Assessment of Vegetation Condition and Health at Claudelands Bush (Jubilee Bush; Te Papanui)

CBER Contract Report 113

Client report prepared for

Hamilton City Council

by

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Abstract

As the largest remnant indigenous natural area, Claudelands Bush is a key asset for Hamilton city. With a history including clearance, logging and grazing; high numbers of plant species have been lost from the bush. Some of these pressures still exist today such as drainage, invasion by adventive plant species, presence of animal pests and the small size of the bush fragment. These pressures continue to contribute to native species losses. To reduce species loss and improve vegetation condition and biodiversity, management has been taking place in the area since the 1980's. Management included planting of native species, weeding of the bush, construction of wind breaks and boardwalks.

Prior to European settlement the vegetation was a semi-swamp forest dominated by kahikatea (*Dacrycarpus dacrydioides*), rimu (*Dacrydium cupressium*) and matai (*Prumnopitys taxifolia*) with a border of manuka (*Leptospermum scoparium*), cabbage tree (*Cordyline australis*) swamp. Today three vegetation types are represented in the forest fragment; kahikatea dominant, mixed broadleaved dominant and tawa (*Beilschmiedia tawa*) dominant forest. The kahikatea dominant forest type is the most similar to the original vegetation type.

In 2009 a large number of kahikatea died mainly on the eastern boundary of the park. Investigations concluded that the high kahikatea mortality was due to a drought in 2008, which stressed trees beyond recovery. It is possible more trees in this area may die from this event as a large lag time can occur in tree mortality after drought events.

Previously three major reports have been produced (1954, 1985 and 1997) on Claudelands Bush. The present survey makes a comparison to these past reports, particularly focusing on vegetation composition and condition. The number of adventive herbaceous species within the forest has probably declined due to intensive weed control and as the understory has developed. Native species richness and diversity has declined from 1997 levels. Eight native species, which occurred in all previous surveys, could not be located in the survey completed in 2009. Of the taxonomic groups, ferns had the largest decline. Recent plantings have reduced species loss by reintroducing natives, which were once found in the bush.

To help guide future management of the bush twenty 10m x 10m permanent quadrats and three water table monitoring probes were installed. Water table probes will be monitored for the period of a year (March 2010-March 2011). Vegetation monitoring plots were placed perpendicular to the newly installed drainage system and span the three vegetation types as well as recent plantings. These plots are to assess any effects the water table changes have on of vegetation composition and it is recommended they be re-measured at five yearly intervals.

Introduction

Located on the north east edge of Claudelands Park and bordered by two main arterial roads, Claudelands Bush (Fig. 1) is a prominent feature in Hamilton city. With less than 10% of kahikatea forest remaining in the Hamilton Ecological District at just over five hectares this bush is also a regionally significant area in the Waikato (Leathwick *et al.* 1995). It is the only remnant of the expansive 800 acre semi-swamp forest known as Claude's Bush, which existed in the 1860's. Subdivision, logging, grazing and drainage have led to the small forest fragment we are familiar with today (Whaley *et al.* 1997).

In 1993 a management plan was produced for Claudelands Bush as a requirement of the Reserves Act 1977. Recommendations from this plan resulted in the fencing of the bush, installation of a wind break on the south western boundary of the bush, the building of raised boardwalks along existing paths in the forest as well as to two new access points on the park side, regular weeding to control adventive species and enrichment plantings within and around the bush. The management plan also recommended the need to monitor both groundwater level and vegetation trends of the forest (Hamilton City Council 1993), these latter two recommendations are the focus of this report.

In 2007 re-development of the Claudelands Event Centre began. This has led to development directly adjacent to Claudelands Bush. A pond and drain have been installed alongside the bush to handle excess stormwater from a new carpark for the showgrounds. Planting of native trees and shrubs has been undertaken alongside the drain and pond, the development has been undertaken to add visual enrichment and enhance the wind buffer to the existing bush.

All reports and management plans related to the bush have noted the lowering of the water table in the park. This results in the drying of the soils, which affect the growth and composition of the forest and reducing connections to its future successional trends (Gudex 1954; Boase 1985; Hamilton City Council 1993; Whaley *et al.* 1997).

Figure 1: 2007 aerial photo of Claudelands Bush (GoogleEarth.com)

Semi-swamp forests

Once a prominent feature of the Hamilton Basin semi-swamp forests have been reduced to a few small pockets scattered across the pastoral and urban landscape (Leathwick *et al.* 1995). Characteristics of a semi-swamp forest are water tables close to or above the ground surface, canopy dominance by conifer species such as kahikatea and matai (*Prumnopitys taxifolia*), a diverse array of divaricating shrubs and gley soils. Manuka (*Leptospermum scoparium*) or other scrub usually surrounds these forests providing a barrier to prevailing winds, and maintaining humidity inside the forest. In previous studies it has been found that reduced soil moisture lowers the native species diversity and associated threatened species in this forest type (Burns *et al*. 1999). Even though kahikatea can survive in drier soils it is often outcompeted by broadleaved species such as tawa and titoki (*Alectryon excelsus* var. *excelsus*) (Whaley *et al*. 1997).

History

In previous years three major reports (Gudex 1955; Boase 1984; Whaley *et al.* 1994) have been produced on Claudelands Bush describe vegetation history, and vegetation changes. Their findings are summarized below.

Gudex (1955) observed that the forest had been reduced from 800 acres to 5ha between 1864 and 1955. Drainage of the area, which included a drain on the western boundary, had obvious effects on the bush's hydrology. Where once it was common to find holes of 3-5ft of water and pooling, by 1955, drainage had "prevented the accumulation of surface water". Logging of the conifers matai and rimu took place from 1964 onwards, with the occasional removal of kahikatea. To reduce plant dessication in the bush, two attempts had been made to reduce the wind flow into the bush from prevailing westerlies; in 1923 flax was planted on the western boundary and in 1951 native trees were also planted there. Up until 1927 stock were allowed to graze in the bush; this resulted in significant soil compaction. Animal pests and weeds such as possums and wandering Jew (*Tradescantia fluminensis*) became established in the forest.

Two vegetation surveys one in 1953, the other in 1955 were conducted by Gudex. Though some were almost certainly present, no adventive species were recorded, but the presence of wandering Jew was noted. Gudex found between his two surveys there was an increase in fern species, shrubby *Coprosma* spp, sedges *Uncinia* spp., *Carex* spp. and *Microlaena avenacea* grass numbers. There had been a decrease in the number of lianes and epiphytes and pukatea (*Laurelia novae-zelandiae*) was found to be in poor condition. No species had been lost from the bush between the two surveys. Wandering Jew was noted as replacing some native species.

Boase (1985) surveyed the area between 1980 and 1984 and found that since 1955 fifty-two species including hybrids had become extinct from the bush and twenty-five new adventive species of plants were present. Of the one-third of species lost from 1995 to 1984, 63% (48) were species Gudex (1955) recorded as having limited populations. Most losses were either ground ferns or shrubs. Losses seemed to be mainly due to drainage and strong prevailing winds causing dehydration in plants and competition from the adventives including wandering Jew.

Whaley *et al.* (1997) found no further species loss in the flora from 1984 to 1996. The major canopy species were now kahikatea, tawa and pukatea. Further management of the park too place with wind breaks, intensive weeding of invasive species and boardwalks.

Sixty adventive species of plants were recorded, the majority being herbs (33) and shrubs (11).Some indigenous species not native to the district; northern lacebark (*Hoheria populnea*), karaka (*Corynocarpus laevigatus*) and coastal karamu (*Coprosma repens*); had become naturalised in the bush. Whaley *et al*. (1997) predicted that species losses were likely to continue in the future and over the long term forest composition and structure will change.

From 1996-2009 a small area was planted with semi-swamp species on the south-western side of the bush. Planned development of Claudelands Park and Waikato Events Centre had led to further development around Claudelands Bush. A pond and drain have been installed on western border of park in 2009. The banks have been planted with indigenous species found in semi-swamp forests or shrublands. In 2009 members of the public reported some kahikatea mainly in the north-west corner of the bush as having died.

