WAHROONGA ESTATE REDEVELOPMENT

Biodiversity Management Plan

For:

AUSTRALASIAN CONFERENCE ASSOCIATION

November 2010

Final Report

Cumberland Ecology
PO Box 2474, Carlingford Court 2118

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Date:	*23 November, 2010*

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Chapter 1

Introduction

1.1 Purpose

The purpose of this Biodiversity Management Plan (BMP) is to prescribe long term ecological, bushfire and stormwater management actions with respect to lands known as the "Wahroonga Estate Redevelopment" (herein referred to as the subject land as shown in Figure 1.1). The subject land, incorporating the Sydney Adventist Hospital, is situated at Fox Valley Road and the Comenarra Parkway, Wahroonga (Figure 1.1).The subject land straddles the Ku-ring-gai and Hornsby Local Government areas.

This document is consistent with the requirements of:

- Department of Planning (DOP) Major Project MP 07_0166 conditions of Part 3A Approval which were issued on 31 March 2010 (refer Condition B4 of this approval); and
- Department of Environment, Water, Heritage & Arts (DEWHA) conditions of *Environment Protection Biodiversity Conservation Act 1999* approval which were issued on 18 June 2010 (EPBC Ref: 2008/4460)

The BMP describes the conservation values of flora and fauna on the subject land and prescribes long term management of the conservation lands. The BMP includes provision for management of weeds, feral animals, bushfire risk, storm water and public access.

1.2 Objectives of the BMP

The objectives of the BMP are:

- To satisfy the conditions of consent of both DOP and DEWHA;
- To provide a guide to the management of retained vegetation within the E2 Environmental Conservation zone;
- To provide a guide to the management of weeds, bushfire, feral animals and hydrology within the E2 zone;

- To provide the landowner and other stakeholders a guide to the conservation, rehabilitation, and long term management of the ecological values of the E2 Environment Conservation zone;
- To provide guidelines on reporting requirements to DOP and DEWHA;
- To provide restrictions on Asset Protection Zones and stormwater management devices extending into the E2 zone land (except as otherwise outlined within this plan); and
- To manage public access through the E2 zone, particularly through the western (or Coups Creek) corridor.

1.3 Background

The subject land has recently been rezoned and a Concept Plan for redevelopment approved under Part 3A of the *Environmental Planning and Assessment Act 1979* (EP&A Act) from the DOP.

The approved concept plan comprises development within the following zones (refer to Figure 1.2):

- B1 Neighbourhood Centre;
- E2 Environmental Conservation;
- R1 General Residential;
- R2 Low Density Residential;
- R3 Medium Density Residential;
- R4 High Density Residential; and
- SP1 Special Activities.

The main elements of the development proposed under the Concept Plan are an upgrade and expansion of the existing hospital to create a total floor area of 94,000m^2; 500 new low, medium and high density private residential dwellings; 538 other accommodation types including seniors living and student accommodation; educational facilities including a K-12 school and faculty of nursing; and commercial / retail floor space.

The 66ha Estate includes 31.4ha of native vegetation that is to be conserved and managed for conservation (zoned E2 Environmental Conservation). The extent of the conservation land was determined following an independent assessment conducted by Sinclair Knight Merz during the Part 3A Concept Plan approval process. This BMP is based on the results of the Sinclair Knight Merz independent assessment.

As a result of Concept Plan rezoning, the E2 zone was increased to include the existing Asset Protection Zones (APZs). Consequently, this plan recognises vegetation that falls outside the E2 zone may be modified to allow development to proceed, consistent with the Department of Planning Part 3A Concept Plan approval (MP 07_0166) as shown in Figure 1.2

Subsequent to the rezoning and Part 3A Concept Plan approvals, DEWHA also issued conditional approval under the *Environment Protection Biodiversity Conservation Act 1999*.

A number of different ecological communities occur within the lands zoned E2. Of these, two conform to Commonwealth and State listed Critically / Endangered Ecological Communities (C/EECs) – being Blue Gum High Forest (BGHF) and Sydney Turpentine-Ironbark Forest (STIF). The E2 zone also provides nesting habitat for a species listed as Vulnerable under the *Threatened Species Conservation Act 1995* (TSC Act), the Powerful Owl. To manage these important ecological issues, an integrated multi-disciplinary BMP was requested as part of the conditions of consent.

1.4 Scope

This BMP incorporates a multi-disciplinary approach and integrates several plans of management to provide one comprehensive plan to guide the management of sensitive environmental issues on the subject land. This BMP incorporates separate reports provided by Hyder Consulting for hydrology and nutrient management and Australian Bushfire Protection Planners (ABPP) for bushfire management.

The BMP contains the following plans of management:

- Weed Management Plan;
- Vegetation Management Plan;
- Fire Management Plan (prepared by ABPP);
- Pest Management Plan;
- Habitat Corridor and Linkages Management Plan; and
- Hydrology and Nutrient Management Plan (prepared by Hyder Consulting).

As required by the Commonwealth Government consent conditions, the BMP includes:

b) Conservation Interface Management Plan with clear objectives, performance criteria and targets, which must address, but not limited to:

   i. measures to protect and manage Turpentine-Ironbark Forest located in the E2 zone from direct impacts, public access, recreational use and edge effects; and

ii. Identifies areas that will be managed as asset protection zones.

The Conservation Interface Management Plan has been incorporated into the Vegetation Management Plan (Chapter 4). Issues relating to Clause b (i) and (ii) have been dealt with, within the Management Zones (Section 4.4) and Bushfire Management Plan (Chapter 5).

The BMP only pertains to the protection, conservation and management of vegetation within the E2 zone. It does not include areas of STIF and BGHF listed under the TSC Act which fall within the areas zoned SP1, B1, R2, R3 and R4. This BMP provides guidelines on monitoring and reporting requirements with respect to the E2 zone land along with financial commitments associated with the long term management of the E2 zone land.

1.5 Terminology

Throughout this report the following terminology will be used.

Subject site	is defined as the parcel of land on which development is proposed
Subject land	refers to the total parcel of land known as the Wahroonga Estate Redevelopment and as depicted in Figure 1.1.
Study area	refers to the subject land and immediate surrounds that may be indirectly affected by the proposal
Locality	refers to the land within a 5km radius of the subject site
DOP	abbreviates (NSW) Department of Planning
TSC Act	abbreviates the *Threatened Species Conservation Act 1995*
EPBC Act	abbreviates the *Environment Protection and Biodiversity Conservation Act 1999*
EP&A Act	abbreviates the *Environmental Planning and Assessment Act 1979*
Threatened species	refers to those flora and fauna species listed as vulnerable, endangered or critically endangered under the TSC Act or EPBC Act
CEEC	abbreviates Critically Endangered Ecological Community
EEC	abbreviates Endangered Ecological Community

NSW NPWS	abbreviates New South Wales National Parks Wildlife Service
DECCW	abbreviates (NSW) Department of Environment, Climate Change and Water
DEWHA	abbreviates (Commonwealth) Department of Environment, Water, Heritage and Arts
SKM	abbreviates Sinclair Knight Merz
ABPP	abbreviates Australian Bushfire Protection Planners
Aerial Fuels	The standing & supporting combustibles not in direct contact with the ground and consisting mainly of foliage, twigs, branches, stems. Bark and creepers
Assets at Risk	The natural resources or improvements that may be impacted if a fire occurs;
Asset Protection Zones [APZ]	These are zones adjacent to built assets [such as homes and other structures]. Fuels are intensively managed in these areas to provide a buffer of very low combustible fuel levels between an asset and the bushfire hazard. In many cases an APZ will be created and maintained using mechanical methods or in some cases, for example where terrain is very steep or rough, fire may be used to reduce combustible fuels;
Backburning	A fire started intentionally along the inner edge of a fire-line to consume the fuel in the path of a wildfire;
Burning Program	All prescribed burns scheduled for a designated area over a nominated period of time;
Edge Burning	A term used to describe perimeter burning of an area in mild conditions prior to large scale prescribed burning;
Fine Fuels	Grass, leaves, bark and twigs less than 6mm in diameter;
Fire Behaviour	The manner in which a fire reacts to the variables of fuel, weather and topography. Changes in any of these will result in a change in the fires behaviour;
Fire Break	Any natural or constructed discontinuity in a fuel bed used to separate, stop and control the spread of a wildfire or to provide a line from which a back burn can be implemented;

Fire Intensity The rate of energy released per unit length of fire front, expressed in kW/m2;

Fire Management All activities associated with the management of bushfire prone land, including the use of fire to address land management responsibilities under Section 63 of the *NSW Rural Fires Act;*

Fire Regime The history of fire in a particular vegetation type or area including the frequency, intensity and season of burning;

Fire Season The period of the year during which fires are likely to occur, spread and do sufficient damage to warrant organised fire control. The designated Fire Season in NSW is from the 1st October to the 30th March, however this can be adjusted in accordance with the level of Fire Danger Index [FDI];

Fuel Any combustible material such as grass, bark, leaf litter and living vegetation which can be ignited and sustains a fire [Measured in tonnes/hectare of dry weight of fuel;

Fuel Management Modification of fuels by prescribed burning, manual removal, slashing, grazing or other means to reduce the fuels available to fire events[Also referred to as Hazard Reduction];

Fuel Type An identifiable association of fuel elements of distinctive species, form, size, arrangement that will cause predictable rate of spread or difficulty of control under specified weather conditions;

Land Management Zones [LMZ] Land management zones are large land areas that have been mapped for prescribed, mosaic burning;

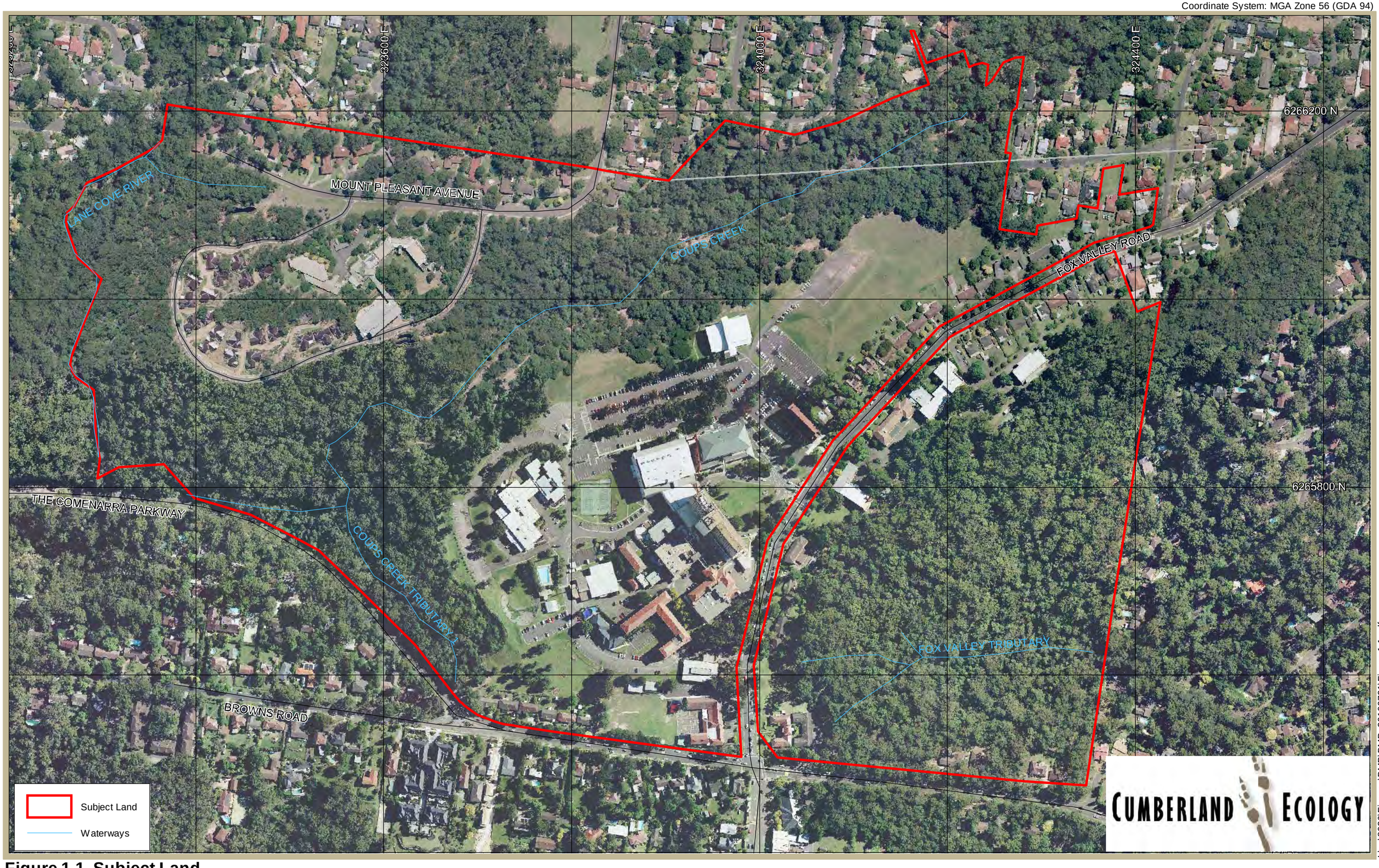
Prescribed Burning The controlled application of fire under specified environmental and weather conditions to a predetermined area and at the time, intensity and rate of spread required to attain planned resource management objectives;

Strategic Fire Advantage Zones [SFMZ] These are bushfire hazard reduced areas where combustible fuels are managed to slow a bushfire and reduce intensity and are often located adjacent to an APZ to enhance the effectiveness of the APZ.

SFMZs can be established in strategic locations, such as adjacent to fire trails in high ignition areas or fire-paths to enhance fire control options and to provide opportunities

	to contain fires before they threaten communities or assets. Generally fuel loads in these areas are reduced using prescribed burning techniques;
Wildfire [Unplanned fire]	An unplanned fire including grass, forest fires and scrub fires.

Coordinate System: MGA Zone 56 (GDA 94)



I:\...\8036\Figures\BMP\BMP_20100721\Figure 1.1.pdf

Figure 1.1. Subject Land

100 0 100 200 300 400 m

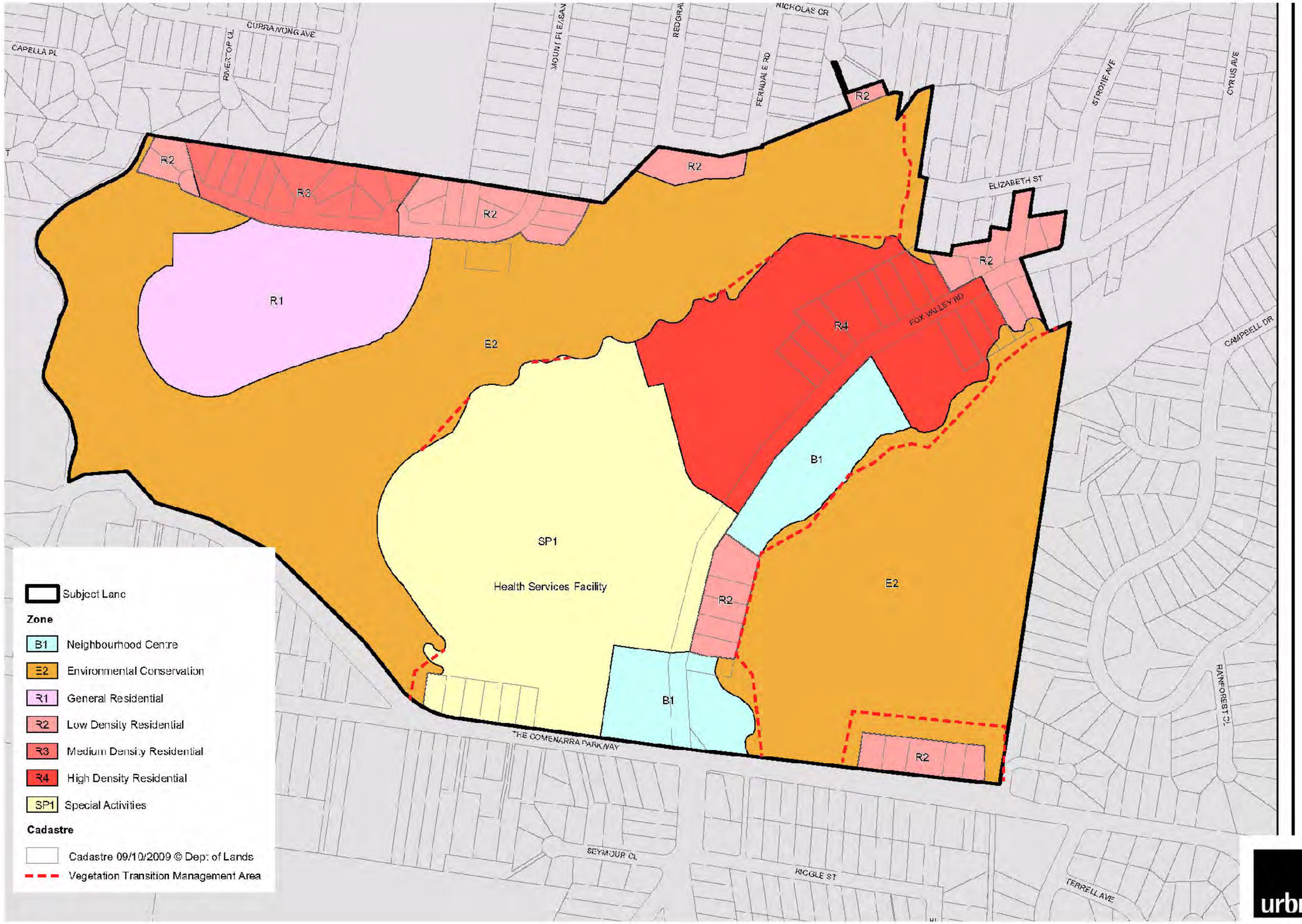


Figure 1.2. Wahroonga Estate Rezoning Plan

Chapter 2

Site Description

2.1 General

Wahroonga Estate covers approximately 66 ha and is located on the northern side of The Comenarra Parkway at the intersection with Fox Valley Road (Figure 1.1). Approximately 40% of the subject land supports urban bushland that is connected to Lane Cove National Park through recreation reserves and creek corridors to the southeast. The current land uses on the subject land include hospital, aged care, school, residential and church facilities. Existing development includes the Sydney Adventist Hospital; Adventist Church Regional Headquarters and administration offices; Seventh-day Adventist Churches; an Adventist primary school; commercial medical practices; Normanhurst Adventist Retirement Village and staff housing. Parts of the subject land have been cleared of native vegetation for historic farming activities and are not currently developed. These cleared lands have been rezoned as R4, High Density Residential to allow for future development according to the approved Concept Plan.

2.2 Soils and Geology

Soils landscape mapping by (Chapman and Murphy, 1989) have mapped three different soil landscapes on the subject land.

Table 2.1 SOIL LANDSCAPES ON THE SUBJECT LAND

Name	Location	Soil
Hawkesbury	Central and north-western corner of the subject land associated with Coups Creek	Shallow (<50 cm), discontinuous Lithosols/Siliceous Sands associated with rock outcrop; Earthy Sands, Yellow Earths and some Yellow Podzolic soils on inside of benches and along joints and fractures; localised Yellow and Red Podzolic Soils associated with shale lenses; Siliceous Sands and secondary Yellow Earths along drainage lines
Glenorie	Along the ridgeline following Fox Valley Road with a large intrusion in the	Undulating to rolling low hills on Wianamatta Group Shales

Table 2.1 SOIL LANDSCAPES ON THE SUBJECT LAND

Name	Location	Soil
	northwest	Shallow to moderately deep (<100 cm) Red Podzolic soils on crests; moderately deep (70-150cm) Red and Brown Podzolic Soils on upper slopes; deep (>200cm) Yellow Podzolic Soils on upper slopes and Humic Gleys, Yellow Podzolic Soils and Gleyed Podzolic Soils along drainage lines.
Gymea	south-eastern corner of the subject land	shallow to moderately deep (30-100 cm) Yellow Earths and Earthy Sands on crests and inside of benches; shallow (<20 cm) Siliceous Sands on leading edges of benches; localised Gleyed Podzolic Soils and Yellow Podzolic Soils on shale lenses; shallow to moderately deep (<100 cm) Siliceous Sands and Leached Sands along drainage lines

2.3 Topography and Hydrology

The site elevation varies between 130 and 170 metres Australian Height Datum (AHD) with slopes within the riparian corridors generally exceeding 18^{o}. Slopes outside of the riparian corridors are generally $0 – 10^{o}$.

The subject land slopes away from Fox Valley Road, which bisects the site. The western side of the subject land has a westerly aspect and drains to Coups Creek. The eastern side of the subject land has an easterly aspect and drains into Fox Valley Creek. Both creeks are tributaries of the Lane Cove River.

Generally, the subject land has four watercourses:

- Coups Creek flows in a north-east to south-west direction through the subject land. This creek is part of the greater Lane Cove River Catchment and meets Lane Cover River within the boundaries of the subject land (Figure 1.1);
- The western boundary of the subject land is defined by the Lane Cove River (DOP 2010) and flows in a north to south direction (Figure 1.1);
- Coups Creek Tributary 1 (DOP 2010) flows into Coups Creek prior to its confluence into Lane Cover River. This tributary flows in an east-west direction roughly following part of The Comenarra Parkway (Figure 1.1); and
- Fox Valley Tributary (DOP 2010) flows in a west-east direction in lands east of Fox Valley Road. (Figure 1.1)

2.4 Vegetation

2.4.1 Vegetation Mapping

The vegetation mapping of the subject land prepared by SKM (2009) and approved by DOP identifies three vegetation communities (refer to Figure 2.1). Of these, two communities BGHF and STIF are listed as threatened ecological communities under the TSC Act and the EPBC Act.

The three vegetation communities SKM identified are:

- Sydney Turpentine Ironbark Forest (listed as an EEC under the TSC Act and listed as a CEEC under the EPBC Act)
- Blue Gum High Forest (listed as a CEEC under the TSC Act and the EPBC Act)
- Sydney Sandstone Gully Forest, comprising
  - Forest/Woodland Form; and
  - Tall Open Forest Form

A description of the vegetation types associated with these communities is presented below (sourced by SKM 2009).

i. Sydney Turpentine Ironbark Forest

STIF is fairly widespread across the subject land occurring on gentle to moderate slopes with clay soils derived from Wianamatta Shale. STIF was once widespread across western Sydney, with only 4.5% of the original extent remaining intact (DEC (NSW), 2005b). Historical clearing has reduced this vegetation community to the periphery of urban development across the subject land (Figure 2.1). STIF transitions into Sydney Sandstone Gully Forest (SSGF) where the shale capping has weathered and underlying sandstone geology has been exposed. STIF also transitions in to BGHF at the top of the shale slopes.

The vegetation community on the subject land conforms to the definition of STIF as listed under the TSC Act and Turpentine Ironbark Forest as listed under the EPBC Act, with up to 41% (average of 26%) of the listed characteristic species (NSW Scientific Committee, 2008). STIF was recorded in a range of condition states at the subject land, ranging from areas comprising high floristic and structural diversity with limited disturbance, to areas with only canopy species and a highly modified understorey (Figure 2.1). A significant proportion of the STIF on the subject land is currently managed as a fuel reduced APZ, particularly to the east of Fox Valley Road (Figure 2.1). Due to regular mowing and weed invasion, the area of Sydney Turpentine Ironbark Forest managed as an APZ is likely to

have reduced ecological function associated with reduced structural diversity and it is generally in poorer condition.

On the subject land, STIF is dominated by *Syncarpia glomulifera* (Turpentine), Blackbutt (*Eucalyptus pilularis*), Grey Ironbark (*Eucalyptus paniculata*) and Red Mahogany (*Eucalyptus resinifera* subsp. *resinifera*) up to 30 m in height with foliage projected cover typically in the order of 40% or more which gives the vegetation its' characteristic open forest structure. Other trees growing in occasional association with this vegetation community included the Smooth-barked Apple (*Angophora costata*) and Sydney Blue Gum (*Eucalyptus saligna*). This vegetation community is present in a number of condition states across the study area ranging from isolated remnant trees to mature old growth stands.

The mid-storey is moderately dense in structure with foliage projected cover of approximately 19% and dominated by regenerating eucalypts, Turpentine and a number of other species including Elderberry Panax (*Polyscias sambucifolia*), Forest She-oak (*Allocasuarina torulosa*), Mock-olive (*Notelaea longifolia* forma *longifolia*), Narrow-leaf Geebung (*Persoonia linearis*) and Sweet Pittosporum (*Pittosporum undulatum*).

Photograph 2.1 Sydney Turpentine Ironbark Forest on the Subject Land (SKM 2009)

The shrub layer (<1m) was generally sparse, with a foliage projected cover of approximately 5%. The shrub layer consisted of scattered individuals of Coffee Bush (*Breynia oblongifolia*), Handsome Flat-pea (*Platylobium formosum*), Long-flowered Beard-heath (*Leucopogon juniperinus*), Rough Guinea-flower (*Hibbertia aspera*), Rusty-petals

(*Lasiopetalum ferrugineum*), Sandfly Zieria (*Zieria smithii*), White Dogwood (*Ozothamnus diosmifolius*) and Yellow Pittosporum (*Pittosporum revolutum*).

A high diversity of native groundcover species was recorded overall across this vegetation community. Native herbs, forbs and sedges accounted for 16% of the groundcover cover within this community, with native grasses accounting for 11% cover on average. Native groundcovers frequently recorded included Appleberry (*Billardiera scandens*), Blue Flax-lily (*Dianella caerulea*), Blue Trumpet (*Brunoniella australis*), Broad-leaved Basket Grass (*Oplismenus aemulus*), Common Maidenhair Fern (*Adiantum aethiopicum*), Headache Vine (*Clematis glycinoides*), Kidney-weed (*Dichondra repens*), Meadow Rice-grass (*Microlaena stipoides*), Narrow-leaved Basket Grass (*Oplismenus imbecillis*), Native Geranium (*Geranium homeanum*), Pastel Flower (*Pseuderanthemum variabile*), Poa Tussock (*Poa affinis*), Spiny-headed Mat-rush (*Lomandra longifolia*), Sweet Sarsaparilla (*Smilax glyciphylla*), Twining Glycine (*Glycine clandestina*), Variable Sword-sedge (*Lepidosperma laterale*), Wattle Mat-rush (*Lomandra filiformis* subsp. *filiformis*), Whiteroot (*Pratia purpurascens*), Wiry Panic (*Entolasia stricta*) and Wombat Berry (*Eustrephus latifolius*).

Exotic species accounted for 35% of the foliage projected cover on average. Commonly recorded exotic species included Asparagus Fern (*Asparagus aethiopicus*), Blackberry (*Rubus* sp.), Broadleaved Privet (*Ligustrum lucidum*), Lantana (*Lantana camara*), Mickey Mouse Plant (*Ochna serrulata*), Panic Veldgrass (*Ehrharta erecta*), Small-Leaved Privet (*Ligustrum sinense*) and Wandering Jew (*Tradescantia fluminensis*). As Sydney Turpentine Ironbark Forest adjoins developed areas at the subject land, the forest edges and creeklines are the most disturbed and weed dominated.

ii. Blue Gum High Forest

BGHF has a restricted distribution on the subject land, occurring in small patches in the north-eastern corner and as scattered trees within the existing development. BGHF occurs on the higher ridges of the subject land on gentle slopes in association with clay soils derived from Wianamatta Shale. BGHF was once widespread within the Ku-ring-gai LGA, with only 4.5 % of the original extent remaining intact (DEC (NSW), 2005a). Historical clearing at the subject land has reduced this vegetation community to small disturbed remnants and isolated trees (Figure 2.1). BGHF grades into STIF on steeper slopes generally around 150 m in elevation.

This vegetation community conforms to BGHF as listed under the TSC Act. BGHF was recorded in a range of condition states at the subject land, ranging from areas comprising moderate floristic and structural diversity and high levels of disturbance, to areas with canopy species only with a highly modified understorey.

On the subject land, BGHF is dominated by Sydney Blue Gum (*Eucalyptus saligna*), Blackbutt (*Eucalyptus pilularis*) and Red Mahogany (*Eucalyptus resinifera)* up to 30 m in height with foliage projected cover in the order of 57% which gives the vegetation its' characteristic open forest structure. Other trees growing in occasional association with

this vegetation community included the Smooth-barked Apple (Angophora costata). This vegetation community is present in a number of condition states across the subject land ranging from isolated remnant trees to old growth stands with a modified understorey.

The mid-storey was sparse in structure with foliage projected cover of 12.5% and dominated by regenerating eucalypts and Sweet Pittosporum (*Pittosporum undulatum*). The shrub layer (<1m) was generally absent due to a history of disturbance, with a foliage projected cover of approximately 2%. The shrub layer consisted of isolated individuals of Elderberry Panax and Bleeding Heart (*Omalanthus populifolius*).

A low diversity of native groundcover species was recorded overall across this vegetation community. Native herbs, forbs and sedges accounted for 2% of the groundcover cover within this community, with native grasses accounting for less than 1% cover on average. Native groundcovers recorded included Cockspur Flower (*Plectranthus parviflorus*), Kidney-weed, Narrow-leaved Basket Grass, Native Geranium, *Vernonia cinerea* and Whiteroot.

Exotic species accounted for 16% of the foliage projected cover on average. Exotic species recorded included Arum Lily (*Zantedeschia aethiopica*), Asparagus Fern, Black Thistle (*Cirsium vulgare*), Broad-leaved Privet, English Ivy (*Hedera helix*), Madeira Vine (*Anredera cordifolia*), Moth Vine (*Araujia sericifera*), Nasturtium (*Tropaeolum majus*), Paspalum (*Paspalum dilatatum*), Senna and Wandering Jew.

Photograph 2.2 Blue Gum High Forest – modified understorey (SKM 2009)

iii. Sydney Sandstone Gully Forest – Forest Woodland Form

The forest/woodland form of SSGF in the subject land is dominated by Sydney Peppermint (*Eucalyptus piperita*), Red Bloodwood (*Corymbia gummifera*) and Smooth-barked Apple (*Angophora costata*) up to 20 m in height with foliage projected cover in the order of 33%. Other trees growing in occasional association with this vegetation community included Blackbutt (*Eucalyptus pilularis*) and Turpentine (*Syncarpia glomulifera*). This vegetation community is generally in excellent condition at the subject land, with high floristic diversity and low levels of weed invasion. This form of SSGF occurs on gentle sloping sandstone soils above steep sided gullies in the north-western corner of the subject land (Figure 2.1).

The mid-storey was moderately dense with foliage projected cover of 17% and was dominated by species such as Blueberry Ash (*Elaeocarpus reticulatus*), Broad-leaved Geebung (*Persoonia levis*), Flax-leaved Wattle (*Acacia linifolia*), Guinea-flower (*Hibbertia bracteata*), Linear-leaf Grevillea (*Grevillea linearifolia*), Needlebush (*Hakea sericea*), Paperbark Tea-tree (*Leptospermum trinervium*) and Pineleaf Geebung (*Persoonia pinifolia*).

The shrub layer (<1m) was dense and practically impenetrable in places due to recent fire regrowth and had a foliage projected cover of approximately 17%. The shrub layer consisted of numerous individuals of Forest Grass-tree (*Xanthorrhoea arborea*), Hairpin Banksia (*Banksia spinulosa* var. *spinulosa*), Handsome Flat-pea, Hopbush (*Dodonaea triquetra*), Native Parsley (*Lomatia silaifolia*), Pilose-leafed Zieria (*Zieria pilosa*), Rice Flower (*Pimelea linifolia*), Rusty-petals, Sandfly Zieria and *Styphelia longifolia*.

A high diversity of native groundcover species were recorded overall across this vegetation community. Native herbs, forbs and sedges accounted for 29% of the groundcover cover within this community, with native grasses accounting for 7% cover on average. Native groundcovers frequently recorded included Blue Flax-lily, Bracken (*Pteridium esculentum*), *Cyathochaeta diandra,* Devil's Twine (*Cassytha pubescens*), *Lomandra confertifolia*, *Lomandra obliqua*, Native Parsley (*Lomatia silaifolia*), Raspwort (*Gonocarpus teucrioides*), Rock Xanthosia (*Xanthosia tridentata*), *Schoenus* sp., Sweet Sarsaparilla, Tartan Tongue Orchid (*Cryptostylis erecta*), Thyme Spurge (*Phyllanthus hirtellus*) and Wiry Panic.

Exotic species were generally absent from this community, accounting for less than 1% of the foliage projected cover on average. Exotic species recorded included Tall Fleabane (*Conyza sumatrensis*) and Passionfruit (*Passiflora edulis*).

This vegetation community conforms to Western Sandstone Gully Forest (NSW NPWS, 2002) and also to SSGF as originally described by (Benson and Howell, 1994). SSGF was recorded in high to very high condition at the subject land (Figure 2.2).

Photograph 2.3 **Sydney Sandstone Gully Forest – woodland forest form (SKM 2009)**

iv. Sydney Sandstone Gully Forest – Tall Open Forest Form

The tall open forest form of SSGF is dominated by Blackbutt (*Eucalyptus pilularis*) and Turpentine (*Syncarpia glomulifera*) up to 30 m in height with foliage projected cover in the order of 38%. Other trees growing in occasional association with this vegetation community included the Smooth-barked Apple (*Angophora constata*). This form of SSGF occurs on steep sided sandstone gullies and valley floors and is likely to be have been enriched through downwards movement of shale soils. SSGF transitions into STIF in close proximity to the shale/sandstone boundary.

The mid-storey was moderately dense with foliage projected cover of 25% and was dominated by Turpentine, with other commonly recorded species such as Blueberry Ash, Coffee Bush, Forest She-oak, Illawarra Flame-tree (*Brachychiton acerifolius*), Mock-olive and Sweet Pittosporum.

The shrub layer (<1m) was generally sparse with a foliage projected cover of 4%. The shrub layer consisted of scattered individuals of Elderberry Panax, Hopbush, Long-flowered Beard-heath, Muttonwood (*Myrsine variabilis*), Native Parsley and Sandfly Zieria.

Photograph 2.4 **Sydney Sandstone Gully Forest – tall open forest form (SKM 2009)**

A high diversity of native groundcover species was recorded overall across this vegetation community. Native herbs, forbs and sedges accounted for 25% of the groundcover cover within this community, with native grasses accounting for 7% cover on average. Native groundcovers frequently recorded included Blue Flax-lily, Gnat Orchid (*Acianthus fornicatus*), Guinea-flower (*Hibbertia dentata*), *Lomandra confertifolia,* Meadow Rice-grass, Morinda (*Morinda jasminoides*), Narrow-leaved Basket Grass, Nodding Greenhood (*Pterostylis nutans*), Poa Tussock, Rainbow Fern (*Calochlaena dubia*), Spiny-headed Mat-rush, Sweet Sarsaparilla, Twining Glycine, Variable Sword-sedge (*Lepidosperma laterale*), Whiteroot, Wiry Panic, Wombat Berry and Wonga Vine (*Pandorea pandorana*).

