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Ecology of *Eucalyptus aquatica* (Myrtaceae), a restricted eucalypt confined to montane swamp (fen) habitat in south-eastern Australia

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***Abstract*:** The Paddys River Wetlands in the New South Wales Southern Highlands, southwest of Sydney, are characterised by several watercourses with associated swamps (fens), some of which, on Forestry Corporation of NSW land, have been the focus for removal of *Pinus radiata* wildings by the Penrose Swamps Conservation Group. In this study we map a population of *Eucalyptus aquatica* trees in one of these swamps perched above Paddys River (latitude 34.65575° S, longitude 150.21831° E; 600 m elevation). *Eucalyptus aquatica* is geographically restricted to the Paddys River area and is listed as a threatened species at state and national levels. New findings on the physical characteristics of the swamp in relation to the bedrock geology, stream geomorphology, peat development and the main native plant species, are presented.

The occurrence of clumps of *Eucalyptus aquatica* appears to be independent of the type or thickness of the growing substrate. Rather it is suggested that a continuous supply of water and the shelter afforded by the narrow valley may be key factors determining the distribution of the trees at the study site. An on-going programme of research is underway to study other occurrences of *Eucalyptus aquatica.*

Keywords: montane swamp, threatened species, peat depth, incised watercourse, Hawkesbury Sandstone.

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Introduction

Eucalyptus aquatica (Broad-leaved Sally) (family Myrtaceae) is a small tree known only from the Penrose area in the Southern Highlands of New South Wales where it occurs sporadically in swampy ground (Harden 1991; Benson & McDougall 1998; Australian Government 2008; NSW Office of Environment & Heritage 2012). Previously considered a sub-species of *Eucalyptus camphora* (Brooker & Kleinig, 1999), *Eucalyptus aquatica* was described as a separate species by Wiecek (2011). It is listed as aVulnerable Species under both NSW State and Federal threatened species legislation (Australian Government 2008; NSW Office of Environment & Heritage 2012). The swamp (fen) habitats associated with *Eucalyptus aquatica* are also listed as Endangered Ecological Communities "Temperate Highland Peat Swamps on Sandstone" under the Federal *Environment Protection and Biodiversity Conservation Act* 1999 (Australian Government 2005) and "Montane Peatlands and Swamps of the New England Tableland, NSW North Coast, Sydney Basin, South East Corner, South Eastern Highlands and Australian Alps bioregions" under the NSW *Threatened Species Conservation Act* 1995 (NSW Scientific Committee 2004).

This study focuses on a local population of *Eucalyptus aquatica* in an (unnamed) montane swamp at 600 m altitude in Penrose State Forest, Penrose (latitude -34.656 E, longitude 150.218 S decimal degrees) (Figure 1). We have also recorded *Eucalyptus aquatica* in Hanging Rock Swamp, Stingray Swamp and a number of unnamed swamps on the valley sides of Paddys River within and around Penrose State Forest. The montane swamp habitat has been described as a peat forming fen (see Mactaggart, 2008; Keith, 2004 p.210; Kodela 1994; NSW Office of Environment & Heritage, undated) and a study of lower elevation but similar 'upland swamps or dells' on the Woronora Plateau near Wollongong (Young, 1982) suggested that these communities result from reduced permeability in some of the Hawkesbury Sandstone strata. The vegetation in all these swamps as typically treeless being dominated by shrubs and sedges, and the occurrence of a swamp-dependent eucalypt is quite unusual.

Like many threatened species, little is known of the ecology of *Eucalyptus aquatica*. Since 2008 Penrose Swamps Conservation Group has been working in Penrose State Forest removing weeds (predominately *Pinus radiata* wildings) and studying the factors influencing the occurrence of *Eucalyptus aquatica* in the swamps. This paper provides information on the distribution and occurrence of a local population and places the species' ecology into a geological and geomorphological context.

Methods

Swamp setting

The swamp studied is an (unnamed) montane swamp in Flora Reserve No. 97556 of Penrose State Forest, Penrose in the NSW Southern Highlands, southwest of Sydney (Figure 1). The State Forest is managed for softwood pine (*Pinus radiata*) production by Forestry Corporation of NSW. The swamp is bordered by a public road on two sides and is crossed by a forestry track (known as Webbers Road) at its western end (Figure 1).

The swamp is located on a tributary of Paddys River (latitude 34.65575° S, longitude 150.21831° E) (Figure 1), two kilometres to the south of Stingray Swamp. It is perched above the river and has a total length of approximately 1500 m (Figure 2). The lowermost 200 m segment of the swamp contains the *Eucalyptus aquatica* population, below Webbers Road and before the watercourse joins Paddys River. Surrounding vegetation includes mature *Pinus radiata* plantations and Eucalypt woodland (Figure 1). The site occurs within the Moss Vale 1:100,000 map sheet area.

