APPENDIX K

Appendix K - Terrestrial Ecology Assessment, Aquatic Ecology Assessment, Stygofauna Assessment

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Tahmoor South Project

Biodiversity Assessment Report

Prepared for SIMEC Mining - Tahmoor Coal Pty Ltd.

November 2018

Document control

Project no.:	3680
Project client:	Tahmoor Coal Pty Ltd
Project office:	Sydney
Document description:	Biodiversity Assessment report for the Tahmoor South Project
Project Director:	Matthew Richardson
Project Manager:	Sian Griffiths
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Internal review:	Amanda Griffith
Document status:	Rev4
Document address:	P:\Projects\3000s\3600s\3680_Tahmoor_South_-Ecology Assessment 2017 SEARs\Report\Drafts
Local Government Area:	Wollondilly LGA

Document revision status

Author	Revision number	Internal review	Date issued
Sian Griffiths, Luke Baker	Draft 1	Amanda Griffith	9 November 2017
Luke Baker, Amanda Griffiths	Rev 0	SIMEC Mining - Tahmoor Coal Pty Ltd Review (Nicole Armit)	02 February 2018
Luke Baker	Rev 2	SIMEC Mining - Tahmoor Coal Pty Ltd Review (Nicole Armit)	10 October 2018
Luke Bkaer	Rev 3	SIMEC Mining - Tahmoor Coal Pty Ltd Review (Nicole Armit)	14 November 2018

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Cover photograph: Native vegetation recorded in Study Area (© Niche Environment and Heritage Pty Ltd)

Executive summary

Context

Simec Mining - Tahmoor Coal Pty Ltd (Tahmoor Coal) owns and operates the Tahmoor Mine, an underground coal mine approximately 80 kilometres south-west of Sydney in the Southern Coalfields of NSW (Figure 1).

Tahmoor Coal is seeking approval for the Tahmoor South Project (the proposed development), being the extension of underground coal mining at Tahmoor Mine to the south of the existing Tahmoor Mine surface facilities area. The proposed development seeks to extend the life of underground mining at Tahmoor Mine until approximately 2035. The proposal will enable mining to be undertaken within the southern portion of Tahmoor Coal's existing lease areas and for operations and employment of the current workforce to continue for approximately a further 13 years.

Niche Environment and Heritage Pty Ltd (Niche) was commissioned by Tahmoor Coal to assess the ecological values and impacts associated with the Tahmoor South Project, and provide a Biodiversity Assessment Report.

The impacts to biodiversity associated with the Project have been assessed under the *Framework for Biodiversity Assessment - NSW Biodiversity Offsets Policy for Major Projects* (FBA) (OEH 2014), in accordance with the transitional arrangements provided under the NSW *Biodiversity Conservation Act 2016* (BC Act).

The primary objective of this report is to use the methodology provided in the FBA to describe and assess the ecological values within the Study Area and surrounds, and determine how the Project is likely to impact on threatened biodiversity listed under the BC Act and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). This report also addresses the Secretary's Environmental Assessment Requirements (SEARs), and identifies avoidance, mitigation and offsets for the Project.

The assessment has utilised the findings of other specialist studies in preparation of the impact assessment, in particular that of MSEC (2018) in regards to the subsidence predictions associated with the Project.

Study Area

The Study Area for the Biodiversity Assessment Report includes:

- The area within the predicted 20mm subsidence contour.
- The extent of the proposed Reject Emplacement Area (REA) Extensions.
- The proposed surface infrastructure including ventilation shaft sites and proposed carpark extension.

The Study Area is approximately 2,156 hectares in size, of which 49.2 hectares of native vegetation would be cleared for the surface infrastructure.

Subsidence impacts are predicted by MSEC (2018) to occur within the 20mm Subsidence Contour, and as such, we have utilised this area in this assessment for impact calculations.

Survey effort

The Study Area, and wider Project Area has been the subject of extensive targeted threatened biodiversity surveys since 2012, with the most recent survey completed in September 2018. The survey effort concentrated on areas that would be directly impacted by the clearing associated with surface infrastructure, and natural features that may be susceptible to subsidence related impacts ie. Watercourses and cliff lines.

Native vegetation assessment

Vegetation within the Study Area has been mapped previously as part of the Native Vegetation of South Eastern NSW (Tozer et al. 2006) and as part of the Cumberland Plain Revised Mapping Project (OEH 2013). Vegetation validation of this mapping was undertaken within area proposed for surface infrastructure.

The validation confirmed that the surface infrastructure footprint contained the following Plant Community Types (PCTs):

- HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin
- HN564 Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin.

HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest corresponds to Shale Sandstone Transition Forest, which is listed as a Threatened Ecological Community (TEC) under both the BC Act and EPBC Act.

Threatened flora

Based on the results of a data review, 47 threatened flora species have been recorded or have potential habitat within 10 km of the study area. Seven threatened flora were recorded in the Study Area and immediate surrounds during current and previous field surveys undertaken by Niche. Species include: *Acacia bynoeana, Epacris purpurascens var. purpurascens, Grevillea parviflora subsp. parviflora, Persoonia hirsuta, Persoonia glaucescens var. glaucescens, Persoonia bargoensis,* and *Pomaderris brunnea.* Only *Grevillea parviflora* subsp*. parviflora,* and *Persoonia bargoensis* were recorded in the area proposed for surface infrastructure.

Threatened fauna

Seventy-four threatened fauna have been recorded or are predicted to occur within 10 km of the Study Area. Of those species listed under the BC Act, 18 are regarded as 'species credit species' which unlike 'ecosystem credit species' cannot be assumed to be present based on the presence of habitat surrogates.

Twelve threatened fauna species listed on the BC Act and/or EPBC Acts were recorded within the Study Area or immediately adjacent. These include: Glossy Black Cockatoo, Little Eagle, Powerful Owl, Scarlet Robin, Sooty Owl, Varied Sittella, Eastern Bentwing Bat, Eastern Free-tail Bat, Large-footed Myotis, Eastern Cave Bat, Eastern False Pipistrelle and Red-crowned Toadlet.

Impacts - Vegetation

The main impact on biodiversity associated with the Project is clearing of native vegetation and removal of habitat for surface infrastructure. The extent of clearing of native vegetation communities is estimated at 49.2 hectares.

Of the native vegetation to be cleared, approximately 43.4 hectares of the TEC Shale Sandstone Transition Forest (HN556) would be impacted for surface infrastructure.

Subsidence has the potential to result in gas emissions and changes to hydrology which could result in dieback of native vegetation. However, based on subsidence predictions by MSEC (2018) and previous events in the Southern Coalfield, the likelihood for such an event to occur and result in detrimental change to native vegetation is highly unlikely.

An offset for the impact to the PCTs impacted by the vegetation clearing has been provided in this assessment in accordance with the requirements of the FBA. An Assessment of Significance under the EPBC Act has also been completed for the impact on Shale Sandstone Transition Forest, which concluded the Project is likely to significantly impact the TEC.

Impacts – Threatened flora

The clearing of native vegetation for the surface infrastructure would result in an impact to the following threatened flora:

- Removal of approximately 100 individuals of *Persoonia bargoensis*
- Removal of an estimated 2,324 individuals of *Grevillea parviflora* subsp. *parviflora.*

An offset in accordance with the FBA has been provided in this assessment for the impact to each of the threatened flora.

Assessments of Significance under the EPBC Act has also been completed for threatened flora that would be impacted by the Project. The assessments concluded that the Project would result in a significant impact to *Persoonia bargoensis,* and a non-significant impact to *Grevillea parviflora* subsp. *parviflora* given the large size of the population that would not be impacted by the Project. However, despite the conclusions, both species would be offset accordingly as per the FBA.

Impacts – Threatened fauna

Thirty-four threatened and migratory fauna have been attributed a moderate or higher likelihood of occurrence within the Study Area. The majority of these species are highly mobile species (such as threatened birds and microbats) that are likely to use the Study Area on an intermittent basis and would not be solely dependent upon the habitat features within the area to be disturbed by the surface infrastructure works.

Of these species considered, the Red-crowned Toadlet, Large-eared Pied Bat, Large-footed Myotis, Eastern Cave Bat and Koala are the only species credit fauna with potential to occur within the Study Area.

The Project has been determined to have the following impacts to the following species credit fauna:

- Koala: Whilst not detected during the field survey, given the importance of the Koala within the locality, the removal of 43.5 hectares of potential Koala habitat would be offset. The Koala is unlikely to be impacted by subsidence.
- Large-eared Pied Bat: the species was not detected during the survey. Within the area proposed to be cleared for surface infrastructure, no breeding habitat features (such as caves, rocky crevices, old mine workings) would be removed.
- The Large-footed Myotis: was recorded within the surface area footprint of the REA during targeted surveys. The Large-footed Myotis is regarded as a species credit species given its dependence on habitat surrounding waterways for roosting. The OEH Bionet database notes that hollow-bearing trees, bridges, caves or artificial structures within 200 metres of a riparian zone are areas of important habitat for the species. Portions of the proposed surface infrastructure for the REA contain hollow-bearing trees that are within 200 metres of Tea Tree Hollow Creek. The portion of habitat within 200 metres of a riparian zone that would be removed is 7.4 hectares. As such, the removal of this area of habitat would require an offset.
- The Eastern Cave Bat: was recorded within the surface area footprint during targeted surveys. However, important foraging habitat or roosting habitat is unlikely impacted by vegetation clearing or subsidence.
- A population of the Red-crowned Toadlet was recorded within the Study Area at Hornes Creek during the Tahmoor South Project Terrestrial Ecology Monitoring Program. The Red-crowned Toadlet was not recorded within any other riparian areas within the Study Area and surrounds, including Dog Trap Creek, Tea Tree Hollow Creek, Bargo River and its tributaries, Eliza Creek, Cow Creek, Dry Creek and

Carter Creek. Habitat for the species would not be impacted by the surface instructure. Based on subsidence prediction detailed in MSEC (2018), and surface water assessments by HECONS (2018b), it is unlikely that the portion of Hornes Creek where the Red-corwned Roadlet occurs would be impacted by the Project (section 7.5.5), and as such no offset for the species has been proposed.

In relation to EPBC Act listed threatened fauna, the Project was determined to potentially impact habitat associated with the following species: Fork-tailed Swift, Great Egret, Cattle Egret and Rainbow Bee-eater, Satin Flycatcher, Swift Parrot, Large-eared Pied Bat, Grey-headed Flying Fox, Koala, and Greater Glider. An EPBC Act Assessment of Significance for each of these species has been completed and concluded that a significant impact to any EPBC Act listed threatened fauna is unlikely.

Avoidance and minimisation

Site selection for the Project has been largely dictated by the existing REA and supporting infrastructure within the development consent boundary. The Project has been designed to avoid/minimise impacts to adjacent areas of high biodiversity value by consideration/implementation of the following:

- The REA was redesigned to minimise the potential impacts on Shale Sandstone Transition Forest, *Persoonia bargoensis* and *Grevillea parviflora* subsp. *parviflora*, and was moved away from Tea Tree Hollow Creek and the population of *Pomaderris brunnea*.
- A powerline originally proposed through a population of *Epacris purpurascens* var. *purpurascens* was removed from the Project.
- The longwalls in the north of the Study Area have been designed to stand back from the Bargo River and Nepean River. This design maximises the protection of the natural features within these rivers and reduces any potential for the Project to impact the biodiversity values associated with those two rivers.
- The longwalls in the south of the Study Area have been re-designed to stand back from the Nepean State Conservation Area, and avoid impacts to Cow Creek. This avoids impacts to the Giant Burrowing Frog which was recorded during field surveys by Niche along Cow Creek.
- The longwalls originally proposed in what was called the 'Eastern Domain' have been removed from the project.

Mitigation and management

The Project will reduce impacts to biodiversity through:

- Implementation of a Biodiversity and Subsidence Management Plan with active monitoring.
- All surface infrastructure areas would be progressively rehabilitated in accordance with a Landscape and Rehabilitation Management Plan, to create a stable landform that does not result in sediment laden runoff or fugitive dust emissions, blends well with the adjacent natural landscapes and re-establishes a native bushland.
- Fencing and/or the use of highly visible rope or tape boundaries will be used to delineate the boundary of vegetation clearing.
- Signposting will be used to inform Project personnel and site visitors of areas of conservation value to restrict entry or inform behaviour that will reduce incidental interactions with threatened species - e.g. speed limits along access roads to reduce potential for fauna vehicle strikes.
- Update of the existing Tahmoor Coal Bushfire Management Plan.
- Dust suppression.
- Procedures for the management of spills throughout the Study Area including the requirements for vehicles to carry spill kits.
- Management and removal of all rubbish from the Study Area.

Credit calculations

The ecosystem credits required to offset the Project equate to the following:

- 2,246 credits for the impact to HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion
- 287 credits for the impact to Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion.

The species credits required to offset the Project equate to the following:

- 7,700 credits for the removal of 100 *Persoonia bargoensis* plants
- 32,536 credits for the removal of 2,324 *Grevillea parviflora* subsp. *parviflora* plants.
- 163 for the removal of 7.4 hectares of potential habitat for the Large-footed Myotis.
- 1,131 for the removal of 43.5 hectares of potential Koala habitat.

Offsetting

Tahmoor Coal propose a two stage offset approach spanning over a 7 year period, as not all the surface infrastructure would be cleared in the first year.

Tahmoor Coal propose to undertake a combination of the following offset mechanisms to offset the Project:

1. Establishment of Biodiversity Stewardship Agreement sites within Tahmoor Coal landholdings
2. Purchase of the required credits available on the Public Register
3. Payment into the NSW Biodiversity Offsets Fund.

Glossary

Term	Definition
Cumulative impacts	Combination of individual effects of the same kind due to multiple actions from various sources over time.
Direct impacts	Those that directly affect habitat and individuals of a species, population or ecological community. They include, but are not limited to, death through predation, trampling, poisoning of the animal/plant itself and the removal of suitable habitat. In the context of the Project, direct impacts will result in the direct removal of 49.2 hectares of native vegetation.
Habitat critical to survival (EPBC Act)	'Habitat critical to the survival of a species or ecological community' refers to areas that are necessary: • for activities such as foraging, breeding, roosting, or dispersal • for the long-term maintenance of the species or ecological community (including the maintenance of species essential to the survival of the species or ecological community, such as pollinators) • to maintain genetic diversity and long term evolutionary development, or • for the reintroduction of populations or recovery of the species or ecological community. Such habitat may be, but is not limited to: habitat identified in a recovery plan for the species or ecological community as habitat critical for that species or ecological community; and/or habitat listed on the Register of Critical Habitat maintained by the minister under the EPBC Act.
Indirect impacts	Indirect impacts can include loss of individuals through starvation, exposure, predation by domestic and/or feral animals, loss of breeding opportunities, loss of shade/shelter, deleterious hydrological changes, increased soil salinity, erosion, inhibition of nitrogen fixation, weed invasion, fertiliser drift, or increased human activity within or directly adjacent to sensitive habitat areas.
Local population:	The population that occurs in the Study Area. The assessment of the local population may be extended to include individuals beyond the study area if it can be clearly demonstrated that contiguous or interconnecting parts of the population continue beyond the study area, according to the following definitions. The local population of a threatened plant species comprises those individuals occurring in the study area or the cluster of individuals that extend into habitat adjoining and contiguous with the study area that could reasonably be expected to be cross-pollinating with those in the study area. The local population of resident fauna comprises those individuals known or likely to occur in the study area, as well as any individuals occurring in adjoining areas (contiguous or otherwise) that are known or likely to utilise habitats in the study area. The local population of migratory or nomadic fauna comprises those individuals that are likely to occur in the study area from time to time.
Study Area	The area contained within the 20 mm predicted subsidence zone, and all proposed surface infrastructure. It encompases the area of direct and indirect impact.
Subject site:	Means the area directly affected by the Tahmoor South Project.
Threatened ecological community (TEC)	An ecological community identified by the NSW *Biodiversity Conservation Act 2016* (BC Act) or Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* as critically endangered, endangered or vulnerable.

Abbreviations

Acronym	Term/Definition
BAR	Biodiversity Assessment Report
BBAM	BioBanking Assessment Methodology
BBCC	BioBanking Credit Calculator
BC Act	Biodiversity Conservation Act
BMP	Biodiversity Management Plan
CMA	Catchment Management Authority
CEEC	Critically Endangered Ecological Community
Dbh	Diametre at breast height
DoEE	Commonwealth Department of Environment and Energy
DPE	Department of Planning and Environment
FBA	Framework for Biodiversity Assessment
EEC	Endangered Ecological Community
EP&A Act	*Environmental Planning and Assessment Act 1979* (NSW)
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
FBA	Framework for Biodiversity Assessment
Ha	Hectare/s
IBRA	Interim Biogeographic Regionalisation for Australia
JAMBA	Japan-Australia Migratory Bird Agreement
Km	Kilometre
KTP	Key Threatening Process
LGA	Local Government Area
Mm	Millimetre
MNES	Matters of National Environmental Significance (from the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*).
NPWS	National Parks and Wildlife Service
OEH	Office of Environment and Heritage (formerly DECCW, DECC, DEC)
PCT	Plant Community Type
REF	Review of Environmental Factors
RUKAMBA	Republic of Korea-Australia Migratory Bird Agreement
SEARs	Secretary's Environmental Assessment Requirements
SEPP	State Environmental Planning Policy
SEPP 44	*State Environmental Planning Policy 44 – Koala Habitat Protection*
SSTF	Shale Sandstone Transition Forest
TEC	Threatened Ecological Community

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1. Introduction

1.1 Overview

Tahmoor Coal Pty Ltd (Tahmoor Coal) owns and operates the Tahmoor Mine, an underground coal mine between the townships of Tahmoor and Bargo, approximately 80 km south-west of Sydney in the Southern Coalfields of NSW. Tahmoor Mine produces up to 3 million tonnes per annum (Mtpa) of run-of-mine (ROM) coal (Figure 1).

Tahmoor Coal is seeking approval for the Tahmoor South Project (the proposed development), being the extension of underground coal mining at Tahmoor Mine to the south of the existing Tahmoor Mine surface facilities area. The proposed development seeks to extend the life of underground mining at Tahmoor Mine until approximately 2035. The proposal will enable mining to be undertaken within the southern portion of Tahmoor Coal's existing lease areas and for operations and employment of the current workforce to continue for approximately a further 13 years.

The Tahmoor South Study Area comprises an area adjacent to, and to the south of, the existing Tahmoor approved mining area. It also overlaps a small area of the existing Tahmoor approved mining area.

Niche Environment and Heritage Pty Ltd (Niche) was commissioned by Tahmoor Coal to assess the ecological values and impacts associated with the Tahmoor South Project, and provide a Biodiversity Assessment Report. In accordance with the transitional arrangements provided under the NSW *Biodiversity Conservation Act 2016* (BC Act), this Biodiversity Assessment Report has been completed according to the requirements of the *Framework for Biodiversity Assessment - NSW Biodiversity Offsets Policy for Major Projects* (FBA) (OEH 2014). Further detail on recent changes to NSW environmental legislation and the applicable transitional arrangements that relate to the approval and assessment process for this Project are provided in section 2.1. This report also addresses the Secretary's Environmental Assessment Requirements (SEARs), and identifies avoidance, mitigation and offsets for the Project.

1.2 The Project

Tahmoor Coal is seeking development consent for the continuation of underground mining at Tahmoor Mine, extending underground operations and associated infrastructure south, within the Bargo area.

The proposed development will use longwall mining to extract coal from the Bulli seam within the bounds of CCL 716 and CCL 747. Coal extraction of up to 4 million tonnes (Mt) of ROM coal per annum is proposed as part of the development, with extraction of up to 48 Mt of ROM coal over the life of the project. The majority of product coal produced will be coking coal, with a small secondary thermal coal product.

Once the coal has been extracted and brought to the surface, it will be processed at Tahmoor Mine's existing Coal Handling and Preparation Plan (CHPP) and coal clearance facilities, and then transported via the existing rail loop, the Main Southern Railway and the Moss Vale to Unanderra Railway to Port Kembla and Newcastle (from time to time) for Australian and international markets.

The proposed development will utilise the existing surface infrastructure at the Tahmoor Mine surface facilities area. Some upgrades are proposed to facilitate the extension. The proposed development also incorporates the planning for rehabilitation and mine closure once mining ceases.

The proposed development will make use of three ventilation shafts currently being used for the operations at Tahmoor North, being one upcast (T2) and two downcast shafts (T1 and T3). The two additional vent shafts proposed for the Tahmoor South Project will be located in the Central Domain as follows:

- TSC1: an upcast ventilation shaft that will be located on Tahmoor Coal's Charlies Point Road property; and
- TSC2: a downcast ventilation shaft that will be located on Crown Land adjacent to Tahmoor Coal's Charlies Point Road property.

An additional 50 -175 personnel will be required for the Tahmoor South Project development works, which may occur concurrently with the ongoing mining operations at Tahmoor North. Additional site amenities, including bath houses and additional onsite car parks will be required to accommodate the increased workforce during the transition period from mining operations at Tahmoor North and the Tahmoor South Project's development works.

In summary, the key components of the proposed development comprise:

- longwall mining in the Central Domain
- mine development including underground redevelopment, ventilation shaft construction, pre-gas drainage and service connection
- upgrades to the existing surface facilities area including:
    - upgrades to the CHPP
    - expansion of the existing REA
    - additional mobile plant for coal handling
    - additions to the existing bathhouses, stores and associated access ways; and
    - upgrades to onsite and offsite service infrastructure, including electrical supply.
- rail transport of product coal to Port Kembla, and Newcastle (from time to time)
- mine closure and rehabilitation
- environmental management.

The components of the proposed development and Tahmoor South Project are listed above, and those relevant to the biodiversity assessment are shown on Figure 2.

1.2.1 Project timeframes

The proposed development seeks to extend the life of underground mining at Tahmoor Mine beyond the predicted completion of mining at Tahmoor North in 2022, with this timing depending upon geological, mining and economic conditions.

A number of pre-mining activities are required to be completed prior to commencement of longwall mining for the Tahmoor South Project. These pre-mining activities include:

- gas drainage
- redevelopment of the pit bottom
- longwall development including establishment of gate roads
- installation of electrical, water and gas management networks, and
- the purchase and installation of equipment.

The proposed development's pre-mining activities are anticipated to take approximately three years to complete before longwall mining can commence in the Central Domain. Longwall mining is proposed to commence in the Central Domain once mining is completed at Tahmoor North. Mining at Tahmoor North is anticipated to be completed by 2022 depending upon geological, mining and economic conditions.

Mining for the proposed development would be complete by approximately 2035, with surface works, rehabilitation and mine closure occurring after the completion of mining activities.

1.3 Proposed operations relevant to the terrestrial ecology impact assessment

Components of the Project that relate to the terrestrial ecology impact assessment are detailed below, within further detailed in the main body of the EIS.

1.3.1 Underground mining

Mining Area

Tahmoor Coal holds CCL 747 and CCL 716, within which coal will be mined from the Bulli seam as part of the Tahmoor South Project.

The proposed development seeks to undertake longwall mining of the Bulli seam within the Central Domain, at a depth of between approximately 375 metres and 430 metres below ground level.

During the mine planning process, a constraints analysis, risk assessment and preliminary fieldwork were undertaken to identify sensitive natural surface features (such as waterways, cliffs, and Aboriginal heritage sites) and to develop RMZs. Subsequent to the risk assessment, the proposed longwall layout was modified to minimise significant subsidence impacts to these natural features.

The proposed extent of longwall panels is shown on Figure 2, which defines the maximum extent of the footprint of the proposed longwall mining and consists of both first (roadways) and secondary (longwall) workings. The Subsidence Study Area encompasses the area of investigation of specialist studies as part of the Project. It has been provided on the figures for this Biodiversity Assessment to provide context.

The extent of longwalls provides for some flexibility for changes to mining development work and longwall layout during detailed design, subject to geological conditions. It is proposed that minor changes to the layout would be approved under the Extraction Plan (EP) approval process. The final detailed design of the longwall layouts would be subject to review and approval in consultation with the relevant authorities and to the satisfaction of the Secretary of the DPE. Mining operations which are proposed to be undertaken within the area designated as the extent of longwalls include first workings; comprising main headings, gate roads and cut throughs, as well as the development of the longwall panels (secondary workings).

Mine Ventilation

The proposed development will utilise the existing mine's ventilation system, including the existing three ventilation shafts. Additionally, the proposed development will require the construction of two additional ventilation shafts to provide a reliable and adequate supply of ventilation air to personnel in the mine.

The proposed development would make use of three vent shafts currently being used for the operations at Tahmoor North, being one upcast (T2) and two downcast shafts (T1 and T3). The two additional vent shafts proposed for the Tahmoor South Project would be located in the Central Domain as follows:

- TSC1: an upcast ventilation shaft that would be located on Tahmoor Coal's Charlies Point Road property, and
- TSC2: a downcast ventilation shaft that would be located on Crown Land adjacent to Tahmoor Coal's Charlies Point Road property.

The proposed vent shafts are shown on Figure 2.

The construction of the ventilation shafts will require the disturbance of a footprint of approximately four to six hectares in area at each location. Access to TSC1 and TSC2 will be from the existing road network.

Following the construction phase, the footprint of the operational area of each ventilation shaft would be reduced to approximately two hectares, plus provision for an access road. The area immediately surrounding the ventilation shaft would be rehabilitated following the construction phase. The ventilation fans would operate for the life of the proposed development.

1.2.4 Gas Drainage Operations

Coal mines need to control underground gas concentration levels to below safe limits so that miners are able to work in a safe environment and mining operations can be undertaken as efficiently as possible.