Exotic species accounted for 8% of the foliage projected cover on average. Commonly recorded exotic species included Camphor-laurel (*Cinnamomum camphora*), Lantana, Mickey Mouse Plant, Small-Leaved Privet and Yellow Ginger (*Hedychium gardnerianum*). As this form of SSGF adjoins developed areas at the subject land and large sections occur along Coups Creek, the forest edges and riparian zones are the most disturbed and weed dominated.

This vegetation community conforms to SSGF as originally described by (Benson and Howell, 1994). SSGF was recorded in a moderate to high condition on the subject land (Figure 2.1).

2.4.2 Threatened Flora

No threatened flora species were detected during previous flora surveys conducted by UBMC (2005), SKM (2009) or Cumberland Ecology (2009). However NSW NPWS Wildlife Atlas database searches indicated that several threatened species occur in the locality and have the potential to occur on the subject land.

Table 2.2 analyses the likelihood of occurrence on the subject land for each threatened flora species recorded within the 10km radius during flora surveys conducted by Cumberland Ecology (2009).

Table 2.2 HABITAT REQUIREMENTS FOR THREATENED FLORA SPECIES KNOWN TO OCCUR WITHIN THE LOCALITY

Species	Legal Status	Habitat Requirements	Presence of Suitable Habitat in the Subject Land and Likelihood of Occurrence
Acacia bynoeana	E1 (TSC Act); V (EPBC Act)	Occurs in heath or dry sclerophyll forest on sandy soils. Prefers open, sometimes slightly disturbed sites such as trail margins, etc.	No suitable habitat is present. Not observed during floristic survey.
Acacia gordonii	E1 (TSC and EPBC Acts)	Dry sclerophyll forest and heathlands amongst or within rock platforms on sandstone outcrops	No suitable habitat is present. Not observed during floristic survey.
Acacia pubescens	V (TSC and EPBC Acts)	Alluviums, shales and at the intergrade between shales of the Cumberland Plain and sandstones. The soils are characteristically gravely soils, often with ironstone.	No suitable habitat is present. Not observed during floristic survey.
Callistemon linearifolius	V (TSC Act)	Dry sclerophyll forest on the coast and adjacent ranges	Suitable habitat is present. Not observed during floristic survey.
Darwinia biflora	V (TSC and EPBC Acts)	Edges of weathered shale-capped ridges, where these intergrade with Hawkesbury Sandstone	Suitable habitat is present. Not observed during floristic survey.
Darwinia peduncularis	V (TSC Act)	On or near rocky outcrops on sandy, well drained, low nutrient soil over sandstone	Suitable habitat is present. Not observed during floristic survey.
Epacris purpurascens var. purpurascens	V (TSC Act)	A range of habitat types, most of which have a strong shale soil influence	Suitable habitat is present. Not observed during floristic survey.
Eucalyptus camfieldii	V (TSC and EPBC Acts)	Poor coastal country in shallow sandy soils overlying Hawkesbury sandstone. Coastal heath	Suitable habitat is present. Not observed during floristic survey.

Table 2.2 HABITAT REQUIREMENTS FOR THREATENED FLORA SPECIES KNOWN TO OCCUR WITHIN THE LOCALITY

Species	Legal Status	Habitat Requirements	Presence of Suitable Habitat in the Subject Land and Likelihood of Occurrence
		mostly on exposed sandy ridges	
Grevillea caleyi	E1 (TSC and EPBC Acts)	Ridge tops between elevations of 170 to 240m asl, in association with laterite soils and a vegetation community of open forest, generally dominated by *Eucalyptus sieberi* and *Corymbia gummifera*	No suitable habitat is present. Not observed during floristic survey.
Haloragodendron lucasii	E1 (TSC and EPBC Acts)	Moist sandy loam soils in sheltered aspects, and on gentle slopes below cliff-lines near creeks in low open woodland	Suitable habitat is present. Not observed during floristic survey.
Hibbertia superans	E1 (TSC Act)	Sandstone ridge tops often near the shale/sandstone boundary.	No suitable habitat is present. Not observed during floristic survey.
Lasiopetalum joyceae	V (TSC and EPBC Acts)	In heath above sandstone.	No suitable habitat is present. Not observed during floristic survey.
Leptospermum deanei	V (TSC and EPBC Acts)	In woodland on lower hill slopes or near creeks. Sandy alluvial soil or sand over sandstone	Suitable habitat is present. Not observed during floristic survey.
Melaleuca deanei	V (TSC and EPBC Acts)	In heath on sandstone	No suitable habitat is present. Not observed during floristic survey.
Persoonia hirsuta	E1 (TSC and EPBC Acts)	Sandy soils in dry sclerophyll open forest, woodland and heath on sandstone	No suitable habitat is present. Not observed during floristic survey.
Persoonia mollis ssp. *maxima*	E1 (TSC and EPBC Acts)	Sheltered aspects of deep gullies or on the steep upper hillsides of narrow gullies on Hawkesbury Sandstone	Not likely to be present as outside the highly restricted range of this species. Not observed during floristic survey.
Pimelea curviflora	V (TSC and	Shaley/lateritic soils over sandstone and	Suitable habitat is present. Not observed during floristic

Table 2.2 HABITAT REQUIREMENTS FOR THREATENED FLORA SPECIES KNOWN TO OCCUR WITHIN THE LOCALITY

Species	Legal Status	Habitat Requirements	Presence of Suitable Habitat in the Subject Land and Likelihood of Occurrence
var. *curviflora*	EPBC Acts)	shale/sandstone transition soils on ridge tops and upper slopes amongst woodlands	survey.
Syzygium paniculatum	V (TSC and EPBC Acts)	Grey soils over sandstone or gravels, sands, silts and clays in riverside gallery rainforests and remnant littoral rainforest communities	Sub-optimal habitat is present. Not observed during floristic survey.
Tetratheca glandulosa	V (TSC and EPBC Acts)	Shale-sandstone transition habitat on ridge tops and upper-slope sandstone benches.	Suitable habitat is present. Not observed during floristic survey.

Source: Cumberland Ecology (2009)

Coordinate System: MGA Zone 56 (GDA 94)

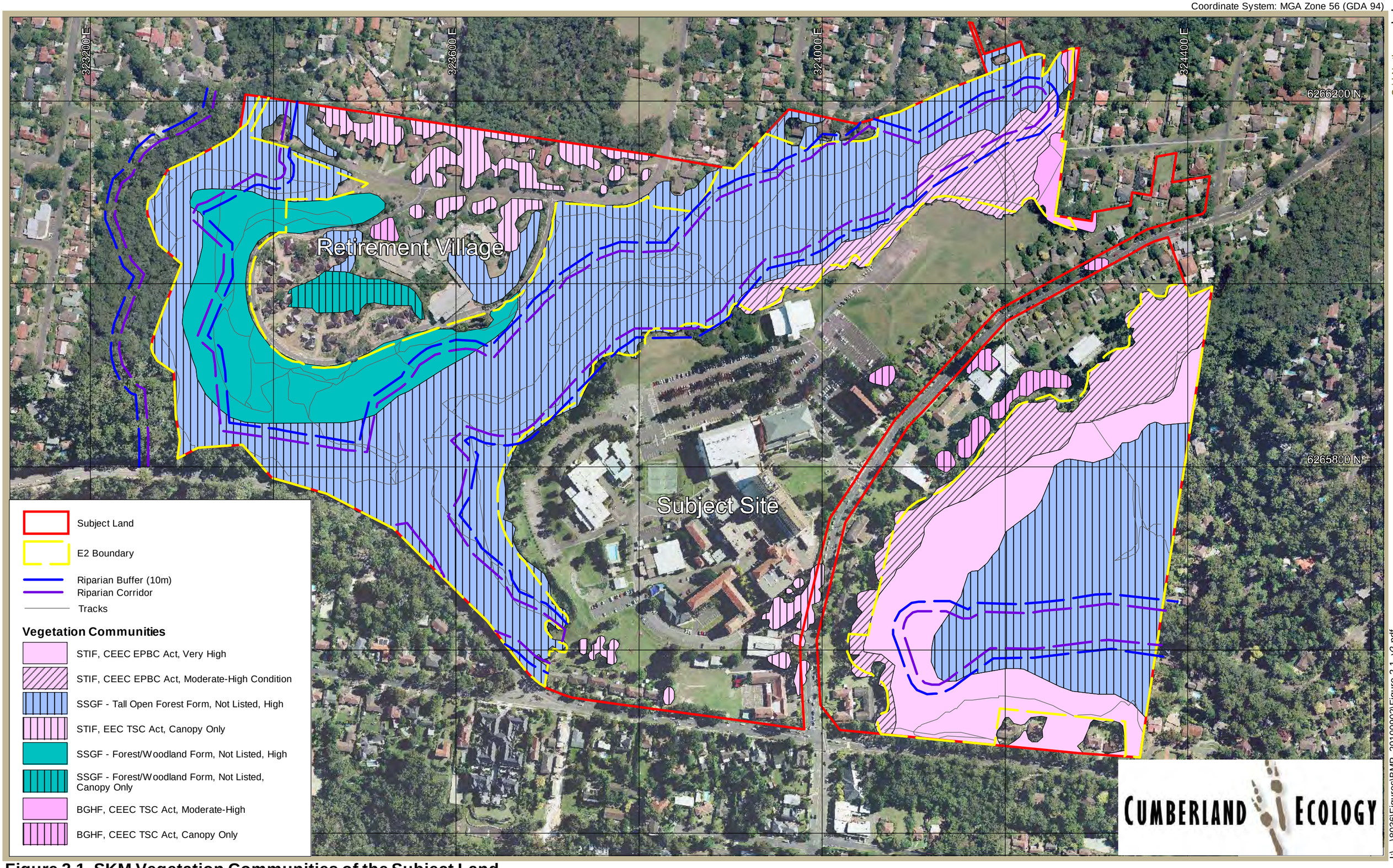


Figure 2.1. SKM Vegetation Communities of the Subject Land

100 0 100 200 300 400 m

Chapter 3

Weed Management Plan

3.1 Introduction

This Weed Management Plan (WMP) has been prepared to guide the management of weeds within the E2 Environmental Conservation zone on the subject land. The purpose of this WMP is to assist contractors in the implementation of appropriate weed management measures and to prevent the introduction and spread of pest and weed species.

3.1.1 Objectives

The objectives of the WMP include:

- To protect, conserve and rehabilitate vegetation occurring within the E2 zone and to promote local biodiversity values, particularly in areas of BGHF and STIF;
- To ensure that redevelopment of the Wahroonga Estate does not exacerbate any Key Threatening Process;
- To provide a weed control strategy;
- To identify weed control methods and techniques; and
- To maintain and improve connectivity locally and within the subject lands, principally through weed removal.

3.2 Policy Context

Weed legislation provides guidelines aiding the development of weed management plans. Conservation legislation is also relevant to weed control programs because the management of weeds can affect, and is often an integral part of the conservation of threatened species and communities.

3.2.1 Noxious Weeds Act 1993

The *Noxious Weeds Act 1993* provides for the identification, classification and control of noxious weeds in New South Wales. Changes to the Act came into force in March 2006 via the *Noxious Weeds Amendment Act 2005*. Plants that are declared noxious weeds by the Minister are placed into the following weed control categories:

- Class 1 – State prohibited weeds
  - These are plants that pose a potentially serious threat to primary production or the environment and are not present in the State or are present only to a limited extent.
- Class 2 – Regionally prohibited weeds
  - These are plants that pose a potentially serious threat to primary production or the environment of a region to which the order applies and are not present in the region or are present only to a limited extent.
- Class 3 – Regionally controlled weeds
  - These are plants that pose a serious threat to primary production or the environment of an area to which the order applies, are not widely distributed in the area and are likely to spread in the area or to another area.
- Class 4 – Locally controlled weeds
  - These are plants that pose a threat to primary production, the environment or human health, are widely distributed in an area to which the order applies and are likely to spread in the area or to another area.
- Class 5 – Restricted plants
  - These are plants that are likely, by their sale or the sale of their seeds or movement within the State or an area of the State, to spread in the State or outside the State.

A noxious weed that is classified as a Class 1, 2 or 5 noxious weed is referred to in the Noxious Weed Act as a notifiable weed.

3.2.2 EPBC Act

The EPBC Act lists Key Threatening Processes, some of which relate to the impacts of weeds. A Key Threatening Process is a process that may threaten the survival, abundance or evolutionary development of a native species or ecological community. The following Key Threatening Process is relevant to the subject land:

- Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants.

3.2.3 TSC Act

The TSC Act also lists Key Threatening Processes that relate to weeds in NSW. Key Threatening Processes (KTP) under the TSC Act are processes that harm threatened species or could cause other species to become threatened. The following are a list of KTP under the TSC Act which may occur on subject land:

- Invasion and establishment of exotic vines and scramblers;
- Invasion of native plant communities by exotic perennial grasses; and
- Invasion, establishment and spread of *Lantana camara*.

3.3 Methodology

3.3.1 Literature Review

A number of previous reports have been prepared for the subject land. The following literature has been reviewed during preparation of this WMP, including:

- Director General's Environmental Assessment Report (NSW Department of Planning, 2010);
- Vegetation Management Plan for Bushland in the Private Recreation Reserve, Coups Creek (Urban Bushland Management Consultants, 2005);
- Bushfire Protection Report (Conacher Travers, 2004);
- Bushfire Protection Assessment (Australian Bushfire Protection Planners Pty Limited, 2008);
- Ecological Assessment Report (Sinclair Knight Merz, 2009); and
- Flora and Fauna Assessment (Cumberland Ecology, 2009).

3.3.2 Field Investigations

i. Current Survey

Cumberland Ecology Ecologists Nathan Campbell and Ryan Sims carried out a site inspection on 3rd June 2010. The investigation aimed to ground truth previous weed

mapping produced by Urban Bushland Management Consultants (2005) and a weed map produced during the preparation of Flora and Fauna Impact Assessment by Cumberland Ecology (2009).

ii. Previous Surveys

The condition of the vegetation on the subject lands was assessed by botanist David Thomas on 25th, 27th & 28th January 2009 following an initial site inspection and familiarisation. The condition of bushland remnants were mapped using targeted meander observations as well as the completion of 31 quadrats (5 m x 5 m) using survey pro-formas.

3.3.3 Weed Mapping

Previous weed mapping of the subject land has been conducted by UBMC (2005) and Cumberland Ecology (2009). Cumberland Ecology (2009) produced a weed map of the entire E2 Environmental Conservation zone using similar methods to UBMC (2005) which recorded the abundance of target weeds in each stratum. These methods are explained below.

i. Cumberland Ecology (2009)

The weeds on the subject land (see Figure 3.1) were mapped according to the weed infestation method described by Ku-ring-gai Council (Ku-ring-gai Municipal Council, 1995).

Weed Classes were defined to provide a logical basis for the sequence of weed management using the following criteria:

- The type and density of weed infestation occurring;
- The potential for native plant regeneration from the soil seed bank (i.e. site resilience); and
- Weed codes - an estimate of the relative weed density within each stratum.

Vegetation quality definitions were modified from the Ku-ring-gai Council Guidelines (Ku-ring-gai Municipal Council, 1995). Vegetation quality was based on the stratum layer with the highest percentage cover of exotic weeds, where:

- Good quality vegetation was considered to be equivalent to vegetation falling into Weed Class 1. Where the stratum layer with the highest percentage cover of exotic weeds is less than 10%;
- Moderate quality vegetation was considered to be equivalent to vegetation falling into Weed Class 2 or 3. Where the stratum layer with the highest percentage cover of exotic weeds is between 11 and 60%;and

- Poor quality vegetation was considered to be equivalent to vegetation falling into Weed Class 4. Where the stratum layer with the highest percentage cover of exotic weeds is greater than 61%.

ii. Current Weed Mapping

The previous mapping undertaken by Cumberland Ecology in 2009 was used as the basis for the current Weed Class map of the subject land (see Figure 3.1).

The subject land was separated into polygons consisting of the four weed classes used in 2009, however two polygons have been changed to better represent their current condition (see Figure 3.1).

This figure is indicative only, and the exact polygon boundaries may vary. On ground, Bush Regenerators will need to use vegetation condition as a guide to delineate weed polygons.

Coordinate System: MGA Zone 56 (GDA 94)

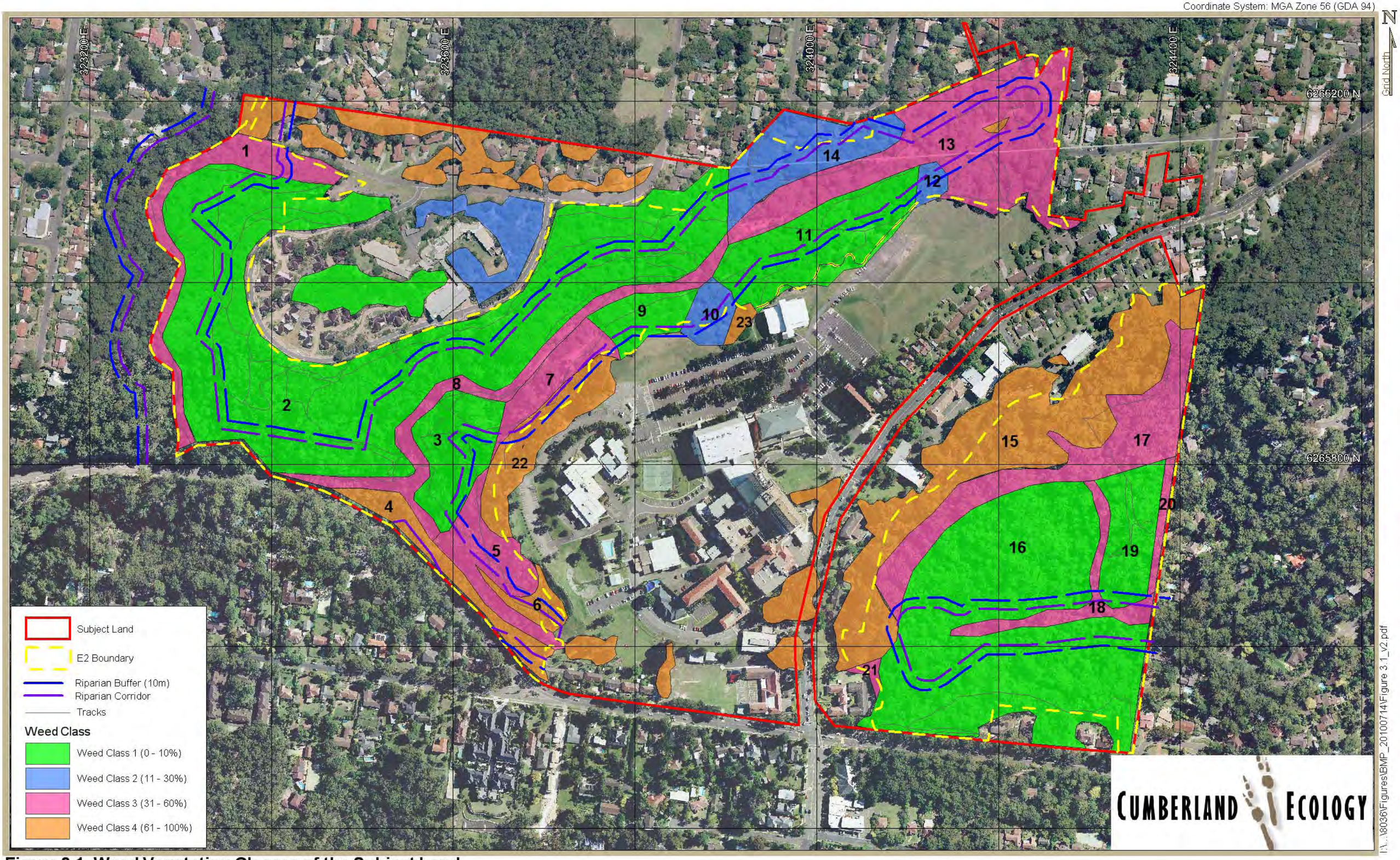


Figure 3.1. Weed Vegetation Classes of the Subject Land

3.4 Weed Ecology

Generally, weeds are exotic plants that grow at the expense of a native plant and that produce large numbers of seeds or other propagules and so can reproduce and spread quickly. They typically benefit from disturbance to soils or native vegetation. Grazing, soil erosion, floods, fires, urban run-off, increased nutrients, sedimentation or mechanical soil disturbance can trigger major outbreaks of weeds. Weeds can:

- compete with native plants;
- reduce germination of native plants;
- suppress native tree and seedling growth;
- alter fire regimes;
- modify nutrient cycling within an ecosystem;
- change soil conditions;
- affect food and habitat opportunities for native fauna;
- provide harbour for feral animals; and
- reduce recreation potential of bushland.

Weed outbreaks are often from seeds that have lain dormant in the soil until disturbance, providing the conditions necessary for germination.

Weeds can spread and establish by the following pathways:

- seeds and other propagules travelling on vehicles, people and animals from one place to another;
- invading open areas that have been disturbed by over grazing, earthworks and other activities that disturb the soil;
- establishing in areas with reduced tree cover (poorly competitive weeds); and
- dispersing from infested areas to weed free areas via wind or water.

3.5 Weed Control Methods

3.5.1 Primary Weeding

Some exotic species pose serious threats to native vegetation communities. These introduced species typically invade, out compete and eventually modify ecosystems so that native plants species cannot survive. Priority must be given to the removal of such weeds during weed control programs. Primary weeding aims at removing keystone weeds including noxious weeds and reducing weed cover to < 30%. Table 3.2 lists keystone weed species identified on the subject land which are to be removed during primary weeding. It is expected that this is not a comprehensive list, and that additional weed species may be present. Best practice should be employed to control weed species that are not listed in Table 3.2.

3.5.2 Secondary Weeding

Unlike keystone weeds, some introduced plants do not pose serious threats to native vegetation communities. These weed species are typically less aggressive and easier to manage. Species include short lived annuals, some herbaceous perennials, and even hardy pioneer species. Generally, these species can be managed by re-establishing a canopy cover which suppresses their growth through providing dense shade. Secondary weeding efforts occur after primary weeding objectives are achieved. Secondary weeding efforts will aim to further reduce weed cover to < 5%. Table 3.2 below summarises secondary weed species recorded within the subject land. It is expected that this is not a comprehensive list, and that additional weed species may be present. Best practice should be employed to control weed species that are not listed in Table 3.2.

Table 3.2 presents a list of the weed species recorded from the subject land and categorises these species into keystone and secondary weeds.

Table 3.1 LIST OF TARGET WEEDS RECORDED ON THE SUBJECT LAND

Botanical Name [1]	Common Name	Status [2]	Keystone or Secondary
Woody Weeds			
Acer negundo	Box Elder	Environmental Weed	Keystone
Ailanthus altissima	Tree of Heaven	Environmental Weed	Keystone
Brachychiton acerifolius	Flame Tree	Environmental Weed	Secondary
Cinnamomum camphora	Camphor Laurel	Noxious Weed Class 4	Keystone
Cotoneaster sp.	Cotoneaster	Environmental Weed	Keystone
Erythrina x sykesii	Coral Tree	Environmental Weed	Keystone
Jacaranda mimosifolia	Jacaranda	Environmental Weed	Secondary
Lantana camara	Lantana	Noxious Weed Class 4	Keystone
Ligustrum lucidum	Large leaved Privet	Noxious Weed Class 4	Keystone
Ligustrum sinense	Small leaved Privet	Noxious Weed Class 4	Keystone
Lycium ferocissimum	African Boxthorn	Environmental Weed	Keystone
Morus alba	Mulberry	Environmental Weed	Keystone
Ochna serrulata	Ochna	Noxious Weed Class 4	Keystone
Olea europaea	African Olive	Environmental Weed	Keystone
Phoenix canariensis	Phoenix Palm	Environmental Weed	Keystone
Pinus radiata	Monterey Pine	Environmental Weed	Keystone
Rhaphiolepis indica	Indian Hawthorn	Environmental Weed	Keystone
Rubus fruticosus	Blackberry	Noxious Weed Class 4	Keystone
Salix babylonica	Weeping Willow	Environmental Weed	Secondary
Sida rhombifolia	Paddy's Lucerne	Environmental Weed	Secondary
Senna pendula var. glabrata	Cassia / Arsenic Bush	Environmental Weed	Keystone
Solanum mauritianum	Wild Tobacco	Environmental Weed	Secondary
Herbaceous Weeds			
Ageratina adenophora	Crofton Weed	Environmental Weed	Keystone
Ageratina riparia	Mist Flower	Environmental Weed	Keystone
Avena fatua	Wild Oats	Environmental Weed	Secondary
Asparagus aethiopicus	Ground Asparagus (fern)	Noxious Weed Class 4	Keystone
Asparagus plumosus	Climbing Asparagus	Noxious Weed Class 4	Keystone
Briza spp.	Quaking/Shivery Grass	Environmental Weed	Secondary
Chloris gayana	Rhodes Grass	Environmental Weed	Secondary
Cirsium vulgare	Spear Thistle	Environmental Weed	Secondary
Cortaderia selloana	Pampas Grass	Noxious Weed Class 3	Keystone

Table 3.1 LIST OF TARGET WEEDS RECORDED ON THE SUBJECT LAND

Botanical Name [1]	Common Name	Status [2]	Keystone or Secondary
Crocosmia x crocosmiiflora	Montbretia	Environmental Weed	Keystone
Cyperus eragrostis	Umbrella Sedge	Environmental Weed	Secondary
Ehrharta erecta	Panic Veldt Grass	Environmental Weed	Keystone
Eragrostis curvula	African Love Grass	Environmental Weed	Secondary
Erigeron karvinskianus	Mexican Daisy	Environmental Weed	Secondary
Hedera helix	English Ivy	Environmental Weed	Keystone
Hedychium gardnerianum	Ginger Lily	Environmental Weed	Secondary
Impatiens spp.	Busy Lizzie / Impatiens	Environmental Weed	Secondary
Paspalum dilatatum	Paspalum	Environmental Weed	Secondary
Pennisetum clandestinum	Kikuyu Grass	Environmental Weed	Keystone
Phytolacca octandra	Inkweed	Environmental Weed	Secondary
Senecio madagascariensis	Fireweed	Environmental Weed	Secondary
Solanum nigrum	Black Nightshade	Environmental Weed	Secondary
Verbena spp.	Purpletop / Verbena	Environmental Weed	Secondary
Vines & Scramblers			
Araujia sericifera	White Moth Plant	Environmental Weed	Keystone
Cardiospermum grandiflorum	Balloon Vine	Noxious Weed Class 4	Keystone
Delairea odorata	Cape Ivy	Noxious Weed Class 4	Keystone
Ipomoea indica	Morning Glory	Noxious Weed Class 4	Keystone
Lonicera japonica	Japanese Honeysuckle	Environmental Weed	Keystone
Jasminum polyanthum	Jasmine	Environmental Weed	Keystone
Thunbergia alata	Black-eyed Susan	Environmental Weed	Keystone
Tradescantia fluminensis	Wandering Jew	Noxious Weed Class 4	Keystone
Wisteria sinensis	Wisteria	Environmental Weed	Secondary

1. This list is combined from previous surveys conducted by Cumberland Ecology (2009) and UBMC (2005)

2. Ku-ring-gai Council Control Area

3.6 Specific Weed Control Methods

3.6.1 Hand Weeding

Hand weeding involves pulling weeds by hand instead of using herbicide spray. This approach is preferred in areas where significant native plants exist as using herbicide may result in inadvertent poisoning of native species. Hand weeding is beneficial where a low impact on existing vegetation is priority. This approach is most suitable for shallow rooted annuals, perennials and juvenile plants that can be removed by hand with minimal soil disturbance. In many cases this is the preferred methods of weed removal in sensitive areas.

3.6.2 Dig Out

Digging out a weed uses similar approaches to hand pulling. This method involves removing the entire plant including the roots and underground bulbs. Some species like *Asparagus* have spreading roots systems with underground water bubbles which have regeneration potential. If off-site disposal is not practicable hanging the plant in a tree will ensure the plant properly dries out.

3.6.3 Rake and Pile

Many succulent species are typically shallow rooted and can be easily removed using a rake to pull them out and pile them in a heap. These species can still survive or re-root once they have been removed and left on the ground. Rake and pile removes the species and concentrates them in area pile where they can be managed to prevent regeneration by turning the piles regularly. Alternatively the piles may be removed off site.

3.6.4 Herbicide Spray

Herbicide spray is applied to and absorbed through the leaves. Foliar application is best practiced in areas where exotic grasses and ground covers are dominant. Unlike hand weeding situations which involve minimal impacts to surrounding vegetation, foliar spraying is typically broader scale. Unwanted over spray often kills neighbouring native plants and reduces regeneration potential. When controlling exotic groundcovers adjacent natives it may be beneficial to hand weed or pull back the weed to create an area of bare ground between the two. This will reduce accidental overspray and damage to natives and encourage them to colonise into the bare ground.

3.6.5 Cut and Paste

This method involves cutting the stem or trunk of the weed just above ground level and immediately applying non-residual herbicide to the remaining stem or trunk. Herbicide dilution is typically 50/50 (50% water; 50% herbicide). This is an effective herbicide application method for woody weeds. It is also practical in sensitive areas as only individual stems are treated. Cut and paste methods retain root structure which can be beneficial for soil stabilisation.

3.6.6 Scrape and Paste

The scrape and paste method involves scraping the trunk or stem of a weed and applying 50/50 herbicide to the fresh wound. This method is most effective to remove exotic vines not easily eradicated using cut and paste or hand removal, as it allows for greater surface areas to be treated. It increases the amount of herbicide application which may be needed to kill aerial or ground tubers. Caution must be taken when using this method not to scrape too deep around the entire circumference of the stem otherwise a 'ring-barking' effect may result, and the weed may regrow beneath the ring-bark.

3.6.7 Stem Injection

Stem injection is a method of removing large weedy trees by drilling holes at 2 cm increments around the trunk of the tree, and filling the holes immediately with 50/50 herbicide. Caution must be taken when using this method as dead tree material becomes brittle and could become a potential public/site safety risk.

With large trees, using a chainsaw to create a series of shallow diagonal connected cuts can also provide a pool to hold herbicide.

3.6.8 Mechanical Removal

Machinery cannot be warranted in sensitive areas; particularly saturated soils and areas naturally regenerating. Generally, this technique of removal is effective for thick stands or thickets of Lantana etc. where monocultures of weeds portray little natural regeneration. It is common for the area to be replanted. Thickets can be controlled using small Posi-track with a mulching head. It is important to follow up freshly mulched/cut stems with herbicide application of 50/50 dilution. Prior to any broad scale mechanical removal the area must be surveyed and assessed on natural regeneration and level of soil saturation.

3.6.9 Burning

Burning is a useful way to destroy weed material and stimulate native seed germination from residual seed banks. Burning at the right time of year (prior to seed fall) can also be used to control weeds.

It is anticipated that the burning schedule prescribed in Chapter 5 may coincide with weed control efforts within the E2 zone. This is of great benefit to bush regeneration as prescribed burns can be used as a tool for controlling weeds. Burnt areas will require monitoring to assess weed regeneration with corrective action to follow; particularly along bushland edges and in weed classes 3 and 4.

Table 3.3 summarises the appropriate weed control techniques for weed species recorded on the subject land.

