TRANSPORT FOR NSW

DECEMBER 2021

PUBLIC

OPTIONS TO REDUCE KOALA VEHICLE STRIKE ALONG HEATHCOTE ROAD, NEAR DEADMANS CREEK

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Options to reduce Koala vehicle strike along Heathcote Road, near Deadmans Creek

Transport for NSW

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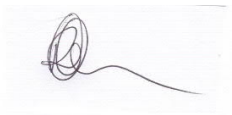
Reviewed by:	Rodney van der Ree	13.12.2021	
Approved by:	Alex Cockerill	13.12.2021	

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ABBREVIATIONS

BAM	Biodiversity Assessment Methodology (2020)
BC Act	NSW *Biodiversity Conservation Act 2016*
Defence	Department of Defence
DPIE	NSW Department of Planning, Industry and Environment
DPI	Department of Primary Industries
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
GLALC	Gandangara Local Aboriginal Lands Council
LCC	Liverpool City Council
PCT	Plant Community Type
NPA	National Parks Association of NSW
NPWS	NSW National Parks and Wildlife Service
PKFT	Preferred koala food tree
SCC	Sutherland Shire Council
TfNSW	Transport for New South Wales
WVC	Wildlife-vehicle collision

EXECUTIVE SUMMARY

One of the commitments of the NSW Koala Strategy 2018-21 is to improve the safety and health of koala populations by 'fixing priority koala roadkill hotspots across NSW'. In consultation with NSW National Parks and Wildlife Service, Sutherland Shire Council (SCC), Liverpool City Council (LCC), Department of Defence and Gandangara Local Aboriginal Lands Council, Transport for NSW (TfNSW) and Department of Planning, Industry and Environment (DPIE) are investigating options to reduce koala vehicle-strike along Heathcote Road, near Deadmans Creek, in south-western Sydney. The options assessment is not funded through the NSW Koala Strategy.

WSP has been engaged by TfNSW to develop mitigation options that could be implemented to reduce koala vehicle-strike on Heathcote Road, near Deadmans Creek.

To achieve this, the following was undertaken:

- a review of relevant and available background information
- field survey to validate vegetation mapping and determine the nature and condition of vegetation within the study area
- site visit with relevant stakeholders (DPIE, TfNSW, Southern Sydney Branch of National Parks Association of NSW, LCC, Sutherland Shire Environment Centre and Sandy Point residents)
- assessment of koala habitat around Deadmans Creek and predicted used of the locality by koalas
- identification of potential mitigation locations and options, and a qualitative assessment of the various mitigation options.

Information collected during the desktop assessment and field survey was used in the mitigation option assessment.

The feasible options for reducing koala vehicle strike along Heathcote Rd are limited to the installation of fauna fencing and improving the conditions of the existing bridge over Deadmans Creek. The main differences in the various options relate to the length of fauna fencing proposed and how the fence ends are treated.

The main options assessed included:

- **Option 1**: Fencing Heathcote Rd road reserve (including fencing above the rock cutting near St George Crescent), improving the conditions of the Deadmans Creek bridge underpass and installing a koala grid on St George Crescent.
- **Option 2**: Install shorter lengths of fauna fence along the road reserve of Heathcote Road (north-west of the bridge) and utilising existing Defence fence (some of which may need to be modified), improving the conditions of the Deadmans Creek bridge underpass and installing a koala grid on St George Crescent.
- **Option 3**: Install shorter lengths of fauna fence along the road reserve of Heathcote Road to avoid impacts to land mapped as coastal wetlands under the Coastal Management SEPP 2018, and improving the conditions of the Deadmans Creek bridge underpass and installing a koala grid on St George Crescent.
- **Option 4**: Extension of fencing along Heathcote Rd up to the Quarry entrance. This can be applied to any of the options and where appropriate, existing Defence fencing would be used (some of which may need to be modified).

Based on the outcomes of the qualitative options assessment the highest scoring option is Option 2. Option 2 is also consistent with 'How to keep koalas off the road – Koala vehicle strike factsheet 2' (DPIE, 2020b), as long, uninterrupted sections of fauna fencing used in conjunction with crossing structures such as bridges are proven to be effective for mitigating koala vehicle strike.

1 BACKGROUND

1.1 CONTEXT

The NSW Koala Strategy 2018-21 is part of a long-term vision to stabilise and then increase the koala population across the State. The strategy supports a range of conservation actions that will provide more habitat for koalas, support local community action, improve koala health and safety, and increase knowledge to improve koala conservation.

The installation of koala exclusion fencing along Picton Road in south-west Sydney to address two known koala vehicle-strike hotspots as part of the Koala Strategy announced in 2019, and ongoing monitoring has shown koalas using existing underpasses to cross Picton Road safely (DPIE, 2020b).

Local evidence shows koalas are killed by vehicle strike on Heathcote Road, particularly near Deadmans Creek. The site was not identified in a 2019 TfNSW statewide analysis of koala vehicle strike hotspots. The southern Sydney branch of the National Parks Association have submitted information to DPIE and TfNSW that shows the site is likely a local priority and is of concern amongst local environmental community groups. Further state-wide analysis will be undertaken by TFNSW and DPIE to assess whether the site is a statewide priority.

In consultation with NSW National Parks and Wildlife Service (NPWS), Sutherland Shire Council (SSC), Liverpool City Council (LCC), Department of Defence (Defence) and Gandangara Local Aboriginal Lands Council (GLALC), TfNSW and DPIE are investigating options to reduce koala vehicle-strike along Heathcote Road, near Deadmans Creek, in south-western Sydney.

This report provides an assessment of proposed mitigation measures designed to minimise koala vehicle-strike in this locality.

1.2 OBJECTIVES AND SCOPE

This project aimed to develop mitigation options to be considered by government and local councils that could be implemented to reduce koala vehicle-strike on Heathcote Road, near Deadmans Creek.

Specifically, the project aimed to:

- reduce koala vehicle-strike through the implementation of mitigation options recommended
- reduce the barrier effects of Heathcote Road and enhance regional connectivity for fauna movement, through the implementation of options that promote safe passage in known wildlife corridors.

To achieve these aims, the following scope was undertaken for this options assessment report:

- a review of relevant and available background information
- field survey to validate vegetation mapping and determine the nature and condition of vegetation within the study area
- site visit with relevant stakeholders (DPIE, TfNSW, NPA, LCC, GLALC, NPWS and Sutherland Shire Environment Centre and Sandy Point residents)
- assessment of koala habitat around Deadmans Creek and predicted used of the locality by koalas
- identification of potential mitigation locations and options, and a qualitative assessment of the various mitigation options.

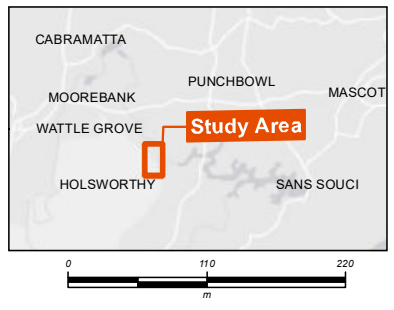
Options to reduce Koala vehicle strike along Heathcote Road

Figure 1.1
Study Area

PLEASURE POINT ROAD
PLEASURE POINT
PICNIC POINT
GEORGES RIVER
BINGARA DRIVE
GAMBIER AVENUE
ST GEORGE CRESCENT
DEADMANS CREEK
SANDY POINT
CARINYA ROAD
HOLSWORTHY
MENAI
HEATHCOTE ROAD

Legend

- Watercourses
- Cadastre
- Road Corridor
- Study Area
- NPWS Reserve
- Defence Area



Coordinate System: GDA2020 MGA Zone 56

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2 METHODOLOGY

The following methods have been undertaken in the preparation of this report. All work was carried out under the appropriate licences, including a scientific licence as required under Part 2 of the BC Act (License Number: SL100630) and an Animal Research Authority issued by the DPI (Agriculture).

The contributors to the preparation of this report, their qualifications and roles are provided in Table 2.1 below.

Table 2.1 Personnel

NAME	QUALIFICATIONS	POSITION	ROLE
Josie Stokes	Bachelor of Science (Conservation Zoology)	Principal Ecologist	Project Manager Reporting Field Survey
Debbie Landenberger	Bachelor of Science (Hons); Accredited BAM Assessor (BAAS 18187)	Principal Ecologist	Reporting and field survey
Alex Cockerill	Bachelor of Science (Hons) Accredited BAM Assessor (BAAS17020)	National Team Executive - Ecology	Technical review
Dr Rodney van der Ree	Bachelor of Science (Hons) Doctor of Philosophy, Deakin University	National Technical Executive - Ecology	Technical expert
David Naiken	Bachelor of Environmental Science (Major GIS). Masters of Climate Change	GIS consultant	Mapping and data management

2.1 DESKTOP ASSESSMENT

A desktop assessment was undertaken to inform potential options to reduce koala vehicle collisions along Heathcote Road, near Deadmans Creek. This involved a review of relevant and available background information about the local koala population, movement corridors, and availability of habitat and resources within the locality and region including:

- SEED Koala Corridors in south-west Sydney (DPIE, 2021b)
- BioNet Atlas of NSW Wildlife – NSW Department of Planning, Industry and Environment (DPIE, 2021)
- NSW Environment, Energy and Science Vegetation Types Database.
- Conserving Koalas in the Wollondilly and Campbelltown LGAs (DPIE, 2019)
- Koala Corridor Project Campbelltown City Council and Wollondilly LGAs (Biolink, 2018)
- Planning Guidelines for Koala conservation and recovery- a guide to best planning practice (McAlpine et al, 2007)
- Koala-sensitive Design Guideline (DES, 2019)
- Koala vehicle strike methodology (TfNSW, 2019)
- Existing broad-scale vegetation maps of the local area.
- Topographic maps and aerial photographs.

A likelihood of occurrence has not been undertaken for threatened flora or fauna species with the potential to occur within the study area as the planning pathway has not yet been determined. A full list of threatened flora and fauna species predicted to occur within the locality is outlined in the Heathcote Road Bridge Widening Biodiversity Assessment Report (TfNSW, 2020).

2.2 NOMENCLATURE

Names of vegetation communities used in this report are based on the Plant Community Types (PCTs) used in the NSW BioNet Vegetation Classification Database (Environment Energy and Science, 2021c). These names are cross-referenced with those used for threatened ecological communities listed under the NSW *Biodiversity Conservation Act 2016* (BC Act) and/or the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Names of plants used in this report follow PlantNet (Royal Botanic Gardens, 2021). Scientific names are used in this report for species of plant. The names of introduced species are denoted with an asterisk (*).

For threatened species of plants, the names used in the BioNet Atlas of NSW Wildlife (Environment Energy and Science, 2021b) are also provided where these differ from the names used in the PlantNet database.

Names of vertebrate fauna follow the Australian Faunal Directory maintained by the Department of Agriculture, Water and Environment (DAWE) (2021a). Common names are used in the report for species of animal. Both common and scientific names are provided in appendices.

For threatened species of animals, the names used in the BioNet Atlas of NSW Wildlife and Department of Primary Industries (DPI) Spatial Data Portal (2021) are provided.

2.3 FIELD SURVEY

The field surveys aimed to ground-truth the results of the background research including desktop analysis of vegetation and habitat assessment. The floristic diversity was assessed using the Biodiversity Assessment Methodology (BAM) (DPIE, 2020). The field survey was undertaken on 10 May 2021 by two WSP ecologists.

2.4 VERIFICATION OF EXISTING VEGETATION MAPPING

Vegetation within the study area and locality has been previously mapped at the regional scale by the *Native Vegetation of the Sydney Metropolitan Area* (OEH, 2013).

Field validation (ground-truthing) of this existing mapping within the study area was completed to confirm the vegetation structure, dominant canopy species, native diversity, underlying geology, condition and presence of threatened ecological communities. This was based on the completion of random meanders, rapid data points and drive-by assessments.

Five vegetation integrity plots, as described in the BAM 2020 (DPIE, 2020) were completed across all vegetation types recorded.

The information collected during the survey was used to determine the Plant Community Type (PCT) for each vegetation type recorded as detailed in the BioNet Vegetation Classification System (Environment Energy and Science Group, 2020b) and whether vegetation within the study area aligned to any State or Commonwealth listed ecological communities.

2.5 PLOT AND TRANSECT SURVEYS

Vegetation surveys were carried out in accordance with the BAM (DPIE, 2020). A plot-based full floristic survey was carried out based on a 20 m x 20 m quadrat, with function data collected using and 20 m x 50 m plot (henceforth referred to as a vegetation integrity plot (VI plot). The locations of the BAM plots are described in Table 2.2 shown in Figure 3.1.

Native vegetation recorded within the study area was aligned to Plant Community Types (PCTs) as contained in the BioNet Vegetation Classification Database (Environment Energy and Science Group, 2021). This was achieved by identifying native vegetation to formation, class and type and its corresponding Threatened Ecological Community (where applicable). Furthermore, other characteristics such as floristic composition, underlying geology, soil type, landform and other description attributes were collected where available and assessed against BioNet Vegetation Classification Database PCT profiles.

Table 2.2 Location of BAM VI plots completed within the study area

PLOT ID	VEGETATION TYPE AND ZONE	CONDITION	EASTING	NORTHING	ORIENTATION
Q1	PCT 1789 Smooth-barked Apple – Blackbutt – Red Bloodwood open forest in enriched sandstone gullies of the western Woronora plateau	Good	314442	6238136	56º
Q2	PCT 1232 Swamp Oak floodplain Forest, Sydney Basin Bioregion and South East Corner Bioregion	Moderate	314385	6238280	310º
Q3	PCT 1232 Swamp Oak floodplain Forest, Sydney Basin Bioregion and South East Corner Bioregion	Moderate	314363	6238303	330º
Q4	PCT 1789 Smooth-barked Apple – Blackbutt – Red Bloodwood open forest in enriched sandstone gullies of the western Woronora plateau	Good	314458	6238209	305º
Q5	PCT 1789 Smooth-barked Apple – Blackbutt – Red Bloodwood open forest in enriched sandstone gullies of the western Woronora plateau	Good	314555	6238050	168º

Note: Zone 56, GDA94

2.6 CONDITION OF VEGETATION

Vegetation in the study area was firstly assessed to a PCT and then aligned to a vegetation zone which is defined in the BAM 2020 as '*an area of native vegetation on the subject land that is the same PCT and has a similar broad condition state'* (DPIE, 2020). A broad condition state infers that the vegetation has a similar tree cover, shrub cover, ground cover, weediness or combinations of these attributes which determine vegetation condition.