The coal seams within the Southern Coalfield are generally known to be gassy, with CH4 and CO2 released from the goaf during mining. Gas in the underground workings will be managed by a series of gas drainage operations including:

- Pre gas drainage, whereby gas will be extracted from the coal seam prior to longwall mining. Pre gas drainage activities are undertaken underground, via drilling and drainage from the roadways developed for longwall panels.
- Post gas drainage, whereby gas will be extracted from the goaf
- Gas extraction via the mine ventilation system, which will occur throughout mining.

Gas management will continue to use the existing infrastructure, including the Tahmoor Mine Gas Plant, Gas Plant Vent and Flare Plant, as well as the WCMG Power Plant. Some components of the existing gas management infrastructure may need to be upgraded throughout the life of the proposed development.

1.3.2 Upgrading the existing Tahmoor Mine surface facilities

The existing surface facilities and infrastructure at the Tahmoor Mine surface facilities area, operating within surface CCL 716 and Mining Lease 1642, will be utilised for the proposed development.

Upgrades to some aspects of the surface facilities area will be required and are associated with the increase in annual coal production for the proposed development. Upgrades to existing surface infrastructure will be undertaken within the footprint of the existing Tahmoor Mine surface lease (Mining Lease 1642) and additional surface lease areas required for the proposed development.

Coal Handling and Preparation Plant

The existing CHPP will be utilised for the proposed development. The existing CHPP would be upgraded including the installation of:

- a new coarse rejects screen
- additional belt press filter capacity
- an increase in thickener capacity
- other upgrades as required.

The existing ROM stockpile area will continue to be utilised by the proposed development. During peak production ROM coal may be trucked from the ROM stockpile to the coal product stockpiles and re-trucked back to the ROM stockpile when required. Reject material generated from the coal washing process at the CHPP would be transported to the expanded REA via the existing reject conveyor to the reject bin for disposal, then transported by haul truck to the REA.

Rejects Management

The existing REA will be expanded onto adjacent areas to accommodate the reject material associated with the proposed development (Figure 2). The expansion area will provide an additional emplacement capacity of approximately 12 million tonnes for the rejects generated during the operation of the proposed development. The maximum height of the REA would be increased from RL 300 metres to RL 305 metres in the southern section of the REA.

The rejects disposal method has been selected based on a review of a number of disposal options taking into consideration a number of project objectives including:

- provide a safe solution, causing no hazards to mine operations and with low impact on mine stability;
- minimise the impact on the environment where possible, including dust emissions, visual impact, groundwater and sub-surface contamination, use of foreign reagents;
- provide an economic solution, with minimal capital and operating cost, returning a positive benefit to cost ratio, providing employment for the local community and minimising the impact on mine production;
- adopt a sound technical solution, utilising proven technology with high availability and reliability, versatility and flexibility;
- provide a solution that will enable the disposal of the total volume of rejects forecast for the Tahmoor South project.

The adopted expansion of the existing REA takes into consideration a balance of environmental impacts of dust, noise and visual impacts to surrounding properties as well as the impacts to biodiversity.

The southern section of the REA is proposed to be increased in height. Consideration was given to raising the northern section of the existing REA which has been rehabilitated; however, this increased the number of impacted properties from dust and noise hence was not included in the proposed final design.

The preferred disposal strategy consists of two new areas adjoining the existing REA, using a staged fill plan approach. The REA will be progressively rehabilitated over the life of the mine.

Construction and maintenance of new internal haul roads around and within the REA will be required to cater for the REA expansion. The existing stormwater infrastructure will be expanded to include bunding, additional surface water drainage controls and sedimentation dams for the additional areas.

Alternative uses for rejects will be investigated during the life of the project and to facilitate benefitical uses of reject material.

Site Amenities and Layout

The existing site amenities at the Tahmoor Mine surface facilities area will be utilised for the proposed development.

Additional bathhouses will be required to accommodate the workforce of the proposed development. Additional bathhouses will be constructed adjacent to the existing amenities and will consist of pre-fabricated modular buildings. The existing sewage treatment plant would be upgraded to accommodate the additional employees.

The proposed development will also require minor upgrades of the existing services such as onsite firefighting, water reticulation and power supply systems.

Infrastructure Services Upgrades

The proposed development will utilise a range of infrastructure services including existing offsite electrical, telecommunications and water reticulation infrastructure currently servicing the Tahmoor Mine. Some upgrade to the existing services may be required. In addition, the construction and commissioning of an extension to the existing 66kV overhead power line from the REA along Charlies Point Road to the vent shaft sites will be required.

Car Parking

The proposed development will involve the construction of a new car parking area with approximately 150 new spaces, to relieve the pressure on existing facilities and to provide additional capacity for the proposed development. The new car parking area will be located to the south of the existing entrance to Tahmoor Mine.

1.3.3 Rehabilitation and Mine Closure

Rehabilitation of the proposed development will be undertaken using a staged approach comprising:

- progressive rehabilitation of the REA; and
- mine closure and rehabilitation of the surface facilities area and ventilation shafts.

Areas of the REA will be progressively rehabilitated over the life of the proposed development. This process will involve capping the reject material with topsoil and establishing vegetation. Annual monitoring will be undertaken to determine the success of revegetation and to inform ongoing management of the rehabilitated areas.

There are a number of post mining land use options that may be applicable to the proposed development including passive recreation, native bushland conservation or employment lands such as light industrial. Currently, it is considered that the likely final land use option for most of the surface areas will be native bushland. However, final land use options will be confirmed in a detailed closure planning process, which involves undertaking a final land use analysis. A detailed closure plan will be developed within five years of mine closure. In broad terms, rehabilitation of the surface facilities area and ventilation shafts will involve:

- removal of infrastructure and services;
- levelling, re-contouring and grading to achieve safely battered slopes and surfaces;
- applying topsoil for rehabilitation where required;
- establishing native bushland vegetation which would require minimal ongoing care and maintenance; and
- monitoring of rehabilitated areas to assess the success and inform the management of areas of re-established vegetation.

Infrastructure and facilities may be retained where compatible with the end land uses which will be identified in the detailed closure planning process

1.3.4 Summary of surface facilities development footprint

Development of the surface infrastructure for the proposed development will result in vegetation clearing and loss of flora and fauna habitat. Vegetation clearing footprints for the various Project elements are shown in Table 1.

Table 1. Development footprint for the surface infrastructure development applicable to biodiversity

Project element	Native vegetation disturbance (ha)	Other (ha)	Total development footprint (ha)
REA Area 1	28.4	1.3	29.7
REA Area 2	11.3	1.3	12.6
TSC 1 Ventilation shaft site	6.1	3.5	9.6
TSC 2 Ventilation shaft site	3.3	0.0	3.3
Carpark extension	0.1	0.4	0.5
Total	49.2	6.5	55.7

1.4 The Study Area

The subject site is defined as the area that will be subject to direct impacts from the proposed development.

The Study Area for the Biodiversity Assessment Report includes:

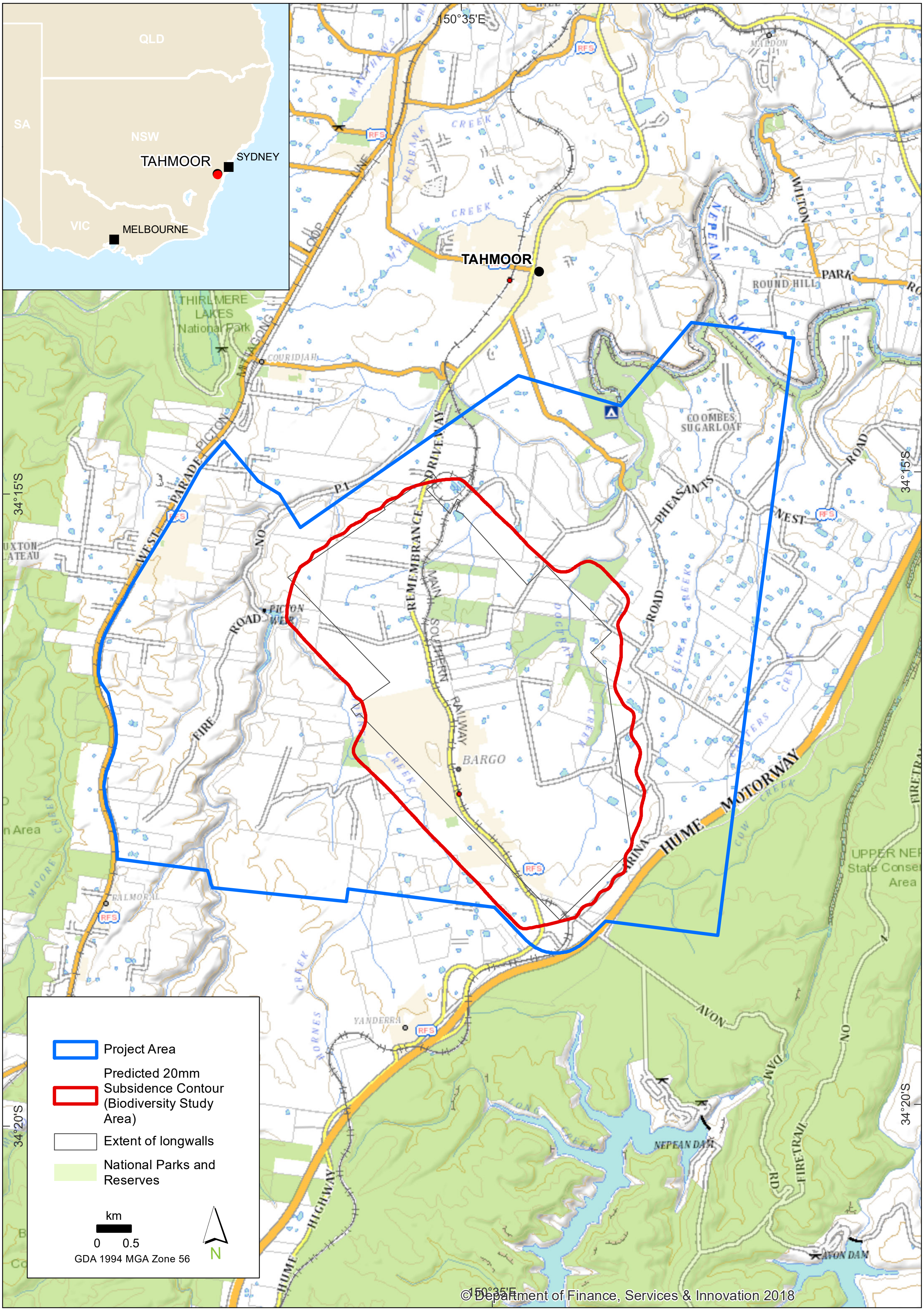
- The predicted 20mm Subsidence Area.
- The extent of the proposed Reject Emplacement Area (REA) Extensions.
- The proposed surface infrastructure including ventilation shaft sites and proposed carpark extension.

The Study Area is approximately 2,156 hectares in size, of which 49.2 hectares of native vegetation would be cleared for the surface infrastructure.

It should be noted that the Study Area for this biodiversity impact assessment does not include the ‘Subsidence Study Area’ as shown on Figure 2. The Subsidence Study Area is the boundary encompassing a minimum of 600 metres from the nearest edge of longwalls within the proposed Extent of Longwalls, as recommended in the independent inquiry report titled “Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield – Strategic Review” (NSW Department of Planning, (DoP), 2008).

Subsidence impacts are predicted by MSEC (2018) to occur within the 20mm Subsidence Area, not within the Subsidence Study Area, and as such, we have not utilised the Subsidence Study Area in this assessment for impact calculations.

The locality for the terrestrial ecology assessment incorporates a 10 km radius around the Study Area detailed above. The locality represents the area within which database searches (detailed in section 3) are extended.

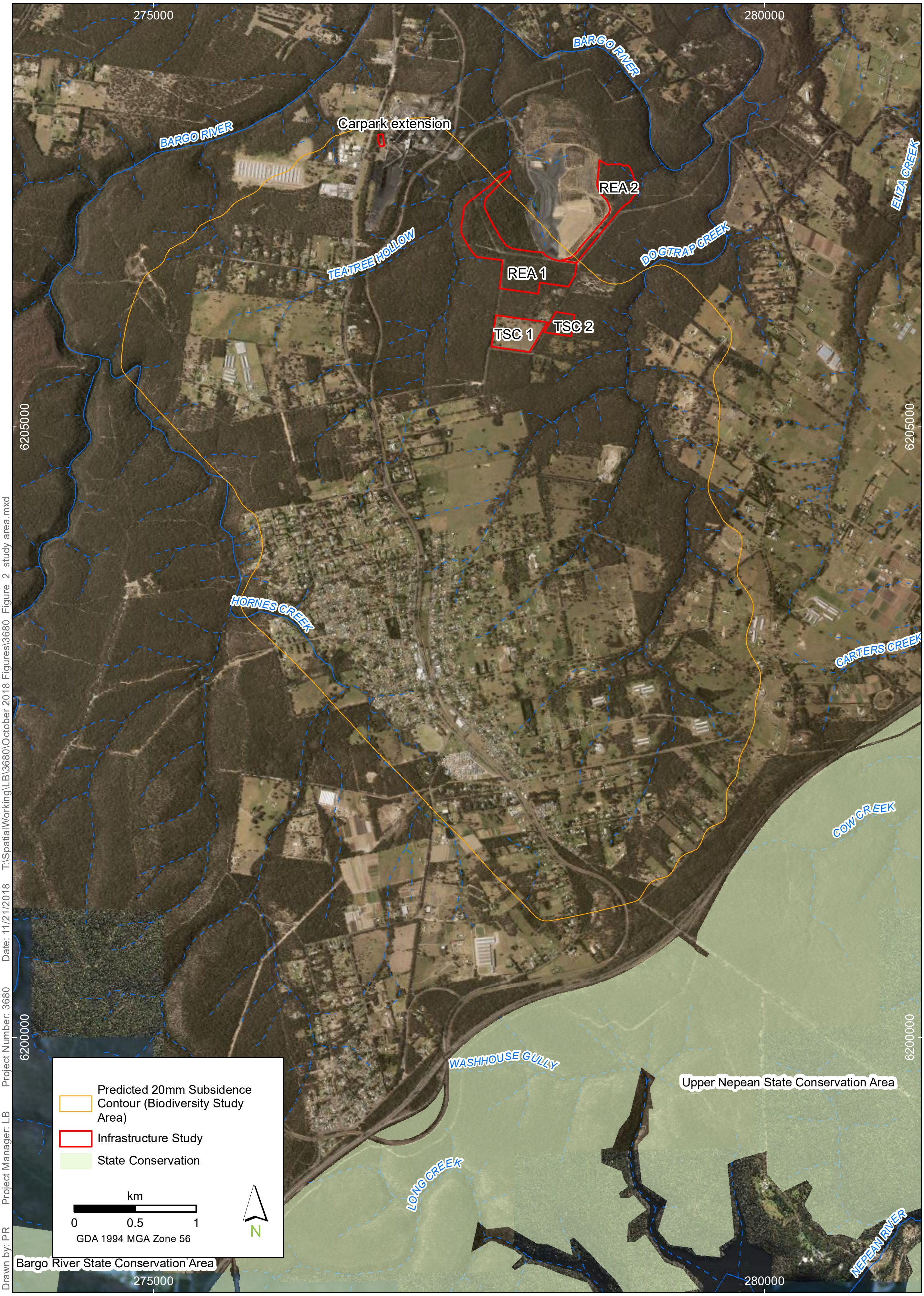


Drawn by: RJ Project Manager: LB Project Number: 3680 Date: 11/21/2018 T:\Spatial\Working\LB\3680\October 2018 Figures\3680_Figure_1_Location.mxd

Locality overview

Tahmoor South Project Biodiversity Assessment Report

FIGURE 1

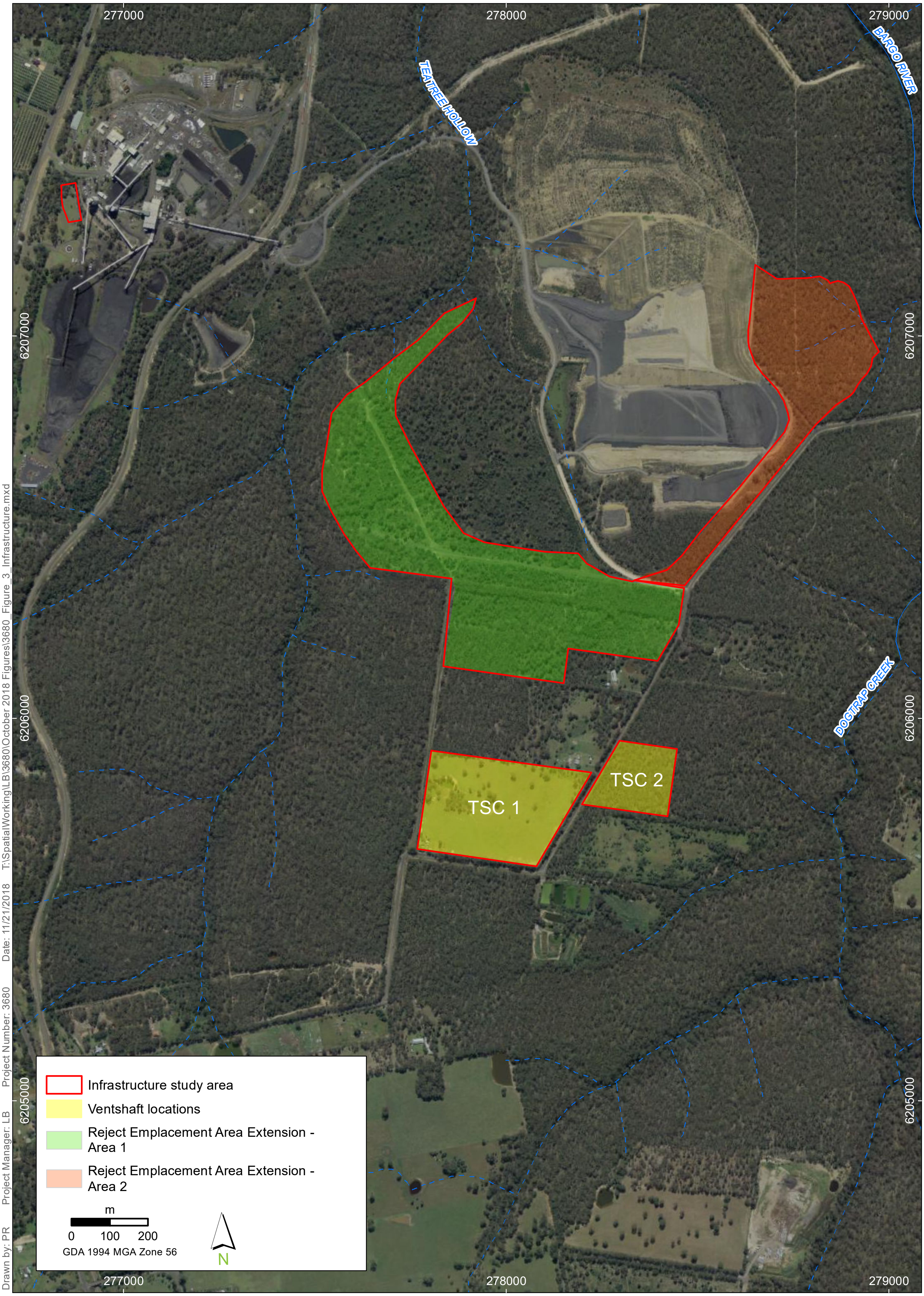


Study area

Tahmoor South Project Biodiversity Assessment Report

FIGURE 2

Imagery: (c) LPI 2013



Surface infrastructure

Tahmoor South Project Biodiversity Assessment Report

FIGURE 3

Imagery: (c) LPI 2013

2. Approach to the Project

2.1 Approval process

2.1.1 Application of the FBA

As described in section 1.1, this Biodiversity Assessment Report has applied the FBA, according to the transitional arrangements provided under the BC Act, to describe and assess the ecological values within the Study Area, and determine how the Project is likely to have an impact on threatened biodiversity listed under the BC Act and the EPBC Act.

On 25 August 2017, the NSW *Threatened Species Conservation Act 1995* (TSC Act) was repealed and replaced with the NSW BC Act. The BC Act provides a new process for assessing impacts to biodiversity based on the Biodiversity Assessment Method (BAM), where impacts and offsets are measured in biodiversity 'credits', as determined by the BAM Calculator. Major Projects (State Significant Development and State Significant Infrastructure) are now subject to assessment under the BAM. However, savings and transitional arrangements specified within the BC Act allow for assessment/consideration under the former FBA under the following circumstances:

- Mining projects that had submitted a conceptual project development plan to the Division of Resources & Geoscience before 25 August 2017 will have until 25 August 2019 to submit a development application under the previous legislation. The Secretary of the Department of Planning and Environment must identify these projects in writing by 25 November 2017.
- Substantial environmental assessment was undertaken before 25 August 2017 (as determined in writing by the Secretary of the Department of Planning and Environment) and the application is made within 18 months of the Secretary's determination, or
- Environmental assessment requirements were issued before 25 August 2017 and the application is made before 25 February 2019. If the environmental assessment requirements are reissued, the application must instead be made within 18 months of the reissue, but no later than 25 August 2020.

As such, this assessment has been completed using the BioBanking Credit Calculator (BBCC) Version 4.0. The Major Project module has been used for all development calculations.

2.1.2 Commonwealth requirements

A Referral to the Commonwealth was submitted for the Project in November 2017. The Referral addressed impacts to biodiversity, specifically Matters of National Environmental Significance (MNES).

The Department of Environment and Energy (DoEE) declared the Project a controlled action, detailing their response in DoEE (2018) *Referral Decision and Designated Proponent – controlled action EPBC 2017/8084 Tahmoor South Project - dated 12th January 2018*.

The Project was regarded by DoEE to have an impact on a number MNES shown in Table 2. Each of these entities in relation to impacts from the Project are detailed in this report. The section in this report addressing the impact toward each MNES has also been provided in Table 2.

It is also stated in the Referral Decision that the 'NSW Government has advised the Department that the Project will be assessed under the assessment bilateral agreement'. As such, the impact assessment has applied the FBA to determine a suitable offset for the Project.

MNES that may be subjected to significant impacts (Shale Sandstone Transition Forest, *Grevillea parviflora* subsp. *parviflora*, and *Persoonia bargoensis*) will be offset in accordance with the Bilateral Agreement (section 11.1.2).

Table 2. DoEE Controlled Action decision

MNES	Section addressed in report
The DoEE has regarded the Project to have a significant impact upon the following species:	
Shale Sandstone Transition Forest (SSTF)	Impacts to Shale Sandstone Transition Forest are detailed in section 7.3. An Assessment of Significance for the TEC has been provided in Appendix 8. The Assessment concluded a significant impact. An offset has been provided in section 11.
Bargo Geebung (*Persoonia bargoensis*)	Impacts to *Persoonia bargoensis* are detailed in section 8.3.1. An Assessment of Significance for the species has been provided in Appendix 8. The Assessment concluded a significant impact was likely. An offset has been provided in section 11.
Small-flower Grevillea (*Grevillea parviflora subsp. parviflora*)	Impacts to *Grevillea parviflora* subsp. *parviflora* are detailed in section 7.4. An Assessment of Significance for the species has been provided in Appendix 8. An offset has been provided in section 11.
Rufous Pomaderris (*Pomaderris brunnea*).	No impacts to *Persoonia brunnea* are likely as detailed in section 7.4. The Project has avoided direct impacts to the species as previously discussed in the Referral. An Assessment of Significance for the species has been provided in Appendix 8. The Assessment concluded a significant impact was unlikely.
DoEE also noted that the following ecological community and threatened species could potentially be impacted by the Project:	
Turpentine-Ironbark Forest of the Sydney Basin Bioregion (Critically Endangered)	Turpentine-Ironbark Forest of the Sydney Basin Bioregion does not occur in the Study Area (section 5.2 and 5.3). No impacts to the community are likely (section 5.3).
Leucopogon exolasius (Woronora Beard-heath, Vulnerable)	*Leucopogon exolasius* does not occur within the Study Area (section 6.1). An Assessment of Significance for the species has been provided in Appendix 8. The Assessment concluded a significant impact was unlikely.
Phascolarctos cinereus (Koala, Vulnerable)	The Koala was not recorded despite targeted survey (section 7.5.1) An impact assessment for the Koala is provided in section 7.5.1.

MNES	Section addressed in report
	An Assessment of Significance for the species has been provided in Appendix 8. The Assessment concluded a significant impact was unlikely. Regardless, the Koala has been offset as detailed in section 11.
Macquaria australasica (Macquarie Perch, Endangered)	An aquatic ecology impact assessment has been completed by Niche (2018) for the Macquarie Perch.
Petauroides volans (Greater Glider, Vulnerable).	The Greater Glider was not recorded despite targeted survey (section 7.5.1) An Assessment of Significance for the species has been provided in Appendix 8. The Assessment concluded a significant impact was unlikely.

2.1.3 Secretary's Environmental Assessment Requirements (SEARs)

In preparing this Terrestrial Ecology Impact Assessment, the Secretary's Environmental Assessment Requirements (SEARs) issued for the Tahmoor South Project (SSD 17-8445) on 9 June 2017, and the Supplementary SEARs received on 14 February 2018 have been addressed. The key matters raised by the Secretary that are applicable to this Terrestrial Ecology Impact Assessment, and the section within this report which addresses each of the SEARs, is outlined in Table 3. The SEARs that relate specifically to aquatic ecology, are assessed in Niche (2018).