Table 3.2 APPROPRIATE WEED CONTROL TECHNIQUES FOR WEED SPECIES ON THE SUBJECT LAND

Weed Species	Category	Hand pull	Rake and pile	Dig out	Cut and paste	Stem injection	Scrape and paste	Spot spray	Mechanical	Comments
WOODY WEEDS										
African Olive (seedling <1m)	Primary	x						x		
(Mature >1m)				x	x	x				
Blackberry (seedling)	Primary			x	x		x			
(Mature)								x	x	Mechanically remove thickets
Cassia / Senna (seedling)	Primary	x			x			x	x	Fruit in winter
(Mature >1m)				x	x	x				
Camphor laurel (seedling)	Primary	x		x	x			x		
(Saplings > 5cm diam. & Mature)					x	x	x	x		May sucker after poisoning. Repeat treatment
Cotoneaster / Pyracantha (Seedlings < 1m)	Primary	x			x			x		Do not stem inject when berries are ripe
(Mature > 1m)				x	x	x	x			

Table 3.2 APPROPRIATE WEED CONTROL TECHNIQUES FOR WEED SPECIES ON THE SUBJECT LAND

Weed Species	Category	Hand pull	Rake and pile	Dig out	Cut and paste	Stem injection	Scrape and paste	Spot spray	Mechanical	Comments
Flame Tree	Secondary	x			x	x				
Indian Coral Tree (Saplings < 1m)	Secondary	x		x	x		x			
(Mature > 1m)					x	x				Material can regenerate if left on ground
Lantana (seedlings)	Primary	x		x	x		x			Woody weed herbicide
(Mature > 1m or 5cm stem diam.)				x	x			x	x	Mechanically remove thickets
Mulberry Tree (Saplings <1m)	Secondary	x			x					
Mature >1m					x	x				Do not stem inject when berries are ripe
Ochna (Seedlings)	Primary			x			x			Deep tap root
(Mature > 5cm or 0.5 m high)					x	x	x			
Sida / Paddys lucerne	Secondary			x	x			x		
Radiata Pine (Seedlings / Saplings < 1 m)	Primary			x	x					

Table 3.2 APPROPRIATE WEED CONTROL TECHNIQUES FOR WEED SPECIES ON THE SUBJECT LAND

Weed Species	Category	Hand pull	Rake and pile	Dig out	Cut and paste	Stem injection	Scrape and paste	Spot spray	Mechanical	Comments
Mature > 1 m					x	x				Trees do not regenerate once cut down
Willow Tree (< 2 m)	Primary				x			x		Material can regenerate if left on ground
(Mature > 2m)					x	x				
Wild Tobacco Tree	Secondary				x			x		
Herbaceous Weeds										
Blackberry Nightshade	Secondary	x						x		
Bulbs (e.g. Freesia, Montbretia)	Primary			x	x			x		Treat after flowering
Coreopsis				x				x		Rhizomatous
Crofton Weed / Mist Flower	Primary	x		x				x		
Fishbone Fern	Primary			x				x		Dispose of spore bearing fronds. Water bubbles may be left in soil
Ginger Lily	Primary			x	x	x				Remove all rhizome

Table 3.2 APPROPRIATE WEED CONTROL TECHNIQUES FOR WEED SPECIES ON THE SUBJECT LAND

Weed Species	Category	Hand pull	Rake and pile	Dig out	Cut and paste	Stem injection	Scrape and paste	Spot spray	Mechanical	Comments
Grasses (rhizomatous) e.g. Kikuyu, Buffalo, Couch, Carpet, Rhodes	Primary/ Secondary			x				x		Fragments will regenerate if left in soil
Grasses (tussock) e.g. Pigeon, Parramatta, Ehrharta, African Love Grass	Primary/Secondary			x				x		
Impatiens / Dizzy Lizzie	Secondary	x						x		Material can regenerate if left on ground and in wet shady areas
Inkweed	Secondary			x				x		
Monstera / Elephant's Ears	Secondary			x	x					
Pampas Grass (seedlings)	Primary	x		x				x		
(Mature tussocks)					x			x		Remove plumes to contain seed spread
Plantain	Secondary			x				x		
Sonchus / Sow Thistle	Secondary	x						x		

Table 3.2 APPROPRIATE WEED CONTROL TECHNIQUES FOR WEED SPECIES ON THE SUBJECT LAND

Weed Species	Category	Hand pull	Rake and pile	Dig out	Cut and paste	Stem injection	Scrape and paste	Spot spray	Mechanical	Comments
Spear Thistle	Secondary			x				x		
Verbena spp.	Secondary			x	x			x		
Vines and Scramblers										
Asparagus spp & Myrsiphyllum										Use Brushoff as folair spray. Collect fruit (ripe and green)
(Seedlings)	Primary	x		x				x		
(Mature Plants)				x				x		
Balloon Vine (seedling)	Primary	x						x		
(Mature vines)				x			x	x		Use Starane foliar spray
Madeira Vine										Scrap soil and dispose off site. Monitor closely. Use Starane as foliar spray
(Tuberling)	Primary	x		x				x		
(Mature Vines)				x			x	x		
Morning Glory Vine (seedling)	Primary	x						x		
(Mature Vines)				x			x	x		Use Starane foliar spray
Turkey Rhubarb (seedlings)	Primary			x				x		Use Starane foliar spray

Table 3.2 APPROPRIATE WEED CONTROL TECHNIQUES FOR WEED SPECIES ON THE SUBJECT LAND

Weed Species	Category	Hand pull	Rake and pile	Dig out	Cut and paste	Stem injection	Scrape and paste	Spot spray	Mechanical	Comments
(Mature Plants)				x			x	x		Collect seed
Wandering Jew	Primary	x	x					x		Use Starane or Glyphosate with surfactant
White Moth Plant	Primary	x						x		
Cape Ivy (seedling)	Primary			x						
(Mature Vines)				x			x	x		

This list is has been expanded from UBMC (2005)

3.7 Sequence of Works

Table 3.3 provides detail of the sequencing of weed control efforts for the E2 Environment Conservation zone. The proposed sequence of works is based on the principle of working from least weed infested areas to the most heavily weed infested areas. Relating this to the site; this means that weed classes 1 and 2 will be controlled prior to weed classes 3 and 4.

Initial weeding will occur to weed classes 1 and 2. This will aim at improving the condition of these classes with minor effort. These areas with low weed abundance are anticipated to have only scattered occurrences of weeds. By removing weeds in these areas first, forest integrity can be maintained.

Once initial weeding objectives have been achieved, primary weeding will occur throughout the entire E2 zone in weed classes 3 and 4 to remove noxious and keystone weeds and to reduce the weed cover to < 30%.

Once all keystone and noxious weeds have been managed and weed cover has been reduced to < 30%, secondary weeding can occur. Secondary weeding will aim at reducing weed cover to < 5% by controlling less invasive weed species and regenerating keystone and noxious weeds.

Table 3.3 SEQUENCE OF WORKS – WEED CONTROL

Objective	Action	Item	Detail	Comment
	1	**Monitoring**	Quadrats and Photo Monitoring Points	Establish locations Record species and take photos To occur every 6 months during primary and secondary weed control (Section 4.8)
Improve condition to < 10% weed cover.		**Initial Weeding**		**Consolidate Weed Classes 1 and 2.**
	1	Weed Polygons 2, 3, 9, 11, 16, and 19	Swath[1] entire weed class 1 areas target all weeds. Target weeds; Small and Large Leaved Privet, Lantana, Blackberry, Ochna, African Olive, Wandering Jew etc.	Minor effort to improve good quality bushland by removing potential weed outbreaks.
	2	Weed Polygons 10, 12 and 14	Swath entire weed class 2 areas target all weeds. Target weeds; Small and Large Leaved Privet, Lantana, Blackberry, Ochna, African Olive, Wandering Jew etc.	Minor efforts to improve existing condition of bushland by removing potential weed outbreaks
Improve condition to < 30% weed cover		**Primary Weeding**		**Improve Weed Class 3. Extend Weed Class 1 and 2 into Weed Class 3**
	3	Weed Polygon 7	Target weeds; Small and Large	Opportunity to consolidate surrounding good

Table 3.3 SEQUENCE OF WORKS – WEED CONTROL

Objective	Action	Item	Detail	Comment
			Leaved Privets, Lantana, Exotic Grasses, Blackberry, Wandering Jew, Cape Ivy, Cassia and Balloon Vine.	condition bushland (polygon 3 and 9)
	4	Weed Polygon 13	Target weeds; Small and Large Leaved Privets, Exotic Grasses, Morning Glory, Blackberry, Asparagus Fern, Lantana, African Olive, Balloon Vine, Moth Vine, Bamboo, Ochna, Wandering Jew	Start at head of catchment and work down stream. Extend good bush in Polygon 11, 12 and 14. Minimise soil disturbance. Cut and paint woody weeds along creek banks.
	5	Weed Polygon 1	Target weeds; Small Leaved Privet, Asparagus Fern, Crofton Weed, Mist Flower, Exotic Grasses, Ginger, Ochna, Wandering Jew and Japanese Honeysuckle.	Start at head of catchment and work down stream. Extend good bush in Polygon 2. Minimise soil disturbance. Cut and paint woody weeds along creek banks
	6	Weed Polygon 17	Target weeds; Exotic Grasses, Cassia, Ochna, Small Leaved Privet, Blackberry and Lantana	Extend good bush in Polygon 16 and 19.
	7	Weed Polygon 20	Target weeds; Garden escapees, Exotic Grasses, Lantana, Blackberry and Cassia	Area managed as APZ
	8	Weed Polygon 21	Target weeds; Lantana, Small	Extend Polygon 16 into Polygon 21.

Table 3.3 SEQUENCE OF WORKS – WEED CONTROL

Objective	Action	Item	Detail	Comment
			and Large Leaved Privet, Exotic Grasses, Cassia and Blackberry and Jasmine	
	9	Weed Polygon 5	Target weeds; Small and Large Leaved Privet, Lantana, Wild Tobacco, Exotic Grasses, Blackberry, Cassia, Coral Tree, Wandering Jew, Cape Icy, Crofton Weed Balloon Vine and Cotoneaster.	Extend Polygon 3 into Polygon 5
	10	Weed Polygon 8	Target weeds; Small Leaved Privet, Lantana, Blackberry, Mist Flower, Exotic Grasses, Impatiens, Crofton Weed, Mulberry, Cassia, Ginger, wild Tobacco and Black Nightshade.	Start at head of catchment and work down stream. Extend good bush in surrounding polygons. Minimise soil disturbance. Cut and paint woody weeds along creek banks
	11	Weed Polygon 18	Target weeds; Small and Large Leaved Privet, Ochna, Mist Flower and Wandering Jew.	Start at head of catchment and work down stream. Extend good bush into Polygon 18.
Improve Weed Class 4				**Improve condition to < 30% weed cover**
	12	Weed Polygon 22	Target weeds; Small and Large Leaved Privet, Lantana, Wild Tobacco, Blackberry, Cassia,	Work from good bush (internal) outwards to interface.

Table 3.3 SEQUENCE OF WORKS – WEED CONTROL

Objective	Action	Item	Detail	Comment
			Cape Ivy, Balloon Vine and Wandering Jew.	
	13	Weed Polygon 6	Target weeds; Small and Large Leaved Privet, Lantana, Exotic Grasses, Blackberry, Japanese Honeysuckle, Cassia, Wandering Jew and Monsteria	Work from good bush (internal) outwards to interface
	14	Weed Polygon 4	Target weeds; Small and Large Leaved Privet, Lantana, Exotic Grasses, Blackberry, Japanese Honeysuckle, Cassia, Wandering Jew	Work from good bush (internal) outwards to interface.
	15	Weed Polygon 15	Target all weeds in preparation for revegetation. Target weed; Small and Large Leaved Privet, Lantana, Cassia, Blackberry, Exotic Grasses, Murraya, Flame Tree and Jacaranda.	Area to receive plantings (Section 4.4.3)
	16	Produce Weed Map	See Section 3.3.3	
Improve condition to < 5% weed cover		**Secondary Weeding**		**Improve entire E2 zone**

Table 3.3 SEQUENCE OF WORKS – WEED CONTROL

Objective	Action	Item	Detail	Comment
	17	Weed Polygons 2, 3, 9, 11, 16, and 19	Swath[1] entire weed class 1 areas Target all weeds. Target weeds; Small and Large Leaved Privet, Lantana, Blackberry, Ochna, African Olive, Wandering Jew etc	Minor effort to improve good quality bushland by removing potential weed outbreaks.
	18	Weed Polygons 10, 12 and 14	Swath entire weed class 2 areas Target all weeds. Target weeds; Small and Large Leaved Privet, Lantana, Blackberry, Ochna, African Olive, Wandering Jew etc	Minor efforts to improve existing condition of bushland by removing potential weed outbreaks
	19	Weed Polygon 7	Target secondary weeds and regenerating keystone weeds Target weeds; Small and Large Leaved Privets, Exotic Grasses, Lantana, Blackberry, Wandering Jew, Cape Ivy, Cassia and Balloon Vine.	Opportunity to consolidate surrounding good conditioned bushland (polygon 3 and 9)
	20	Revegetation Area 2	Prepare site for revegetation. Install sediment fence	Refer to Section 4.4.1
	21	Weed Polygon 13	Target secondary weeds and regenerating keystone weeds. Target weeds; Small and Large	Start at head of catchment and work down stream. Extend good bush in Polygon 11, 12 and 14. Minimise soil disturbance. Cut and paint woody

Table 3.3 SEQUENCE OF WORKS – WEED CONTROL

Objective	Action	Item	Detail	Comment
			Leaved Privets, Morning Glory, Blackberry, Exotic Grasses, Asparagus Fern, Lantana, African Olive, Balloon Vine, Moth Vine, Bamboo, Ochna, Wandering Jew	weeds along creek banks.
	22	Revegetation Area 3	Prepare site for plantings	Refer to Section 4.4.3
	23	Weed Polygon 1	Target secondary weeds and regenerating keystone weeds. Target weeds; Small Leaved Privet, Asparagus Fern, Exotic Grasses, Crofton Weed, Mist Flower, Ginger, Ochna, Wandering Jew and Japanese Honeysuckle	Start at head of catchment and work down stream. Extend good bush in Polygon 2. Minimise soil disturbance. Cut and paint woody weeds along creek banks
	24	Weed Polygon 17	Target secondary weeds and regenerating keystone weeds. Target weeds; Exotic Grasses, Cassia, Ochna, Small Leaved Privet, Blackberry and Lantana	Extend good bush in Polygon 16 and 19.
	25	Weed Polygon 20	Target secondary weeds and regenerating keystone weeds. Target weeds; Garden escapees, Exotic Grasses,	Area managed as APZ

Table 3.3 SEQUENCE OF WORKS – WEED CONTROL

Objective	Action	Item	Detail	Comment
			Lantana, Blackberry and Cassia	
	26	Weed Polygon 21	Target secondary weeds and regenerating keystone weeds. Target weeds; Lantana, Small and Large Leaved Privet, Cassia and Blackberry and Jasmine	Extend Polygon 16 into Polygon 21.
	27	Weed Polygon 5	Target secondary weeds and regenerating keystone weeds. Target weeds; Small and Large Leaved Privet, Lantana, wild Tobacco, Blackberry, Cassia, Coral Tree, Wandering Jew, Cape Icy, Crofton Weed Balloon Vine and Cotoneaster.	Extend Polygon 3 into Polygon 5
	28	Weed Polygon 6	Target secondary weeds and regenerating keystone weeds. Target weeds; Small and Large Leaved Privet, Exotic Grasses, Lantana, Blackberry, Japanese Honeysuckle, Cassia, Wandering Jew and Monsteria	Work from good bush (internal) outwards to interface
	29	Revegetation Area 1	Prepare site for plantings	Refer to Section 4.4.1
	30	Weed Polygon 8	Target secondary weeds and	Start at head of catchment and work down stream.

Table 3.3 SEQUENCE OF WORKS – WEED CONTROL

Objective	Action	Item	Detail	Comment
			regenerating keystone weeds. Target weeds; Small Leaved Privet, Lantana, Blackberry, Mist Flower, Impatiens, Exotic Grasses, Crofton Weed, Mulberry, Cassia, Ginger, wild Tobacco and Black Nightshade.	Extend good bush in surrounding polygons. Minimise soil disturbance. Cut and paint woody weeds along creek banks
	31	Weed Polygon 18	Target secondary weeds and regenerating keystone weeds. Target weeds; Small and Large Leaved Privet, Ochna, Mist Flower and Wandering Jew.	Start at head of catchment and work down stream. Extend good bush in Polygon 18.
	32	Weed Polygon 22	Target secondary weeds and regenerating keystone weeds. Target weeds; Small and Large Leaved Privet, Exotic Grasses, Lantana, Wild Tobacco, Blackberry, Cassia, Cape Ivy, Balloon Vine and Wandering Jew.	Work from good bush (internal) outwards to interface.
	33	Weed Polygon 4	Target secondary weeds and regenerating keystone weeds. Target weeds; Exotic Grasses, Small and Large Leaved Privet,	Work from good bush (internal) outwards to interface.

Table 3.3 SEQUENCE OF WORKS – WEED CONTROL

Objective	Action	Item	Detail	Comment
			Lantana, Blackberry, Japanese Honeysuckle, Cassia, Wandering Jew	
	34	Weed Polygon 15	Target secondary weeds and regenerating keystone weeds. Target all weeds in preparation for revegetation. Target weed; Small and Large Leaved Privet, Lantana, Cassia, Exotic Grasses, Blackberry, Exotic grasses, Murraya, Flame Tree and Jacaranda	Work from good bush (internal) outwards to interface .
	35	Revegetation Area 4	Prepare site for plantings	Refer to Section 4.4.3
	36	Produce Weed Map	See Section 3.3.3	
Maintain weed cover < 5%	37	**Maintenance**	See Section 4.7	**Duration of 5 years** Periodic weed sweeps throughout entire E2 zone. Monitor revegetation sites. Target known weed sources – stormwater outlets, creeks, entry points, interface. Quadrats and photo monitoring annually (Section 4.8)

1. Swath refers to sweeping/searching the area for weeds and taking corrective action

Chapter 4

Vegetation Management Plan

4.1 Introduction

The purpose of this Vegetation Management Plan (VMP) is to assist contractors in the implementation of appropriate vegetation management practices and to prevent the introduction and spread of weed species.

This VMP has been prepared to guide the management of vegetation within the E2 zone at Wahroonga Estate following the completion of weed control (Chapter 3). It also provides guidance on areas which require revegetation. Furthermore, it considers the DEWHA Condition 2 b. and 2 c. and incorporates the Conservation Interface Management Plan into this Chapter.

4.1.1 Objectives

The objectives of the VMP include:

- To conserve and rehabilitate vegetation occurring within the E2 zone and to promote local biodiversity values. Particularly STIF which conform to CEECs listed under the EPBC Act;
- Measures to protect and manage Turpentine-Ironbark Forest located in the E2 zone from direct impacts, public access, recreational use and edge effects;
- To manage the bushland rehabilitation process to ensure the retention of suitable habitat for those threatened and/or significant flora and fauna species present within the E2 zone;
- To maintain and improve connectivity locally and within the E2 zone, principally through weed removal;
- To identify and manage Key Threatening Processes identified on site;
- Provide clear performance criteria and targets for monitoring bushland within the E2 zone; and
- Provide an indicative costings of bush regeneration works.

4.2 Methodology

4.2.1 Literature Review

A number of previous reports have been prepared for the subject land. The following literature has been reviewed during preparation of this VMP, including:

- Director General's Environmental Assessment Report (NSW Department of Planning, 2010);
- Vegetation Management Plan for Bushland in the Private Recreation Reserve, Coups Creek (Urban Bushland Management Consultants, 2005);
- Bushfire Protection Report (Conacher Travers, 2004);
- Bushfire Protection Assessment (Australian Bushfire Protection Planners Pty Limited, 2008);
- Ecological Assessment Report (Sinclair Knight Merz, 2009); and
- Flora and Fauna Assessment (Cumberland Ecology, 2009).

4.2.2 Field Investigations

Cumberland Ecology Ecologists Nathan Campbell and Ryan Sims carried out a site inspection on 3rd June 2010 to determine the configuration of management zones for the subject land.

Management zones were identified with consideration to the following issues:

- Land use;
- Point source impacts;
- Existing vegetation condition; and
- Vegetation type.

4.3 Vegetation Management

4.3.1 Edge Effects

"Edge effects" is the term given to impacts that occur at the interface between natural habitats and disturbed or developed land. Edge effects alter microclimates and generally favour weed growth, and therefore edges of bushland remnants are typically affected by

weeds and other disturbances including inappropriate plantings on neighbouring properties and dumping of lawn and garden clippings. Encroachment of weeds into bushland can slowly alter the community structure by encouraging exotic groundcovers and inhibiting tree and shrub regeneration. Maintenance issues will always remain high at the development/bushland interface.

The E2 zone is surrounded by residential development and is likely to be edge effected on all sides. Maintenance weeding should regularly monitor bushland edges to reduce weed invasion. The dumping of lawn and garden clipping is prohibited within the E2 zone.

4.3.2 Bush Regeneration and Site Resilience

Generally, bush regeneration removes weeds and encourages native plant regeneration from residual or nearby seed sources. This approach relies on suitable landscapes with intact seed banks or nearby bushland, where there is sufficient species diversity capable of restoring structural components of the vegetation community. These sites are considered to be viable and have a high 'site resilience'. Less resilient sites require other bush regeneration approaches such as assisted natural regeneration and in more degraded sites, complete reconstruction of ecological communities.

The subject land contains large areas of good quality bushland which are structurally intact, and natural regeneration in all strata is apparent throughout the lands. Therefore, it is likely that there is a large seed bank within the E2 zone that is viable and capable of replenishing structural and floristic elements missing in most areas. However, some areas closer to development are in poorer condition and will require supplementary planting.

4.3.3 Seed Collection

It is desirable to collect seed for use in bush regeneration from as close as possible to the area being regenerated, in order to maintain genetic diversity and gene pools.

On site seed collection is recommended for use in rehabilitation of STIF Management Zone 2 (see below). High quality STIF capable of providing seed for all strata can be found to the east in STIF Management Zone 1. Seed collection, processing and storage should follow the Flora Bank Seed Collection Guidelines (National Heritage Trust / Bushcare /Greening Australia 2002), which are found at www.florabank.org.au.

4.4 Vegetation Management Requirements

This section outlines the vegetation management requirements for vegetation within the E2 zone. For the purposes of this report, the E2 zone has been separated into management zones, and these are discussed separately below.

4.4.1 Riparian Management Zone

The Riparian Management Zone follows the streams within the subject land. Generally the vegetation within this management zone comprises largely SSGF which occurs on Sydney Sandstone soil in wetter sheltered areas. There are small occurrences of STIF at the headwaters of the Fox Valley Tributary and the northern section of Coups Creek. The Riparian Management Zone boundaries replicate mapping by Urbis (2009), which complies with the specifications of the *Water Management Act 2000*. The Riparian Management Zone for the purpose of this plan contains the core zone only. The buffer zone which protects the environmental integrity of the core from weed invasion, microclimate changes, litter, trampling and pollution has not been included in this management zone.

The Riparian Management Zone varies in widths and covers much of the subject land (Figure 4.1).

Widths of the Riparian Management Zone range from:

- 20m core around Fox Valley Tributary (Figure 1.2); and
- 40m core around Coups Creek and Lane Cover River (Figure 1.2)

i. Weeding

In contrast to the soils that STIF and BGHF occur on, SSGF occurs on low-nutrient Sydney sandstone soil which usually requires some kind of disturbance for weeds to become established. On this premise areas of bushland in good condition (weed classes 1 and 2) require less attention during maintenance. Weeding efforts should focus on areas historically weedy (classes 3 and 4). These areas are typically disturbed and have a higher abundance of weeds which will require more regular monitoring. Weed seed banks are anticipated to be persistent in these areas. Soil stabilisation is a high priority when managing this zone.

Ongoing weed pressures in the Riparian Management Zone are anticipated to be high due to unmanaged lands upstream and weed polygon 13. Other degraded areas requiring more regular attention includes polygon 4 which follows The Comenarra Parkway, parts of polygons 5, 6, and 7. Figure 3.1 maps the weed polygons and Table 3.3 describes the weed species present in each polygon. Forest edges should also be monitored regularly as edge effects encourage weed growth.

ii. Revegetation

Several areas within the Riparian Management Zone require assisted regeneration. These areas are typically weed dominated and occur on modified soils. Plantings of native tubestock will commence as scheduled within Table 3.3 once weeds are controlled within these areas. Areas receiving revegetation in this management zone include; Area 1

and Area 2 (see Figure 4.1). Please note the locations of the revegetation areas are indicative. These areas are discussed in more detail below.

a. Area 1

Area 1 occurs in the south-western corner of the subject land (see Figure 4.1). This area will require the control of exotic grasses with herbicide spray and the control of woody weeds using the cut and paste method. Lawn areas may require ripping to loosen soils. Ripping is to occur two weeks after herbicide application to ensure herbicide translocation throughout the groundcovers.

Once selected areas are ripped and weeds are controlled, a blanketing of imported mulch 100mm thick can be applied. The mulch must be weed free certified. This mulch will suppress weed growth and will also aid in stabilising the soil, preventing erosion during rain events.

Once mulch has been applied, native tubestock will be installed. Supplementary plantings within this area will aim to recreate the structure and floristics of the natural community (SSGF) and will be carried out as follows:

- Replanting of additional canopy species will be carried out in areas where the remnant canopy is relatively open;
- Replanting of shrubs and small trees will be carried out to spacing indicated in Appendix C.2;
- Replanting of herbs and grasses will be performed where the understorey is sparse, or in areas where significant weed removal has created a lack of native groundcover vegetation;
- Planted tubestock should receive generous watering prior to being planted and after; and
- Tubestock will require regular watering during their establishment period and as part of maintenance.

A planting list for SSGF has been provided in Appendix C.2

Photograph 4.1 **Area 1 requiring revegetation. Note the weedy understorey and sparse native canopy.**

b. Area 2

Area 2 occurs in weedy vegetation west of the subject site (see Figure 4.1). This area will require revegetation as it is dominated by exotic canopy trees and shrubs and weed control efforts will result in the removal of most of the vegetation. Once weeds are removed using cut and paste methods, a blanketing of mulch 100mm thick can be applied. The mulch must be weed free certified. Sediment fences should be installed upslope of Area 2 to reduce scour and soil transportation. There is evidence of scour from stormwater outlets which need to be remediated prior to any mulching or plantings.

Once mulch has been applied native tubestock can be installed. Supplementary plantings within this area will aim to recreate the structure and floristics of the natural community (SSGF) and will be carried out as follows:

- Replanting of additional canopy species will be carried out in areas where the remnant canopy is relatively open;
- Replanting of shrubs and small trees will be carried out to spacing indicated in Appendix C.2;

- Replanting of herbs and grasses will be performed where the understorey is sparse, or in areas where significant weed removal has created a lack of native groundcover vegetation;
- Planted tubestock should receive generous watering prior to being planted and once installed to bed them in and remove air pockets around the roots, and
- Tubestock will require regular watering during their establishment period and as part of maintenance.

A planting list for SSGF has been provided in Appendix C.2

Photograph 4.2 **Area 2 requiring revegetation. Note the high abundance of weeds and open canopy.**

4.4.2 Asset Protection Zones (APZs)

An APZ is a requirement of the NSW Rural Fire Service and is designed to protect assets from potential bushfire damage by maintaining the APZ in a fuel reduced state. These managed landscapes should contain a sparse understorey of predominately groundcovers with occasional scattered shrubs so long as they are not contiguous to assets. The APZs have been given their own management zone to satisfy Commonwealth Government conditions (Section 1.4) and because their management objectives will differ from other management zones.

Please refer to Chapter 5 for more information on APZ locations and widths.

i. Weeding

Generally, APZs require regular management of understorey vegetation to reduce fuel loads. This requirement encourages weed species to colonise, producing weed sources and points of entry into bushland. Weed control efforts within these areas should aim to target known invasive species (refer to Table 3.3). All native trees will be retained. If native canopy trees die, they will be replaced by trees of the same species.

Further details of land management in the APZ are contained within the Fire Management Plan, in Chapter 5.

ii. Revegetation

No revegetation is proposed within this management zone except the replacement of native canopy trees when existing trees die.

4.4.3 Sydney Turpentine Ironbark Forest Management Zone

STIF is an open-forest community occurring on moderately wet sites. The community grows on clay soils derived from Wianamatta shale (DECC (NSW), 2008b). This vegetation community has been designated its own management zone because of its conservation significance (Figure 4.1) and to satisfy Commonwealth Government Condition b (i) (see Section 1.4)

The STIF occurring within the E2 zone conforms to a Critically Endangered Ecological Community (CEEC) listed under the EPBC Act (Figure 2.1). According to mapping by SKM (2009), this vegetation community occurs as two condition classes within the E2 zone; very high and moderate high condition.

For the purposes of this management plan the two conditions have been incorporated into one management zone, with areas of lower condition requiring revegetation.

i. Inappropriate Fire Regimes

Since fire is an important factor in the evolution of many native plant communities (DECC (NSW), 2008b) an appropriate fire regime is important. Long inter-fire periods result in break down of species diversity and community structure (DECC (NSW), 2008b). For STIF, the minimum fire frequency is seven years and the maximum fire frequency is 30 years, with only a small area of the remnant burnt at a time (DECC (NSW), 2008b). Ideally, prescribed burns should be conducted between 15 and 30 years (DECC (NSW), 2008b). However, fuel reduction as part of bushfire management must be considered as

the vegetation is bushfire prone and adjacent urban development. Burning schedules have been provided in Chapter 5.

ii. Precautions against Phytophthora

Due to the wet soils that are associated with STIF, it is particularly susceptible to invasion by *Phyotphtora cinnamomi*. This is a microscopic organism that attacks the roots of plants, and can kill a wide variety of native species. To inhibit the spread of *Phytophthora*, the NSW Government has developed the following procedures (DECC (NSW), 2008b):

- Sanitation of tools and machinery – tools must have all traces of soil washed off then be regularly drenched in a solution of disinfectant. (A solution of one per cent bleach is sufficient for disinfecting machinery.) When planting several plants, disinfect tools in a portable container of disinfectant before and after planting each one;

- Boots and tyres – soil clinging to boots and tyres is a common vector in transporting Phytophthora. To limit the spread of this fungus, ensure all soil is scrubbed clean and the surface is disinfected (using a one per cent solution of bleach, or a 70 per cent solution of methylated spirit. Using disinfectant according to the manufacturer's directions is also suitable.); and

- Infected vegetation – Phytophthora can persist for many years in the dead organic tissue of any trees it has infected. Infected vegetation must be disposed of carefully. Never woodchip any vegetation suspected of being infected by Phytophthora.

These procedures will be implanted during any works being undertaken in this community on the subject site.

iii. Weeding

This community occurs on nutrient rich soils derived from Wianamatta shale. This emphasises the need for long-term management of weeds as they easily establish themselves on wet, high-nutrient soils (DECC (NSW), 2008b). A strict weed control program followed by maintenance will ensure the integrity of the STIF within the E2 zone is improved and maintained in perpetuity. Regular monitoring and control of weed outbreaks will ensure this threatened ecological community is protected from threats such as weed invasion.

STIF Management Zone occurs in two areas of the subject land and varies in condition. There are areas within this management zone which require assisted regeneration. These areas are shown in hash in Figure 4.1.

Areas which do not require revegetation, generally, are in good condition and bush regeneration will rely on natural regeneration. These areas portray natural recruitment of

native species in all strata. During maintenance weeding periodic weed sweeps removing potential seed sources will be sufficient to ensure a high quality of bushland is maintained in the long term. Weed efforts during maintenance should targets areas associated with weed polygons 17, 13 and parts of 15 (see Table 3.3 for weed species). Refer to Table 3.3 for descriptions of weed species present.

Areas 3 and 4 which require revegetation should be prepared accordingly, and are explained in more detail below.

iv. Revegetation

a. Area 3

Area 3 occurs in STIF vegetation north of the subject site (see Figure 4.1). This area will require revegetation as the native vegetation in this area is sparse with little natural recruitment occurring. Furthermore, weed control will result in the removal of most vegetation leaving the area open and prone to more weed invasion. Plantings of native tubestock will commence once weeds are controlled within this area. Mulch will be limited to a ring around each planted tubestock to encourage natural regeneration in the spaces between tubestock. This will also reduce the risk of large quantities of mulch entering the Coups Creek during flood events. Imported mulch will be weed free certified.

Supplementary plantings within this area will aim to recreate the structure and floristics of the natural community (STIF) and will be carried out as follows:

- Replanting of additional canopy species will be carried out in areas where the remnant canopy is relatively open;
- Replanting of shrubs and small trees will be carried out to spacing produced in Appendix C.1;
- Replanting of herbs and grasses will be performed where the understorey is sparse, or in areas where significant weed removal has created a lack of native groundcover vegetation;
- Planted tubestock will receive generous watering prior to being planted;
- Each tubestock will be ring mulched and watered; and
- Tubestock will require regular watering during their establishment period as part of maintenance.

A planting list for STIF has been provided in Appendix C.1 which identifies planting densities for individual species.

Photograph 4.3 **Area 3 requiring revegetation. Note the sparse understorey and presence of weeds.**

b. Area 4

Area 4 is located along the development/bushland interface east of Fox Valley Road. It consists of canopy trees above mown vegetation and was historically managed as a fuel reduced APZ. Area 4 starts where the line of understorey vegetation has been retained and finishes along the outer APZ boundary which will be marked on ground.

Structural elements are missing particularly in the shrub and small tree stratum. Impacts associated with maintaining the APZ have resulted in gradual attrition of the area and native seed bank. This area portrays low resilience and supplementary planting will be required. The ground stratum comprises of predominantly exotic groundcovers ranging from 42% to 66% weed cover SKM (2009). It is unlikely that natural regeneration will occur as the ground is slightly compacted, the ground stratum is dominated by exotic species and the native seed bank seems depleted.

The main priority is to remove the weeds in the ground stratum and replant missing structural and floristic elements. In order to do this the area will require herbicide application targeting exotic groundcovers and cut and paste of woody weeds. Herbicide application is to occur two weeks prior to mulching. A subsequent follow up spray after the initial spray may be required to fully control exotic grasses. Two weeks should be allowed between herbicide applications, and before mulching to provide sufficient time for herbicide translocation throughout the plant especially rhizomes. Mulch will not only

suppress regenerating exotic ground covers, but will also stabilise the land. It has been documented that mulching within STIF prevents the native seed bank from germinating (DECC (NSW), 2008b), however mulching in this area is acceptable considering the land is dominated by weeds and portrays little natural regeneration.

Photograph 4.4 **Area 4 (land managed as APZ). Notice existing line of bushland to the right.**

Area 4 will receive native tubestock plantings. Planting will take place once weeds are controlled within this area and a layer of imported mulch 100mm thick has been applied. Imported mulch will be weed free certified. This management zone will receive no burns for a period of at least 6 years. This technique is expected to ensure an average tubestock survival rate of 70%, as has been reported for other situations (Greening Australia, 2009).

Supplementary plantings will aim to recreate the structure and floristics of the natural community and will be carried out as follows:

- Replanting of additional canopy species will be carried out in areas where the remnant canopy is relatively open;
- Replanting of shrubs and small trees will be carried out to spacing produced in Appendix C.1;

- Replanting of herbs and grasses will be performed where the understorey is sparse, or in areas where significant weed removal has created a lack of native groundcover vegetation;
- Planted tubestock should receive generous watering prior to being planted and once planted to bed in the plant and remove air pockets around the roosts; and
- Tubestock will require regular watering during their establishment period as part of maintenance.

A planting list for STIF has been provided in Appendix C.1

4.4.4 Northern SSGF Management Zone

The Northern SSGF Management Zone comprises of good quality SSGF in the western and north-western section of the subject land (Figure 4.1).

i. Weeding

SSGF occurs on sandstone soils typically with low nutrient levels and subsequently low levels of weeds. The low abundance of weeds in this management zone enables a less intensive management approach. Periodic weed sweeps removing potential seed sources will ensure the high quality bushland is maintained in the long term. It is anticipated that weed invasion will occur at bushland/development interfaces and areas adjoining polygon 13 (Figure 3.1).

ii. Revegetation

No revegetation is proposed in this management zone. The land shows high resilience with natural regeneration occurring in all strata throughout the zone.

4.4.5 Western SSGF Management Zone

The Western SSGF Management Zone is situated west of development (**Figure 4.1**). The SSGF within this zone varies in condition, however the majority of the vegetation shows high resilience.

i. Weeding

Weeding will be undertaken in areas of vegetation that are in low condition within this zone. Refer to Figure 3.1 which illustrates areas of vegetation in low condition within this zone, in particular parts of polygons 4, 5, 6, and 22 (Figure 3.1). These areas will require more frequent weed maintenance with visits to this area must be given priority Areas

historically weedy will exhibit continual weed recruitment from established persistent weed seed banks.

ii. Revegetation

No revegetation is proposed in this management zone. The land shows high resilience with natural regeneration occurring in all strata throughout.

4.4.6 Eastern SSGF Management Zone

The Eastern SSGF Management Zone is situated in bushland east of the development and surrounds Fox Valley Tributary (Figure 4.1).

i. Weeding

The vegetation within this zone varies in condition (refer to Figure 3.1). Areas that are historically weedy will require more frequent weed maintenance visits. Particular attention must be given to potential weed seed sources from polygon 20, 17 and 18. Areas that are historically weedy will exhibit continual weed recruitment, and weed seed banks are anticipated to be very persistent in these areas.

ii. Revegetation

No revegetation is proposed in this management zone. The land shows high resilience with natural regeneration occurring in all strata throughout.