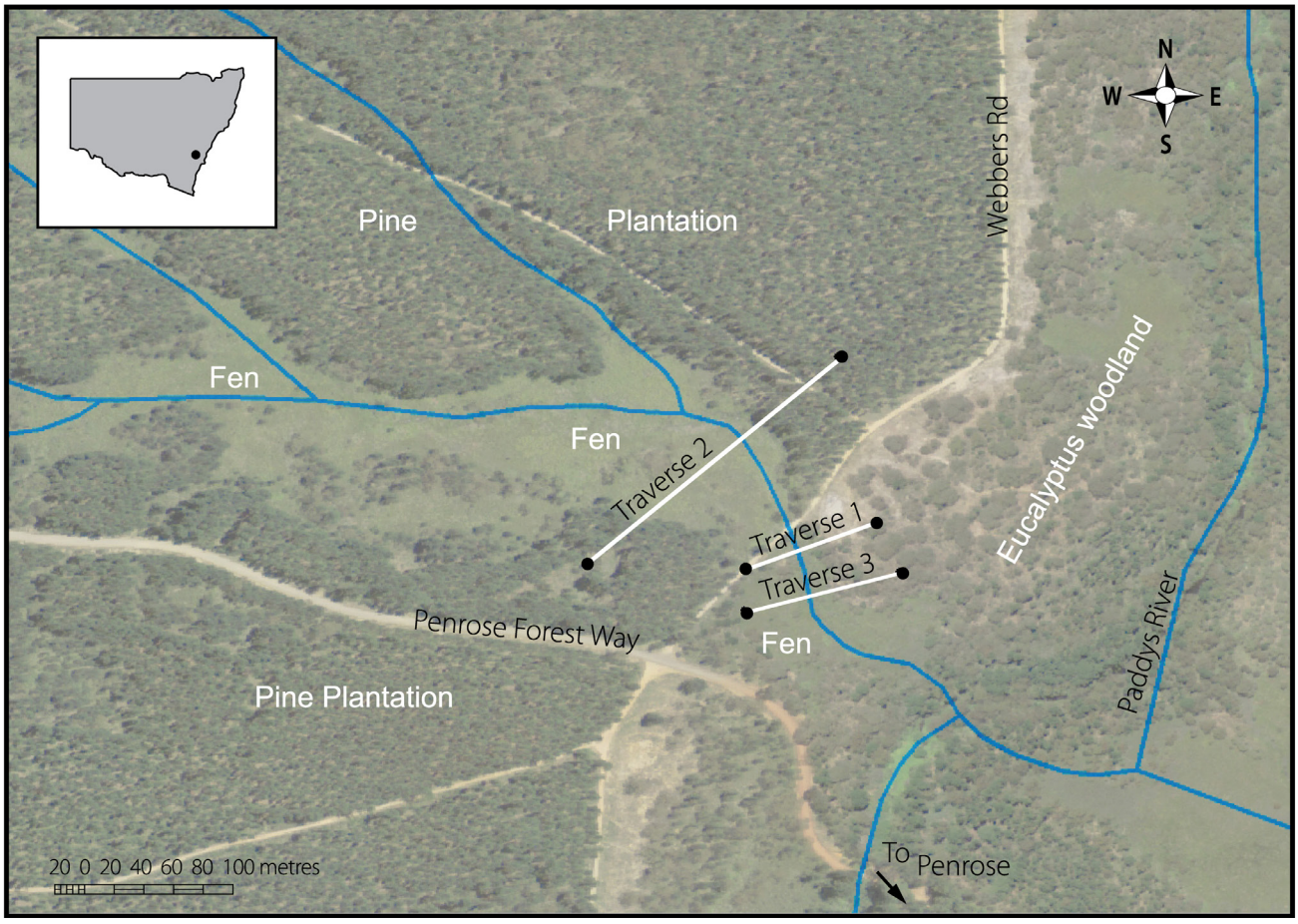

Fig. 1. Location of swamp study area in Flora Reserve, Penrose State Forest (including locality inset). Background imagery is ADS40 Moss Vale 1:100,000 (2008).

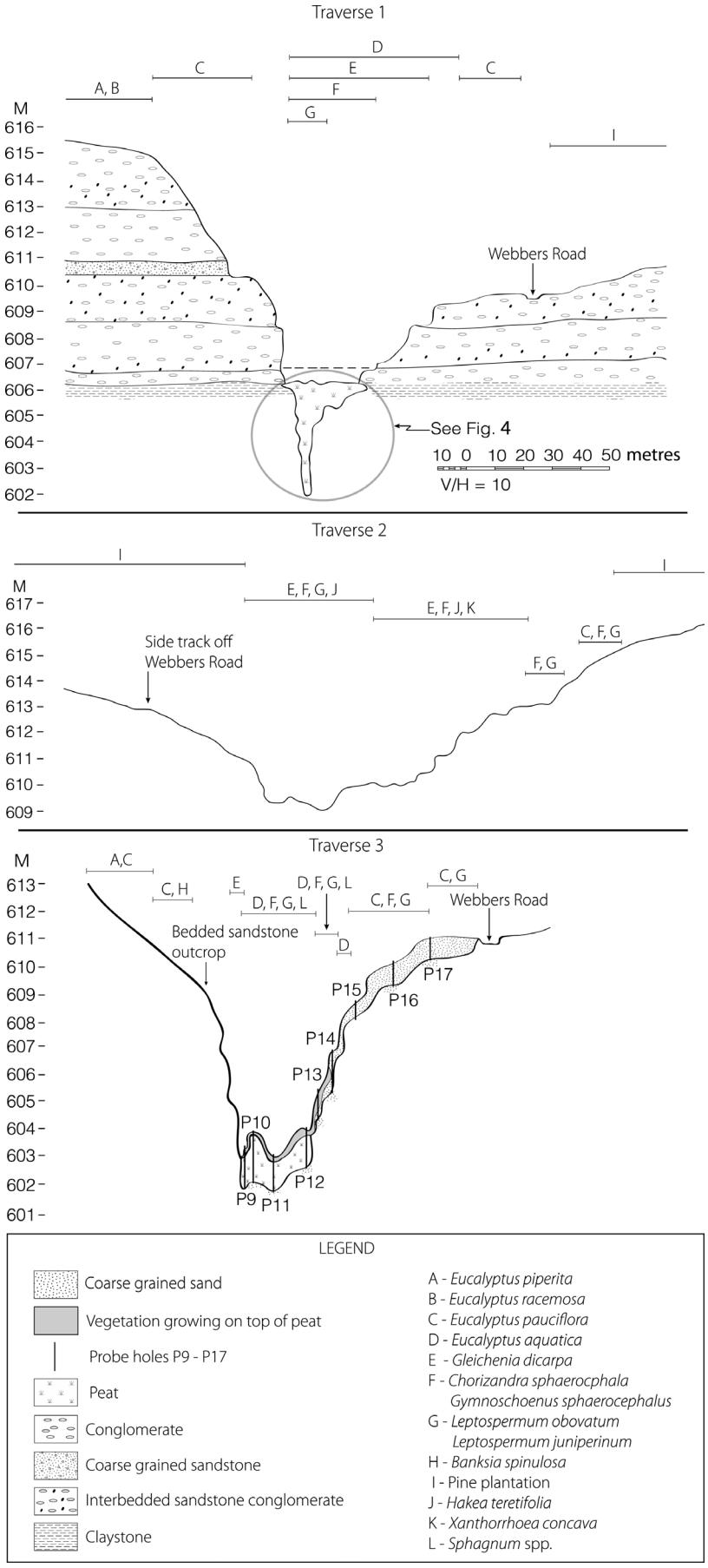

Fig. 2. Geological cross section of the gorge at Traverse 1 showing the deep, narrow peat deposit and occurrence of the main flora compared with cross section of Traverse 2 showing flora distribution, plus valley cross section of Traverse 3 showing peat deposits and flora distribution (Flora Reserve, Penrose State Forest).

Field mapping methods

Fieldwork was carried out in August 2012. Our mapping focused on the lower segment of the swamp where *Eucalyptus aquatica* is located. The locations of the approximately 350 *Eucalyptus aquatica* plants that occur in the swamp along with associated vegetation were mapped using a hand held GPS. Tree height, canopy width, tree trunk type (single or mallee habit), percentage green foliage present and tree condition were estimated for each tree. Tree condition was estimated visually by the recorder based on percentage canopy alive, (dead = 0, poor = 1–40%, moderate =41–75%, good >75%) to provide a baseline data set for future comparison (see Appendix 1).