Table 3. Secretary's Environmental Assessment Requirements applicable to Terrestrial Ecology

Study Requirements		Section Addressed
Secretary's Environmental Assessment Requirements		
Biodiversity	An assessment of the likely biodiversity impacts of the development, including impacts to terrestrial and aquatic species and habitats, in accordance with the Framework for Biodiversity Assessment, by a person accredited in accordance with 5142(8)(1)(c) of the Threatened Species Conservation Act 1995, and having regard to OEH's requirements (Attachment 2); and	This document
	a strategy to offset any residual impacts of the development in accordance with the NSW Biodiversity Offsets Policy for Major Projects	Offset strategy proposed in section 11
Key Agency Requirements		
The NSW Office of Environment and Heritage		
Biodiversity	Biodiversity impacts related to the proposed development are to be assessed and documented in accordance with the Framework for Biodiversity Assessment including the Addendum to the NSW Biodiversity Offsets Policy for Major Projects (Upland Swamps impacted by longwall mine subsidence (December 2016) as relevant, unless otherwise agreed by OEH, by a person accredited in accordance with 5142(8)(1)(c) of the Threatened Species Conservation Act 1995.	This document
	The project team's attention is drawn to the Addendum to NSW Biodiversity Offsets Policy for Major Projects (Upland swamps impacted by longwall mining subsidence), particularly in relation to any swamp communities which may be impacted by the proposal. We also recommend for impacts upon upland swamps and 3rd order or above streams that a full justification, including reasons for drainage, alternative and suggested remediation and offsets for any such damage, be presented. Any	No Upland swamps occur in Study Area – Appendix 2. Impacts to riparian areas discussed in section 8.1.

Study Requirements		Section Addressed
	monitoring data undertaken as required during the EIS process should also be supplied to assist in our assessment.	Impacts associated with riparian vegetation discussed in section 7.3.2.
Attachment B	Impacts on the following species will require further consideration and provision of the information specified in s9.2 of the Framework for Biodiversity Assessment: • River-flat Eucalypt Forest on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions (EEC) • Shale Sandstone Transition Forest in the Sydney Basin Bioregion (CEEC) • Southern Highlands Shale Woodlands (CEEC) • Cumberland Plain Woodland in the Sydney Basin Bioregion (CEEC) • *Persoonia bargoensis* (Bargo Geebung) • *Persoonia glaucescens* (Mittagong Geebung) • *Persoonia hirsuta* (Hairy Geebung) • *Haplocephalus bungaroides* (Broad-headed Snake)	Section 8
Wollondilly Shire Council		
Protection of Koala habitat	The undertaking of detailed Koala surveys that takes into account the following activities to determine the presence of Koala habitat (as requested by Council's submission in regards to the review of SEPP 44: • The analysis of historical records to determine the previous presence of Koalas and the behavioural patterns of Koalas on the site. • The undertaking of comprehensive surveys to determine the presence of Koalas consistent with best practice across all vegetation communities present on a site proposed for development. • An analysis of the observed and identified potential behavioural usage of the site by Koalas across all vegetation types within the site based on a detailed assessment, (which is not restricted to the habitat species listed in the revised SEPP 44) • The role of the site in a landscape context in allowing for the movement of Koala based on a detailed assessment and analysis of existing records. Intended measures to protect Koala habitat consistent with Guidelines in the updated SEPP 44 which must be development in consultation with OEH and Council	No Koalas present within the area to be disturbed. Comprehensive surveys including spotlighting, SAT analysis have been completed (section 6.2.2). Koala discussed in section 6.2 and section 8.
Protection of threatened species	Impacts to threatened species associated with Tahmoor South be assessed and consistent with requirements contained in its current Development Control Plan.	Impact assessments have been completed as part of this report in accordance with the requirements of the FBA.
NSW Department Planning and Environment – Supplementary SEARs (dated 14 February 2018)		
	The EIS must include an assessment of the relevant impacts of the action on threatened species and communities and water resources; including: • A description and detailed assessment of the nature and extent of the likely direct, indirect and consequential impacts, including short-term and long-term relevant impacts; • A statement whether any relevant impacts are likely to be known, unpredictable or irreversible'; • Analysis of the significance of the relevant impacts; • Any technical data and other information used or needed to make a detailed assessment of the relevant impacts.	This assessment has utilised the specialist reports completed as part of the Project to determine impacts toward biodiversity. Direct and indirect impact in relation to biodiversity are

Study Requirements		Section Addressed
		discussed in section 7.
	For each of the relevant matters protected that are likely to be significantly impacted by the development, the EIS must provide information on proposed avoidance and mitigation measures to deal with the relevant impacts of the action, including: • a description and an assessment of the expected or predicted effectiveness of the mitigation measures; • Any statutory policy basis for the mitigation measures; • The cost of the mitigation measures; • An outline of an environmental management plan that sets of the framework for continuing management mitigation and monitoring programs for the relevant impacts of the action, including any provision for independent environmental auditing; and • The name of the agency responsible for endorsing or approving each mitigation measures of monitoring program.	Mitigation measures are detailed in section 9. The cost of mitigation measures are provided in the Economic Impact Assessment for the Project (Cadence Economics 2018) (section 9.2). The main body of the EIS document outlines the Tahmoor Environmental Management System (EMS), which includes a series of Environmental Management Plans (EMPs) (section 9.2.4).
	Where a significant residual adverse impact to a relevant protected threatened species or community is considered likely, the EIS must provide information on the proposed offset strategy, including discussion of the conservation benefit associated with the proposed offset strategy.	Offset strategy provided in section 11
	For each of the relevant matters likely to be impacted by the action the EIS must provide reference to, and consideration of, relevant Commonwealth guidelines and policy statements including any: • Conservation advice or recovery plan for the species or community • Relevant threat abatement plan for a process that threatens the species or community • Wildlife conservation plan for the species; and • Any strategic assessment.	Relevant Commonwealth guidelines and policy statements referred to in Appendix 8
	The EIS must identify each EPBC Act listed threatened species and communities likely to be impacted by the action. For any species and communities that are likely to be impacted, the proponent must provide a description of the nature, quantum and consequences of the impact. For species and communities potentially located in the Study Area or in the vicinity that are not likely to be impacted, provide evidence why that are not likely to be impacted.	Appendix 1 – likelihood of occurrence Impacts are discussed in Section 7.
	For each of the EPBC Act listed threatened species and communities likely to be impacted by the action the EIS must provide a separate: • Description of habitat (including identified and mapping of suitable breeding habitat, suitable foraging habitat, important population and habitat critical for survival), with consideration of, and reference to, any relevant Commonwealth guidelines and policy statement including listing advice conservation advice and recovery plans:	Impacts are discussed in Section 7. Separate assessments for EPBC Act listed biodiversity are

Study Requirements		Section Addressed
	• Details of the scope, timing and methodology for studies or surveys used and how they are consistent with (or justification for divergence from) published Australian Government guidelines and policy statements; • Description of the relevant impacts of the action having regards to the full national extent of the species or communities range; and • Description of the specific proposed avoidance and mitigation measures to deal with relevant impacts of the action; • Identification of significant residual adverse impacts likely to occur after the proposed activities to avoid and mitigate all impacts are taken into account; • Description of any offsets proposed to address residual adverse significant impacts and how these offsets will be established • Details of how the current published FBA has been applied in accordance with the objects of the EPBC Act to offset significant residual adverse impacts; • Details of the offset package to compensate for significant residual impacts including details of the credit profiles required to offset the action in accordance with the FBA and/or mapping and description of the extent and condition of the relevant habitat and/or threatened communities occurring on proposed offset sites	provided in Appendix 8. Survey effort is provided in sections 6.1.1 and 6.2.2 Impacts are assessed in section 7 and EPBC Act Assessmentes of Significance provided in Appendix 8. Mitigation measures provided in section 9. Biodveristy offsets provided in 11.
	The EIS should provide a description of the location, extent and ecological characteristics and values the identified water resource potentially affected by the project. The assessment of impacts should include information on: The habitat or lifecycle of native species, including invertebrate fauna and fish species, depend upon the water resource bring seriously affected.	Impacts to aquatic ecology assessed in Niche (2018).
	Based on the information in the referral documentation, the location of the action, species records and likely habitat present in the area, there are likely to be significant impacts to: • Shale Sandstone Transition Forest in the Sydney Basin Bioregion (CEEC) • *Persoonia bargoensis* (Bargo Geebung) • *Grevillea parviflora* subsp. *parviflora* (Small-flower Grevillea) • *Pomaderris brunnea* (Rufus Pomaderris) There is some risk that there may be significant impacts on the following matters and levels of impact should be further investigated: • Turpentine Ironbark Forest of the Sydney Basin Bioregion (CEEC) • *Leucopogon exolasius* (Woronora Beard-heath • Koala (*Phascolarctos cinereus*) • Macquarie Perch (*Macquaire australasica*) • Greater Glider (*Petauroides volans*)	Impacts to each of these entities discussed in section 7.

2.2 Assessment resources and assessor qualifications

This Biodiversity Assessment Report has been prepared by the following accredited assessors:

- Simon Tweed (Senior Ecologist and Accredited BioBanking Assessor): fauna field survey, data management, data entry, review of credit calculations, report preparation.
- Luke Baker (Senior Botanist and Accredited BioBanking Assessor): field survey, data management, data entry, credit calculations, report preparation.
- Sian Griffiths (Senior Botanist and Accredited BioBanking Assessor): report preparation, review of report.

Other specialist staff involved in preparing the assessment include:

- Matthew Richardson (Director): field survey, report review, quality assurance.
- Dr Amanda Griffiths (Senior Ecologist): reporting.
- Dr Ross Jenkins (Team Leader GIS and Systems Analyst): mapping.

- Dr Cairo Forrest (Ecologist): field surveys, reporting.
- Dr Frank Lemckert: (Team Leader Ecology): fauna field survey, expert amphibian assessment.
- Anna Senior (Ecologist): field survey, data management, data entry.
- Greg Tobin (GIS Analyst): mapping.
- Matthew Stanton (Research Ecologist): field survey, Anabat analysis.

3. Background review

In completing this Biodiversity Assessment Report, a number of threatened species databases and previous documents relevant to the Project have been reviewed as detailed in this section.

3.1 Database searches

Threatened species potentially impacted by the Project were identified through the database and literature review process detailed below. The list of potentially impacted species was determined by considering the likelihood of occurrence and the likelihood of impacts for each species.

Five categories for 'likelihood of occurrence' (Table 4) were attributed to the list of threatened species after consideration of criteria such as known records, presence or absence of important habitat features on the subject site, results of the field surveys and professional judgement. This process was completed on an individual species basis.

Species considered further were those in the 'Known' to 'Moderate' categories and where impacts for the species could reasonably occur from the Project.

Table 4. Likelihood of occurrence criteria

Likelihood rating	Threatened flora criteria	Threatened and migratory fauna criteria
Known	The species was observed within the Study Area.	The species was observed within the Study Area.
High	It is likely that a species inhabits or utilises habitat within the Study Area.	It is likely that a species inhabits or utilises habitat within the Study Area.
Moderate	Potential habitat for a species occurs on the site. Adequate field survey would determine if there is a 'high' or 'low' likelihood of occurrence for the species within the Study Area.	Potential habitat for a species occurs on the site and the species may occasionally utilise that habitat. Species unlikely to be wholly dependent on the habitat present within the Study Area.
Low	It is unlikely that the species inhabits the Study Area.	It is unlikely that the species inhabits the study area. If present at the site the species would likely be a transient visitor. The site contains only common habitat for this species which the species would not rely on for its on-going local existence such as limited breeding habitat resources.
None	The species has not been recorded within the study area and habitat within the Study Area is unsuitable for the species.	The species has not been recorded within the Study Area and habitat within the Study Area is unsuitable for the species.

3.1.1 BioBanking Credit Calculator

Threatened species predicted to occur within the CMA subregion (BioBanking Threatened Species Profile Database) were reviewed and included within the Threatened Species Likelihood of Occurrence Tables (Appendix 1). The list of species predicted to occur within the CMA Subregion was refined for the Study Area within the BioBanking Credit Calculator (BBCC). This involved refining the list on the basis of answering a series of 'Geographic and habitat feature' questions within the BBCC, which further filtered the threatened species that are likely to be relevant to the habitats present within the development footprint. The details of the inputs to generate the list are provided below.

Table 5 outlines the responses to geographic/habitat feature questions in the BBCC.

Table 5. Project relevant geographic and habitat questions

Impact?	Common name	Scientific name	Feature
Yes	Rosenberg's Goanna	*Varanus rosenbergi*	land within 250 m of termite mounds or rock outcrops
Yes	Red-crowned Toadlet	*Pseudophryne australis*	heath or eucalypt forest on sandstone with a build-up of litter or other debris and containing, or within 40 m of ephemeral or intermittent drainage lines
Yes	Cumberland Plain Land Snail	*Meridolum corneovirens*	land containing bark or leaf litter accumulation
Yes	Large-eared Pied Bat	*Chalinolobus dwyeri*	land containing escarpments, cliffs, caves, deep crevices, old mine shafts or tunnels
Yes	Giant Burrowing Frog	*Heleioporus australiacus*	land within 40 m of heath, woodland or forest
Yes	*Hibbertia superans*	*Hibbertia superans*	Ridgetops
Yes	Green and Golden Bell Frog	*Litoria aurea*	land within 100 m of emergent aquatic or riparian vegetation
No	*Wahlenbergia multicaulis* (Tadgells Bluebell) population, Auburn, Bankstown, Baulkham Hills, Canterbury, Hornsby, Parramatta and Strathfield local government areas	*Wahlenbergia multicaulis - endangered population*	land situated in damp, disturbed sites
Yes	*Lasiopetalum joyceae*	*Lasiopetalum joyceae*	lateritic to shaley ridgetops

The responses to the geographic and habitat questions generated the following list of species credit predicted species for consideration in this assessment along with the suggested survey time (Table 6).

Table 6. Species credit predicted species for consideration and survey time matrix

Common name	Scientific name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Acacia gordonii	*Acacia gordonii*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Allocasuarina glareicola	*Allocasuarina glareicola*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bargo Geebung	*Persoonia bargoensis*	Yes	Yes	Yes	Yes	Yes							Yes
Brown Pomaderris	*Pomaderris brunnea*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bynoe's Wattle	*Acacia bynoeana*	Yes	Yes	Yes						Yes	Yes	Yes	Yes
Cumberland Plain Land Snail	*Meridolum corneovirens*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Darwinia biflora	*Darwinia biflora*	Yes	Yes							Yes	Yes	Yes	Yes
Darwinia peduncularis	*Darwinia peduncularis*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Deane's Paperbark	*Melaleuca deanei*	Yes	Yes										Yes
Dillwynia tenuifolia	*Dillwynia tenuifolia*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dillwynia tenuifolia (a shrub) population, Kemps Creek	*Dillwynia tenuifolia* - endangered population Kemps Creek	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Downy Wattle	*Acacia pubescens*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Eastern Pygmy-possum	*Cercartetus nanus*												
Epacris purpurascens subsp. *purpurascens*	*Epacris purpurascens subsp. purpurascens*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Eucalyptus sp. Cattai	*Eucalyptus sp. Cattai*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Gang-gang Cockatoo population, Hornsby and Ku-ring-gai Local Government Areas	*Callocephalon fimbriatum* population in the Hornsby and Ku-ring-gai Local Government Areas	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Giant Burrowing Frog	*Heleioporus australiacus*	Yes	Yes	Yes	Yes	Yes				Yes	Yes	Yes	Yes
Green and Golden Bell Frog	*Litoria aurea*	Yes	Yes	Yes					Yes	Yes	Yes	Yes	Yes
Grevillea parviflora subsp. *supplicans*	*Grevillea parviflora subsp. supplicans*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Gyrostemon thesioides	*Gyrostemon thesioides*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Hairy Geebung	*Persoonia hirsuta*	Yes	Yes	Yes	Yes	Yes							Yes
Haloragodendron lucasii	*Haloragodendron lucasii*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Hibbertia superans	*Hibbertia superans*							Yes	Yes	Yes	Yes	Yes	Yes

Common name	Scientific name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Koala	*Phascolarctos cinereus*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Large-eared Pied Bat	*Chalinolobus dwyeri*	Yes	Yes	Yes	Yes					Yes	Yes	Yes	Yes
Lasiopetalum joyceae	*Lasiopetalum joyceae*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Leucopogon fletcheri subsp. *fletcheri*	*Leucopogon fletcheri subsp. fletcheri*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Marsdenia viridiflora subsp. *viridiflora* in the Bankstown, Blacktown, Camden, Campbelltown, Fairfield, Holroyd, Liverpool and Penrith local government areas	*Marsdenia viridiflora subsp. viridiflora* - endangered population	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Matted Bush-pea	*Pultenaea pedunculata*									Yes	Yes	Yes	
Mittagong Geebung	*Persoonia glaucescens*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Nodding Geebung	*Persoonia nutans*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Persoonia mollis subsp. *maxima*	*Persoonia mollis subsp. maxima*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pimelea curviflora subsp. *curviflora*	*Pimelea curviflora subsp. curviflora*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Red-crowned Toadlet	*Pseudophryne australis*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regent Honeyeater	*Anthochaera phrygia*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Rosenberg's Goanna	*Varanus rosenbergi*	Yes	Yes									Yes	Yes
Small-flower Grevillea	*Grevillea parviflora subsp. parviflora*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Squirrel Glider	*Petaurus norfolcensis*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sydney Plains Greenhood	*Pterostylis saxicola*									Yes	Yes	Yes	
Tetratheca glandulosa	*Tetratheca glandulosa*							Yes	Yes	Yes	Yes	Yes	
Wahlenbergia multicaulis (Tadgells Bluebell) population, Auburn, Bankstown, Baulkham Hills, Canterbury, Hornsby, Parramatta and Strathfield local government areas	*Wahlenbergia multicaulis* - endangered population	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Woronora Beard-heath	*Leucopogon exolasius*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Zieria involucrata	*Zieria involucrata*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

3.1.2 Atlas of NSW Wildlife Database

A review of spatial records of threatened flora and fauna within the locality and wider region was undertaken using data obtained from the Atlas of NSW Wildlife. Records were obtained prior to field survey and searches of the Atlas updated in September 2018. Results from the database searches have been incorporated into the Threatened Species Likelihood of Occurrence Table provided in Appendix 1.

3.1.3 EPBC Act Protected Matters Search

A Protected Matters Search was carried out for a 10 km area around the Study Area. Results from the database searches have been incorporated into the Threatened Species Likelihood of Occurrence Table provided in Appendix 1.

3.2 Review of relevant studies

Literature and data sources reviewed included:

- AECOM (2012) Tahmoor South Project Preliminary Environmental Assessment, prepared for Tahmoor Coal August 2012
- HECONS (2018a) Tahmoor South Project – Surface Water Impact Assessment
- HECONS (2018b) Tahmoor South Project – Flood Study
- EMM Consulting (2018) Tahmoor South Project – Noise and Vibration Assessment
- Fluvial Systems (2013) Tahmoor South Project – Environmental Impacts Statement Technical Specialists Report –Geomorphology – Final Report
- GeoTerra (2014) Tahmoor South Project – Shallow Groundwater Baseline Monitoring
- DEC (2004a) The Native Vegetation of the Nattai and Bargo Reserves. Unpublished Report. Department of Environment and Conservation, Hurstville
- DEC (2004b) "The Vertebrate Fauna of the Nattai and Bargo Reserves." Unpublished report funded by the Central Directorate Parks and Wildlife Division Biodiversity Survey Priorities Program by NSW Department of Environment and Conservation, Conservation Assessment and Data Unit Conservation Programs and Planning Branch; Metropolitan, Environment Protection and Regulation Division
- Niche (2012) Tahmoor South Pilot Study, Prepared for Tahmoor Coal
- Niche (2013) Tahmoor South Terrestrial Monitoring Project Year 2012-2013
- Niche (2010a) Bargo Exploration Program Surveys 1 Review of Environmental Factors
- Niche (2010b) Bargo Exploration Program Surveys 2 Review of Environmental Factors
- Niche (2010c) Bargo Exploration Program Surveys 3 Review of Environmental Factors
- Niche (2010d) Bargo Exploration Program Surveys 4 Review of Environmental Factors
- Niche (2011a) Tahmoor Coal Ventilation Shaft Fenceline Clearing Assessment
- Niche (2011b) Bargo Project Offsetting Strategy
- Niche (2011c) Tahmoor South Project Pilot Study
- Niche (2011d) Bargo Exploration Program Surveys 6 Review of Environmental Factors
- Niche (2011e) Bargo Exploration Program Surveys 7 Review of Environmental Factors
- Niche (2011f) Bargo Exploration Program Surveys 8 Review of Environmental Factors
- Niche (2011g) Bargo Exploration Program Surveys 9 Review of Environmental Factors
- Niche (2011h) Bargo Exploration Program Surveys 10 Review of Environmental Factors
- NPWS (2003) Native Vegetation of the Woronora, O'Hares and Metropolitan Catchments
- NPWS (2002) The native vegetation of the Cumberland Plain, Western Sydney
- Tozer et al. (2006) Native vegetation of south east NSW.
- OEH (2013) Remnant Vegetation of the western Cumberland subregion, 2013 Update.

4. Landscape assessment

4.1 Landscape features of the Study Area

The key landscape features of the Study Area are concentrated around the watercourses, namely Tea Tree Hollow Creek, Dog Trap Creek, and Hornes Creek (Figure 4). Vegetation corridors along each of these watercourses are more prominent toward the far west of the Study Area near the Bargo River. This area is typically away from rural and residential lands.

As the watercourses occur within the lowest part of the landscape, the gullies are typically occupied by steep slopes (defined by MSEC (2018) as an area of land having a gradient greater than 1 in 3 (33% or 18.3)).

According to MSEC (2018), a total of 24 cliffs are located within the Study Area. The cliffs are generally located within the valleys of the Dog Trap Creek and Hornes Creek. The cliffs are commonly between 10 and 20 metres in height and less than 100 metres in length.

All cliffs, with the exception of one cliff along Dog Trap Creek, will not be directly mined beneath by the proposed development. Further discussion on cliffs within the Study Area is provided in 7.2.

4.2 Landscape Assessment in the BBCC

As detailed in section 4 of the FBA, a Landscape Assessment is required to be entered into the BBCC. Landscape Value is an assessment of the spatial configuration of vegetation, including percent native vegetation cover, adjacent remnant area and connectivity. For each, there is one assessment of the current state of the landscape around the entire Project and one assessment of the state of the landscape if the Project were to proceed using spatial configuration of Assessment Circles.

4.2.1 Assessment circles

Two Assessment Circles were placed over the Study Area as per the FBA. The largest Assessment circle combination (15,000 hectares for outer circle, and 1,500 hectares for inner circle) was centred over the entire area of greatest disturbance. This is shown in Figure 5.

4.2.2 Landscape setting

The Study Area occurs within the Sydney Basin IBRA region, and incorporates the following three IBRA subregions: Cumberland, Burragorang, and Sydney Cataract (Figure 5). The Cumberland IBRA subregion occupies the majority of the Study Area, and has therefore been entered into the BBCC.

The following Mitchell landscapes occurs across the Study Area: Picton – Razorback Hills, Woronora Plataea, Nattai Plateau, and Upper Nepean Gorges (Figure 5). The Picton – Razorback Hills occupies the majority of the Study Area and has therefore been entered into the BBCC.

4.2.3 Native vegetation cover

GIS interrogation was used to determine the vegetation cover percentage as provided in Table 7.

Table 7. Native vegetation cover – assessment circles

Native vegetation cover class (%)			
Before development		**After development**	
15,000 ha	**1,500 ha**	**15,000 ha**	**1,500 ha**
71-75%	71-75%	71-75%	71-75%

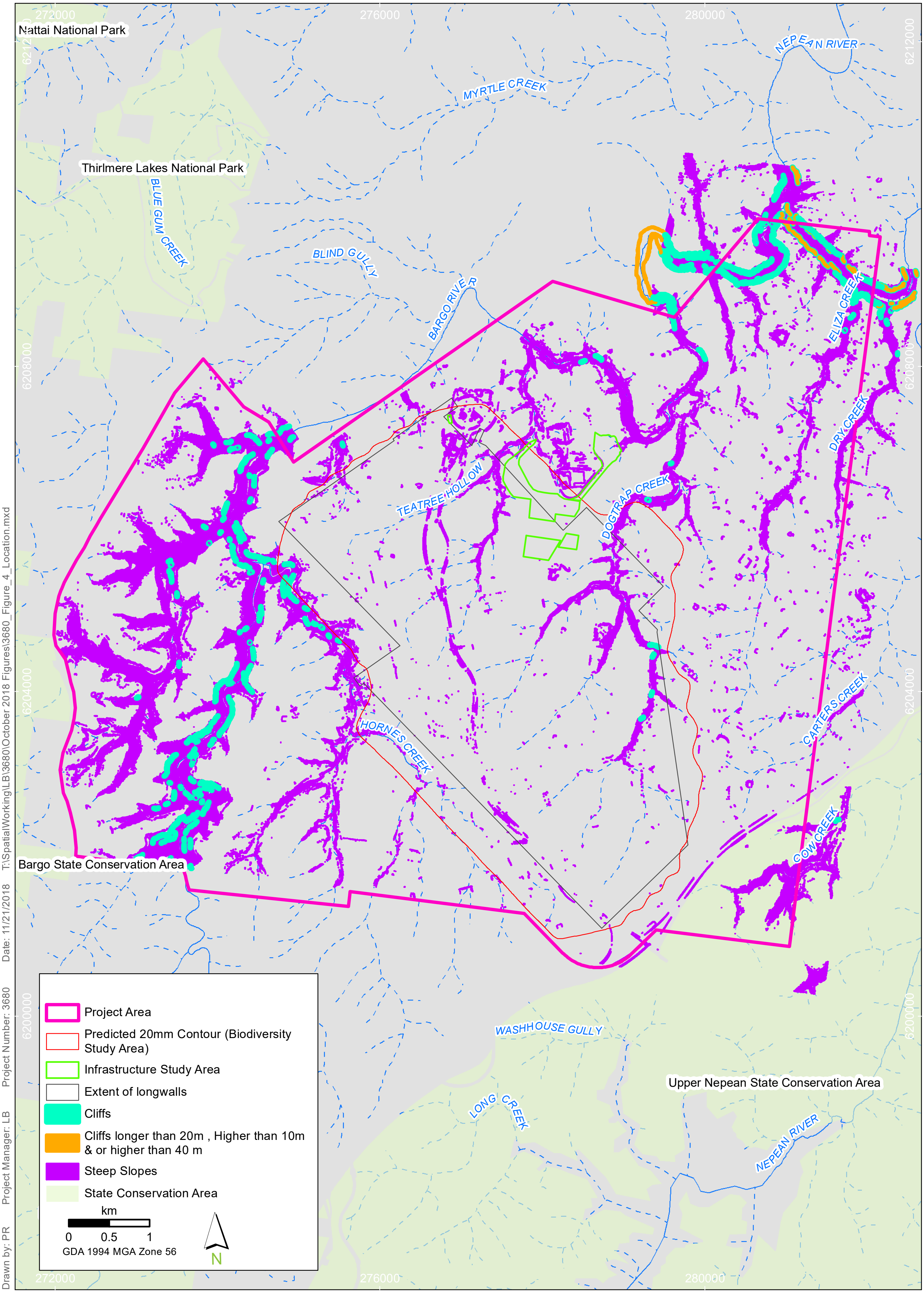
4.2.4 Connectivity value

The Study Area occurs within a strategic location[1] as it contains riparian buffers that are of a 4th order or higher strahler level (Bargo River) (Figure 5). As such, this has been added to the BBCC.