The broad condition states which were applied to vegetation in the study area are summarised in Table 2.3 below. These factors were defined by using factors such as levels of disturbance, weed invasion and resilience.

Table 2.3 Vegetation broad condition states

CONDITION CATEGORY	DESCRIPTION
Good	Vegetation still retains full species complement and structural characteristics. The vegetation displays resilience to weed invasion due to intact groundcover, shrub and canopy layers. Native species diversity is relatively high. Weeds may exist in this vegetation type but generally exhibit <5% foliage cover.
Moderate	Vegetation has retained a native canopy but the understorey and groundcover layers are generally co-dominated by exotic species that generally exhibit between 5–49% foliage cover. The mid and low stratums may have been structurally modified as a result of previous clearing.
Low	Vegetation has retained a native canopy or the canopy cover is showing occasional signs of regeneration. The understorey and groundcover layers of this condition are absent and/or the understorey is generally dominated or co-dominated by exotic species (i.e. foliage cover >50%). Native species diversity is generally relatively low and the mid and low stratums have been structurally modified.

2.7 CONSULTATION

Consultation was undertaken with representatives from:

- Transport for New South Wales
- Department of Planning Industry and Environment
- Southern Sydney Branch, National Parks Association of NSW
- Liverpool City Council
- George's River Environmental Alliance
- Sutherland Shire Environment Centre
- Sandy Point Residents.

This included a site visit to Deadmans Creek Bridge on 26 May 2021, and ongoing email correspondence with Sutherland Shire Environment Centre relating to concern about koala roadkill in the study area and locality.

Additional consultation was undertaken with koala expert Dr Steve Phillips (Biolink) to confirm koala feed tree species and likely movement corridors within the locality.

2.8 KOALA RECORDS WITHIN THE LOCALITY

All koala observation and vehicle strike records for the past 10 years records within a 10-kilometre radius of the study area were obtained from the BioNet Atlas of NSW Wildlife (DPIE, 2021) and are presented for regional context in Figure 3.2.

Koala observation and vehicle-strike records for the past 10 years along Heathcote Road and St George Crescent were mapped and are presented in Figure 3.3.

BioNet data has been updated recently and now includes records from the I Spy Koala App and the NSW Wildlife Rehab Database. Koala habitat and potential movement corridors are discussed in Section 3.6 and presented in Figure 3.3.

3 EXISTING ENVIRONMENT

This section describes the environmental context of the study area including abiotic and biotic features of the landscape area. The context of the study area assists in determining PCTs and potential impacts on existing PCTs if clearing is required for installation of fauna fencing.

3.1 SUMMARY OF LANDSCAPE FEATURES

The landscape context of the study area, including IBRA bioregions and subregions, Mitchell landscapes, catchment areas and land uses are described in Table 3.1 below.

Table 3.1 Landscape features

LANDSCAPE FEATURE	SUBJECT LAND
IBRA bioregions and subregions	Sydney Basin Bioregion/SYB10 Sydney Cataract
NSW landscape regions (Mitchell landscapes)	Woronora Plateau
Local Government Area (LGA)	Liverpool City Council and Sutherland Shire Council
Rivers and streams	Deadmans Creek, Georges River
Wetlands	Coastal Management SEPP 2018 has mapped coastal Wetlands and associated proximity buffers within the study area.
Connectivity features	Native vegetation within the study area is part of a large extent of native vegetation. To the north are patches of native vegetation which occur on the banks of the Georges River and extend into Georges River National Park. A large area of high quality intact native vegetation occurs to the south of Heathcote Road which is part of the Holsworthy Defence Base.
Areas of Geological Significance and Soil Hazard Features	There are no areas identified to have geological significance. Potential high-risk acid sulphate soils to occur along Deadmans Creek and have been identified within the study area.
Areas of outstanding biodiversity value	None recorded

3.2 PLANT COMMUNITY TYPES

Two NSW Plant Community Types (PCTs) were recorded in the study area:

- PCT 1789 Smooth-barked Apple – Blackbutt – Red Bloodwood open forest in enriched sandstone gullies of the western Woronora plateau– high condition.
- PCT 1232 Swamp Oak floodplain Forest, Sydney Basin Bioregion and South East Corner Bioregion – moderate condition.

In addition, one non-native vegetation type was assigned to a miscellaneous ecosystem class, being:

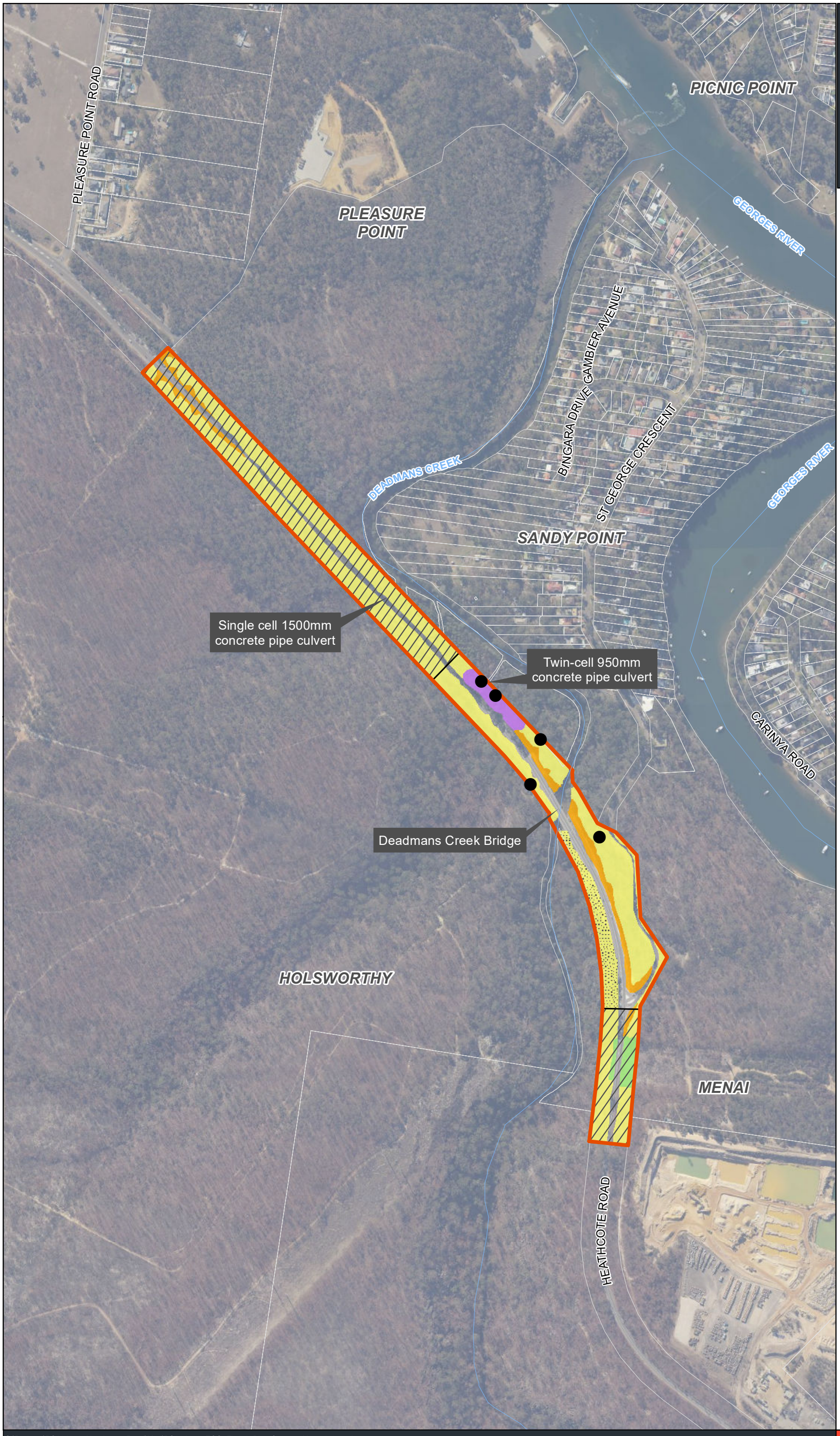
- Miscellaneous ecosystem – Exotic Grassland.

A summary of PCTs and associated vegetation zones are presented in Table 3.2 with the extent and distribution shown in Figure 3.1.

A detailed description of each PCT and justification for assigning the vegetation to each PCT and vegetation zone is provided in Appendix B. The western-most section and a small section in the east of the study area were not fully ground-truthed or subject to BAM plots due to access constraints. The vegetation type and condition in these two areas were extrapolated from the PCTs recorded during the survey and aerial photo interpretation. The areas not fully ground-truthed are shown on Figure 3.1.

Table 3.2 Plant community types

PLANT COMMUNITY TYPE (PCT)	CONDITION CLASS	THREATENED ECOLOGICAL COMMUNITY?	STUDY AREA (HA)
PCT 1789 Smooth-barked Apple – Blackbutt – Red Bloodwood open forest in enriched sandstone gullies of the western Woronora plateau	High	No	6.73
PCT 1789 Smooth-barked Apple – Blackbutt – Red Bloodwood open forest in enriched sandstone gullies of the western Woronora plateau	Moderate	No	0.24
PCT 1232 Swamp Oak floodplain Forest, Sydney Basin Bioregion and South East Corner Bioregion	Moderate	Yes – Swamp Oak Floodplain Forest of the NSW North Coast, Sydney Basin and South East Corner Bioregions. Listed as Endangered (BC Act)	0.29
		Total extent of native vegetation	**7.26**
Miscellaneous ecosystem – exotic grassland	n/a	No	0.66
		Total extent of non-native vegetation	**0.66**
		Total native and non-native vegetation	**7.92**



Options to reduce Koala vehicle strike along Heathcote Road

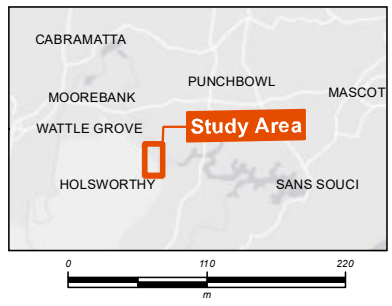
Figure 3.1
Plant Community Types

Legend

- BAM Plots
- Watercourses
- Cadastre
- Study Area
- Area not Field Surveyed

Vegetation Type (Field Verified)

- PCT 1232 - Swamp Oak floodplain Forest, Sydney Basin Bioregion and South East Corner Bioregion - moderate condition (listed as endangered on the BC Act)
- PCT 1789 - Smooth-barked Apple – Blackbutt – Red Bloodwood open forest in enriched sandstone gullies of the western Woronora plateau – high condition
- PCT 1789 - Smooth-barked Apple – Blackbutt – Red Bloodwood open forest in enriched sandstone gullies of the western Woronora plateau – moderate condition
- PCT 1789 - Smooth-barked Apple – Blackbutt – Red Bloodwood open forest in enriched sandstone gullies of the western Woronora plateau – disturbed
- Exotic Grassland



Coordinate System: GDA2020 MGA Zone 56

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3.3 THREATENED ECOLOGICAL COMMUNITIES

3.3.1 BC ACT THREATENED ECOLOGICAL COMMUNITIES

One threatened ecological community was recorded within the study area: Swamp Oak Floodplain Forest of the NSW North Coast, Sydney Basin and South East Corner Bioregions (Swamp Oak Floodplain Forest). This threatened ecological community is listed as endangered under the BC Act. The occurrence of this threatened ecological community within the study area is shown in Table 3.1.

PCT 1232 Swamp Oak floodplain Forest, Sydney Basin Bioregion and South East Corner Bioregion recorded in the study area is consistent with the Swamp Oak Floodplain Forest final determination (NSW Scientific Committee, 2011).

A comparison of the Swamp Oak Floodplain Forest final determination and PCT 1232 attributes within the study area is provided in Table 3.3 below.

Table 3.3 A comparison of Swamp Oak Floodplain Forest final determination criteria and PCT 1232 attributes within the study area

FINAL DETERMINATION LISTING CRITERIA	SWAMP OAK FLOODPLAIN FOREST	PCT 1232 SWAMP OAK FLOODPLAIN FOREST, SYDNEY BASIN BIOREGION AND SOUTH EAST CORNER BIOREGION
Area occupied by the EEC	Occurs in the NSW North Coast, Sydney Basin and South East Corner Bioregions.	The study area occurs in the Sydney Basin Bioregion.
Soils and Landscape position	The community associated with grey-black clay-loams and sandy loams, where the groundwater is saline or sub-saline, on waterlogged or periodically inundated flats, drainage lines, lake margins and estuarine fringes associated with coastal floodplains.	The study area occurs on the coastal floodplain associated with drainage line of Deadmans Creek. The soils are black clay and are regularly inundated by high tides.
Elevation	Does the PCT occur below 20 m in elevation (ASL)?	The PCT occurs at elevations between 10 m and 20 m.
Floristic Structure	The structure of the community may vary from open forests to low woodlands, scrubs or reedlands with scattered trees. Typically, these forests, woodlands, scrubs and reedlands form mosaics with other floodplain forest communities and treeless wetlands, and often they fringe treeless floodplain lagoons or wetlands with semi-permanent standing water.	The PCT within the study area is that of an open forest, with a dense canopy layer. It occurs on a coastal floodplain and is periodically inundated during high tide events.

FINAL DETERMINATION LISTING CRITERIA	SWAMP OAK FLOODPLAIN FOREST	PCT 1232 SWAMP OAK FLOODPLAIN FOREST, SYDNEY BASIN BIOREGION AND SOUTH EAST CORNER BIOREGION
Assemblage of Species	49 characteristic species of Swamp Oak Floodplain Forest are listed in the Scientific Determination.	4 species of the characteristic species were recorded within PCT 1232. Two BAM plots were conducted within this PCT with the area of this PCT being small. The ground layer was absent due to regular inundation reducing the number of species recorded. However, dense stands of *Melaleuca styphelioides* (Prickly-leaved Paperbark), *Melaleuca linariifolia* (Snow-in Summer), with *Casuarina glauca* as a co-dominant canopy species was recorded which is a characteristic of this threatened ecological community.
Location within LGAs	Occurs within one of the LGA's listed in Paragraph 3 of the Scientific determination.	Yes, this PCT occurs within the Liverpool LGA.
Is PCT 1232 commensurate with the threatened ecological community of Swamp Oak Floodplain Forest?		**Yes**

3.3.1 EPBC ACT THREATENED ECOLOGICAL COMMUNITIES

PCT 1232 Swamp Oak floodplain Forest, Sydney Basin Bioregion and South East Corner Bioregion has the potential to meet the threatened ecological community of Coastal Swamp Oak (*Casuarina glauca*) Forest of New South Wales and South East Queensland ecological community listed as endangered on the EPBC Act.