Altitudinal data for each tree was taken at the top of the peat surface using an altimeter calibrated to a point of known nearby spot height on the Department of Lands 1:25 000 topographic sheet (2005), making it possible to measure altitudes to ± 1 m. Frequent checks were made to ensure that the altimeter was only used in stable meteorological (pressure) conditions. Distance versus altitude profiles were constructed from field measurements.

A peat probe (a form of penetrometer), which extends to 5.2 m, was used to map sandy horizons, peat type and peat depth, in some cases down to bedrock. The bedrock under the swamp peat was inferred from mapping in the valley sidewalls.

Three traverses (T1–T3) across the swamp were mapped on approximate bearings of 237° (TN), that is, from NE to SW. Two of these (T1 and T3) were across the stands of *Eucalyptus aquatica*. T2 was made for comparison upstream of Webbers Road, across the treeless sedges (Figure 2). In addition, a longitudinal traverse was made from just below Webbers Road to the lowest extent of the swamp. Mapping in the swamp was arduous work due to dense vegetation and wet peat conditions.

Results

Bedrock strata and geomorphologic features

Limited rock outcrops of the mid Triassic age Hawkesbury Sandstone form bare ledges on the northern side of the swamp (Trigg & Campbell 2011), whereas on the southern side sandstone benches are almost completely covered in vegetation (see Traverse 1 in Figure 1). This sandstone includes pebble conglomerates, inter-bedded and occasionally cross-bedded with coarse grained sandstones. Clearly observed bedding planes separate the strata of different grain sizes. Just above the swamp level, at an elevation of 609–610 m, a thin shale/claystone lens is present; it outcrops in a small quarry exposure that is used for local road-base material.

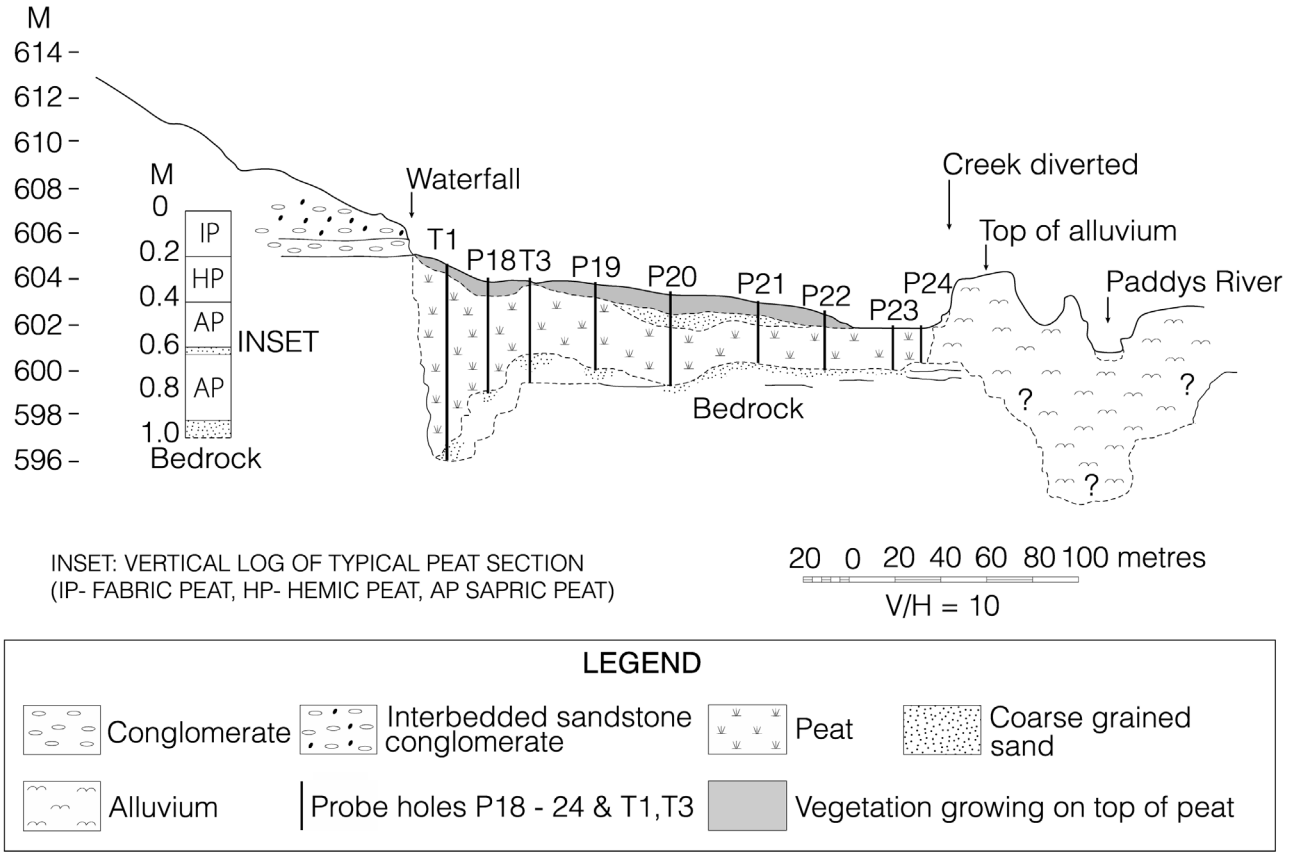

Fig. 3. Longitudinal section of the swamp showing the peat deposit and the fluvial deposits of Paddys River (Flora Reserve, Penrose State Forest).