4.2.5 Landscape score calculation

The information presented in the above section was entered into the BBCC, resulting in a landscape score calculation of 21.0 for the development.

[1] Land that is: part of a state significant biodiversity link and in a plan approved by the Chief Executive OEH; a regionally significant biodiversity link and in a plan approved by the Chief Executive OEH; or in the riparian buffer area of a 4th order stream or higher, an important wetland or an estuarine area.

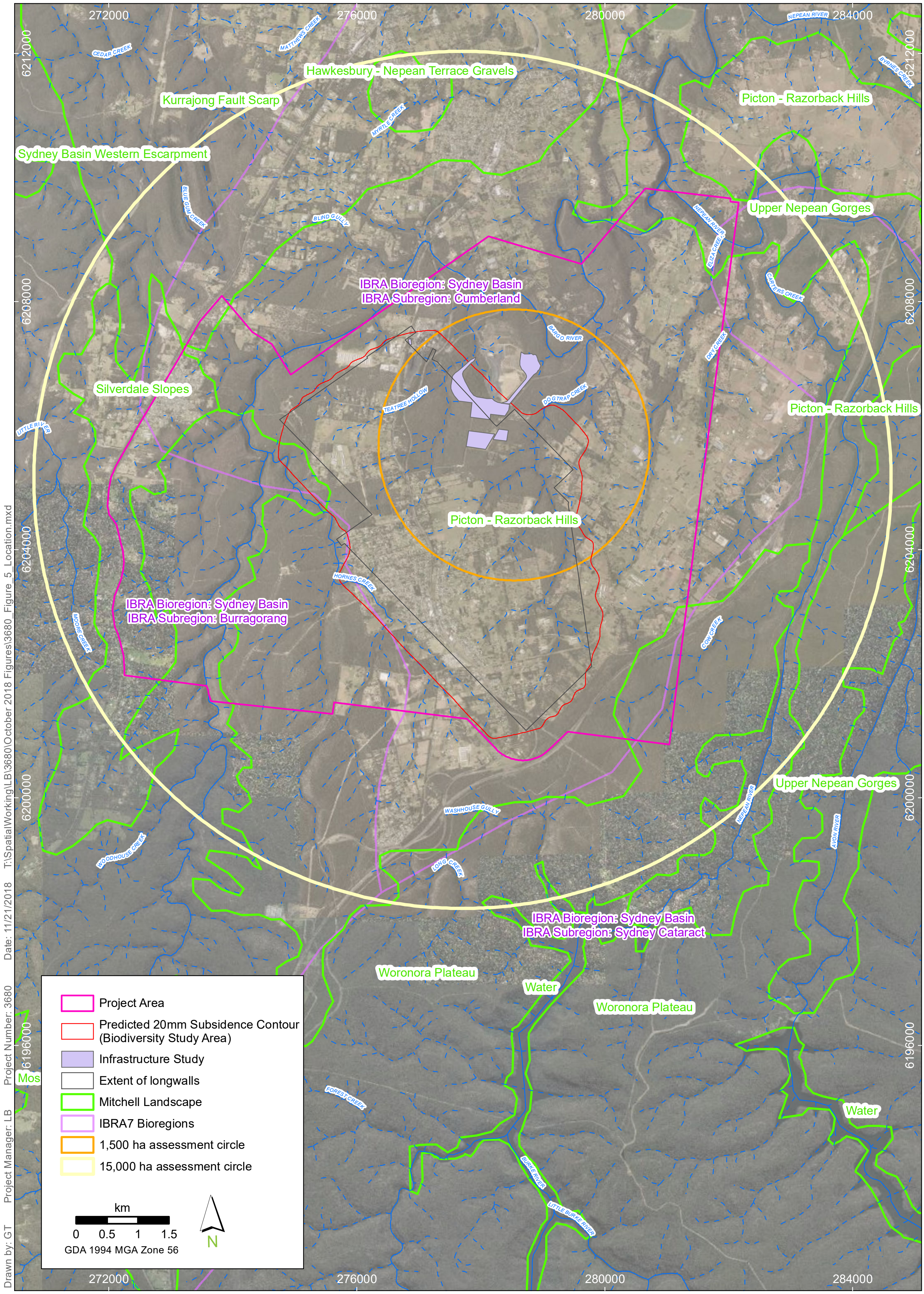


Landscape features of the Project Area

Tahmoor South Project Biodiversity Assessment Report

FIGURE 4

Imagery: (c) LPI 2013

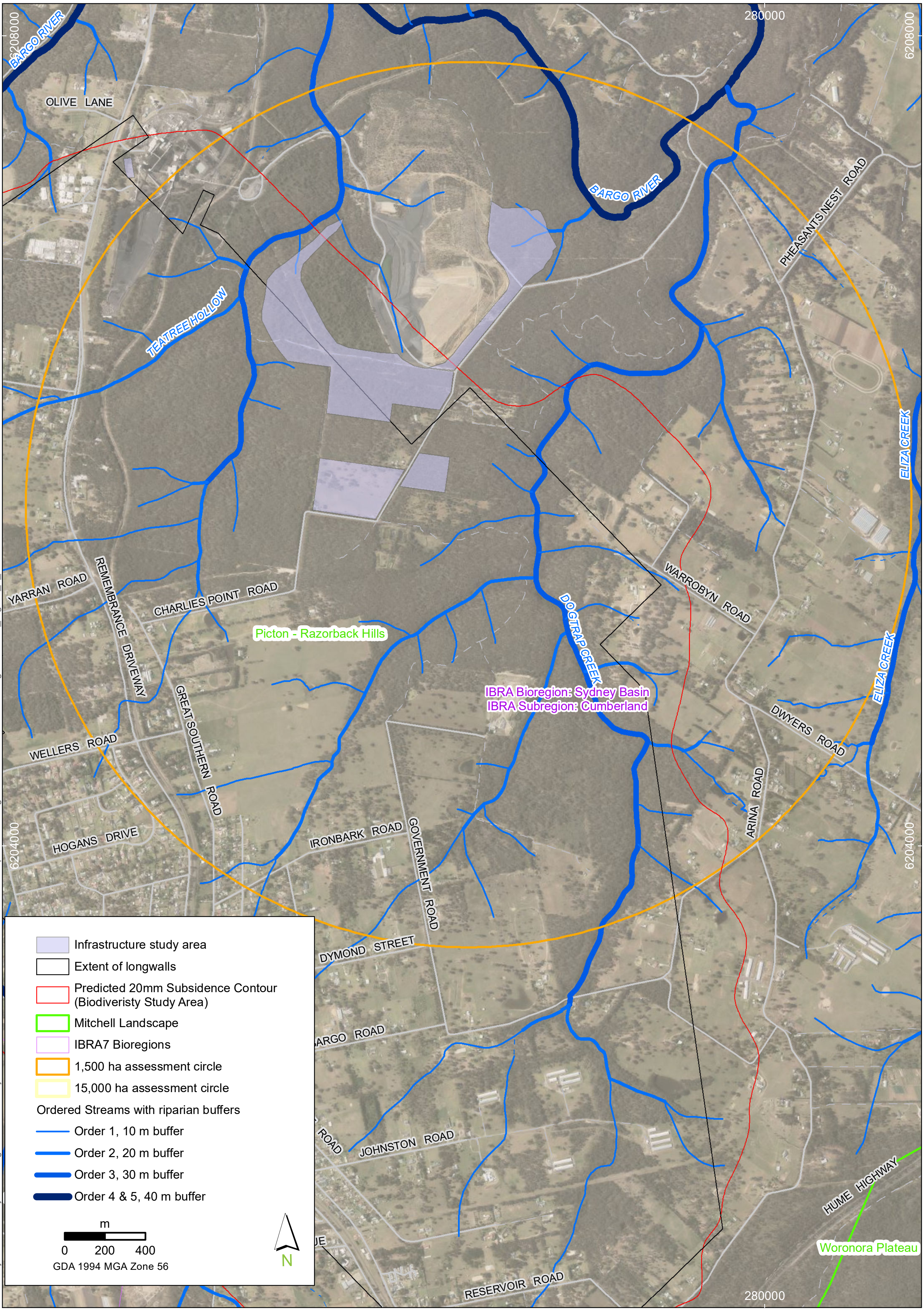


Landscape Assessmnet - Location map

Tahmoor South Project Biodiversity Assessment Report

FIGURE 5

Imagery: (c) LPI 2013



Landscape Assessment - Site map of surface infrastructure

Tahmoor South Project Biodiversity Assessment Report

FIGURE 6

Imagery: (c) LPI 2013

5. Assessing native vegetation

5.1 Vegetation verification

The study area has had a history of extensive vegetation survey completed by Niche since 2012, with the most recent field survey completed in September 2018. An overview of the survey effort history relevant to vegetation verification has been provided in Table 8 with additional detail provided in Appendix 3.

In summary, the vegetation validation survey concentrated on areas within the Study Area that would be directly impacted by infrastructure, or potentially impacted by subsidence (eg. riparian zones). For areas not directly impacted, the existing vegetation mapping completed by Tozer et al. (2006) and OEH (2013) was used.

The field survey completed the required number of BioBanking plots as per the FBA for PCTs impacted by the Project. The location of each plot is shown in Figure 7, and the plot data is provided in Appendix 5.

Additional information (abundance, structure etc.) was recorded on the basis of current best practice flora survey guidelines for assessment of a large site, particularly OEH's Working Draft Threatened Biodiversity Survey and Assessment – Guidelines for Developments and Activities (DEC 2004) and OEH (2016) NSW Guide to Surveying Threatened Plants.

BioBanking plots/transects were completed to collect the following attributes:

- native species richness (20 x 20 m)
- native over-storey cover (Projective foliage cover at 5 m intervals along 50 m transect)
- native mid-storey cover (Projective foliage cover at 5 m intervals along 50 m transect)
- native ground cover (grasses) (frequency tally at 1 m intervals along 50 m transect)
- native ground cover (shrubs) (frequency tally at 1 m intervals along 50 m transect)
- native ground cover (other) (frequency tally at 1 m intervals along 50 m transect)
- exotic cover (as for native over-storey, mid-storey and groundcover)
- over-storey regeneration (proportion of overstorey dominants present as immature recruitment)
- number of trees with hollows (within 50 x 20 m plot)
- total length of fallen logs (within 50 x 20 m plot).

In addition to the prescribed BioBanking plot methodology above, within each 20 x 20 m plot all vascular plant species were identified (to species level where sufficient plant material was available) and assigned a cover abundance score.

Random meanders for threatened flora and their habitats were conducted between BioBanking plots, RDP locations, and fauna survey points.

Table 8. Vegetation and threatened flora survey effort

Survey	Survey details
Pilot study (2011-2012)	A terrestrial ecology pilot study was conducted over four days from the 5th to the 8th of December 2011, and on the 11th and 16th of April 2012 to determine ecological values that would require consideration during the Environmental Impact Statement (EIS) for the Project. The survey associated with the Pilot Study involved a rapid based vegetation validation assessment using Tozer et al. (2006) as a base. The assessment also included a habitat based assessment for threatened flora to determine which threatened flora may need to be considered further in targeted surveys as part of the EIS for the Project.
Riparian monitoring (2012-2013)	A riparian monitoring project was completed for two monitoring years. The purpose of the riparian monitoring project was to gain baseline floristic data at 42 permanent monitoring sites along riparian areas within the Study Area, and within a number of Control sites. BioBanking plots were completed at each monitoring site. The data would be used in a Before-After-Control Impact Assessment (BACI) for the Project. The first year of riparian vegetation monitoring was conducted by two botanists from 18 to 27 June 2012, and again from 5 to 13 December 2012. The second year of riparian vegetation monitoring was conducted between the 3 of June and the 15 of June 2013. Two different survey periods were aimed at targeting any potential seasonal differences in species presence.
REA detailed survey (2013)	The proposed REA expansion area and vegetation immediately surrounding the REA was investigated by four ecologists from November 2012 to January 2013. The assessment included detailed vegetation mapping and threatened flora survey. The survey resulted in the collection of over 43 BioBanking plot/transects, rapid survey points, and targeted threatened flora survey and population counts for *Grevillea parviflora* subsp. *parviflora*, *Persoonia bargoensis*, and *Pomaderris brunnea*.
Ventilation shafts, haul road and transmission line (2013) – Now removed from the Project.	The original location of the ventilation shaft sites, haul road and transmission line were investigated by two ecologists over five days in June 2013 and one day in September 2013. The assessment included detailed vegetation mapping and threatened flora survey. The survey of these areas involved a habitat assessment and BioBanking plots and random meanders.
Detailed survey across study area (2017)	Survey assessments were completed by two ecologists on 13th September 2017 to the 17th of September 2017. The purpose was to inspect the condition of the vegetation, re-count flora populations, and gain additional floristic plot data. During the assessment an additional four BioBanking plots/transects were completed to accompany the four plots/transects completed during the 2013 survey. Targeted threatened flora surveys were undertaken across the disturbance areas, along with a population count for *Grevillea parviflora* subsp. *parviflora*.
Ventilation shaft sites and Hornes Creek and	Survey assessments were completed by two ecologists on 12th September 2018 to the 19th of September 2017. The purpose was to validate the vegetation mapping within the ventilation shaft sites and carpark, and to complete threatened flora survey and counts

Survey	Survey details
carpark (2018)	within these area. During the assessment an additional seven BioBanking plots/transects were completed. Targeted threatened flora surveys were undertaken across the proposed disturbance areas, along with a population count for *Grevillea parviflora* subsp. *parviflora* and *Persoonia bargoensis.*

Table 9. Vegetation validation survey effort plot requirement

Niche vegetation mapping	Plant Community Type (PCT) best fit	Condition	Total (ha)	Plots required	Plots conducted (Riparian Monitoring Program 2013)	Plots completed (2013 survey)	Plots completed (2017 and 2018 survey)	Plot completed immediately outside the study area during the survey effort since 2013
Upper Georges River Sandstone Woodland	HN564 Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin.	Moderate/ Good	5.7	3	0	3[2]	0	7
Cumberland Shale Sandstone Transition Forest	HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin	Moderate/ Good	26.0	4	0	5	3	13
		Moderate/ Good_ medium	11.8	3	0	3	1	1
		Moderate/ Good_ derived	5.6	1	0	0	3	3
Plantings	HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin (Plantings – Non-EEC)	Other	0.1	1	0	0	1	0
Riparian vegetation within the Study Area	Combination of both: HN586 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest in sandstone gullies of western Sydney, Sydney Basin, and HN564 Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin.	Moderate/ Good	[3]16.0 (approx.)	4	15	0	0	0
Non-native	-	-	6.5	0	-	-	-	-

[2] Note, due to development footprint design changes, two of the plots were completed immediately outside of the area to be directly disturbed within HN564 Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin. This is a minor limitation as the condition class is the same as that impacted by the Project.

[3] Determined by placing a 10 metre buffer along each riparian course in the Study Area.

5.1.1 Limitations

Due to the size of the Study Area, and location across a significant number of private landholdings, not all vegetation within the Study Area could be inspected. As such, the OEH (2013) vegetation mapping has been used for areas that were unable to be inspected. However, vegetation to be directly disturbance for surface instrastructure was surveyed in accordance with the FBA.

Given land access restrictions, the mapping of species polygons that occurred outside of Tahmoor Coal landholdings was not possible.

While some plant species are cryptic and detection can be difficult, given the surveys were completed across numerous years during different months, this has provided a suitable period to sufficiently detect the range of native and threatened flora species should they be present.

5.2 Vegetation community delineation and mapping

Vegetation in the Study Area has been mapped as part of the Cumberland Plain Mapping Project (OEH 2013) (Figure 8). This assessment has relied upon the existing vegetation mapping of OEH (2013) for the broader Project Area, with detailed refinement of the mapping completed within the those areas that may be impacted by the proposed infrastructure or subsidence.

Within the Study Area five PCTs were identified. Different condition classes were assigned to vegetation where obvious differences in structure and quality occurred.

An alignment of each of these vegetation types with the associated PCT and area is provided in Table 10.

Descriptions for those vegetation communities that would be impacted by surface infrastructure, along with details regarding condition, are provided in Appendix 5.

Table 10. Vegetation communities mapped within the Study Area

Vegetation community	Plant Community Type (PCT)	Formation	Class	Condition	Surface infrastructure						
					REA Area 1	REA Area 2	Car park	TSC1 – Ventilation shaft	TSC 2 Ventilation Shaft	Total	Subsidence area
Shale Sandstone Transition Forest	HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin	Dry Sclerophyll Forests (Shrub/grass subformation)	Cumberland Dry Sclerophyll Forests	Moderate/ Good	15.5	6.7	0.0	0.5	3.3	**26**	**308.2**
				Moderate/ Good_medium	11.8	0.0	0.0	0.0	0.0	**11.8**	**11.8**
				Moderate/ Good_derived	0.0	0.0	0.0	5.6	0.0	**5.6**	**5.6**
Upper Georges River Sandstone Woodland	HN564 Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin.	Dry Sclerophyll Forests (Shrubby subformation)	Sydney Hinterland Dry Sclerophyll Forests	Moderate/ Good	1.1	4.6	0.0	0.0	0.0	**5.7**	**493.8**
Plantings	No best fit – have used HN564 Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin.	No best fit - Dry Sclerophyll Forests (Shrubby subformation	No best fit - Sydney Hinterland Dry Sclerophyll Forests	Poor	0.0	0.0	0.1	0.0	0.0	**0.1**	**0.2**
Cumberland Plain Woodland	Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion	Grassy Woodlands	Coastal Valley Grassy Woodland	Moderate/Good	0.0	0.0	0.0	0.0	0.0	**0**	**9.0**

Vegetation community	Plant Community Type (PCT)	Formation	Class	Condition	Surface infrastructure						
					REA Area 1	REA Area 2	Car park	TSC1 – Ventilation shaft	TSC 2 Ventilation Shaft	Total	Subsidence area
Hinterland Sandstone Gully Forest	HN586 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest in gullies of western Sydney, Sydney Basin sandstone	Dry Sclerophyll Forests (Shrubby subformation)	Sydney Coastal Dry Sclerophyll Forests	Moderate/ Good	0.0	0.0	0.0	0.0	0.0	**0**	**1.0**
Sandstone Riparian Scrub	HN607 Water Gum - Coachwood riparian scrub along sandstone streams, Sydney Basin	Forested Wetlands	Eastern Riverine Forests	Moderate/ Good	0.0	0.0	0.0	0.0	0.0	**0**	**0.0**
Infrastructure/cleared/not mapped					1.3	1.3	0.4	3.5	0.0	**6.2**	**1328.0**
Total					29.7	12.6	0.5	9.6	3.3	**55.7**	**2156.6**

5.3 Threatened Ecological Communities

A list of Threatened Ecological Communities (TECs) occurring or potentially occurring within the locality as generated from the database searches detailed in section 3, is provided in Appendix 2. The database searches identified 27 TECs that have been identified as potentially occurring within the locality. However, based on the results of the detailed vegetation validation, an analysis of existing vegetation mapping by OEH (2013), and review of the Conservation Advice of the TECs, two TECs are known to occur within the Study Area:

- HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin, aligns to Shale Sandstone Transition Forest which is listed as Critically Endangered under both the BC Act and EPBC Act. The validated vegetation mapping confirmed the presence of Shale Sandstone Transition Forest within the disturbance areas as shown in Figure 9.

  Three condition classes were attributed to the TEC within the Study Area based on the structure and occurrence of weeds (see Appendix 5 for details). The extent of this TEC has been mapped in Figure 10.
- Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion aligning to Cumberland Plain Woodland s listed as Critically Endangered under both the BC Act and EPBC Act. This unit has been mapped by OEH (2013) as occurring in the Study Area. Given the expanse of the Study Area within private property, survey was limited to accessible areas. As such, it is possible that Cumberland Plain Woodland may occur as small patches within some private properties throughout the Study Area. Regardless, this limitation is relatively minor given Cumberland Plain Woodland occurs away from riparian areas that may be subject to impacts from subsidence, and similarly is not specifically ground-water dependant, and thus any surface soil cracking within the TEC should it occur, is unlikely to result in any significant floristic or structural change to the community. It should be noted that this community would not be directly impacted by surface instrastucture.

Turpentine Ironbark Forest in the Sydney Bioregion was identified by DoEE (2018) as a TEC that could potentially be impacted by the Project 2.1.2. However, this TEC was not recorded during the field survey, nor has previously been mapped as occurring within the Study Area by Tozer et al (2006) and OEH (2013). The Study Area also occurs predominately within the Wollondilly LGA which is not an LGA listed in the Scientific Determination for the Sydney Turpentine Ironbark Forest. However, it is noted in OEH (2012) that a similar form of Sydney Turpentine Ironbark Forest occurs more widely in the Wollondilly and Hawkesbury areas. Based on the results of the field survey, and existing vegetation mapping, no similar communities to Sydney Turpentine Ironbark Forest occur. As such, it is highly unlikely that Sydney Turpentine Ironbark Forest occurs within the Study Area, nor would be impacted by the Project.

5.4 Site Values scoring

The Site Value score used in the BBCC are obtained from the collection of transects and plots completed for each of the PCTs and condition classes within the Study Area. The Site Value scores are used to determine the present condition of the PCT to be impacted.

5.4.1 Flora

Fifty-eight BioBanking plots were undertaken within the Study Area, with 17 completed within the surface infrastructure footprint (Table 9). The results of the plot and transect data recorded during the field assessment is provided in Appendix 5.

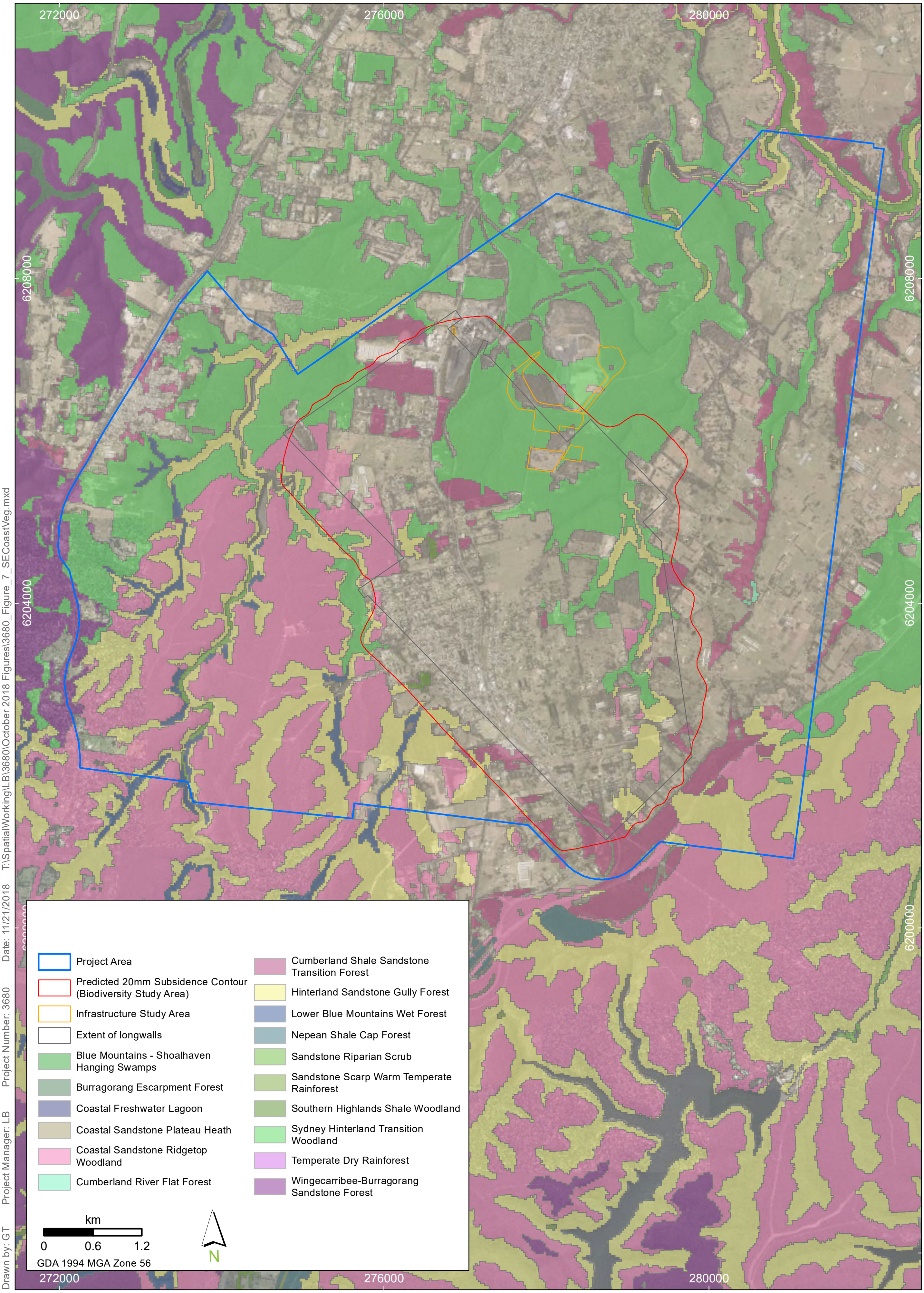
During the field survey over 265 flora were recorded across the Study Area. This included a total of 75 introduced species.