To meet the EPBC Act listing for this endangered ecological community it must meet the key diagnostic characteristics and the condition thresholds outlined in the listing advice.

PCT 1232 meets all the key diagnostic characteristics for the EPBC Act listing (Table 3.4). However, it does not meet the EPBC Act condition thresholds for this endangered community, as the patch size is less than 2 hectares (Table 3.5).

No threatened ecological communities listed on the EPBC Act occur within the study area.

Table 3.4 A comparison of Swamp Oak Forest EPBC Act diagnostic characteristics and PCT 1232 within the study area

KEY DIAGNOSTIC CHARACTERISTICS		PCT 1232 SWAMP OAK FLOODPLAIN FOREST, SYDNEY BASIN BIOREGION AND SOUTH EAST CORNER BIOREGION WITHIN THE STUDY AREA
Area occupied by the EEC	Occurs from south-east Queensland to Southern NSW within the South eastern Queensland, NSW North Coast, Sydney Basin or South East Corner Bioregions.	The study area occurs in the Sydney Basin Bioregion.
Elevation and landscape position	Occurs in coastal catchment at elevations of up to 50 m ASL typically less than 20 m ASL, on coastal flats, floodplains, drainage lines, lake margins, wetlands and estuarine fringes where soils are at least occasionally saturated, water-logged or inundated.	The PCT occurs at elevations between 10 m and 20 m. Occurs on the coastal floodplains associated with the drainage line of Deadmans Creek. The vegetation is regularly inundated by high tides and during high rainfall events
Soils	Occurs on soils derived from unconsolidated sediments (including alluvium), typically hydrosols (grey-black, clay-loam and/or sandy loam soils).	The PCT occurs on soils are black clay
Floristic Structure	Has an open woodland, woodland, forest, or closed forest structure, with tree canopy that has a total crown cover of at least 10%.	The PCT within the study area is that of an open forest, with a dense canopy layer of at least 30%.
Dominant tree species	Has a copy of trees dominated by *Casuarina glauca* (Swamp-oak)	The canopy is dominated by *Casuarina glauca.*
Does PCT 1232 meet the key diagnostic characteristics?		**Yes**

Table 3.5 A comparison of Coastal Swamp Oak (*Casuarina glauca*) Forest against the condition criteria and PCT 1232 attributes within the study area

VEGETATION QUALITY CLASS	PATCH SIZE CLASSES				PCT 1232 SWAMP OAK FLOODPLAIN FOREST, SYDNEY BASIN BIOREGION AND SOUTH EAST CORNER BIOREGION
	Large Patch The patch is at least 5 ha	**Medium Patch** The patch is at least 2ha and less than 5 ha	**Small contiguous patch** patch size – At least 0. 5 ha and less than 2 ha, and is connected to a larger area of native vegetation of at least 4 ha	**Small Patch** The patch is at least 0. 5 ha and less than 2 ha	
High Quality Predominantly native understorey Non-native species comprise less than 20% of total understorey vegetation cover.	CATEGORY A A large patch that meets key diagnostics and has a predominantly native understorey.	CATEGORY B A medium patch that meets key diagnostics and has a predominantly native understorey OR A small patch that meets key diagnostics and has a predominantly native understorey and is contiguous with another large area of native vegetation.		CATEGORY C A small patch that meets key diagnostics and has a predominantly native understorey.	The patch size is 0. 29 ha and does not meet any of the patch size classes. Meets the key diagnostics. Understorey species comprise of 35% native species. Understorey species comprise of 20% non-native species.
Good Quality Mostly native understorey Non-native species comprise of less than 50% of total understorey vegetation cover AND Transformer species comprise of less than 30% of the total understorey vegetation cover.	CATEGORY B A large patch that meets the key diagnostics and has a mostly native understorey.	CATEGORY C A medium patch that meets key diagnostics and has a mostly native understorey OR A small patch that meets key diagnostics and has a mostly native understorey and is contiguous with another large area of native vegetation.			Does not meet large or medium patch sizes. Meets the key diagnostics. Understorey species comprise of 35% native species. Non-native species are at least 20% of total understorey species. Transformer species are 2% of the total understorey species.
Moderate Quality Some native understorey Non-native species comprise of less than 80% of total understorey vegetation cover AND Transformer species comprise of less than 50% of total understorey vegetation cover	CATEGORY C A large or medium patch that meets the key diagnostic criteria and has some native understorey				Same as above.
Is PCT 1232 commensurate with the threatened ecological community of Coastal Swamp Oak (*Casuarina glauca)* Forest?					**No**

3.4 COASTAL MANAGEMENT SEPP 2018

Parts of the study area have been mapped as Coastal Management SEPP 2018 as both “coastal wetlands” and “proximity area for Coastal Wetlands” (refer Appendix C). This includes vegetation that occurs on the banks of Deadmans Creek at the bridge over Heathcote Road. A longer patch is mapped in the north-west of the study area on the northern side of Heathcote Road.

Direct impacts on wetlands mapped as ‘Coastal Wetlands’ under the Coastal Management SEPP 2018 would trigger the requirement for assessment under Division 4.1 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) as designated development, therefore requiring an Environmental Impact Statement (EIS) and the consent authority is Local Council. The project footprint within these mapped areas would require assessment through the preparation of an EIS and supported by a Biodiversity Development Assessment Report (BDAR) in accordance with BAM. Alternatively, if all areas of ‘Coastal Wetlands’ are avoided and only ‘Proximity Coastal Wetlands’ are impacted, Division 4.1 of the EP&A Act would not be triggered and the preparation of an EIS would not be required. Justification would however be required as part of the Review of Environmental Factors to demonstrate that the project would not have a significant impact on the Coastal Wetlands surrounding the project.

3.5 EXISTING ROAD INFRASTRUCTURE

Heathcote Road is a two-lane arterial road that connects the M5 Motorway, near Moorebank in the west and the Princes Highway, near Heathcote to the east. In the study area, Heathcote Road is bordered by extensive vegetated areas of Defence land and National Park to the south, and Georges River National Park, council reserves, residential developments and the Georges River to the north. The current speed limit for this section of Heathcote Road is 80 kilometres per hour.

The existing infrastructure along this section of Heathcote Road includes a concrete bridge, concrete pipe culverts and several stretches of ‘W’-beam safety barriers (refer Figure 4.1).

The central section of the study area contains the Deadmans Creek Bridge which crosses the tidally influenced Deadmans Creek. It is a multi-span concrete bridge and provides some fauna connectivity under Heathcote Road. Camera traps placed under the bridge in March 2021 have shown use of the bridge underpass by Deer, Eastern Grey Kangaroos, Swamp Wallabies, Red-necked Wallabies, Foxes and Black Rats. However, the connectivity for the koala underneath the bridge is limited by the amount of scour protection on the creek banks which reduces its suitability for the species.

Photo 3.1 The multi-span concrete bridge that crosses Deadmans Creek (L) and the rip-rap scour protection that surrounds the bridge abutments and creek banks (R)

About 200 metres to the north-west of Deadmans Creek Bridge is a twin-cell 950 mm diameter concrete pipe drainage culvert that crosses under Heathcote Road. This is in the low-lying section of the study area and connects to Deadmans Creek in the north. It is tidally influenced, usually contains water and forms part of the "coastal wetlands" and "proximity area for Coastal Wetlands" under the Coastal Management SEPP 2018. Fauna connectivity for terrestrial species in this location is limited due to the tidal presence of water in the culverts and relatively small culvert size (950mm) which many terrestrial species will avoid because it is too wet and dark. The vegetation in this location is Swamp Oak Floodplain Forest (EEC, BC Act), which is more extensive on the north-eastern side of Heathcote Road.

Photo 3.2 The twin-cell concrete pipe drainage culvert that crosses underneath Heathcote Road. The northern cell contains water most of the time (L) while the southern cell typically contains less water (R)

About 470 metres to the north-west of Deadmans Creek Bridge is a reinforced single-cell 1500 mm diameter concrete pipe drainage culvert that crosses under Heathcote Road, connecting Defence land. This is the beginning of the elevated section of the study area and connects to the bend in Deadmans Creek to the north. Due to the gentle slope and elevation, it contains less water than the culverts closer to the bridge and is likely dry most of the time. Fauna connectivity for terrestrial species in this location is moderate but somewhat limited by the relatively small size and darkness of the culvert. The vegetation in this location is sandstone enriched dry sclerophyll forest with the canopy dominated by *Eucalyptus pilularis* (Blackbutt), *Eucalyptus punctata* (Grey Gum) and *Angophora costata* (Smooth-barked Apple).

Photo 3.3 Single-cell concrete pipe drainage culvert that crosses under Heathcote Road on the northern side (L) and connects to Defence land on the southern side (R). 'W'-beam safety barrier is also present in this section of the study area

There are two types of fences that run along the boundary of Defence land adjacent to the road reserve of Heathcote Road:

— 5-strand barbed wire stock fencing
— 1.8 metre-high chain link with 400 mm of 3-strand barbed wire 'controlled access fencing'.

The 5-strand barbed wire fence runs in a north-westerly direction from Deadmans Creek bridge for about 260 metres on Defence land on the southern side of Heathcote Road and runs parallel to the road.

The 2.2 metre high controlled access fencing is set back from the road shoulder by about 30 metres and is installed on Defence land at the road boundary edge. On the southern side of Heathcote Road, the fence runs in a westerly direction for about 2 kilometres (toward the Holsworthy Defence Base) starting about 500 metres west of Deadmans Creek Bridge on Defence land, on top of the rock escarpment. At the time of writing, new sections of controlled access fencing have been installed on Defence land on the southern side of Heathcote Road from near the outlet of the single concrete pipe culvert to the next section between the two culverts.

On the northern side of Heathcote Road, the controlled access fencing starts about 100 metres from the creek bank of Deadmans Creek and runs in a westerly direction on Defence land for about 700 metres to Pleasure Point Road.

The extent, type and condition of this fence means it would be somewhat effective in preventing fauna from accessing Heathcote Road, but it would need to be retrofitted with 600mm wide metal sheet panels at the top of the fence to prevent koalas from climbing over and ground mesh pegged out to prevent animals getting under gaps. However, there are several large breaks in the fencing on the northern and southern sides of Heathcote Road, near the single cell pipe culvert that could provide egress out of Defence land and into the road corridor for the koala and other wildlife.

3.6 IMPORTANCE OF KOALA HABITAT AND CONNECTIVITY

Very few formal studies of the koala population or their movements in this area have been undertaken, however the number of koala records in the area, including koala roadkill, combined with the presence of preferred feed trees, strongly indicates the study area provides important habitat for the conservation of koalas.

Local evidence shows koalas are killed by vehicle strike on Heathcote Road, particularly near Deadmans Creek. The site was not identified in a 2019 TfNSW statewide analysis of koala vehicle strike hotspots. The southern Sydney branch of the National Parks Association have submitted information to DPIE and TfNSW that shows the site is likely a local priority and is of concern to local environmental community groups.

Close (2019) reports the longest dispersal route of a young, tagged female koala, Wilhelmina, who travelled north from Campbelltown, across the Defence Firing range to Heathcote for a distance of about 20 kilometres. Male koalas generally travel further than females, especially when dispersing from their mother.

Dispersal distances of male koalas from the Campbelltown population to the north towards Heathcote and the George's River ranged from 14 – 19 kilometres (Close, 2019). Recently, the median female koala home range in this locality has been estimated at 34 hectares with a density of 0. 052 – 0. 056 koalas per hectare (S Phillips, personal communication, 14 May 2021).

Close (2019) states the long-term survival of the Campbelltown koalas depends on preserving habitat and maintaining dispersal routes. The Holsworthy Defence land would be considered an important dispersal route for this population as it allows for north-south movement of koalas to large areas of habitat.

Vegetation within the study area is dominated by a canopy of Blackbutt (*Eucalyptus pilularis*), Grey Gum (*Eucalyptus punctata*) and Smooth-barked Apple (*Angophora costata*). Schedule 2 of the Koala Habitat Protection SEPP (2021) lists Smooth-barked Apple and Blackbutts as a 'use tree' in the Central Coast Management area. However, Grey Gum is the preferred koala food tree (PFKT) species in PCT's within the study area and locality and can be used as an indicator of transition soils and likely koala presence (Phillips and Callaghan, 2011). Blackbutts may be opportunistically browsed and sat in, but they are not preferentially used (S Phillips, personal communication, 14 May 2021).

The Koala Habitat Protection SEPP (2021) defines core koala habitat as:

a an area of land which has been assessed by a suitably qualified and experienced person as being highly suitable koala habitat and where koalas are recorded as being present at the time of assessment of the land as highly suitable koala habitat, or

b an area of land which has been assessed by a suitably qualified and experienced person as being highly suitable koala habitat and where koalas have been recorded as being present in the previous 18 years.

No specific koala surveys were undertaken as part of this study, and the vegetation in areas not surveyed was extrapolated based on mapping in the Native Vegetation of the Sydney Metropolitan Area (OEH, 2013).

Vegetated areas within the study area and the locality that contain the following PCT's is likely to be considered 'core koala habitat' under the Koala Habitat Protection SEPP (2021):

- PCT 1789 Smooth-barked Apple – Blackbutt – Red Bloodwood open forest in enriched sandstone gullies of the western Woronora plateau.
- PCT 1790 Red Bloodwood - Grey Gum - Stringybark open forest on enriched sandstone ridges of the western Woronora plateau and lower Blue Mountains.
- PCT 1776 – Smooth-barked Apple – Red Bloodwood open forest on enriched sandstone slopes around Sydney and the Central Coast.
- PCT 1785 – Smooth-barked Apple - Sydney Peppermint - Blackbutt tall open forest on enriched sandstones around Helensburgh.