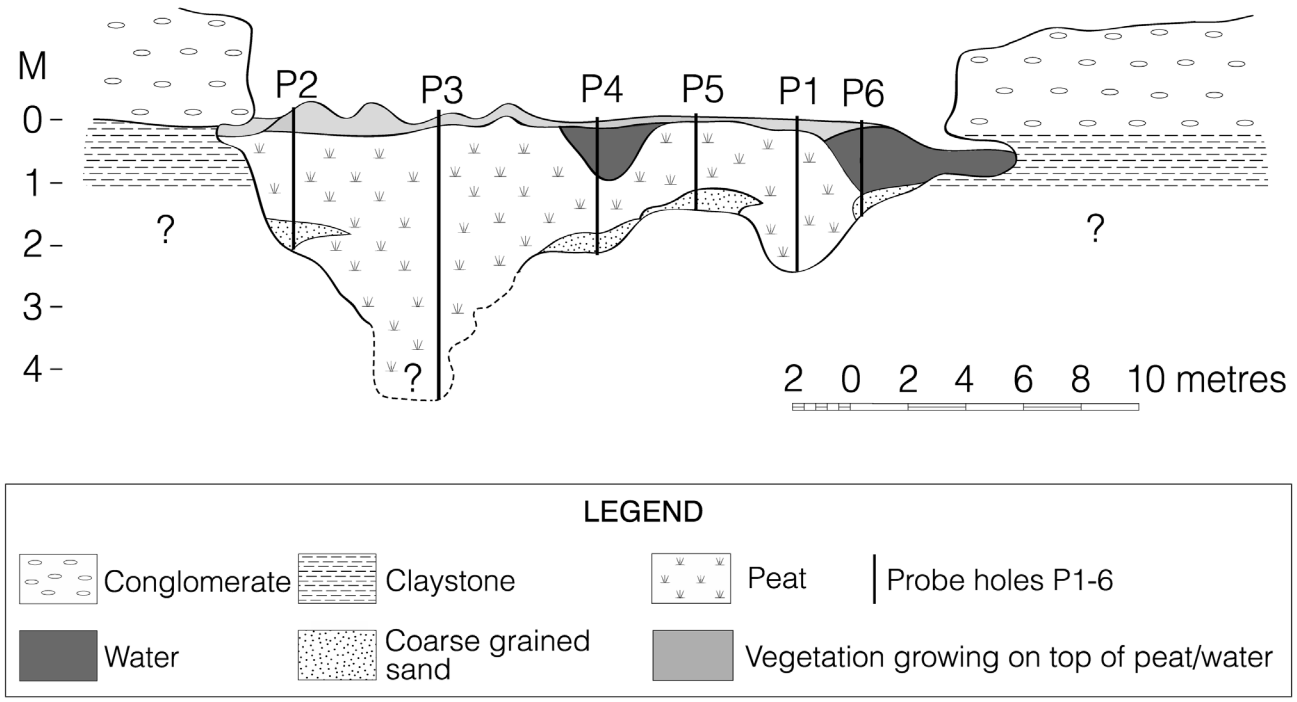

Fig. 4. Detailed cross section of the peat deposits along Traverse 1 (Flora Reserve, Penrose State Forest).

Fig. 5. View of the swamp showing *Eucalyptus aquatica* and associated plants (Flora Reserve, Penrose State Forest).

Below a hard conglomerate bed, there are overhangs above the swamp, indicating a weaker, possibly claystone bed and there is a small waterfall 0.75 m high, on this conglomerate bed. The valley cross section below the waterfall defines a gorge section of the watercourse and the waterfall is a primary knick point (Traverse 3 in Figure 2). Downstream in the swamp at Traverse 3, the valley is still in the form of an incised gorge with steep sides, but it widens out towards the bottom of the swamp (Figure 3). In contrast upstream of Webbers Road along Traverse 2, the valley is much wider with relatively gentle side slopes (Figure 1).

At the bottom of the swamp the watercourse turns abruptly 90° into a southerly direction. At this location, shown in the long section (Figure 3), fluvial sand forms a barrier across to Paddys River. This feature is reminiscent of a flood plain levee type deposit and may indicate an older and elevated river channel (abandoned channel accretion) (Nanson & Croke, 1992; see also Brierley & Fryirs, 2005, Figure 4.6d). The swamp watercourse has been diverted by the levees and enters Paddys River downstream where the levee peters out above a river knick point.

Nature of peat deposits

The swamp occupies the organic-rich sediments of the drainage line and the accumulating materials represent peat (or organosol – Nat. Comm. on Soil and Terrain, 2009) of variable thickness above a basal sandy horizon on top of the Hawkesbury Sandstone bedrock. The top 200 mm of peat was sampled (5 tests) and found to have a pH of 6.0–6.5 , characteristic of the more alkaline nature of a swamp (Mactaggart et al., 2008; Keith 2004 p.210). Below the waterfall knick point the peat reaches a maximum thickness

of 4.2 m (Figure 4), thinning rapidly downstream to <2 m and then tapering off towards the bottom of the swamp in a wedge-shaped profile (Figure 3). Between probe holes P19 to P22 there is a sandy deposit in the upper peat layers. A typical section in the thinner peat is shown in the inset of Figure 3. In most places there is 200–300 mm of fibric (fibrous) peat directly underneath the vegetation and this is underlain by hemic (semi-fibrous) and sapric (humified) peats (Nat. Comm. on Soil and Terrain, 2009). The latter is dark brown to black in colour and very wet. At the bottom of the swamp next to hole P24 the peat appears to overlay the sandy Paddys River fluvial deposits.

The thickest peat below the waterfall appears to be infilling a plunge pool cut, suggesting that the stream had much greater down cutting power in the past (Figure 3). On the valley sides above the peat there are thin sandy loams up to 750 mm thick covering the bedrock.

Swamp vegetation

Eucalyptus aquatica trees grow in association with sedge and shrub plants, mainly the tussock sedge *Gymnoschoenus sphaerocephalus* (Button grass) with *Gleichenia dicarpa* (Pouched coral fern) and two species of *Leptospermum*, *Leptospermum juniperinum* (Prickly tea tree) and *Leptospermum obovatum* (Blunt leafed tea tree). The sedge and coral fern combine to form dense high mats of vegetation up to 1.6 m, under the *Eucalyptus aquatica* trees (Figure 5). *Sphagnum* is also present in the swamp in the wettest areas, but generally limited in extent (in accord with the findings of Whinam and Chilcott, 2002). The overall health of *Eucalyptus aquatica* surveyed was good, with significant numbers of juveniles recorded (Appendix 1). However although *Eucalyptus aquatica* has been noted flowering (in January) and forming fruit, no small seedlings have been sighted, possibly due to the thick ground layer inhibiting recruitment.

Eucalyptus aquatica distribution

Dense clumps of *Eucalyptus aquatica* occur in wet deep peat below the waterfall, spanning the full gorge width (Figure 6). Clumps of up to 10 trees grow continuously along the main watercourse down to the bottom of the swamp to a point where the wet peat conditions appear to peter out. From the