5.4.2 Site Values

The Site Value assessment was carried out by entering the data obtained from transects and plots into the BBCC. The data provides quantitative measures of 10 site attributes (section 5.1) for each vegetation zone impacted by surface infrastructure. The BBCC compares the benchmark for the vegetation type or class to provide the Site Value score. This score represents the overall condition of the vegetation compared against the benchmark.

Vegetation that would be cleared for surface infrastructure, was then assigned a future Site Value score of zero given the biodiversity values in these areas would be lost.

The score from these inputs, coupled with other data in the following section of this report, is used to determine the number of ecosystem credits that are required to offset the biodiversity impacts associated with the Project.



Landscape Assessment - Existing Vegetation Mapping OEH (2013)

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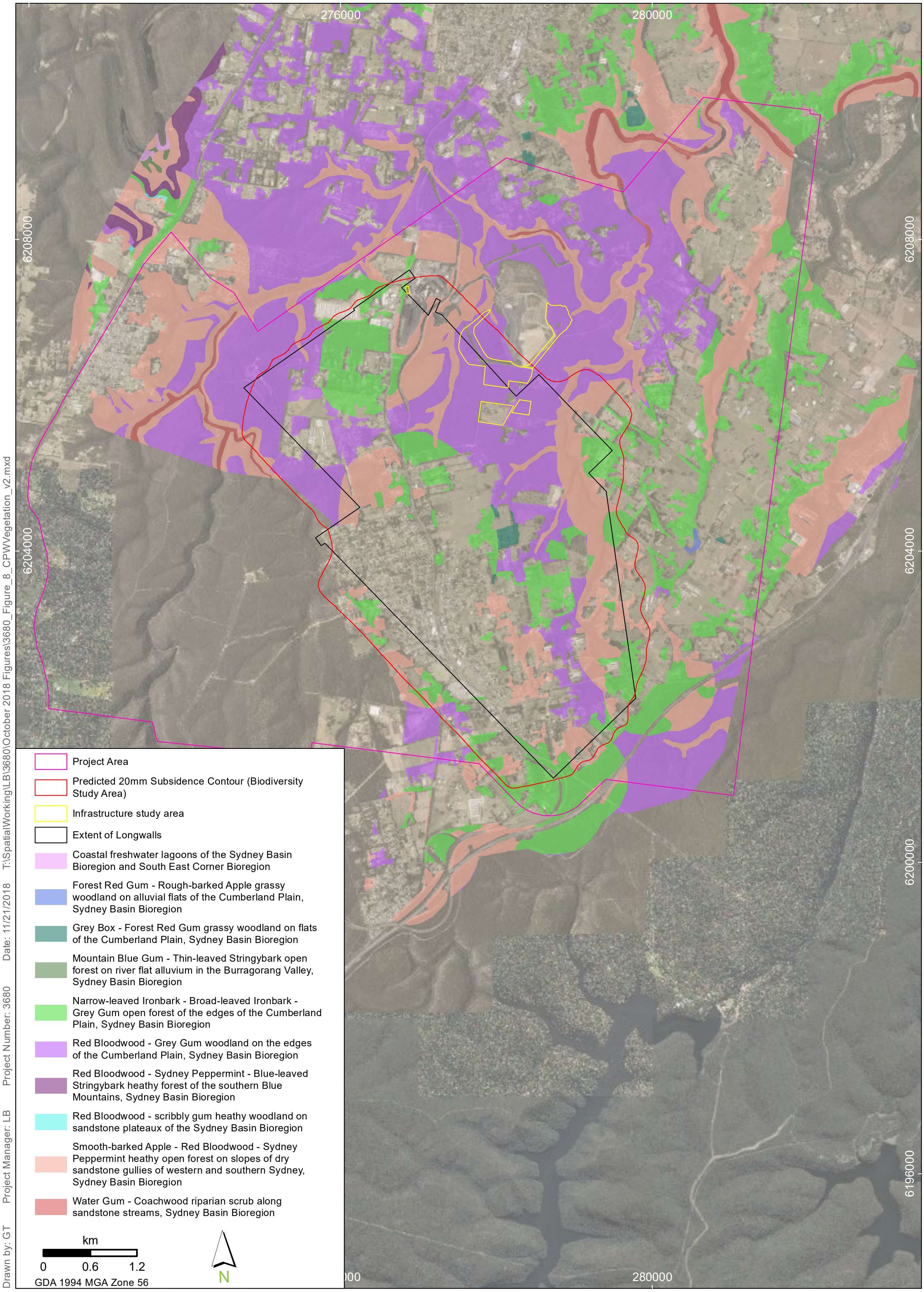
FIGURE 7

Imagery: (c) LPI 2013



Landscape Assessment - Existing Vegetation Mapping OEH (2013)

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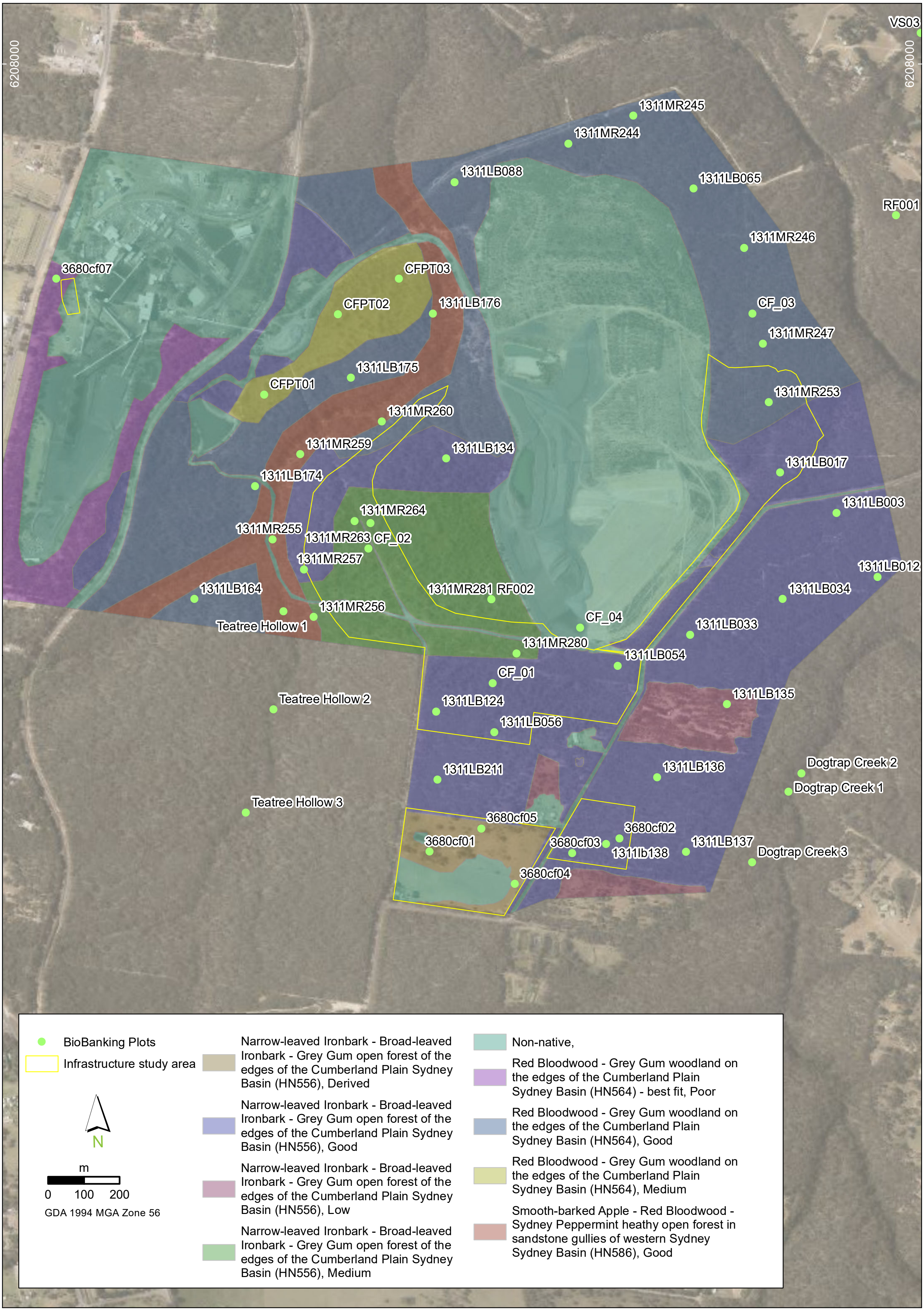
FIGURE 8

Imagery: (c) LPI 2013



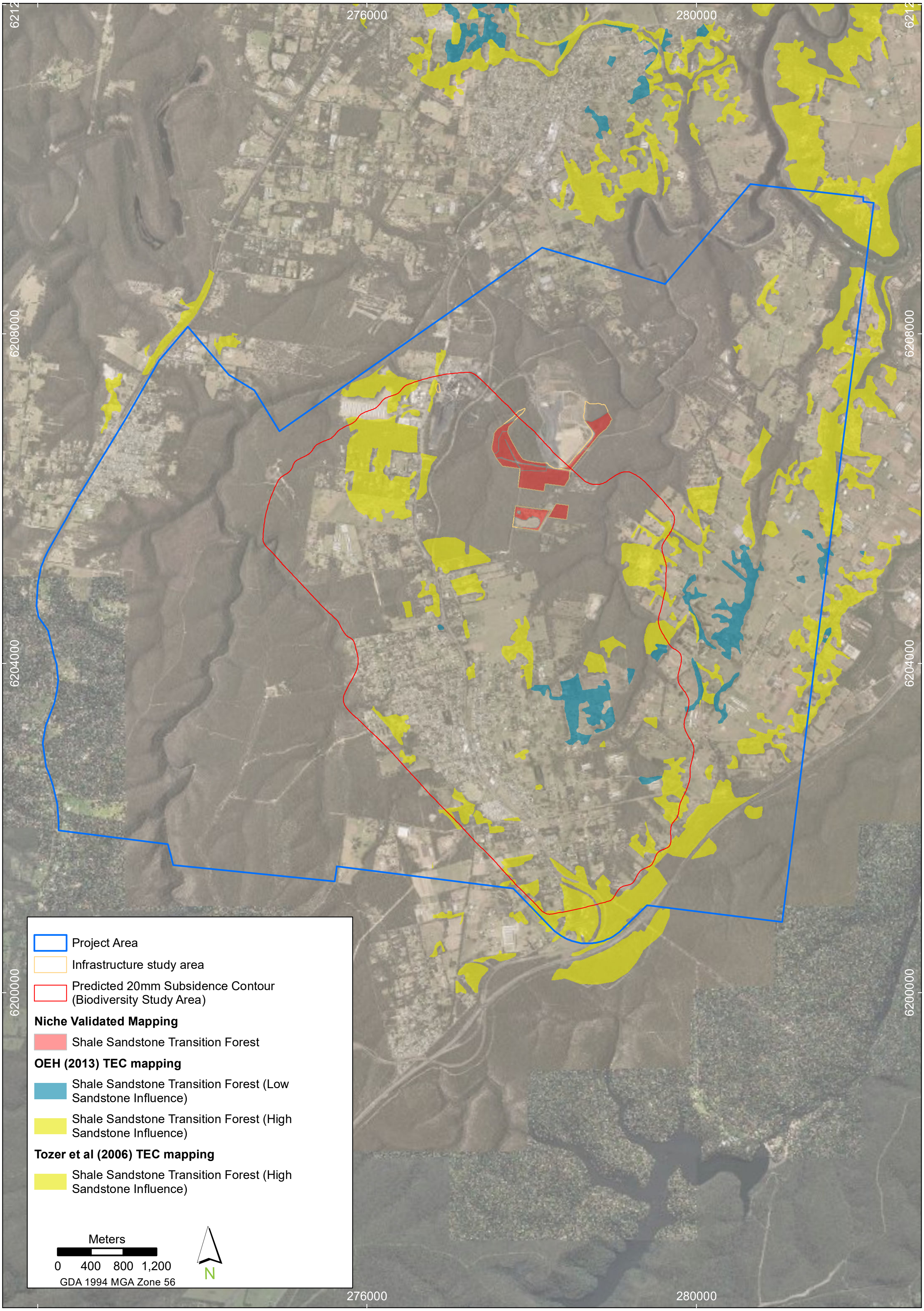
Drawn by: GT Project Manager: LB Project Number: 3680 Date: 11/21/2018 T:\SpatialWorking\LB\3680\October 2018 Figures\3680_Figure_9_validatedvegetation.mxd

Validated vegetation mapping

Tahmoor South Project Biodiversity Assessment Report

FIGURE 9

Imagery: (c) LPI 2013



Drawn by: GT Project Manager: LB Project Number: 3680 Date: 11/21/2018 T:\SpatialWorking\LB\3680\October 2018 Figures\3680_Figure_10_TEC mapping.mxd

Threatened Ecological Communities mapping in disturbance area

Tahmoor South Project Biodiversity Assessment Report

FIGURE 10

Imagery: (c) LPI 2013

6. Assessing threatened species and populations

6.1 Threatened flora

6.1.1 Threatened flora survey

Based on the results of the database review, 47 threatened flora species have been recorded or have potential habitat within 10 km of the Study Area.

The potential for these species to occur within the Study Area is discussed in Appendix 1.

Extensive targeted threatened flora survey has been completed by Niche across the Study Area since 2013. The survey, in the first instance was to detect the presence and habitat for those threatened flora listed as key species for consideration on the SEARs: *Persoonia bargoensis, Persoonia glaucescens, Persoonia hirsuta*; and secondly to detect all threatened flora that has the potential to occur within the Study Area.

The survey effort was completed during recommended survey times identified in the BBCC, which is consistent with survey times recommended in Commonwealth Guidelines.

The survey entailed the following:

- Targeted walking meanders through habitat types to be disturbed by the infrastructure footprint
- Targeted walking transects within riparian habitats of the Study Area
- Threatened flora population counts for *Epacris purpurascens* var. *purpurascens*, *Persoonia bargoensis, Grevillea parviflora* subsp. *parviflora* and *Pomaderris brunnea*.

In total, approximately 170 hours of threatened flora transects and random meanders have been completed within areas proposed for surface disturbance, and habitat immediately surrounding such areas from 2011. A further 160 hours was completed within watercourses in the Study Area associated with the Tahmoor South Monitoring Project. The survey effort, completed over different years and seasons, provides a greater level of certainty on the presence/absence of threatened flora within the Study Area.

A summary of the survey effort is provided in Table 11 with detailed effort provided in Appendix 3.

Table 11. Summary of the threatened flora survey effort

Survey	Survey details	Estimated total hours of survey effort
Pilot study (2011-2012)	A habitat based flora assessment and opportunistic threatened flora survey was completed over four days from the 5th to the 8th of December 2011, and on the 11th and 16th of April 2012.	6 hours
Riparian monitoring (2012-2013)	Threatened flora surveys were completed whilst traversing the Study Area on foot to get to monitoring site locations. Many of the traverses were along riparian zones within the following watercourses within the Study Area – Tea Tree Hollow Creek, Dog Trap Creek, Hornes Creek, Eliza Creek, Carter Creek and Dry Creek. The first year of riparian vegetation monitoring was conducted by two botanists from 18 to 27 June 2012, and again from 5 to 13 December 2012. The second year of riparian vegetation monitoring was conducted between the 3 of June and the 15 of June 2013.	80 hours during 2012 monitoring 80 hours during 2013 monitoring
REA detailed survey (2013)	Targeted threatened flora surveys were completed within the surface disturbance area surrounding the existing REA from November 2012 to January 2013.	100 hours

Survey	Survey details	Estimated total hours of survey effort
	The proposed REA expansion and vegetation immediately surrounding the REA was investigated by four ecologists from November 2012 to January 2013. Targeted threatened flora survey and population counts for *Grevillea parviflora* subsp. *parviflora*, *Persoonia bargoensis*, and *Pomaderris brunnea* were completed.	
Ventilation shafts, haul road and transmission line easement (2013)	The originally location of the ventilation shaft sites, haul road and transmission line were investigated by two ecologists over five days in June 2013 and a day in September 2013. The assessment included detailed vegetation mapping and threatened flora survey. The location of the ventilation shaft sites, haul road and transmission line have since been removed from the current Project design.	40 hours
Detailed survey across study area (2017)	An update of the previous survey assessments was completed by two ecologists on 13th to the 17th of September 2017. The purpose was to inspect the condition of the vegetation, re-count flora populations, and gain additional floristic plot data. During the assessment an additional four BioBanking plots/transects were completed to accompany the 53 plots/transects completed during the 2013 survey. Targeted threatened flora surveys were undertaken across the disturbance areas, along with a population count for *Grevillea parviflora* subsp. *parviflora*.	24 hours
Ventilation shafts, Hornes Creek and carpark.	Survey assessments was completed by two ecologists on 12th September 2018 to the 19th of September 2018. The purpose was to validate the vegetation mapping within the ventilation shaft site and carpark, complete threatened flora survey and counts within these area. During the assessment an additional seven BioBanking plots/transects were completed. Targeted threatened flora surveys were undertaken across the disturbance areas, along with a population count for *Grevillea parviflora* subsp. *parviflora* and *Persoonia bargoensis*. Following the results of the subsidence assessment, a small portion of Hornes Creek in the north-west of the Subsidence study area was surveyed given it was not originally in the area proposed to experience subsidence.	32 hours

Table 12. Recommended threatened flora survey time matrix as specified in BBCC

Scientific name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Addressed in survey
Acacia gordonii	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.
Allocasuarina glareicola	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.
Persoonia bargoensis	Yes	Yes	Yes	Yes	Yes							Yes	Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.
Pomaderris brunnea	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.
Acacia bynoeana	Yes	Yes	Yes						Yes	Yes	Yes	Yes	Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.
Darwinia biflora	Yes	Yes							Yes	Yes	Yes	Yes	Survey completed during known flowering time. Conspicuous species

Scientific name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Addressed in survey
													unlikely to remain undetected.
Darwinia peduncularis	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.
Melaleuca deanei	Yes	Yes										Yes	Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.
Dillwynia tenuifolia	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.
Dillwynia tenuifolia - endangered population Kemps Creek	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.
Acacia pubescens	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.
Epacris purpurascens	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Survey completed during known flowering time.

Scientific name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Addressed in survey
subsp. purpurascens													Conspicuous species unlikely to remain undetected.
Eucalyptus sp. Cattai	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.
Grevillea parviflora subsp. supplicans	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.
Gyrostemon thesioides	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.
Persoonia hirsuta	Yes	Yes	Yes	Yes	Yes							Yes	Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.
Haloragodendron lucasii	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.

Scientific name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Addressed in survey
Hibbertia superans							Yes	Yes	Yes	Yes	Yes	Yes	Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.
Lasiopetalum joyceae	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.
Leucopogon fletcheri subsp. fletcheri	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.
Marsdenia viridiflora subsp. viridiflora - endangered population	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.
Pultenaea pedunculata									Yes	Yes	Yes		Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.
Persoonia glaucescens	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Survey completed during known flowering time. Conspicuous species

Scientific name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Addressed in survey
													unlikely to remain undetected.
Persoonia nutans	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.
Persoonia mollis subsp. maxima	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.
Pimelea curviflora subsp. curviflora	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.
Grevillea parviflora subsp. parviflora	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.
Pterostylis saxicola									Yes	Yes	Yes		Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.

Scientific name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Addressed in survey
Tetratheca glandulosa							Yes	Yes	Yes	Yes	Yes		Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.
Wahlenbergia multicaulis - endangered population	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No habitat present. Survey completed during the flowering time for the species.
Leucopogon exolasius	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.
Zieria involucrata	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Survey completed during known flowering time. Conspicuous species unlikely to remain undetected.

6.1.2 Threatened flora survey results

Seven threatened flora species were recorded during field surveys undertaken by Niche. These included: *Acacia bynoeana, Epacris purpurascens var. purpurascens, Grevillea parviflora* subsp*. parviflora, Persoonia hirsuta, Persoonia glaucescens var. glaucescens, Persoonia bargoensis,* and *Pomaderris brunnea*.

However, within the area proposed for the clearing of surface infrastructure, only *Grevillea parviflora* subsp*. parviflora,* and *Persoonia bargoensis* were recorded. A population of *Pomaderris brunnea* was also recorded immediately adjacent to the riparian habitat of Tea Tree Hollow Creek which occurs within the Study Area adjacent to the existing REA.

None of the other threatened flora were recorded within portions of the Study Area that would be cleared, or within, or adjacent to riparian vegetation according to MSEC (2018) which may exhibit some localised die back in association with gas emissions from subsidence.

The location of each of the recorded species is provided in Figure 13 and discussed below.

Acacia bynoeana

No individuals of *Acacia bynoeana* were recorded during the threatened flora surveys completed by Niche within the Study Area despite targeted survey. Furthermore, no records by OEH occur within the Study Area (Figure 13).

Approximately 20 records for *Acacia bynoeana* were recorded during the current survey immediately to the west of the Study Area within the land owned by Tahmoor Coal. The population was recorded sporadically along the entrance to a Fire Road off Ashby Close within PCT HN566 Red Bloodwood - scribbly gum heathy woodland on sandstone plateaux, Sydney Basin.

This PCT does not occur within the area to be cleared for the Project, and does not occur within any habitat that may be impacted by subsidence. Based on these reasons, and the absence of records for *Acacia bynoeana* within the Study Area, the species has therefore not been assessed further.

Epacris purpurascens* var. *purpurascens

A large population of *Epacris purpurascens* var*. purpurascens* was recorded along both sides of Anthony Road, Bargo, and within Crown Land immediately to the north of Anthony Road (Figure 13). The population of *Epacris purpurascens* var. *purpurascens* within this area consists of more than 500 individuals. The population occurs within Shale Sandstone Transition Forest (HN556).

Epacris purpurascens var. *purpurascens* was not recorded in the area proposed to be disturbed for surface infrastructure. As such, the known population would be avoided. Furthermore, the population is located away from habitat that may be impacted by subsidence. Therefore, impacts to *Epacris purpurascens* var. *purpurascens* have therefore not been discussed further.

Grevillea parviflora* subsp*. parviflora

Grevillea parviflora subsp*. parviflora* was recorded extensively during field surveys at the following areas:

- REA Areas 1 and 2.
- Ventilation shaft sites.
- Outside of the REA development footprint to the east of Charlies Point Road.
- Within the Anthony Road property owned by Tahmoor Coal.

- Along Fire Road 5 in the Upper Nepean State Conservation Area.
- Within land owned by Tahmoor Coal off Ashby Close Bargo.

Within the vicinity of surface infrastructure, counting individual *Grevillea parviflora* subsp. *parviflora* plants was too difficult given the large size of the population encountered. As such, a population estimate was generated by undertaking the following:

- Traversing the disturbance area to determine the extent of the species and differential between core habitat and isolated occurrences.
- Where isolated individuals were encountered, their location was recorded with a handheld GPS and individuals counted.
- Where extensive clumps were located, these were also recorded with a handheld GPS and flagged as being a part of the core population.
- Within the 'core' population area (5.1 hectares), five transects (100 metres long by 15 metres wide – 0.15 hectares) were traversed with all individuals counted by two botanists.
- The counts within the traverses were then extrapolated to the area of 'core' habitat.

The results of the population count are provided in the table below, which concludes that a total of 2,324 plants were estimated to occur within the core habitat areas to be impacted (Figure 14).

A further 12 plants occur outside of the core habitat areas which would be cleared for the Project.

In total, the disturbance associated with the proposed surface infrastructure works would remove approximately 3,324 plants from a larger population of the species.

Table 13. Transect result for *Grevillea parviflora* subsp. *parviflora*

Transect	Core habitat location	Transect start (zone 56)	Transect end (zone 56)	No. recorded per 0.15 ha
Transect 1	REA Area 2	278716/6207066	278693/6207212	75
Transect 2	REA Area 2	278790/6207190	278599/6207068	82
Transect 3	REA Area 2	278574/6206508	278503/6206415	32
Transect 4	Ventilation shaft	278283/6205902	278227/6205808	85
Transect 5	Ventilation shaft	278134/6205696	278193/6105799	64
Total				338
Average per 0.15 ha				68
No. recorded within 5.1 ha of core habitat				2,312
Additional isolated plants outside of core habitat				12
Total impacted				2,324

The impacts to *Grevillea parviflora* subsp*. parviflora* are discussed further in section 7.4.