In 2009/10 Hamilton City Council requested that CBER assess the current and future condition of Claudelands Bush and the effects the new stormwater system is having on the forest. Specifically, we were asked to:

- Investigate the high mortality of kahikatea in 2009
- Create an updated plant species list for the bush and adjacent planted areas
- Install vegetation monitoring plots in the bush and adjacent planted areas
- Monitor the water table in the bush with water table probes for a year.

The results of these investigations are outlined in the present report.

1. Kahikatea tree deaths

In 2009 there was a noticeable increase in kahikatea mortality at Claudelands Bush (Fig. 2; Plate 1). An assessment was completed to determine how many trees had recently died and what could have caused their deaths. Two hypotheses were proposed; deaths were a result of natural self thinning or the deaths were due to severe stress caused by the 2007/8 drought. If self thinning was occurring all dead trees would be of a similar size leaving a few large trees surviving. If deaths were caused by drought, trees in a discrete area of the bush more prone to drought because of microtopography or some other factor would have died. Neither hypothesis is however mutually exclusive.

Method

Increment cores were taken from the apparently dead trees to assess cell structure to quantify which were actually dead. To test if the causes of these deaths was due to self thinning diameters of the dead trees and their five nearest neighbours were recorded as well as distances between them. This was followed by an ANOVA to determine if there were statistically significant differences between the diameters of living and dead kahikatea in the same area. Distance from the boundary fences and elevation were recorded to assess possible microclimatic effects on the trees.

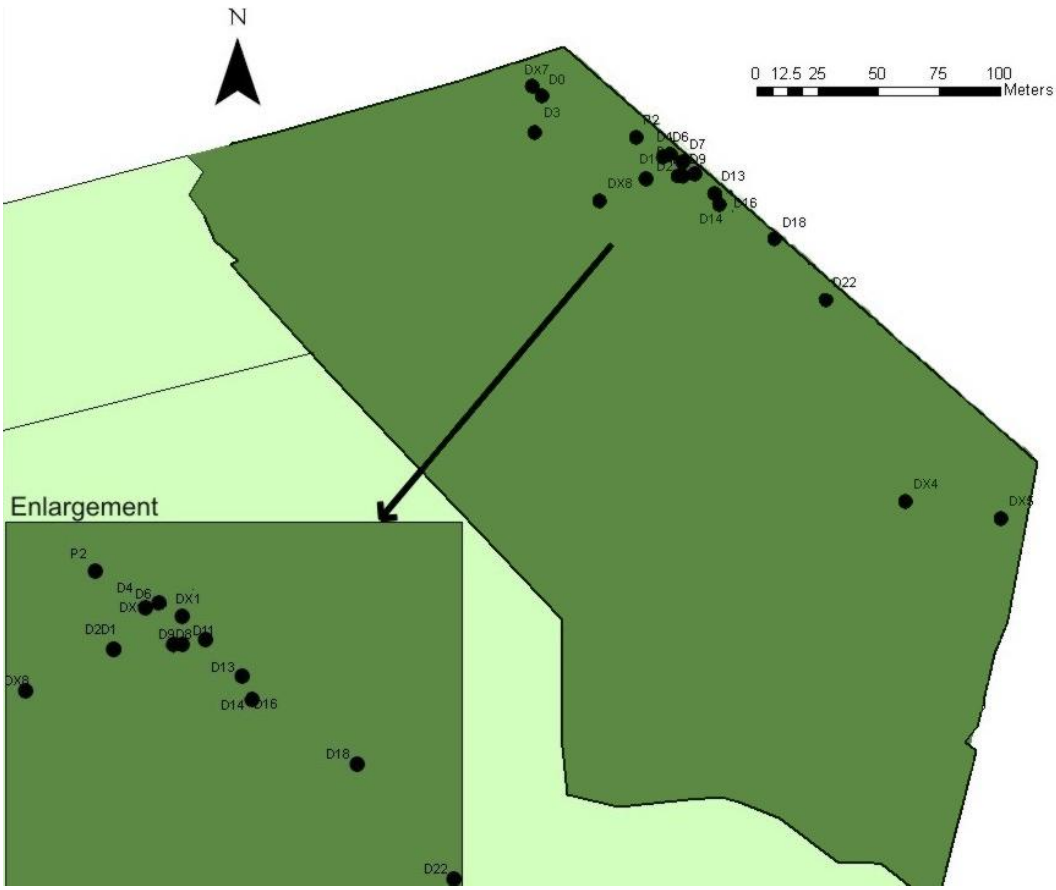

Figure 2: Dead kahikateas in Claudelands Bush.

Results

Fourteen trees were found to be recently dead. Due to their level of decay some trees such as those labelled D0, D3 and D14 had apparently died before 2009.No significant difference (P=0.46) was found between diameters of dead trees and their nearest poor and healthy neighbours. Also both dead and living trees had wide ranging diameters (Table 1). Spatially, these recent dead trees were clumped mainly in the north eastern boundary of the bush. This area of the bush had little in the way of understory and the ground is slightly elevated in parts compared to other areas of the bush.

Table 1: Means of stem diameters of dead kahikatea in Claudelands Bush and their five nearest neighbours

	Dead	Good	Poor
Mean	42.9	42.5	52.6
Standard Error	4.2	2.5	7.9
Minimum	7.9	10.4	21.8
Maximum	100.9	110	124

Discussion

There was little difference between stem diameters of dead trees and their closest healthy neighbours. This suggests natural self thinning was not the predominant cause of increased kahikatea mortality in Claudelands Bush. Recent deaths were found to be clustered in one area of the bush. These trees were on a slightly elevated area with fewer hedges on the margin and a reduced understory compared to other areas. Kahikatea also have roots close to the grounds surface unlike most other trees in the bush. These factors contribute to an increased exposure to the sun and wind and increase water stress. This coupled with the extreme drought event faced in the summer of 2007/8 suggests these trees suffered from extreme drought stress resulting in their deaths. Studies have shown an increase in tree mortality due to drought effects can lag behind the actual drought event by years (Bigler *et al.* 2007). This lag also means more trees could die in the near future due to the 2007/8 drought event.

Due to the extreme weather events of 2007/8 the increase in kahikatea mortality was probably not preventable. In 2008 higher levels of mortality were noticed across a range of plant species in Hamilton city. These tended to be in areas of higher wind and sun exposure, on free draining soils, plants of a younger age and drought intolerant species. In the short time from January to March in 2008 mortality of recently planted hillslopes at Waiwhakareke Natural Heritage Park went from eight stems.ha^{-1} to twenty six stems.ha^{-1} (Cornes *et al*. 2008). At Hayes Paddock some 135 trees and shrubs died.

Having a higher water table across the bush may potentially have reduced the number of deaths. Higher water tables may have buffered against drought effects and increased the time for water levels to become low enough to cause water stress in the trees.

The first aim for Claudelands Bush in the management plan is "To maintain and enhance the natural characteristics of the kahikatea forest and its fauna". Therefore, where dead trees need to be felled the remains of the trunks should be left in the forest. This will help provide habitat for insects and other organisms in the bush. This recommendation was followed during the felling of dead trees present in the park in 2009.

Key points/ Recommendations

- Extreme drought events can cause increased rates of tree mortality, especially on the edges of forest fragments
- Deaths due to drought occurred across Hamilton city
- Kahikatea may be more susceptible to drought due to a high amount of surface root growth
- Where possible to mimic natural processes let dead trees undergo natural decomposition
- If trees do need to be felled keep the logs in the bush as it for habitat
- To maintain a kahikatea dominant forest plant kahikatea saplings in canopy gaps
- To reduce the probability of deaths from extreme drought in the future maintain or enhance the water table

2. Species list

Method

A species list was compiled following a brief inspection on 14th to 16th October 2009. This list included not only the 5ha of original bush but also areas planted in 1994 and 2009 on the western and southern boundaries of the bush (planted species marked on species list; Appendix 1). These results were compared to previous surveys completed in 1954, 1984 and 1994. In the 1954 measurement native species were recorded but no adventives. All other lists recorded both native and adventive plants. These lists can be used to investigate changes in plant richness and diversity with the caution that the earlier lists were the result of more time intensive surveys. Some species may have been missed in the present low intensity survey.

