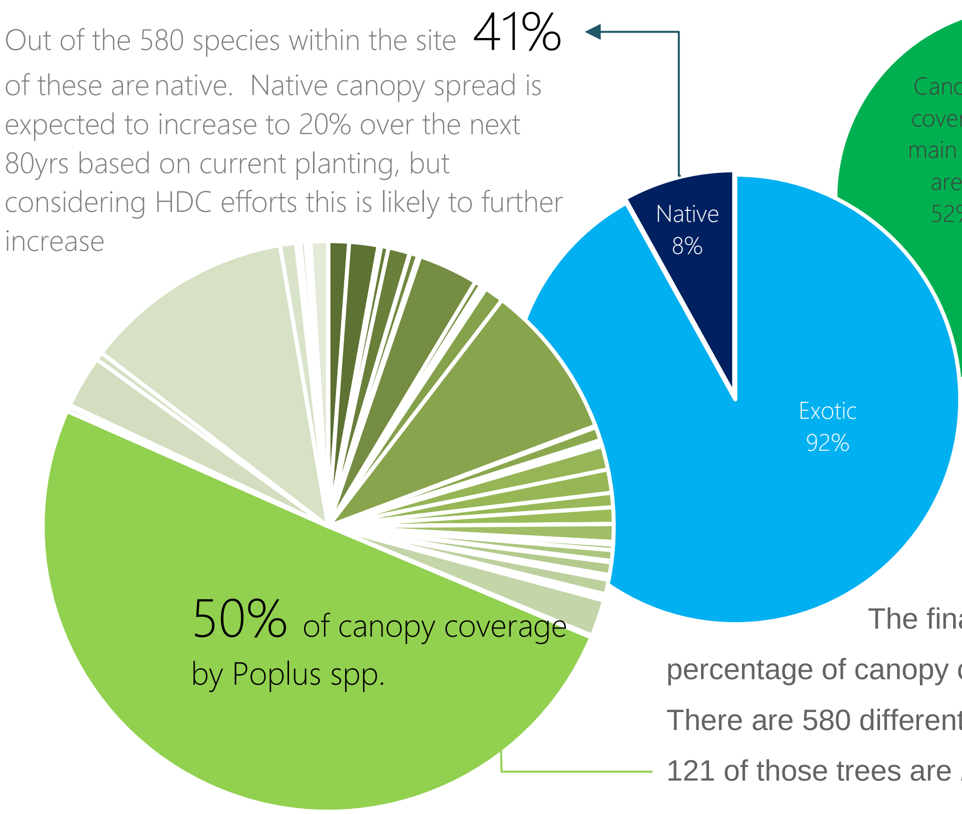


2.5 *Canopy coverage*

Canopy coverage is a measurable indicator of tree coverage for the site. Many of the benefits we receive from trees come from the tree's leaf area, shading, cooling, rainwater interception (amount of rainwater that does not fall to the ground during a rain event), and buffering of winds. Additionally, canopy coverage can also facilitate ecological restoration by regulating temperature extremes for plant establishment and provide habitat. As the canopy is a measurable output, it can be used to monitor site coverage over time, create targets and highlight when intervention is required.

Overall the site has 32% canopy coverage, but if the restricted grazing area is removed from the measurement, the site has a 52% canopy coverage.





The final chart shows the percentage of canopy coverage by species. There are 580 different species within site, where 121 of those trees are *Populus spp.*

2.6 *Climate change*

Climate change predictions for the region are for temperature increases and extended periods of prolonged dry weather with decreases in rainfall and increases in winds and fire.

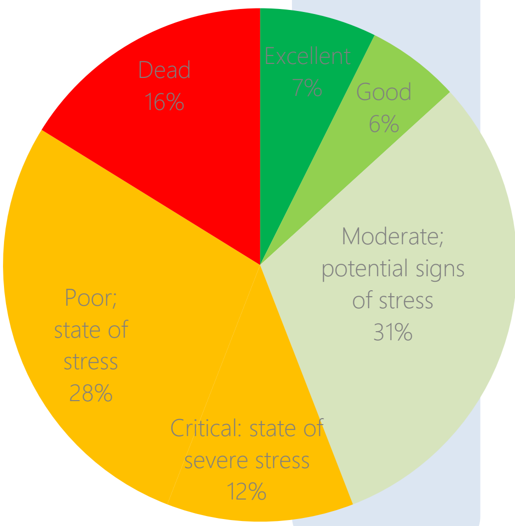
"Climate change-induced hazards, such as changes in the temperature, rainfall and CO2 concentration, could impact natural and modified forests substantially (Kirilenko and Sedjo, 2007, FAO, 2018). The possible impacts of climate change on forests include, but are not limited to, shorter or longer growing seasons, modifications in the forest's biodiversity including

its macro and microbiota, changes in the pests and disease factors and their spread pattern" (NIWA 2020)

2.6.1 The above highlights climate change will have an impact on tree growth, plant establishment and how trees can react to environmental stress. These effects are likely to be more severe for species which are currently at the edge of their climatic zone (e.g., tolerances to dry periods). At the eastern end of the Park, within the grazing area, stand a group of Eucalyptus trees (92% of the canopy area in the group are Eucalyptus) see fig 2.

Fig. 2 Blue areas highlighting Tree Groups 4, 6 and 7, which are all primarily eucalyptus trees.

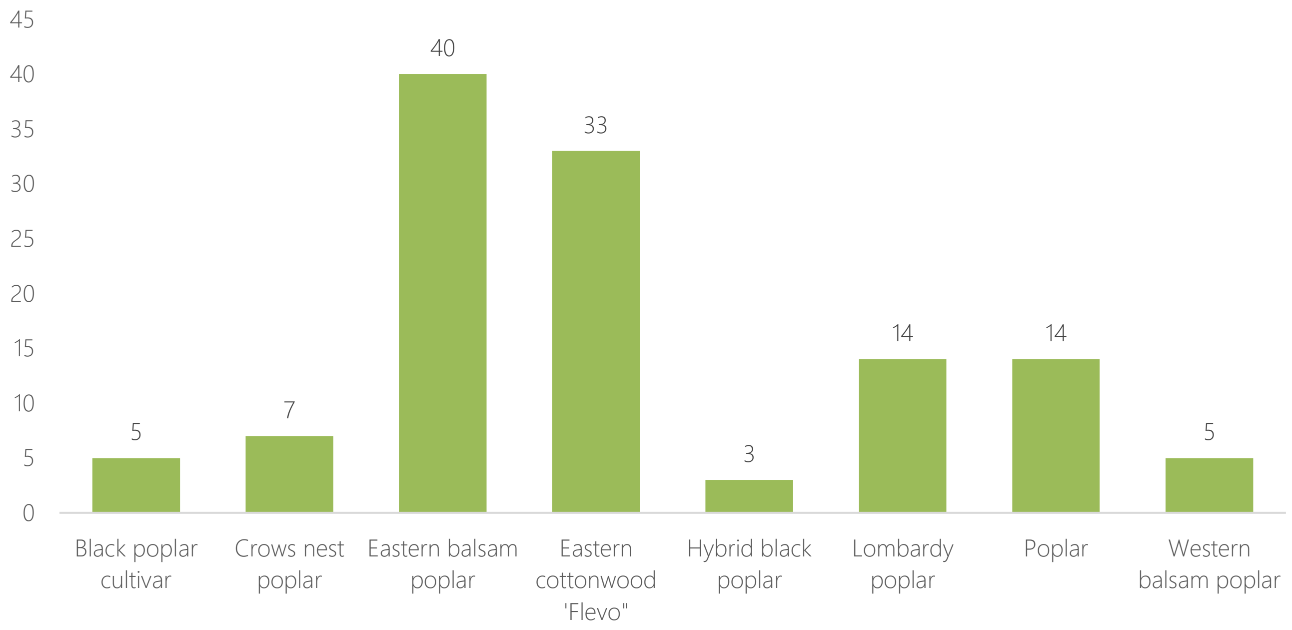
2.6.2 Eucalyptus is a genus of over 900 specimens. Around 240 species have been introduced into New Zealand (Ecroyed 2010). These trees come from a range of climatic regions, where certain species have limited tolerance to prolonged dry periods, mainly the stringybark and ash eucalyptus (Florence, 1996). The area has had a couple of years of prolonged periods of dry conditions, which is likely to have contributed to the trees' current conditions. Another contributing factor could be from pest species (bronze bug (*Thaumastocoris peregrinus)* and brown lace lerp (*Cardiaspina fiscella*), which under climate change, the frequency and intensity of pests are likely to increase where It is likely that the stand will continue to decline over the years.