Persoonia bargoensis

During the current survey *Persoonia bargoensis* was recorded throughout the Study Area as shown in Figure 13.

The population was counted in the area in the surface infrastructure study area, with locations of the plants marked with a GPS.

In total, 692 individuals of *Persoonia bargoensis* were recorded during the current assessment with the bulk of the population occurring around the REA Area 2 (Figure 15).

Development of the surface infrastructure associated with the proposed development will remove 96 plants for the REA infrastructure, and four individuals within the ventilation shaft sites.

The impacts to *Persoonia bargoensis* are discussed further in section 7.4.

Persoonia hirsuta

Persoonia hirsuta was not recorded within the area proposed for surface infrastructure, or the riparian areas of the Study Area despite targeted survey. One record obtained from the OEH bionet database occurs to the far west of the Study Area (Figure 13). The records occur within private landholdings which could not be verified as part of this assessment. The records coincide with Dry Sclerophyll Forest vegetation located away from riparian zones within the Study Area. The potential impacts to this record are discussed further in further in section 7.4 and section 8.

During the field survey, a large population of *Persoonia hirsuta* was recorded outside of the Study Area within land owned by Tahmoor Coal. The parcel of land consists of extensive bushland which provides habitat for the species, which is typically scattered along the edges of existing Fire trails and access tracks. None of this population occurs within land that would be impacted by the development.

Persoonia glaucescens

Persoonia glaucescens was not recorded within the area proposed for surface infrastructure, or the riparian areas of the Study Area despite targeted survey. However, a number of records obtained from the OEH bionet database occur throughout the Study Area (Figure 13). One OEH record occurs within the vegetation proposed to be cleared for REA Area 2. No further details regarding the record were obtained during this assessment, however the field survey confirmed the absence of the species within the area. The remainder of records occur within private landholdings which could not be verified as part of this assessment. The records coincide with Dry Sclerophyll Forest vegetation located away from riparian zones within the Study Area. The potential impacts to these records are discussed further in further in section 7.4 and section 8.

During the field survey, scattered individuals of *Persoonia glaucescens* were recorded outside of the Study Area within land owned by Tahmoor Coal.

Pomaderris brunnea

Pomaderris brunnea was recorded along Tea Tree Hollow during the field survey, which occurs immediately to the west of the existing REA. A large population of the species was recorded in this location, with the greatest concentration of the population occurring within the Tahmoor Coal mining lease near the REA (Niche 2013). Over 300 individuals were recorded within Hinterland Sandstone Gully Forest (HN586) along Tea Tree Hollow within Tahmoor Mine owned or managed land (Figure 13). None of these individuals occur within the area proposed to be cleared for the surface infrastructure. The potential impacts to *Pomaderris brunnea* are discussed further in section 7.4.

6.1.3 EPBC Act listed flora

Of the threatened flora recorded, *Acacia bynoeana, Grevillea parviflora* subsp. *parviflora, Persoonia hirsuta, Persoonia glaucescens var. glaucescens, Persoonia bargoensis,* and *Pomaderris brunnea*, are listed under the EPBC Act.

The remaining EPBC Act listed threatened flora have been assigned a low likelihood of occurrence due to not being detected during targeted threatened flora survey, or having limited habitat within the Study Area.

Of particular note, *Leucopogon exolasius* has been nominated by DoEE as potentially being impacted by the Project. However, this species was not recorded during the current survey, nor has been recorded previously within the Study Area. The species is known to prefer woodland on sandstone amongst rocky hillsides along creek banks. Such features are present along the creeklines of the Study Area, however, the species is relatively conspicuous, and unlikely to remain undetected during the riparian monitoring program. Furthermore, the areas proposed for surface infrastructure would not clear habitat for the species as it is situated away from riparian areas. The closest known record occurs approximately 1.8 kilometres to north-west of the Study Area, and another approximately 2.2 kilometres to the south of the Study Area. Neither records would be impacted by the Project. Given the lack of detection, and no known records in the Study Area, it is unlikely that *Leucopogon exolasius* would be present within the Study Area.

The impacts toward EPBC Act listed flora are discussed in section 7.4.

6.2 Threatened fauna

6.2.1 Database analysis

Seventy-four threatened fauna species have been recorded or predicted to occur within 10 km of the study area (Appendix 1). Of these species listed under the BC Act, 22 are regarded as 'species credit species' which unlike 'ecosystem credit species' cannot be assumed present based on the presence of habitat surrogates. Species credit fauna include:

- **Birds:** Eastern Bristlebird**,** Red Goshawk
- **Amphibians:** Giant Burrowing Frog**,** Green and Golden Bell Frog**,** Littlejohn's Tree Frog, Stuttering Frog, Red-crowned Toadlet
- **Reptiles:** Broad-headed Snake**,** Rosenberg's Goanna
- **Invertebrates:** Cumberland Plain Land Snail
- **Mammals:** Eastern Pygmy-possum**,** Large-eared Pied Bat**,** Southern Brown Bandicoot**,** Eastern Bent-wing Bat (only if breeding habitat present), Little Bent-wing–Bat (only if breeding habitat present), Large-footed Myotis (only if breeding habitat present), Squirrel Glider, Brush-tailed Rock-wallaby, Koala, Grey-headed Flying-fox (only if breeding habitat present), Eastern Cave Bat (only if breeding habitat present) and Greater Glider.

The results of the database search assisted in formulating the targeted fauna survey design, which had an emphasis on species credit fauna, and the Broad-headed Snake and Koala as both these species were specified for consideration in the SEARs.

6.2.2 Fauna survey effort

The fauna field surveys incorporated both targeted survey using established survey techniques (as described in Table 14 and Appendix 4) and habitat-based assessment taking into consideration State and Commonwealth survey guidelines.

The fauna survey design had an emphasis on the detection of species credit fauna where habitat was present. Since ecosystem credit species (see Appendix 1) have a high likelihood of being present on the site (based on the presence of habitat surrogates) specific targeted survey was not always performed for these species. However, the design attempted to detect the range of fauna using the Study Area in order to assist with evaluating its importance to fauna more generally.

The current survey effort aimed at accompanying and adding further rigour to the survey effort completed during 2013. The current effort focused on filling any gaps within the 2013 surveys and concentrated on spotlighting for the Koala within areas proposed to be disturbed for the Project.

Details regarding the survey effort and techniques employed are provided below, and the location of each survey are provided in Figure 11. Further detail regarding dates of field survey and weather details during the survey period are provided in Appendix 4.

Table 14. Fauna survey details and effort

Method	Survey effort (hours/trap nights)	Total hours	Species credit fauna targeted	EPBC Act listed fauna targeted
2018 survey effort (focused on the ventilation shaft sites, Hornes Creek)				
Camera traps	10 camera traps over 10 nights	2,400 hours	Threatened mammals: Eastern Pygmy-possum, Southern Brown Bandicoot, and Brush-tailed Rock-wallaby. Reptiles including Rosenberg's Goanna,	Eastern Pygmy-possum, Spotted-tail Quoll, Southern Brown Bandicoot, Long-nosed Potoroo, New Holland Mouse and Brush-tailed Rock-wallaby.
Call play-back	2 hours over two nights	2 hours	Koala, Greater Glider, Squirrel Glider.	Koala, Greater Glider
Spotlighting	12 hours over two nights	12 hours	Koala, Greater Glider, Squirrel Glider.	Koala, Greater Glider
Birds surveys	three mornings	2.5 hours	All threatened birds.	All threatened and migratory birds
Koala scat searches	6 hours	6 hours	Koala	Koala
Cumberland Plain land Snail Searches within ventilation shaft sites and REA	24hours	24 hours	Cumberland Plain Land Snail	-
Songmeters	3 nights in one location	68 hours	Large-eared Pied Bat, Eastern Bent-wing Bat, Little Bent-wing–Bat, Large-footed Myotis, Eastern Cave Bat.	Large-eared Pied Bat,
Songmeter (Hornes Creek)	3 nights in one locations	72 hours	Large-eared Pied Bat, Eastern Bent-wing Bat, Little Bent-wing–Bat, Large-footed Myotis, Eastern Cave Bat.	Large-eared Pied Bat,
2017 survey effort (focused on the REA and surrounds)				
Camera traps	29 camera traps over 10 nights	6,980 hours	Threatened mammals: Eastern Pygmy-possum, Southern Brown Bandicoot, and Brush-tailed Rock-wallaby. Reptiles including Rosenberg's Goanna,	Eastern Pygmy-possum, Spotted-tail Quoll, Southern Brown Bandicoot, Long-nosed Potoroo, New Holland Mouse and Brush-tailed Rock-wallaby.
Call play-back	3 hours over three nights	3 hours	Koala, Greater Glider, Squirrel Glider.	Koala, Greater Glider

Method	Survey effort (hours/trap nights)	Total hours	Species credit fauna targeted	EPBC Act listed fauna targeted
Spotlighting	24 hours over three nights	24 hours	Koala, Greater Glider, Squirrel Glider.	Koala, Greater Glider
Birds surveys	three mornings	2.5 hours	All threatened birds.	All threatened and migratory birds
Koala scat searches	6 hours	6 hours	Koala	Koala
Frog searches (Dog Trap Creek, Tea Tree Hollow Creek, Eliza Creek)	3 days and 2 nights	24 hours	Giant Burrowing Frog, Green and Golden Bell Frog, Littlejohn's Tree Frog, Stuttering Frog, Red-crowned Toadlet.	Giant Burrowing Frog, Green and Golden Bell Frog, Littlejohn's Tree Frog, Stuttering Frog, Red-crowned Toadlet.
Cumberland Plain land Snail Searches	18 hours	18 hours	Cumberland Plain Land Snail	-
Niche 2013 survey effort within REA and surrounds				
Camera traps	9 days (18 camera traps)	3,888 hours	Threatened mammals, reptiles including Rosenberg's Goanna, Eastern Pygmy-possum, Southern Brown Bandicoot, and Brush-tailed Rock-wallaby.	Eastern Pygmy-possum, Spotted-tail Quoll, Southern Brown Bandicoot, Long-nosed Potoroo, New Holland Mouse and Brush-tailed Rock-wallaby.
Koala scat searches	7 hours, 2 ecologists	14 hours	Koala	Koala
Spotlighting/stag watch	16 hours, 2 ecologists	32 hours	Koala, Squirrel Glider, and threatened owls	Koala, threatened owls
Snail searches	3.25 hours, 2 ecologists	6.5 hours	Cumberland Plain Land Snail	Cumberland Plain Land Snail
Call playback	24 hours	24 hours	Koala, Greater Glider, Squirrel Glider.	Koala, Greater Glider, Powerful Owl
Cumberland Plain land Snail Searches	17.5 hours	17.5 hours	Cumberland Plain Land Snail	-
Frog searches	12 hours, 2 ecologists	24 hours	Giant Burrowing Frog, Green and Golden Bell Frog, Littlejohn's Tree Frog, Stuttering Frog, Red-crowned Toadlet.	Giant Burrowing Frog, Green and Golden Bell Frog, Littlejohn's Tree Frog, Stuttering Frog, Red-crowned Toadlet.
Songmeters	5 nights in one location	60 hours	Giant Burrowing Frog, Green and Golden Bell Frog, Littlejohn's Tree Frog, Stuttering Frog, Red-crowned Toadlet.	Giant Burrowing Frog, Green and Golden Bell Frog, Littlejohn's Tree Frog, Stuttering Frog, Red-crowned Toadlet.
Harp traps	5 nights in four locations	72 hours	Large-eared Pied Bat, Eastern Bent-wing Bat, Little Bent-wing–Bat, Large-footed Myotis, Eastern Cave Bat.	Large-eared Pied Bat
Songmeters	9 nights in three locations	324 hours	Large-eared Pied Bat, Eastern Bent-wing Bat, Little Bent-wing–Bat, Large-footed Myotis, Eastern Cave Bat.	Large-eared Pied Bat,
Arboreal cage traps	150 trap nights (30 traps, 5 nights)	1,800 hours	Greater Glider, Squirrel Glider	Greater Glider, Squirrel Glider
Hair tubes	9 days (30 tubes)	6,480 hours	Southern-brown bandicoot, Squirrel Glider, Greater Glider	Eastern Pygmy-possum, Spotted-tail Quoll, Southern Brown Bandicoot, Long-nosed Potoroo, New Holland Mouse and Brush-tailed Rock-wallaby.
Reptile spotlighting	4 hours, 2 ecologists	8 hours	Broad-headed Snake	

Method	Survey effort (hours/trap nights)	Total hours	Species credit fauna targeted	EPBC Act listed fauna targeted
Reptile habitat search/rock turning	4 hours, 2 ecologists	8 hours	Broad-headed Snake	
Bird searches	20 minutes each site (6), 2 ecologists + opportunistic	5 hours	All threatened birds	All threatened and migratory birds
Habitat search and site familiarisation	2 hours, 2 ecologists	4 hours	All species	All species
Niche 2013 Survey effort within ventilation shaft and powerline (locations since removed from Project)				
Camera traps	5 traps, 10 days	1,200 hours	Threatened mammals Eastern Pygmy-possum, Southern Brown Bandicoot, and Brush-tailed Rock-wallaby and reptiles ncluding Rosenberg's Goanna,	Eastern Pygmy-possum, Spotted-tail Quoll, Southern Brown Bandicoot, New Holland Mouse and Brush-tailed Rock-wallaby.
Spotlight	2 hours, 2 ecologists, 2 nights	8 hours	Koala, Squirrel Glider	Koala
Habitat assessment - Vent Shaft TSC1	4 hours	4 hours	All species	All species
Habitat assessment - Vent Shaft TSC2	8 hours	8 hours	All species	All species
Habitat assessment - Vent Shaft TSC3	8 hours	8 hours	All species	All species
Habitat assessment - Powerline	8 hours	8 hours	All species	All species
Niche 2012-2013 Amphibian Monitoring Project				
Targeted amphibian monitoring - Dog Trap Creek	4 hours per ecologist	8 hours	Giant Burrowing Frog, Green and Golden Bell Frog, Littlejohn's Tree Frog, Stuttering Frog, Red-crowned Toadlet.	Giant Burrowing Frog, Green and Golden Bell Frog, Littlejohn's Tree Frog, Stuttering Frog.
Songmeter - Dog Trap Creek	4 nights	36 hours		
Targeted amphibian monitoring - Tea Tree Hollow	4 hours per ecologist	8 hours		
Songmeter - Tea Tree Hollow	3 nights	36 hours		
Targeted amphibian monitoring - Eliza Creek	3.5 hours per ecologist	7 hours		
Targeted amphibian monitoring - Dry Creek	3.25 hours per ecologist	6.5 hours		
Targeted amphibian monitoring - Hornes Creek	5.5 hours per ecologist	11 hours		
Targeted amphibian monitoring - Cow Creek	4.5 hours per ecologist	9 hours		
Songmeter - Cow Creek	8 nights	72 hours		
Targeted amphibian monitoring - Carter Creek	2 hours per ecologist	4 hours		

Method	Survey effort (hours/trap nights)	Total hours	Species credit fauna targeted	EPBC Act listed fauna targeted
Targeted amphibian monitoring - Bargo River tributary	2.25 per ecologist	4.5 hours		
Targeted amphibian monitoring - Bargo River	2 hours per ecologist	4 hours		

Niche 2018 survey effort

The trapping techniques used during the survey are detailed in the table below.

Table 15. Trapping methodology employed during the 2018 survey

Trapping technique	Details
Infra-red Camera traps	Camera trapping was conducted over 10 nights. Ten infra-red motion sensing cameras were deployed across the ventilation shaft site and the surrounding habitat. A PVC tube baited with a mixture of honey, oats and peanut butter was placed in front of the camera traps.
Koala searches	Searches were conducted during two days by two ecologists within areas of potential habitat in ventilation shaft sites. Potential Koala habitat was determined by the presence of known feed tree species (mostly *Eucalyptus punctata*) and trees suitable for shelter. Two ecologists conducted the searches, focusing on separate trees. Each tree was examined for scratches and a scat search was performed for at least one minute around the base of the tree and under the tree canopy.
Spotlighting/stag watch	Spotlighting surveys were conducted over two nights. The spotlighting survey targeted Koalas, owls and arboreal mammals. Opportunistic stag watch occurred during the spotlighting survey. The surveys were performed on foot throughout the ventilation shaft footprint and immediate surrounds.
Call playback	Call playback was conducted over two nights. After an initial listening period of up to 30 minutes, calls of the target species were broadcast through a 10 watt megaphone for five minutes followed by a five minute listening period and a period of spotlighting. Target species included: Koala, Powerful Owl, Barking Owl, Sooty Owl, Masked Owl, Squirrel Glider and Greater Glider.
Diurnal bird searches	Bird surveys were undertaken over three mornings when birds are at their most active, between 7 am and 10 pm. The surveys involved listening and searching for birds using binoculars. Each survey lasted 20 minutes and was conducted by one ecologist within areas of the surface infrastructure footprint and immediate surrounds. Opportunistic sightings of bird species (particularly threatened species) were also noted during other field work.
Cumbelrand Plain Plain Land Snail	Two ecologists spent 6 hours each over three days looking for the Cumebrland Plaion Land Snail within the ventilation shaft sites, REA and immediate surrounds. This involved looking amongst leaf litter, bark, and under logs.

Niche 2017 survey effort

The trapping techniques used during the survey are detailed in the table below.

Table 16. Trapping methodology employed during the 2017 survey

Trapping technique	Details
Infra-red Camera traps	Camera trapping was conducted over 10 nights. Twenty-nine infra-red motion sensing cameras were deployed across REA Area 1 and REA 2 and the surrounding habitat. A PVC tube baited with a mixture of honey, oats and peanut butter was placed in front of the camera traps.
Koala searches	Searches were conducted during one day by two ecologists within areas of potential habitat in REA Area 1 and REA Area 2. Potential Koala habitat was determined by the presence of known feed tree species (mostly *Eucalyptus punctata*) and trees suitable for shelter. Two ecologists conducted the searches, focusing on separate trees. Each tree was examined for scratches and a scat search was performed for at least one minute around the base of the tree and under the tree canopy.
Spotlighting/stag watch	Spotlighting surveys were conducted over three nights. The spotlighting survey targeted Koalas, owls and arboreal mammals. Opportunistic stag watch occurred during the spotlighting survey. The surveys were performed on foot throughout the surface infrastructure area footprint and immediate surrounds.
Call playback	Call playback was conducted over three nights. After an initial listening period of up to 30 minutes, calls of the target species were broadcast through a 10 watt megaphone for five minutes followed by a five minute listening period and a period of spotlighting. Target species included: Koala, Powerful Owl, Barking Owl, Sooty Owl, Masked Owl, Squirrel Glider and Greater Glider.
Reptile habitat search	Herpetological surveys were conducted opportunistically and included diurnal targeted searches under rocks, timber, logs and tree bark in identified potential habitat throughout the surface infrastructure footprint.
Diurnal bird searches	Bird surveys were undertaken over three mornings when birds are at their most active, between 7 am and 10 pm. The surveys involved listening and searching for birds using binoculars. Each survey lasted 20 minutes and was conducted by one ecologist within areas of the surface infrastructure footprint and immediate surrounds. Opportunistic sightings of bird species (particularly threatened species) were also noted during other field work.
Amphibian survey	An amphibian survey of Tea Tree Hollow Creek, Eliza Creek, Dry Creek and Dog Trap Creek was conducted by Dr Frank Lemckert (amphibian expert) to determine habitat potential for threatened amphibians including: Red-crowned Toadlet, Giant Burrowing Frog and Littlejohn's Tree Frog. This involved traversing portions of the creeks to identify key areas of habitat, and inspecting existing pools for exotic fish which may inhibit tadpole development/survival should the species occur.
Cumbelrand Plain Plain Land Snail	Two ecologists spent 6 hours each over three days looking for the Cumberland Plain Land Snail within the ventilation shaft sites, REA and immediate surrounds. This involved looking amongst leaf litter, bark, and under logs.

Niche 2013 survey effort

During the 2013 survey effort, six fauna trap sites were established. Each trapping area incorporated infra-red camera traps, hair tubes and tree mounted cage traps. All other survey techniques were conducted broadly within each of the six sites, in and around the trapping areas.

Table 17. Trapping methodology and survey effort during the 2013 surveys

Trapping technique	Details
Infra-red Camera traps	Camera trapping was conducted in November 2012 and March 2013. Eighteen infra-red motion sensing cameras were deployed at the six trapping sites, with three cameras at each trapping site. A PVC tube baited with sardines or a mixture of honey, oats and peanut butter was placed in front of the camera traps. Upon recovery, the pictures were individually analysed and animals were identified to the lowest possible taxonomic level. Each camera trap was deployed for nine days (and nights). In March 2013, three cameras were deployed to address gaps in previous survey effort. The cameras were deployed for seven days (and nights).
Koala searches	Searches were conducted during November 2012 and March 2013 in the proposed REA and control sites within areas of potential habitat. Potential Koala habitat was determined by the presence of known feed tree species (mostly *Eucalyptus punctata*) and trees suitable for shelter. Two ecologists conducted the searches, focusing on separate trees. Each tree was examined for scratches and a scat search was performed for at least one minute around the base of the tree and under the tree canopy.
Spotlighting/stag watch	Spotlighting surveys were conducted in November 2012 and March 2013. The spotlighting survey targeted owls and arboreal mammals. Opportunistic stag watching occurred throughout the spotlighting survey. The surveys were performed either on foot or via a vehicle around roads and tracks of the proposed REA and adjacent areas.
Call playback	Call playback was conducted during November 2012 and March 2013. Call-playback sites were established at each trapping site to enable maximum coverage. After an initial listening period of up to 30 minutes, calls of the target species were broadcast through a 10 watt megaphone for five minutes followed by a five minute listening period and a period of spotlighting. Target species included: Koala, Powerful Owl, Barking Owl, Sooty Owl and Masked Owl.
Remote bat detectors - SM2 detection	Wildlife Acoustics SM2 Bat detector units were deployed along identified flyways and around watercourses throughout the proposed REA and control sites during November 2012 and March 2013 survey. Data was analysed by qualified specialists: Amy Rowles (Ecotone) and Matthew Stanton (Niche).
Harp trapping	During November 2012 survey, harp traps were set up in trapping areas at REA 1 and in areas adjacent to the Study Area. The harp traps were set up in areas which were regarded as ideal flyways. Traps were checked at sunrise daily.
Arboreal cage traps	Trapping was conducted during the November 2012 field work. At each of the six trapping areas, five wire cage traps were used to target arboreal mammals (approximate cage dimensions of 18 x 18 x 55 centimetres). Each trap was mounted at a height of approximately three metres above the ground, with the Elliott and cage traps mounted on wooden brackets. Each trap tree was sprayed daily with a brown sugar/honey mixture. Traps were checked daily at sunrise.
Cage trap	Where suitable habitat occurred for ground dwelling mammals (e.g. Spotted-tail Quoll), one wire cage trap was placed on the ground within the trap line.

Trapping technique	Details
Hair tubes	Hair tubes were set up in November 2012 for nine days (and nights). PVC hair tubes were attached to trees with electrical tape and secured under logs or other debris on the ground at each of the six sites. Double sided tape was only adhered to the upper and lateral inner surface of the tubes so as to limit the incidence of 'by catch'. Tubes were baited with a mixture of honey, oats and peanut butter. Hair samples were sent to Barbara Triggs (Dead Finish) for analysis. Targeted fauna included arboreal and ground dwelling mammals.
Reptile spotlighting	Herpetological surveys were conducted in November 2012 and March 2013. Surveys were conducted during spotlighting for other species and were performed either on foot or via a vehicle around roads and tracks of the proposed REA and control sites.
Reptile habitat search	Herpetological surveys were conducted in November 2012 and March 2013, and included diurnal targeted searches under rocks, timber, logs and tree bark in identified potential habitat throughout the proposed REA and along the ridgetop environments when traversing to the amphibian and riparian monitoring sites.
Diurnal bird searches	Bird surveys were undertaken in the morning when birds are at their most active, between 7 am and 10 pm. The surveys involved listening and searching for birds using binoculars. Each survey lasted 20 minutes and was conducted by two ecologists at each of the six sites during November 2012. Opportunistic sightings of bird species (particularly threatened species) were also noted during other field work.
Habitat based assessment	Habitat assessments were conducted at each of the vent shaft sites and along the transmission line route. At each site, observations of important fauna habitat were made. Habitat characteristics and parameters that were assessed included: ▪ Aspect/slope of the site ▪ Dominant vegetation, floristic composition and structure ▪ Composition of ground layer (bare earth, litter, fungi, moss, lichen etc.) ▪ Presence and relative abundance of key habitat features (e.g. tree hollows, large logs, exfoliating rock, flowering resources, aquatic features) ▪ Vegetation age structure. Key habitat features were recorded on a GPS. Bird species were opportunistically surveyed for during habitat assessment at each of the sites.