Results

Adventive and native richness

Numbers of native and adventive species were reduced in 2009 (134 species) compared to the 1994 (153 species) measurement, with adventives having the largest decrease (Fig 3). In total more species were present in 2009 compared to 1980 (91 species) measurement. Forty-five species recorded as present in 1994 were not recorded during the 2009 survey; nineteen natives and twenty-six adventives. Of these a total of eight native species not recorded in 2009, have been recorded at Claudelands Bush in all previous surveys. Twenty-four species had their first record at Claudelands in 2009; half natives and half adventives. The majority of new native species (eight) had been planted. *Mida salicifolia* and puriri (*Vitex lucens*) however, were recorded within the original boundary. Four species present at the time of the 1994 survey were recorded only found in the new plantings.

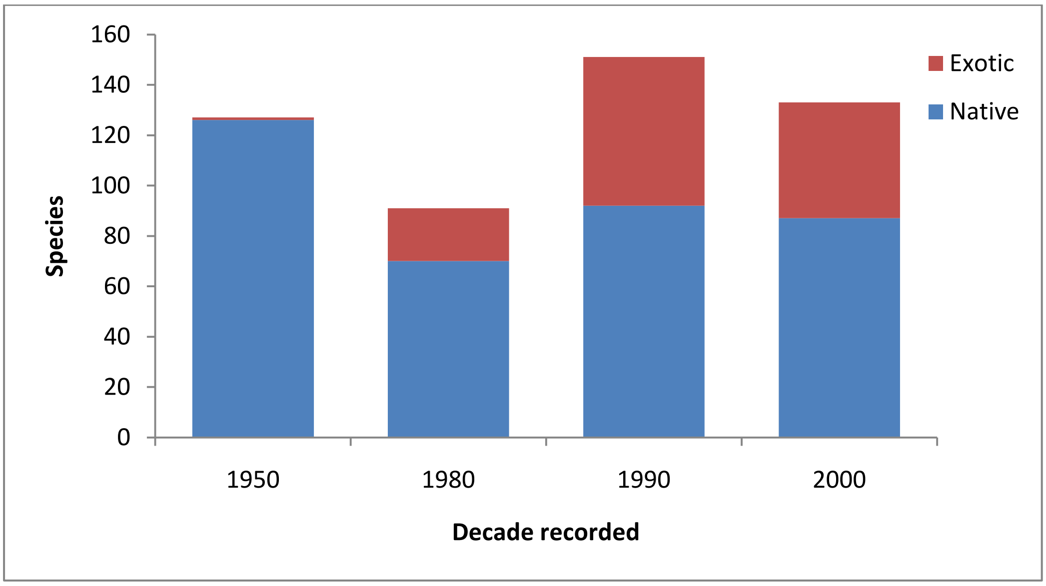

Figure 3: Number of native and adventive species present in each species list

For further investigation species were split into their taxonomic life forms (Fig 4). In the 2009 survey of the native species seven ferns, three dicot trees, seven dicot shrubs, one dicot herb and two sedges were missing. Of the new species recorded in 2009 there was one fern, one conifer, four dicot trees, five dicot shrubs, three dicot herbs and ten species in the other monocot category. Less ferns were recorded in 2009 than in any other year. There was a reduction in 2009 of total species richness in the taxonomic groups of dicot shrubs, lianes and herbs from 1994 levels. There was the same or slightly higher (up to five extra species) species richness across all other taxonomic groups between 2009 and 1990 levels.

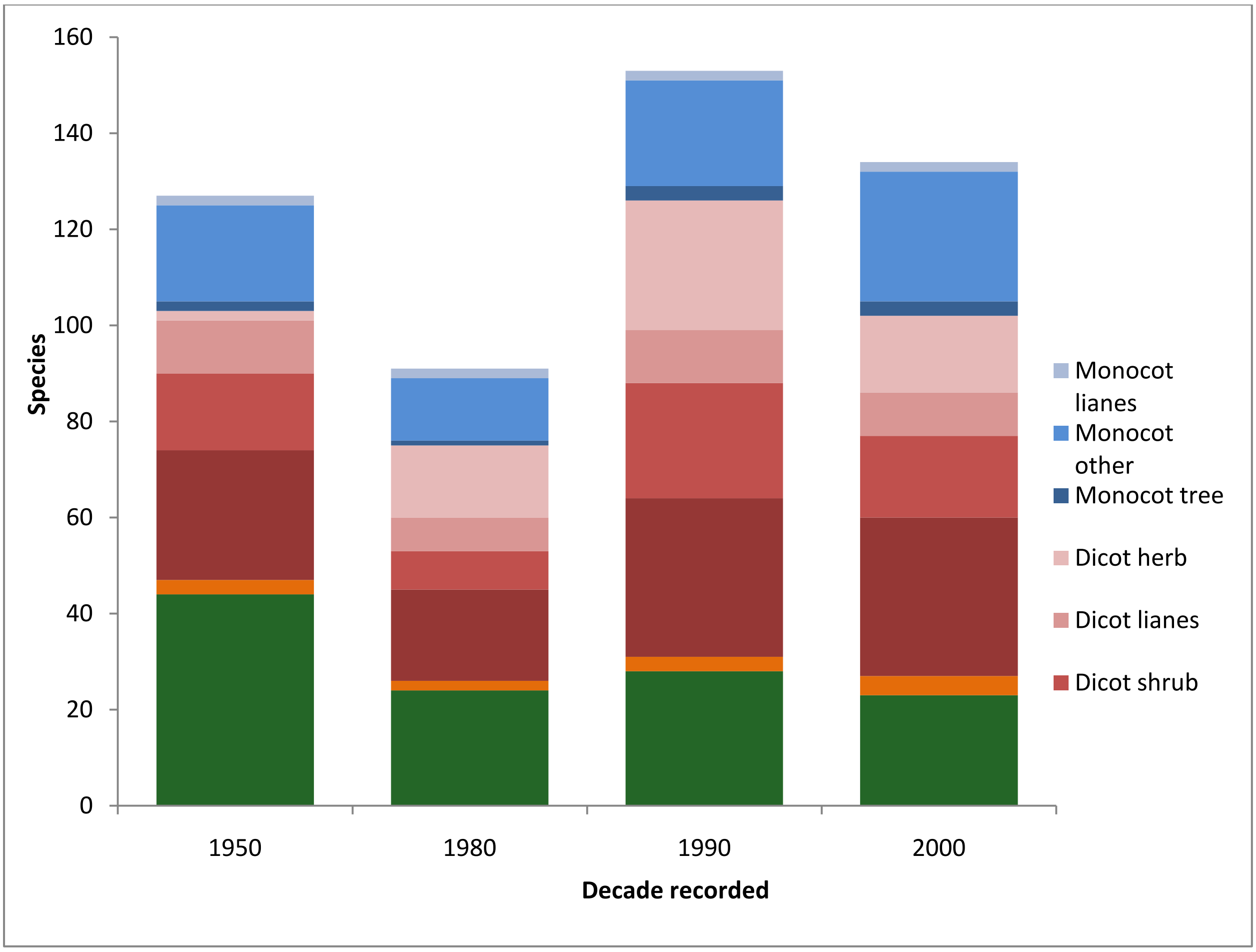

Figure 4: Number of species present in each plant taxonomic life form group

Discussion

Whaley *et al.* (1997) noted that since Claudelands Bush is an isolated forest remnant native species are unlikely to recolonise the bush from outside sources. Instead existing species will either persist or be lost from the area. Although it is likely species were missed during this low intensity survey, it is probable native species have continued to decline inside Claudelands Bush. Of the species lost most are commonly found in damp areas, mature forests and swamps. Until the 1980's no ecological management took place in the park. Factors such as logging, cattle grazing, habitat fragmentation and isolation, draining and competition with adventive species have contributed to the decline in native flora. The 1997 species list showed an increase in native species from planting as part of management. Plantings of native species around the boundary have probably compensated for the loss of some species within the main remnant. Some species such as swamp coprosma (*Coprosma tenuicaulis*) and marbleleaf (*Carpodetus serratus*) which were once found within the bush are now only located in these new plantings. Since the first survey in the 1950's species prone to moisture stress such as ground ferns, understory shrubs and one swamp tree (*Syzgium maire*) have become extinct from the bush. This overall trend has continued in the 2009 measurement.