While specific data on actual movement patterns within the study area is relatively scant and is dependent on a handful of tagged individuals, based on our knowledge of the area and our experience in koala behavioural ecology, we consider it highly likely that koalas are using the extensive Holsworthy Defence land for dispersal.

Sandy Point Residents have recorded koalas in Grey Gums in the Sandy Point Reserve car park and the BioNet Atlas includes records of observations of koalas in Grey Gums and to a lesser extent, Blackbutts.

STUDY AREA

HEATHCOTE ROAD
PLEASURE POINT
SANDY POINT
HENRY LAWSON DRIVE
DEADMANS CREEK
PICNIC POINT
HOLSWORTHY
GEORGES RIVER
MENAI

1:12,000

KOALA RECORDS WITH 10KM OF THE STUDY AREA

CLEAR PADDOCK CREEK
GREEN VALLEY CREEK
ELIZABETH DRIVE
CABRAMATTA
CABRAMATTA CREEK
PROSPECT CREEK
WARWICK FARM
HUME HIGHWAY
YAGOONA
STRATHFIELD
LIVERPOOL ROAD
ROBERTS ROAD
COOKS RIVER
COOKS CREEK
CANTERBURY ROAD
CONDELL PARK
SALT PAN CREEK
ANZAC CREEK
NEWBRIDGE ROAD
MILPERRA ROAD
MAXWELLS CREEK
MILPERRA
WOLLI CREEK
SOUTH WESTERN MOTORWAY
CASULA
PANANIA
GEORGES RIVER ROAD
DAVIES ROAD
BELMORE ROAD
FOREST ROAD
STONEY CREEK ROAD
KING GEORGES ROAD
GLENFIELD
HARRIS CREEK
STUDY AREA
PICNIC POINT
MENAI
OATLEY
ALFORDS POINT ROAD
GEORGES RIVER
ILLAWONG
OYSTER BAY
STILL CREEK
PRINCES HIGHWAY
COMPLETE CREEK
WILLIAMS CREEK
DEADMANS CREEK
MILL CREEK
MENAI ROAD
NEW ILLAWARRA ROAD
KINGSWAY
PRESIDENT AVENUE
MINTO HEIGHTS
HOLSWORTHY
LUCAS HEIGHTS
FORBES CREEK
GYMEA BAY
KENTLYN
HACKING RIVER

1:100,000

PENRITH
HORSLEY PARK
MOSMAN
WARRAGAMBA
MOOREBANK
HOLSWORTHY
KURNELL

wsp

Options to reduce Koala vehicle strike along Heathcote Road

Figure 3.2
Koala records

Legend

- Koala records in the locality
- Koala Vehicle Strike Records
- Watercourses
- Cadastre
- Study Area
- Study Area 10km Buffer
- NPWS Reserve
- Defence Area

Coordinate System: GDA2020 MGA Zone 56

Scale ratio correct when printed at A3

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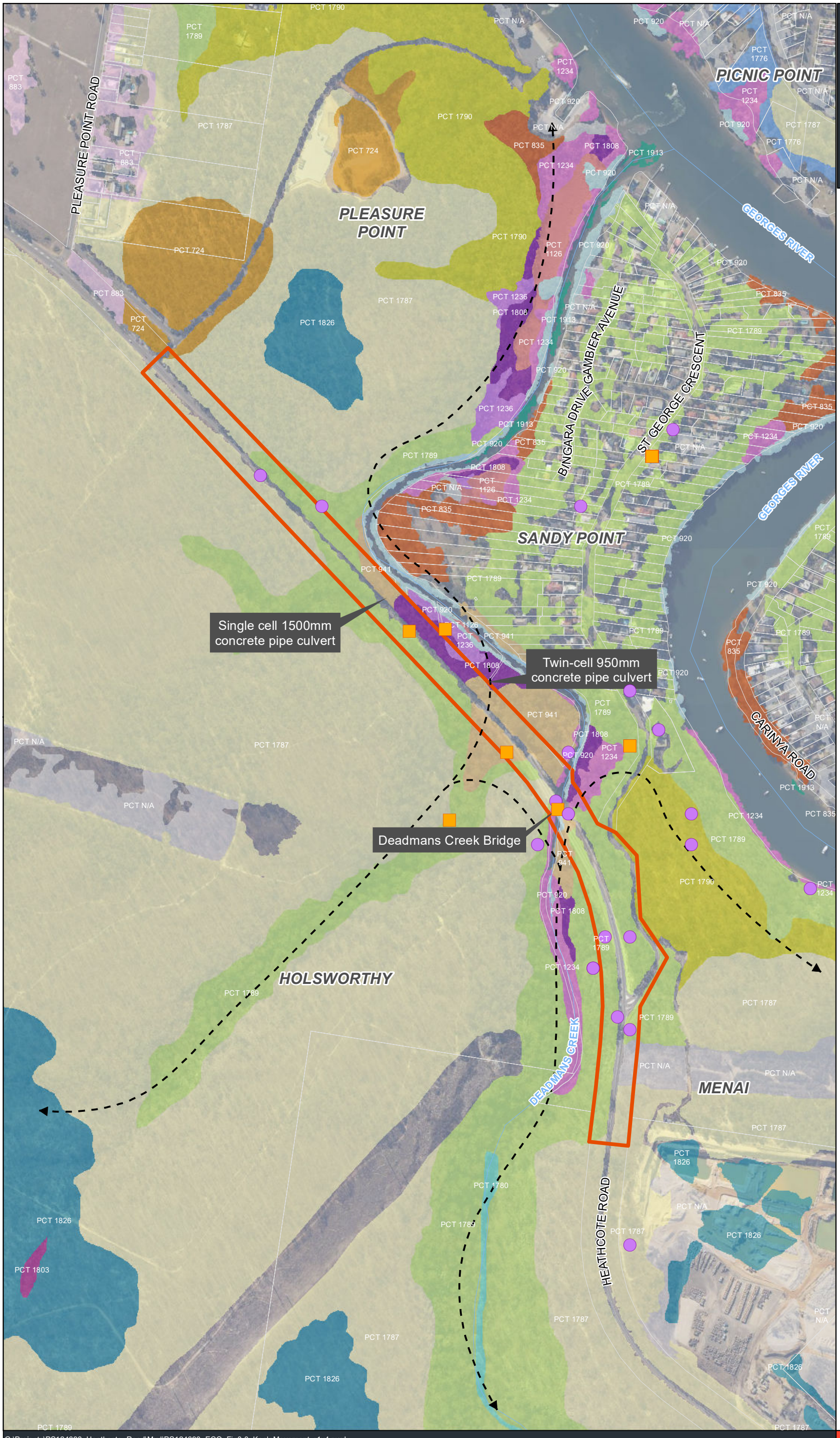


Options to reduce Koala vehicle strike along Heathcote Road

Figure 3.3
Koala Movement

Legend

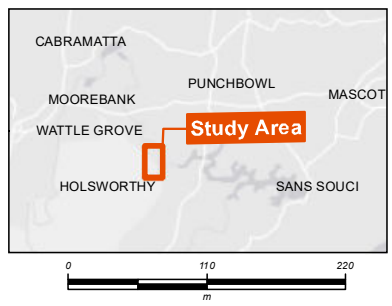
- Watercourses
- Koala Movement
- Cadastre
- Study Area

BioNet Koala Records

- Koala records in the locality
- Koala Vehicle Strike Records

Native Vegetation of the Sydney Metro Area (OEH 2013)

- PCT1126 - Estuarine Saltmarsh
- PCT1234 - Estuarine Swamp Oak Forest
- PCT1236 - Coastal Swamp Paperbark-Swamp Oak Scrub
- PCT1776 - Coastal Enriched Sandstone Dry Forest
- PCT1780 - Coastal Sandstone Riparian Forest
- PCT1787 - Sydney Hinterland Exposed Sandstone Woodland
- PCT1789 - Sydney Hinterland Apple-Blackbutt Gully Forest
- PCT1790 - Sydney Hinterland Grey Gum Ridgetop Forest
- PCT1803 - Coastal Upland Damp Heath Swamp
- PCT1808 - Estuarine Reedland
- PCT1826 - Sydney Hinterland Dwarf Apple Heath-Woodland
- PCT1913 - Seagrass Meadows
- PCT724 - Castlereagh Shale-Gravel Transition Forest
- PCT835 - Cumberland Riverflat Forest
- PCT883 - Castlereagh Scribbly Gum Woodland
- PCT920 - Estuarine Mangrove Forest
- PCT941 - Hinterland Riverflat Eucalypt Forest
- Artificial Wetland, Cleared, Undifferentiated Regenerating Shrubs, Urban Exotic/Native, Weeds and Exotics



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4 MITIGATION OPTIONS ASSESSMENT

4.1 OPTIONS DEVELOPMENT

Options for reducing koala vehicle-strike along Heathcote were developed using a landscape-scale approach and based on proven mitigation measures, topography, location of potential crossing structures, known koala roadkill hotspots, predicted koala movement corridors, location of core koala habitat and engineering and environmental considerations.

Information collected during the desktop assessment and one day field survey was used in the development of the mitigation options and their assessment.

The following mitigation options for reducing koala vehicle-strike along Heathcote were developed and are shown on Figure 4.1:

- **Option 1**: Fencing the road reserve of Heathcote Road along the entire road reserve (including fencing above the rock cutting near St George Crescent), improving the conditions of the Deadmans Creek bridge underpass and installing a koala grid on St George Crescent.
- **Option 2**: Install shorter lengths of fauna fence along the road reserve of Heathcote Road (north-west of the bridge) and utilising existing Defence fence (some of which may need to be modified), improving the conditions of the Deadmans Creek bridge underpass and installing a koala grid on St George Crescent.
- **Option 3**: Install shorter lengths of fauna fence along the road reserve of Heathcote Road to avoid impacts to land mapped as coastal wetlands under the Coastal Management SEPP 2018.
- **Option 4**: Extension of fencing along Heathcote Rd up to the Quarry entrance. This can be applied to any of the options and where appropriate, existing Defence fencing would be used (some of which may need to be modified).

4.2 DESCRIPTION OF OPTIONS

The feasible options for reducing koala vehicle-strike along Heathcote Rd are limited to proven mitigation measures such as the installation of fauna fencing and improving the conditions of the existing bridge over Deadmans Creek. Other potential options such as rumble strips, activated signage, flashing lights/static signage and pavement painting were investigated but not considered further as they are not proven mitigation measures to reduce koala vehicle-strike.

The main differences in the four proposed options relate to the length and location of fauna fencing proposed and how and where the fence ends are treated. The length of fencing is based on minimum requirements to effectively funnel koalas towards Deadmans Creek Bridge, in relation to koala records within the vicinity.

Potential mitigation options are detailed further in Table 4.1 and presented in Figure 4.1.

Table 4.1 Summary of mitigation options feasibility assessment

OPTION 1 – FENCE ROAD RESERVE OF HEATHCOTE ROAD ALONG ENTIRE STUDY AREA	PHOTOS

Option 1 description:
— Install fauna fence both sides of Heathcote Rd road reserve adjacent to existing Defence fence from the bridge abutments to local access road near Pleasure Point and to St George Crescent (including fencing above the rock cutting near St George Crescent)
— Tie in with existing 'W' beam safety barrier to go above the culverts
— Install 'koala grid' on St George Crescent and tie in fauna fence to grid
— Improve connectivity for koalas under Deadmans Creek Bridge:
  — infill existing rip-rap near bridge abutments with finer rocks, or retrofit with shotcrete, concrete or geo-fab
  — install concrete or timber ledge (min 1 m wide) under eastern side of bridge span
  — install predator refuge pole on bridge approaches.
Constructability:
— Rock face treatment may be considered by TfNSW in steep, rocky areas to prevent koalas coming down tracks between rocks.
— No crossing of creeks required as fencing would be installed above the W-beam safety rail and culvert headwalls.
Fencing cost: 2.8 kilometres @ $100 p/m = approximately **$280,000** (not including geo-tech, surveyors, clearing contractors if required, other investigations)
Extent of clearing: The removal of approximately 1.68 hectares of native vegetation would be required to achieve a 3 metre buffer either side of the new fence.
Maintenance requirements: Can implement TfNSW Routine Maintenance specification
Land tenure: TfNSW single tenure.
Effectiveness: Long, uninterrupted sections of fauna fencing are most effective when used in conjunction with crossing structures such as bridges.
Ecological considerations:
— There is potential for fauna to be trapped between the new fence and the existing Defence fencing. This would be minimised through the placement of tie-ins and if required, escape mechanisms.
— Minimises direct impacts to Coastal SEPP areas.
	