Table 18. Recommended threatened fauna survey time matrix as specified in BBCC

Common name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Addressed in survey
Cumberland Plain Land Snail	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Targeted surveys completed during September and June.
Eastern Pygmy-possum													None specified, however targeted surveys completed during September, November and June.
Gang-gang Cockatoo population, Hornsby and Ku-ring-gai Local Government Areas	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Surveys completed during November, December. Not in LGA regardless.
Giant Burrowing Frog	Yes	Yes	Yes	Yes	Yes				Yes	Yes	Yes	Yes	Amphibian monitoring completed in April, May, November, and December.
Green and Golden Bell Frog	Yes	Yes	Yes					Yes	Yes	Yes	Yes	Yes	Amphibian monitoring completed in November, December.
Koala	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Targeted surveys completed during September, November and June.
Large-eared Pied Bat	Yes	Yes	Yes	Yes					Yes	Yes	Yes	Yes	Anabats used during September and November.
Red-crowned Toadlet	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Targeted surveys completed during September, November and June.
Regent Honeyeater	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Targeted surveys completed during September, November and June.
Rosenberg's Goanna	Yes	Yes									Yes	Yes	Targeted surveys completed during November.
Squirrel Glider	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Targeted surveys completed during September, November and June.

Targeted amphibian monitoring

The amphibian monitoring was conducted by two ecologists during spring and autumn in 2012, and again in 2013. Details regarding the survey dates and weather conditions are provided in Appendix 4.

A total of 39 locations were surveyed for frogs at riparian sites covering 13 creeks in the Study Area. The monitoring locations consisted of 18 control sites and 21 impact sites (Figure 11).
Surveys at each site were conducted along a 200 metre transect that was searched once in each of the two above mentioned survey periods.

The monitoring surveys along transects comprised:

- Nocturnal aural and visual searches of selected watercourses to locate and record the presence of Red-crowned Toadlet, Green and Golden Bell Frog, Littlejohn's Tree Frog, Giant Burrowing Frog and Stuttering Frog. The searches were area constrained, searching within 10m either side of the selected 200m length of stream.
- Nocturnal call playback, based on OEH guidelines for effort, to further increase survey success for the above-mentioned species. This was conducted at the same time as the aural/visual searches.
- Tadpole searches, using effort-constrained dip net surveys, was conducted as part of daytime transect surveys, providing on-going monitoring of reproductive success within the study area. Dip netting was undertaken in permanent pools greater than 1m in diameter and other selected pools where tadpoles were located. The number of sweeps required to thoroughly sample the pool was recorded along with the size of the pool at the time of sampling. This provided a unit of effort per sample that could be standardised for comparisons. Diurnal searches and call playbacks were carried out opportunistically at the same time as the tadpole sampling.
- Automated recording of frog calls using Song Meters to monitor the presence of the listed threatened species of concern along transects located in areas that are difficult/unsafe to reach for night surveys.

6.3 Fauna survey results

6.3.1 Fauna

A total of 78 fauna species were recorded during the current assessment and 2013 survey effort. This included: eight amphibians, 45 birds, 17 mammals and eight reptiles. The results of the survey are provided in Appendix 7.

6.3.2 Threatened fauna

Twelve threatened fauna listed on the BC Act were recorded within the Study Area, within, or immediately adjacent to the proposed surface infrastructure disturbance footprint. These are listed in Table 19.

Table 19. Threatened fauna recorded during Niche surveys

Common Name	Scientific Name	BC Act Status	EPBC Act Status	Species credit or Ecosystem Credit species
Glossy Black Cockatoo	*Calyptorhynchus lathami*	V	-	Ecosystem
Little Eagle	*Hieraaetus morphnoides*	V	-	Ecosystem
Powerful Owl	*Ninox strenua*	V	-	Ecosystem
Scarlet Robin	*Petroica boodang*	V	-	Ecosystem
Sooty Owl	*Tyto tenebricosa*	V	-	Ecosystem
Varied Sittella	*Daphoenositta chrysoptera*	V	-	Ecosystem

Common Name	Scientific Name	BC Act Status	EPBC Act Status	Species credit or Ecosystem Credit species
Eastern Bentwing Bat	*Miniopterus schreibersii oceanensis*	V	-	Ecosystem/Species (breeding habitat in surface infrastructure disturbance area is unlikely)
Eastern Free-tail Bat	*Mormopterus norfolkensis*	V	-	Ecosystem (breeding habitat in surface infrastructure disturbance area is unlikely)
Large-footed Myotis	*Myotis macropus*	V	-	Ecosystem (breeding habitat in surface infrastructure disturbance area is unlikely)
Eastern Cave Bat	*Vespadelus troughtoni*	V	-	Ecosystem (breeding habitat in surface infrastructure disturbance area is unlikely)
Eastern False Pipistrelle	*Falsistrellus tasmaniensis*	V	-	Ecosystem (breeding habitat in surface infrastructure disturbance area is unlikely)
Red-crowned Toadlet	*Pseudophryne australis*	V	-	Species

Key: V = species listed as vulnerable under relevant legislation

Two threatened amphibians - Red-crowned Toadlet (*Pseudophryne australis*) and Giant Burrowing Frog (*Heleioporus australiacus*), were recorded during the Amphibian Monitoring Program in 2013. The Giant Burrowing Frog was recorded outside of the Study Area, within Cow Creek, whilst the Red-crowned Toadlet was recorded within the Study Area at Hornes Creek. The record for the Red-crowned Toadlet is shown on Figure 13.

An additional nine threatened fauna species have been previously recorded in the Study Area according to OEH Bionet records (Figure 13). These include: Brown Treecreeper, Diamond Firetail, Sooty Tern, Black-chinned Honeyeater, Eastern Freetail-Bat, Koala, Large-eared Pied Bat, Varied Sittella and Greater Broad-nosed Bat. The record for Sooty Tern was an isolated occurrence and unusual as the Study Area does not provide habitat for this species.

Given the size of the Study Area, the relatively mobile nature of the majority of the threatened fauna predicted to occur within the locality, and the presence of suitable habitat, a further 34 species were considered to have a moderate to high likelihood of occurrence within the Study Area; however, only 8 of which are regarded as species credit fauna.

Given the emphasis on species credit fauna, consideration for each in relation to the Study Area is provided in Table 20.

It should be noted that the Broad-headed Snake, whilst nominated in the SEARs and listed as a species credit fauna, has been attributed a low likelihood of occurrence to occur in the Study Area and the area proposed for surface infrastructure works. The Broad-headed Snake has not been recorded in the Study Area during current surveys, nor has the species previously been recorded within the Study Area.

The closest records obtained from the OEH Bionet database is a record approximately 4 kilometres to the west of the Study Area along the ridgeline of the Bargo River, and a record 6 kilometres to the south along Avon River. Both these areas are within conservation lands managed by NSW NPWS and WaterNSW respectively.

Important rock outcrops for this species are those on ridgelines facing north or west, as the species relies upon specific thermal conditions that are only attained in such ridgelines. These outcrops must have limited to no shading from the woodland canopy, again to allow penetration of high levels of sunlight. Finally, the outcrop must also include suitable rock exfoliations, which take the form of thin layers of rock resting directly on larger rock and without sand or debris between the layers (Pringle et al. (2003), Webb and Shine (1994) and Webb and Shine (1998a, 1998b & 1998c)).

Table 20. Species credit threatened fauna with moderate to higher likelihood of occurrence

Common name	Scientific name	BC Act	EPBC Act	Likelihood in Study Area	Likelihood in surface infrastructure footprint	Consideration	BioBanking
Red-crowned Toadlet	*Pseudophryne australis*	V	-	Known	Low	The Red-crowned Toadlet was recorded within the Study Area at Hornes Creek during the Tahmoor South Project Amphibian Monitoring Program. The portion where the species was recorded is just within the limits of subsidence along a downstream section of Hornes Creek. The Red-crowned Toadlet was not recorded within any other riparian area within the Study Area during the amphibian monitoring program. Impacts to the Red-crowned Toadlet are discussed further in section 7.5.5.	Species
Large-eared Pied Bat	*Chalinolobus* dwyeri	V	V	Moderate	Moderate	The Large-eared Pied Bat was not detected during the survey. However, records for the species exist along the Nepean River immediately outside of the Study Area. The Large-eared Pied bat is known to roost in caves, crevices in cliffs, old mine workings and in the disused, bottle-shaped mud nests of the Fairy Martin (*Petrochelidon ariel*). Crevices in sandstone overhangs are known to occur along the cliff lines within the Study Area. However, breeding habitat is quite specific to caves. According to DERM (2010) the following is known about the specific breeding habitat: 'the structure of maternity roosts appears to be very specific (arch caves with dome roofs) - Caves need to be high and deep enough to allow juvenile bats to learn to fly safely inside and have indentations in the roof. These physical characteristics are very uncommon in the landscape'. Within the Study Area, no caves were encountered during surveys completed by Niche, nor have any caves been reported by MSEC (2018). However, the prior records for the Large-eared Pied Bat just outside of the far north of the Study Area coincide with the cliff lines of the Nepean River. It is possible that crevices within this area provide marginal habitat for the species. Impacts associated with the species is provided in section 7.5.3.	Species

Common name	Scientific name	BC Act	EPBC Act	Likelihood in Study Area	Likelihood in surface infrastructure footprint	Consideration	BioBanking
Eastern Bent- wing Bat	*Miniopterus schreibersii oceanensis*	V	-	Known	Known	This species was recorded within the surface area footprint during targeted surveys. The species is likely to use the range of habitat types present in the Study Area for foraging. The Eastern Bent-wing Bat is a dual credit species, with the presence of breeding habitat triggering the species credit requirement. Not a great deal is known about the Eastern Bent-wing bat however it is known that the species uses caves for breeding (OEH 2014). The maternity caves are reported to have very specific temperature and humidity regimes, and populations can disperse within about 300 km range of maternity caves (OEH 2014). Within the Study Area, no caves were encountered during surveys completed by Niche, nor have any caves been reported by MSEC (2018). Furthermore, cliff line environments which may indicate cave-like habitat, are generally limited to the Nepean River to the north of the Study Area with some scattered cliff lines along the Dog Trap Creek, and Hornes Creek. Given the specific cave requirements, the ability of the species to traverse over 300 kilometres from a breeding site, lack of known breeding colonies in the area, it seems quite unlikely that breeding habitat occurs within the Study Area. As such, this species has been regarded as an ecosystem credit species for this assessment.	Ecosystem & Species
Large-footed Myotis	*Myotis macropus*	V	-	Known	Known	This species was recorded within the surface area footprint of the REA during targeted surveys. The large-footed Myotis is regarded as a species credit species given its dependence of habitat surrounding waterways for roosting. The OEH Bionet database notes that hollow-bearing trees, bridges, caves or artificial structures within 200 m of riparian zone are areas of important habitat for the species. Portions of the proposed surface infrastructure for the REA is within 200 metres of Tea Tree Hollow Creek. The creeks in the Study Area also	Species

Common name	Scientific name	BC Act	EPBC Act	Likelihood in Study Area	Likelihood in surface infrastructure footprint	Consideration	BioBanking
						provide habitat for the species given hollow-bearing trees occupy the length of all creeklines in the Study Area. Furthermore, given the Large-footed Myotis may forage over streams and pools catching insects and small fish, the pools within the creeklines may provide foraging habitat for the species. Impacts to the species are discussed in section 7.5.3.	
Koala	*Phascolarctos cinereus*	V	-	High (Previously recorded by OEH).	Low	The Koala was not recorded in the area proposed for surface infrastructure despite targeted survey. However, numerous records from OEH Bionet exist for the Koala within the Study Area. Most of these records occur toward the far south of the Study Area, which borders the Upper Nepean State Conservation Area and land managed by WaterNSW. A number of other records exist near the Bargo township toward the far south of the Study Area, and one record for the Koala along Eliza Creek. Potential habitat for the Koala is within the dry sclerophyll vegetation communities throughout the Study Area, in particular, areas of habitat that are connected to larger vegetated parcels of land. Whilst no records for the Koala were detected during the current survey despite targeted survey, the habitat features of the area proposed for surface infrastructure form part of a corridor of vegetation along Tea Tree Hollow Creek which may support movement of the Koala throughout the area. Impacts to the Koala are discussed further in section 7.5.1.	Species
Grey-headed Flying-fox	*Pteropus poliocephalus*	V	V	High	High	The Grey-headed Flying-fox was not recorded during the current survey. A number of previous records occur to the east and south of the locality within Sydney Catchment Authority lands. The Grey-headed Flying-fox is a canopy-feeding frugivore and nectarivore, which utilises vegetation communities including rainforests, open forests, closed and open woodlands, Melaleuca swamps and Banksia woodlands. It also feeds on commercial fruit crops and on introduced tree species in urban areas. The primary	Ecosystem & Species

Common name	Scientific name	BC Act	EPBC Act	Likelihood in Study Area	Likelihood in surface infrastructure footprint	Consideration	BioBanking
						food source is blossom from Eucalyptus and related genera (DoEE 2012). Given these features occur throughout the Study Area, the Grey-headed Flying Fox may utilise the habitat types for foraging. The Grey-headed Flying Fox is a dual credit species, with breeding habitat triggering the species credit requirement. No known breeding camp sites have been recorded in the Study Area by Niche and no camp sites have been previously recorded in the area. It is highly unlikely that camp sites exist in the Study Area. Therefore the species is regarded as an ecosystem credit species for this assessment.	
Eastern Cave Bat	*Vespadelus troughtoni*	V	-	Known	Known	This species was recorded within the surface area footprint during targeted surveys. The Eastern Cave Bat is regarded as a species credit species as according to the OEH bionet database, the species cannot be reliably predicted to occur on a site based on vegetation and other landscape features (breeding or foraging). The species is known to have breeding habitat identified by the presence of rocky areas containing caves, or overhangs or crevices or escarpments, old, tunnels or culverts. As the species was recorded within the surface area footprint, it is likely that this would be regarded as foraging habitat. Furthermore, given the species has potential habitat within crevices of sandstone formations, it is possible the species may also use the cliff lines along the creeks in the Study Area. The impacts toward the species are discussed further in section 7.5.4.	Species

6.3.3 EPBC Act listed threatened fauna

None of the threatened fauna recorded during the field survey are listed under the EPBC Act.

Whilst not detected, the results of the database analysis in Appendix 1 has indicated the following threatened fauna species have a moderate to high likelihood of occurrence within the Study Area:

- Migratory birds: Fork-tailed Swift, Great Egret, Cattle Egret and Rainbow Bee-eater, Satin Flycatcher
- Endangered birds: Swift Parrot
- Vulnerable mammals: Large-eared Pied Bat, Grey-headed Flying Fox, Koala, Greater Glider.

Many of these species, in particular the threatened birds, may utilise a wide range of habitat types for foraging, and as such cannot be ruled out from occurring within the Study Area.

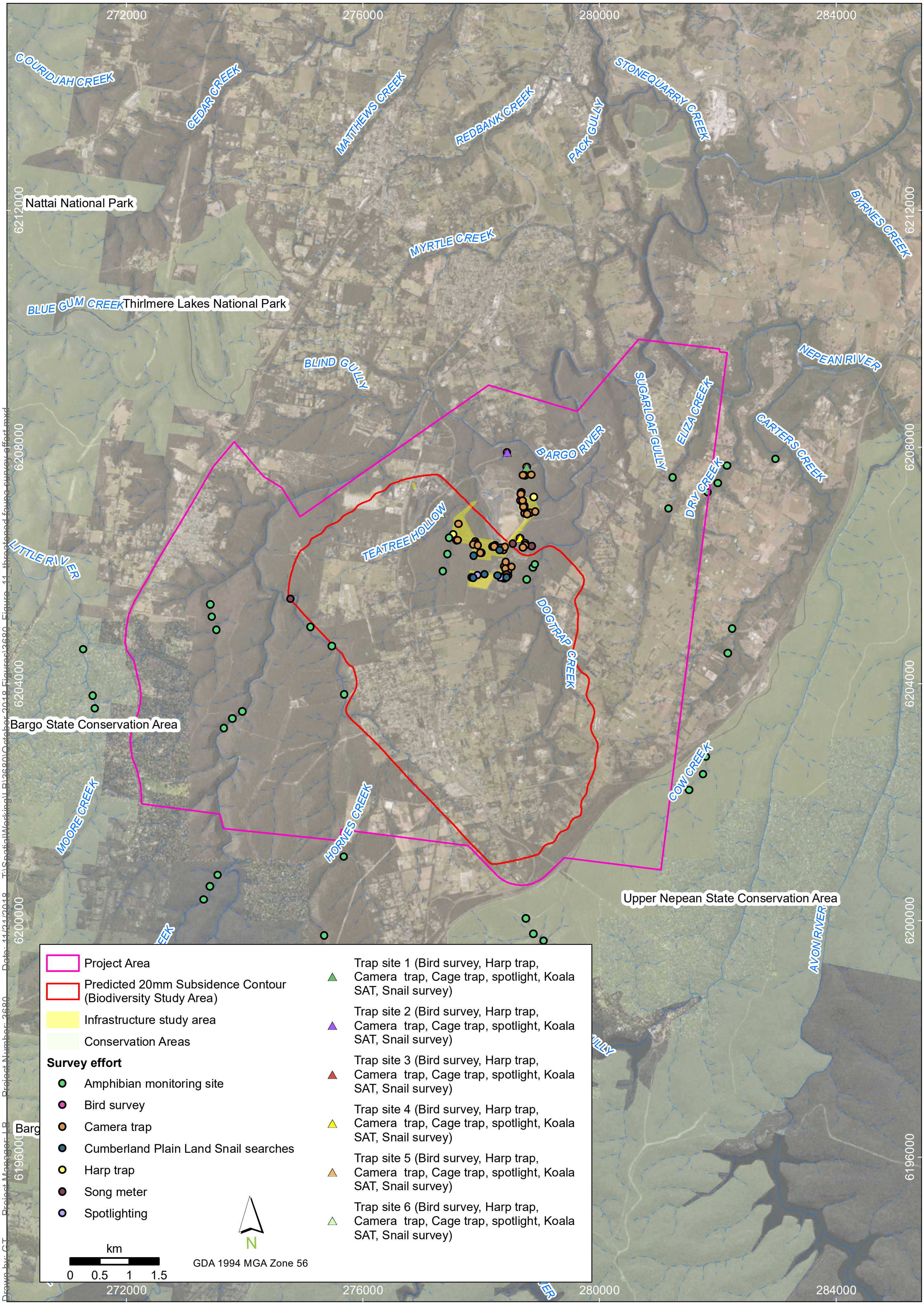
Similarly, as discussed in section 6.3.2, the Grey-headed Flying Fox may forage within the Study Area given the species may use a wide variety of eucalypts as a food source.

The Koala and Large-eared Pied Bat are both discussed in 6.3.2. The Koala was not detected during the current survey despite targeted survey, however records throughout the Locality exist for the species. The habitat features of the area proposed for surface infrastructure form part of a corridor of vegetation along Tea Tree Hollow Creek which may support movement of the Koala throughout the area. As such, the species has been assigned a high likelihood of occurrence within the Study Area.

The Large-eared Pied Bat was not detected during the field survey, however records for the species occur outside the far north of the Study Area which coincides with cliff lines of the Nepean River. It is possible that crevices within this portion of the Study Area may provide some marginal habitat for the species. As such, the species has been assigned a moderate likelihood of occurrence within the Study Area.

The Greater Glider is highly unlikely to be present within the areas proposed for surface infrastructure given the lack of detection over differing time periods. The species is also typically found in highest abundance in taller, montane, moist eucalypt forests with relatively old trees and abundant hollows, which is limited within the area proposed for surface infrastructure. Within the Study Area, some marginal habitat exists along the gullies of the Bargo and Nepean River due to previous records for the species along the Bargo River. The records for Greater Glider occur along the Bargo River, approximately 500 metres to the far north of the Study Area. This area of the Bargo River is more deeply incised than the other creeklines in the Study Area, and may offer a more sheltered moist eucalypt forest to which the species is known to prefer. As such, the Greater Glider has been given a moderate likelihood of occurrence within the Study Area.

Potential impacts to these species are discussed further in section 7.5.