In 1996 the ground layer had a significantly greater number of adventive species. The reduction in adventive herbaceous species in 2009 is likely due to the denser understory leading to low light conditions. With changes made to the forest e.g. wind breaks removal of cattle, weeding of invasive species, replanting of natives and building boardwalks the understory of Claudelands Bush has benefited by having an increase in understory and shrub layer growth. This dense layer has reduced light levels reaching to the ground layer, which has in turn reduced the number of adventive species with low shade tolerance. Of the 26 herbaceous adventive dicot species recorded in 1998 only 16 still remain in the bush. Most of the others recorded are still on grassy areas on the perimeter of the bush or in the open newly planted areas. The decline in fern species is most likely due to the dry conditions of the bush.

One native species present in 2009; *Mida salicifolia* is considered to be in gradual decline in New Zealand. This plant has probably been present in the remnant for many years but has been overlooked since it resembles both white and black maire. It was originally drawn to our attention in 2006 by Stan Evans.

Factors known to increase weed invasion are all present at Claudelands Bush. Situated in a suburban area close to both roads and railway lines with high human visitation, as well as having fertile soils and a high edge/area ratio all increase likelihood of weed invasion. This means the area will always need regular weed control to stop adventive species establishing and spreading (Timmins and Williams 1991).

Adventive species can find their way into the reserve through a number of vectors. These can be introduction by birds, wind or other animals or dumping of garden waste by humans. In the 1991 study birds were identified as an obvious invasion point for adventives species into Claudelands Bush. Species such as karaka can only invade after dispersal by birds. Wandering Jew can only spread by vegetative means and most likely results from dumping of garden wastes (Whaley *et al*. 1997). Plants could also be moved by passive means such as from water flow or on people's shoes and clothing.

Key points/ Recommendations

- The 2009 survey was less intensive than previous floristic surveys
- Numbers of native species appear to have reduced from 1994 levels
- New plantings have compensated for species loss
- Fewer adventive herbaceous species grow in the bush due to lower light levels
- Reintroduce missing species where conditions are suitable
- Continued control of wandering Jew is required
- Continued removal of invasive weeds is required

3. Water table monitoring

The hydrology of a semi-swamp forest is one of its defining features. All the major reports written on Claudelands Bush have noted the water table lowered with loss of pools and surface water. Apart from these observations, we are unsure if any quantitative sampling of the water table has occurred at the bush. To coincide with the vegetation monitoring and the installation of new stormwater management, water table probes were placed in the bush to measure water level for a year. Monitoring of the water table is desirable as it is possible that the newly installed drain will exacerbate decreases in the water table. On the other hand the new drain (Plate 2) and pond (Plate 3) could be an opportunity to re-develop the hydrology of the bush to more adequately replicate true semi-swamp forest conditions.

Method

On 11th March 2010 three 1.5m Odyssey water probes (Plate 4) were installed in Claudelands Bush, one by the western boundary beside a cutting, one in the middle of the bush and the other on the eastern boundary (Fig 5). These were set in March 2010 to take water table readings every 30 minutes for 12 months. Results of this monitoring will not be available until March 2011.

Discussion

The kahikatea semi-swamp forest type developed with a completely different hydrological regime than exists today. Claudelands Bush was once connected to the Waikato Rivers flood regime. This regular input into the hydrological system of the area would have created a consistently high water table. The higher water table which once existed would have favoured semi-swamp species, reduced dryland weeds, increased suitability for ferns and favoured kahikatea dominance. At the current water levels, the forest will progressively succeed to a dryland angiosperm dominant forest without intervention. This is evident today from the high proportion of the forest now dominated by dryland species.

It is unlikely that the water table at Claudelands Bush can ever be restored to an original state. The main focus should now be on not intensifying or exacerbating the problem due to poor water management practices. This is where it is crucial to establish whether the new drain on the western boundary is lowering the water table further. As it has been excavated below the ground level of the forest fragment there is a high likelihood of this. There is potentially an opportunity that instead of allowing this drain to lower the water table further it can be reengineered to divert stormwater overflow into the forest fragment. This may in a small area of the fragment simulate past flooding regimes which once occurred across the whole forest.

4. Vegetation of Claudelands Bush

Three forest types are found at Claudelands Bush; kahikatea dominant, mixed broadleaved dominant and tawa dominant forest (Fig 5). The kahikatea forest type is a relict of the original forest once found in this area. In the past kahikatea was co-dominant with matai and rimu with an understory rich with divaricate shrubs. Semi-swamp forests of this type are a characteristic feature of alluvial flood plains of the Waikato region. Now with pressures such as draining, logging and clearance only fragments of these forests remain across the region. The large conifers once found there were logged out in the 1950-80s. Kahikatea forest at Claudelands has a dominant canopy of kahikatea over a sub canopy of broadleaved trees such as mahoe with the occasional titoki in the canopy. This forest type makes up the majority of Claudelands Bush (Whaley *et al.* 1997).

Mixed broadleaved forest developed due to the lack of a natural disturbance regime and from a lowering of the water table. Kahikatea needs high light levels to grow from saplings into canopy trees. When canopy gaps do form dry forests species such as titoki and mahoe can utilise them and become canopy dominants. The broadleaved forest type consists mainly of titoki, pukatea and mahoe (*Melicytus ramiflorus*) with few emergent kahikatea. This type is found mainly on the northern and western sides of the bush.

Tawa, which is commonly found on the ranges and hillslopes of the Waikato region, has become a canopy dominant in Claudelands Bush. This forest type is found mainly in the interior of the bush.

In 2009 the length of the western boundary was planted along the banks of a newly completed drain (Plate 5). These planting not only increased the size of the area but also the biodiversity as some lost species were planted. The western boundary will also provide an increase in protection from the prevailing westerly winds. In 1998 a small area on the south side of the forest was planted with semi-swamp species.

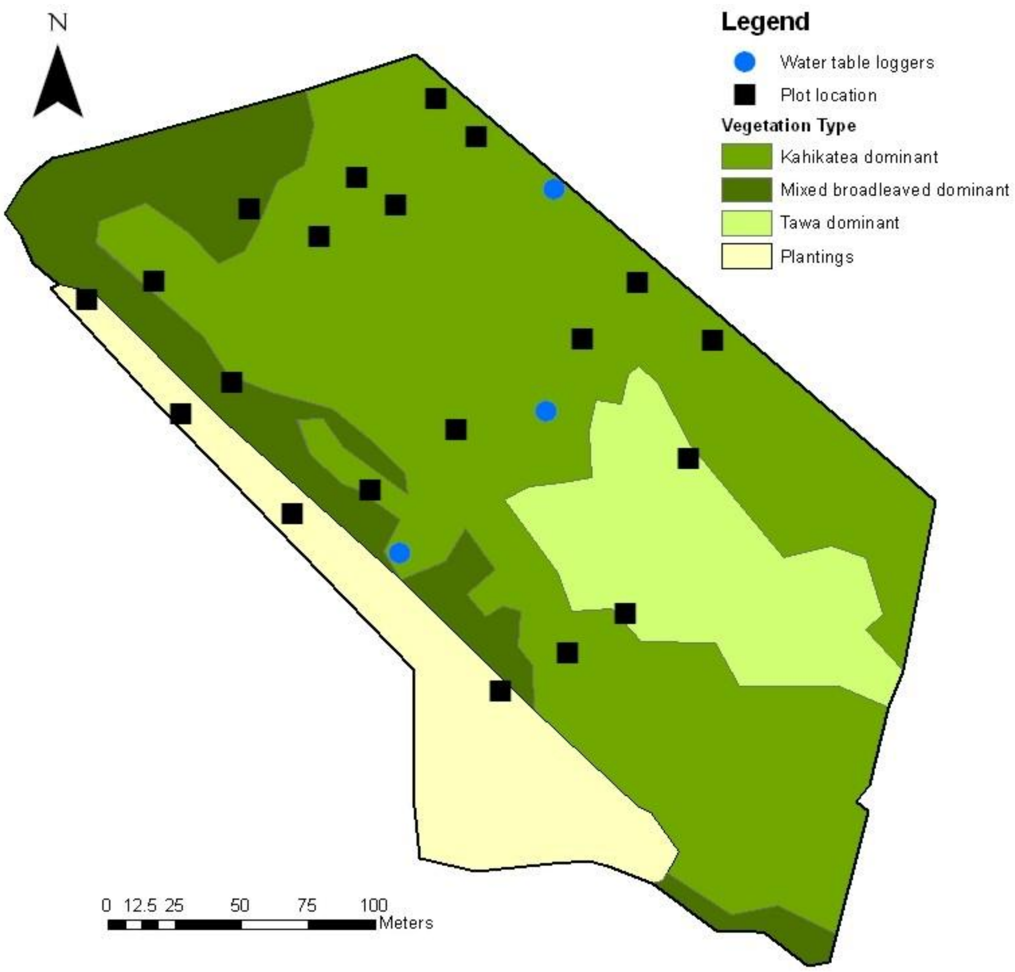

Figure5: Vegetation types of Claudelands Bush with water table loggers and 10m x 10m plot locations marked

A key aspect of any restoration project is to have an adequate monitoring programme. Monitoring will allow assessment of whether desired outcomes are being achieved and if problems are occurring. An adaptive management approach can then be applied. Vegetation plots were set up to help with management decisions about the park and assess what if any impact the new stormwater management system is having on the vegetation composition overtime.