	Photo 4.1 Example fauna fence for Koalas installed behind 'W' beam safety barrier on Picton Road

OPTION 2 – INSTALL SHORTER SECTIONS OF FAUNA FENCE AND TIE INTO DEFENCE FENCE	PHOTOS

Option 2 description:
— Install fauna fence both sides of Heathcote Rd road reserve for ~ 600 metres from the bridge abutments to existing Defence fencing and to St George Crescent (tie in fencing to the rock cutting near St George Crescent)
— A section of Defence fencing (~260 metres) would need to be replaced or modified (while meeting Defence controlled access fencing requirements) along its current alignment.
— Option 2 fencing then cuts back into the road reserve to avoid fencing in the creek, and then ties back into the new Defence fencing.
— Tie in with existing 'W' beam safety barrier to go above the culverts
— Tie into bridge abutment and recently installed Defence fence
— Install 'koala grid' on St George Crescent and tie in fauna fence to grid
— Improve connectivity for koalas under Deadmans Creek Bridge:
  — infill existing rip-rap near bridge abutments with finer rocks, or retrofit with shotcrete, concrete or geo-fab
  — install concrete or timber ledge (min 1m wide) under eastern side of bridge span
  — install predator refuge pole on bridge approaches.
Constructability:
— Rock face treatment may be considered by TfNSW in steep, rocky areas to prevent koalas coming down tracks between rocks.
— No crossing of creeks required as fencing would be installed above the W-beam safety rail and culvert headwalls
— Tie fencing into rock cuttings or equivalent geographical barrier
— Gaps under fencing may not be able to be filled in
— Sections of Defence fencing to be modified to prevent koala egress (north-western section of study area). This may include metal sheeting and ground mesh.
Fencing cost: 1.5 kilometres @ $100 p/m = approximately **$150,000** + ~300 metres of metal panels (for modifying sections of Defence fence) @$30 p/m = **$9,000**. Approximate total for Option 2 = **$160,000** (not including geo-tech, surveyors, clearing contractors if required, other investigations)
Extent of clearing: The removal of approximately 1.04 hectares of native vegetation would be required to achieve a 3 metre buffer either side of the new fence.
Maintenance requirements: Will require consultation with Defence
Land tenure: TfNSW and Defence tenure
Effectiveness: Long, uninterrupted sections of fauna fencing are most effective when used in conjunction with crossing structures such as bridges.
Ecological consideration: Minimises direct impacts to Coastal SEPP areas
	
	Photo 4.2 Newly installed Defence fence at Deadmans Creek. This may require modification or replacement for Option 2 to be effective. Image courtesy of TfNSW

OPTION 3 - INSTALL SHORTER SECTIONS OF FAUNA FENCE	PHOTOS

Option 3 description:
— Install shorter sections of fauna fence both sides along Heathcote Rd road reserve adjacent to existing Defence fence for ~ 200 metres from the bridge abutments to the twin cell culverts and ~ 300 metres to St George Crescent (tie in fencing to the rock cutting near St George Crescent)
— Tie into bridge abutments
— Install 'koala grid' on St George Crescent and tie in fauna fence to grid
— Improve connectivity for koalas under Deadmans Creek Bridge:
  — infill existing rip-rap near bridge abutments with finer rocks, or retrofit with shotcrete, concrete or geo-fab
  — install concrete or timber ledge (min 1m wide) under eastern side of bridge span
  — install predator refuge pole on bridge approaches.
Constructability:
— Tie fencing into rock cuttings or equivalent geographical barrier.
— No creek crossing required as fence stops at the first crossing point.
Fencing cost: 1.1 kilometres @ $100 p/m = approximately **$110,000** (not including geo-tech, surveyors, clearing contractors if required, other investigations)
Extent of clearing: The removal of approximately 0.67 hectares of native vegetation would be required to achieve a 3 metre buffer either side of the new fence.
Maintenance requirements: Can implement TfNSW Routine Maintenance specification
Land tenure: TfNSW single tenure
Effectiveness: Less ecologically effective as shorter sections of fence are not as effective as longer sections.
Ecological consideration: Minimises direct impacts to Coastal SEPP areas.
	
	Photo 4.3 View of Heathcote Road from Defence land about 200m north-west of Deadmans Creek Bridge. This area is mapped as both "coastal wetlands" and "proximity area for Coastal Wetlands". Fencing to this location will minimise impacts to the Coastal Wetland mapped areas but will be less ecologically effective

OPTION 4 – EXTENSION OF FENCING	PHOTOS
Option 4 description: — Extension of fencing along Heathcote Road up to the Quarry entrance. — This can be applied to any of the options and if applied to Option 2, Defence fencing would be used (some of which may need to be replaced or modified (while meeting Defence controlled access fencing requirements) along its current alignment. **Constructability:** Tie fencing into rock cuttings or equivalent geographical barrier **Fencing cost:** 2.2 kilometres @ $100 p/m = approximately **$220,000** (not including geo-tech, surveyors, clearing contractors if required, other investigations or the other costs required by the relevant Option this is applied to). **Extent of clearing:** The removal of approximately 1.33 hectares of native vegetation would be required to achieve a 3 metre buffer either side of the new fence. This in addition to the vegetation removal required by the relevant Option this is applied to. **Maintenance requirements:** Can implement TfNSW Routine Maintenance specification if applied with Option 1 or Option 3. **Land tenure:** If applied with Option 1 and Option 3 = TfNSW and Quarry tenure and if applied with Option 2 = TfNSW, Defence and Quarry tenure. **Effectiveness:** Long, uninterrupted sections of fauna fencing are most effective when used in conjunction with crossing structures such as bridges. **Ecological consideration:** Minimises direct impacts to Coastal SEPP areas.	 Photo 4.4 View of Quarry entrance

Options to reduce Koala vehicle strike along Heathcote Road

Figure 4.1
Options to reduce Koala Vehicle Strike

PLEASURE POINT
SANDY POINT
PICNIC POINT
MENAI
HOLSWORTHY
BINGARA DRIVE
CAMBIER AVENUE
ST GEORGE CRESCENT
CARINYA ROAD
HEATHCOTE ROAD
GEORGES RIVER
DEADMANS CREEK

Single cell 1500mm concrete pipe culvert

Twin-cell 950mm concrete pipe culvert

Deadmans Creek Bridge

Legend

- Watercourses
- Culverts
- Defence Fencing
- Koala Grid
- Option 1 - indicative location
- Option 2 - indicative location
- Option 3 - indicative location
- Option 4 - indicative location (extension can be applied to all the options)
- Bridge concrete barrier
- W-beam
- Cadastre
- Study Area
- Steep rocky areas

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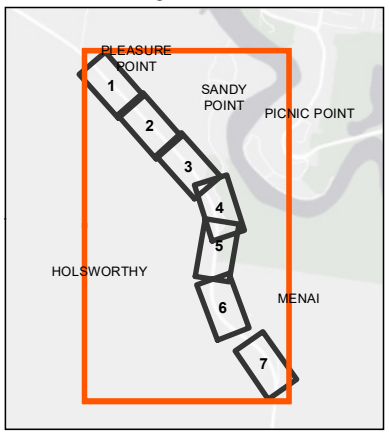

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Options to reduce Koala vehicle strike along Heathcote Road

Figure 4.1
Options to reduce Koala Vehicle Strike

Legend

- Defence Fencing
- Option 1 - indicative location
- Study Area
- Cadastre

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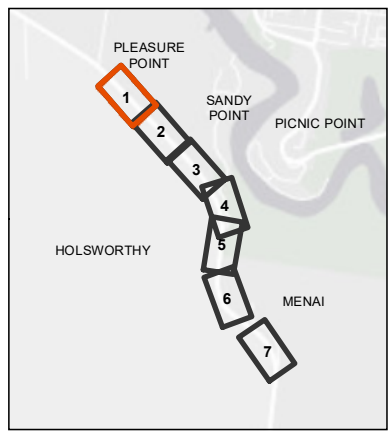

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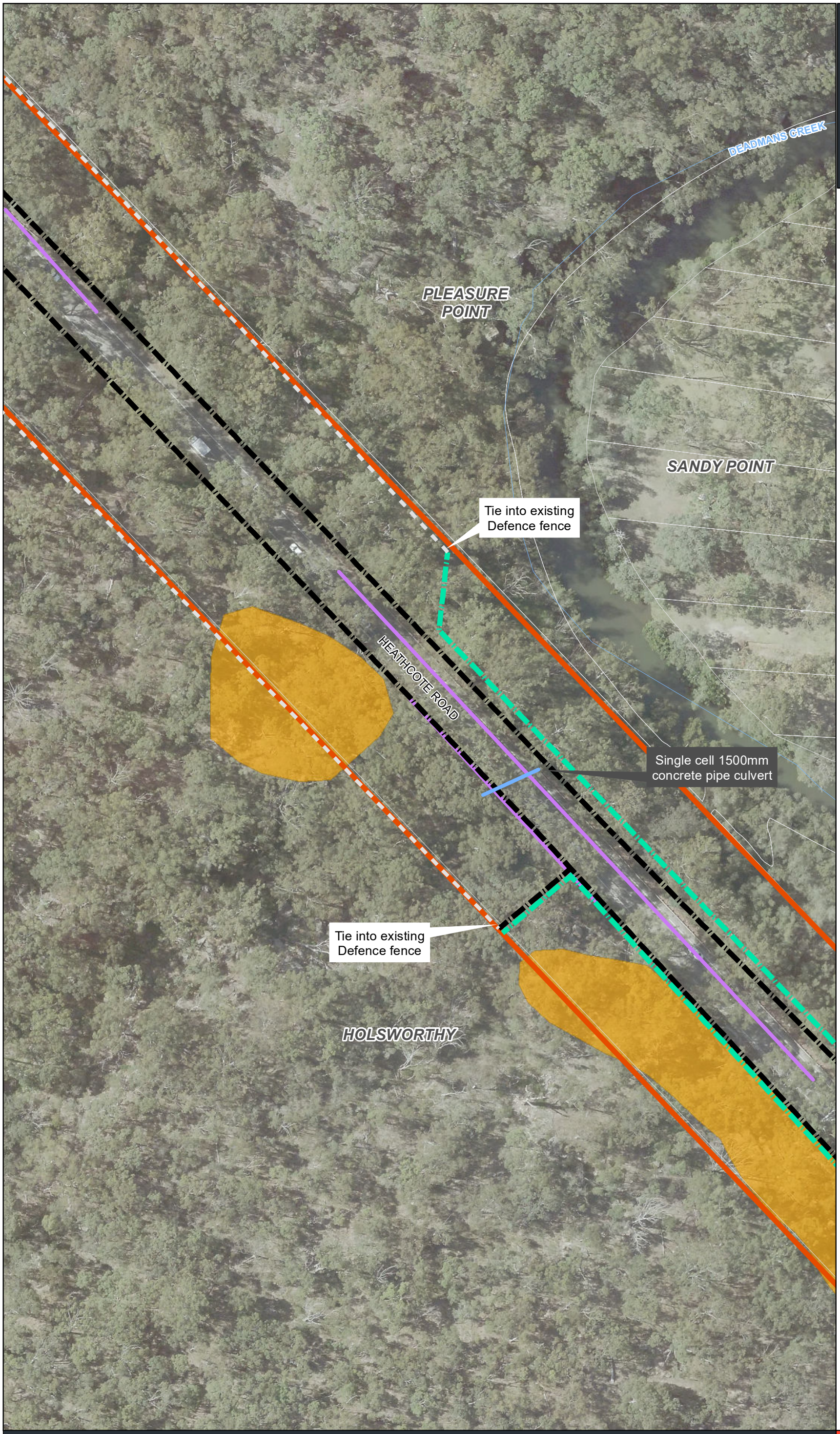
Options to reduce Koala vehicle strike along Heathcote Road

Figure 4.1
Options to reduce Koala Vehicle Strike



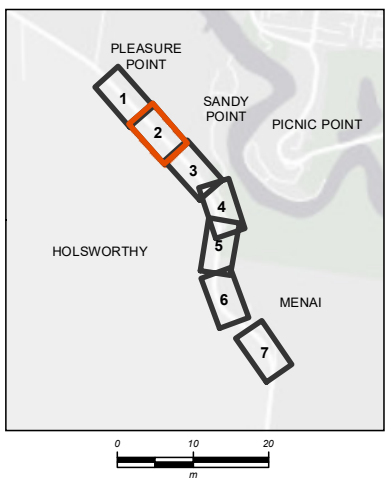
Legend

- Defence Fencing
- Option 1 - indicative location
- Option 2 - indicative location
- Culverts
- Watercourses
- Study Area
- Cadastre
- Steep rocky areas

Existing fencing

- W-beam

Page 3 of 8



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SANDY POINT

DEADMANS CREEK

Twin-cell 950mm concrete pipe culvert

PLEASURE POINT

HEATHCOTE ROAD

Tie in fencing to bridge abutment

Maintenance gate

HOLSWORTHY

Tie into bridge abutment and upgrade existing Defence fence

Deadmans Creek Bridge

DEADMANS CREEK

wsp

Options to reduce Koala vehicle strike along Heathcote Road

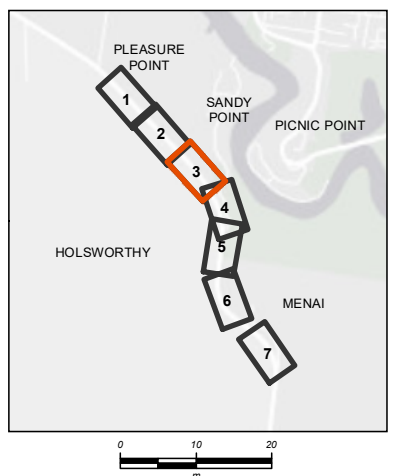
Figure 4.1
Options to reduce Koala Vehicle Strike

Legend

- Defence Fencing
- Option 1 - indicative location
- Option 2 - indicative location
- Option 3 - indicative location
- Culverts
- Watercourses
- Study Area
- Cadastre
- Steep rocky areas

Existing fencing

- Bridge concrete barrier
- W-beam



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PLEASURE POINT

SANDY POINT

ST GEORGE CRESCENT

Maintenance gate

Tie in fencing into rock cutting

MENAI

Rock face treatment (not applicable to Option 1)

HEATHCOTE ROAD

HOLSWORTHY

Tie in fencing into rock cutting

DEADMANS CREEK

Indicative location of Koala Grid

Tie fencing into Koala grid

Options to reduce Koala vehicle strike along Heathcote Road

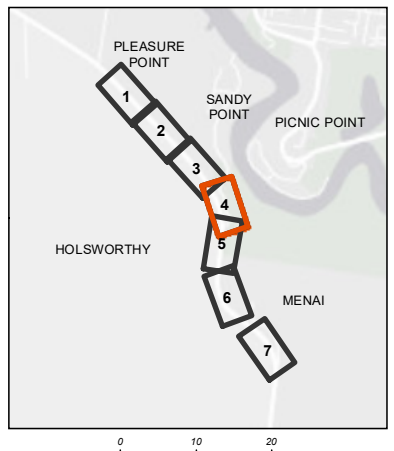
Figure 4.1
Options to reduce Koala Vehicle Strike

Legend

- Koala Grid
- Option 1 - indicative location
- Option 2 - indicative location
- Option 3 - indicative location
- Watercourses
- Study Area
- Cadastre
- Steep rocky areas