Coordinate System: MGA Zone 56 (GDA 94)

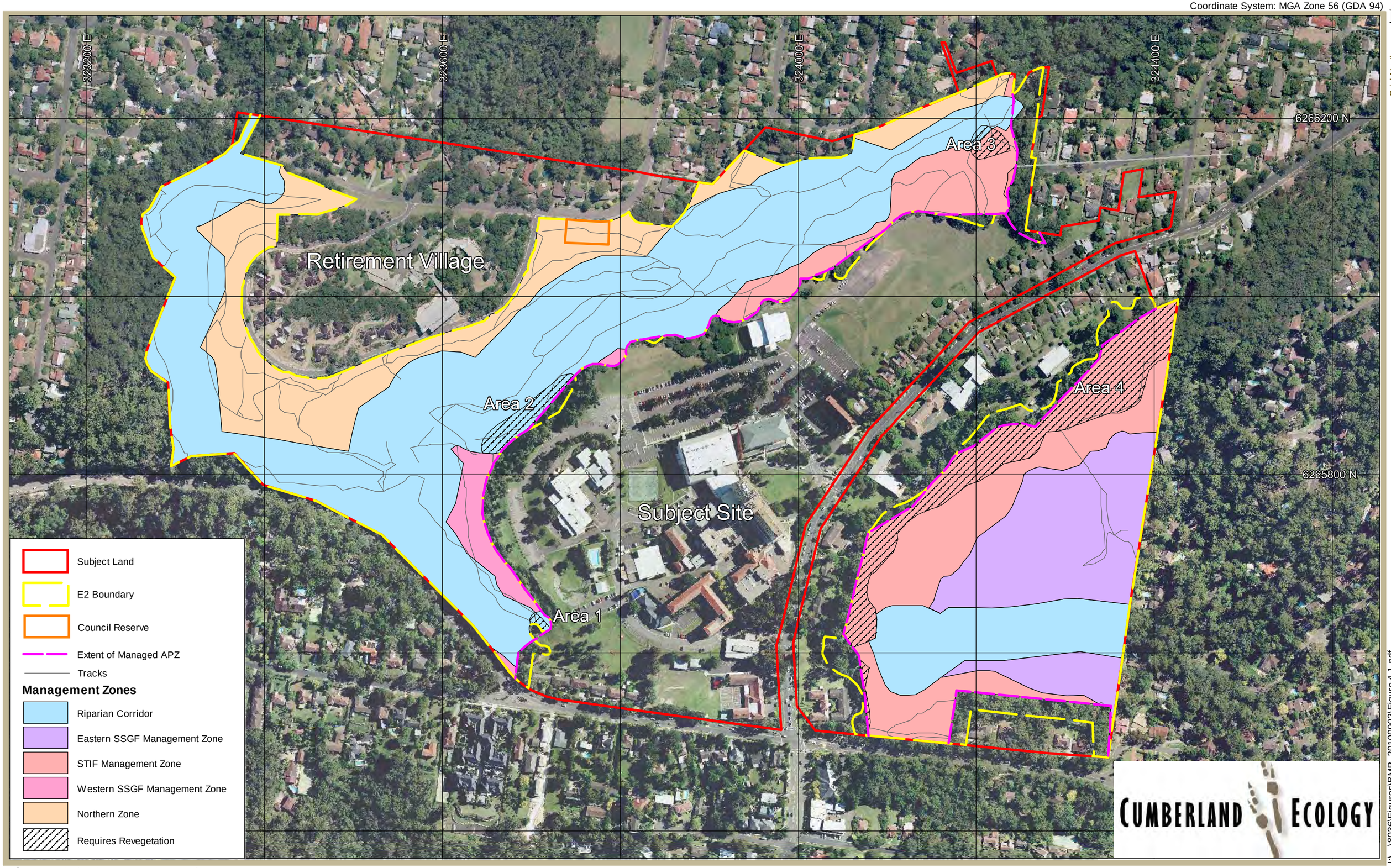


Figure 4.1. Management Zones

100 0 100 200 300 400 m

4.5 Public Access and Impact Avoidance

The APZ boundary indicated in pink of Figure 4.1 will be fenced to reduce public access into the bushland. This will reduce the impact of walking tracks which lead to degradation and fragmentation of remnants, particularly STIF (DECC (NSW), 2008b). For this reason it is preferable to minimise access to these remnants and reduce the potential for additional new track formation. The fence will provide several points of access into the bushland where existing tracks occur or where bushfire service tracks are recommended to be maintained. Fencing materials should be resistant to fire and should not restrict the movement of fauna (DECC (NSW), 2008b).

A style of fence should accommodate the following:

- Reduce multiple public access points into the E2 zone;
- Allow access to areas of bushland during the implementation of vegetation management including fuel reduction and during bushfire crisis;
- Fence materials will be resistant to fire and will not restrict the movement of fauna (DECC (NSW), 2008b); and
- Reduce mower creep into the bushland during APZ maintenance;

4.6 Ownership

The Australasian Conference Association (ACA) (or its successor) will have full ownership of the E2 Environmental Conservation zone. Bush regeneration and all maintenance, monitoring and reporting associated with the E2 zone will be the responsibility and burden of the ACA (or its successor).

4.7 Maintenance

4.7.1 Maintenance - 5 years

Initial maintenance will commence once secondary weeding has been completed (weed cover of <5%) and when planted tubestock are established. Maintenance will include weeding and maintenance of planted native species and will aim to maintain weed cover to <5% throughout the E2 zone.

i. Maintenance Weeding

Works will include 6 visits a year with monthly visits in the summer months between November and February when weed growth is more prolific. Maintenance weeding will occur throughout the entire E2 zone targeting known weed sources; stormwater outlets, watercourse entry points, revegetation sites, bushland edges and weedy areas which have recently been fuel managed (burnt). Bush Regenerators will follow the information provided for weeding within each management zone in Section 4.4.

ii. Revegetation Maintenance

Revegetation sites will require the following maintenance activities:

- Replacement of plant stock will ensure that a minimum of 80% of the original plant stock is maintained for the contract period;
- Supplementary mulching to maintain sufficient depth and quality of the mulch layer to suppress weed growth and assist native plant growth;
- Replaced tubestocks will be regularly watering during their establishment phase and during drier months; and
- Spot spraying and hand weed revegetation sites.

4.7.2 Maintenance in Perpetuity

Generally, as regenerating natives become established, the need for maintenance lessens. However, the E2 Environmental Conservation zone is surrounded by established dwellings and it is expected that invasion of weeds from neighbouring areas may be an ongoing issue. Accordingly, maintenance will continue in perpetuity and as follows.

Maintenance will continue on from the completion of the initial 5 year maintenance period and will include 3 visits per year. Maintenance will include weeding of the entire E2 zone targeting known weed sources; stormwater outlets, watercourse entry points and bushland edges. Maintenance weeding will aim to maintain weed cover to < 5% throughout the E2 zone. Bush Regenerators will follow the information provided for each management zone (Section 4.4).

4.8 Monitoring

Monitoring involves observing and recording the changes that take place before, during and after restoration work (Underwood, 1991). Keeping comprehensive records will provide information on the effectiveness of management practices, in order to determine whether the natural vegetation is improving or declining (DECC (NSW), 2008a).

Qualified bushland management consultants will carry out a program of regular monitoring of the implementation of the VMP, following the methods outlined below.

4.8.1 Monitoring by Quadrats

Permanent 20m x 20m quadrats will be used for baseline and post-treatment monitoring. Information on site details, habitat features, disturbance and floristic composition in each area will be recorded onto data sheets. There will be a minimum of 1 quadrat per management zone, or 1 quadrat per 10 hectares, whichever is greater.

These quadrats will be monitored every 6 months during weed control efforts and then on an annual basis in perpetuity.

4.8.2 Revegetation Area

General observations of the nature and condition of revegetation Areas 1, 2, 3 and 4 will be taken during monitoring surveys, including:

- Estimates of the success rate of plantings and assessment of plant replacement requirements;
- Evidence of erosion and sedimentation and the correct function of erosion control devices;
- Depth and condition of mulch; and
- Recommendations for corrective measures and/or vegetation management.

The following performance indicators for revegetation works will be monitored (Table 4.1).

Table 4.1 STRUCTURAL PERFORMANCE OF REVEGETATION

	On Maintenance	Year 1	Year 2	Year 3	Year 4	Year 5 Off Maintenance
Canopy Cover	< 30 %	< 30%	30% – 50 %	> 60%	Increase in cover	Increase in cover
Canopy Height	< 0.3 m	0.3m – 0.7m	0.7m – 1.5m	> 2m	Increase in height	Increase in height
Percentage Weed cover	< 5%	<5%	<5%	<5%	<5%	<5%

Table 4.1 STRUCTURAL PERFORMANCE OF REVEGETATION

	On Maintenance	Year 1	Year 2	Year 3	Year 4	Year 5 Off Maintenance
Natural Seedling Recruitment	nil	nil	Limited but present	present	present	present

4.8.3 Photo Monitoring

Photo monitoring allows visual documentation of the vegetation regrowth as a result of bush regeneration. Photo points will be selected in each management zone within areas that are representative of the vegetation in each zone. Photo monitoring will be undertaken every 6 months during weed control efforts. During the maintenance period, photo monitoring will be undertaken on an annual basis. A minimum of 1 photo point per management zone or 1 photo point per 5 hectares will be established, whichever is greater. Each photo point will be logged with GPS and once rehabilitation has commenced marked with a numbered peg.

4.8.4 Vegetation Condition Map

A vegetation condition map similar to Figure 3.1 will be created to illustrate the progress of weed control efforts. A map will be produced on the completion of Primary and Secondary Weeding which will progressively assess the performance of weed control efforts.

4.9 Documenting and reporting

The VMP will be an adaptive plan of management that is updated as required to take account of the rate of progress of the aforementioned measures within the plan and also the success of vegetation management measures. Changes may be made to the plan in consultation with DEWHA in the event that problems are detected in the management of the bushland on site.

The consultant will be responsible for ensuring the measures outlined in this VMP are implemented and that performance criteria are satisfied.

DEWHA require a report to be submitted every 12 months until the Minister is satisfied that the proponent has complied with all the conditions of approval. This will be prepared by the vegetation management consultant and forwarded to DEWHA within three months of

every 12 month anniversary of the commencement of the action taking place. The progress reports will:

- State the findings of the monitoring activities;
- Discuss any problems encountered in implementing the BMP; and
- Comment on the stability of and condition of any associated stream works.

Chapter 5

Fire Management Plan

5.1 Introduction

5.1.1 Objectives of this Fire Management Plan

Australian Bushfire Protection Planners Pty Limited has been commissioned by the Australian Conference Association Conference Ltd [ACA] to prepare a Bushfire Management Plan [BMP] for the Wahroonga Estate, comprising the following land parcels.

Within the Ku-ring-gai Local Government Area:

Part Lot 62 in DP 1017514 – [No. 185,148 & 172 Fox Valley Road];

Lots 3 – 6 in DP 834964 – [Nos. 158 – 164 Fox Valley Road];

Lots 7 & 8 in DP 834966 – [Nos. 166 & 168 Fox Valley Road];

Vol. 4506 Fol. 44 known as 172a Fox Valley Road;

Lots 1- 4 in DP 834963 – [Nos. 130 136 Fox Valley Road];

Part Lot 2 in DP 965637 [Vol. 16721 Folio 104] – known as No. 153 Fox Valley Road;

Lots 7 – 8 in DP 834961 – [Nos. 155 – 157 Fox Valley Road];

Lots 1 – 4 in DP 834967 – [Nos. 159 – 167 Fox Valley Road];

Lot 1 in DP 834961 – [No. 169 Fox Valley Road];

Lot 1 – 2 in DP 834960 - [Nos. 171 – 173 Fox Valley Road];

Lots 1 – 2 in DP 834968 – [Nos. 191 – 193 Comenarra Parkway];

Lots 50 – 52 in DP 880017 –[Nos. 195 – 201 Comenarra Parkway];

Lots 1 – 6 in DP 834965 – [Nos. 203 – 213 Comenarra Parkway];

Lots 1 – 12 in DP 834969 – [Nos. 64 – 80 & 73 – 77 Mt Pleasant Avenue];

Part Lot 53 in DP 880017 – [No. 79 Mt Pleasant Avenue]; and Lots 50 – 61 in DP 1017514 – [Nos. 82 – 104 Mt Pleasant Avenue.

Within the Hornsby Local Government Area:

Lot 2 in DP 410875;

Lots 46 – 53 in DP 15946 – [No. 53 – 67 Ferndale Road].

The objectives of this plan are:

- Provide protection of the conservation values of the site;
- Provide a network of managed access trails within the site that connect to the existing public road/fire trail network in order for fire-fighters to provide property protection during a bushfire and assist hazard management works as prescribed in this Plan;
- To prevent the occurrence of human caused unplanned bushfire on the site;
- To minimise the potential for the spread of bushfires on, from, or into the site;
- To protect from bushfires, persons and property immediately adjoining the site;
- To manage bushfires to avoid the extinction of species which are known to naturally occur within the site; and
- To prevent damage by bushfires to Aboriginal Sites that may exist within the site.

5.1.2 Strategies for Bushfire Management.

The fire management strategies identified within this Plan include:

- Provision of bushfire fuel management measures which maintain the bio-diversity values of the vegetation whilst providing a reduction of the amount of combustible fuels in order to lessen wildfire intensity and the potential bushfire threat to adjoining assets;
- The provision of strategic fire management zones bounded by existing and new tracks/trails and management lines as a practical means of dealing with a range of environmental factors and the physical problems associated with fire management when working in steep and difficult terrain such as that existing on the site;

These strategies will not prevent the occurrence of unplanned fires but under most weather conditions the management strategies should permit wildfire ignitions to be controlled within the capability of the NSW Fire Brigade and NSW Rural Fire Service.

There are a number of factors involving the implementation of this plan that require ongoing commitment from The Australian Conference Association Ltd [ACA] and the joint co-operation of the NSW Rural Fire Service/NSW Fire Brigade. These include:

- Commitment to the fire regime for hazard reduction burning with flexibility to adjust this around any wildfire event;
- The construction and annual maintenance of the Strategic Fire Advantage Zones and fire trails/fire breaks and the removal of exotic weed species.

5.1.3 Strategies for Life & Property Protection.

Strategies for life and property protection are:

- Immediately suppress or contain wildfires, investigate suspected arson;
- Maintain reduced fuel levels in Asset Protection Zones [APZ] locations to protect assets;
- Maintain fire and ecological protection objectives in Strategic Fire Management Zones [SFMZ] by providing a mosaic of areas with varying fuel load structures and to assist with control of wildfires;
- Maintain a network of strategic access tracks, walking tracks/control lines;
- Develop a process of fuel level monitoring in asset and strategic fire management zone areas.

5.1.4 Strategies for Cultural & Heritage Management.

Strategies for Cultural and Heritage management include:

- Application of fire regime guidelines for vegetation communities;
- Maintenance of a diversity of fire regimes for the purpose of creating a mosaic pattern of fuel reduction;
- Monitoring and protection of fire sensitive plant communities/threatened species; and
- Prevention of a single wildfire event burning the entire area of vegetation within the site which will affect potential habitats of flora and fauna species.

5.1.5 Legislative & Policy Documentation.

The following legislation and other documents as listed have been taken into consideration in the preparation of this Fire Management Plan:

- Threatened Species Conservation Act 1995;
- Rural Fires Act 1997;
- Local Government Act 1993;
- Heritage Act 1977;
- Bushfire Environmental Assessment Code – NSW Rural Fire Service – 2006;
- Planning for Bushfire Protection 2006;
- Environmental Protection and Biodiversity Conservation Act 1999; and
- The Hornsby & Ku-ring-gai Councils Bushfire Risk Management Plan.

5.1.6 Information Reviewed.

To achieve the objectives of this report, a review of the information relevant to the development has been undertaken. Information sources reviewed include the following:

- Estate Concept Plan;
- Wahroonga Estate Zoning Plan;
- Aerial Photographs of site including location of tracks & trails prepared by Cumberland Ecology;
- *'Planning for Bushfire Protection 2006'* prepared by the NSW Rural Fire Service and Planning NSW;
- NSW Rural Fire Service "Standards for Asset Protection Zones";
- Rural Fires Act 1997 [Amended 1st August 2002]; and
- NSW Rural Fire Service Bushfire Environmental Assessment Code for New South Wales – February 2006.

5.2 Site Description

5.2.1 Location and Surrounding Land Use.

The Estate is located at Wahroonga in the northern suburbs of Sydney and traverses the Local Government Areas of Hornsby and Ku-ring-gai with an approximate area of 65 hectares.

Fox Valley Road bisects the Estate into two distinct sections, the larger being approximately two thirds of the Estate which is located to the northwest of Fox Valley Road and incorporates the Sydney Adventist Hospital [SAH]; residential development; Adventist Church; Conference Centre; Adventist School and the Elizabeth Lodge Hostel and Esther Somerville Nursing Home.

The smaller section of the Estate, to the southeast of Fox Valley Road, contains residential development and the ACA Administration Complex.

The southern boundary of the Estate is formed by a 1.2 km. length of The Comenarra Parkway extending to the east from Lane Cove River to the western edge of Warwick Place.

Both residential and commercial development occupies the land to the south of The Comenarra Parkway with the exception of a 200 metre stretch on the western end which links with the Lane Cove National Par. This section of the southern boundary of the Estate, opposite The Lane Cove National Park, contains the western end of the Coups Creek riparian corridor.

The western boundary, which follows the Lane Cove River, adjoins an unnamed bushland reserve and the rear of residential development on Pine Street, Blue Gum Street, Capella Place and Mt Pleasant Avenue where it intersects with the northern boundary of the Estate. The northern boundary nominally runs along the rear boundary of the residential development fronting Mt Pleasant Avenue. It continues east, crossing Mt Pleasant Avenue, following the northern boundary of Lot 1, which faces Mt Pleasant Avenue and again continues along the rear of the existing residential development which has access off Redgrave Road, Ferndale Road and Nicholas Crescent.

A short section of Coups Creek of approximately 75 metres forms the eastern section of the northern boundary before it intersects with the eastern boundary.

Part of the northern boundary also serves as the boundary between Hornsby and Ku-ring-gai Local Government Areas. The landuse to the north of the northern boundary is predominantly residential with the Loreto Ladies College adjoining a short section to the west of Mt Pleasant Avenue.

The eastern boundary is broken in direction and like the northern boundary follows the rear boundary of residential development that fronts Elizabeth Street, crosses Fox Valley Road, running between residential developments. It then continues again behind

residential development that faces Georgina Close, Campbell Drive and Warwick Close where it meets the eastern end of the southern boundary on The Comenarra Parkway.

The existing landuse to the east of the Estate is residential. Please refer to Figure 1.2 for aerial of the subject land.

5.2.2 Topography

The topography of the land within the Estate is influenced by the shape of the Coups Creek and Lane Cove River gully systems within the north-western portion of the Estate and the steep sided gully that occupies the south-eastern section of the Estate. Fox Valley Road runs along the top of the ridgeline formed by the gully systems.

The existing development precinct along Fox Valley Road has mostly undulating topography with gradients of 5 – 10 degrees with some steep areas falling in to the riparian corridor to Coups Creek, the gully in the southwest and southeast. Slopes within the riparian corridor to Coups Creek, between The Comenarra Parkway boundary to behind the Community Centre building, exceed 18 degrees with the eastern section of the corridor, from the Community Centre displaying slopes of 5 – 15 degrees.

The landform within the Retirement Village/residential precinct along Mt Pleasant Ave has undulating topography with gradients of 5 – 10 degrees falling towards Coups Creek and the Lane Cove River.

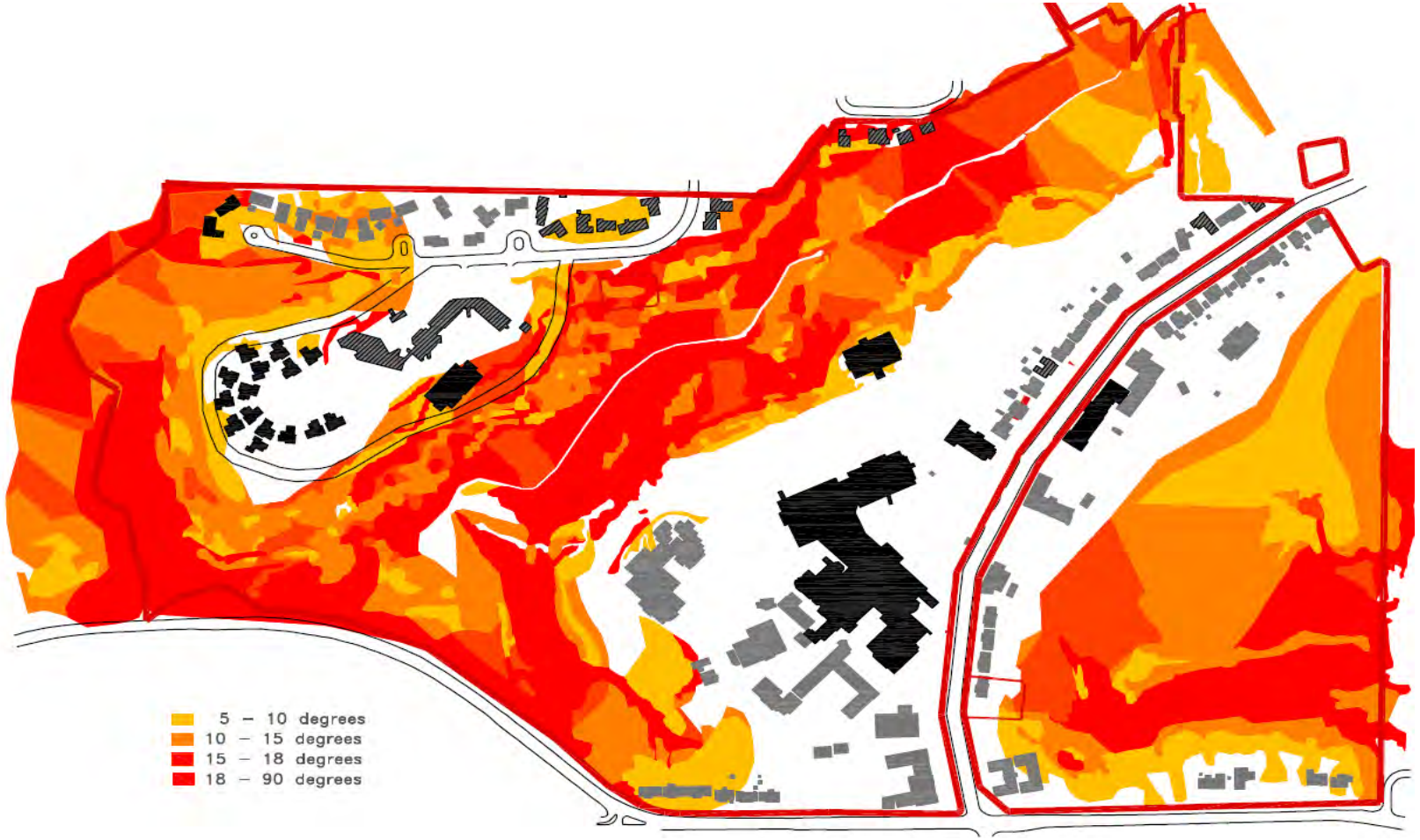
Slopes within Coups Creek and Lane Cove River riparian corridors exceed 18 degrees [33%], decreasing to 10 – 15 degrees as the land rises above the steeper lower sections of the valley system.

The topography of the land within the south-eastern corner of the Estate slopes from Fox Valley Road gradually increasing in gradient as it falls into the gully system in the south-eastern corner. Slopes within the gully line exceed 18 degrees with extensive areas of 10 – 18 degree slopes bordering the southern aspect of the riparian corridor and the central section of the precinct.

Slopes of 5 – 10 degrees are located adjacent to Fox Valley Road and within the north-eastern section of the Estate, southeast of Fox Valley Road

[Refer to Figure 5.1 – Slope Analysis - below].

Figure 5.1 SLOPE ANALYSIS



5.2.3 Flora.

The vegetation within the Estate varies from managed landscaped gardens/open mown lawns adjoining the existing facilities and within the cleared areas to predominantly Dry Sclerophyll Open Forest on the dryer escarpment to Coups Creek and the Lane Cove River and the gully line in the southwest/southeast of the Estate and Wet Sclerophyll Open Forest within the damper sections of the riparian corridors of the watercourses.

Detailed surveys were conducted by Cumberland Ecology and SKM as part of the studies undertaken for the Part 3A Concept Plan Application and confirmed the identification and distribution of the following four vegetation communities within Estate:

- Sydney Turpentine Forest [EEC listed under the TSC and EPBC Act;
- Blue Gum High Forest [EEC listed under the TSC Act and EPBC Act;
- Sydney Sandstone Gully Forest which is comprised of two distinct forms:
- Forest/Woodland Form; and
- Tall Open Forest Form.

The remainder of the Estate contains managed landscaped gardens and mown lawns. No threatened flora species were observed within the Estate.

The Sydney Turpentine Ironbark Forest is fairly widespread across the Estate occurring on gentle to moderate slopes with clay soils derived Wianamatta Shale.

The Blue Gum High Forest has a restricted distribution at the Estate, occurring in small patches in the north-eastern corner and as scattered trees within the existing development and occurs on the higher ridges on gentle slopes in association with clay soils derived from Wianamatta Shale.

Sydney Sandstone Gully Forest is the most widespread vegetation community within the Estate occurring in large, highly connected corridors associated with generally steep sloped sandstone gullies. Two main forms of Sydney Sandstone Gully Forest were identified within the Estate: one form is a forest/woodland dominated by Sydney Peppermint, Red Bloodwood and Smooth-barked Apple and the other is a tall open forest dominated by Blackbutt and Turpentine.

Refer to Figure 2.1 – SKM Plan of Vegetation Communities

5.2.4 Fauna.

The SKM assessment undertaken for the Department of Planning [DoP] deferred reference to the Fauna on the Estate to the studies undertaken by Cumberland Ecology.

Cumberland Ecology found that three threatened species listed as vulnerable under the TSC Act were detected during the surveys undertaken by Cumberland Ecology and Conacher Travers. These species are the Powerful Owl *[Ninox strenus],* Grey-headed Flying-fox *[Pteropus poliocephalus]* which is also listed as Vulnerable under the EPBC Act, and Eastern False Pipistrelle *[Falsistrelllus tasmaniensis].*

Three other threatened species likely to occur on the Estate are the Glossy Black Cockatoo *[Calyptorynchus lathami],* Gang Gang Cockatoo *[Calliocephalon fimbriatum]* and Swift Parrot *[Lathamus discolour].*

Powerful Owls were observed by Cumberland Ecology roosting and were considered likely to be nesting in the riparian vegetation in the south-eastern corner of the Estate. The suspected nest tree, a large Blackbutt contained a large basal hollow through the entire trunk to the top and a large living branch with right-angle hollow spout which could provide a potential nest site however, 2 or 3 large *Angophora Costata* [Smooth Barked Apple] located at the edge of the gully – out of the denser riparian vegetation – provided suitable nesting hollows.

5.3 Fire Behaviour

5.3.1 Introduction.

Fire behaviour is defined as the manner in which a fire reacts to the variables of combustible fuel loadings [fuel quantity, distribution and moisture]; climate / weather patterns [fire weather] and the topography or slope of the land on which the fire is burning.

Aspect of the land and its exposure to prevailing “bushfire winds” [normally the hot north to south-westerly winds] also influences bushfire behaviour. These factors are examined in the following sections of the BFMP and also include the fire history of the site to provide an indication of the exposure of the site to unplanned fires.

5.3.2 Fire History.

Natural, large scale fires have not impacted the bushland areas within the Estate for many years. The 1994 Lane Cove River bushfire did not impact upon the site with the most recent bushfire to burn out parts of the Lane Cove National Park, to the south of The Comenarra Parkway, occurring during the 2003 bushfire season. In August 2002 a fire which was started by a children’s campfire, burnt out a small area of vegetation between the Adventist Retirement Village and the upper reaches of the Lane Cove River.

A hazard reduction burning program was undertaken in 2000 in the bushland in the south-eastern corner of the Estate. This hazard reduction burn was undertaken within the framework of the Hornsby/Ku-ring-gai Bushfire Management Committee’s Bushfire Risk

Management Plan with future hazard reductions planned, as recommended in the Bushfire Risk Management Plan.

5.3.3 Ignition / Fire Sources.

Causes of bushfire ignition are either natural or by human activity. Human activity can be categorised as:

- Malicious – including arson;
- Careless – such as escaped campfires, children and burning off without a permit; and
- Accidental – uncommon, but includes motor vehicle accidents/ignition by farm machinery/work operations [welding etc.].
- The only natural cause of bushfire ignition is lightning.

A review of the causes of bushfire ignitions within the Lane Cove National Park has found that this natural phenomenon has a negligible incidence within the vegetation to the southwest of The Comenarra Parkway. However, arson has been found to be the likely cause of the most recent bushfire occurrences.

5.3.4 Climate.

i. Temperatures & Humidity.

The fire season in the Sydney Metropolitan Area corresponds with the summer months' high temperatures and low rainfall, and can occur from September to April with a proclaimed bushfire danger period from October to March. There is significant variability in temperature and rainfall from year to year.

The nearest Meteorological Station to the Estate is Pennant Hills [Station No. 067019], elevation 61 metres located approximately 2 km to the west. The climate data for Pennant Hills indicates that average annual rainfall is 1068.3mm with highest monthly rainfall occurring in March. The lowest rainfall occurs in September. Average annual maximum temperature is 22.3^{O} C whilst the minimum is 11^{O} C.

The highest mean monthly temperature is 27.6^{O} C in January and the lowest mean monthly temperature is 5.2^{O} C in July.

Average minimum humidity varies from 58% to 72% from January to July and 47% to 58% from August to December. Diurnal variations in relative humidity can have a marked influence of fire behaviour.

Fire seasons may be serious in three out of every 15 years, but this can also vary considerably.

Bushfire risk management, planning and operations must take into account the likelihood of severe fire weather and the challenges it presents. Extreme and uncontrollable bushfires typically occur when the fire danger rating is over 50, a rating of Extreme.

Many of the major property loss events in NSW have occurred at fire danger ratings over 70, on a scale of 0 to 100. The Very High and Extreme Forest Fire Danger conditions mainly occur between November and March. Among the projected changes in climate, as a result of global warming, is that southern Australia will see greater variability in its climate with hotter and drier droughts are possible.

As the temperatures increase, the Forest Fire Danger indices will also increase, perhaps leading to a trend of larger, more intense fires in the landscape.

Climate change remains a complex issue and only one of a range of factors that may be creating an environment conducive to large-scale fires.

ii. Wind.

Wind is also an important factor in bushfire behaviour as it influences the rate of spread of the fire front and spreads burning embers / sparks, providing ignition sources for spot fires ahead of the main fire front.

The shape of the Lane Cove River corridor and Coups Creek valley and the adjoining land-form influences the direction and speed of the prevailing wind and therefore the speed and direction of fire runs within these valleys.

Strong southwest winds have the potential to spread embers into these vegetated corridors from fires burning in the Lane Cove National Park, south of The Comenarra Parkway.

However, these are not the prevailing summer winds with this wind direction occurring mostly during the cooler winter months of June/July with the winds in August shifting to the west thence northwest during the summers months.

Whilst south-westerly winds do occur during the summer bushfire danger season, they are notably for short periods of duration – normally under 30 minutes, during which time they have the ability to change the direction of a run of a fire burning under predominant north-westerly or westerly winds. It is this short period that the vegetation within the Estate is most at risk of ignition from a major fire event in the National Park Estate to the south of The Comenarra Parkway as there is the potential for fire and embers to breach the separation that this road provides to the vegetation in the Lane Cove River and Coups Creek corridors within the Estate.

5.3.5 Surface Characteristics.

The surface characteristics of the land is important in the determination of fire behaviour as the higher the land the more likely the topography is exposed to strong wind influences and the shape of the terrain affects wind direction in the valley formations.

High ridgelines create wind turbulence on the windward and lea side of the landform and often causes wind eddies and wind shear for many kilometres to the lea side of the landform.

Open level ground can also be problematic as winds often increase in speed due to there being no change in topography or vegetation to modify the wind speed or redirect wind.

The landform within the Estate will create acceleration of the south-westerly wind speeds up the steep slopes of the Coups Creek corridor and turbulence in the valley. Rapid chances in wind direction increases the difficulty of fire fighting operations and in some cases leads to an unsafe fire ground.

5.3.6 Slope.

Slope has a significant influence on fire behaviour. Increases in slope generally increase bushfire intensity and rate of spread due to pre-heating of the combustible fuels ahead of the fire front, causing ground fires to extend into the tree crowns, which are closer to the ground on steep land. Slope is divided into four classes; flat, level, hilly and steep on the basis of slope gradients [0 degrees – Flat; 0 – 5 degrees – Level, 5 – 10 degrees – Hilly and over 15 degrees – Steep.

The rate of fire propagation doubles up a slope of 10 degrees (18%) and increases almost fourfold up a slope of 20 degrees (40%). The rate of progress downslope tends to slow at a corresponding rate however wind direction in the lee of the hills/ridgelines tends to be unpredictable and can cause fires to change direction unpredictably.

The average slope of the Lane Cove River/Coups Creek corridors is < 5 degrees) to the south and southwest, however gully lines to the river/creek increase the slopes to each side of the corridor to 15 - >18 degrees.

Bushfires entering the riparian corridors from the southwest will spread upslope, initially impacting upon the land to the southwest of the Retirement Village thence extending along the Coups Creek corridor.

5.3.7 Potential Fire Paths.

The following figures provide an indication of the potential direction of fire which may occur within the Lane Cove River / Coups Creek corridors.