Methods

Between November and December 2009 twenty permanent plots (10m x 10m) were established to monitor the effects the new drain will have on the vegetation at Claudelands Bush (Figure 5). Four plots were placed on the outside of the bush in the new plantings; four one meter inside the western boundary fence; eight plots in the centre of the park and another four five meters from the eastern boundary fence. One plot was placed where a wedge had been cut into the bank of the drain as a possible stormwater overflow into the bush.

Along with cover classes; densities of stems following the diameter classes outlined in Whaley *et al.* (1997) were recorded. Cluster analysis was performed on plots inside the Claudelands Bush boundary using complete linkage and city block analysis (STATISTICA version 9.0, 2009) to confirm the forest types present in the forest.

Results are tentatively compared with Whaley *et al.* (1997) as in 2009 an area of 1500m^2 was sampled inside the forest fragment and 400m^2 in the newly planted area; this compares to 3900m^2 sampled inside the forest fragment in the 1990's. Therefore; less than 40% of the area sampled by Whaley *et al.* (1997) was sampled in 2009. This gives a total sampling intensity of 2.9% within the forests boundary, leading to only general comparisons being made between the two measurements as the data is not robust enough to justify stronger comparisons.

Results

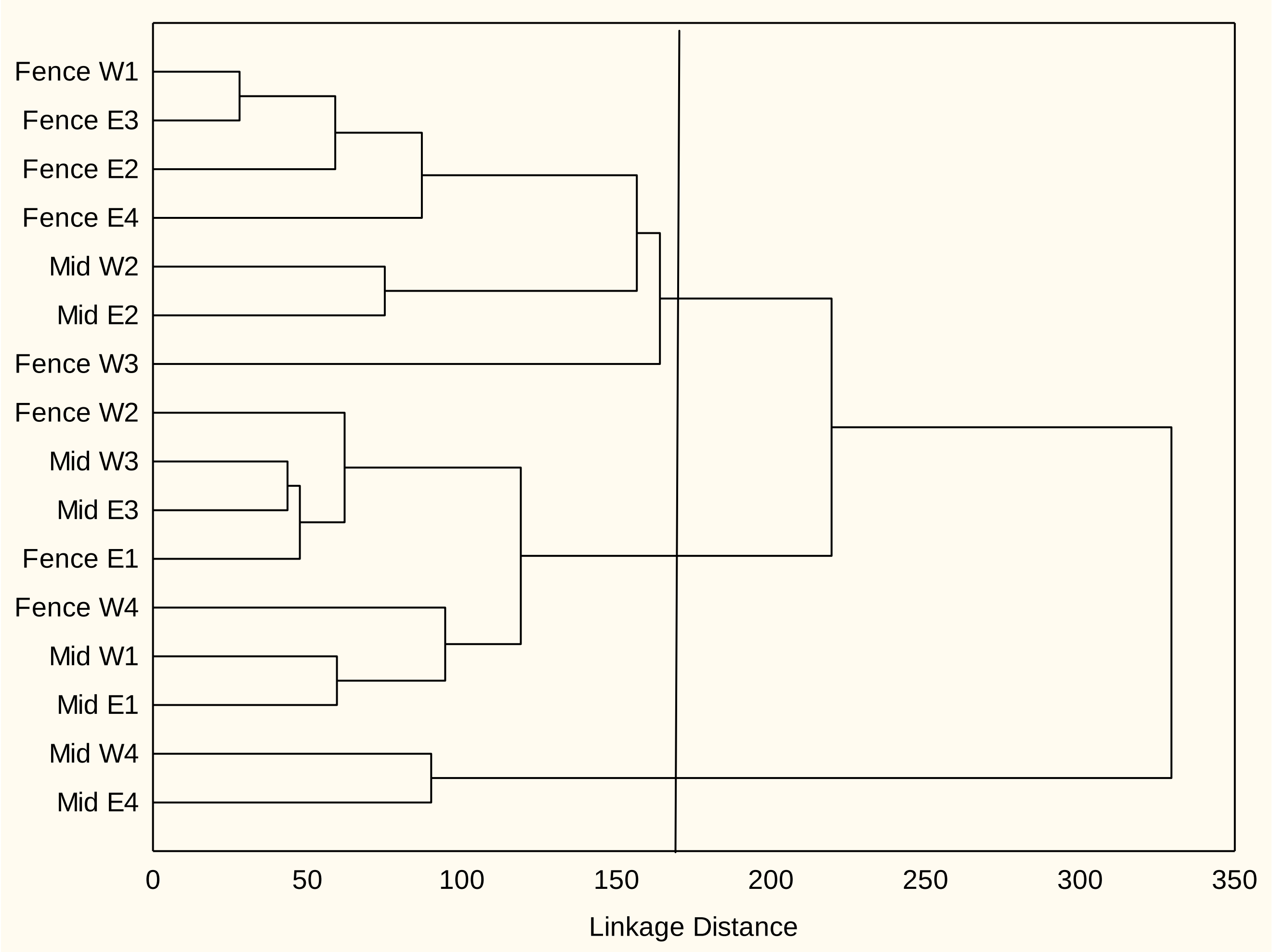

Figure 6: Cluster analysis of monitoring plots inside Claudelands Bush

The permanent plots inside the forest fragment represent the three main vegetation types found at Claudelands Bush. Two plots have the tawa forest type while seven plots a piece are found in the kahikatea dominant and the mixed broadleaved forest. Four kahikatea dominant plots have an almost pure kahikatea canopy. Three other plots have kahikatea with titoki and mahoe entering into the canopy or being dominant in the understory. Four of the mixed broadleaved dominant forest types are dominated by mahoe with emergent kahikatea. The other three broadleaved dominant plots are dominated by mahoe, titoki and cabbage tree. The two tawa forest type plots had a canopy dominated by tawa. Plots based in the 2009 plantings were dominated by bare ground as no permanent ground or canopy cover has had time to form (Fig 6).

Kahikatea is clearly the dominant tree in Claudelands Bush by basal area. In 2009 mahoe had the highest density of stems of any species. The majority of kahikatea trees were between 20 to 60cm dbh. Tawa trees were primarily between 2cm to 40cm in diameter. Most mahoe, pukatea and titoki stems were less than 20cm in diameter. No saplings of kahikatea were recorded in any plots in either survey (Table 2). Large mahoe, pukatea, tawa and titoki were not recorded in 2009.Despite this, large pukatea, tawa and titoki were seen in areas of the forest not surveyed.

Table 2: Density of major canopy species (stems ha^{-1}) in each diameter class (d.b.h) for stems 1.35cm+ height

Species	<2cm (saplings)	2-19.9cm	20-39.9cm	40-59.9cm	60-79.9cm	80-99.9cm	100+
Kahikatea		40	70	85	15	5	10
Mahoe	1600	1100	90				
Pukatea	155	55	5				
Tawa	5	20	20	10			
Titoki	30	90	10	25			
Total	1790	1305	195	120	15	5	10

As past surveys have shown kahikatea is the dominant canopy tree (over 12m tall) in Claudelands Bush. Kahikatea, pukatea and titoki were the tallest trees recorded. Tawa and titoki both form over 10% of the canopy. Mahoe is the dominant sub canopy tree, with the highest cover in all forest tiers under 12m in height. Mahoe and northern lacebark had the highest covers for understory trees. Mahoe, northern lacebark, pukatea and *Coprosma areolata* had the highest number of saplings in 2009. Kiekie (*Freycinetia banksii*) was a major groundcover species (Table 3).