Existing fencing

- Bridge concrete barrier
- W-beam



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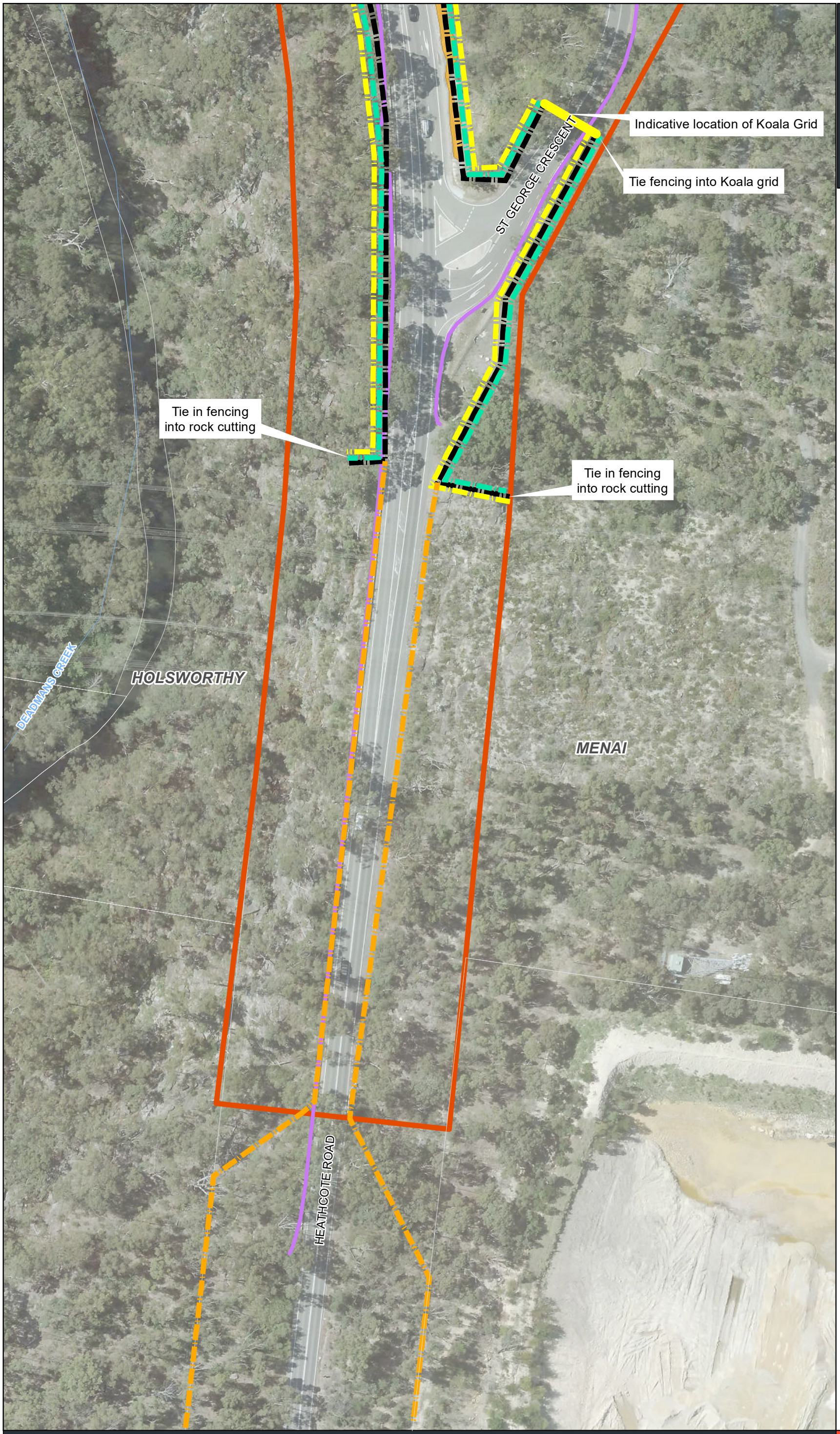


Options to reduce Koala vehicle strike along Heathcote Road

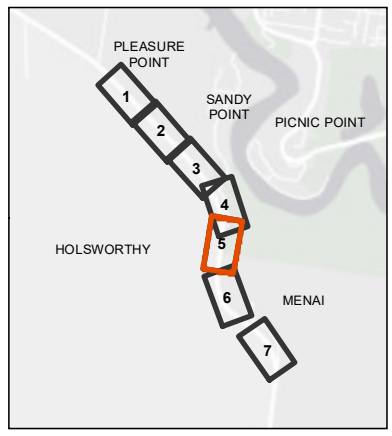
Figure 4.1
Options to reduce Koala Vehicle Strike

Legend

- Koala Grid
- Option 1 - indicative location
- Option 2 - indicative location
- Option 3 - indicative location
- Option 4 - indicative location (extension can be applied to all the options)
- Watercourses
- Study Area
- Cadastre
- Steep rocky areas

Existing fencing

- W-beam



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Options to reduce Koala vehicle strike along Heathcote Road

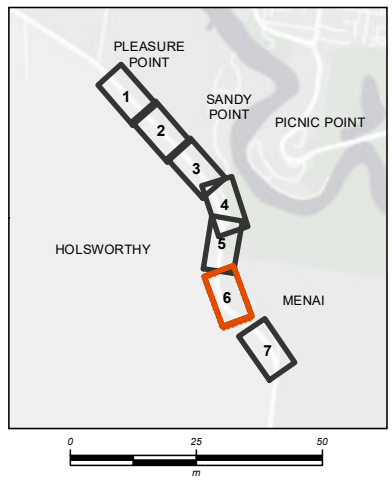
Figure 4.1
Options to reduce Koala Vehicle Strike

Legend

- Option 4 - indicative location (extension can be applied to all the options)
- Watercourses
- Study Area
- Cadastre

Existing fencing

- W-beam



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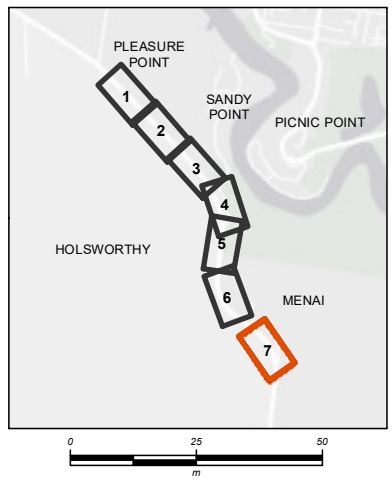
Options to reduce Koala vehicle strike along Heathcote Road

Figure 4.1
Options to reduce Koala Vehicle Strike

Legend

- Option 4 - indicative location (extension can be applied to all the options)
- Cadastre



Coordinate System: GDA2020 MGA Zone 56

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4.3 OPTIONS ASSESSMENT

The feasibility of each potential mitigation option has been assessed following the criteria in Table 4.2 below.

Table 4.2 Criteria used to assess the feasibility of potential mitigation options to reduce koala vehicle strike

CRITERIA	DESCRIPTION	CLASSIFICATION	SCORE
Relative constructability	How easy is it to construct?	Easy to construct	2
		Hard to construct	1
Relative cost	What is the cost including design, construction and maintenance?	Low cost	2
		High cost	1
Extent of habitat clearing	How much native vegetation needs to be cleared?	< 1 ha clearing	2
		> 1 ha clearing	1
Relative maintenance requirements	How expensive or difficult is it to maintain?	Easy to maintain	2
		Hard to maintain	1
Land tenure	Is the land under single or multiple jurisdiction?	Single jurisdiction	2
		Multiple jurisdiction	1
Effectiveness	Is it proven to be effective for reducing koala vehicle strike?	Effective	2
		Not proven	1

Table 4.3 Summary assessment of mitigation options

FEASIBILITY CRITERIA	OPTION 1	OPTION 2	OPTION 3	OPTION 4*
Constructability	2	2	2	2
Cost	1	2	1	2
Extent of clearing	1	2	2	1
Maintenance	2	2	2	2
Land tenure	2	1	2	1
Ecological effectiveness	2	2	1	2
Total score	**10**	**11**	**10**	**10**

*Criteria for Option 4 are assessed on the extension of the fencing only. The total score is subject to change depending on which other Option it is applied to.

4.4 DESIGN CONSIDERATIONS

4.4.1 FAUNA FENCING

The most effective method to reduce rates of WVC of terrestrial wildlife is to install appropriate fencing that prevents them from accessing the roadway. A recent review of the international scientific literature showed that fencing that is correctly designed can reduce rates of mortality by an average of approximately 50%, and up to almost 100% in some situations (Rytwinski et al. 2016). Fencing that is effective at reducing rates of WVC and wildlife mortality necessarily increase the barrier effect of the road because they are designed to keep animals off the road. Therefore, fencing is typically recommended where crossing structures can also be installed.

Fencing is used to reduce the rate of WVC by preventing wildlife from entering the roadway and to increase landscape connectivity by funneling wildlife towards the crossing structures (Rytwinski et al. 2016).

The length of fencing at a crossing structure will depend on the extent of habitat in the area, the movement patterns of the target species and occurrence of other roadway access points for vehicles. Fence ends need a specific treatment, and where possible, should be angled back into the habitat to encourage wildlife to turn back, rather than simply have them move around the fence end and onto the roadway. Ensure fencing is strongly and tightly attached to each crossing structure so that animals are unable to squeeze between the fence and (for example) the abutment walls.

Other important considerations include fence height, mesh size and whether the fence needs to be buried to prevent burrowing animals such as wombats from digging underneath it. Fencing for species that climb (e. g. koalas) may need a band of sheet metal at the top that prevents them from climbing over. Inevitably, fencing along roads will need breaks in it to allow vehicles to access the road, such as at intersecting roads or property access points. Where these occur, effort must be made to prevent animals from accessing the road, such as the use of gates, grids across the intersecting road, or fencing that is run up the intersecting road for a few hundred metres.

Photo 4.5 Example of koala fencing along Picton Road in Sydney's south-west. The photo on the right shows a break in koala fence to provide vehicle access. The gap underneath the gate is ~500 mm, which fauna can easily navigate their way under. Gaps underneath gates need to be minimised as much as possible

In accordance with the Draft Wildlife Connectivity Guidelines (TfNSW, 2011), the following design requirements for fauna fencing are recommended for proposed detailed design:

- use cyclone-mesh with a galvanised steel sheet across the top section of fence
- do not use barbed wire
- minimum 1.8 metres in height to prevent kangaroos from jumping over
- use fence returns
- be used in conjunction with fauna crossing structures (e. g. bridges and underpasses).

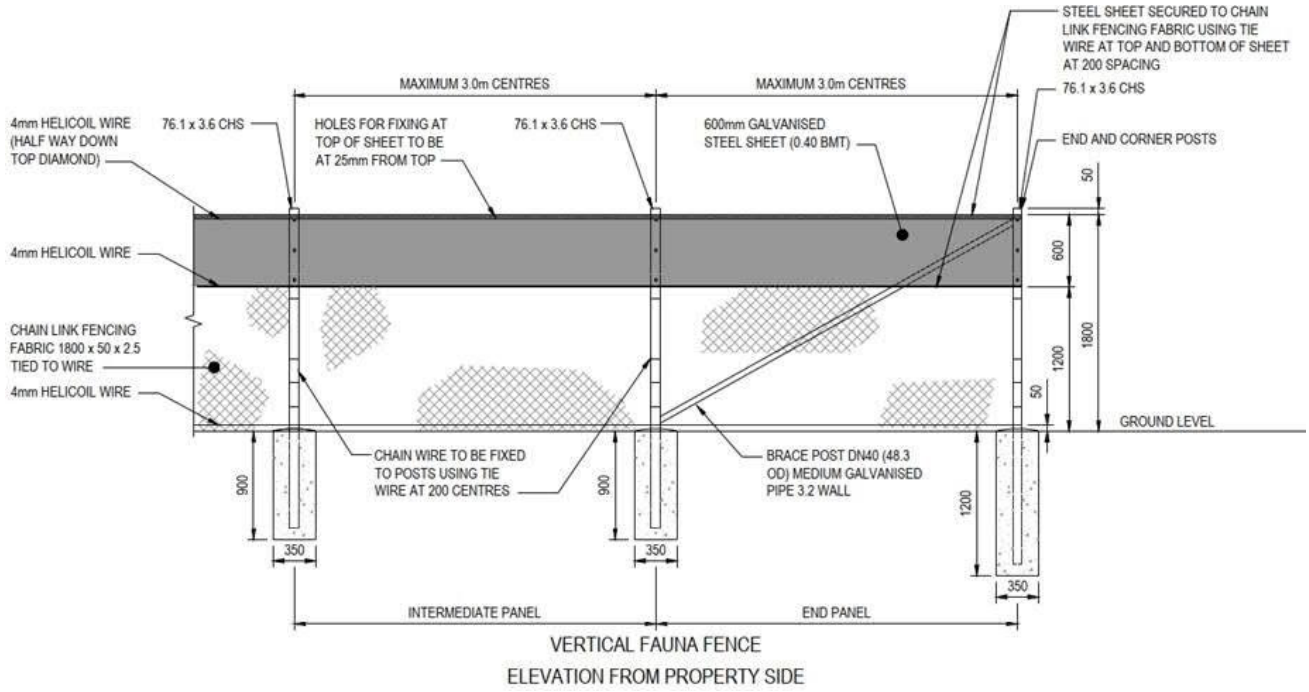

Figure 4.2 Example of a fauna fence suitable to prevent koala access (WSP, 2021)

4.4.2 KOALA GRIDS

Koala grids can be installed when there is a break in long, continuous fauna fencing (e.g. residential access or local road) and they are a modified cattle grid. Koala grids can maintain the flow of human traffic while potentially preventing egress onto road corridors by koalas. While there is limited data demonstrating their success, koala grids installed on a road in the Lismore Local Government Area reportedly prevented koala roadkill over a 6-year period (DPIE, 2020b).

Photo 4.6 Example of a koala grid along Picton Road, where there is a break in continuous fencing for residential access

5 CONCLUSIONS

5.1 HIGHEST SCORING OPTION

The outcomes of the qualitative options assessment in Table 4.3 are very similar but the highest scoring option was Option 2 (score of 11).

Option 2 involves install fauna fencing both sides of Heathcote Rd road reserve for ~ 600 metres from the bridge abutments to existing Defence fencing and to St George Crescent (tie in fencing to the rock cutting near St George Crescent). A section of Defence fencing (~260 metres) would need to be replaced or modified (while meeting Defence controlled access fencing requirements) along its current alignment. Option 2 fencing then cuts back into the road reserve to avoid fencing in the creek, and then ties back into the new Defence fencing.

Option 2 is consistent with recommendations outlined in best practice *Planning Guidelines for Koala Conservation and Recovery* (McAlpine et al, 2006), *How to keep Koalas off the road: Koala vehicle-strike Fact Sheet 2* (DPIE, 2020) and *Conserving Koalas in the Wollondilly and Campbelltown Local Government Area*s (DPIE, 2019) as long, uninterrupted sections of fauna fencing used in conjunction with crossing structures are proven to be effective for mitigating koala vehicle strike.