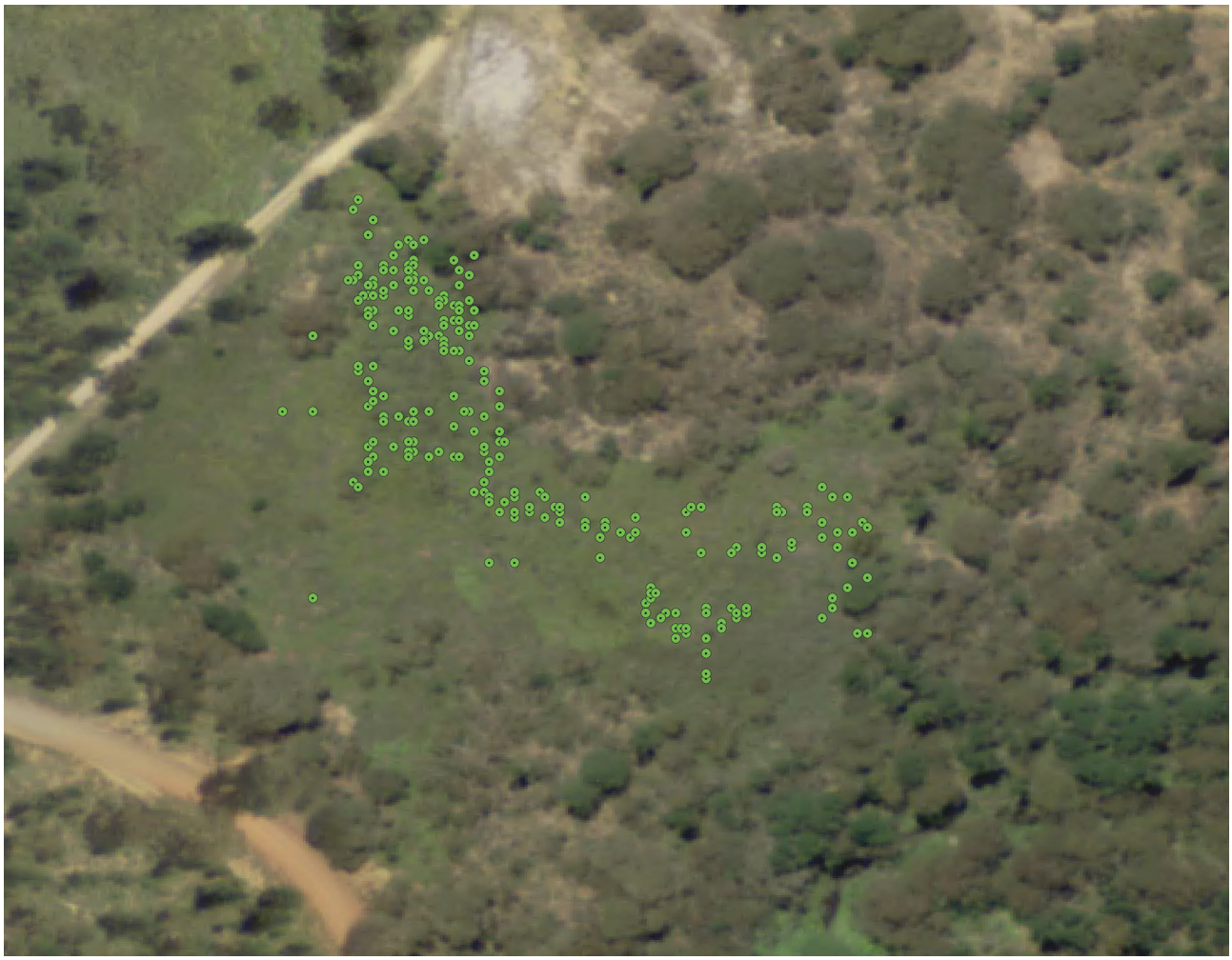

Fig. 6. Distribution of *Eucalyptus aquatica* in the swamp study area in August 2012 (Flora Reserve, Penrose State Forest).

population of 350 trees, only 34 have mallee multistems visible through the ground layer.

On the southwestern edge of the swamp there are two clumps of *Eucalyptus aquatica* growing on sandstone ledges approximately 3 m higher than the current swamp peat level (Figure 6). These clumps contain up to 10 closely spaced trees, some only 1–1.5 m apart including several larger trees with heights of 4–6 m. Using the peat probe, it was found that these trees are growing in only 300–350 mm of sandy loam (not peat), directly on the bedrock (Figure 2). It is possible that these trees once occurred in peat that has now eroded away. Several isolated and elevated trees also occur in thin sandy peat less than 750 mm thick. There is a possibility that these clumps of trees are linked in the organosol by lignotubers as has been described for some Eucalypt species (Boland et al. 1984). Recent mapping in another nearby swamp (also perched above Paddys River) shows some denuded peat with clear lignotubers (12–40 mm in diameter) connecting trees 1–2 m apart.

The height range for the majority of *Eucalyptus aquatica* trees is 2–5 m (details of individual trees are in Appendix 1). This range of heights and the presence of young trees at <1.5 m indicates that the population is currently stable (Figure 7). Common stem diameters are in the range 30–75 mm; the largest recorded is 190 mm. Stems are round and sinuous with abundant strips of loose bark present. Fruit and seed are present but we have not carried out any germination trials (a voucher specimen with fruit attached collected by us from Stingray Swamp in 2011 has been retained at the National Herbarium of NSW).

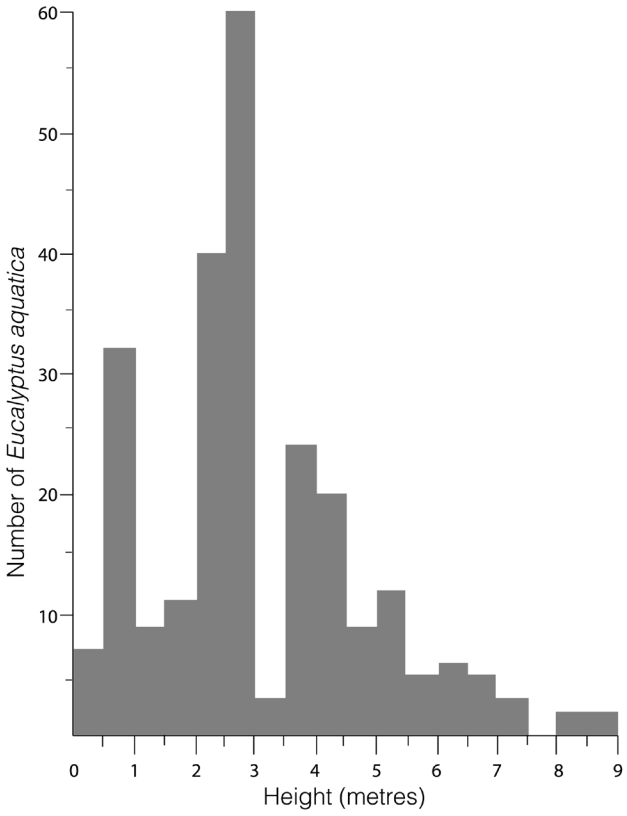

Fig. 7. Histogram of tree heights of *Eucalyptus aquatica* population (n=350) swamp study area (Flora Reserve, Penrose State Forest).