Figure 5.2 POTENTIAL SOUTH WEST FIRE PATH

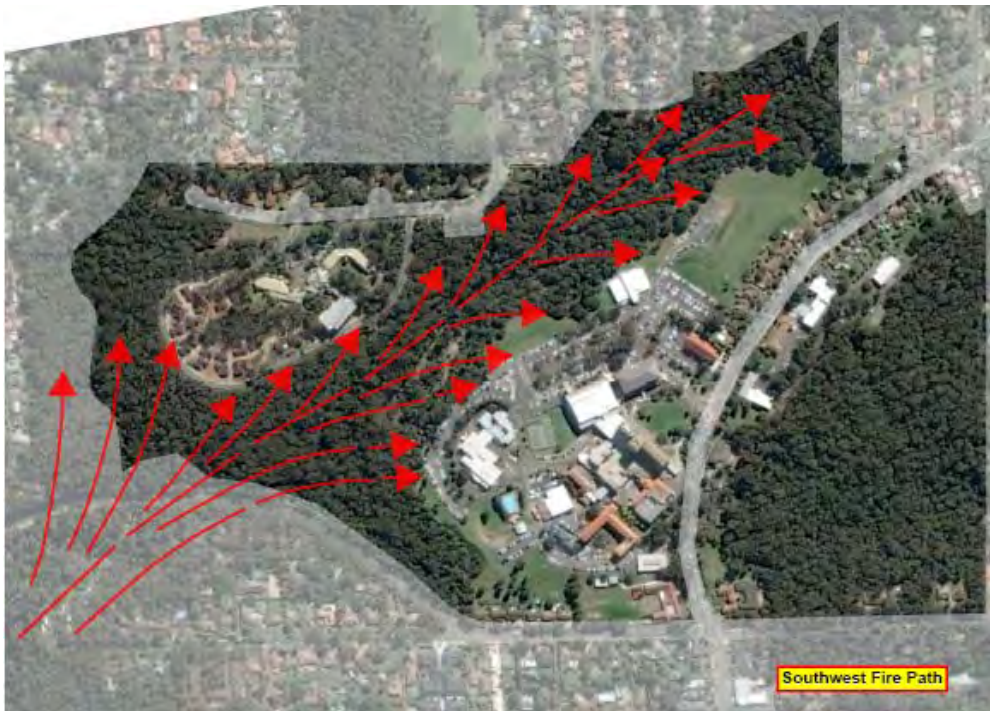


Figure 5.3 POTENTIAL NORTH EAST FIRE PATH

5.3.8 Bushfire Fuels.

Combustible fuel is a critical element in bushfire risk management, as it is the one factor relating to fire behaviour that can be managed. It is for this reason that the ACA commissioned the preparation of the Fire Management Plan for the Estate with the aim to manage and minimise the amount of combustible fuels which are available in the retained vegetation within the Estate.

In an unmanaged landscape there are three 'types' of fuel that contribute to bushfire hazard. They relate to the distribution and nature of combustible material within a vegetated environment and are defined by the Overall Fuel Hazard Guide – Third Edition (NRE May 1999), as:

- Elevated fuel load
- Surface fine fuels; and
- Bark.

Elevated material is defined as shrubs, heath and suspended material greater than 0.5 metres above ground. The level of bushfire hazard depends on fuel continuity, height, amount of dead material, foliage thickness and flammability of live foliage. Flammability of vegetation is at the highest when composition is fine, it contains a lot of dead material, is dense vertically and horizontally and has low moisture content.

Surface fine fuels are defined as the litter bed and vegetation up to 0.5 metres above the ground. Grasses add to the surface fine fuels and therefore need to be taken into account when assessing the hazard. The risk is higher where greater depth and volume of litter and surface material are present – where there is no active fuel management program in place to reduce the availability of dry, combustible fuels within the landscape.

Bark has the potential to travel significant distances in a fire situation (spotting) and act as a ladder between surface fuels and the forest crown. Bark contributes to fire hazard when it is loose and fibrous, present in large quantities and in long loose ribbon forms.

An overall Fuel Hazard for vegetation within the Estate can be determined, based on the combination of these three contributing fuel hazards. However, the level of hazard will vary significantly over time and will depend on the cycle of fuel management undertaken as defined by the Fire Management Plan.

The Fuel Hazard will therefore vary from low – moderate to moderate – high, dependant on the time elapsed since the last management activity.

The aim of the Fire Management Plan is to minimise the amount of combustible fuels available to burn within the retained vegetation on the site whilst recognizing the ecological constraints that exist to management practices in some of the vegetation communities [e.g. Sydney Turpentine Ironbark Forest].

5.3.9 Assessment of Bushfire Risk to the Estate.

Major bushfires have occurred in the Lane Cove National Park, to the southwest of the residential development to the south of The Comenarra Parkway in 1994 and 2003. Neither of these fires impacted the site directly, impacted the vegetation within the site or the facilities on the site.

A small localised fire occurred in the Lane Cove River corridor to the west of the Retirement Village in August 2002 and was attributed to an escape from a children's camp fire. This fire was quickly brought under control and did not threaten buildings or residents.

Whilst there is a bushfire risk to the Estate, it is difficult to quantify the level.

The Retirement Village precinct is most at risk due to exposure of the south-western aspect of this precinct to the unmanaged vegetation within the Lane Cove National Park, located to the south of The Comenarra Parkway. The risk is mitigated by the implementation of the recommendations of this Bushfire Management Plan.

The Hospital precinct is separated from direct impact of a fire event in the Lane Cove National Park by the managed landscaped gardens which occupy the residential development to the southwest and south of The Comenarra Park and to the southeast of the Estate. The potential impact from a fire event in the National Park will be burning embers and smoke.

Fires occurring in the Coups Creek corridor, burning under south-westerly wind influences, will "push" the fire along the creek corridor, rather than towards the Hospital precinct. The risk of such fires, on this precinct, will be low as the impact will be from smoke. Should a fire burn from the west or northwest, across the riparian corridor, the risk from such fire event will be moderate with resultant moderate – high levels of radiant heat, smoke and ember attack with the level of risk dependant on weather conditions and available fuels.

The provision of fire protection measures such as appropriate widths of Asset Protection Zones / Defendable Spaces [dependant on landuse] and construction standards to future buildings will reduce the potential bushfire risk to this precinct.

Fires occurring in the south-eastern corner of the Estate, in its present state, have the potential to pose a low – moderate level of risk to the existing residential development adjoining the eastern boundary of the Estate and the buildings along the eastern/south-eastern side of Fox Valley Road.

5.3.10 Conditions associated with Bushfires.

Climatic and weather conditions associated with serious bushfire seasons and events include:

- Occurrence of an extended drought period [BKDI > 100] and lower than average rainfall through winter drying fuel for spring/summer;
- Summer rainfall is lower than average [Negative SOI], extending the fire season into autumn;
- Prolific fuel accumulation from strong growing seasons the previous summers, followed by extended drought;
- Spring/Summer thunderstorm activity in dry seasons; and
- Persistent west to northwest wind influences.

The greatest wildfire risk is during the months of northwest to west wind influences, high temperatures and low humidity.

5.3.11 Conditions Suitable for Prescribed Burns.

Prescribed burning operations will be carried out in accordance with this Fire Management Plan. The primary objectives of this plan are to:

- Prevent the occurrence of human caused unplanned bushfire on the site;
- Minimise the potential for the spread of bushfires on, from, or into the site;
- Protect from bushfires, persons and property immediately adjoining the site;
- Manage bushfires to avoid the extinction of species which are known to naturally occur within the site;
- Prevent damage by bushfires to Aboriginal Sites that may exist within the site; and
- Provide a network of managed access trails within the site to assist hazard management works as prescribed in this Plan.

i. Season

Fuel Management generally should occur outside the designated Bushfire Danger Period [1st October and the 31st March]. During the non-bushfire danger period, a number of factors allow specific prescription burning to be undertaken; these include:

- Dry surface fuels;
- A high level of moisture recovery in the fine fuels at night to help control burning operations; and

- A low probability of dry north-westerly/westerly winds, high temperatures and low humidity.

The normal period of the year during which these conditions prevail are mid-autumn and late winter/early spring however this may vary due to extended periods of drought.

Prescribed burns may be undertaken during the designated Bushfire Danger Period only with permission from the NSW Rural Fire Service and only if there is a secure boundary and fuel moisture content and weather conditions meet the burn prescriptions.

ii. Weather Conditions

Other periods that may be suitable for prescribed burning are those immediately preceding rain depressions and rain bearing troughs during late November to March. These weather systems may allow hot burns to be undertaken [to gain ecological benefits] and result in the complete extinguishment of the prescribed fire by rainfall. Careful planning is required to implement such strategy.

The limiting factor for winter burns is the retention of moisture content in the surface fuels, however in heavy fuel loads this can be an advantage as it permits retention of a layer of unburnt fuel bed which is beneficial for soil stabilisation and retention of soil moisture. Prescribed burning during early spring can be problematic due to the likelihood of habitat damage, particularly to nesting birds and other fauna.

5.3.12 Potential Fire Behaviour.

Fire behaviour is rated as Low, Medium, High and Very High.

The forest and woodland vegetation on the steeper lands and in the floor of the valleys have a fire behaviour potential of medium due to the aspect [southwest], exposure to hot dry 'fire winds', topography, vegetation structure and unmanaged fuel loads.

5.3.13 Damage Potential.

Should fires occur within the unmanaged vegetation in the Coups Creek and Lane Cove riparian corridors the risk remains that such event will burn out the fuels in these corridors, especially if the fire occurs under strong, dry south-westerly wind influences.

A fire event in the south-eastern corner of the Estate is not likely to endanger the development within the Estate however it may impact upon the residential development to the east.

The planned fuel management of the vegetation within the Estate will reduce the combustible fuels available to such bushfire events and therefore reduce the risk to the facilities within the Estate and to adjoining properties and landowners/fire-fighters.

5.4 Fire Mitigation Consideration

5.4.1 Hazard Reduction Burning

Fire may be considered to be one of the most significant influences at work in the Australian environment today. Virtually all fire management plans are developed with the management of ground fuels as the fundamental goal, commonly accomplished through the application of prescribed burning. Small, low-intensity fires can prevent the development of intense fires that strip soil and nutrients dramatically. Fires that result in entire litter removal, including the decayed or decomposing layer should be avoided. The severe heat release by such fires has a damaging effect on the surface material and is one of the major factors leading to the problems of erosion.

Fire can also affect the physical and chemical characteristics of soil which indirectly influences the composition or growth rate of the protective ground flora and has some bearing on the ability of native fauna to continue life within the area. Frequent fires can be even more detrimental to the ecology resulting in; proliferation of exotic plants and animals; destruction of mature and hollow-bearing (habitat) trees; a decrease of large logs and litter; a decline of understorey structure and plant species; leading to increased predation of mammals. These factors should be considered when setting prescribed burning intervals and burning conditions.

Mosaic pattern burning is most desirable as it creates an assortment of old, dense, unburned vegetation that provides shelter for local fauna species. In addition, newly burned patches provide sprouting leaves and shoots, a desired food source for medium-sized mammals in particular. Wildfires effectively destroy the mosaic of variously aged plants necessary for the survival of the middle-sized mammals (Flannery, 1994).

For the purpose of reducing the fire hazard, prescription burning should be focused on low scorch and the temporary removal of some of the shrub layer in a given area. This Fire Management Plan incorporates this principle, but with a capability of assessing the results by comparison with unburnt fuel within the same zone. Fire of a higher intensity may be prescribed from time to time for ecological purposes. An example of the reasoning behind this is the reliance of some plant species on fire occurrence to activate seed dispersal or initiate germination.

5.4.2 Fuel Reduction.

Fuel removal is required to reduce the density of the shrub layer and fine fuels including fallen leaves, bark and spindly shrubs, particularly in asset protection zones and strategic fire advantage zones.

To limit the speed and spread of unscheduled fire within the site, undergrowth will need to be thinned or removed, and some species managed.

All exotic species of plants should be targeted when clearing to halt their proliferation and colonisation of areas particularly following prescription burns.

5.4.3 Sensitive Areas.

Fire management can cause damage to heritage and cultural areas through construction of fire trails and inappropriately placed control lines.

Burning in proximity to sensitive areas should be avoided to ensure that damage doesn't occur. Alternative options are available. Selective clearing of shrub layers around a sensitive area is one option which would reduce the potential for damage - *Particularly in areas known to support the growth of threatened species.*

5.4.4 Fire Regime Strategies for Biodiversity Conservation.

Fire is a natural driver of ecological processes in the Australian landscape and is an important consideration in its future management. Fire frequency, intensity and season of occurrence are major factors influencing the distribution and composition of plant and animal communities. A variety of fire regimes are required in order to conserve floristic diversity in perpetuity and to provide diversity of habitat. Inappropriate fire regimes (either too short or too long) can cause loss of plant and animal species and/or communities.

Frequent fires will promote the domination of species that seed directly after fire and have a short maturation period, as a result of soil seed loss from mesic, (soft-leaved) native species. Fire also creates increased light opportunities for fast growing species which also tolerate fire or are reproductively adapted to colonising areas following disturbances such as fire.

On the other hand, long-term fire suppression encourages mesic vegetation species to dominate as longer-lived tree species are able to establish and increase canopy cover, therefore reducing light opportunities.

Long-term fire suppression also results in the gradual loss of plant vigour of certain species and reduces soil seed stores of primary coloniser species and fire dependant species.

The future fire management of the vegetation within the Wahroonga Estate must not only consider the safety and protection of human life, capital assets and cultural heritage, but it must also provide a high priority for maintaining ecological diversity, such as the protection of the known threatened species on the site and the riparian corridors and ephemeral streams and watercourses.

Therefore, the timing, frequency extent and methodology of hazard reduction burns must be considered.

Fire frequency must take into account the duration of time required between each fire in any one community to ensure that:

- Sufficient seed banks have developed within each treatment zone otherwise risk the dominance of species that regenerate vegetatively over those dependant on seed germination; and
- Plants have sufficiently recovered from past fires and are capable of surviving another burn.

Fire intensity is also an aspect of ecological burning that should be considered. The intensity of fires must take into consideration:

- The amount of fuel that will burn and the subsequent fire intensity anticipated;
- The depth into the soil and the heat required to trigger germination of the seed bank; and
- The age of canopy trees and whether they are capable of regeneration.

The methodology of hazard reduction burns must include measures which minimise potential impact on species which are not fire tolerant.

In practical terms, conservation is about the prevention of species extinction, especially extinctions brought about by the actions of humans.

Conservation may be facilitated by the incorporation of the following general principles into fire management strategies:

i. Groups of flora and fauna species respond similarly to fire according to characteristics of their life history.

Therefore it is not necessary to individually specify fire regimes for the conservation of every species. Rather, an overview is needed of the requirements for broad groups of species. Requirements for most flora species can be summarised on the basis of a small number of groups.

ii. Flora and fauna are interrelated.

Flora forms an important component of habitat for fauna. Fire management must consider this important interaction.

iii. A diversity of fire regimes may be required in order to maintain native biodiversity.

This means that over time there may be a need to implement fires of high, moderate and low intensity, frequency and size throughout the vegetation. Extinctions may be likely

when fire regimes of relatively fixed intensity, frequency and extent prevail without interruption or are undertaken without sufficient knowledge being available on the impact of fire on a specific species that is considered vulnerable.

Bradstock *et al* (1995) contend that *there is a threshold in fire regime variability that marks a critical change from high species diversity to low species diversity*.

For some groups of biota, these thresholds separating desirable and undesirable fire regimes can be defined.

Management should therefore be targeted toward desirable fire regimes using these thresholds as a guide. The advantage of using thresholds to determine fire regimes is that it is not directing an ecosystem to a single state, but maintaining it in a range of states above the threshold (Walker 1989).

iv. Management strategies involve the manipulation of fire regimes.

Assessment of fire regimes through mapping of the locality and characteristics of all fires will be ongoing so that strategies (manipulation of fire regimes) can be regularly reviewed, refined and adjusted.

v. Methodology of hazard reduction burning.

Preplanning of hazard reduction burning and the preparation of '*Burn Plans'* shall consider, where tracks and other control lines are not available, the need to minimise impact on the habitat of non-fire tolerant threatened species. This shall include moisture content in the fuel bed, ignition points, time of day/increased humidity, potential for rainfall etc.

Recurrent fire is likely to cause changes in the understorey structure, converting multi-layers to a single layer. The post fire succession of floristic communities and species is largely determined by the species composition before the fire. Within any fire there is a mosaic of fire intensity which affects the post-fire regeneration creating a diversity of structure and composition.

Future hazard reduction burns within the Estate may include a range of fire intensities, frequencies and burning methodologies to ensure that a mosaic of age-class flora is maintained, as well as generating refuges for fauna species.

Appropriate fire regimes within the site will be an important management tool in the conservation of the vegetation communities, biodiversity and habitats. Continual evaluation of burning and its impact on flora should be undertaken to ensure appropriate fire regimes are being utilized. Maintenance of habitat within the vegetated areas is essential for conserving viable flora and fauna populations.

5.4.5 Threatened Plants.

Threatened plants are listed under the TSC Act by the NSW Scientific Committee if the Committee is of the opinion that the species is at risk.

Regardless of the type of method of hazard reduction proposed the management prescriptions for plant species are to be applied within an area bounded by at least 100 metres from the centre of the identified location.

i. Mechanical Clearing:

Slashing, trittering, tree removal and bulldozing are generally not allowable for known locations of threatened plants.

ii. Prescribed Fire [Hazard Reduction Burning]:

Minimum fire intervals are prescribed for threatened plants, based on known fire response or based on factors such as the age at which there is sufficient seed production for the plant/s to persist.

5.4.6 Threatened Animals – including populations.

Threatened animals are listed under the TSC Act by the NSW Scientific Committee if the Committee is of the opinion that the species is at risk.

Some animal species are so wide ranging that no practical conditions can be developed for hazard reduction. Other species, such as some owls, are wide ranging but are likely to be disturbed by burning at particular times of the year and specific locations such as around active nest site.

For other species, which are not so wide ranging, such as critical weight range mammals, the specific habitat components are less clear, although factors such as sufficient ground and shrub cover are known to be important.

In all cases it is important to consider the concept of mosaic management of potential habitat.

5.4.7 Endangered Ecological Communities.

Endangered Ecological Communities [EEC] are listed under the TSC Act by the NSW Scientific Committee on the basis of a suite of unique environmental attributes.

i. Mechanical Clearing:

Slashing, trittering, tree removal and bulldozing are generally not allowable for known locations of EECs.

ii. Prescribed Fire [Hazard Reduction Burning]:

- No part of an EEC is to be subjected to successive fires more frequently than the minimum fire interval: and
- At least 50% of the EEC within each Local Government Area [LGA] must exist in a state that has been burnt less frequently than the minimum fire interval.
- Old growth patches of each EEC should be maintained in those areas not critical for protection of life and property.

Table 5.1 provides information on the minimum fire frequency and mechanical forms of hazard reduction for the known Endangered Ecological Communities located within the Estate.

Table 5.2 provides information on the minimum fire frequency and mechanical forms of hazard reduction for the known threatened fauna species located within the Estate.

Table 5.1 MINIMUM FIRE FREQUENCY FOR KNOWN ENDANGERED ECOLOGICAL COMMUNITIES WITHIN THE SITE

Species	Listed in TSC Act	Listed in EPBC Act	Species specific conditions relating to the use of fire	Conditions relating to mechanical forms of hazard reduction
Blue Gum High Forest	EEC	CEEC	No fire more than once every 15 years and of low intensity	No slashing and no trittering or tree removal
Turpentine Ironbark Forest	EEC	CEEC	No fire more than once every 10 years	No slashing, trittering or tree removal

Table 5.2 FIRE MANAGEMENT STRATEGIES FOR THREATENED FAUNA SPECIES

Species	Listed in TSC Act	Listed in EPBC Act	Species specific conditions relating to the use of fire	Conditions relating to mechanical forms of hazard reduction
Grey Headed Flying Fox	Vulnerable	Vulnerable	No burning adjacent to streams and no burning in and around ephemeral	No slashing, trittering or tree removal

Table 5.2 FIRE MANAGEMENT STRATEGIES FOR THREATENED FAUNA SPECIES

Species	Listed in TSC Act	Listed in EPBC Act	Species specific conditions relating to the use of fire	Conditions relating to mechanical forms of hazard reduction
			drainage lines at the headwaters of creeks	
Eastern False-Pipistrelle	Vulnerable		Protect Hollows	No removal of trees
Powerful Owl	Vulnerable		No burning around known nesting sites at any time	No slashing, trittering or tree removal of or around known nesting sites
Gang Gang Cockatoo	Vulnerable		Avoid know roost sites	Avoid know roost sites
Swift Parrot	Endangered	Endangered	Avoid Crown Fires	No removal of trees
Glossy Black Cockatoo	Vulnerable		No burning of Allocasuarina thickets	Yes but avoid Allocasuarina thickets

Appendix E – *"Fire Interval Table for Strategic Fire Advantage Zones & Land Management Zones"* of the NSW Rural Fire Service "Bushfire Environmental Code for New South Wales – February 2006 provides the following information on fire frequency for vegetation communities found within the site.

[Refer to Table 5.3 below].

Table 5.3 VEGETATION COMMUNITY AND FIRE INTERVAL THRESHOLDS TO MAINTAIN BIODIVERSITY IN SFMZS & LMZS

Vegetation Formation	Description	Minimum Fire Interval [Years] for SFMZ	Minimum Fire Interval [Years] for LMZ
Wet Sclerophyll Forest [grassy sub-formations]	Tall forests with dense understorey of shrubs with broad soft leaves – found in sheltered wet valleys & floodplains	25 years	30 years – Low intensity fire only
Dry Sclerophyll Forest [shrubby sub-formations]	Low Forests and Woodland dominated by eucalypts, with understories of hard-leaved shrubs and sparse groundcover	7 years	10 years

These fire interval guidelines define a domain of 'acceptable' fire interval consistent with the maintenance of the existing plant species. The minimum fire intervals provided are based on the minimum maturity requirements of a species sensitive to extinction under frequent fire regimes. They are therefore the length of inter-fire interval which should avoid local species extinctions. The maximum fire intervals provided indicate the time since fire at which it may be expected that species may be lost from the community due to senescence.

It is desirable that any individual fire (or series of fires in quick succession) should not burn across the entire extent of a particular community. Unburnt areas act as a refuge for fauna species that suffer habitat loss during and soon after fire. These areas then become extremely important for the re-colonisation and protection of species.

This is when most individual animals are under greatest threat for survival, as many animals have developed avoidance behaviour to survive the most intense wildfires (Whelan 1995).

The unburnt areas can also act as an important source of propagules for flora species as well, especially for those species that are killed by fire but may have an inadequate or non-existent seed bank in the burnt area.

Table 5.4 outlines the key characteristics of fire regimes that impact upon fauna.

Table 5.4 KEY CHARACTERISTICS OF FIRE REGIMES WHICH IMPACT UPON FAUNA

Characteristic	Description
Frequency	The frequency of fires will determine the complexity and therefore the habitat value of the understorey, with frequent fires increasing exposure to predation and climatic influences, and promoting the potential loss of food and shelter resources.
Season	Fires occurring during the breeding season could adversely affect some species by killing offspring or preventing breeding. Reduction of vegetation density may increase the exposure of the young of some species to predation.
Extent of Patchiness	Burns which are limited or patchy will provide a range of ages of vegetation which will provide a greater variety of food and shelter sources, enabling utilisation of an area by a greater number of animal species. Areas not burnt also act as important refuges for wildlife to congregate in, providing shelter and food sources for survivors, from which re-colonisation of the burnt areas can occur.

Three threatened fauna species listed under the TSC Act have been recorded on the Estate, these being:

- Powerful Owl;

- Grey Headed Flying Fox; and
- Eastern False-Pipistrelle.

Potential habitat exists for a range of other threatened species including:

- Swift Parrot;
- Glossy Black Cockatoo;
- Gang Gang Cockatoo; and
- Microchiropteran bats.

The implementation of the mitigation measures identified for the known threatened species will also have benefits for other native fauna species potentially inhabiting the site.

In order to maintain biodiversity, appropriate fire regimes for vulnerable species need to be implemented within their biodiversity thresholds. Prescription burns should only cover a section of each vegetation community at a time so as to retain a diversity of fire frequency and associated age classes within these communities.

Where thresholds are unknown, a precautionary approach should be applied. Frequent fires of less than 5 years will dramatically simplify understorey vegetation and this must be avoided. Such activity has not been included within this Fire Management Plan.

5.4.8 Areas Infested by Exotic Plants and Weeds.

Weed management should occur primarily through the introduction of cutting and poisoning of Lantana, Privet and other weed species within the riparian corridor to Coups Creek and Lane Cove River [refer to Cumberland Ecology Report]. Some manual clearing [whipper sniping] may also be required in areas not accessible to machinery.

Hazard reduction burning could also be of assistance, though fire may exacerbate the weed problem, particularly if fires are frequently of low intensity.

Fire should be excluded from watercourses and hence, prescription burns will be of little benefit in reducing weed infestation within the riparian corridors. This should be undertaken by hand clearance and poisoning.

Following a prescription burn, or wildfire, a weeding program should be considered as a mandatory follow-up to limit the re-infestation of weed species.

5.4.9 Standards for the protection of riparian buffers.

Mechanical work, Asset Protection Zones and hazard reduction burning must be excluded from all vegetation adjacent to a water body [i.e. the riparian buffer zone] within the

distances as prescribed in Table 6 [below]. The distance [metres] is measured from the highest bank or shore on either side of the water body [i.e. creek].

Table 5.5 STANDARDS FOR THE PROTECTION OF RIPARIAN BUFFERS FOR ASSET PROTECTION ZONES

	Water Body			
Management Method	1st Order and unmapped steams	2nd Order streams; wetlands, lakes & Lagoons – greater than or equal to 0.1Ha but less than 0.5Ha	3rd Order Streams; Wetlands, Lakes & Lagoons greater than or equal to 0.5Ha but less than 2Ha	4th Order Streams & greater Estuaries; Wetlands, Lakes & Lagoons greater than or equal to 2Ha
Use of hand tools & hand held machinery	5 Metres	5 metres	10 Metres	5 metres
Use of slashing machinery	5 Metres	10 metres	15 metres	10 Metres
Use of Graders, ploughs & dozers	10 Metres	15 metres	20 metres	15 Metres
Removal of Trees	5 Metres	20 metres	20 metres	20 Metres

Table 5.6 STANDARDS FOR THE PROTECTION OF RIPARIAN BUFFERS FOR STRATEGIC FIRE ADVANTAGE ZONES [SFAZ].

Water Body				
Management Method	1st Order and unmapped steams	2nd Order streams; wetlands, lakes & Lagoons – greater than or equal to 0.1Ha but less than 0.5Ha	3rd Order Streams; Wetlands, Lakes & Lagoons greater than or equal to 0.5Ha but less than 2Ha	4th Order Streams & greater Estuaries; Wetlands, Lakes & Lagoons greater than or equal to 2Ha
Use of hand tools & hand held machinery	5 Metres	5 metres	10 metres	15 metres
Use of slashing machinery	5 Metres	10 metres	15 metres	20 Metres
Use of Graders, ploughs & dozers	10 Metres	20 metres	30 metres	40 Metres

Table 5.7 STANDARDS FOR THE PROTECTION OF RIPARIAN BUFFERS FOR HAZARD REDUCTION BURNING

Riparian buffer zone width				
Type of Water Body	1st Order and unmapped steams	2nd Order streams; wetlands, lakes & Lagoons – greater than or equal to 0.1Ha but less than 0.5Ha	3rd Order Streams; Wetlands, Lakes & Lagoons greater than or equal to 0.5Ha but less than 2Ha	4th Order Streams & greater Estuaries; Wetlands, Lakes & Lagoons greater than or equal to 2Ha
Width	5 metres	5 metres	10 Metres	20 metres

No lighting of a prescribed hazard reduction burn is permitted within the riparian buffer zone distance specified in Table 8 with the distance measured from the highest bank or shore on either side of the water body.

For prescribed burns being conducted near water bodies, all reasonable steps [excluding clearing vegetation and the use of foams & retardants] should be taken to ensure that the fire does not burn within the riparian buffer zone. Fire shall be lit under conditions so that if they do burn within the riparian zone they are patchy and low intensity.

5.4.10 Smoke Management.

Smoke has the potential to affect local residents, occupants of the Sydney Adventist Hospital and Retirement Village and the public's air quality as well as visibility for road traffic. Hazard reduction burning should be carried out during times of low fuel moisture content to minimize smoke emissions. Notification should be given seven [7] days in advance of prescription burns, in accordance with the notification prescriptions of the Bushfire Environmental Assessment Code.

Where smoke has the potential to detrimentally affect traffic at least 2 weeks prior notice shall be given to police and relevant road authority [RTA/Local Council] to determine when traffic conditions are likely to be most suitable to carry out the burn and any road safety and traffic management requirements including public communications, signage, constraints on ingress and egress from the road carriageway.

Compliance with the requirements so prescribed are mandatory and notification shall be given to the relevant authority at least 24 hours before the proposed burn if the conditions are such that the smoke will affect a nearby road.

5.4.11 Fire Permits.

A person proposing to undertake a hazard reduction burn is required to determine under Section 87 or Section 88 of the *Rural Fires Act 1997* and if a Fire Permit is required this must be obtained prior to conducting the burn.

5.4.12 Notification of Fire Fighting Authorities.

The person acting on a certificate must give at least 24 hours notice prior to lighting the hazard reduction burn as follows:

- In a NSW Rural Fire District, to the Fire Control Officer;
- In a NSW Fire Brigade District, to the officer in charge of the fire station nearest the land on which the burn is to be conducted.

5.4.13 No Burn Days.

Hazard reduction burning shall not be undertaken during periods when a No Burn Notice has been or is likely to be issued by the DEC unless the proposed activity qualifies for an exemption from the No Burn Notice.

5.4.14 Fire Trails, Tracks and Control Lines.

The implementation of the bushfire management programs recommended in this Fire Management Plan cannot be achieved without the establishment and maintenance of trails

and control lines which contain the prescribed burns within the nominated Fuel Management Zones.

The Estate currently contains a number of existing tracks most being well maintained. Each track has been identified by name on the Tracks, Trails and Control Line Plan in Appendix E with upgrade and future maintenance works identified in Section 5.6.5.

Control Lines are also nominated in locations as shown on this plan and form temporary, hand cleared lines to the edges of SFMZs and LMZs where existing tracks and trails do not exist. These lines will be implemented prior to the programmed hazard reduction burn and known as Hand Lines [HL].

5.5 Fuel Management Zone

5.5.1 Introduction

Fuel Management Zones [FMZ] for the maintenance of the vegetated land within the site have been designed to reduce the bushfire risk to life and property and the environment and to mitigate the chance of fires occurring on and escaping from the site.

The FMZ recommended within this Fire Management Plan utilise a zoning system to detail the fuel management guidelines within the site. The zoning system corresponds with the prescriptions provided by the NSW Rural Fire Service for hazard reduction burning.

5.5.2 Fuel Management Zones [FMZ].

The site has been divided into three types of Fuel Management Zones which are further described below. As far as possible, the boundaries of these management zones have been defined by fire control advantages including roads, fire trails and hand tool control lines.

Description of Fuel Management Zones:

i. Asset Protection Zones [APZ].

These are zones adjacent to built assets and are generally 20 – 50 metres wide for residential development and up to 100 metres wide for *'special fire protection purpose development' [e.g. core hospital landuses]*. Fuels are intensively managed in these zones to provide a buffer of very low fuel levels between the asset and a bushfire hazard. Low fuel levels in APZs provide fire crews and home/land owners greater opportunities to safely defend their assets.

The Asset Protection Zone contains two sub-sections – the Inner Protection Area and Outer Protection Area. The Inner Protection Area is located adjacent to the asset.

The management criterion that is required to achieve an Inner Protection Area [Asset Protection Zone sub-formation closest to the asset] includes:

- Maximum fine fuel loading of 3 tonnes/hectare;
- Minimum fine ground fuel;
- A shrub component occupying only 20% of the total area;
- Discontinuous vegetation and tree canopy cover;
- No tree or shrub vegetation is to overhang or come in contact within the building/asset.

ii. Strategic Fire Management Zones [SFMZ].

These are bushfire hazard reduced areas where fuels are managed to slow a bushfire and to reduce its intensity. They are often located adjacent to APZs to enhance the effectiveness of asset protection. SFMZs are normally located in strategic locations, such as adjacent to fire trails in high ignition areas or firepaths and are intended to;

- Provide fuel reduced areas which enable the protection of assets by firefighters when asset protection zones are not in place;
- Compliment asset protection zones where these do not provide adequate protection;
- Provide strategically located fuel reduced areas to reduce the potential fire large scale wildfires to develop;
- Provide areas where fire can be more easily suppressed, or
- Provide strategically located fuel reduced areas to reduce vulnerability of assets which are susceptible to fire [including flora & fauna assets].

iii. Heritage Management Zone [HMZ].

These are zones which are not fuel managed and are retained to enhance the conservation of biodiversity – e.g. riparian corridors and areas of high conservation value.

The zone objective is to manage bushfire to meet the conservation needs of threatened species of flora and fauna, the maintenance of biodiversity in vegetation community composition and structure, which may be at risk of long term damage as a result of the application of inappropriate fire regimes.

5.5.3 Management Techniques.

This section of the Fire Management Plan addresses the management techniques for each of the Fuel Management Zones (FMZ) as identified on the Fuel Management Plan attached to this report as Appendix F. Detailed management prescriptions are listed in Part 3 and Part 4 of the *Bushfire Environmental Assessment Code for NSW, February 2006* prepared by the Rural Fire Service.

i. Asset Protection Zones [APZ]

The purpose of the Asset Protection Zones is to ensure that the presence of fuels that could become involved in a fire are reduced, minimising the impact of direct flame and radiant heat on the development within the Estate.

The implementation of Asset Protection Zones to areas within the site that satisfy these requirements can be achieved through the following permissible works:

(a) Mechanical work for maintenance or establishment of the APZ in accordance with the requirements of Part 4 of the *Bushfire Environmental Assessment Code;*

(b) Pruning and tree removal in accordance with the requirements of Part 4 of the *Bushfire Environmental Assessment Code;*

(c) Prescribed burning in accordance with the requirements of Part 5 of the *Bushfire Environmental Assessment Code;*

(d) Construction of control lines in accordance with the requirements of Part 5 of the *Bushfire Environmental Assessment Code;*

(e) Pile burning for disposal of vegetation removed during APZ works only where the material collected can not be disposed of by normal garbage collection or composted on site.

The maximum extent of work permissible within an undefined Asset Protection Zone, being an Asset Protection Zone to existing development and which does not form part of the required width of Asset Protection Zone created as part of the approval of a new development within the Estate, is as listed in Table 5.8:

Table 5.8 MAXIMUM WIDTH OF ASSET PROTECTION ZONES TO EXISTING DEVELOPMENT – UNLESS OTHERWISE NOMINATED

Slope	Width
Hazard Upslope	20 metre width of managed APZ
Hazard downslope < 10 degrees	20 metres width of managed APZ
Hazard downslope 10 – 15 degrees	30 metres width of managed APZ
Hazard downslope > 15 degrees	40 metres width of managed APZ

5.5.4 Strategic Fire Management Zones [SFMZ].

The following management works are permissible within a SFMZ:

(a) Mechanical clearing along existing linear fire breaks or up to 6.0 metres from boundary fences and must not involve the removal of native vegetation older than ten years;

(b) Prescribed burning in accordance with Part 5 of the *Bushfire Environmental Assessment Code of NSW* [NSW Rural Fire Service 2006];

(c) Construction of Control Lines in accordance with Part 5 of the *Bushfire Environmental Assessment Code of NSW* [NSW Rural Fire Service 2006];

(d) Pile burning for disposal of vegetation material removed during APZ or SFMZ works.