Option 1 scored marginally less because of the higher relative cost of installation (score of 10).

Option 3 scored marginally less because it comprises only short lengths of fencing within the vicinity of Deadmans Creek Bridge and shorter lengths of fencing are less effective in funneling koalas (score of 10).

5.2 MONITORING AND EVALUATION

The NSW Koala strategy 2018-21 includes a range of measures to stabilise and then improve the status of koala populations across the state. The overall effectiveness of the various measures, including mitigating koala roadkill hotspots should be quantified to improve the delivery and effectiveness of future roadkill hotspot investigations.

Monitoring and evaluation should commence prior to construction and include a more rigorous assessment of the current rate and location of koala roadkill. This can be achieved through engagement with the local community recording koala roadkill, both before and after installation. Once installed, it is recommended that monitoring of the Deadmans Creek Bridge and strategic sections of fencing are monitored for koala activity for a period of six years (on the 1st, 2nd, 4th and 6th year) to account for response to climatic variables and stochastic events.

An annual review of roadkill records (from BioNet and recorded by the local community) should be undertaken to quantify the rate of roadkill in the vicinity of the mitigation measures and at the fence ends.

Maintenance of the fencing and other infrastructure should be undertaken in accordance with current TfNSW Routine Services maintenance specifications for the relevant road (e. g. 2, 3 and 5 years).

6 LIMITATIONS

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APPENDIX A

RAW FLORISTIC DATA

Table A.1 Floristic data from Q1 for PCT 1789 Smooth-barked Apple – Blackbutt – Red Bloodwood open forest in enriched sandstone gullies of the western Woronora plateau – High Condition

Q1			Covers	Native	Trees	Shrub	Grass	Forb	Fern	Other	Exotic	High Threat
PCT 1789 - High Condition			# spp	Count	Count	Count	Count	Count	Count	Count	Count	Count
Date: 10/05/2021			32	32	4	11	9	5	2	1	0	0
			Sum cover	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum	Sum
Species	**Cover**	**Abundance**	29.7	29.7	13	8.6	6.8	0.5	1.1	0.1	0	0
Eucalyptus pilularis	10	4	TG		10							
Angophora floribunda	2	3	TG		2							
Eucalyptus punctata	0.5	3	TG		0.5							
Allocasuarina torulosa	0.1	1	TG		0.1							
Petrophile sessilis	1	1	SG			1						
Persoonia linearis	1	5	SG			1						
Acacia terminalis	4	26	SG			4						
Exocarpos cupressiformis	1	3	SG			1						
Lomandra longifolia	5	35	GG				5					
Pomax umbellata	0.1	15	FG					0.1				
Themeda triandra	1	30	GG				1					
Dodonaea triquetra	1	40	SG			1						
Pteridium esculentum	1	30	EG						1			
Dianella caerulea	0.1	3	FG					0.1				
Entolasia stricta	0.1	25	GG				0.1					
Panicum simile	0.1	35	GG				0.1					
Phyllanthus gunnii	0.1	5	SG			0.1						
Daviesia ulicifolia	0.1	10	SG			0.1						
Digitaria parviflora	0.1	20	GG				0.1					
Phyllanthus hirtellus	0.1	30	SG			0.1						
Hardenbergia violacea	0.1	3	OG							0.1		
Lepidosperma laterale	0.2	35	GG				0.2					
Isopogon anethifolius	0.1	3	SG			0.1						

Q1

PCT 1789 - High Condition

Date: 10/05/2021

Species	Cover	Abundance	
Pratia purpurascens	0.1	50	FG
Lomandra obliqua	0.1	15	GG
Pimelea linifolia	0.1	40	SG
Microlaena stipoides var. stipoides	0.1	50	GG
Cheilanthes sieberi	0.1	15	EG
Eragrostis brownii	0.1	20	GG
Goodenia hederacea	0.1	4	FG
Persoonia levis	0.1	4	SG
Dianella revoluta	0.1	2	FG

Covers	**Native**	Trees	Shrub	Grass	Forb	Fern	Other	**Exotic**	High Threat
# spp	**Count**	Count	Count	Count	Count	Count	Count	**Count**	Count
32	**32**	4	11	9	5	2	1	**0**	0
Sum cover	**Sum**	Sum	Sum	Sum	Sum	Sum	Sum	**Sum**	Sum
29.7	**29.7**	13	8.6	6.8	0.5	1.1	0.1	**0**	0

Table A.2 Floristic data from Q4 for PCT 1789 Smooth-barked Apple – Blackbutt – Red Bloodwood open forest in enriched sandstone gullies of the western Woronora plateau – High Condition

Q4			**Covers**	**Native**	Trees	Shrubs	Grass	Forb	Fern	Other	**Exotic**	High Threat
PCT 1789 - High Condition			**# spp**	**Count**	Count	Count	Count	Count	Count	Count	**Count**	Count
Date: 10/05/2021			**16**	**14**	4	3	3	1	2	1	**2**	2
Species	**Cover**	**Abundance**	**Sum cover**	**Sum**	Sum	Sum	Sum	Sum	Sum	Sum	**Sum**	Sum
			101	**101**	24	21	46	0.1	10	0.1	**0.2**	0.2
Eucalyptus pilularis	10	4	TG		10							
Angophora floribunda	10	11	TG		10							
Melia azedarach	2	3	TG		2							
Acacia parramattensis	2	15	TG		2							
Breynia oblongifolia	3	50	SG			3						
Polyscias sambucifolia	3	15	SG			3						
Pteridium esculentum	10	100	EG						10			
Digitaria parviflora	40	100	GG				40					
Clematis aristata	0.1	3	OG							0.1		
Asparagus asparagoides	0.1	1	HT									0.1
Imperata cylindrica	0.5	50	GG				0.5					
Ligustrum sinense	0.1	20	HT									0.1
Pittosporum undulatum	15	1	SG			15						
Adiantum aethiopicum	0.1	100	EG						0.1			
Microlaena stipoides var. stipoides	5	200	GG				5					
Pratia purpurascens	0.1	100	FG					0.1				

Table A.3 Floristic data from Q5 for PCT 1789 Smooth-barked Apple – Blackbutt – Red Bloodwood open forest in enriched sandstone gullies of the western Woronora plateau – High Condition

Q5 - PCT 1789 - High Condition			**Covers**	**Native**	Trees	Shrubs	Grass	Forb	Fern	Other	**Exotic**	High Threat
			# spp	**Count**	Count	Count	Count	Count	Count	Count	**Count**	Count
Date: 10/05/2021			**30**	**30**	4	11	8	4	0	3	**0**	0
Species	**Cover**	**Abundance**	**Sum cover**	**Sum**	Sum	Sum	Sum	Sum	Sum	Sum	**Sum**	Sum
			63.5	**63.5**	17	26.1	20	0.4	0	0.3	**0**	0
Eucalyptus punctata	10	6	TG		10							
Eucalyptus pilularis	5	4	TG		5							
Angophora costata	1	2	TG		1							
Dodonaea triquetra	15	100	SG			15						
Leptospermum polygalifolium	5	20	SG			5						
Persoonia linearis	2	5	SG			2						
Persoonia levis	0.1	3	SG			0.1						
Entolasia stricta	3	500	GG				3					
Themeda triandra	15	500	GG				15					
Dianella revoluta	0.1	15	FG					0.1				
Lomandra filiformis	0.5	50	GG				0.5					
Acacia implexa	3	30	SG			3						
Acacia floribunda	0.1	1	SG			0.1						
Billardiera scandens	0.1	1	OG							0.1		
Phyllanthus hirtellus	0.1	1	SG			0.1						
Lomandra obliqua	0.1	20	GG				0.1					
Lomandra longifolia	0.5	1	GG				0.5					
Glycine clandestina	0.1	1	OG							0.1		
Exocarpos cupressiformis	0.1	1	SG			0.1						
Echinopogon caespitosus	0.1	10	GG				0.1					
Dianella caerulea	0.1	20	FG					0.1				
Lasiopetalum ferrugineum	0.5	3	SG			0.5						
Allocasuarina torulosa	1	4	TG		1							

Q5 - PCT 1789 - High Condition

Date: 10/05/2021

Species	Cover	Abundance	Covers	Native	Trees	Shrubs	Grass	Forb	Fern	Other	Exotic	High Threat
			# spp	**Count**	Count	Count	Count	Count	Count	Count	**Count**	Count
			30	**30**	4	11	8	4	0	3	**0**	0
			Sum cover	**Sum**	Sum	Sum	Sum	Sum	Sum	Sum	**Sum**	Sum
			63.5	**63.5**	17	26.1	20	0.4	0	0.3	**0**	0
Pomax umbellata	0.1	50	FG					0.1				
Ozothamnus diosmifolius	0.1	3	SG			0.1						
Phyllanthus gunnii	0.1	5	SG			0.1						
Xanthorrhoea resinosa	0.1	1	OG							0.1		
Lagenifera stipitata	0.1	50	FG					0.1				
Aristida vagans	0.2	50	GG				0.2					
Panicum simile	0.3	100	GG				0.3					

Table A.4 Floristic data from Q2 for PCT 1232 Swamp Oak floodplain Forest, Sydney Basin Bioregion and South East Corner Bioregion moderate condition

Q2 - PCT 1232 - Moderate			**Covers**	**Native**	Trees	Shrubs	Grass	Forb	Fern	Other	**Exotic**	High Threat
			# spp	**Count**	Count	Count	Count	Count	Count	Count	**Count**	Count
Date: 10/05/2021			**10**	**6**	2	2	2	0	0	0	**4**	3
Species	**Cover**	**Abundance**	**Sum cover**	**Sum**	Sum	Sum	Sum	Sum	Sum	Sum	**Sum**	Sum
			66.4	**46.1**	11	32	3.1	0	0	0	**20.3**	20.2
Melaleuca styphelioides	30	50	SG			30						
Melaleuca linariifolia	2	15	SG			2						
Eucalyptus amplifolia	1	2	TG		1							
Casuarina glauca	10	30	TG		10							
Ehrharta erecta	20	500	HT									20
Baumea juncea	3	50	GG				3					
Microlaena stipoides var. stipoides	0.1	1	GG				0.1					
Setaria parviflora	0.1	1	EX								0.1	
Ligustrum sinense	0.1	25	HT									0.1
Asparagus asparagoides	0.1	10	HT									0.1

Table A.5 Floristic data from Q3 for PCT 1232 Swamp Oak floodplain Forest, Sydney Basin Bioregion and South East Corner Bioregion moderate condition

Q3 - PCT 1232 - Moderate			**Covers**	**Native**	Trees	Shrubs	Grass	Forb	Fern	Other	**Exotic**	High Threat
			# spp	**Count**	Count	Count	Count	Count	Count	Count	**Count**	Count
Date:10/05/2021			**8**	**6**	1	3	2	0	0	0	**2**	2
Species	**Cover**	**Abundance**	**Sum cover**	**Sum**	Sum	Sum	Sum	Sum	Sum	Sum	**Sum**	Sum
			47.3	**40.3**	5	30.1	5.2	0	0	0	**7**	7
Melaleuca styphelioides	25	70	SG			25						
Melaleuca linariifolia	5	20	SG			5						
Casuarina glauca	5	50	TG		5							
Ehrharta erecta	5	500	HT									5
Asparagus asparagoides	2	100	HT									2
Goodenia ovata	0.1	3	SG			0.1						
Juncus continuus	5	10	GG				5					
Gahnia sieberiana	0.2	4	GG				0.2					

APPENDIX B

PLANT COMMUNITY TYPES

B1 PCT 1789 SMOOTH-BARKED APPLE – BLACKBUTT – RED BLOODWOOD OPEN FOREST IN ENRICHED SANDSTONE GULLIES OF THE WESTERN WORONORA PLATEAU

The occurrence of this vegetation type within the study area is illustrated in Figure 3.1 with photographic representation provided in Photo B.1 to Photo B.4. An overview of floristic and structural composition is presented in Table B.1. A general description is provided below.

Vegetation formation: KF_CH5B Dry Sclerophyll Forests (Shrubby sub-formation)

Vegetation class: Sydney Hinterland Dry Sclerophyll Forests

PCT: PCT 1789 Smooth-barked Apple – Blackbutt – Red Bloodwood open forest in enriched sandstone gullies of the western Woronora plateau

Extent in the study area: 6.79 hectares

Conservation status: Not listed

Estimate of percent cleared: 20%

Landscape position: Higher elevations and sandstone gullies of the study area occurring on sandstone substrates

PCT Justification: In assigning this vegetation type, the following three candidate PCTs were considered based on floristic similarities and given the communities are known to intergrade:

- PCT 1790 Red Bloodwood - Grey Gum - Stringybark open forest on enriched sandstone ridges of the western Woronora plateau and lower Blue Mountains.
- PCT 1776 – Smooth-barked Apple – Red Bloodwood open forest on enriched sandstone slopes around Sydney and the Central Coast.
- PCT 1785 – Smooth-barked Apple - Sydney Peppermint - Blackbutt tall open forest on enriched sandstones around Helensburgh.

Based on the overall strength of PCT 1789 analysis, the landscape position of sandstone gullies associated with sandstone substrate. However, some areas of this community occurred on the upper slopes and is likely a transition to PCT 1776. The dominance of *Eucalyptus pilularis* (Blackbutt), *Eucalyptus punctata* (Grey Gum) and *Angophora costata* (Smooth-barked Apple), PCT 1789 was considered the most closely aligned PCT to this vegetation type.

Condition: Three distinct vegetation zones were assigned within this vegetation type based on broad condition state. These are:

- High condition: The vegetation was recorded in relatively intact high condition – the presence of hollow-bearing trees and large *Eucalyptus pilularis* (Blackbutt) trees occur within this vegetation zone. Photographic representation is presented in Photo B.2, Photo B.3 and Photo B.4.
- Moderate condition: This condition class is in a regeneration state due to clearing associated with Heathcote Road and under the power easement for fire management. Photographic representation is presented in Photo B.1.
- Disturbed condition.