Tree condition, estimated visually based on percentage canopy alive, revealed that the majority of trees were in good condition (44%) or moderate condition (30%) ; 24% were in poor condition and 2% of trees were dead (Appendix 1).

The altitudinal range of the *Eucalyptus aquatica* population measured was very limited; all individuals occurred between 600–609 m above sea level only. *Eucalyptus aquatica* trees have been recorded at elevations up to 625 m in nearby Stingray Swamp. The limited elevation range overall is due to the limited occurrence of its particular swamp habitats and their related landscape position.

Discussion

The natural habitat of *Eucalyptus aquatica* does not appear to depend only on peat deposits as trees were also found to be occurring in sandy loam. However, it may be that the trees occurring in sandy loam originally occurred in peat that has since eroded. Water and water flow may be the critical factors that define the current occurrence of *Eucalyptus aquatica*; this hypothesis could be tested with further hydrological study. The shelter provided by the confined valley may also be a key factor in the population's current distribution.

In our particular swamp, the *Eucalyptus aquatica* population has a clumped distribution, although we could not find any visual evidence of lignotubers. Other factors may be influencing this clumping habit, again possibly associated with moisture characteristics at the site, or local conditions at the time of seedling recruitment. Recent mapping in another swamp (also perched above Paddys River) has shown *Eucalyptus aquatica* trees with lignotubers.

The longevity of the trees is unknown but the population of *Eucalyptus aquatica* appears stable and in good health. Although current texts state that *Eucalyptus aquatica* is a tree to 7 m, trees mapped in this study were as tall as 9 m. How the species has responded to fire, particularly with respect to the last two major bushfires, reported by Forestry Corporation of NSW to have occurred in 1939 and 1965, is unknown.

This study raises numerous research questions regarding the occurrence of *Eucalyptus aquatica* in montane swamps. For example, is the present localised population a relic from past colder, wetter climates? It is also possible that the clumps of *Eucalyptus aquatic* presently located adjacent to, but not in, the swamp represent a previously larger extent of swamp, and together with the suggested prior plunge pool, implies past climatic variability.

Eucalyptus aquatica has also been identified at Hanging Rock Swamp, Stingray Swamp and a number of unnamed swamps on the valley sides of Paddys River within and around Penrose State Forest, but it is difficult to determine the importance of our population of 350 trees in regards to the total population of the species overall due to a lack of data

from other sites. Polygon mapping and numerical estimates of trees suggest a population of 750–1000 mature trees in Stingray Swamp. Mapping is also underway in additional areas to identify the extent of several smaller occurrences. This should provide an estimate of the total population of trees on which to base conservation assessment and prioritise particular conservation actions.

Conservation & Management

Scant knowledge of the ecology of many threatened species hinders our efforts to protect and manage them. *Eucalyptus aquatica* appears to have a naturally restricted range and limited available habitat and for the species' continued survival the protection and management of the associated swamp and swamp habitat is necessary. Appropriate management recommendations include:

An effective buffer zone should be placed around these swamps to protect them from forestry actions. Smith & Smith (2010) suggest a buffer of 60 m to protect significant native vegetation in the Blue Mountains region and this could be used as a guide for the Penrose Swamps;

Management should consider factors that might impinge on the current hydrology of these sites and this might include rerouting of existing vehicle tracks e.g. between the existing swamp crossing and Penrose Forest Way (Webbers Rd); as well as restricting public access to minimise impacts from four-wheel driving and rubbish dumping;

Management should also consider the installation of relevant signage highlighting the importance of the high conservation value of the swamps and the possible penalties applicable if damage should occur;

The upper portion of this swamp system has degraded, and contains dense stands of *Pinus radiata* wildings requiring active management and potentially the re-planting of native species. The establishment of *Pinus radiata* in the swamp could have negative effects through shading and competition on native species and on the hydrology, and hence persistence of *Eucalyptus aquatica* at this site.

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Appendix 1. Location, elevation, tree height and tree condition data for individual *Eucalyptus aquatica* trees mapped within the Paddys River swamp study site (Flora Reserve, Penrose State Forest).

Mapped in August 2012 using Google earth imagery (dated 24/10/2009) and a Garmin hand-held GPS to measure tree locations and a Suunto altimeter to measure elevations. Tree height estimated in metres; where trees are mapped in clusters the maximum height is recorded. Tree condition was estimated visually based on percentage of tree canopy alive: dead (0), poor (1–40%), moderate (41–75%), good (>75%).

Tree site #	No. of trees	Latitude	Longitude	Elevation(m)	Tree H(m)	Tree condition assessment
1	1	-34.65560	150.21811	606	6.5	poor
2	1	-34.65558	150.21812	606	3.5	moderate, top 1.5m dead
3	8	-34.65562	150.21815	605	7	moderate, dead in tops, live at half height
4	2	-34.65565	150.21814	604	6	good
5	1	-34.65567	150.21820	602	3	moderate, reshooting at half height
6	1	-34.65566	150.21822	603	3	poor, leaning over
7	1	-34.65569	150.21819	603	3.5	good
8	1	-34.65567	150.21823	603	3.5	poor, almost dead, next to a pine
9	1	-34.65570	150.21823	604	4	poor, green top only
10	1	-34.65571	150.21822	604	3	poor, green top only
11	1	-34.65571	150.21823	604	3	poor, green top only
12	1	-34.65573	150.21823	604	3	poor, green top only
13	1	-34.65571	150.21823	604	2.5	poor, green top only
14	1	-34.65572	150.21822	604	2.5	poor, green top only
15	1	-34.65574	150.21823	604	4	poor, green top only
16	1	-34.65576	150.21826	604	4.5	good
17	1	-34.65576	150.21823	604	5	moderate
18	1	-34.65572	150.21819	604	3.5	good
19	1	-34.65571	150.21817	604	3	good
20	1	-34.65574	150.21815	604	3	good
21	1	-34.65572	150.21817	604	4	moderate, green foliage to half height
22	1	-34.65575	150.21815	604	2	good
23	1	-34.65577	150.21817	604	4	good
24	1	-34.65576	150.21817	604	2	moderate,re-growing with a dead top
25	1	-34.65577	150.21814	604	3	good
26	1	-34.65577	150.21813	604	2.5	good
27	1	-34.65571	150.21812	605	4	moderate
28	1	-34.65573	150.21812	605	3	moderate
29	1	-34.65574	150.21811	605	3	dead
30	1	-34.65575	150.21814	605	5.5	moderate
31	1	-34.65574	150.21810	605	6.5	moderate
32	4	-34.65578	150.21812	604	5	moderate
33	1	-34.65577	150.21815	604	2.5	good
34	1	-34.65580	150.21815	604	3.5	good
35	1	-34.65583	150.21815	604	3	good
36	1	-34.65580	150.21814	604	3.3	good, but a dead top
37	1	-34.65581	150.21814	604	2	good
38	1	-34.65584	150.21819	605	4	moderate
39	1	-34.65580	150.21820	605	4	good
40	1	-34.65581	150.21822	606	2	good
41	1	-34.65580	150.21822	606	4.5	moderate
42	1	-34.65575	150.21819	606	2	dead
43	1	-34.65574	150.21822	606	3	moderate
44	1	-34.65574	150.21825	607	4.5	moderate
45	1	-34.65577	150.21829	607	1	good
46	1	-34.65576	150.21826	607	2	moderate
47	1	-34.65578	150.21829	607	3	poor
48	1	-34.65578	150.21828	607	2	poor, new growth from dead trunk
49	1	-34.65579	150.21831	605	1.2	good
50	1	-34.65582	150.21831	605	2	good