Table 3: Percent cover of main species in each tier (over 1.5% cover in at least one forest tier).

Species	Height					
	>25m	12-25m	5-12cm	2-5m	30cm-2m	30cm>
Cordyline australis		0.59	6.45	0.82	0.57	0.65
Kahikatea	71.54	47.75	24.34	6.68	10.45	10.80
Pukatea	1.73	0.59	0.00	4.74	7.69	4.28
Mahoe		1.76	36.71	54.34	28.20	19.35
Myrsine australis		0.00	5.83	4.83	0.58	0.65
Knightia excelsa		3.02	0.31	0.00	0.00	0.01
Titoki	26.72	15.10	5.73	0.82	0.58	1.99
Tawa		30.01	10.41	4.83	3.90	4.39
Northern lacebark		0.58	1.60	0.54	1.76	0.65
Cyathea dealbata			3.20	13.26	16.33	5.24
Ripogonum scandens	0.01	0.59	5.11	3.61	0.58	0.65
Cyathea medullaris				2.80	0.00	0.00
Pseudopanax hybrid				1.09	2.29	0.02
Geniostoma rupestre var. *ligustrifolium*				0.00	2.33	0.33
Coprosma acerosa				0.27	2.33	0.65
Kiekie		0.00	0.31	0.28	10.45	11.76
Anthoxanthum odoratum					1.47	1.66
Cortaderia fluvida					1.47	1.66
Cyperus ustulatus					1.47	1.66
Manuka					0.57	0.96
Phormium tenax					0.57	2.30
Asplenium oblongifolium					0.58	0.97
Erigeron karvinskianus					0.00	1.66
Crocosmia x *crocosmiiflora*					0.00	1.66
Microsorum scandens			0.00	0.01	0.01	1.98
Asplenium bulbiferum					0.29	0.96
Paspalum sp.					0.29	3.64
Blechnium filiforme				0.00	0.00	3.32
Uncinia spp.					0.00	1.66
Wandering Jew					0.00	5.67

Discussion

The canopy composition determined in 2009is very similar to that described in 1997. One difference is that mahoe and cabbage tree (*Cordyline australis*) have entered the canopy. These species were dominant in areas along the fence line, which had been planted in the 1950's. As described by Whaley *et al.* (1997) kahikatea present at Claudelands are either relicts of the original bush before human influence (1m+ diameter) or medium sized trees from colonisation of canopy gaps after logging. They predicted some of the medium sized trees would be lost due to self thinning. Some kahikatea have died due to natural senescence and self-thinning. But there was also a loss of these medium sized trees on the eastern boundary due to the drought. There seems to also have been loss of some large kahikatea since 1994. Since kahikatea is such a long lived tree (~600 years) without intervention a change from a kahikatea dominated forest to broadleaved dominant should take a very long time.

The large decline in densities of the main species from 1994 to2009 is not as dramatic as the data conveys as the sampling intensities differed between surveys dramatically. Whaley *et al*. (1997) did a stratified survey across the entire forest while the 2009 data was focused more to the northern half of the forest especially near the new drain. Areas where large trees of pukatea, tawa and titoki grow may have been missed due to their localised abundance within the forest. As shown from the distribution of plots within the vegetation types only two plots were within the tawa forest type. Reductions in sapling numbers between surveys could be due to recruitment into the larger stem classes as the understory has become denser since the Whaley *et al*. (1997) survey as shown by cover data.

As shown in Whaley *et al.* (1997) with the lack of new saplings, kahikatea still seems to be experiencing recruitment failure. Having a denser understory would have further reduced the likelihood of natural regeneration of kahikatea. Kahikatea seedlings were found in localised areas of the bush and so may just need more time to reach the sapling stage. As explained by Whaley *et al.* (1997) report this is a common problem for kahikatea forest patches. Kahikatea regenerates in high numbers due to large scale disturbances such as fire, floods, catastrophic wind-throw and logging. In the past large events such as flooding would flatten vegetation in an area of the forest creating a large canopy gap. These areas were then colonised by light demanding kahikatea. Without these large canopy gaps kahikatea seedlings and saplings do not receive enough light to be competitive and reach the canopy. As the bush is so small and entirely disconnected from the original landscape scale flooding regime it can only survive in the long term with active management. In small urban patches like this, gap forming events do not allow kahikatea to regenerate. Regeneration and dominance of broadleaved species is favoured in small forest patches in urban areas. As stated in the management plan the aim is to keep Claudelands Bush as a kahikatea dominant forest (Hamilton City Council 1993). This will require manipulating the current system to favour kahikatea, such as increasing kahikatea recruitment with supplementary planting and stabilizing or perhaps even enhancing the water table levels.

Broadleaved species such as titoki, mahoe and pukatea are showing continual recruitment with an increase in stems growing past the sapling stage. There was an increase in densities of mahoe and pukatea between diameters of 2 to 20cm. Unlike kahikatea these species can grow in low light conditions. The tawa forest type is confined largely to the interior of the forest fragment. Whaley *et al.* (1997) found tawa was not regenerating around the edge of the forest. This was most likely due to the higher rate of desiccation at forest boundaries because of the direct exposure to the elements.

In 1997 Claudelands Bush was 5.2ha in size and with the edge effect extending 50m from the boundary this gave approximately 1ha of interior habitat. With additional plantings the forest fragment has increased in size to just over 6ha. When these plantings have developed into forest the interior habitat would be increased to 1.8ha. This is still a much smaller area than is necessary to have a naturally functioning interior community.

Seedlings have a difficult time establishing in remnants such as Claudelands Bush due to the dry soil conditions. Seedlings in the ground layer are the most vulnerable to effects of drying out and suffer from desiccation. Seedlings are less likely to establish around the boundary of the bush due to the edge effect.

Key points/ Recommendations

- Re-measure vegetation plots at five yearly intervals and correlate with water table data
- Kahikatea is not regenerating effectively and would not be expected to
- To maintain kahikatea dominance requires saplings to be planted in canopy gaps as they arise

Conclusions

Claudelands Bush is an iconic part of Hamilton city, providing an accessible natural area in an urban matrix. Kahikatea is still the dominant species of the forest. Recent deaths of this species due to the drought of 2007/8 have opened up parts of the canopy on the eastern boundary. For kahikatea to fill these gaps saplings will need to be planted and wandering Jew and other aggressive weeds controlled.

One of the key characteristics of semi-swamp forests is the high water table. With past drainage of this area conditions have changed influencing changes in the vegetation composition. The once conifer dominant forest is in the process of becoming a dryland angiosperm dominated forest. Recent manipulation of the hydrology of the area with the re-development of storm water systems could exacerbate this trend or be manipulated to alleviate it.

Some weed species once common in the bush now seem to be only found on the edges of the remnant. These species were mainly shade intolerant herbaceous groundcover species. The development and closure of the forests understory has reduced light intensity to the ground layer to levels below which those herbaceous species could tolerate.

Three forest types are still dominant at Claudelands Bush; kahikatea dominant, broadleaved dominant and tawa dominant. Broadleaved dominant forest is found mainly on the edges of the bush and tawa mainly in the interior. The kahikatea forest type is still the dominant type at Claudelands Bush and kahikatea is still the dominant tree species across the whole remnant with mahoe being the dominant sub-canopy species. Kahikatea will continue to be the dominant tree at Claudelands Bush for a considerable time as it is a long lived tree. Unfortunately it is not successfully recruiting into the canopy and supplementary planting of kahikatea saplings into canopy gaps is required to remedy this.

Due to environmental and anthropogenic factors loss of native species is still taking place. Planting around the fragments boundaries has reduced species loss but not permanently reversed it. As a small urban forest remnant Claudelands Bush cannot support a semi-swamp forest without external management. Methods to improve the conditions inside the bush are:

- Plant kahikatea saplings in canopy gaps
- Continuing the weeding of wandering Jew and other problem weeds

Re-measuring the monitoring plots at five yearly intervals will enable the condition and health of the forest to be appropriately assessed. Should the new storm water management system be shown to exacerbate lowering of the water table appropriate remedial action will be urgently required.