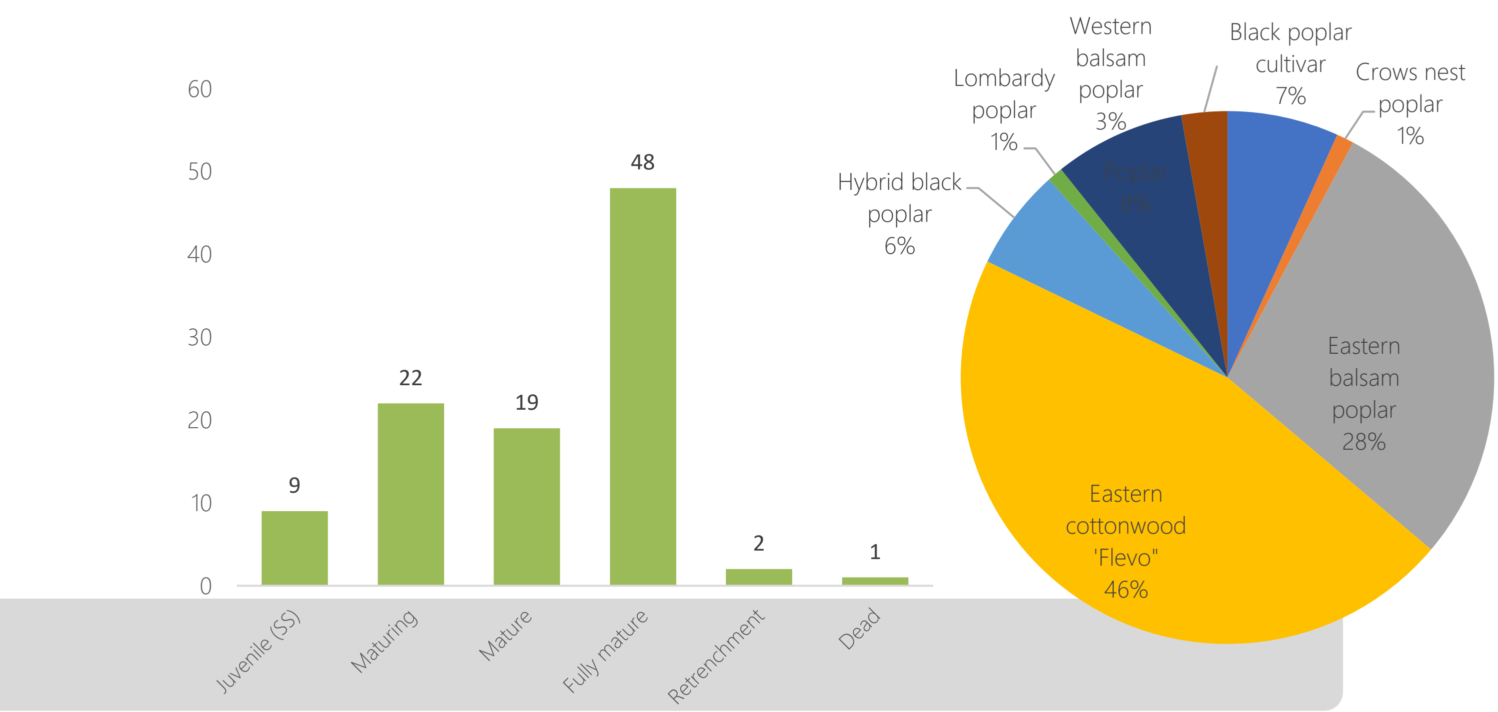


2.7 *Poplar trees*

There are many clones and cultivars of poplar, which all have very different characteristics. Determining which clone or cultivar is very difficult even for experts. There are likely to be at least seven species with traits and forms that would be associated with specific cultivars of the species within site. One category is for species of poplar where identification could not be made (see below graph).

Graph 5 showing the number of poplar species within the site





Graph 6 The graph on the left shows poplar tree life stage. And the graph on the right shows which poplar trees are the dominant canopy coverage within site.

2.7.1 The above charts show that eastern cottonwood and eastern balsam trees make up most of the poplar canopy coverage. These trees provide the most visual value in terms of landscape appeal, especially the eastern cottonwood. Poplars are cultivated to improve resilience (e.g. against diseases such as leaf rusts (*Melampsora larici-populina* and *M. medusae*) and wind breakage.

Fig. 3 The Image on the left shows *Poplus deltiodes* the eastern cottonwood, and the image on the right shows the cultivar that makes up the majority of canopy coverage in the Park. Note the broader and extended canopy spread with the tree in the Park, which is consistent with all these cultivars, which infer the broader spread is under genetic control. The blue highlighted area shows limbs that have been lost due to these limbs spreading beyond the canopy and due to horizontal (greater loads) have snapped in wind events. This failure is seen on all the mature or fully mature cultivars within the Park.

2.7.2 HDC has been proactively managing these trees as a result of increased limb failure. For certain trees there is becoming less suitable reduction points, which would then lead to truncating a limb (i.e. stumping a limb and not cutting it back to a suitable growth point). This is not a species in which that is a recommended action given the rate of growth and propensity for breakage (and being genetically weak resisters of decay).

2.7.3 Looking at stumps around the cricket oval, these trees are likely to be around 47-50 years old

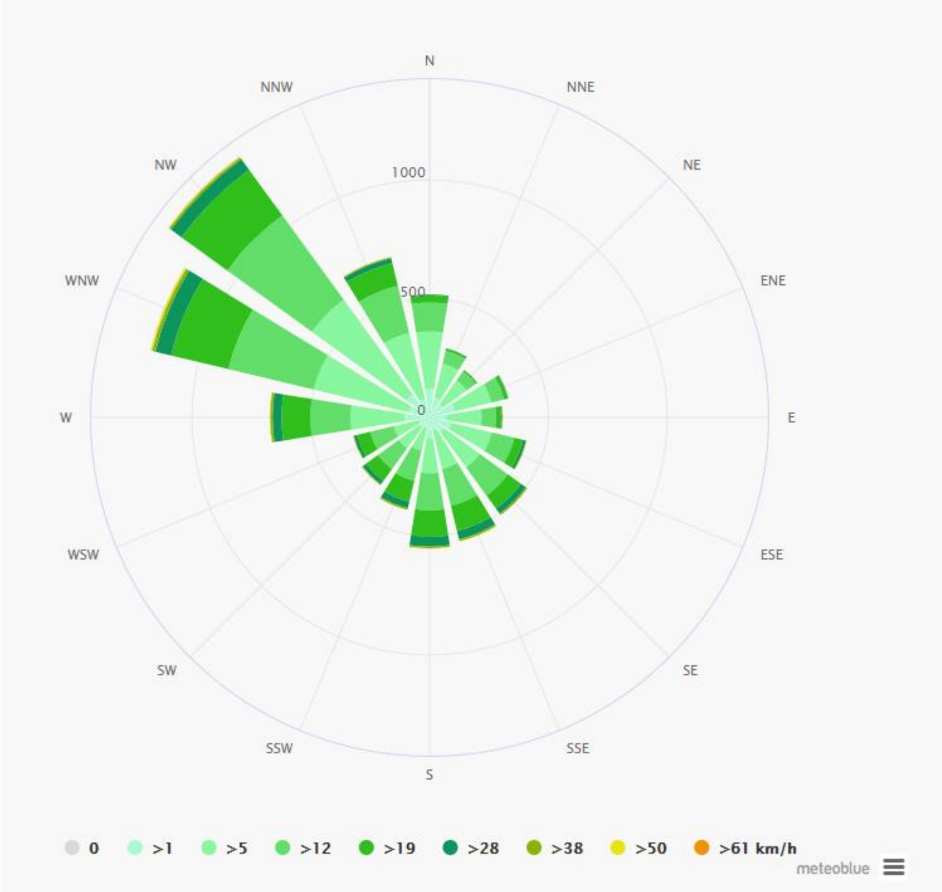
Fig.4 Aerial image of site 1951. Yellow circle highlights cricket oval. No trees present

2.7.4 This would put the trees planted after 1951. Between 1974 and 1996, 343 poplar clones were introduced from overseas within that period. Of these, only 11 clones were found to be acceptable for soil conservation planting. They were also noted that a number of the clones were sensitive to strong winds, and poorly adapted to most North Island conditions. It is possible that this clone could be one of those species. Otherwise, its characteristics match that of the cultivar *P. deltoides x P. nigra* 'Flevo'; described as having a broad crown and prone to wind breakage being extremely difficult to manage except in a pollarded situation (National Poplar and Willow Users Groups, 2007).