5.5.5 Heritage Management Zone [HMZ].

No prescribed fire management works are proposed within this zone as it forms the 40 metre wide riparian corridor to Coups Creek and Lane Cove River and the 20 metre wide riparian corridor to the Coups Creek tributary and the watercourse in the south-eastern corner of the Estate.

5.6 Fire Management Strategies

5.6.1 Introduction

The following section provides advice on the recommended fire management strategies within the prescribed Fuel Management Zones on the site.

[Refer to Appendix F – Fuel Management Plan].

5.6.2 Asset Protection Zones [APZ]

[Refer to Appendix F – Fuel Management Plan].

i. Inner Protection Area [IPA].

a. Location:

The Inner Protection Area is located adjacent to an asset and ensures that the presence of combustible ground fuels [leaf litter/twigs], which could become involved in a fire, are minimised close to the buildings. The following locations shall be managed as an Inner Protection Area in accordance with the performance criteria provided below:

- The existing landscaped gardens, mown lawns and managed vegetation within the Estate as, defined by either the E2 zone boundary or by the modified E2 zone boundary/Asset Protection Zone line;
- Provision of a 20 metre wide managed Asset Protection Zone [APZ No. 1] to the perimeter of the existing dwellings on The Comenarra Parkway [east]; and
- Management of the existing Asset Protection Zone to the west of the existing dwellings on The Comenarra Parkway [west] – APZ No. 11;

b. Performance Criteria – Inner Protection Area:

Management of the Inner Protection Area shall comply with the following:

- Maintain maximum fine fuel loading [leaves and twigs] at 3 tonnes / hectare;
- Maintain shrubs so that they are clear of the external glazing of the building by at least five [5] metres;
- Prune low tree branches 2 metres from the ground to prevent a ground fire from spreading into the tree canopy;
- Avoid the use of flammable mulch in garden beds that adjoin the buildings.
- Maintain landscape gardens by removing dead and dying material;
- Retention of small clumps of trees is acceptable provided that they do not provide a continuous fire-path to the buildings.
- Separate tree crowns by at least 2 metres so that the canopy is not continuous and does not encroach closer than 5 metres from the buildings;
- Landscape species selection shall be drawn from those that are considered to be species which are *"fire retardant"* and do not promulgate the spread of fire.

ii. Management Program – Asset Protection Zones.

Table 5.9 provides a guide to the timing of the works required to maintain the Asset Protection Zones.

Table 5.9 TIMING OF WORKS WITHIN INNER PROTECTION AREA

Management Area		Management Prescription	Method	Timing
Inner Protection Area	Landscaped Gardens	Minimize the accumulation of combustible fuels and accumulated ground litter	Manual removal of combustible fuels; pruning of shrubs	Intervals not to exceed monthly in Spring and Summer
	Trees	Provide canopy separation between trees & buildings; maintain limbs 2m clear of ground & shrubs	Pruning	Annual inspection with works undertaken in Spring
	Lawns	Minimize Fine Fuels	Mowing & slashing	Intervals not to exceed monthly in Spring and Summer
Buildings	External surfaces/ Gutters	Check fire protection measures to buildings. Clean roof gutters	Visual Check & repair if necessary. Manual removal of debris	Annual inspection in August; Removal of combustible materials in gutters/valleys not to exceed monthly in Spring & Summer

iii. Outer Protection Area [OPA].

a. Location:

The following locations shall be managed as an Outer Protection Area in accordance with the performance criteria provided below:

- Provision of a 10 metre wide managed Outer Protection Area [APZ No. 2] along the eastern boundary, within the Sydney Sandstone Gully Forest;
- Management of the existing Outer Protection Area to the west of the existing dwellings on Elizabeth Street – APZ No. 3;

- Provision of a 10 metre wide managed Outer Protection Area [APZ No. 4, APZ No. 5, APZ No. 6 and APZ No. 7] along the rear of the existing properties to the north of Coups Creek; and

- Provision of a managed Outer Protection Area [APZ No. 8, APZ No. 9 and APZ No. 10] along the access road to the Retirement Village.

b. Performance Criteria – Outer Protection Area:

The Outer Protection Area is located adjacent to the hazard and the reduction of combustible fuels in this area substantially decreases the intensity of an approaching fire and restricts the pathways to crown fuels therefore reducing the level of direct flame, radiant heat and ember attack on the Inner Protection Area.

The criterion that is required to maintain an Outer Protection Area includes:

- Maintain maximum fine fuel loading [leaves and twigs] at 8 tonnes / hectare;

- Maintain a discontinuous mature tree canopy cover and shrub layer.

Table 5.10 TIMING OF WORKS WITHIN OUTER PROTECTION AREA

Management Area	Management Prescription	Method	Timing
Outer Protection Areas defined on Appendix F – Fire Management Plan	Maintain fine fuels at < 8 tonnes/hectare	Fuel removal / maintenance by mechanical slashing, thinning of vegetation and pruning of trees	Annual inspection in August with works to be completed, as needed, by the end of September

5.6.3 Strategic Fire Management Zones [SFMZ].

[Refer to Appendix F – Fuel Management Plan].

i. Prescription:

The objective of these zones is to implement ecological hazard reduction burns to contribute towards conserving the species that occur in the Strategic Fire Management Zone whilst managing the fuel loads on the lands beyond the Asset Protection Zones.

This is achieved through the implementation of appropriate fire regimes and controlling the spread of unplanned fires which could otherwise result in species extinctions. Weather conditions are a vital aspect when utilising fire to reduce a particular bushfire hazard. Ecological burns should be carried out during the non-flowering periods of the flora

species within the bushland (autumn). The occurrence of any threatened flora and fauna species may slightly alter the timing and extent of each burn.

The Strategic Fire Management Zones have been broken into separate hazard reduction precincts which form part of the overall land management strategy. This division will provide a guide to the implementation of rotation burning which will conserve and enhance ecological processes within the vegetation communities.

Table 5.11provides details of ecological burns within the SFMZs. The schedule is based on the first hazard reduction burn being undertaken in 2011. If a wildfire occurs within the SFMZs prior to the first hazard reduction burn being completed, the timing of the program will require further review.

Table 5.11 TIMING OF HAZARD REDUCTION BURNS WITHIN THE STRATEGIC FIRE MANAGEMENT ZONES

Year	SFMZ 1	SFMZ 2	SFMZ 3	SFMZ 4	SFMZ 5	SFMZ 6	SFMZ 7	SFMZ 8	SFMZ 9	SFMZ 10	SFMZ 11	SFMZ 12	SFMZ 13	SFMZ 14	SFMZ 15	SFMZ 16	SFMZ 17
2011			✓							✓							
2012		✓													✓		
2013														✓			✓
2014	✓							✓									
2015				✓									✓				
2016											✓					✓	
2017							✓		✓								
2018					✓							✓					
2019			✓														
2020						✓									✓		
2021										✓							✓
2022		✓												✓			
2023				✓				✓									
2024	✓												✓			✓	
2025											✓						
2026												✓					
2027			✓				✓		✓								
2028					✓										✓		
2029																	✓

Table 5.11 TIMING OF HAZARD REDUCTION BURNS WITHIN THE STRATEGIC FIRE MANAGEMENT ZONES

Year	SFMZ 1	SFMZ 2	SFMZ 3	SFMZ 4	SFMZ 5	SFMZ 6	SFMZ 7	SFMZ 8	SFMZ 9	SFMZ 10	SFMZ 11	SFMZ 12	SFMZ 13	SFMZ 14	SFMZ 15	SFMZ 16	SFMZ 17
2030						☑								☑			

Note 1: Once the program has been completed, the rotation can be restarted.

Note 2: It *is recommended that a burn plan for each burn precinct be prepared prior to the implementation of hazard reduction burning. A burn plan will identify the timing of burn, weather conditions, ignition points, containment lines, fire fighting resources and specific burn objectives (i.e. retained fuel loadings) and burn methods in order to protect threatened species – e.g. Powerful Owl nesting tree.*

5.6.4 Heritage Management Zone [HMZ].

The riparian corridors to Coups Creek [and tributary], Lane Cove River and the watercourse in the south-eastern section of the Estate have been identified as a Heritage Management Zone [HMZ] and no prescribed burning / hazard management is to be undertaken in these corridors. Wildfires shall be prevented from entering this corridor, were it is practicable and safe to do so.

5.6.5 Access Roads, Fire Trails and Control Lines.

[Refer to Appendix E – Tracks, Trails & Control Lines].

The Estate contains numerous walking tracks and access trails which extend throughout the Coups Creek and Lane Cove River corridors. These tracks form an important public amenity to the bushland. The south-eastern corner of the Estate contains a smaller number of walking tracks and one access track which provides access to the eastern boundary.

Appendix E – Plan of Tracks/Trails & Hand Lines provides the location of the existing access tracks within the Estate. The Walking Tracks which form part of the management requirements of this Fire Management Plan have been identified and form the 'edge' of fire management precincts.

Appendix E also identifies the location of three existing 'strategic' access tracks which provide maintenance access into the vegetation areas of the Estate and which shall be maintained in perpetuity, unless their use is reviewed by the ACA and determined to be obsolete to their requirements.

There is also a need to implement the construction of 'Control Lines' [temporary walking paths]. These will be constructed by hand as part of the preparation of the programmed hazard reduction burns and identified on the Tracks, Trails & Control Lines plan as Hand Lines [HL].

Table 5.12 provides a list of the strategic access trails, including their current condition and required works.

These trails shall be inspected annually in July/August and maintenance works implemented before the commencement of the prescribed Bushfire Danger Period – [1st October – 31st March or otherwise as determined].

Table 5.12 STRATEGIC ACCESS TRACKS/FIRE TRAILS

Track Name	Location	Present Condition	Works Required	Annual Works	Comments
T1	From existing Tennis Court to eastern boundary	Fair – overgrown	Clearing & earthworks / drainage	Inspection in July/August – maintenance works completed by October	Work to be undertaken by ACA
T2	Runs along northern side of Coups Creek Tributary	Good	Maintenance	Inspection in July/August – maintenance works completed by October	Work to be undertaken by ACA
T3	Track within Water Main Easement – from Carpark to Coups Creek	Good	Maintenance	Inspection in July/August – maintenance works completed by October	Work to be undertaken by ACA
T4	Northern boundary of APZ 1	To be constructed	Clearing	Inspection in July/August – maintenance works completed by October	Work to be undertaken by ACA
Existing Walking tracks nominated on Appendix E	Various	Varies	Maintenance of existing nominated walking tracks to provide perimeter access to fire management zones	Inspection in July/August – maintenance works completed prior to hazard reduction works program	Work to be undertaken by ACA

5.6.6 Monitoring

The objectives of monitoring are to measure the effectiveness of management strategies in achieving the fuel management objectives of the Fire Management Plan. The following ongoing monitoring shall be undertaken:

- Establish sites to monitor fuel loadings in all Strategic Fire Management Zones and Heritage Management Zones;

- In August, undertake annual inspection of the Asset Protection Zones Lot and the Strategic Fire Management Zone;
- Establish sites in each vegetation community to monitor the effect of implemented fire management regimes on biodiversity;
- Document the cause of unplanned fires and the effectiveness of the emergency response. This process of assessment will ensure that the occurrence of unplanned fires is reduced through adaptive management; and
- Mapping of fire regime, both planned and unplanned wildfire is to be undertaken and kept up to date for annual fire management strategy implementation and burn cycle analysis. All elements of fire regime [intensity, frequency and seasonal occurrence] shall be recorded as well as species presence related to time since last burn.

Note: Results of this monitoring program should be examined against the objectives of this Fire Management Plan. This will indicate whether management strategies have been effective in producing an ecologically based fire management programme for the vegetation within the site.

5.6.7 Enforcement.

The Australian Conference Association Ltd [ACA], or its successors, has an ongoing liability to ensure the management of the vegetation/lands within the Estate to prevent the build-up of combustible fuel.

Section 63(2) of the *Rural Fires Act* requires that '*it is the duty of the owner or occupier (including Councils) of land to take the notified steps (if any) and any other practicable steps to prevent the occurrence of fires on, and to minimise the danger of the spread of fires on or from that land*'.

Also, Section 66(1) of the *Rural Fires Act* states that *'a hazard management officer, may, by notice in writing, require the owner or occupier [not being a public authority] of any land to carry out bush fire hazard reduction work specified in the notice on the land'.*

Chapter 6

Pest Management Plan

6.1 Introduction

This Pest Management Plan has been prepared to guide the management of feral/exotic pest and domestic animals within the E2 Environmental Conservation zone at 'Wahroonga Estate'. This plan has been prepared to ensure that impacts of feral/exotic pest, over-abundant native and domestic animals on the conservation values of the subject land are appropriately minimised and that the proposed development does not result in an increase of problematic animals.

Populations of introduced vertebrates fluctuate in space and time and are expected to change in response to the changes in land use and climatic variation that will occur during construction and occupation of the proposed development. It is anticipated that some species may need to be controlled in some years and not others and it is also possible that new introduced species may colonise the subject land.

6.1.1 Objectives

The key objectives of this plan are to:

- ensure that development of the Wahroonga Estate does not directly or indirectly increase populations of, or improve habitats for, feral/exotic pest animals and over-abundant native species;
- ensure that redevelopment of the Wahroonga Estate does not exacerbate any Key Threatening Process including predation or grazing by feral animals; and
- minimise the potential for domestic animals within the Wahroonga Estate to impact on native flora and fauna values of the E2 zone

6.2 Policy Context

State and Commonwealth legislation lists the impacts of some feral animals as Key Threatening Processes.

6.2.1 Environment Protection and Biodiversity Conservation Act 1999

The EPBC Act lists Key Threatening Processes, some of which relate to the impacts of feral animals. A Key Threatening Process is a process that may threaten the survival, abundance or evolutionary development of a native species or ecological community. The following Key Threatening Processes are relevant to the subject land:

- Predation by the European Fox;
- Predation by Feral Cats; and
- Competition and land degradation by Feral Rabbits.

Threat Abatement Plans have been prepared for these species that outline a "feasible, and effective way" to abate the threatening process (Biodiversity Group EA, 1999c, Biodiversity Group EA, 1999a, Biodiversity Group EA, 1999b). The strategies within this document have been formulated with due consideration to these Commonwealth Threat Abatement Plans.

6.2.2 Threatened Species Conservation Act 1995

The TSC Act also lists Key Threatening Processes that relate to feral animals in NSW. Key Threatening Processes (KTP) under the TSC Act are processes that harm threatened species or could cause other species to become threatened. The KTPs listed under the TSC Act include the processes listed under the EPBC Act. The following are a list of KTP under the TSC Act which may occur on subject land:

- Predation by the Feral Cat (*Felis catus*);
- Predation by the European Red Fox (*Vulpes vulpes*); and
- Predation by the Plague Minnow (*Gambusia holbrooki*).

Threat abatement plans have been prepared and approved for the 'Predation by *Gambusia holbrooki*' and Predation by the European Red Fox'. The strategies within this document have been formulated with due consideration to these Threat Abatement Plans.

6.3 Pest Issues

A number of feral and domestic animals are currently known to occur within the E2 zone (Gunninah, 1994) (see Table 6.1) (Gunninah, 1991, Gunninah, 1995, Cumberland Ecology, 2004a, Cumberland Ecology, 2004b). The proposed development of the Wahroonga Estate is not likely to introduce additional feral animal species to the site but a precautionary approach should be adopted. There is potential for the development to improve habitat for some feral/exotic pest animals and there is also the possibility that domestic animals may access the site from the existing surrounding residential developments. This section discusses the current impacts of feral and domestic animals and the potential for additional impacts following the development of the Wahroonga Estate. Table 6.1 shows a list of the feral/exotic pest, overabundant native and domestic fauna species that have been recorded (Cumberland Ecology 2009) or are likely to occur on the subject land.

Table 6.1 DOMESTIC, FERAL AND NATIVE PEST SPECIES THAT OCCUR OR ARE LIKELY TO OCCUR ON THE SUBJECT LAND

Common Name	Status	Potential Impacts
Fish		
Plague Minnow	Introduced species; TSC Act KTP	Competes aggressively with native fish species, preys upon frog eggs and tadpoles
Birds		
Common Myna	Introduced species	Competes aggressively with native birds and mammals for nest hollows
Common Starling	Introduced species	Competes aggressively with native birds and mammals
House Sparrow	Introduced species	Occurs in large numbers
Noisy Miner	Native; potential pest species; Protected	Excludes most small birds from their territories, creating areas with a low diversity of small birds.
Red-whiskered Bulbul	Introduced species	Destructive of native plant species, spreads seeds of privet
Rock Dove/Feral pigeon	Introduced species	Competes with native birds, occurs in large numbers.
Spotted Turtle-Dove	Introduced species	Competes with native birds, occurs in large numbers
Mammals		
Black Rat	Introduced species	Predation on small fauna, competition with native rodents

Table 6.1 DOMESTIC, FERAL AND NATIVE PEST SPECIES THAT OCCUR OR ARE LIKELY TO OCCUR ON THE SUBJECT LAND

Common Name	Status	Potential Impacts
Brown Hare	Introduced species	Degradation of habitats through grazing and burrowing
Cat	Introduced species; EPBC Act KTP and TSC Act KTP	Predation on small to medium sized fauna
Dog	Introduced species	Predation on small to medium sized fauna
Fox	Introduced species; EPBC Act KTP and TSC Act KTP	Predation on small to medium sized fauna
House Mouse	Introduced species	Degradation of habitats through grazing

*KTP=Key Threatening Process; TSC Act=Threatened Species Conservation Act 1995; EPBC= Environment Protection and Biodiversity Conservation Act 1999

6.4 Pest Control Methods

6.4.1 Plague Minnow

A threat abatement plan has been prepared for the Plague Minnow by the DECC (NSW National Parks Wildlife Service, 2003), as this species is listed as a Key Threatening Process (KTP) under the TSC Act. The primary actions identified within the threat abatement plan to minimise the impact of this species are to:

- Minimise human dispersal of the Plague Minnow through public education; and
- Minimise the introduction of Plague Minnow into the natural environment.

Humans have been the main mechanism in the spread of the Plague Minnow and it is essential that residents of the Wahroonga Estate do not dump aquarium fish in the streams of the E2 zone or stormwater devices.

It is possible that the streams within the E2 zone and stormwater devices contain the Plague Minnow. Habitat free of the Plague Minnow can be created with the construction of detention basins, provided that waterways containing the species do not drain into them. Draining and drying out water bodies is a successful way of eradicating the Plague Minnow from wetland habitat if it has been introduced, therefore it would be beneficial if these detention basins were designed in such a way that they could be drained if Plague Minnows were found to colonize them at a later date.

6.4.2 Bird Species

The increase of urban-aggressive feral bird species, including the Common Myna, can be minimised by reducing feeding opportunities for these species and promoting habitat for other native species.

There are a number of actions that can be taken to minimise the impact of these species including:

- Prevent access to food in rubbish bins by modifying the design or by ensuring that a lid is attached and used; and
- Avoid providing nectar resources within landscaping such as *Callistemon* and hybrid *Grevillea*.

Common Starlings, House Sparrows, Spotted Turtle Doves, Rock Doves, Red-whiskered Bulbul are widespread and common species; therefore damage control is best accomplished by targeting problem areas. The best management strategy is to reduce numbers of these bird species by decreasing access to nesting, roosting and food and water resources through habitat modification. For example, avoiding planted species such as *Callistemon* and Hybrid *Grevillea* as part of landscaping can reduce food sources for the Noisy Miner. Populations can also be controlled to a degree by minimising habitat availability through the creation of structurally complex vegetation communities, as introduced species typically thrive in open vegetation. Signage should be erected to inform the general public not to feed birds in or near the E2 zone.

6.4.3 Rodents

Redevelopment of the Wahroonga Estate may increase opportunities for rodents by increasing food sources and creating favourable habitat conditions. However, any increase is likely to be relatively small and localised to the developed areas. Rubbish should not be left uncovered within the development area, but contained within closed bins. If managed correctly a small increase in introduced rodents should not significantly impact upon native species in the E2 zone through competition or by attracting and supporting predators in the area.

If rodents do become a problem in the developed areas, a baiting program may need to be implemented; however this is not warranted at the present.

6.4.4 European Red Fox

Predation by the European Red Fox is listed as a Key Threatening Process (KTP) under the TSC Act and the EPBC Act. Following this listing, DECC prepared a Threat Abatement Plan (TAP) to propose actions to reduce the impacts of fox predation on threatened species. This plan establishes priorities for fox control, effective control

programs and provides methods to measure the response of native fauna to fox control (Biodiversity Group EA, 1999c).

While foxes are likely to occur in the E2 zone, they are unlikely to have a sufficient impact on native fauna to warrant baiting. This may also be problematic due to the proximity to residential areas and the possibility of domestic dogs taking baits. Therefore, management strategies recommended for the subject site relate to minimising impacts through non-lethal methods, as this is the most suitable and cost effective approach.

A suitable method for discouraging and decreasing the impact of foxes is through habitat manipulation. This entails modifying the habitat so that the habitat is less favourable for foxes. Ensuring that the canopy is continuous so that arboreal species do not have to leave trees to forage will help reduce the impact of foxes on threatened arboreal species.

6.4.5 Feral Cats

Predation by Feral Cats is listed as a Key Threatening Process (KTP) under the TSC Act and the EPBC Act. A Threat Abatement Plan (TAP) has been prepared on predation by feral cats by the Department of the Environment and Heritage (now the Department of the Environment, Water, Heritage and the Arts) (Biodiversity Group EA, 1999b). This document provides information on feral cat control programs, development of innovative and humane control methods and education of land managers and other about feral cat impacts.

Feral cats are likely to exist in the E2 zone and surrounding developed lands. There are a number of control methods that may be utilised to reduce cat numbers. The recommended method to reduce the impact of feral cats on threatened species is to discourage cats from the E2 zone by ensuring that there are no potential food sources available. Rubbish should not be left uncovered within the development area, but contained within closed bins. Other initiatives may include education regarding desexing pet cats and encouraging residents to keep cats indoors at night.

6.4.6 Feral Dogs

Wild or feral dogs include dingoes, domestic dogs living in the wild and hybrids (crosses between dingoes and wild dogs). While no feral dogs have been sighted at Wahroonga Estate, stray dogs do occur from time to time and may reside on the subject lands periodically.

The impact of stray dogs on native fauna within the E2 zone is expected to be relatively small and there are very few ground-dwelling native fauna that are likely to function as prey species for dogs.

The recommended action for decreasing the impact of stray dogs on native prey species is to discourage dogs from the area by limiting the food supply to prevent scavenging.

Rubbish should not be left uncovered within the development area, but contained within closed bins.

6.5 Community Education

A key component to minimising potential impacts of feral and domestic animals on the native species of the E2 zone will be community education. It is essential to educate the community of the potential impacts of feral and domestic animals and of their responsibilities to minimise these impacts.

Information packs should be provided to all new residents and an ongoing campaign of community education will be actively promoted. This may take the form of information displays, hand out literature and website information. Education and awareness programs on feral and domestic animal management should be implemented within the Wahroonga Estate in conjunction with other programs concerning flora and fauna and weeds. Residents should be educated about the risk to native fauna from stray dogs, and will be encouraged to report any stray dogs to the Council so that they may be collected and removed from the area. Residents will be informed to keep their own dogs contained at all times and to avoid taking them off the leash while in or near the E2 zone. Residents will be informed to keep their cats indoors at night to avoid impacts of from predation on native fauna.

Educational programs concerning ecological issues in the E2 zone (including domestic and feral animals) will be made available as pamphlets and distributed during induction courses.

Chapter 7

Habitat Corridor and Linkages Management Plan

7.1 Introduction

The Department of the Environment, Water, Heritage and the Arts (DEWHA) have approved the concept plan development with conditions. Condition 2, a), iv) stipulates that a Biodiversity Management Plan for the subject land must address habitat corridor and linkages management.

The subject land supports two viable ecological corridors connecting intact areas of vegetation to the north and south of the subject lands. Management of these ecological corridors is necessary under the proposed development to ensure that the corridors continue to function effectively in the long term.

7.2 Ecological Corridors

Ecological corridors are increasingly used to connect isolated habitats. These corridors are generally thought to allow plants and animals to disperse (or migrate) from one habitat area to another, facilitating gene flow and colonisation of suitable sites.

Ecological corridors, to be of high significance, must provide a link between relatively large patches of remnant vegetation and should accommodate a variety of species. For example, a narrow, densely vegetated corridor that runs along a creek will not be suitable for species that require larger areas. However, if a wider area was provided on either side of the creek it would produce a higher quality corridor, suitable to a variety of species. The corridors within the subject land are considered important linkages for transfer of genetic material (both flora and fauna) between adjoining habitat with a largely urban surrounding. These corridors provide known habitat for a number of threatened fauna, including the Powerful Owl, Grey-headed Flying-fox and the Eastern False-Pipistrelle (Cumberland Ecology 2009). Suitable habitat for a number of other threatened species including microchiropteran bats, Swift Parrot, Glossy Black Cockatoo and Gang-gang Cockatoo also occurs within these corridors (Cumberland Ecology, 2009)

7.2.1 Suitability of Corridors

There are several factors that determine the suitability of vegetation to act as a corridor, and these are discussed below.

i. Type and Quality of Habitat

To function effectively as an ecological corridor, vegetation within the corridor needs to provide the habitat and particular resources required by all species dependant on the corridor. For example, some species may require thick patches of dense understorey or ground cover, others may require logs and litter for foraging and shelter, and others still may require tree hollows for refuge and nesting. The E2 zone includes all of the above mentioned habitat features.

ii. Potential for Edge Effects

Development adjacent to ecological corridors has the potential to increase the vulnerability of the corridors to disturbance along edges. Edge effects will influence the diversity and type of fauna that will live in the corridor. Some species thrive with disturbance, while other more specialist species will be affected by change. The pest and weed management plan will reduce edge effects along the E2 zone.

iii. Animal Mobility

The relative mobility of animals will influence the type and length of ecological corridor that they can use. For example, many birds will be able to fly over gaps in suitable vegetation communities and move substantial distances, whereas for small lizards, effective connectivity may require continuous suitable habitat.

iv. Predation and Competition

The presence of predators or competitors in an ecological corridor may inhibit movement, or impose an increased risk on mortality. Movement of introduced predators such as the Fox (*Vulpes vulpes*) or Cat (*Felis catus*) is often facilitated through the clearing of natural vegetation. Other native fauna species able to adapt to disturbed environments such as the Noisy Miner (*Manorina melanocephala*), often dominate narrow ecological corridors, discouraging other species from using them.

v. Corridor Width

The necessary width of a useful corridor varies greatly among wildlife species. For example, small reptiles may utilise narrow corridors whereas larger animals such as kangaroos require wider areas for daily movement. In addition, the habitat retained within the corridor may not be suitable for all wildlife species, and therefore wider corridors are

required to include several vegetation types. For example, a densely vegetated riparian corridor would be unlikely to support the dispersal of Koalas, which prefer a corridor of readily accessible trees. Conversely, sparsely vegetated woodland corridors would not be preferred by species such as the Swamp Wallaby (*Wallabia bicolor*), which prefers thick undergrowth.

7.3 Habitat Corridors and Linkages of the Subject Land

A rapid habitat assessment conducted within Sydney Metro Catchment Management Authority Area (DECC 2008) was reviewed by SKM (2009). This review indicated that the subject land supports two major ecological corridors.

The first corridor is associated with Coups Creek and facilitates a northeast to southwest passage across the subject land into Lane Cove National Park. This corridor is in moderate-good condition and varies in width from approximately 95m to 250m. This corridor is large, well vegetated and highly connected.

The second corridor is associated with vegetation to the east of Fox Valley Road. This corridor facilitates north-south passage across the landscape. This corridor connects relatively large remnants of STIF with vegetation in Lane Cove National Park. This corridor is at its widest within the subject land (over 300m) and narrows to 150m outside of the subject land before joining up with Lane Cove Valley. This corridor is large, well vegetated and highly connected. Figure 7.1 shows the ecological corridors of the subject land.

Both of the corridors identified within the subject land are classed as "Very High Fauna Values" under the Rapid Fauna Habitat Assessment (DECC 2008) and as reported by SKM. This category indicates that the corridors provide a high faunal diversity and a range of habitat types from estuarine to woodland and forest on a range of geological formations.

The Coups Creek and Fox Valley Road corridors provide important linkages for the transfer of genetic material (both flora and fauna) between adjoining populations and provide known habitat for a number of threatened fauna, including the Powerful Owl (*Ninox strenua*), Grey-headed Flying-fox (*Pteropus poliocephalus*) and the Eastern False Pipistrelle (*Falsistrellus tasmaniensis*) (Cunberland Ecology 2009). These corridors also support suitable habitat for a number of additional threatened species including microchiropteran bats, Swift Parrot (*Lathamus discolor*), Glossy Black Cockatoo (*Calyptorhynchus lathami*) and Gang Gang Cockatoo (*Callocephalon fimbriatum*) (Cumberland Ecology 2009).

The proposal will not result in any reduction in width for either of the ecological corridors within the subject land. The minimum width of the Coups Creek corridor within the subject land will remain 95m and the widest point within the subject land will remain 250m. The minimum widths of the Fox Valley Road corridor within the subject land will remain 120m

in the north, and 135m in the south. The Fox Valley Road corridor is at its widest point within the subject land, and this will remain greater than 300m.

Areas adjacent to ecological corridors within the subject land will be managed as Asset Protection Zones (APZs). Activities under the APZ management are likely to include fuel reduction (through slashing/mowing/manual removal) and hazard reduction burning. These activities are likely to promote the retention of the existing simplified vegetation structure adjacent to ecological corridors. These areas may not be suitable for the passage of all faunal groups and would not therefore contribute as an expansion of the width of these corridors.

All threatened fauna known or likely to occur within the subject land are highly mobile species. None of these species are heavily reliant on habitat connectivity as they typically move and forage throughout the broader landscape. However, habitat linkages and corridors do provide some value to these species as movement corridors for prey, as well as a path for genetic exchange between plant species providing forage, roosting and nesting habitat. The proposal is unlikely to significantly impact on the corridor values of the subject land, as all current corridors will be retained.

Coordinate System: MGA Zone 56 (GDA 94)

N
Grid North

Subject Land
Sydney Metro CMA Rapid Habitat Assessment
Very High Fauna Values
Fauna Movement Corridors
Coups Creek Corridor
Fox Valley Road Corridor

CUMBERLAND ECOLOGY

I:\...\8036\Figures\BMP\BMP_20100721\Figure 7.1.pdf

Figure 7.1 Fauna Movement Corridors

125 0 125 250 375 500 m

7.4 Management Objectives and Actions

The habitat corridor and linkages management objectives for the subject land are:

- To protect the ecological values of the Coups Creek and Fox Valley Road corridors;
- To minimise the impacts of the proposal within the subject land on Coups Creek and Fox Valley Road corridors during construction and development of adjacent residential areas; and
- To maintain biodiversity and protect native flora and fauna species (including threatened species) and habitats.

These objectives will be achieved on the subject land through the following management actions:

- Retention of all native vegetation within the E2 zone;
- Management of pests and weeds within the Coups Creek and Fox Valley Road corridors as prescribed in the pest and weed management plans for the subject land;
- Bushfire management of APZ's adjacent to the Coups Creek and Fox Valley Road corridors within the subject land in accordance with the attached Fire Management Plan; and
- Exclusion fencing along the boundaries of the Coups Creek and Fox Valley Road corridors within the subject land.

7.4.1 Vegetation Retention

As part of a condition of consent significant areas of bushland within the subject land were zoned E2 Conservation Zone. This was based on an independent review conducted by SKM and as directed by the NSW DoP and DECCW, as well as the Federal DEWHA. The E2 zone will protect land with high conservation value on the subject land. Areas which were previously managed as APZ's will be protected under the current zoning with some areas encouraged to regenerate. Vegetation within the two existing vegetated corridors on the subject land will be managed long-term through regular maintenance visits and monitoring which will manage weeds and promote biodiversity.

7.4.2 Weed Management

Weeds prevent natural regeneration by completely covering the soil. They replace native flora by forming dense thickets which reduce species diversity and structure. Exotic vines

also smother native flora preventing them growing and eventually killing them. The removal of weeds from the E2 zone will improve the current condition of the vegetation in the E2 zone. Increases in native flora diversity and structure through weed control will provide suitable habitat for more native fauna species. Regular weed control will ensure the vegetation maintains a high conservation value and protected habitat for fauna.

7.4.3 Pest Management

Managing pest animals likely to utilise the E2 zone will consist of mainly habitat modification. This approach modifies suitable habitat in a way that renders it undesirable to the pest. For example, containing rubbish will prevent scavenging from dogs and cats which prey on native fauna, and avoiding planting known food sources for introduced avifauna such as *Grevillea sp*. will help reduce habitat for these species. By discouraging pest species within the E2 zone and the surrounding lands habitat value will be increased for native fauna.

A key component of minimising potential impacts of feral and domestic animals on the native species of the E2 zone will be community education. It is essential to educate the community of the potential impacts of feral and domestic animals and of their responsibilities to minimise these impacts. Refer to Chapter 6 for more information on pest management on the subject land.

7.4.4 Bushfire Management

Bushfire management is an integral component to every development located within bushfire prone land, and can significantly impact upon native vegetation. The subject land has been divided into four types of Fuel Management Zones (FMZ). These include APZs, Heritage Management Zones (no burn schedule), Strategic Management Zones and Land Management Zones which are further described in Chapter 5. Generally, the creation of APZs require vegetation modification to reduce fuel loads. As the majority of APZs on site are already in existence significant areas of vegetation will not need modification – only maintenance. The creation of a new APZ (in the south-eastern corner of the subject land) will result in some modification of some understorey vegetation. The creation of this APZ can be achieved without major vegetation clearance and is unlikely to impact upon connectivity or fauna habitat values within the E2 zone.

Fire plays an important role in maintaining forest integrity. Many plants rely on fire for seed germination, and dispersal while inappropriate fire regimes can gradually simplify forests and encourage weeds. Mosaic burning small areas at different times reduces the impacts expansive fires have on removing large areas of forage habitat and refugia. By following appropriate fire regimes and fire intensity as described in Chapter 5 forest structure and diversity will be maintained and potentially enhanced. For more information on bushfire management please refer to Chapter 5.