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Appendix one: Species List

Indigenous and adventives plant taxa recorded in Claudelands Bush

Abundance rating for species in 1933-54

D = dominant F = few A = abundant 1,2 = 1 specimen or group

Notes for 1990 and 2009 measurements

* adventive species; (A) adventive native species, (P) planted species; (Pn) planted native species; (s) seedlings present only; (?) doubtful records, (O) adventives only in new plantings.

	1933-54		1980-84	1994-96	2009
Ferns and Fern Allies					
Adiantum cunninghamii	X	2	-	-	-
Anarthropteris lanceolata	X	F	-	-	-
Arthropteris tenella	X	A	X	X	X
Asplenium bulbiferum ssp. *bulbiferum*	X	D	X	X	X
Asplenium bulbiferum ssp. *gracillimum*	X	F	-	X	X
A. flaccidum ssp. flaccidum	X	A	X	X	X
A. bulbiferum x *flaccidum*	-		-	-	X
A. oblongifolium	X	A	X	X	X
A. polyodon	X	A	X	X	X
A. oblongifolium x *polyodon*	-		-	X	-
Blechnum sp.1	-		X	X	-
B. chambersii	X	F	-	-	-
B. discolor	X	F	-	-	-
B. filiforme	X	A	X	X	X
B. procerum (?)	X	F	-	-	-
Cyathea cunninghamii	X	1	-	-	-
C. colensoi (?)	X	1	-	-	-
C. dealbata	X	D	X	X	X
C. medullaris	X	F	-	X	X

C. smithii	X	F	-	X	-
Deparia petersenii	X	F	-	-	-
Dicksonia fibrosa	X	F	-	-	-
D. squarrosa	X	A	X	X	X
Diplazium australe	X	A	X	X	X
Doodia media	X	F	-	-	X
Grammitis billardierei	X	F	-	-	-
Histiopteris incisa	X	F	X	X	X
Hymenophyllum desmissum	X	F	-	-	-
H. revolutum	X	1	-	-	-
Hypolepis ambigua	X	F	X	X	-
H. rufobarbata	-		X	X	-
Lastreopsis glabella	x	A	X	X	X
L. hispida	X	F	-	-	-
L. microsora ssp. *pentangularis*	X	F	X	X	X
Leptopteris hymenophylloides	X	F	-	-	-
Lygodium articulatum	X	1	-	-	-
Paesia scaberula	X	F	X	X	X
Pelleaa rotundifolia	X	A	X	X	X
Phymatosorus diversifolius	X	A	X	X	X
P. scandens	X	D	X	X	X
Pneumatopteris pennigera	X	A	X	X	-
Polystichum richardii	X	F	-	-	-
P. vestitum	X	F	-	-	-
Pteridium esculentum	X	F	X	X	-
Pteris tremula	X	F	X	X	X
P. macilenta	X	F	-	-	-
Pyrrosia eleagnifolia	X	A	X	X	X
Rumohra adiantiformis	X	1	-	-	-
**Selaginella kraussiana*	-		X	X	X
Gymnosperm trees					
Dacrycarpus dacrydioides	X	D	X	X	X
Dacrydium cupressium	X	F	-	X	X
Podocarpus totara	-		-	-	X (Pn)
Prumnopitys taxifolia	X	2	X	X	X
Dicot trees					
Alectryon excelsus var. *excelsus*	X	A	X	X	X
*Aristotelia serrata (*Pn)	X	F	X	X	X(Pn)
Ascarina lucida (P)	-		-	X	-
Beilschmiedia tawa	X	D	X	X	X
Carpodetus serratus	X	F	-	X	X (Pn)
Corynocarpus laevigatus (A)	-		-	X	X
Elaeocarpus dentatus	X	F	-	-	-
E. hookerianus	X	F	X	X	X(Pn)
Fuchsia excorticata	X	F	X	X	-
**Grevillea robusta* (s)	-		-	X	-
Griselinia littoralis	-		-	-	X(Pn)
Hedycarya arborea	X	F	X	X	X
*Hoheria populnea (*AP)	X	F	X	X	X
*H. sextylosa (*Pn)	-		-	X	X(Pn)
**Idesia polycarpa*(s)	-		-	X	-
Knightia excelsa	X	F	X	X	X
Laurelia novae-zelandiae	X	A	x	X	X
**Ligustrum lucidum*	-		-	X	X
**L. sinense*	-		X	X	X
Litsea calicaris	X	1	X	X	X
Lophomyrtus bullata	X	F	-	-	X(Pn)
Melicytus lanceolatus	X	F	-	-	-
M. ramiflorus ssp. *ramiflorus*	X	D	X	X	X
Metrosideros robusta	-		-	X	-
Mida salicifolia	-		-	-	X
Myrsine australis	X	D	X	X	X
Nestegis cunninghamii	X	F	X	X	X
N. lanceolata	X	F	X	X	X

N. montana	X	2	-	-	-
Olearia rani	X	F	-	-	-
Pennantia corymbosa	-		-	-	X(Pn)
Pittosporum eugenioides (s, A)	-		-	X	X
P. cornifolium	X	1	-	-	-
P. tenufolium (Pn)	X	F	X	X	X
**Prunus laurocerasus*	-		-	X	X
**P. serrulata*	-		-	X	X
Pseudopanax arboreus (Pn)	X	1	-	X	X
P. crassifolius	X	F	X	X	X (Pn)
P. hybrids (A)	-		-	X	X
Schefflera digitata	X	A	X	X	X
Sophora microphylla (s, A)	-		-	X	X
Streblus heterophyllus	X	A	X	X	X
Syzgium maire	X	1	-	-	-
Vitex lucens	-		-	-	X
Dicot shrubs					
**Abutilon* x *hybridum*	-		-	X	-
Alseuosmia quercifolia	X	F	X	X	X
**Berberis glaucocarpa*	-		-	X	-
Brachyglottis repanda var. *repanda*	X	F	X	X	X
**Camellia japonica* (s)	-		-	X	X
**Citrus limonum*	-		-	-	X
Coprosma areolata	X	A	X	X	X
C. grandifolia	X	1	X	X	-
C. lucida	X	F	.	-	-
C. propinqua	X	F	.	-	-
C. propinqua x *C. robusta*	X	F	.	X	-
C. repens (A)	-		.	X	-
C. rhamnoides	-		.	X	-
C. robusta	X	A	X	X	X
C. rotundifolia	X	F	-	-	-
C. tenuicaulis	X	A	-	-	X(Pn)
C. tenuicaulis x *C. areolata*	X	F	-	-	-
**Cryphomandra betacea*	-		-	X	X
Dodonaea viscosa (P)	-		-	X	-
**Elaeagnus* x *reflexa*	-		-	X	X
**Euonymus japonicus*	-		-	X	-
**Fatsia japonica*	-		-	X	X
Geniostoma rupestre var. *ligustrifolium*	X	D	X	X	X
Hebe stricta	-		-	-	X(Pn)
**Hydrangea* sp.	-		-	-	X
Leptospermum scoparium	X	F	-	-	X(Pn)
Leucopogon fasciculatus	X	A	-	-	-
Macropiper excelsum	-		-	-	X
Melicytus micranthus	X	F	-	-	-
M. novae-zelandiae (P)	-		-	X	-
**Nandina domestica*	-		-	-	X
**Rhaphiolepis umbellata* (s)	-		-	X	-
**Rhamnus alaternus*	-		-	X	-
Solanum aviculare	X	F	-	X	-
**S. mauritianum*	-		X	X	X
**S. pseudocapsicum*	-		X	X	X
**Tecomaria capensis*	-		-	X	-
Dicot lianes					
**Araujia sericifera*	-		-	X	-
Calystegia sepium	X	F	X	X	X
Clematis paniculata	X	1	-	-	-
**Hedera helix*	-		-	X	X
**Lonicera japonica*	-		X	X	X
Metrosideros diffusa	X	A	X	X	X
M. perforata	X	A	X	X	X
Muehlenbeckia australis	X	A	X	X	X
M. complexa	X	F	-	-	-