Fig 5 Example of splayed form from multiple failures (tree 143). Limbs left now more exposed, increasing the likelihood for failure with minimal reduction points left, where such works will require 30m access. Based on the pruning wounds, the tree would appear to have had up to three pruning visits currently where a number of large failures have occurred.

Fig. 6 The pine plantation North and Northwest of the site is currently being harvested. The tree closest in the image is the tree in Fig. 5. These trees and a row of trees to the east of the cricket ground show a history of failure. A number of large trees were removed west of the site near the boundary and could have been the reason for increased failure in these trees, which highlights how sensitive these trees are to change.

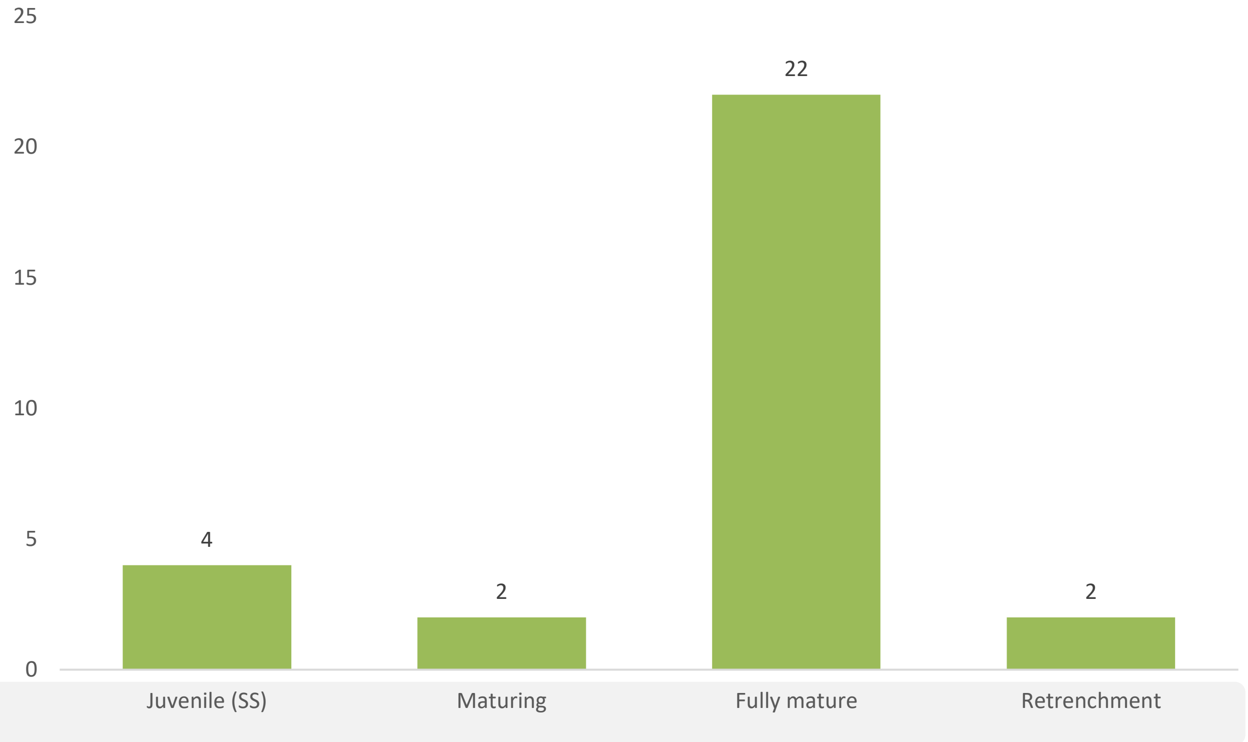
2.7.5 Removal of the pine plantation north and northeast of the site will likely lead to increased wind speeds into the site. Below is a graph from Meteoblue, which shows the prominent wind direction for site



Graph 7
The meteoblue climate diagrams are based on 30 years of hourly weather model simulations. This is used to provide an indication of typical climate patterns and expected conditions. The wind rose for Eskdale shows how many hours per year the wind blows from the indicated direction. Example SW: Wind is blowing from South-West (SW) to North-East (NE). (www.meteoblue.com).

2.7.6 Management of poplar trees

Reports on lifespan from polar can range from as low as 30yrs to 200yrs for poplar species. Species genetics plays an important role in life expectancy, especially its survival strategy. Poplar naturally grow big and dominate the landscape; they either produce lots of seeds though most clones cannot produce seeds) or split sucker grow big, then split sucker etc. As we can see within site only the Eastern cottonwood cultivar shows a high level of failure closely followed by the balsam poplar. The other poplar trees within site show less failure. Having a high failure rate and being a tree that reaches 30m is problematic within a public space. Having a large number of these trees all reaching large dimensions and maturity at the same time become unsustainable to manage in the long term.



Graph 8 Life stage of the eastern cottonwood poplar trees

2.8 *Herbicide Damage*

A number of the trees in the park show signs of herbicide related damage:

Fig.7 Bunya bunya (*Araucaria bidwillii*) note bent tips and deformed needles.

Fig.8 Coastal redwood in the Park is pictured on the left. Coastal redwood 277m from the Par redwood located outside the Park

Fig.9 Redwood are shallow-rooted species. As an example, this root was unearthed just under the mulch layer adjacent to the redwood in the Park. Any herbicide within this area would be absorbed by these roots.

This section summarises the management works and provides management options to reduce, control or remove the potential for an event to occur.

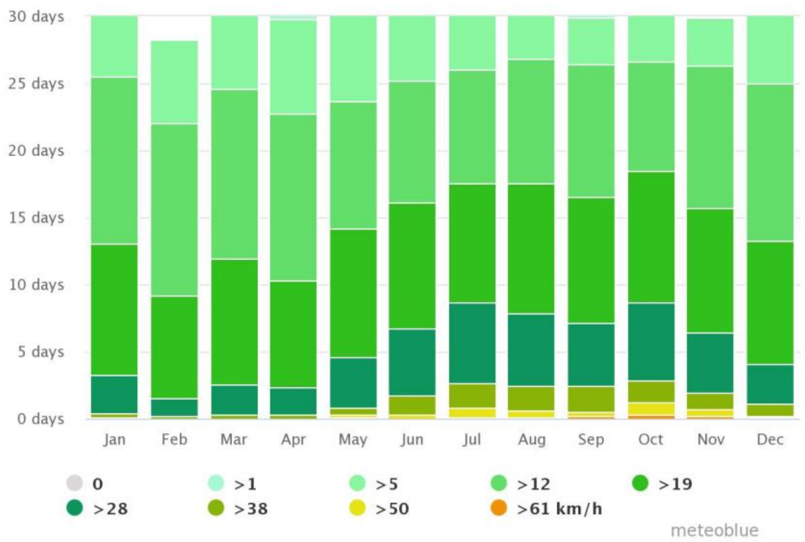
3.1 *Tree risk*

Reducing the risk of harm to people and property will always be a priority, but consideration is given to limit intervention works to allow the retention of trees with realistic potential to contribute to other important objectives such as enhancing ecological diversity, conserving heritage value sustainable management and optimising canopy cover. Further information on tree risk and how it is assessed is provided in Appendix 1.

3.1.1 Being a rural park with no commuter routes, the site is generally of low occupancy (during the site inspections highest daily people count was 62 and the lowest 11). There are some localised public generators such as playground equipment, benches, toilets and off-road access to residential property, but generally speaking, the site is of low occupancy. But as the Park is located adjacent to the stream, high occupancy has been noted by HDC and the residents during the summer months. Additionally, as noted during the tree inspections, the occasional freedom camper users the site when the gates are unlocked.