7.4.5 Fencing

The bushland within the E2 zone is proposed to be fenced to reduce public access and their associated impacts on native fauna. Fencing will be carried out so as not to impede fauna movements. For more information refer to Section 4.5.

Chapter 8

Hydrology and Nutrient Management Plan

8.1 Introduction

8.1.1 Purpose

The purpose of this hydrology and nutrient management plan is to ensure that appropriate management measures are taken during and post the development of the Wahroonga Estate site to mitigate hydrology and nutrient impacts on the native ecological communities within the environmental conservation zones of the site. This hydrology and nutrient management plan is to form part of the broader biodiversity management plan for the Wahroonga Estate.

The intention of this plan is not to provide a detailed concept plan for the Wahroonga Estate site on how to mitigate hydrology and nutrient impacts from the proposed development on the receiving environment, but rather to provide framework and guidance for appropriate management measures to mitigate such impacts and protect bushland and aquatic health objectives. This plan is to be used as follows:

- By regulators as guidelines to assess new development applications within the Wahroonga Estate site with regard to meeting the bushland and aquatic health objectives of this plan.
- By asset owners and managers to monitor the implementation of the plan and evaluate its effectiveness in meeting its objectives.

8.1.2 Description of the Receiving Environment

About 50% of the Wahroonga Estate site (31.3 ha) is identified as native vegetation areas, which contain a number of complex ecological issues including the critically endangered ecological community Blue Gum High Forest and the Sydney Turpentine-Ironbark Forest. They also contain habitat for a number of threatened fauna species such as microchiropteran bats and other birds. This area also supports riparian corridors for the Lane Cove River, Coups Creek and some of their tributaries, in addition to tributaries for Fox Valley. These riparian corridors with their associated aquatic habitats provide habitat for a number of bird, mammal, reptile and amphibian species

8.1.3 Urbanisation Impacts on the Receiving Environment

Extensive research exists about the impact of urbanisation on aquatic ecosystems and bushland (EPA 1997 and Engineers Australia 2006). Catchment urbanisation, especially the increase of impervious area can lead to detrimental impacts on receiving environments such as native bushlands and the aquatic health of natural streams. Conventional stormwater drainage, which involves draining the catchment as fast as possible using pits and concrete lined pathways (pipes, culverts and channels) would lead to the following impacts on receiving environments:

- Increase stormwater flows and pollutant loads from the upstream catchment into the aquatic environment of the receiving streams, especially sediments, nutrients (phosphorus and nitrogen) and litter. This can lead to excessive weed growth and poor water quality in the receiving streams in addition to nutrient enriching of soils along the path of urban stormwater runoff.

- Increase in frequencies of small to moderate flows resulting from direct surface runoff, which otherwise would have been absorbed by the soil in a non-urbanised catchment. Moderate flows have greater potential to negatively impact on the plants and animals of small streams due to the significant hydraulic disturbance associated with these flows.

- Increase in frequencies of smaller floods that approach or exceed bank-full, which are estimated to be 1.5-2 year ARI storm events, thus causing stability and scour problems to the channel form in natural creek systems.

- The collective changes to flow patterns, channel form and water quality that result from conventional stormwater drainage of urban areas would have severe and predictable consequences for stream ecosystems. Compared with streams of undeveloped catchments, stream of conventionally drained urban catchments typically retain or process less nutrients in stream water, have greater in-stream plant growth and have fewer animal species.

The detailed Flora and Fauna assessment of the site undertaken by Cumberland Ecology (Appendix M of the Final Preferred Project Report & Concept Plan, Jan 2010) identified that the existing urbanisation of the catchments draining to these bushland areas and creek corridors already have the following impacts on the ecological communities of the site:

- Negative impacts on water quality in the riparian corridors;

- Nutrient enrichment of soils, negatively impacting on native bushland, especially the endangered ecological community of Blue Gum High Forest.

- Increasing weed infestation and introduction of exotic vegetation, especially at areas of stormwater paths and in the gullies, where stormwater is concentrated. In

most gully areas, exotics usually form 50% to 90% of the shrub and ground cover strata.

- Evidence of erosion and sedimentation impacts.

8.2 Bushland & Aquatic Health Protection Objectives

8.2.1 Objectives

The following hydrological and nutrient control objectives are proposed to protect the site's ecological communities, especially the sensitive and protected communities in the environmental conservation zones of the site. These are based on understanding the impacts of urbanisation on downstream bushland and aquatic health, which were discussed earlier and researching relevant best practice guidelines.

i. Vegetation & Bushland protection:

- Control phosphorus levels in stormwater;
- Control stormwater discharges to below erosive levels; and
- Control the frequency of wetting (for weed control).

ii. Stream health and aquatic protection:

- Control stormwater pollutant loads (gross pollution, suspended solids, phosphorus and nitrogen);
- Reduce the frequency of moderate storms to reduce impact on in-stream biota; and
- Reduce duration of stream bank erosive flows.

8.2.2 Performance Targets

The adopted best practice management measures to mitigate the impacts of increasing the site's imperviousness due to the proposed development should be designed so that a net positive environmental outcome is achieved when compared to the existing condition of the site development.

8.3 Management Strategy

8.3.1 Construction-stage Stormwater Management

Land disturbances within the Wahroonga Estate development site associated with the construction, installation or maintenance of buildings, roads and other infrastructure has the potential for significant levels of soil erosion and consequent sediment pollution of the downstream environments. Detailed strategies, controls and measures should be developed according to relevant Council and state government guidelines before construction within the Wahroonga Estate development site starts to ensure that construction stage erosion and sediment impacts are mitigated. The following principles should be adhered to:

- Limit soil disturbance within the development site where possible;
- Minimise soil erosion resulting from the construction activities over the precinct development site; and
- Protect downstream environments from sedimentation.

8.3.2 Management of Stormwater Discharges

Direct stormwater discharges from new areas within the Wahroonga Estate development site into the surrounding bushland and stream riparian corridors shall incorporate the following measures:

- Disperse all stormwater runoff entering the bushland sufficiently so as not to cause downstream erosion or scour. This can be achieved using a dispersal trench when the soil and geotechnical conditions are suitable.
- If the discharged runoff is concentrated from a large catchment and/or if there is a nearby watercourse or formal drainage path in the bushland, then the discharge point should be extended to that watercourse and measures are taken to ensure all potential erosion and sedimentation impacts are mitigated.

8.3.3 Water Sensitive Urban Design Measures

There are various Water Sensitive Urban Design (WSUD) measures, which utilise a combination of mechanisms that involve physical, chemical and biological processes to remove pollutants, reduce discharged stormwater volume and attenuate flows impacting on the sensitive receiving environments. Such mechanisms include:

- Pollutant removal through processes such as screening, sedimentation, filtration and subsequent chemical and biological transformation of captured pollutants;

- Stormwater capture and reuse, mainly for non-potable water demands within the development;

- Temporary detention of flows, especially those from medium storms that have the potential to hydraulically impact on the aquatic habitat of the receiving streams and erode their banks; and

- Promote stormwater infiltration into the natural ground thus reducing stormwater volume and the frequency of stormwater flows discharged to the sensitive receiving environments. Care should be taken when locating infiltration systems not to adversely impact on the nearby structures such as buildings, retaining walls and carparks.

It should be noted that current best practice WSUD measures take many forms and can be implemented in series or concurrently forming a treatment train approach to stormwater management. In many circumstances, adopting source controls or controls placed at the individual allotment level can be more practical and efficient than larger end of pipe management measures. The correct utilisation of the various components of the treatment train is a vital design consideration and requires a holistic approach to their performance specifications and positions in the treatment train.

Many of the current best practice WSUD measures can potentially utilise multiples of the above-mentioned mechanisms and thus can serve to address a number of the bushland & aquatic health protection objectives. The following WSUD measures can be utilised for hydrological and nutrient management within the Wahroonga Estate site:

i. Gross Pollutant Traps

These devices remove solids typically larger than 5mm such as sediments and litter conveyed by stormwater. They are used as the first treatment elements in a stormwater treatment train and usually are positioned upstream of other more effective treatment measures as a pre-treatment to protect these measures and improve their sustainability and pollutant reduction efficiency.

ii. Bioretention Systems (also known as biofiltration systems or rain-gardens)

They promote the removal of particulate and soluble contaminants by passing stormwater through a filter medium, either for infiltration into surrounding soils, or for collection by an underdrain. Compared to other measures, these systems are usually very effective in removing stormwater pollutants. When designed appropriately, they can provide multiple mechanisms to address a number of bushland and aquatic health protection objectives as follows:

- Provide extended detention as part of the above-ground storage component of the system. This component can be used for flow management benefits such as to attenuate bank-full erosive flows.

- Effectively treat stormwater pollutants such as Total Suspended Solids and nutrients. A range of factors affect the treatment performance of the bioretention systems, including the type and composition of filter media (e.g. loamy sand), the presence and type of vegetation used, and the presence of design enhancements such as the use of a submerged zone to enhance de-nitrification.

- Promoting infiltration of filtered stormwater into the surrounding soils by not lining the base and the sides of the filtration system. This would help to reduce incidents of flow occurrences and return excess stormwater back to its natural water cycle. Earlier investigation indicated that the site is not within high risk salinity impact and its close proximity to bushland and riparian corridors makes infiltration into the site's soil a sustainable practice.

iii. Extended Detention Basins.

These can be incorporated into the Onsite Detention basins usually designed for flood control in new developments by utilising part of the provided storage for extended detention. They specifically target smaller floods (estimated to be 1.5-2 year ARI storm events) that approach or exceed stream bank-full and, thus cause stability and scour problems to the channel form in natural creek systems. More information about this approach can be obtained from the most recent Onsite Stormwater Detention policy and handbook for the Upper Parramatta River Catchment Trust.

iv. Rainwater Tanks

Rainwater tanks can be incorporated into the proposed residential, commercial and hospital buildings within the Wahroonga Estate development site. Roof water is collected in these rainwater tanks for reuse for non-potable demands such as garden watering, irrigation, washdown, coldwater supply of washing machines and toilet flushing. First flush, which usually contains washed-off pollutants from roof areas should be diverted away from these rainwater tanks. Effective use of rainwater tanks can reduce the directly connected impervious area of a catchment, and help to reduce flow incidents and attenuate medium flows to downstream sensitive environments.

v. Wetlands and Ponds

These are usually used as stormwater treatment measures for the removal of fine suspended solids and associated nutrients. They are less efficient (i.e require larger treatment area) than bioretention system in meeting the treatment targets but provide greater visual quality, habitat biodiversity and amenity for the site than bioretention systems. They can be incorporated into OSD systems and provide extended detention and water quality control benefits. Ponds can be used as effective measure for stormwater reuse.

vi. Vegetated Swales

These are open channel systems which use vegetation to aid the removal of sediment and suspended solids with some infiltration into the soil. These systems are often used in association with other stormwater management measures to achieve the required treatment targets.

vii. Porous Paving

Porous paving can be used as a stormwater management device by enabling infiltration and retention of runoff. When applied correctly, they can help to reduce discharged stormwater volume, attenuate flows and improve stormwater quality. Permeable interlocking concrete pavements have been used successfully in Australia. The following issues should be considered to ensure the sustainability and longevity of porous paving systems:

- Geotechnical advice should be obtained and testing carried out where infiltration devices are proposed;
- Permeable pavement should not be placed downstream of sediment sources, unless pre-filtering devices are installed; and
- Care should be taken in the establishment of vegetation and planting density; expert advice should be sought.

8.3.4 Non-structural Stormwater Management Measures

Non-structural stormwater management measures involve techniques that aim to change human behaviour to reduce the amount of pollutants that enter stormwater systems. The main advantages of using non-structural management measures are:

- Long-term sustainability
- Cost-effectiveness
- Minimisation or prevention
- Reducing ongoing operation or maintenance liability
- Effective use of all resources including the community.

Non-structural stormwater management measures mainly include.

i. Development Assessment & Control

Enforcement of the proposed management strategy elements, especially the structural stormwater management measures on developments within the Wahroonga Estate site is the cornerstone of implementing this proposed strategy. It is therefore, proposed that each development within the Wahroonga Estate site should demonstrate that it incorporates best practice WSUD measures to mitigate the impact of increasing the development's impervious areas.

There should be a condition of approval on each development within the Wahroonga Estate site to meet all the bushland and aquatic health protection objectives stated earlier in Section 8.2 of this document and achieve a net positive environmental outcome compared to the existing site development condition. Further demonstration of this condition and how to use available analytical tools for this purpose is presented in Section 4.0 of this document.

ii. Community Education and Participation

Community education and participation can play a significant role in the improvement of stormwater quality. The impact of allowing a can to leak oil, washing paint brushes into drains, not cleaning up after dogs or inappropriate use of household chemicals may seem relatively minor. However, when the individual impacts are added across the catchment, these actions become a significant source of pollution entering the downstream sensitive environments. People are often not aware of the negative impacts of their activities. However, once they are aware and have learnt simple solutions to reduce or avoid causing stormwater pollution, changes to their behaviour are more likely.

Of specific relevance here is the education of the community living and working in the Wahroonga Estate development site through specific programs such as drain stencilling, stormwater education campaigns, involving local schools and residents in the management and monitoring of the local bushland and streams.

iii. Council Management Activities

Local councils can influence the quality of stormwater within a catchment when planning and managing its construction and maintenance activities and during its day to day management decisions. It should be noted that catchments beyond the site boundaries extend into Ku-ring-gai and Hornsby local government areas. These catchments have more impact on the hydrology and water quality of the protected bushland and riparian zones than the local catchments within the site. Table 8.1 lists some council management activities that have a direct or indirect influence on stormwater management of these activities.

Table 8.1 COUNCIL ACTIVITIES AND THEIR POTENTIAL INFLUENCE ON STORMWATER

Council activities	Potential influence on stormwater
Environmental planning	Section 94 for stormwater management
	Stormwater management practices for new developments.
Building approvals and inspection	Soil and water management for building sites
Parks and gardens	Maintenance activities (eg. tree planting, fertiliser application, grass cutting).
Road & drainage system maintenance	Sediment and waste introduction
	Litter and sediment management
Waste collection	Litter management
Road & drainage design	Introduction of WSUD
Finance	Budgets for stormwater management

iv. Wahroonga Estate Development Site Activities

Many of the activities mentioned in point (c) above, are applicable to the individual entities responsible for managing the buildings, assets and infrastructure within the Wahroonga Estate development site. Of particular importance is the issue of long-term maintenance and management of the implemented stormwater management measures, especially the structural measures, which require ongoing resources and expenditure to ensure their sustainability and longevity. The commitment of these entities for ongoing allocation of the required resources and funds should be confirmed and management systems should be in place to ensure the long-term sustainability of this commitment.

8.4 Analytical Evaluation of the Proposed Management Strategy

This section provides analytical evaluation of the proposed best practice WSUD measures, outlined earlier in Section 8.3.3 to assess the effect of using these measures to mitigate the impacts of increasing the site's imperviousness due to the proposed development. It can also be used as a demonstration on how individual developments within the Wahroonga Estate site can be assessed to demonstrate meeting all the bushland and aquatic health protection objectives and achieving a net positive environmental outcome compared to the existing condition of the site development. For this purpose, mathematical modelling using MUSIC (Model for Urban Stormwater

Improvement Conceptualisation) software was undertaken. MUSIC provides the ability to simulate both quantity and quality of runoff from urban catchments

8.4.1 Model set up

A site-specific MUSIC model was set up for the medium density residential zone of Mount Pleasant Precinct (shown in Figure 1), as a demonstration of the Wahroonga Estate's potential development and the effectiveness of the proposed WSUD measures in meeting the bushland and aquatic health protection objectives.

The model, which simulates hydrological and water quality catchment processes and the performance of best practice stormwater management measures included 6-minute simulations for a period of ten years (Jan 1963 – Dec 1972). The following site conditions were modelled:

- Existing condition, which represents the site under existing state of development with mainly single low density house in each lot. The impervious fraction of this case was 46%.

- Proposed development condition, which represent the site under the current approved proposal of medium density zoning with 38 townhouses. The impervious fraction of this case was 64%.

- Proposed development condition with WSUD measures. This represents the site under the current approved medium density zoning while incorporating the following WSUD measures:

    - 1500 L rainwater tank per townhouse to collect roof runoff to be used for irrigation, toilet flushing and coldwater supply of washing machines. This is considered in line with BASIX requirements for residential developments.

    - A bio-retention system with filter area of about 1% of the area of the upstream remaining catchment (other than roof areas). This bioretention system would treat the remaining paved and landscaped areas of the site and the overflow from the rainwater tank. The system would utilise current best practice design elements such as appropriate filter material, effective nutrient removal plants, submerged zone and be without base and side lining to promote infiltration to the surrounding soil.

More information about the MUSIC model details is presented in Appendix D.

Figure 8.1. Location of the Medium Density Residential Zone in Mount Pleasant Precinct

8.4.2 Model results

The results of this modelling exercise are presented below:

i. Existing conditions

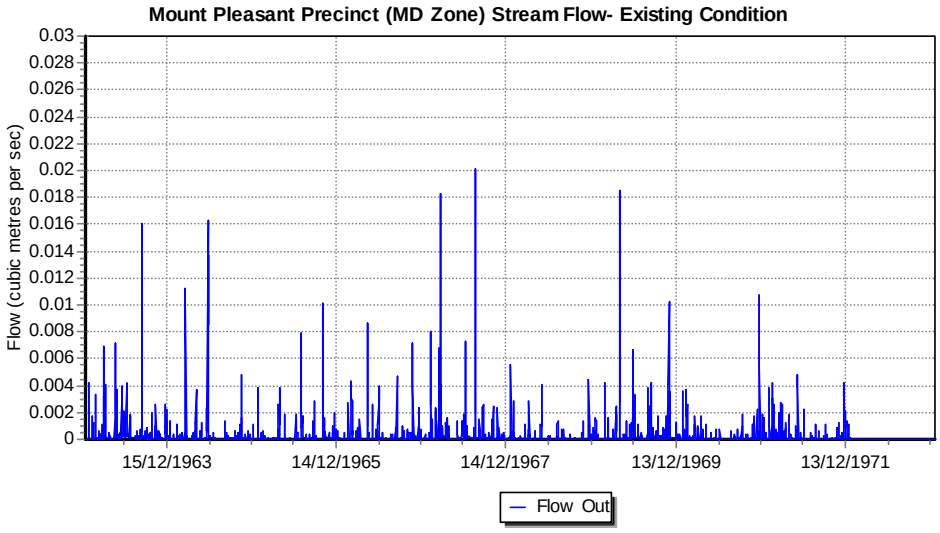
- Average annual flow and pollutant loads from the investigated site under existing conditions are shown below:

Flow (ML/year)	7.81
Total Suspended Solids (kg/year)	1470
Total Phosphorus (kg/year)	2.9
Total Nitrogen (kg/year)	15.6

- An estimated 553 stormwater runoff events over 10 years were calculated for the investigated site under existing conditions.

- The frequency of moderate storm flows, which have greater potential to negatively impact on the receiving stream's ecology (with average daily flow between 0.002 m^3/s and 0.01 m^3/s) was calculated to be 97 events.

- The time-series plot of the average daily outflow from the investigated site for the existing condition is presented below.

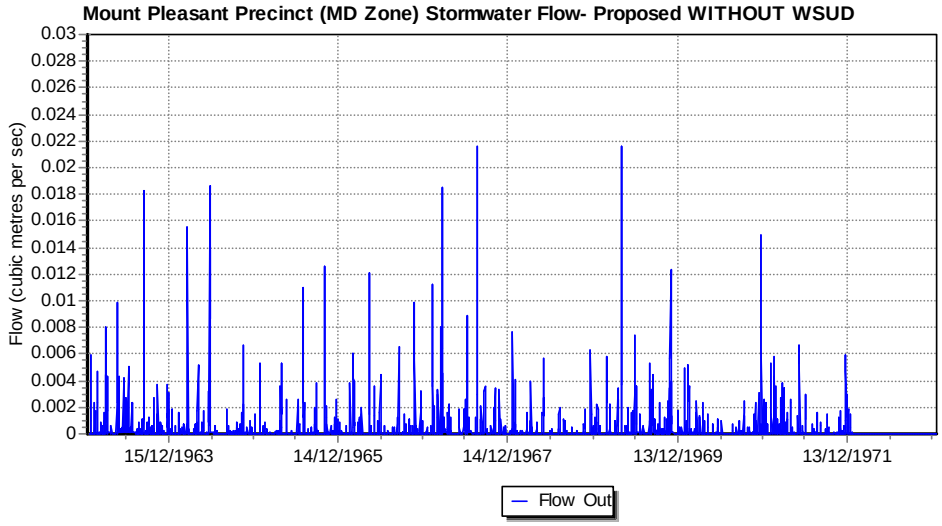


*ii. Proposed Development Conditions **without** Best Practice WSUD Measures.*

- Average annual flow and pollutant loads from the investigated site under proposed development conditions with conventional stormwater drainage (without WSUD measures) are shown below:

Flow (ML/year)	9.91
Total Suspended Solids (kg/year)	1560
Total Phosphorus (kg/year)	3.39
Total Nitrogen (kg/year)	20.5

- An estimated 590 stormwater runoff events over 10 years were calculated for the investigated site under proposed development conditions without WSUD measures.
- The frequency of moderate storm flows, which have greater potential to negatively impact on the plants and animals of the receiving streams (with average daily flow between 0.002 m^3/s and 0.01 m^3/s) was calculated to be 133 events.
- The time-series plot of the average daily outflow from the investigated site for the proposed conditions without WSUD measures is presented below.



*iii. Post-development Conditions **with** Best Practice WSUD Measures.*

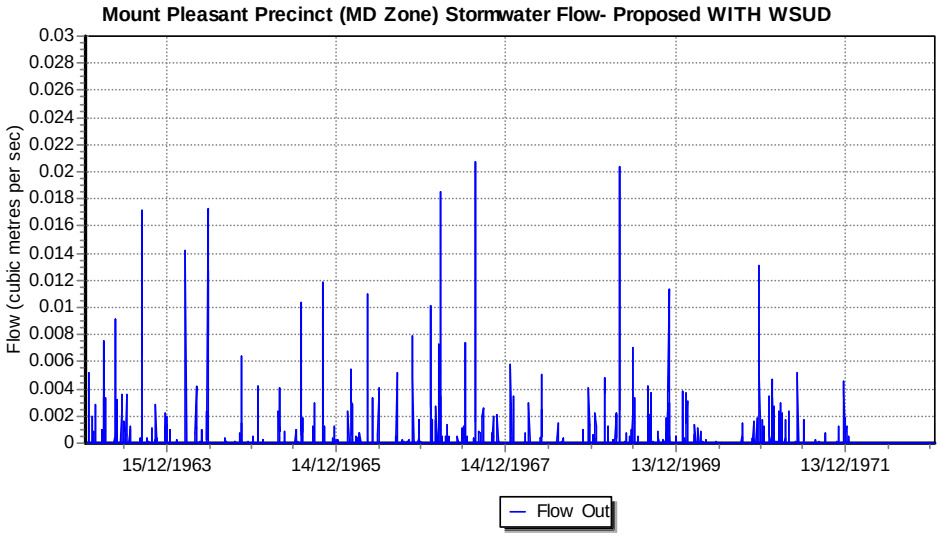
- Average annual flow and pollutant loads from the investigated site under proposed development conditions with WSUD measures are shown below:

Flow (ML/year)	6.06
Total Suspended Solids (kg/year)	330
Total Phosphorus (kg/year)	1.07
Total Nitrogen (kg/year)	10.1

- An estimated 300 stormwater runoff events over 10 years were calculated for the modelled site under post-development conditions with best practice WSUD are incorporated into the stormwater management system.

- The frequency of moderate storm flows, which have greater potential to negatively impact on the plants and animals of the receiving streams (with average daily flow between 0.002 m^3/s and 0.01 m^3/s) was calculated to be 92 events.

- The time-series plot of the average daily outflow from the investigated site for the proposed conditions with WSUD measures is presented below.



8.4.3 Comment

The above results show that:

- There were significant increases in the average flow and pollutant loads from the investigated site under proposed conditions without WSUD measures when compared to the existing development condition (27%, 6%, 17% and 31% increase in average annual flow, TSS, TP and TN respectively). Adopting WSUD measures as described above would substantially reduce average annual stormwater flow and pollutant loads to less than existing levels (22%, 78%, 63% and 35% reduction in average annual flow, TSS, TP and TN respectively);

- The frequency of stormwater discharges from the investigated site under proposed conditions without WSUD measures has increased by 7% compared to the existing development condition, which would increase the potential for weed infestation. Adopting WSUD measures as described above would reduce the

frequency of stormwater discharges significantly (45% reduction compared to the existing conditions); and

- There was significant increase (37% increase) in the frequency of moderate storms from the investigated site under proposed conditions without WSUD measures when compared to the existing development condition, which would increase the potential for hydraulic impact on the receiving stream's ecology. Adopting WSUD measures as described above would reduce the frequency of stormwater discharges to less than the existing levels (5% reduction).

8.4.4 Conclusion

Hydrological and water quality modelling for a medium density development area within the Wahroonga Estate site using MUSIC software was used to analytically evaluate the effect of the proposed management strategy in mitigating the impacts of increasing the site's imperviousness due to the proposed development. The modelling results indicated that under the current proposal for the investigated site, there would be increase in the impervious areas of the site.

If no WSUD measures are adopted, this would result in deteriorating the water quality of runoff from the site, increase in frequency of stormwater discharges and significant increase in the frequency of moderate storms, which would collectively have severe impacts on the downstream ecosystems. However, adopting current best practice WSUD measures of reusing roof water for non-potable water demands, treating stormwater runoff from the rest of the catchment in addition to infiltration of collected stormwater to the surrounding soil would mitigate these potential impacts. These results indicated that all bushland and aquatic health protection targets can be reached and a net positive environmental outcome can be achieved.

8.5 Monitoring and Evaluation

Monitoring and evaluation of the proposed hydrological and nutrient management plan will ultimately allow the assessment of the plan's effectiveness in meeting its objectives. The following monitoring program is proposed:

Table 8.2 MONITORING PROGRAM

Item	Action	Outcomes	Timeframe
1	Review implementation of the proposed structural and non-structural management measures	Develop understanding of the efficiency of implementing the proposed management measures.	Ongoing
2	Review of available water quality information for the natural streams within the site	Better understanding of the status of nutrient and hydrological impacts and identify gaps.	Ongoing

Table 8.2 MONITORING PROGRAM

Item	Action	Outcomes	Timeframe
3	Implement water quality monitoring program (TSS, TP & TN) for the natural streams within the site	Continued data collection and interpretation of nutrient levels	Yearly
4	Involve local community in monitoring the extent and severity of bushland and riparian areas affected by littering, erosion, sedimentation and weed infestation.	Increase awareness of these issues and community participation. Gauge level of progress in tackling these issues.	Quarterly

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Appendix A

Flora Species recorded on the Subject Land from Cumberland Ecology (2009)

Family	Scientific Name	Common Name
Trees		
Aceraceae	*Acer negundo**	Box Elder
	*Archontophoenix cunninghamiana**	Bangalow Palm
	Livistona australis	Cabbage Tree Palm
Bignoniaceae	*Jacaranda mimosifolia**	Jacaranda
Casuarinaceae	*Allocasuarina littoralis*	Black She-oak
	Allocasuarina torulosa	Forest Oak
	Casuarina glauca	Swamp Oak
Cunoniaceae	*Callicoma serratifolia*	Black Wattle
	Ceratopetalum apetalum	Coachwood
Cyatheaceae	*Cyathea australis*	Rough Tree-fern
	Cyathea leichhardtiana	Prickly Treefern
Eleocarpaceae	*Elaeocarpus reticulatus*	Blueberry Ash
Euphorbiaceae	*Glochidion ferdinandii*	Cheese Tree
Fabaceae	*Erythrina X sykesii**	Coral Tree
Lauraceae	*Cinnamomum camphora**	Camphor Laurel
Meliaceae	*Melia azedarach* var. *australasica*	White Cedar
	Synoum glandulosum	Scentless Rosewood
	*Toona ciliata**	Red Cedar
Mimosaceae	*Acacia baileyana*	Cootamundra Wattle
	Acacia decurrens	Black Wattle
	Acacia elata	Cedar Wattle
	Acacia irrorata subsp. *irrorata*	Green Wattle
	Acacia mearnsii	Black Wattle
	Acacia schinoides	-
Moraceae	*Ficus coronata*	Sandpaper Fig
	Ficus superba	Fig Tree
	*Morus alba**	Mulberry
Musaceae	*Musa acuminata**	Banana
Myrtaceae	*Acmena smithii*	Lillypilly
	Angophora costata	Smooth-barked Apple
	Corymbia gummifera	Red Bloodwood
	Eucalyptus crebra	Narrow-leaved Ironbark
	Eucalyptus paniculata subsp. *paniculata*	Grey Ironbark
	Eucalyptus pilularis	Blackbutt

Family	Scientific Name	Common Name
	Eucalyptus piperita subsp. *piperita*	Sydney Peppermint
	Eucalyptus resinifera subsp. *resinifera*	Red Mahogany
	Eucalyptus robusta	Swamp Mahogany
	Eucalyptus saligna	Sydney Blue Gum
	Melaleuca quinquenervia	Broad-leaved Paperbark
	Syncarpia glomulifera	Turpentine
Oleaceae	*Notelaea longifolia*	Mock Olive
	Notelaea ovata	Mock Olive
	Olea europa subsp. *africana**	Common Olive
Pinaceae	*Pinus radiata**	Radiata or Monterey Pine
Pittosporaceae	*Pittosporum undulatum*	Sweet Pittosporum
Proteaceae	*Banksia serrata*	Old Man Banksia
	*Macadamia sp**	
	Xylomelum pyriforme	Woody Pear
Salicaceae	*Salix babylonica**	Weeping Willow
Sapindaceae	*Diploglottis australis*	Native Tamarind
	Guioa semiglauca	Guioa
Simaroubaceae	*Ailanthus altissima**	Tree of Heaven
Sterculiaceae	*Brachychiton acerifolius**	Illawarra Flame Tree
Small Trees		
Mimosaceae	*Acacia maidenii*	Maiden's Wattle
Shrubs		
Apiaceae	*Platysace lanceolata*	Lance-leaf Platysace
	Platysace linearifolia	Narrow-leafed Platysace
	Xanthosia tridentata	Rock Xanthosia
Araceae	*Philodendron* sp. (cultivar)*	-
Araliaceae	*Astrotricha floccosa*	-
	Astrotricha latifolia	Broad-leaf Star-hair
	Polyscias sambucifolia	Elderberry Panax
Asteliaceae	*Cordyline stricta*	Narrow-leaf Palm Lily
Asteraceae	*Ozothamnus diosmifolius*	Ball Everlasting
Caprifoliaceae	*Sambucus australasica*	Yellow Elderberry
Celastraceae	*Maytenus silvestris*	-
Cesalpinioideae	*Senna pendula* var. *glabrata**	-
Cunoniaceae	*Ceratopetalum gummiferum*	Christmas Bush
Epacridaceae	*Dracophyllum secundatum*	-

Family	Scientific Name	Common Name
	Epacris longiflora	Native Fuschia
	Epacris pulchella	NSW Coral Heath
	Leucopogon ericoides	
	Leucopogon juniperinus	Prickly Beard-heath
	Leucopogon lanceolatus	Lance-leaf Beard-heath
	Melichrus procumbens	Jam Tarts
	Monotoca scoparia	Prickly Broom-heath
	Trochocarpa laurina	Tree Heath
	Styphelia laeta subsp. *latifolia*	Five Corners
	Styphelia longiflora	-
	Woollsia pungens	-
Euphorbiaceae	*Micrantheum ericoides*	-
	Omalanthus populifolius	Bleeding Heart
	Phyllanthus hirtellus	Thyme Spurge
	*Ricinus communis**	Castor Oil Plant
Fabaceae	*Bossiaea heterophylla*	Variable Bossiaea
	Bossiaea obcordata	Spiny Bossiaea
	Daviesia ulicifolia	Gorse Bitter Pea
	Dillwynia floribunda var. *floribunda*	Parrot Pea
	Dillwynia retorta var. *retorta*	Eggs and Bacon
	*Genista monspessulana**	Montpellier Broom
	Gompholobium grandiflorum	Golden Glory Pea
	Gompholobium minus	Dwarf Wedge-pea
	Hovea linearis	-
	Indigofera australis	Native Indigo
	Mirbelia rubiifolia	-
	Platylobium formosum subsp. *formosum*	Handsome Flat-pea
	Pultenaea daphnoides	Large-leaf Bush Pea
	Pultenaea stipularis	-
	Pultenaea felxis	-
Faboideae	*Phyllota phylicoides*	Heath Phyllota
Lamiaceae	*Westringia fruiticosa*	Coast Westringia
Malaceae	*Cotoneaster glaucophyllus**	Grey-leaved Cotoneaster
	*Rhaphiolepis indica**	Indian Hawthorn
Mimosaceae	*Acacia echinula*	Hooked Wattle
	Acacia floribunda	Sally Wattle

Family	Scientific Name	Common Name
	Acacia linifolia	Flax Wattle
	Acacia longifolia var. *longifolia*	Sydney Golden Wattle
	Acacia myrtifolia	Red Stem Wattle
	Acacia suaveolens	Sweet Scented Wattle
	Acacia terminalis	Sunshine Wattle
	Acacia ulicifolia	Prickly Moses
Myrsinaceae	*Rapanea variabilis*	Muttonwood
Myrtaceae	*Callistemon salignus*	Willow Bottlebrush
	Kunzea ambigua	Tick Bush
	Leptospermum arachnoides	-
	Leptospermum polygalifolium	Lemon Scented Tea-tree
	Leptospermum trinervium	Flaky-barked Tea-tree
	Melaleuca armillaris	Bracelet Honey Myrtle
Ochnaceae	*Ochna serrulata**	Mickey Mouse Plant
Oleaceae	*Ligustrum lucidum**	Large-leaved Privet
	*Ligustrum sinense**	Small-leaved Privet
Phytolaccaceae	*Phytolacca octandra**	Inkweed
Pittosporaceae	*Pittosporum revolutum*	Yellow Pittosporum
Podocarpaceae	*Podocarpus elatus*	Plum Pine
Polygalaceae	*Comesperma ericinum*	Matchheads
Proteaceae	*Banksia ericifolia* var. *ericifolia*	Heath-leaved Banksia
	Banksia spinulosa var. *spinulosa*	Hairpin Banksia
	Grevillea buxifolia subsp. *buxifolia*	Grey Spider Flower
	Grevillea linearifolia	White Spider Flower
	Grevillea longifolia	Fern-leaved Spider Flower
	Hakea dactyloides	Broad-leaved Hakea
	Hakea sericea	Needlebush
	Isopogon anemonifolius	Flat-leaved Drumsticks
	Lambertia formosa	Mountain Devil
	Lomatia silaifolia	Crinkle Bush
	Persoonia laurina	Laurel Geebung
	Persoonia linearis	Pine-leaved Geebung
	Persoonia levis	Broad-leaved Geebung
	Persoonia pinifolia	Pine-leaved Geebung
	Petrophile pulchella	Conesticks
Rubiaceae	*Opercularia aspera*	Common Stinkweed