Parsonsia capsularis	X	F	-	-	-
P. heterophylla	X	D	X	X	X
Passiflora tetrandra	X	A	X	X	X
Rubus schmidelioides	X	F	-	-	-
R. squarrosus (?)	X	F	-	-	-
**Rumex sagittatus*	-		-	X	X(O)
**Wisteria sinensis*	-		-	X	-
Dicot herbs					
Acaena anserinifolia	X	F	-	-	-
Begonia sp.	-		-	-	X
**Beta vulgaris*	-		-	X	-
**Cardamine hirsuta*	-		-	X	X (O)
**Cirsium arvense*	-		X	X	-
**C. vulgare*	-		X	X	-
**Conyza albida*	-		X	X	X (O)
**Erigeron karvinskianus*	-		X	X	-
**Euphorbia peplus*	-		X	X	X
**Fragaria vesca*	-		X	X	-
Fumaria muralis	-		-	-	X
**Galium aparine*	-		X	X	X
Haloragis erecta	X	F	X	X	-
**Lamium purpureum*	-		-	X	X
**Leucanthemum maximum*	-		-	X	-
**Lunaria annua*	-		-	X	X
**Myosotis sylvatica*	-		-	-	X
**Oxalis* sp.	-		X	X	X
**Plantago major*	-		-	X	X(O)
**Plectranthus ciliatus*	-		-	X	-
**Prunella vulgaris*	-		X	X	-
**Ranunculus repens*	-		X	X	X
**Rumex obtusifolius*	-		X	X	X(O)
**Senecio bipinnatisectus*	-		X	X	-
**S. jacobaea*	-		X	X	-
**Stachys sylvatica*	-		-	X	-
**Solunum americanum*	-		-	X	X
**S. nigrum*	-		-	X	X
**Sonchus oleraceus*	-		-	X	X (O)
**Taraxacum officinale*	-		-	X	X
**Trifolium repens*	-		X	X	X(O)
Monocot trees					
Cordyline australis	X	A	X	X	X
Rhopalostylis sapida (s)	X	1	-	X	X
**Trachycarpus fortunei*	-		-	X	X
Orchids					
Corybas trilobus	X	1	-	-	-
Earina mucronata	X	F	X	X	X
Pterostylis banksii	X	1	-	-	-
Grasses					
**Anthoxanthum odoratum*	-		-	-	X(O)
Cortaderia fluvida	-		-	-	X (Pn)
**Dactylis glomerata*	-		-	X	-
Microlaena avenacea	x	D	X	X	X
M. stipoides	X	F	-	-	-
Oplismenus imbecillis	X	A	X	X	X
**Paspalum* sp.	-		-	-	X
**Secale cereale*	-		-	-	X (O)
Sedges					
Carex comans	X	F	-	-	-
C. dissita	X	A	-	X	X
C. lambertiana	X	F	X	X	-
C. secta	-		-	-	X(Pn)
C. solandri	-		-	-	X(Pn)
Cyperus ustulatus	X	F	X	X	-
Gahnia xanthocarpa	X	F	X	X	X

Uncinia banksii	X	F	X	X	X
U. filiformis (?)	X	A	-	-	-
U. uncinata	X	A	X	X	X
Rushes					
**Juncus bufonius* var. *bufonis*	-		-	-	X (O)
**Juncus filicaulis*	-		-	X	X(O)
J. gregiflorus	X	F	-	-	-
Other monocot herbs					
**Agapanthus orientalis*	-		-	X	X
**Allium triquetrum*	-		-	X	X(O)
**Alocasia macrorrhiza*	-		X	X	-
**Alstroemeria aurantiaca*	-		-	X	X
**Asparagus setaceus*	-		-	-	X
Astelia fragrans	-		X	X	X
A. nervosa	X	F	-	-	-
A. solandri	X	F	-	-	-
Collospermum hastatum	X	F	X	X	X
**Crocosmia* x *crocosmiiflora*	-		X	X	X
**Hedychium gardnerianum*	-		-	X	X
Phormium cookianum (Pn)	-		-	-	X (Pn)
Phormium tenax (Pn)	X	F	X	X	X
**Tradescantia fluminensis*	-		-	X	X
**Zantedeschia aethiopica*	-		-	X	X
Monocot lianes					
Freycinetia banksii	X	A	X	X	X
Ripogonum scandens	X	F	X	X	X

Appendix two: Photographs

Plate 1: Dead kahikatea trees in the canopy of Claudelands Bush. Visible from both Boundary and Brooklyn Roads

Plate 2: Newly installed drain along the western boundary, created in 2009

Plate 3: Manmade pond created in 2009

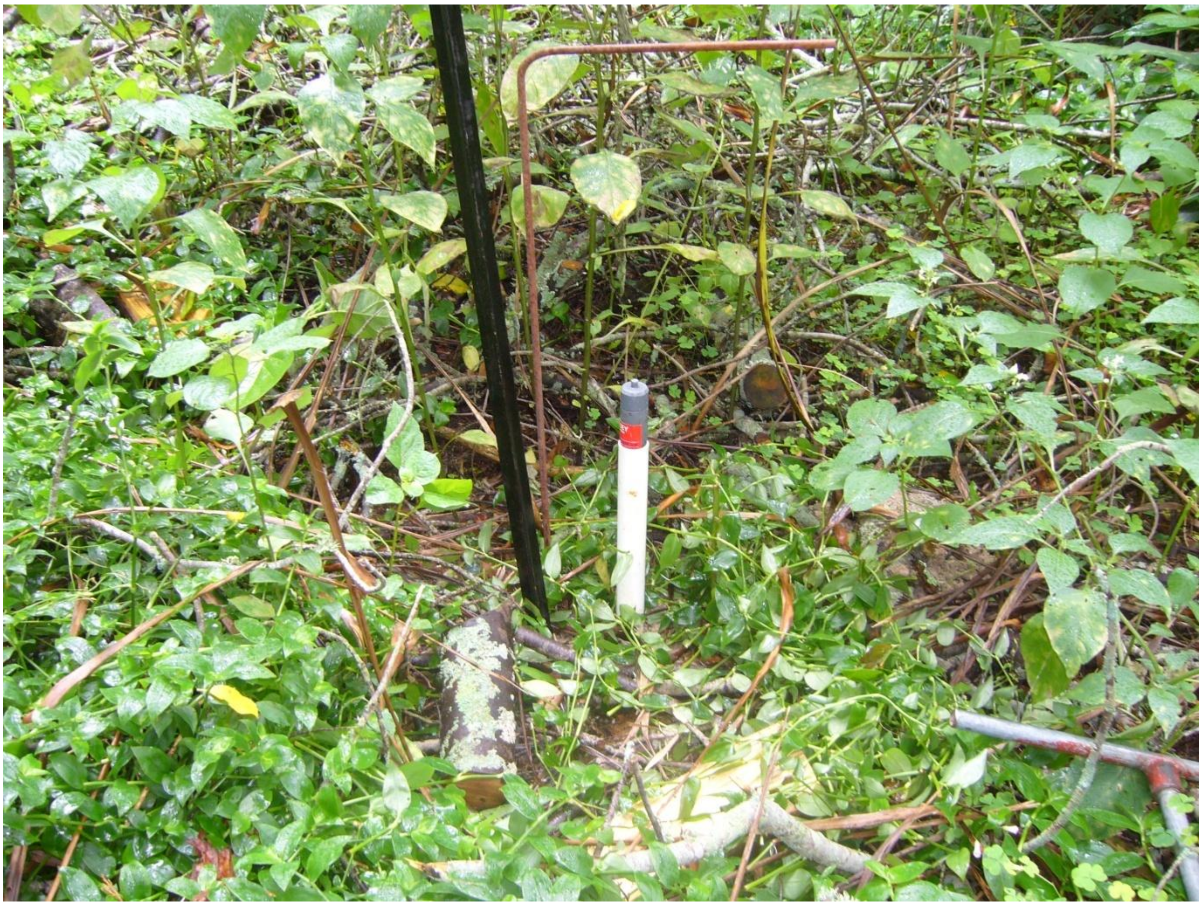

Plate 4: Water table probe

Plate 5: 2009 plantings on western boundary alongside the drain and pond