3.2 *Storms*

High wind events play a critical role in the frequency in which failure occurs



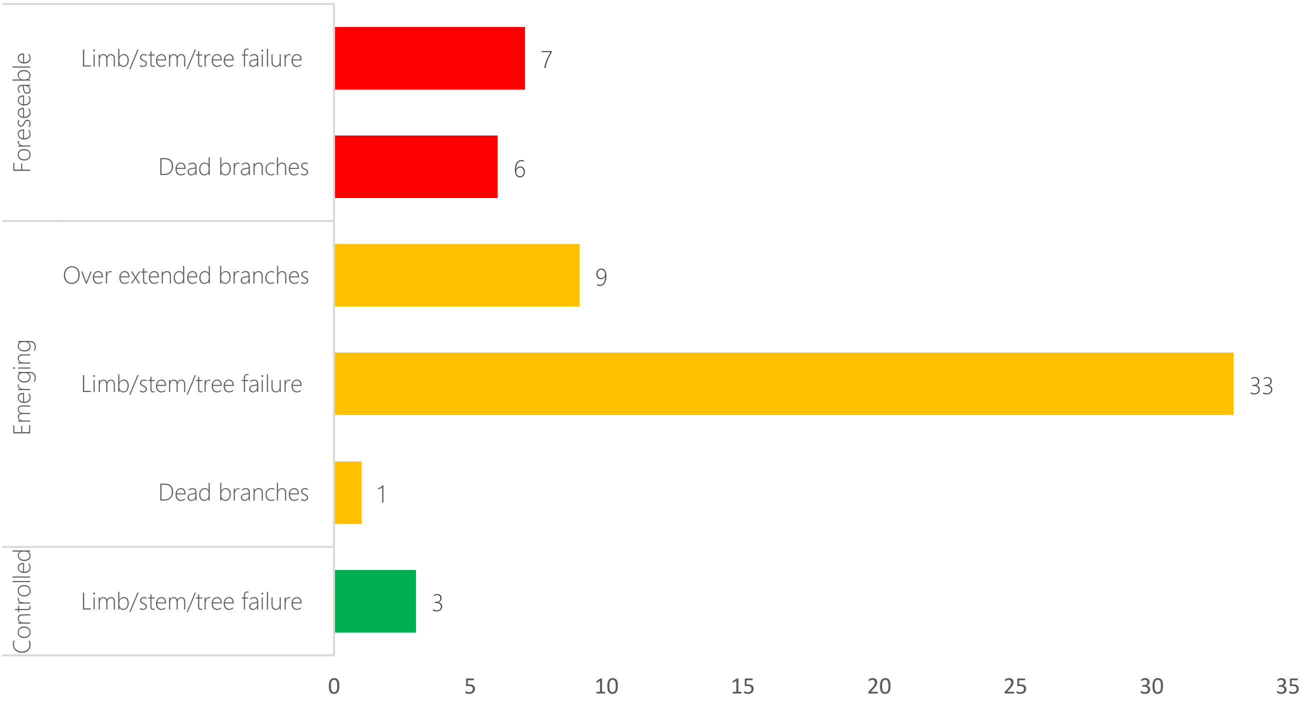
Windspeed	Tree Impacts
<1kph	
1-5 kph	
6-11 kph	Leaves rustle
12-19 kph	Small twigs move
20-28 kph	Large twigs move
29-38 kph	Small trees sway,
39-49 kph	large branches on trees move
50-61 kph	Trees sway,
62-74 kph	Twigs and branches break off of trees.
75-88 kph	Small to medium branches break
89-102 kph	Trees break or are uprooted.
103-118 kph	Widespread damage to vegetation
119-220 kph	Widespread destruction.

Graph 9 Shows the current frequency of when a high wind event is likely to occur (meteoblue)

3.3 *Occupancy during storm events*

As the Park is used purely for recreational use, occupancy during a storm is likely to be greatly reduced, though there is no site data currently available to demonstrate site reductions. The trees show a number of failures, and to my knowledge, there have been no near misses, which suggests the Park is mainly empty during high wind events.

3.4 *Likelihood of failure of an event occurring within a 3yr period*



Graph 10 Likelihood of failure occurring within the inspection period. And failure events that could occur

3.4.1 The above graph shows the majority of the risks are emerging. This is largely due to the condition of the poplar trees for the reasons outlined in previous sections.

3.5 *HDC management of risk within the site*

HDC have acted on the increase in limb failure by carrying out reduction works on failure-prone species over areas of higher use (e.g. picnic tables, access road, around play equipment). Additionally, regular checks are carried out by staff to inspect for any obvious defects, (e.g. large hangers, windthrow trees).

3.6 *Risk of harm occurring from a tree-related failure*

HDC has been carrying out proactive works to increase safety factors of limbs that overhang areas of obvious occupancy (e.g. access roads. picnic benches). The combination of proactive works and the site's general low occupancy, especially in relation to the reduction during storm events, means the risks are currently being controlled and are low. However, during the site inspection, freedom camping was observed during three of my site visits. This type of site use generally would mean a vehicle is parked under a tree for a longer period of time than what would otherwise be expected, and a camper would not be deterred by storm events and even more likely to park under a tree for shelter. Therefore this activity does present an increased risk during seasons where increased high wind events are expected.

3.7 *Risk of damage to structures*

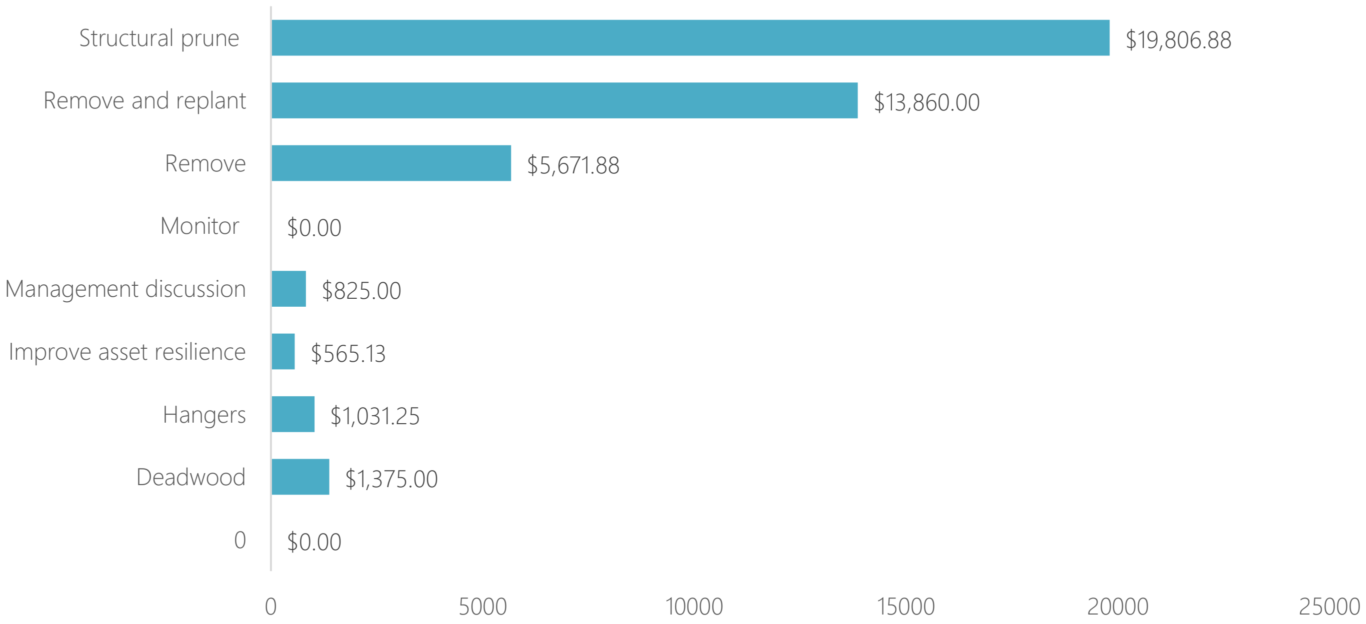
Risk to structures is likely to be related to car parking as the Park has no restriction to vehicles. Cars park in a variety of locations, and during the summer months, this is likely to take place under the trees, so there are some risks associated with parking, but current management practices are controlling the risk as far as reasonably practical.

3.8 *Current risk management of trees*

Current risk management carried out by HDC is reasonable and proportionate to the current risks. Further recommendations are made in section 4 to ensure the trees are sustainably managed.

3.9 *Management costs*

Below is a summary of management recommendations and costs



Graph 12 Management objective and associated costs

3.9.1 The above chart shows the estimation of costs for the works prescribed for the management recommendations over a 3yr period, including the staged proactive removal of nine poplar trees (one group within 3yr period and the other group within a 3-6yr period).