Tree site #	No. of trees	Latitude	Longitude	Elevation(m)	Tree H(m)	Tree condition assessment
51	1	-34.65582	150.21831	605	2	moderate
52	1	-34.65579	150.21832	605	2.5	good
53	6	-34.65582	150.21829	606	2.5	good
54	1	-34.65584	150.21832	606	4	good
55	1	-34.65583	150.21829	606	6	good
56	1	-34.65585	150.21828	606	5	moderate
57	1	-34.65585	150.21828	606	2	good
58	1	-34.65585	150.21803	606	3	good
59	1	-34.65585	150.21826	606	3	good
60	1	-34.65586	150.21825	606	6.5	moderate
61	1	-34.65584	150.21825	606	6.5	good
62	2	-34.65587	150.21822	606	0.75	good
63	1	-34.65586	150.21822	606	3	good
64	1	-34.65592	150.21812	606	3.5	poor, but new green shoots
65	1	-34.65591	150.21812	605	1	good
66	1	-34.65591	150.21815	606	2.2	moderate, dead in top
67	1	-34.65594	150.21814	606	1.8	moderate, young tree dead in top
68	1	-34.65596	150.21815	606	3	good
69	4	-34.65601	150.21817	606	4	moderate, brown growths
70	2	-34.65599	150.21814	607	2.2	good
71	1	-34.65598	150.21815	607	3.5	moderate, brown growths
72	1	-34.65597	150.21817	607	4	poor, brown growths
73	1	-34.65602	150.21817	607	5	good, leaning at 45 deg
74	2	-34.65601	150.21820	607	1	good
75	1	-34.65602	150.21822	607	1.5	good, young tree
76	1	-34.65602	150.21823	607	2.75	poor ,green top, brown growths
77	1	-34.65600	150.21823	607	5	poor ,green top, brown growths
78	1	-34.65600	150.21826	609	2.2	poor ,green top, brown growths
79	6	-34.65603	150.21831	609	5	poor ,green top, brown growths
80	3	-34.65608	150.21828	609	3	good
81	1	-34.65609	150.21831	609	5	moderate, brown growths
82	1	-34.65609	150.21832	609	2.5	poor
83	2	-34.65609	150.21826	609	3.5	good
84	1	-34.65606	150.21823	609	2.5	good
85	1	-34.65606	150.21822	609	1.75	good
86	1	-34.65608	150.21823	608	1.1	good, young tree
87	2	-34.65607	150.21819	608	1.1	good, young tree
88	1	-34.65609	150.21815	608	2	good, young tree
89	1	-34.65607	150.21814	607	3.5	moderate
90	1	-34.65606	150.21815	608	3.5	good
91	1	-34.65610	150.21814	609	2.5	moderate
92	2	-34.65608	150.21822	608	1.5	good, young trees
93	2	-34.65609	150.21822	608	1	good, young trees
94	1	-34.65612	150.21817	608	3.5	good, young trees
95	1	-34.65612	150.21814	608	6	good, minor dead branches
96	1	-34.65614	150.21811	608	6	good, minor dead branches
97	1	-34.65615	150.21812	608	8	moderate
98	1	-34.65600	150.21803	609	3.5	good, some brown growths
99	2	-34.65600	150.21797	609	4	moderate, but new shoots
100	1	-34.65566	150.21825	603	4.5	poor
101	1	-34.65570	150.21831	604	3.5	good
102	1	-34.65569	150.21835	605	4	moderate, green at half height, dead top
103	1	-34.65572	150.21832	605	4.5	poor
104	1	-34.65573	150.21834	605	2.1	good
105	1	-34.65575	150.21832	606	3.5	poor, green shoots at 1.2m height
106	2	-34.65578	150.21834	606	2.25	moderate
107	3	-34.65580	150.21832	606	1.2	good
108	4	-34.65579	150.21828	606	1.3	good
109	1	-34.65582	150.21832	606	5.5	good
110	1	-34.65580	150.21835	606	3	good