A comparison of PCT 1789 Smooth-barked Apple – Blackbutt – Red Bloodwood open forest in enriched sandstone gullies of the western Woronora plateau plot data recorded against PCT condition benchmark data is provided in Table B.2 below.

Vegetation integrity survey plots: Q1, Q4 and Q5 (High condition). No BAM plots were conducted within the Moderate or disturbed condition of this PCT. See Appendix A for full floristic and structural data.

Photo B.1 PCT 1789 Moderate condition – regrowth under the powerline in the east of the study area

Photo B.2 PCT 1789 High condition – Q1 adjoining Holsworthy Defence base on the western side of Heathcote Road.

Photo B.3 PCT 1789 High condition – on the western side of Heathcote Road in the west of the study area

Photo B.4 PCT 1789 High condition –at the intersection of St George Crescent and Heathcote Road (western side is high condition)

Table B.1 PCT 1789 overview of floristic and structural composition

GROWTH FORM	AVERAGE % FOLIAGE COVER	DOMINANT SPECIES (NATIVE AND EXOTIC)
Trees	18%	*Eucalyptus pilularis* (Blackbutt), *Eucalyptus punctata* (Grey Gum), *Angophora costata* (Smooth-barked Apple), *Allocasuarina torulosa* (Forest She Oak)
Shrubs	19%	*Acacia terminalis* (Sunshine Wattle), *Petrophile sessilis* (Conesticks), *Persoonia linearis* (Narrow-leaved Geebung), *Persoonia levis* (Broad-leaved Geebung), *Exocarpos cupressiformis* (Ballart Cherry), and *Dodonaea triquetra* (Large-leaved Hop-bush)
Grass and grass like	24%	*Entolasia stricta* (Wiry Panic), *Themeda triandra* (Kangaroo Grass), *Lomandra longifolia* (Spiked Mat-rush), *Lomandra obliqua*, *Aristida vagans* (Threeawn Speargrass) and *Panicum simile* (Two-colour Panic)
Forb	0. 2%	*Dianella revoluta var. revolute* (Blue Flax-lily), *Phyllanthus gunnii* (Scrubby Spurge), *Lobelia purpurascens* (Whiteroot)
Fern	3.3%	*Pteridium esculentum* (Bracken Fern)
Other	0.16%	*Billardiera scandens* (Hairy Apple Berry), *Glycine tabacina*, *Hardenbergia violacea* (False Sarsaparilla)
Exotic	0%	None
High threat weed	0.07%	*Ligustrum sinense** (Small-leaved Privet) and *Senecio madagascariensis* (Fireweed)

Table B.2 Comparison of PCT 1789 Smooth-barked Apple – Blackbutt – Red Bloodwood open forest in enriched sandstone gullies of the western Woronora plateau plot data against PCT condition benchmark data

PLOT	TREE RICHNESS	SHRUB RICHNESS	GRASS RICHNESS	FORB RICHNESS	FERN RICHNESS	OTHER RICHNESS	TREE COVER	SHRUB COVER	GRASS COVER	FORB COVER	FERN COVER	OTHER COVER	LENGTH TIMBER	LEAF LITTER	LARGE TREE
BM[1]	**6**	**22**	**9**	**9**	**2**	**4**	**60**	**56**	**23**	**6**	**0**	**3**	**45**	**75**	**3(50)**
Q1	4	11	9	5	2	1	12.6	8.6	6.8	0.5	1.1	0.1	24	24	3
Q4	4	3	3	1	2	1	24	21	45.5	0.1	10.1	0.1	25	26	4
Q5	4	11	8	4	0	3	17	26.1	19.7	0.4	0	0.3	16	47	2

(1) Benchmark data for equivalent community in Sydney Basin IBRA bioregion (Vegetation Type: PCT 1789 Smooth-barked Apple – Blackbutt – Red Bloodwood open forest in enriched sandstone gullies of the western Woronora plateau Keith Formation KF_CH5B Dry Sclerophyll Forests (Shrubby sub-formation) Keith Class: Sydney Hinterland Dry Sclerophyll Forests, source (Office of Environment & Heritage 2018).

B2 PCT 1232 SWAMP OAK SWAMP FOREST SYDNEY BASIN BIOREGION AND SOUTH EAST CORNER BIOREGION

The occurrence of this vegetation type within the study area is illustrated in Figure 3.1 with photographic representation provided in Photo B.5 and Photo B.6. An overview of floristic and structural composition is presented in Table B.3. A general description is provided below.

Vegetation formation: KF_CH9 Forested Wetland

Vegetation class: Coastal Swamp Forests

PCT: 1232 Swamp Oak floodplain Forest, Sydney Basin Bioregion and South East Corner Bioregion

Extent in the study area: 0.29 hectares

Conservation status: Endangered Ecological Community BC Act - Swamp Oak Floodplain Forest of the NSW North Coast, Sydney Basin and South East Corner Bioregions

Estimate of percent cleared: 90%

Landscape position: occurs on saline sediments of Deadmans Creek, which is periodically inundated by saline water at high tides from the Georges River.

PCT Justification: In assigning this vegetation type, the following three candidate PCTs were considered based on floristic similarities and given the communities are known to intergrade:

- PCT 1234 Swamp Oak Swamp Forest fringing estuaries, Sydney Basin Bioregion and South East Corner Bioregion
- PCT 1236 – Swamp Paperbark - Swamp Oak tall shrubland on estuarine flats, Sydney Basin Bioregion and South East Corner Bioregion
- PCT 1800 Swamp Oak open forest on riverflats of the Cumberland Plain and Hunter Valley.

Casuarina glauca (Swamp Oak) and *Melaleuca styphelioides* (Prickly-leaved Paperbark) were the dominant canopy species. Several dominant canopy species identified in PCT 1232 are absent from the PCT present within the study area. However, it is likely that this PCT has previously been cleared which has resulted in a dense regrowth of *Melaleuca styphelioides* (Prickly-leaved Paperbark) and *Melaleuca linariifolia* (Flax-leaved Paperbark).

Based on the overall strength of PCT 1232 analysis, the landscape position on saline sediments which occurs below the high tide mark and dominant canopy species, the PCT recorded within the study area is most closely aligned with PCT 1232.

Condition: Moderate – the vegetation has previously been cleared with a dense regrowth of *Melaleuca styphelioides* (Prickly-leaved Paperbark) and *Melaleuca linariifolia* (Flax-leaved Paperbark). This PCT is subject to ongoing edge effects from Heathcote Road. A comparison of PCT 1232 Swamp Oak floodplain Forest, Sydney Basin Bioregion and South East Corner Bioregion plot data recorded against PCT condition benchmark data is provided in Table B.4.

Vegetation integrity survey plots: Q2 and Q3. See Appendix A for full floristic and structural data.

Photo B.5 PCT 1232 at Q2 on the eastern side of Heathcote Road in Moderate condition

Photo B.6 PCT 1232 Moderate condition

Table B.3 PCT 1232 overview of floristic and structural composition

GROWTH FORM	AVERAGE % FOLIAGE COVER	DOMINANT SPECIES (NATIVE AND EXOTIC)
Trees	8%	*Casuarina glauca*
Shrubs	32%	*Melaleuca styphelioides* (Prickly-leaved Paperbark), *Melaleuca linariifolia* (Snow-in Summer)
Grass and grass like	4%	*Microlaena stipoides* var. *stipoides* (Weeping Grass), *Cynodon dactylon* (Couch), *Machaerina juncea* (Bare Twig-rush) and *Carex inversa*
Forb	0%	-
Fern	0%	-
Other	0%	-
Exotic	0.1%	*Setaria parviflora** (Pidgeon Grass)
High Threat Weed	13%	*Ehrharta erecta** (Panic Veldtgrass) *Ligustrum sinense** (Small-leaved Privet) and *Asparagus asparagoides** (Bridal Creeper)

Table B.4 Comparison of PCT 1232 Swamp Oak floodplain Forest, Sydney Basin Bioregion and South East Corner Bioregion plot data against PCT condition benchmark data

PLOT	TREE RICHNESS	SHRUB RICHNESS	GRASS RICHNESS	FORB RICHNESS	FERN RICHNESS	OTHER RICHNESS	TREE COVER	SHRUB COVER	GRASS COVER	FORB COVER	FERN COVER	OTHER COVER	LENGTH TIMBER	LEAF LITTER	LARGE TREE
BM[1]	**4**	**9**	**8**	**7**	**2**	**5**	**16**	**23**	**56**	**3**	**2**	**3**	**44**	**42**	**5**
Q2	2	2	2	0	0	0	11	32	3.1	0	0	0	100	70	1
Q3	1	3	2	0	0	0	5	30.1	5.2	0	0	0	75	49	1

(1) Benchmark data for equivalent community in Sydney Basin IBRA bioregion (Vegetation Type: PCT 1232 Swamp Oak floodplain Forest, Sydney Basin Bioregion and South East Corner Bioregion Keith Formation KF_CH9 Forested Wetlands Keith Class: Coastal Swamp Forests, source (Office of Environment & Heritage 2018).

B3 MISCELLANEOUS ECOSYSTEM – EXOTIC GRASSLAND

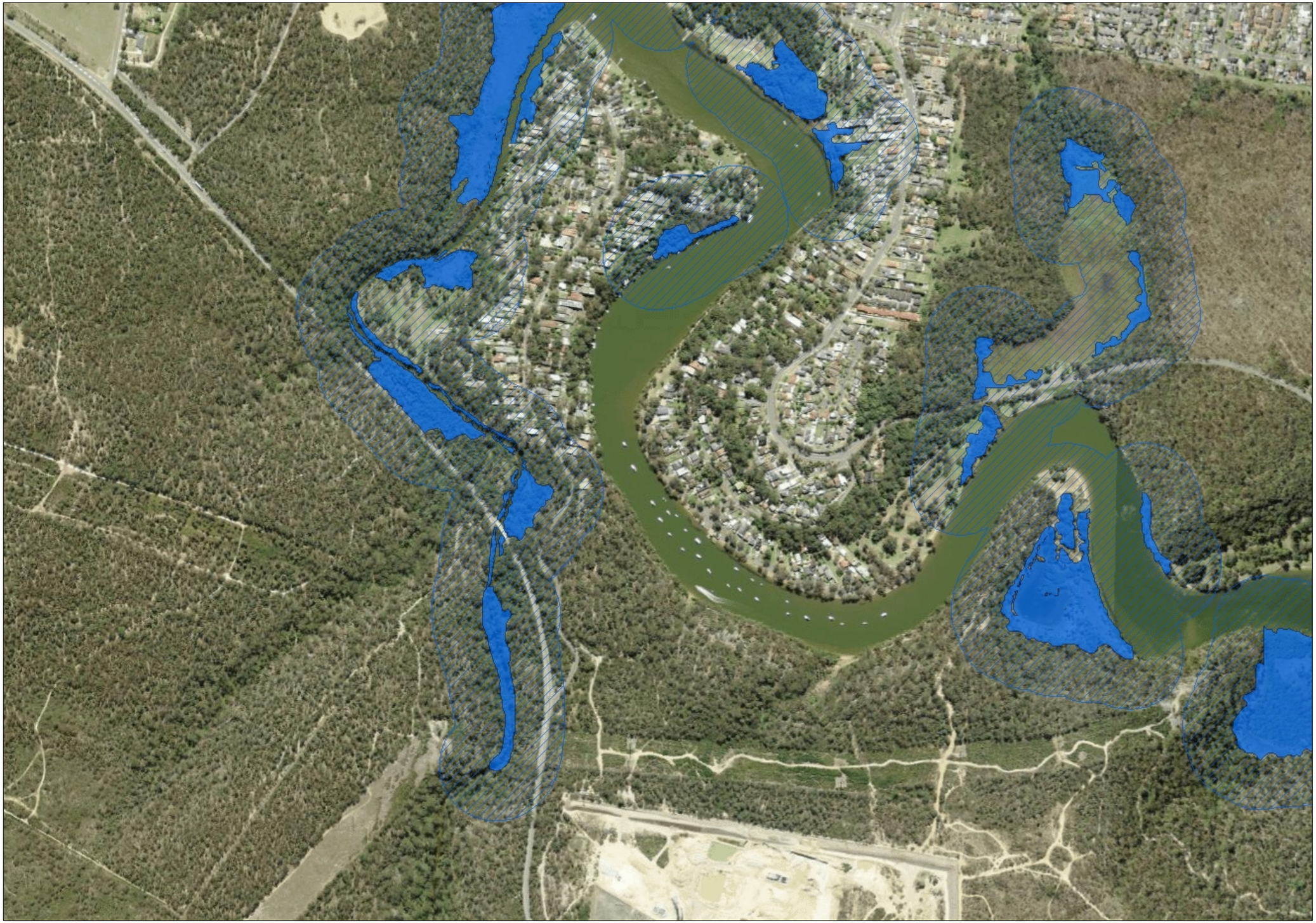
This non-native vegetation type consists of exotic forbs and grasses. The grassland that occurs on the road verges is the old bridge location and is regularly slashed as part of routine maintenance associated with Heathcote Road. The distribution of the exotic grassland is shown in Figure 3.1. Photographic representation is provided in Photo B.7 below. Overall, this vegetation formed 0.66 hectares within the study area.

This vegetation type does not align to any recognised plant community type in NSW due to its limited native vegetation and degraded condition. As such, it has been aligned to exotic grassland. Within the study area this vegetation type was mostly dominated by exotic species such as *Ehrharta erecta** (Panic Veldtgrass), *Setaria parviflora** (Pidgeon Grass), *Senecio madagascariensis* (Fireweed), *Verbena bonariensis** (Purpletop), *Sida rhombifolia* (Paddy's Lucerne), *Gomphocarpus fruticosus* (Narrow-leaved Cotton Bush), *Bidens pilosa** (Cobblers Pegs), and *Cenchrus clandestinum** (Kikuyu).

Photo B.7 Miscellaneous ecosystem – Exotic grassland near Deadmans Creek Bridge

APPENDIX C

COASTAL SEPP MAPPING



Planning & Environment

Coastal Management SEPP 2018

Legend

Coastal Wetlands

Proximity Area for Coastal Wetlands

Notes:

0 0.10 0.2 0.39 kilometres

Heathcote Road Koala Fence Options

Map created: 25-May-2021

The information in this map is correct to the best of our knowledge. No warranty or guarantee is provided and no liability is accepted for any loss or damage resulting from any person relying upon or using the information contained in the map.

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