3.9.2 Currently, the ongoing management of the poplar trees is not sustainable. Poplar trees and specific cultivars, in particular, have a fairly limited life within the landscape. HDC is currently controlling the risk, but for certain trees, they are at the end of what is reasonably practical to continue to maintain. Therefore, staged removal over a period of time in conjunction with successive planting of large, long-lived trees should take place, to be reviewed at each inspection interval to ensure management action can respond to the site risks.

3.9.3 Staged removal is to be carried out under existing controls to maintain the problematic cultivars as far as reasonably practical whilst staging and planning for their removal. This would take place over a number of years, with the first stages proposed within 3yrs:

Proposed removal within 3yrs

Removal of 4 x Eastern Cottonwood 'Flevo" trees (139, 140, 142 and 143). (see map to the left for tree locations and image below for the trees to be removed.

Fig.10 Trees 139, 140, 142 and 143

Proposed removal within 3-6yrs

Next 3-6yrs the staged removal and replacement of trees, 156, 157, 158, 159 160, 161 and 162 (5 'Flevo' trees and 2 willow trees). Map on the right showing tree location and image below showing trees

Fig 11 Trees 156, 157, 158, 159 160, 161 and 162

3.10 *Alternative options*

The other option to proactive management is taking a minimal intervention approach, letting the trees fall apart, and then replacing them when appropriate. But this is unlikely to be a defendable approach, given the species and the history of failure. The current risks are low, but as noted within the survey, the structural weaknesses of these trees are increasing (emerging), and therefore a management plan is required:

- Progress with the removal of problematic species at staged intervals, with reviews at each 3yr inspection to ensure works can target the most problematic trees.
- Select and plant successive trees suitable to the location with community consultation
- Continue to reduce the likelihood of limb failure in areas of higher use as recommended within the management recommendations

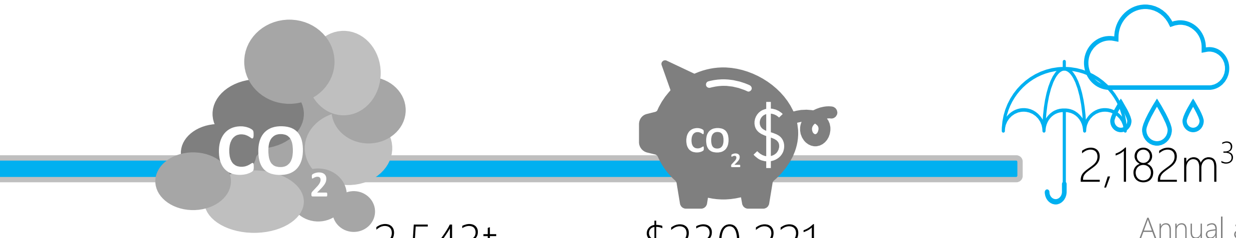
3.10.1 *Other tree removal for general tree management*

Within the management recommendations, it is proposed to remove 13 other trees for general management purposes:

Above plan highlighting trees to be removed for the following reasons:

- G1 (2 willow trees) and T2 Poplar; dead standing trees
- T27 (Western balsam poplar) historic failure throughout canopy codominant union within inclusion and likely split,
- T66 Silky oak Gummosis at base and heavy dieback likely to be caused by Phytophthora spp.
- T75 Eucalyptus. Cavity at base on north and south sides. Lack of taper possible girdled root and lean southeast. Apical dieback within canopy
- T102 Lombardy poplar significant codominant union near base. No separation of canopy was noted during the inspection. Juvenile specimen cost-effective to remove at this stage.
- T116 Eastern cottonwood Sucker growth. Codominant union.
- T195 Willow Split at base 1m in length
- T23 and G24 (4) Robinia juvenile trees manage sucker growth

3.11 *Environmental values of the captured trees*



2,543t

The estimated amount of carbon stored

$230,221

The estimated value of the carbon stored

2,182m^3

Annual amount of water estimated not to hit the ground, reducing stormwater runoff

3.11.1 Loss of environmental benefits from proposed removal

Carbon: -187t | Carbon value -$7,068 | Rainwater -103m^3

To mitigate the environmental and amenity loss, it is recommended to plant 14 London plane trees at 15m intervals around the cricket oval. 14 fully mature London plane trees would provide:

Carbon: 402t

114% increase over existing

Carbon value $15,095.10

113% increase over existing

Rainwater interception 1314m3

1,175% Increase over existing

3.11.2 Additionally, HDC has planted/provided 486 plants. Which further assits in offsets from environmental loss from any poplar removal. The planting will lead to further net environmental and amenity gains.

Pin oaks have been recently planted around the oval for successive planting, which is a great option. Over the last 5yrs, I have been noticing an increase in stem bleeding and cankering within maturing and mature pin oak specimens where mature trees exhibit considerable dieback. This may be a coincidence and not be the causal factor. But a maturing tree within the site has cankering and bleeding at its base but currently show little in terms of a reduction in health. As a precautionary measure, I have recommended London plane as an alternative species.

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Fig. 12 bleeding and cankering at base of pin oak

This section provides the final management recommendations based on the previous sections analysis.

4.1 *Management works*

4.1.1 All Management works are to be discussed with the operation manager to ensure all works details are understood in terms of works and risk requirements for the next 3yr period.

4.1.2 Proactive removal of poplar trees. Remove trees 139, 140, 142 and 143 within the first 3yrs and trees 155, 156, 157, 158, 159 160, 161 and 162 in the next 3- 6yrs. Review proactive removal stages each 3yrs, using the information in Section 4.2. to inform stage removal process

4.1.3 Consult with community on new planting and plant around oval either this planting season or to be implemented during next planting season.

4.1.4 Continue to monitor and implement management works where necessary as informed by details in the following section (section 4.2).

4.2 *Risk management*

4.2.1 HDC to maintain regular checks throughout the year and after storm events by employees and contractors. The type of check must be a walked visual check looking from accessible viewpoints for obvious defects from a distance and close-up. Should the visual check identify areas of concern, a detailed inspection should be carried out by competent personnel with enough training and experience working with trees to identify obvious and subtle defects and recommend how to manage them.

4.2.2 This regime should be supported by periodic inspection by a suitably qualified arborist with suitable training and experience in risk management. The arborist is to provide recommendations and critically analyse the advice and recommendations received from other tree contractors and arborists for any risks under current controls.

4.2.3 Failures that do not cause harm or damage provide a useful opportunity to identify opportunities to improve the management system and inform further recommendations based on intelligent analysis. Therefore its recommended that a system is established that records the following information:

- Trees that failed and types of failure.
- Date and time when the failure occurred.
- Weather event at the time of failure.
- Any notes images by the contractor on failure.
- Notes on what action was taken and any recommendations.

This information can then be used to inform current and future management decisions and provide a documented account of how the risks are being pragmatically managed

4.3 *Planting*

4.3.1 Establish and maintain a public herbicide register. Check all current chemical controls with a specialist who has experience in this area (see section 4.4).

4.3.2 Establish a mulching schedule with clear specs, extending current mulch rings as far as practicable.

4.3.3 Increase planting densities within native planted areas, Including rabbit protection guards for trees that show susceptibility to damage (e.g. ribbonwood). Continue or further engage with the community and schools to encourage planting days and connection to place.

4.3.4 Plant to current industry standards. Monitor and inspect new plants for successful establishment.

4.4 *Next arboricultural inspection*

Reinspect trees in 3 years.

This section reviews the recommendations against relevant SDGs to ensure management action promotes sustainable action to protect and enhance the urban ngahere.

5.1 Sustainable development goals

5.1.1 There will be a temporary loss of amenity and environmental value when a large tree is removed. But stepping back and looking in the long term objectives, replacing these trees with long-lived specimens will provide improved benefits, greater landscape resilience, maintenance cost savings – these are the main drivers for the management decisions. This will take time to mitigate, but it can also be an opportunity for the community to engage and continue creating value within an important greenspace with planting days to a maintain existing landscape structures (e.g. the tree oval around the cricket pitch).

5.1.2 The management works have also been tailored so that the proactive removal can be flexible to react when necessary to the site risks base on intelligent analysis. HDC has carried out a number of planting works, as I'm sure the community has also. These are important partnerships that work very effectively where they offer the greatest success in plant establishment, connection to place passive monitoring and the sharing of knowledge; working together to shape the future landscape.