Tree site #	No. of trees	Latitude	Longitude	Elevation(m)	Tree H(m)	Tree condition assessment
111	1	-34.65583	150.21834	605	4	good
112	2	-34.65583	150.21835	605	4.5	moderate
113	2	-34.65585	150.21834	605	3	poor, green reshooting at half height
114	1	-34.65588	150.21832	605	4.5	good
115	1	-34.65588	150.21831	605	4.5	good
116	1	-34.65586	150.21829	605	2.5	moderate
117	1	-34.65587	150.21829	605	2	good
118	1	-34.65588	150.21829	606	2	good
119	1	-34.65588	150.21832	606	5	good ,some brown growths
120	1	-34.65588	150.21831	606	4	dead and brown growths
121	10	-34.65590	150.21834	606	4	moderate, brown growths
122	1	-34.65592	150.21837	604	1.8	good
123	1	-34.65599	150.21840	605	3	poor, dead top, brown growths, shoots half height
124	1	-34.65592	150.21837	606	1.7	dead
125	1	-34.65597	150.21831	606	1.7	moderate, brown growths
126	1	-34.65596	150.21840	604	4	good
127	1	-34.65594	150.21837	604	1	good
128	1	-34.65600	150.21834	604	2.1	good
129	1	-34.65600	150.21833	604	4	dead
130	3	-34.65608	150.21837	604	5	moderate, brown growths
131	1	-34.65604	150.21835	604	3	good
132	1	-34.65601	150.21837	604	3.5	moderate
133	2	-34.65607	150.21837	604	5	good
134	1	-34.65604	150.21840	604	3.5	moderate
135	1	-34.65606	150.21840	605	3.25	poor
136	6	-34.65609	150.21840	605	4.5	good, trees 1m apart
137	2	-34.65606	150.21841	604	3	poor, dead top reshooting at half height
138	1	-34.65610	150.21838	603	3.5	poor, reshooting, brown clusters
139	2	-34.65612	150.21838	603	3	poor, leaning, reshooting, brown growths
140	1	-34.65614	150.21837	602	2.5	poor, reshooting
141	1	-34.65616	150.21835	602	3.5	good
142	1	-34.65616	150.21837	602	1	good, young tree
143	1	-34.65617	150.21838	602	2.5	dead
144	1	-34.65618	150.21838	602	2.5	poor
145	1	-34.65616	150.21835	601	2.5	moderate
146	1	-34.65617	150.21843	602	1	good, young tree
147	1	-34.65618	150.21841	602	1.2	good, young tree
148	1	-34.65620	150.21840	602	1	good, young tree
149	1	-34.65621	150.21843	602	1.2	good, young tree
150	1	-34.65616	150.21843	602	3	poor, brown growths
151	1	-34.65620	150.21843	602	0.75	good, young tree, 100% good green foliage
152	1	-34.65620	150.21846	602	2.75	good
153	6	-34.65616	150.21848	603	4	poor, brown growths
154	4	-34.65619	150.21846	602	3.25	good
155	1	-34.65630	150.21838	603	1.2	moderate, dead top, reshooting at half height
156	1	-34.65630	150.21843	601	1.5	good
157	1	-34.65621	150.21849	601	3	good
158	3	-34.65617	150.21849	601	2.5	moderate
159	1	-34.65619	150.21851	601	0.75	good, young tree
160	2	-34.65620	150.21852	601	2.2	moderate
161	1	-34.65622	150.21852	601	2	good
162	2	-34.65619	150.21852	601	2	poor, almost dead, reshooting at half height
163	1	-34.65622	150.21857	600	3	good
164	1	-34.65623	150.21861	600	1.2	good
165	1	-34.65617	150.21857	600	3.5	poor, reshooting
166	1	-34.65622	150.21861	601	3.5	poor, reshooting, brown growths
167	3	-34.65623	150.21861	601	1.75	good
168	1	-34.65623	150.21857	601	1.2	good
169	2	-34.65625	150.21860	601	1.2	good
170	1	-34.65629	150.21860	601	1.1	good

Tree site #	No. of trees	Latitude	Longitude	Elevation(m)	Tree H(m)	Tree condition assessment
171	1	-34.65624	150.21864	601	1.1	good
172	1	-34.65625	150.21866	601	1.5	good
173	1	-34.65624	150.21867	601	1.5	good
174	1	-34.65621	150.21867	601	1.1	good
175	1	-34.65624	150.21877	603	2	good
176	1	-34.65620	150.21877	602	1	good
177	3	-34.65628	150.21880	602	2	moderate, brown growths
178	5	-34.65628	150.21880	602	2.5	moderate
179	1	-34.65619	150.21880	603	2.1	good
180	1	-34.65619	150.21878	603	1	good
181	1	-34.65627	150.21887	602	2	poor
182	1	-34.65628	150.21886	602	1.2	good
183	1	-34.65628	150.21892	602	1	good
184	1	-34.65629	150.21895	603	3.5	poor, reshooting
185	1	-34.65619	150.21895	603	8	moderate
186	1	-34.65625	150.21904	603	3	poor
187	1	-34.65627	150.21892	603	0.5	good
188	2	-34.65627	150.21898	603	2.3	poor, reshooting from base
189	2	-34.65626	150.21898	603	2.2	poor
190	1	-34.65620	150.21896	604	2	poor
191	1	34.65620	150.21895	604	2	moderate
192	3	-34.65619	150.21901	604	2.5	moderate
193	1	-34.65620	150.21901	604	1.8	moderate
194	1	-34.65622	150.21904	604	2	poor
195	7	-34.65615	150.21904	604	3	poor, reshooting from base
196	1	-34.65617	150.21906	604	1.5	poor
197	1	-34.65617	150.21909	604	1.1	moderate
198	1	-34.65622	150.21912	603	2.25	moderate
199	2	-34.65623	150.21913	603	2	moderate
200	1	-34.65624	150.21910	603	1.5	poor
201	1	-34.65624	150.21907	603	0.75	moderate
202	1	-34.65627	150.21907	602	4	moderate and brown growths
203	1	-34.65630	150.21910	604	2.5	poor
204	1	-34.65633	150.21913	604	2.5	poor
205	1	-34.65635	150.21909	604	1.5	good
206	1	-34.65637	150.21803	604	5	good
207	1	-34.65639	150.21886	604	0.5	good, young tree
208	1	-34.65640	150.21889	604	1.8	good
209	1	-34.65639	150.21881	603	3	good
210	1	-34.65641	150.21887	603	2.3	good
211	1	-34.65639	150.21889	604	1.6	good
212	1	-34.65640	150.21887	604	3.5	poor, reshooting
213	2	-34.65640	150.21881	604	4	moderate
214	1	-34.65642	150.21884	603	9	poor
215	2	-34.65643	150.21884	603	5.5	poor
216	1	-34.65653	150.21881	603	3.5	poor
217	1	-34.65652	150.21881	604	4	poor
218	2	-34.65648	150.21881	605	3	poor
219	1	- 34.65643	150.21878	605	2.75	moderate
220	2	-34.65645	150.21881	605	2.75	moderate
221	1	-34.65644	150.21877	605	2.5	good
222	1	-34.65643	150.21875	606	2	good
223	1	-34.65645	150.21875	606	1	good, young tree
224	1	-34.65643	150.21876	606	1	good, young tree
225	5	-34.65643	150.21877	606	1.2	good, young tree
226	1	-34.65640	150.21875	606	2	good
227	1	-34.65640	150.21873	606	4	moderate
228	2	-34.65641	150.21872	606	3	poor, reshooting
229	1	-34.65642	150.21870	606	1.5	good
230	4	-34.65640	150.21869	606	2	poor, reshooting

Tree site #	No. of trees	Latitude	Longitude	Elevation(m)	Tree H(m)	Tree condition assessment
231	2	-34.65638	150.21869	606	1	good, young tree
232	1	-34.65637	150.21870	606	6	poor, brown growths
233	1	-34.65635	150.21870	606	0.75	good, young tree
234	1	-34.65636	150.21870	606	1.2	dead
235	1	-34.65636	150.21871	606	4	good
236	3	-34.65637	150.21906	603	3	moderate
237	2	-34.65639	150.21906	603	7	moderate
238	1	-34.65644	150.21913	602	5.5	moderate
239	2	-34.65644	150.21911	602	3	moderate, reshooting
240	1	-34.65641	150.21904	602	9	poor