Family	Scientific Name	Common Name
	Psychotria loniceroides	-
Rutaceae	*Boronia ledifolia*	Sydney Boronia
	Boronia parviflora	Swamp Boronia
	Zieria pilosa	-
	Zieria smithii	Sandfly Zieria
Santalaceae	*Leptomeria acida*	Native Currant
	Exocarpos cupressiformis	Native Cherry
Sapindaceae	*Dodonaea triquetra*	Hop Bush
Solanaceae	*Lycium ferocissimum**	African Boxthorn
	*Solanum mauritianum**	Wild Tobacco
Sterculiaceae	*Lasiopetalum ferrugineum* var. *ferrugineum*	Rusty Velvet-bush
Theaceae	*Camellia japonica**	Camellia
Theaceae	*Camellia sasanqua**	Camellia
Verbenaceae	*Lantana camara**	Lantana
	*Monstera deliciosa**	Fruit-salad Plant
	Nandina domestica 'Nana'*	Dwarf Sacred Bamboo
Groundcovers		
Acanthaceae	*Brunoniella australis*	Blue Trumpet
	Pseuderanthemum variabile	Pastel Flower
	*Thunbergia alata**	Black-eyed Susan
Adiantaceae	*Adiantum aethiopicum*	Common Maidenhair
	Adiantum formosum	Giant Maidenhair
Amaryllidaceae	*Crinum pedunculatum*	Swamp Lily
Anthericaceae	*Caesia parviflora* var. *parviflora*	Pale Grass Lily
	Thysanotus tuberosus	Fringed Lily
Apiaceae	*Centella asiatica*	Swamp Pennywort
	Hydrocotyle laxiflora	Stinking Pennywort
	Hydrocotyle peduncularis	Pennywort
	Xanthosia pilosa	Woolly Xanthosia
Araceae	*Gymnostachys anceps*	Settlers Flax
Asparagaceae	*Asparagus densiflorus**	Asparagus Fern
	*Protasparagus plumosus**	Climbing Asparagus Fern
	*Asphodelus fistulosus**	Onion Weed
Aspleniaceae	*Asplenium australasicum*	Birds Nest Fern
Asteraceae	*Actinotus minor*	Lesser Flannel Flower
	*Ageratina adenophorum**	Crofton Weed

Family	Scientific Name	Common Name
	*Ageratina riparia**	Mist Flower
	*Bidens pilosa**	Cobbler's Pegs
	Brachycome angustifolia	-
	*Cirsium vulgare**	Spear Thistle
	*Conyza albida**	Fleabane
	*Erigeron karvinskianus**	Mexican Daisy
	Euchiton involucratus	Star Cudweed
	*Gamochaeta americana**	Cudweed
	*Gamochaeta spicata**	Cudweed
	*Hypochaeris radicata**	Flatweed
	*Senecio madagascariensis**	Fireweed
	Sigesbeckia orientalis	Indian Weed
	*Soliva pterosperma**	Bindii
	*Sonchus oleraceus**	Common Sow-thistle
	*Taraxacum officinale**	Dandelion
Blechnaceae	*Blechnum cartilagineum*	Gristle Fern
	Blechnum nudum	-
	Doodia aspera	Rasp Fern
	Doodia caudata var. caudata	
Bromeliaceae	*Bromeliad* sp.*	-
Campanulaceae	*Wahlenbergia gracilis*	Australian Bluebell
Caryophyllaceae	*Stellaria media**	Common Chickweed
Chenopodiaceae	*Einadia hastata*	Berry Saltbush
Commelinaceae	*Commelina cyanea*	Scurvy Weed
	*Tradescantia fluminensis**	Wandering Jew
Convolvulaceae	*Dichondra repens*	Kidney Weed
Cyperaceae	*Carex inversa*	Knob Sedge
	Caustis pentandra	-
	*Cyperus eragrostis**	Umbrella Sedge
	Cyperus sanguinolentus	-
	Gahnia melanocarpa	Black-fruit Saw-sedge
	Gahnia sieberiana	Red-fruited Saw-sedge
	Lepidosperma laterale	Variable Sword-sedge
	Lepidosperma urophorum	-
Davalliaceae	*Nephrolepis cordifolia**	Fish-bone Fern
Dennstaedtiaceae	*Hypolepis muelleri*	Harsh Ground Fern

Family	Scientific Name	Common Name
	Pteridium esculentum	Bracken
Dicksoniaceae	*Calochlaena dubia*	False Bracken
Dilleniaceae	*Hibbertia aspera*	Rough Guinea Flower
	Hibbertia monogyna	-
	Hibbertia diffusa	-
	Hibbertia empetrifolia subsp. uncinata	-
	Hibbertia fasciculata	-
	Hibbertia linearis	-
	Hibbertia obtusifolia	Grey Guinea Flower
Euphorbiaceae	*Euphorbia peplus**	Spurge
	Poranthera microphylla	
Fabaceae	*Medicago polymorpha**	Burr Medic
	*Trifolium repens**	White Clover
Fumariaceae	*Fumaria muralis**	Wall Fumitory
Geraniaceae	*Geranium homeanum*	Northern Cranesbill
Gleicheniaceae	*Sticherus flabellatus*	Umbrella Fern
Goodeniaceae	*Dampiera stricta*	Blue Dampiera
	Goodenia bellidifolia	Daisy-leaved Goodenia
	Goodenia hederacea subsp. *hederacea*	Ivy-leaved Goodenia
	Goodenia heterophylla subsp. *heterophylla*	Variable Leaved Goodenia
Haemodoraceae	*Haemodorum corymbosum*	Bloodroot
	Haemodorum planifolium	Bloodroot
Haloragaceae	*Gonocarpus teucroides*	Raspwort
Iridaceae	*Crocosmia* X *crocosmiiflora**	Montbretia
	Patersonia glabrata	Leafy Purple-flag
	Patersonia sericea	Wild Iris
Juncaceae	*Juncus usitatus*	Common Rush
Lindsaeaceae	*Lindsaea linearis*	Screw Fern
	Lindsaea microphylla	Lacy Wedge-fern
Liliaceae	*Agapanthus praecox**	Agapanthus
Lobeliaceae	*Lobelia alata*	-
	Lobelia dentata	-
	Pratia purpurascens	Whiteroot
Lomandraceae	*Lomandra filiformis* subsp. *coriacea*	Wattle Mat-rush
	Lomandra filiformis subsp. *filiformis*	Wattle Mat-rush
	Lomandra gracilis	

Family	Scientific Name	Common Name
	Lomandra longifolia	Spiky-headed Mat-rush
	Lomandra multiflora	Many-flowered Mat-rush
	Lomandra obliqua	Twisted Mat-rush
Malvaceae	*Sida rhombifolia**	Paddy's Lucerne
Onagraceae	*Epilobium hirtigerum*	Hairy Willow Herb
Orchidaceae	*Acianthus fornicatus*	Pixie Caps
	Cymbidium suave	Native Cymbidium
	Calochilus robertsonii	Purplish Beard Orchid
	Cryptostylis subulata	Large Tongue Orchid
	*Epidendrum ibaguense**	Crucifix Orchid
	Pterostylis grandiflora	Cobra Greenhood
	Pterostylis nutans	Nodding Greenhood
	Pterostylis reflexa	Rusty Hood
Oxalidaceae	*Oxalis corniculata**	Yellow Wood Sorrel
	*Oxalis latifolia**	Pink Fishtail
	Oxalis perrenans	-
Phormiaceae	*Dianella caerulea* var. *assera*	Flax Lily
Phormiaceae	*Dianella prunina*	-
Plantaginaceae	*Plantago lanceolata**	Ribwort
Poaceae	*Aristida vagans*	Three-awn Speargrass
	Austrostipa pubescens	Tall Speargrass
	*Avena fatua**	Wild Oats
	*Briza maxima**	Quaking Grass
	*Briza minor**	Shivery Grass
	*Bromus cartharticus**	Prairie Grass
	*Chloris gayana**	Rhodes Grass
	*Cortaderia selloana**	Pampas Grass
	Cynodon dactylon	Common Couch
	Dichelachne micrantha	Short-hair Plume Grass
	Echinopogon caespitosus var. *caespitosus*	Tufted Hedgehog Grass
	Echinopogon ovatus	Forest Hedgehog Grass
	*Ehrharta erecta**	Panic Veldtgrass
	Entolasia marginata	Bordered Panic
	Entolasia stricta	Wiry Panic
	Eragrostis brownii	Brown's Lovegrass
	*Eragrostis curvula**	African Lovegrass

Family	Scientific Name	Common Name
	Imperata cylindrica var. *major*	Blady Grass
	*Lolium perrenne**	Perennial Ryegrass
	Microlaena stipoides var. *stipoides*	Weeping Rice Grass
	Oplismenus aemulus	Basket Grass
	Oplismenus imbecillis	-
	Panicum simile	Two Colour Panic
	*Paspalum dilatatum**	Paspalum
	*Pennisetum clandestinum**	Kikuyu
	Themeda australis	Kangaroo Grass
Polygonaceae	*Persicaria decipiens*	Slender Knotweed
	Persicaria hydropiper	Water Pepper
	Rumex brownii	Swamp Dock
	*Rumex crispus**	Curled Dock
Polypodiaceae	*Platycerium bifurcatum* subsp. *bifurcatum*	Elkhorn
Primulaceae	*Anagallis arvensis**	Scarlet Pimpernel
Ranunculaceae	*Ranunculus repens**	Creeping Buttercup
Rosaceae	*Duchesna indica**	Wild Strawberry
Rubiaceae	*Galium aparine**	Cleavers
Rubiaceae	*Pomax umbellata*	Pomax
Rutaceae	*Leionema dentatum*	
Schizaeaceae	*Schizaea bifida*	Forked Comb-fern
Scrophulariaceae	*Veronica plebia*	Creeping Speedwell
Sinopteridaceae	*Cheilanthes sieberi* subsp. *sieberi*	Poison Rock Fern
Solanaceae	*Solanum aviculare*	Kangaroo Apple
	*Solanum nigrum**	Black Nightshade
	Solanum prinophyllum	Forest Nightshade
	*Solanum pseudocapsicum**	-
Stackhousiae	*Stackhousia viminea*	-
Strelitzeaceae	*Strelitzea juncea**	Bird of Paradise
Stylidiaceae	*Stylidium graminifolium*	Trigger Plant
Thelypteridaceae	*Christella dentata*	-
Thymelaeaceae	*Pimelea linifolia* subsp. *linifolia*	Slender Rice Flower
Typhaceae	*Typha orientalis*	Cumbungi
Verbenaceae	*Verbena bonariensis**	Purpletop
	*Verbena rigida**	Veined Verbena
Violaceae	*Viola betonicifolia*	-

Family	Scientific Name	Common Name
	Viola hederacea	Ivy-leaved Violet
Xanthorrhoaceae	*Xanthorrhoea arborea*	Broad-leaf Grass Tree
	Xanthorrhoea media subsp. *media*	Forest Grass Tree
Climbers		
Araliaceae	*Hedera helix**	English Ivy
Asclepiadaceae	*Araujia hortorum**	Mothvine
	Marsdenia suaveolens	Scented Marsdenia
	Tylophora barbata	Bearded Tylophora
Bignoniaceae	*Pandorea pandorana*	Wonga Vine
Caprifoliaceae	*Lonicera japonica**	Japanese Honeysuckle
Convolvulaceae	*Ipomoea indica**	Coastal Morning Glory
Dilleniaceae	*Hibbertia dentata*	Twining Guinea Flower
Fabaceae	*Desmodium varians*	-
	Glycine clandestina	Twining Glycine
	Glycine microphylla	-
	Glycine tabacina	Twining Glycine
	Hardenbergia violacea	False Sarsparilla
	Kennedia rubicunda	Dusky Coral Pea
	Vicia sativa subsp. *sativa**	Common Vetch
	*Wisteria sinensis**	Wisteria
Lauraceae	*Cassytha glabella* forma *glabella*	Slender Devil's Twine
	Cassytha pubescens	Common Devil's Twine
Luzuriagaceae	*Eustrephus latifolius*	Wombat Berry
	Geitonoplesium cymosum	Scrambling Lily
Menispermiaceae	*Sarcopetalum harveyanum*	Pearl Vine
	Stephania japonica var. *discolor*	Snake Vine
Passifloraceae	*Passiflora edulis**	Common Passionfruit
Pittosporaceae	*Billardiera scandens* var. *scandens*	Apple Dumplings
Polygalaceae	*Comesperma volubile*	Love Creeper
Ranunculaceae	*Clematis aristata*	Old Man's Beard
Rubiaceae	*Morinda jasminoides*	-
Rosaceae	*Rubus parvifolius*	Native Raspberry
Smilacaceae	*Smilax australis*	Lawyer Vine
	Smilax glyciphylla	Sarsaparilla
Vitaceae	*Cissus antarctica*	Native Grape
	Cissus hypoglauca	Water Vine

Appendix B

Fauna Species recorded on the Subject Land from Cumberland Ecology (2009)

Table B.1 BIRD SPECIES LOCATED ON THE SUBJECT SITE IN PREVIOUS SURVEYS

Common name	Scientific name
Masked Lapwing	*Vanellus miles*
Spotted Turtle-Dove	*Streptopelia chinensis*
Crested Pigeon	*Ocyphaps lophotes*
Sulphur-crested Cockatoo	*Cacatua galerita*
Long-billed Corella	*Cacatua tenuirostris*
Galah	*Cacatua roseicapilla*
Rainbow Lorikeet	*Trichoglossus haematodus*
Australian King-Parrot	*Afsterus scapularis*
Crimson Rosella	*Platycerous elegans*
Eastern Rosella	*Platycercus eximius*
Powerful Owl [TS]	*Ninox strenua*
Tawny Frogmouth	*Podargus strigoides*
Southern Boobook	*Ninox novaeseelandiae*
Common Koel	*Eudynamys scolopacea*
Dollarbird	*Eurystomus orientalis*
Laughing Kookaburra	*Dacelo novaeguineae*
White-throated Treecreeper	*Cormobates leucophaeus*
Olive-backed Oriole	*Oriolus sagittatus*
Noisy Miner	*Manorina melanocephala*
Red Wattlebird	*Anthochaera carunculata*
Little Wattlebird	*Anthochaera chrysoptera*
Lewin's Honeyeater	*Meliphaga lewinii*
White-eared Honeyeater	*Lichenostomus leucotis*
Scarlet Honeyeater	*Myzomela sanguinolenta*
Eastern Spinebill	*Acanthorhynchus tenuirostris*
Brown Thornbill	*Acanthiza pusilla*
Buff-rumped Thornbill	*Acanthiza reguloides*
Spotted Pardalote	*Pardalotus punctatus*
Eastern Yellow Robin	*Eopsaltria australis*
Grey Fantail	*Rhipidura fuliginosa*
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*
White-browed Scrubwren	*Sericornis frontalis*
Welcome Swallow	*Hirundo neoxena*

Table B.1 BIRD SPECIES LOCATED ON THE SUBJECT SITE IN PREVIOUS SURVEYS

Common name	Scientific name
Grey Butcherbird	*Cracticus torquatus*
Pied Currawong	*Strepera graculina*
Spangled Drongo	*Dicrurus bracteatus*
Australian Magpie	*Gymnorhina tibicen*
Australian Raven	*Corvus coronoides*
Satin Bowerbird	*Ptilonorhynchus violaceus*
Red-browed Finch	*Neochmia temporalis*
Superb Fairy-wren	*Malurus cyaneus*
Common Myna *	*Acridotheres tristis*
Common Starling *	*Sturnus vulgaris*
Red-whiskered Bulbul *	*Pycnonotus jocosus*

Notes: [TS] *indicates Threatened Species, * indicates Introduced Species*

Table B.2 AMPHIBIAN AND REPTILE SPECIES LOCATED ON THE SUBJECT SITE IN PREVIOUS SURVEYS

Common name	Scientific name
AMPHIBIANS	
Striped Marsh Frog	*Limnodynastes peronii*
Green Leaf Tree Frog	*Litoria phylochroa*
Common Eastern Froglet	*Crinia signifera*
REPTILES	
Garden Skink	*Lampropholis guichenoti*
Red-Bellied Black Snake	*Pseudechis porphyriacus*
Blue Tongue Lizard	*Tiliqua nigrolutea*
Eastern Water Dragon	*Physignathus lesueurii*
Eastern Water Skink	*Eulamprus quoyii*

Table B.3 MAMMAL SPECIES LOCATED ON THE SUBJECT SITE IN PREVIOUS SURVEYS

Common name	Scientific name
Gould's Wattled Bat	*Chalinolobus gouldii*
Eastern False Pipistrelle TS	*Falsistrellus tasmaniensis*
Grey-Headed Flying-fox TS	*Pteropus poliocephalus*
Cat *	*Felis cattus*
European Red Fox *	*Vulpes vulpes*
Brushtail Possum	*Trichosurus vulpecula*
Common Ringtail Possum	*Pseudocheirus peregrinus*
Brown Rat *	*Rattus norvegicus*
Black Rat*	*Rattus rattus*

*Note: * indicates introduced species.*

Appendix C

Planting List

Table C.1 Sydney Turpentine Ironbark Forest Planting List

Scientific Name	Common Name	Height (m)	Density (units/m2)	Comments
Canopy Trees (> 20 m)				
Angophora costata	Smooth-barked Apple	30	1/20m2	
Angophora floribunda	Rough-barked Apple	20-30	1/20m2	Plant in gaps in canopy – moist, deep soils
Corymbia gummifera	Red Bloodwood	30	1/20m2	
Eucalyptus acmenoides	White Mahogany	30	1/20m2	
Eucalyptus globoidea	White Stringybark	30	1/20m2	
Eucalyptus paniculata	Grey Gum	30	1/20m2	
Syncarpia glomulifera	Turpentine	25	1/20m2	Plant in moist, well drained soils: attractive in groves
Sub-Canopy/Small Trees and Large Shrubs (>6m)				
Acacia decuurens	Black Wattle	6-10	1/8m2	Early pioneer species
Acacia implexa	Hickory Wattle	2-12	1/10m2	Early pioneer species
Acacia longifolia		8	1/10m2	Early pioneer species
Acacia parramatensis	Parramata Wattle	2-10	1/10m2	Early pioneer species
Allocasuarina torulosa	Forest Oak	8	1/8m2	Plant in groves 3 – 5 units
Clerodendrum tomentosum	Hairy Clerodendrum	1-10	1/8m2	
Elaeocarpus reticulatus	Blueberry Ash	10	1/10m2	Ornamental species: attracts birds: sheltered sites only
Notelaea longifolia	Native Olive	2-9	1/8m2	Slow growing

Table C.1 Sydney Turpentine Ironbark Forest Planting List

Scientific Name	Common Name	Height (m)	Density (units/m2)	Comments
Shrubs				
Acacia falcata		2-5	1/8m2	Early pioneer species
Breynia oblongifolia	Breynia	2	1/1m2	Suckers well & will stabilise banks or slopes
Clerodendrum tomentosum	Hairy Clerodendrum	2-4	1/1m2	Understorey species: shade
Daviesia ulicifolia	Gorse Bitter Pea	2	1/1m2	
Dodonaea triquetra	Hop-bush	3	1/1m2	
Indigofera australis	Indigofera	1.5	1/1m2	Loose open habit: plant in filtered sunlight, in groves
Kunzea ambigua	Tick Bush	3.5	1/1m2	
Leucopogon juniperinus	White Beard-heath	To 1	1/1m2	Tolerates very dry soils
Pittosporum revolutum	Rough-fruited Pittosporum	2	1/4m2	Small shrub with colourful fruit: landscape candidate
Polyscias sambucifolia	Elderberry Panax	2	1/1m2	Shady sites under canopy
Rapanea variabilis	Mutton Wood	3	1/4m2	Hardy pioneer, although slow to grow to maturity
Zieria smithii	Sandfly Zieria	1.5	1/1m2	Small shrub with open habit
Ground covers				
Aristida vagans	Three awned Speargrass	0.8	4/1m2	prefers light
Austrostipa pubescens		1.5	4/1m2	prefers light
Centella asiatica	Centella	N/A	1 divot / 5 m2	Creeping herb: widespread Transplant : use divots
Cheilanthes sieberi		0.25	1/5m2	

Table C.1 Sydney Turpentine Ironbark Forest Planting List

Scientific Name	Common Name	Height (m)	Density (units/m2)	Comments
Clematis aristata	Old Man's Beard	6	1/5m2	
Clematis glycinoides	Headache Vine	6	1/5m2	Can get rampant: prune to contain as required
Commelina cyanea	Scurvy Weed	N/A	1 divot / 5 m2	Transplant : use divots
Dianella caerulea, D. revoluta	Blue Flax Lily	<1	1/5m2	Hardy: mass plant in high light situations: landscaped garden beds
Echinopogon caespitosus	Hedgehog Grass	0.5	4/1m2	High light levels required: edge sites and gaps only
Entolasia marginata	Bordered Panic Grass	< 0.20	4/1m2	Shade tolerant: very common
Entolasia stricta	Wiry Panic	< 0.20	4/1m2	Shade tolerant
Hardenbergia violacea	False Sarsaparilla		1/5m2	Hardy: mass plant in high light situations: landscaped garden beds: edges & slopes
Glycine clandestina			1/5m2	
Goodenia heterophylla	Variable Goodenia	0.2-0.3	1/5m2	
Kennedia rubicunda	Dusky Coral Pea	N/A	1/8-10m2	Vigorous: may need cutting back: plant small numbers: use on slopes/embankments
Lepidosperma laterale		0.3-1	4/1m2	
Lomandra longifolia	Spiny Mat-rush	1.5	3-4/1m2	Line watercourses: landscaped garden beds: edge sites: earthen bund
Microlaena stipoides	Weeping Meadow Grass	0.5	4/1m2	Damp shady sites only
Oplismenus aemulus	Basket Grass	< 0.20	4/1m2	Widespread in shady/damp soils: transplant plugs or allow to volunteer into site naturally

Table C.1 Sydney Turpentine Ironbark Forest Planting List

Scientific Name	Common Name	Height (m)	Density (units/m2)	Comments
Oxalis exilis		< 0.20	4/1m2	
Poa affinis	A tussock grass	0.6-1.20	4/1m2	Plant in clumps among other ground covers
Pseuderanthemum variabile	Blue Pastel Flower	0.1-0.3	4/1m2	Delicate ground cover: will not withstand foot traffic
Smilax glyciphylla	Sweet Sarsparilla	5	1/8-10m2	
Themeda australis	Kangaroo Grass	1	4/1m2	High light levels required: plant on edge sites: mass plant along pathways etc: landscaped garden beds
Tylophora barbata	Tylophora	N/A	4/1m2	Sprawler/ scrambler: slopes or embankments

Table C.2 Sydney Sandstone Gully Forest Planting List

Scientific Name	Common Name	Height (m)	Density (units/m2)	Comments
Canopy Trees (> 20 m)				
Angophora costata	Smooth-barked Apple	30	1/20m2	
Corymbia gummifera	Red Bloodwood	30	1/20m2	Plant in drier areas
Eucalyptus paniculata	Grey Gum	30	1/20m2	
Eucalyptus piperita	Sydney Peppermint	31	1/20m3	
Eucalyptus saligna	Sydney Blue Gum	30	1/20m2	Plant in gaps in canopy – moist, deep soils
Syncarpia glomulifera	Turpentine	25	1/20m2	Plant in moist, well drained soils: attractive in groves
Tristaniopsis laurina	River Gum	up to 30	1/20m2	Plant along creek bank
Sub-Canopy/Small Trees and Large Shrubs (>6m)				
Allocasuarina littoralis	Black She Oak	8		Plant in groves 3 – 5 units
Allocasuarina torulosa	Forest Oak	8	1/8m2	Plant in groves 3 – 5 units
Ceratopetalum apetalum	Christmas Bush	8-10	1/8m2	
Elaeocarpus reticulatus	Blueberry Ash	4-10	1/8m2	Grows in a variety of conditions
Glochidion ferdinandi	Cheese Tree	4-8	1/8m2	Early pioneer species
Omalantbus populifolius	Bleeding Heart Tree	1-8	1/8m2	Pioneer species useful for re-establishment of community
Shrubs				

Table C.2 Sydney Sandstone Gully Forest Planting List

Scientific Name	Common Name	Height (m)	Density (units/m2)	Comments
Acacia floribunda	Sally Wattle	2-4	1/4m2	Early pioneer species
Acacia terminalis	Sunshine Wattle	1.5	1/4m2	Early pioneer species
Backhousia myrtfolia	Grey Myrtle	3-4	1/4m2	Plant beside streams
Banksia serrata		4-8	1/4m2	
Callicoma serratifolia	Blackwattle	4-15	1/8m2	Plant in gullies and wet places
Clerodendrum tomentosum	Hairy Clerodendrum	2-4	1/4m2	Understorey species: shade
Dodonaea triquetra	Hop-bush	3	1/1m2	
Leptospermum polygalifolium	Yellow Tea-tree	2.5	1/1m2	
Leucopogon juniperinus	White Beard-heath	To 1	1/1m2	Tolerates very dry soils
Persoonia linearis	Narrow-leaved Geebung	3	1/4m2	
Pittosporum revolutum	Rough-fruited Pittosporum	2	1/4m2	Small shrub with colourful fruit: landscape candidate
Polyscias sambucifolia	Elderberry Panax	2	1/1m2	Shady sites under canopy
Pultenaea flexilis	Graceful Bush-pea	4	1/4m2	
Zieria smithii	Sandfly Zieria	1.5	1/1m2	Small shrub with open habit
Ground covers				
Adiantum aethiopicum	Common Maidenhair	To 0.2	1/4m2	
Blechnum cartilagineum	Gristle Fern	0.5	1/1m2	Moist, sheltered locations: may be hard to establish.
Calochlaena dubia	False Bracken Fern	1.5	1/1m2	As above: may be hard to buy commercially (transplant?)

Table C.2 Sydney Sandstone Gully Forest Planting List

Scientific Name	Common Name	Height (m)	Density (units/m2)	Comments
Cisus antartica	Kangaroo Grape	N/A	Occasional	Robust climber, can smother trees at forest edges. Ideal as weed barrier
Cissus hypoglauca	Water Vine	N/A	Occasional	Robust climber, can smother trees at forest edges. Ideal as weed barrier
Clematis glycinoides	Old Man's Beard		1/5m2	Can get rampant: prune to contain as required
Commelina cyanea	Scurvy Weed	N/A	1 divot / 5 m2	Transplant : use divots
Dianella caerulea, D. revoluta	Blue Flax Lily	<1	1/5m2	Hardy: mass plant in high light situations: landscaped garden beds
Echinopogon caespitosus	Hedgehog Grass	0.5	4/1m2	High light levels required: edge sites and gaps only
Entolasia marginata	Bordered Panic Grass	< 0.20	< 0.2	Shade tolerant: very common
Eustrephus latifolius	Wombat Berry	N/A	Occasional	Delicate scrambler
Hardenbergia violacea	False Sarsaparilla		1/5m2	Hardy: mass plant in high light situations: landscaped garden beds: edges & slopes
Kennedia rubicunda	Dusky Coral Pea	N/A	1/8-10m2	Vigorous: may need cutting back: plant small numbers: use on slopes/embankments
Lomandra longifolia	Spiny Mat-rush	1.5	3-4/1m2	Line watercourses: landscaped garden beds: edge sites: earthen bund
Microlaena stipoides	Weeping Meadow Grass	0.5	4/1m2	Damp shady sites only

Appendix D

MUSIC Model

6 minute interval pluviograph data were used from the nearest BoM stations to the site. Pluviograph record from Wahroonga Reservoir (Station no. 66063) from 1st January 1963 through until 31 December 1972 was selected for the MUSIC modelling because this period had an average annual rainfall of 1034mm, which is closest to the average annual rainfall for the Wahroonga Estate.

The following input parameters were used (Music Modelling Guidelines for South East Queensland- Draft Dec 2009):

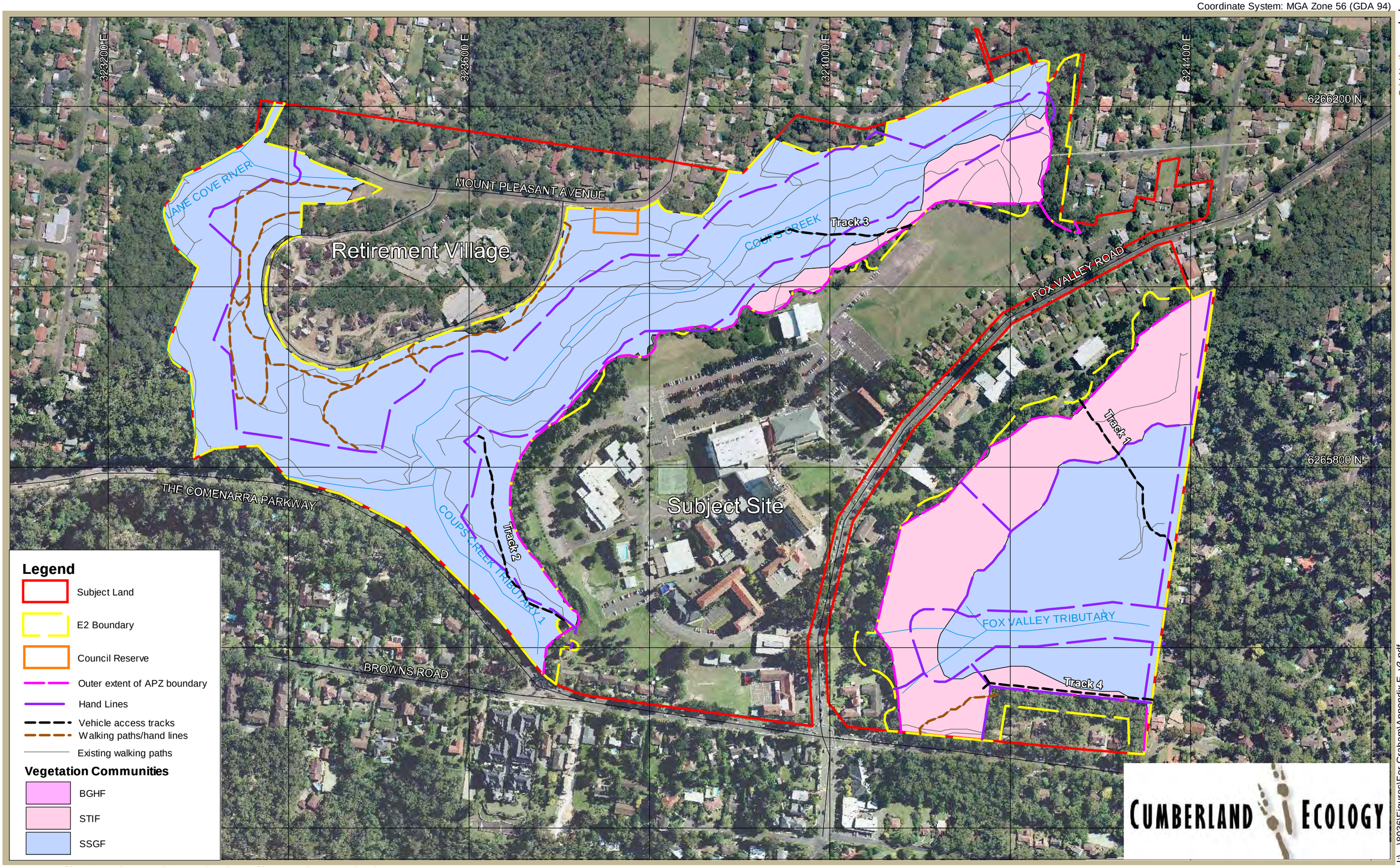
	Storm Flow						Base Flow					
	Total Suspended Solids		Total Phosphorus		Total Nitrogen		Total Suspended Solids		Total Phosphorus		Total Nitrogen	
Land Use	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
(all values expressed as log_{10}mg/l												
Open space/ pervious areas	2.18	0.39	-0.47	0.31	0.26	0.23	1	0.34	-0.97	0.31	0.2	0.2
Road/impervious areas	2.43	0.39	-0.3	0.31	0.26	0.23	1	0.34	-0.97	0.31	0.2	0.2
Roofs	1.3	0.39	-0.89	0.31	0.26	0.23	N/A	N/A	N/A	N/A	N/A	N/A

Note: SD = Standard Deviation

Appendix E

Plan of Fire Trails, Tracks and Control Lines

Coordinate System: MGA Zone 56 (GDA 94)



Appendix E. Plan of Tracks/Trails and Hand Lines

100 0 100 200 300 400 m

Appendix F

Plan of Fuel Management Zones

Coordinate System: MGA Zone 56 (GDA 94)

323200 E
323600 E
324000 E
324400 E
6266200 N
6265800 N
Grid North

Retirement Village
Subject Site
MOUNT PLEASANT AVENUE
THE COMENARRA PARKWAY
BROWNS ROAD
FOX VALLEY ROAD
LANE COVE RIVER
COUSINS PENINSULA CREEK
FOX VALLEY TRIBUTARY
COUSINS PENINSULA CREEK

APZ 1
APZ 2
APZ 3
APZ 4
APZ 5
APZ 6
APZ 8
APZ 9
APZ 10
APZ 11
HMZ
SFMZ 1
SFMZ 2
SFMZ 3
SFMZ 4
SFMZ 5
SFMZ 6
SFMZ 7
SFMZ 8
SFMZ 9
SFMZ 10
SFMZ 11
SFMZ 12
SFMZ 13
SFMZ 14
SFMZ 15
SFMZ 16
SFMZ 17
Track 1
Track 2
Track 3
Track 4

Legend

- Subject Land
- E2 Boundary
- Council Reserve
- Outer extent of APZ boundary
- Hand Lines
- Walking paths/hand lines
- Vehicle access tracks
- Exisitng walking paths

Vegetation Communities

- BGHF
- STIF
- SSGF

CUMBERLAND ECOLOGY

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Appendix F. Fuel Management Plan

100 0 100 200 300 400 m