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EST. PS 2013

ATTACHMENTS

Appendix 1 ***Tree risk details***

REFERENCES

C. Ecroyd Eucalypt Identification Workshop, Nelson 2010

Florence, RG. (1996). Ecology and Silviculture of Eucalypt Forests. CSIRO Publications, Australia. 400 pp.

National Poplar and Willow Users Group (2007) Growing Poplar and Willow Trees on Farms

NIWA Climate change projections and impacts for Tairāwhiti and Hawke's Bay (2020)

Wilkinson, A.G.(2000). Introduced Forest Trees in New Zealand Recognition, Role, and Seed Source

The following information sets out how Paper Street (PS) assesses risk and inspects the trees. The appendix has been divided into three sections so the reader can view the section relevant to their interest:

Part one

This section outlines the background and provides the basis of tree risk management. This is to provide some context to a subject that can create a lot of uncertainty and subjectivity. This section also contains current (at the time of the report) guidance. PS risk management recommendations and strategies are continually reviewed during each project, based on updated information and site specifics. To this end, PS does not use or subscribe to a "risk method" as such methods offer limitations in implementing improvements in assessment processes. It should be noted that risk methods can improve certainty for practitioners with inexperience, high uncertainty, or who are in general risk-averse by nature. Such tools can aid decision making for experienced practitioners for comparative analysis, should such analysis be required.

Part Two

Sets out PS inspection process

Part Three

Provides additional information on PS tools used to facilitate risk analysis.

Part one

P1.1 ***Introduction***

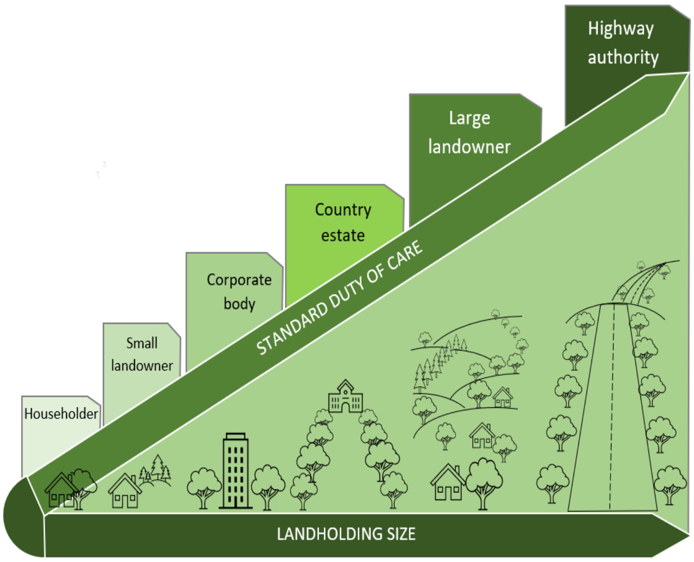
Although trees can be a liability, there is a growing research base documenting the benefits that arise from the close integration of trees with society. Those benefits are many, including buffering heat extremes, reducing heating and cooling costs, slowing rainwater runoff, ecological enhancement, air pollution reduction, carbon sequestration, increasing property values, conserving living cultural connections to the past and future, visual enhancement, and improving human health and wellbeing, to list the most obvious.

P1.2 For communities to make the most of these benefits, trees must be close to where people live and work, so spread evenly across the built environment. Urban trees are most useful when growing alongside roads and other transport routes, close to buildings, in gardens, and throughout urban recreational spaces. Unsurprisingly, there is a strong link between tree size and the number of benefits received. Although the precise relationship will vary from species to species, the amount of benefit is significantly influenced by the three-dimensional crown volume, which is a reliable proxy for leaf area, rather than the two-dimensional area projected beneath the branch spread. This results in an exponential relationship between tree size and benefit delivery, so big trees are significantly more useful than small trees.

P1.3 However, trees are natural shedding organisms. This natural process can lead to potential damage or harm to occur where trees are located adjacent to areas of high occupancy. Within this context, management recommendations need to manage those important community benefits whilst minimising the likelihood of harm or damage occurring.

P1.4 *Legal requirements*

In the civil context, a duty holder carrying out a business or undertaking has obligations under the HSWA, as far as reasonably practicable, to prevent and minimise foreseeable harm or damage occurring from trees that are under their ownership and control. A good way to visualise the level of care from a duty holder is on the adjacent graph (Graph 1)



Graph 1 Duty holder level of standard of care

P1.5 *Risk management*

In the broader management context, risk is defined as the:

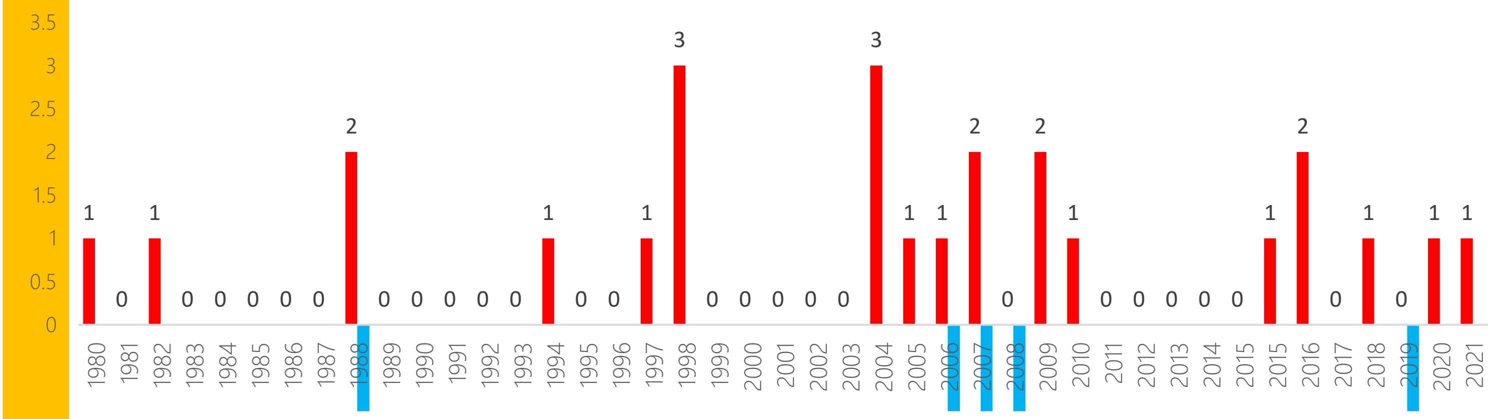
> *"effect of uncertainty on objectives"*
>
> (AS/NZS ISO 31000:2009 and ISO 31000:2018)

The effect is a deviation from the expected (positive and/or negative). As trees provide multiple benefits, action or management could control one risk but adversely affect another objective if the risks are not assessed in context (HSWA).

P1.6 *Perceptions of tree risk of harm occurring*

Before determining the risk of harm, it is important to establish the risks to ensure any guidance recommended is proportionate and reasonable.

Unpublished research currently identifies that over a 41yr period, 25 deaths have occurred in NZ due to a tree-related failure. This equates to around 1:7 million chance of a tree related death occurring (Cadwallader, 2021)



Graph 2: Number of fatalities in the 41yr period. Blue lines indicates when an inquest was carried out. Risk assessment methods introduced; Matheny & Clark (1993), QTRA (2005), TRAQ (2017) and VALID (2019)

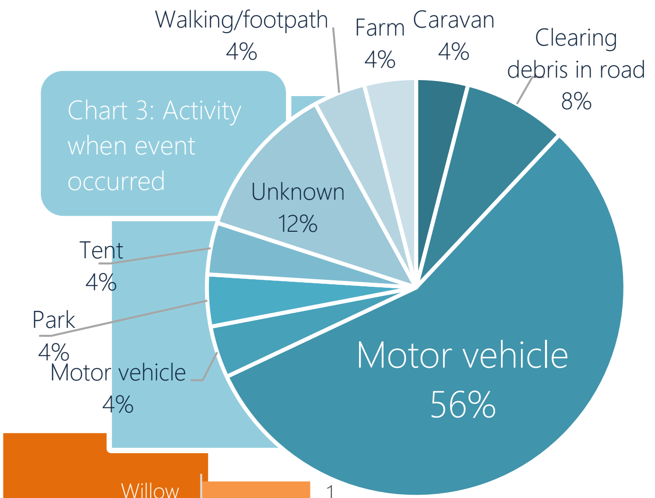


Chart 3: Activity when event occurred

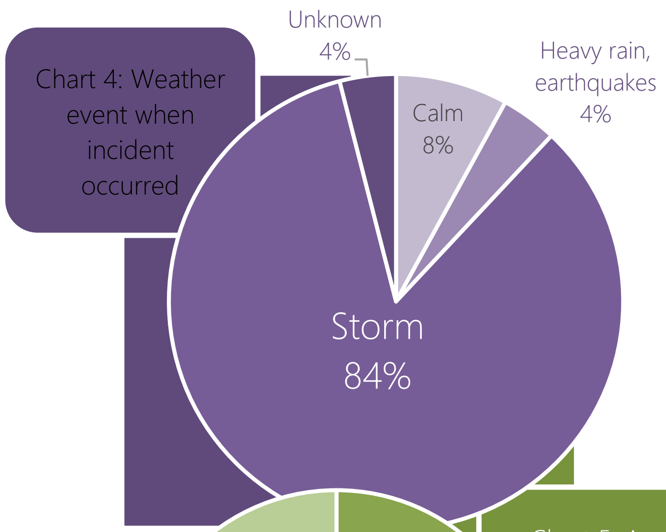


Chart 4: Weather event when incident occurred

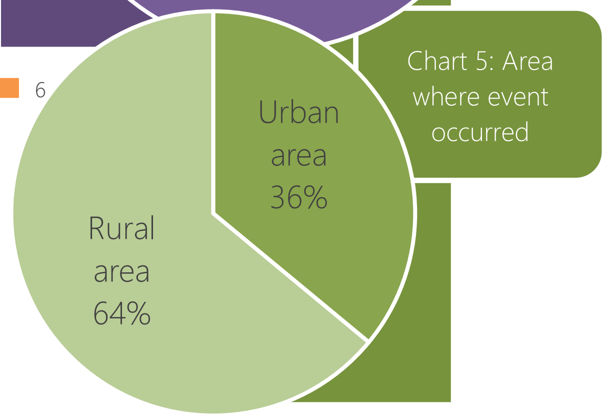


Chart 5: Area where event occurred

Chart 6: Species that failed

P1.5 *International statistics*

In Australia, research works carried out found that over 168yr period 280 deaths occurred, equating to a 1:4million chance (Hartly 2019). In the UK, the research identified 64 deaths in a 10-year period equating to a 1:10million chance (NTSG, 2011). In the US, the research identified 407 deaths in a 13yr period, equating to a 1:11 million chance (Schmidlin, 2008). To put that into some form of context, fatalities resulting from driving in NZ over a 1yr period (2019-2020) equated to 1/14 thousand chance. In the absence of having national guidance on risk thresholds, the HSE (UK) classed any risk below 1:1 million as being broadly acceptable, in other words;

> *"the levels of risk characterising this region are comparable to those that people regard as insignificant or trivial in their daily lives" (HSE, 2001),*

This would, in the broadest context, define trees as being very low risk.

P1.6 *Perception of risk and biases*

The overall risk from trees may be low, but our perception can be strongly influenced by media showing images of limb/tree failures after high wind events (NTSG, 2011).

Fig.2 Image from recent storm in Auckland (03.08.21) RickyWilsonStuff.co.nz

This can influence our perception and can create a strong bias towards risk aversion. Trees are complex, and there are many unknown variables in predicting when a failure event may occur. This can create a lot of uncertainty, even within a tree "risk assessment". The personal bias and experience of the assessor and decision-maker has a greater influence on a risk rating than the tree itself (Koeser,2017). However, it is very important to acknowledge the differences between the broad concept of risk, which as highlighted above is generally low, and the localised potential for risk which could be high. Taking a minimal invention approach, therefore, is highly unlikely to be defendable in the localised context, e.g., a dead tree overhanging a high occupancy area will always be a high risk, not a low one. This could be why we see that only 36% of fatalities happen in urban areas (which are of higher occupancy) as risks are more likely to be proactively managed there.

P1.7 *Calculating tree risk*

Determining failure of a living structure that is constructed of a dynamic material such as wood is an imprecise undertaking. Currently, there is not enough data to reliably calculate tree risk (Matheny, Clark, 2009). As previously mentioned, the perception of risk, acceptance of risk, and an arborist's professional bias and their experience have more influence over the final risk determination than the actual tree assessed (Norris 2007; Koeser and Smiley 2017). This can lead to a wide range of opinions and mixed "risk terminology" and risk methods from arborists;

> *"Unfortunately, consistency (while an important aspect of making risk assessment more reproducible) is not the same as accuracy. Variability in ratings means some portion of the assessments will be inaccurate. However, false precision in a risk assessment method could create a very consistent bias that pulls the perceived level of risk away from the actual level of risk for all who subscribe to the method."*
> (Koeser 2016)

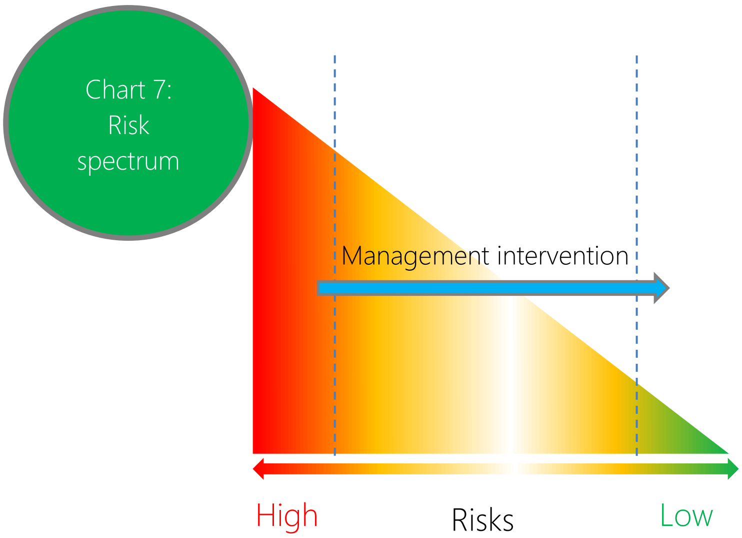
Therefore, the experience and objectivity of an assessor are critical if a proportionate management intervention is to take place.

P1.8 *Identifying a tree risk*

In risk identification risk can be simply expressed as risk = potential events, the consequences, and their likelihood (ISO 2009, 2018). Simply put for trees, for a tree to be considered a risk it would need to exhibit signs of foreseeable failure (Potential Event) standing in an area of sufficient occupancy (Likelihood) where a person is likely to be beneath the weak point when a failure occurs (Consequence). The likelihood of impact occurring strongly correlates to occupancy, and whether a tree exhibits a defect where failure is foreseeable within an inspection period. Therefore, a tree has to have a foreseeable failure within a high occupancy area for it to be a high risk. Conversely, a tree with foreseeable failure in an area with little occupancy would be of low risk.

P1.9 *Taking a tree-oriented approach*

For a decision-maker to understand tree risk is to conceptualise tree risk on a spectrum where risk is either increasing in one direction or the other. It is not possible to pinpoint the level of risk due to each site and a tree's condition being different, but it can be described as sitting on one end of the spectrum or the other. For example, a large tree with a significant defect in a high occupancy area could be described as sitting at the higher end of the risk spectrum and the intention of management interventions would be to shift it towards the lower end (Barrell, 2020).



Part two

P2.1 ***How PS inspects the trees***

Trees are inspected from ground level using binoculars where necessary. A visual criterion is used to assess the mechanical integrity of the trees[1,2]. If a defect is identified that has a foreseeable chance of harm or damage occurring, the tree and all necessary information is captured. Additionally, a sounding hammer is used to aid detection of any extensive decay within the stem buttress zone or bases of roots, should such an investigation be warranted. Trees are assessed in consideration to the weather events to which they would be typically subjected, and the environment in which they stand.

P2.2 All inspections are GPS tracked to provide a record of where the inspections were carried out.

P2.3 Reducing the risk of harm to people and property will always be a priority, but consideration will also be given to limit intervention works to allow the retention of trees with realistic potential to contribute to other important objectives such as enhancing ecological diversity, conserving heritage value, and optimising canopy cover.

P2.4 Intelligent tree management interventions are applied to the recommendations so not to just focus on managing the risk from tree failures, but also to be sensitive to the wider implications, so careful, considered and balanced outcomes can be reached.

P2.5 ***Inspection periods***

All assessments of risk are set against an inspection interval. Inspection intervals are determined during each assessment based on the condition of the tree being assessed. As tree condition is dynamic, so needs to be the inspection interval. Each inspection interval is based on trees being checked by contractors who can identify a significant defect that has the potential to cause harm after storm events. Additionally, works/inspections are carried out after a service request is raised by the public (e.g., a member of the public contacts the council to report a fallen tree).

Part three

P3.1 ***Additional details***

Additional analysis is carried out where necessary if risk falls outside of common-sense management (i.e. large hanging limb over a busy path) to support recommendations. Below are the methods PS used to assist in the analysis the risk where there are no measures to use:

P3.2 ***Occupancy***

To determine or measure the likelihood of impact as a consequence of a limb failure, a person or target needs to be beneath. Occupancy, or the duration in which something is underneath the tree or tree part assessed to fail, is a significant factor in determining the risk of harm occurring. Therefore, for it to be considered high risk, a tree needs to show foreseeable failure where failure would occur over a high enough occupancy area for the likelihood of a person to be beneath it when it fails.

P3.3 Occupancy could also be viewed on a spectrum, with high and low being at either end and the area between being harder to distinguish in terms of where one classification stops and another begins (e.g., low to moderate occupancy). Currently, there are no standards or classifications for how many people equal a low, moderate or high level for site occupancy. For this assessment, any defect that has around 3% of occupancy beneath it (45minutes a day of permanent occupancy) is used as a benchmark as the start of the higher occupancy end of the spectrum.

P3.4 ***Calculating occupancy***

People counts are factual measures and can assist as a base level for occupancy within site. During a PS survey, people counts are manually recorded where no people count data is available.

- **Frimley Park**

The maximum people count over an 8hr period (22.04.21): was 264 people (week day)

P3.5 The time of year strongly influences people counts, especially for most park sites when inspecting trees in the winter months, as site use is generally at its lowest.

P3.6 People counts are becoming more common, and reviewing data for certain areas with annual counts can provide meaningful information on anticipated seasonal change and likely reductions during storm events. Chart 4 shows that 84% of all recorded fatalities in NZ have occurred during high wind events. Knowing that occupancy is much reduced in storm events is therefore important. Historic people counts show reductions in occupancy during those times, apart from CBD areas or commuter routes which show minimal reductions.

P3.7 I have not been able to source annual people counts information for parks in NZ yet. Therefore, data used from Central Park in New York City is used to provide an indication of anticipated human behavioural patterns for seasonal fluctuations for storm events. Below are the estimated data on people counts based on site recordings.

Estimation of occupancy Frimley Park					
Site description:	Public open space	Season decrease	% of total value remaining	Estimated weekend increase	Estimated weekend Occupancy
Season counted:	Autumn	32%	68%	84%	486
Max occupancy recorded	264	Estimated average week occupancy:			327
Seasons:	Summer	Autumn	Winter	Spring	
Est. seasonal decreases from high occupancy season (%)	0%	32%	65%	22%	
Estimated daily seasonal ave considering % seasonal changes:	481	264	168	206	
Est. annual daily occupancy mean:	235	Ave walking speed (m/s):	1.3		
Storm reduction:	46%				

P3.8 ***Putting occupancy into context***

Occupancy is considered over a 24hr period. Occupancy is difficult to determine with accuracy due to the unpredictability of public movement. Additionally, people often move in groups which can be influenced by peak flows and not equally spread out. Nonetheless, justification needs to be reached as to why a site is defined as low or high occupancy. To provide a base indication of occupancy, the size of each defect (estimated base dia, length and width) is recorded to estimate the duration in which a person may be beneath the part deemed to fail. The largest measurement is then used, and the average walking speed of 1.3 meters a second is used, to estimate the duration a person may be beneath the part. The weight of the defective part is also estimated based on cylinder and wood density to indicate force. Road volumes are also considered, with speed limits and annual average daily traffic counts based on road type, provided by NZ Transport Agency.

P3.9 Additional details are also considered where occupancy levels are reduced based on site usage e.g., a tree at the periphery edge of a park would have less of the site occupancy than the main path. Additionally, public generators are considered, such as seats with estimates of site duration.

P3.10 ***Storm events***

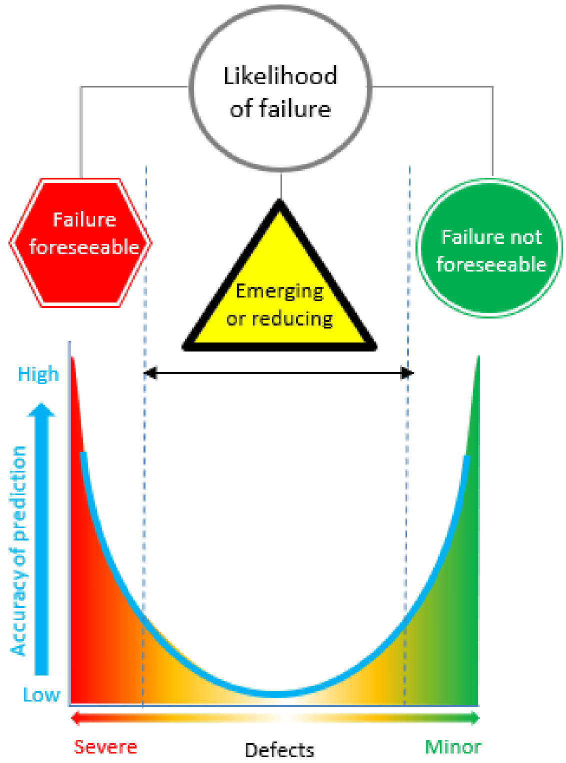
If a defect is identified, it is then assessed if the likelihood of failure will occur in a storm event or at any time. If a defect is considered to fail in a storm event, then the estimated occupancy is reduced by the estimated % taken from other site data of occupancy reductions during storm events.

P3.11 ***Assessing the likelihood of failure***

Predicting the likelihood of failure is difficult to determine with a high level of accuracy. There is limited research to show the validity of arborists assessments for the likelihood of failure. What limited research there is suggests that unless a defect is severe, it is unlikely to increase the likelihood of a failure.

Research carried out during a high wind event used 673 trees, which were risk assessed by three experienced, trained practitioners and then revisited to assess storm damage. Trees were rated qualitatively where imminent was the highest likelihood of failure followed by probable, possible and improbable. The study found:

- 94.1% of trees that had an imminent rating failed
- 38.8% of trees failed that were rated as probable
- 15.3% of trees failed that were rated as possible.
- 0% of trees failed that were rated as failure being improbable.



The study highlights the less obvious a defect the greater the uncertainty of predicting the likelihood of failure. Therefore, unless a defect is obvious it is unlikely to be reliably assessed as foreseeable. The greater the uncertainty for failure the more inaccurate the determination, which has implications on management actions if wide ranges of terminologies are used.

Therefore, each defect is rated as:

- Imminent: an event that is predicted to occur at any moment
- Foreseeable: an event that a competent inspector would consider as likely to occur within a checked period.
- Emerging: an event which may take place within a checked period, but the significance of the defect is considered to increase over time
- Controlled: for defects being actively controlled where further controls may be necessary
- Further analysis: areas where further analysis is required to evaluate the risk.

References

Barrell, J. (2020). The implications of recent English legal judgments, inquest verdicts, and ash dieback disease for tree risk management regimes.

Cadwallader, B. (2020). Lists of deaths from accidental tree failures in New Zealand (unpublished research).

Hartley, M & Chalk, J. (2019). Australian Fatalities associated with Tree Failures, a Review of Deaths in Australia from Accidental Tree Failures

Health and safety executive (2001). Reducing risks, protecting people – HSE's decision-making process.

Koeser, A & Smiley, E. (2017). Impact of Assessor on Tree Risk Assessment Ratings and Prescribed Mitigation Measures. Urban Forestry & Urban Greening. 24. 109-115. 10.1016/j.ufug.2017.03.027.

National Tree Safety Group (2011). Common Sense Risk Management of Trees, guidance on trees and public safety in the UK for owners, managers and advisers. ISBN 978-0-85538-840-9

Norris, M.,2007. Tree Risk Assessments – What Works – What Does Not – Can We Tell? A review of a range of existing tree risk assessment methods.

Schmidlin, T.W. 2008. Human fatalities from wind-related tree failures in the United States, 1995-2007.