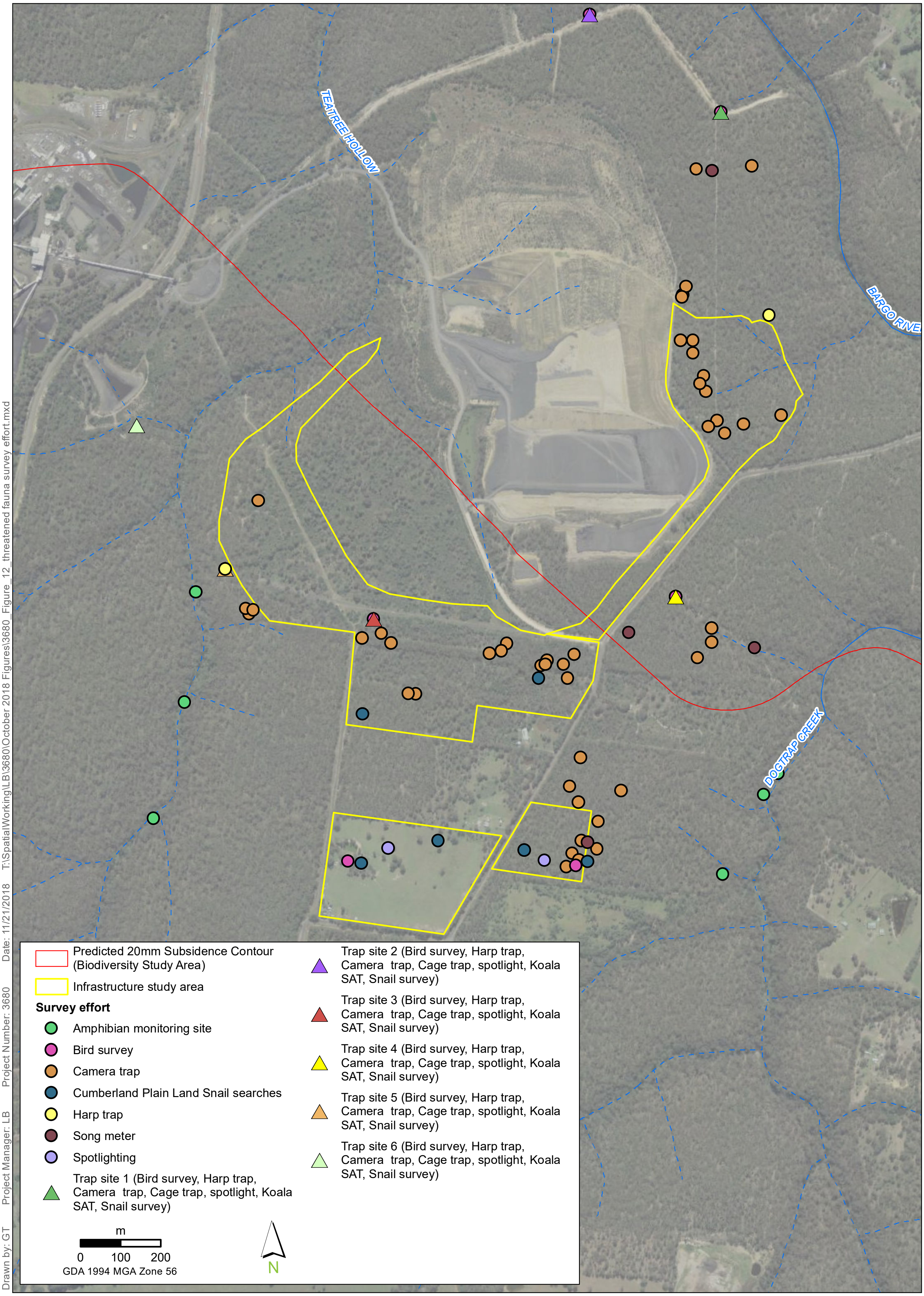


Threatened fauna survey effort

Tahmoor South Project Biodiversity Assessment Report

FIGURE 11

Imagery: (c) LPI 2013

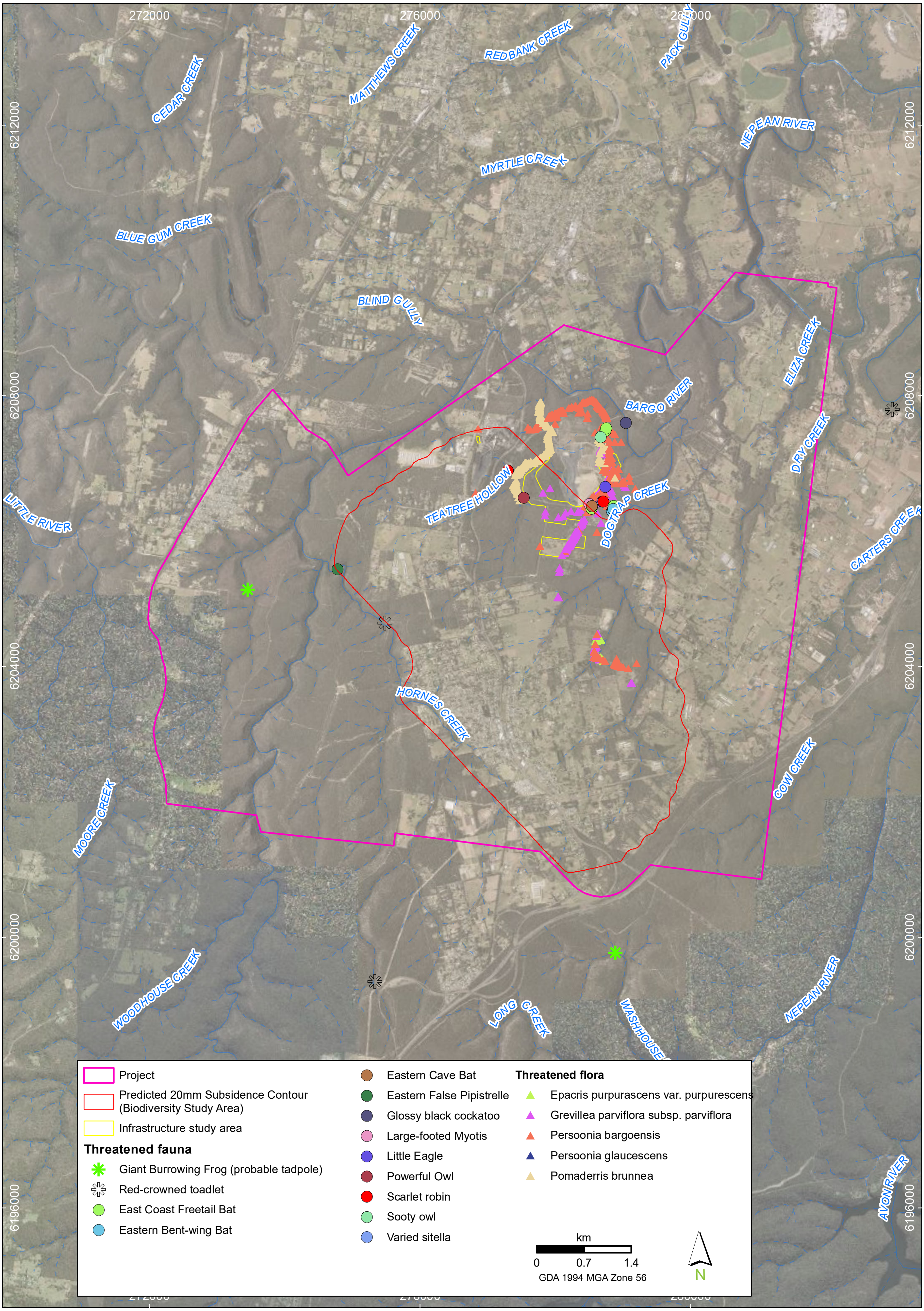


Threatened fauna survey effort

Tahmoor South Project Biodiversity Assessment Report

FIGURE 12

Imagery: (c) LPI 2013



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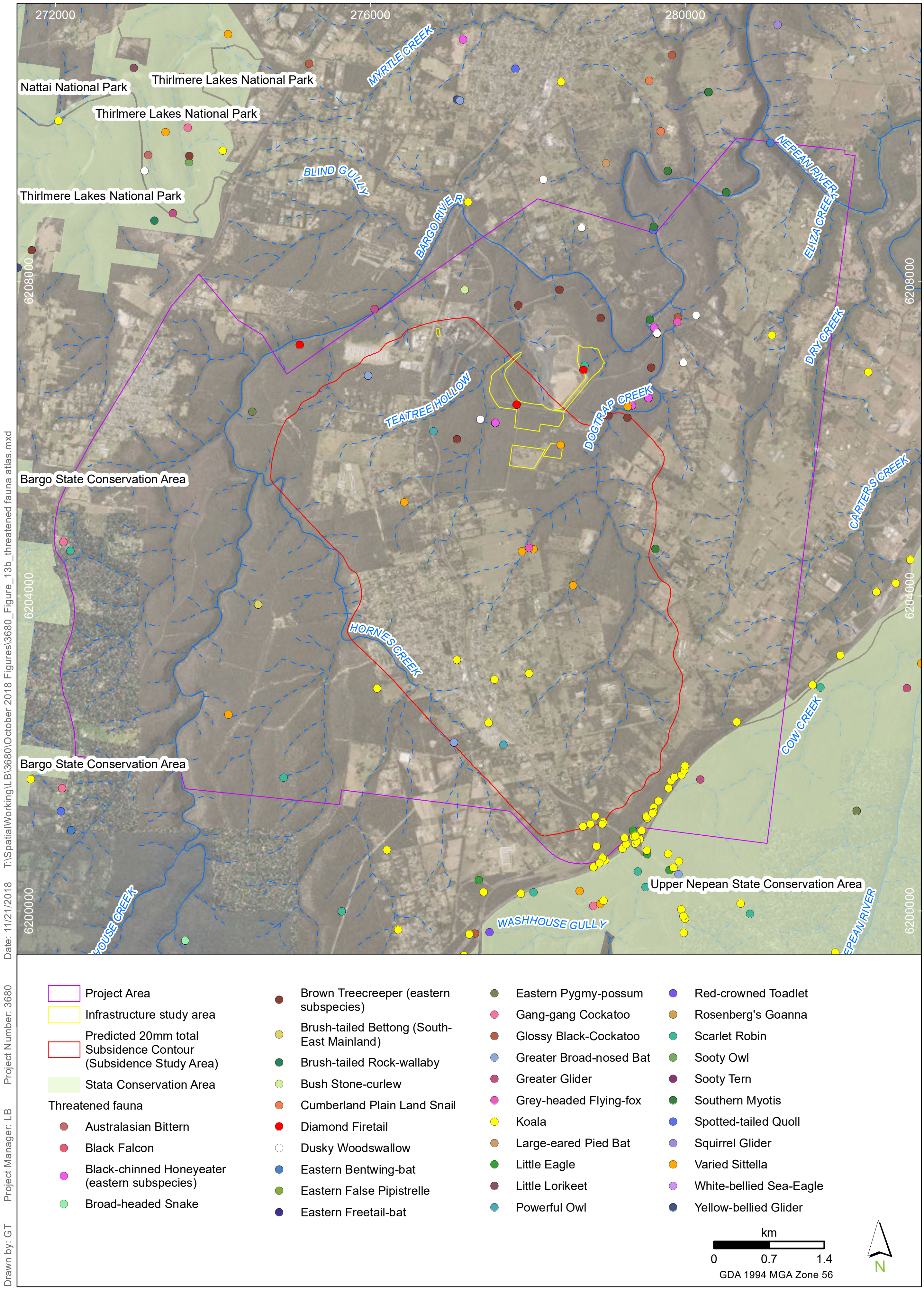
Threatened flora and fauna

Tahmoor South Project Biodiversity Assessment Report

FIGURE 13

Imagery: (c) LPI 2013

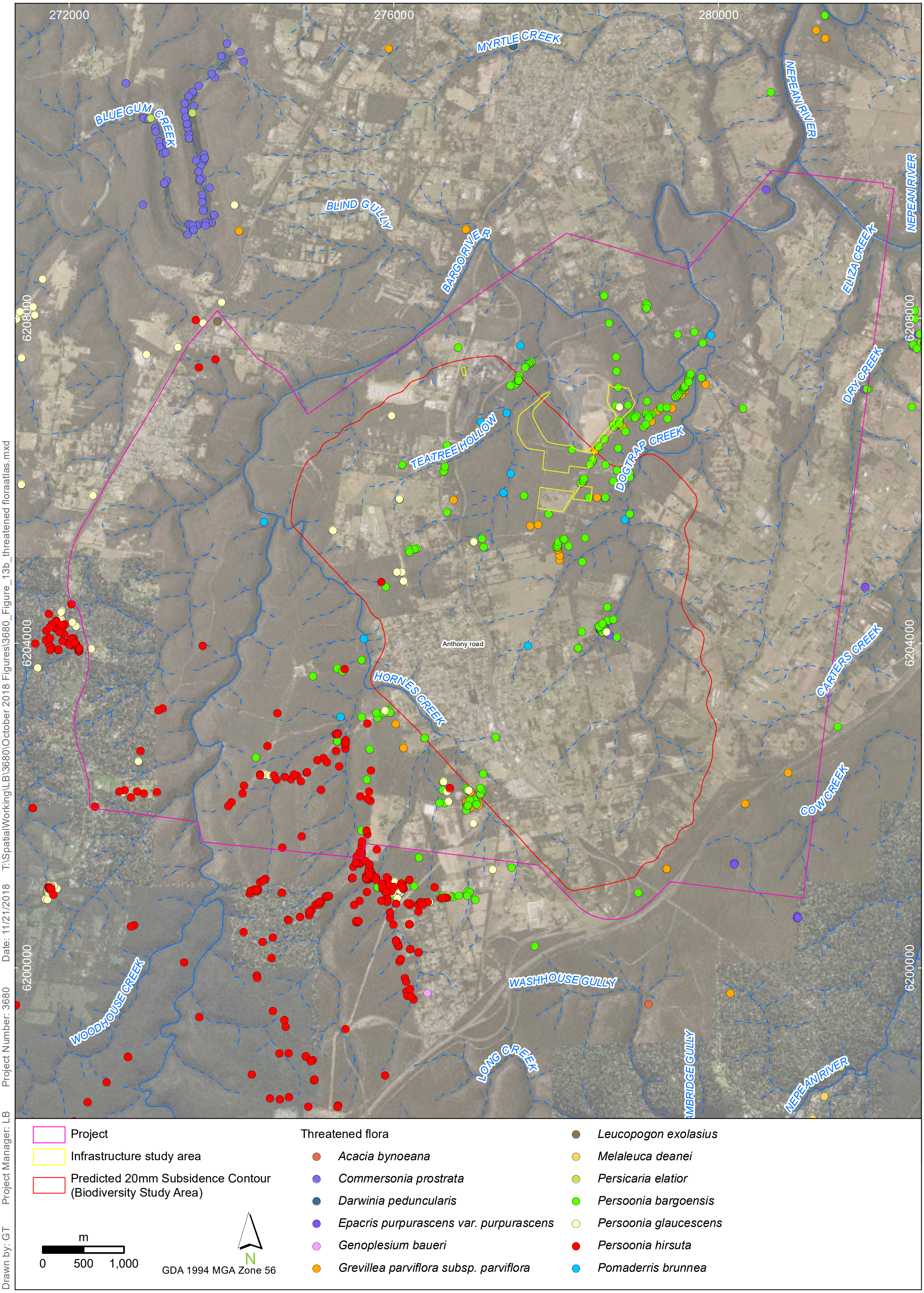


Threatened fauna - Atlas records

Tahmoor South Project Biodiversity Assessment Report

FIGURE 13b

Imagery: (c) LPI 2013

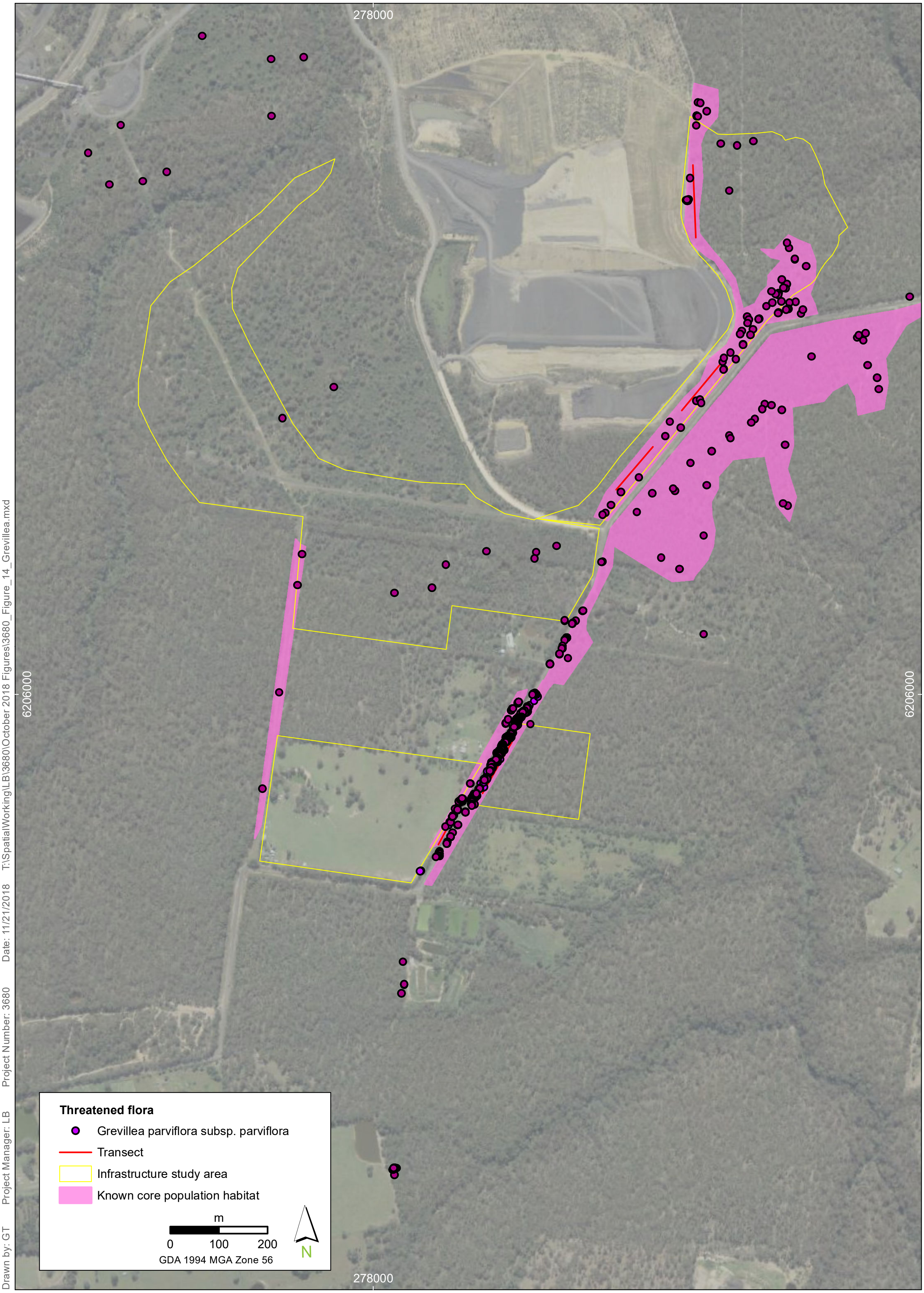


Threatened flora - Atlas records

Tahmoor South Project Biodiversity Assessment Report

FIGURE 13c

Imagery: (c) LPI 2013

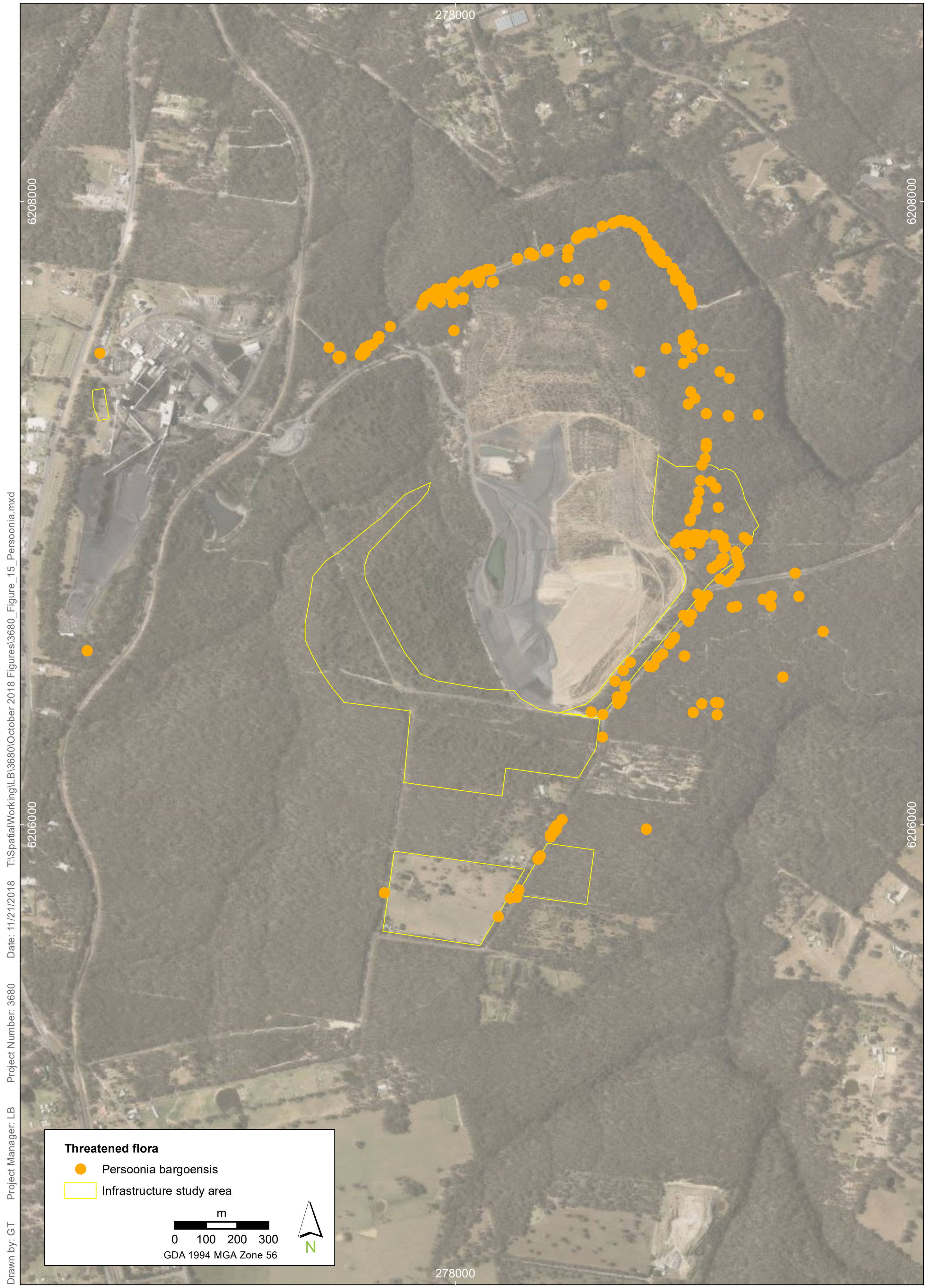


Grevillea parviflora subsp. parviflora population

Tahmoor South Project Biodiversity Assessment Report

FIGURE 14

Imagery: (c) LPI 2013

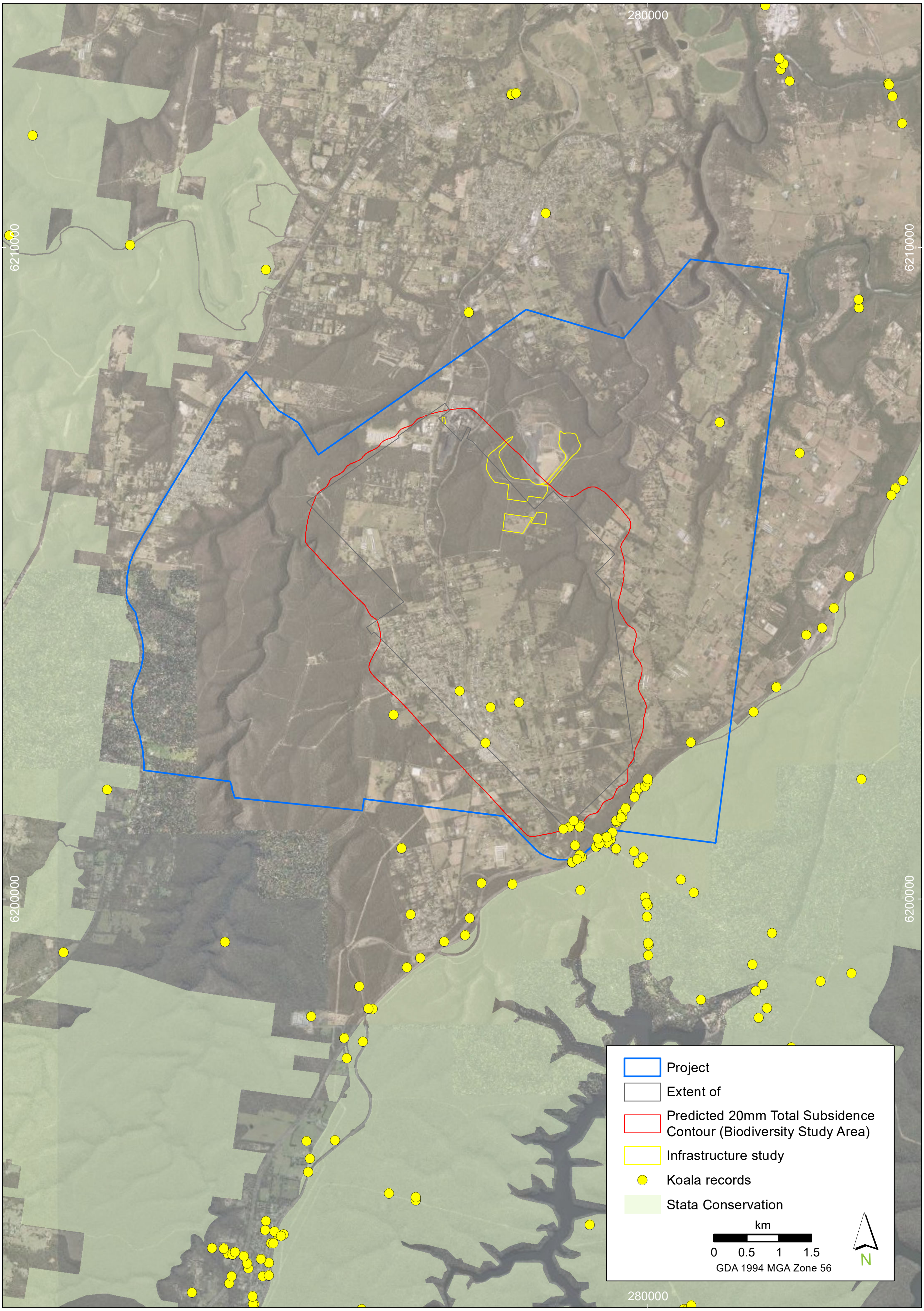


Persoonia bargoensis population

Tahmoor South Project Biodiversity Assessment Report

FIGURE 15

Imagery: (c) LPI 2013



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Koala records within the locality

Tahmoor South Project Biodiversity Assessment Report

FIGURE 16

Imagery: (c) LPI 2013

7. Impact assessment

The Impact Assessment forms Stage 2 of the Biodiversity Assessment Report as detailed in the FBA. Further Assessments of Significance have been carried out for those species listed under the EPBC Act that may potentially be impacted by the Project. The impact assessment has incorporated the findings from the specialist studies in order to determine the severity and potential for impacts toward biodiversity.

7.1 Vegetation clearing and removal of habitat

The Project would result in the direct impact to approximately 49.2 hectares of native vegetation associated with the clearing for surface infrastructure. The cleared areas would be rehabilitated following works, and all potential indirect impacts minimised using the mitigation measures detailed in section 9.2.

7.2 Subsidence and its potential to impact terrestrial ecology values

Predictions regarding the likelihood and potential impact of subsidence for the Tahmoor South Project were investigated, and reported by MSEC (2018). Natural surface features sensitive to subsidence movements identified by MSEC (2018) include the following:

- Streams within the predicted limits of 20 mm total upsidence and 20 mm total closure
- Cliffs
- Bargo River.

These features provide habitat for a range of biodiversity, and therefore consideration of the potential effects of subsidence on these features and threatened biodiversity has been addressed in this report.

The potential effects of subsidence include:

- Fracturing of river and creek beds, which may result in:
    - increased levels of ponding, scouring or desiccation due to mining tilt
    - fracturing and surface water flow diversion in the streams
    - potential water quality changes/contamination
    - contamination of surface waters by gas drainage
    - potential for gas emissions and changes to water quality
- Instability and rock falls along cliff-faces
- Slippages, erosion and rock falls on steep slopes and rock ledges.

A summary of the predicted impacts that the Project may have on natural surface features sensitive to subsidence (as described by MSEC 2018), and the associated potential impacts to ecology, are described in Table 21 below. An assessment of the potential subsidence related impacts on native vegetation and species credits are discussed in the sections following.

Table 21. Predicted effects of subsidence on natural features within the Tahmoor South Study Area (MSEC 2018)

Type	Description of natural feature	Subsidence impact	Potential biodiversity impact
Bargo River	The Bargo River commences north of Colo Vale and near the townships of Hill Top and Yerrinbool and flows generally towards the north and to the west of the Bargo township. The Bargo River then flows to the west and north of the proposed Tahmoor South longwalls. The Bargo River then drains into the Nepean River approximately 4.5 kilometres north-west of the proposed Longwall 109. Only a 165 metres long length of the Bargo River that is immediately upstream from the Picton Weir is located inside the Subsidence Study Area. This length of the river that is within the Subsidence Study Area is a 4th order perennial stream as defined by the Strahler Stream Order Method.	The surface water flows in this section of the river are controlled by the Picton Weir, (also called the Bargo Weir) with discharge regulated by a fixed discharge valve. The reports by Fluvial Systems (2013) and Hydro Engineering and Consulting (2018a) provide a detailed description of this River. The 165 metres long length of the Bargo River that is immediately upstream from the Picton Weir and located inside the Subsidence Study Area is approximately 1,130 metres from the nearest basecase longwall panel, i.e. the north west corner of the proposed Longwall LW105, and this section of the river is also 530 metres from the nearest part of the Extent of Longwalls boundary. At this distance from the basecase longwall panels and with these low predicted ground movements, the river is not expected to experience any noticeable subsidence or upsidence movements. There has been a long history of mining directly beneath or near the Bargo River at Tahmoor Mine. While impacts have occurred when various previously extracted longwalls were mined directly beneath the river, impacts have been not observed when mining has been undertaken more than 500 metres away from the river. Based on the previous experience at Tahmoor Mine, it is unlikely, that the extraction of the proposed longwalls would result in any adverse impacts on the river. Even if the predictions and impact assessments were exceeded, the likelihood of pool drainage is considered extremely low given the water flows in the river.	Subsidence within the Bargo River has the potential to impact on the range of aquatic, riparian and terrestrial flora and fauna dependant on the riverine habitat and its water. However, given it has been concluded that it is extremely unlikely that the extraction of the proposed longwalls would result in any adverse impacts on the river, it is considered unlikely that ecological values dependant on the river would be significantly or adversely impacted by the Project. Any impact are likely to be highly localised and relatively minor in nature. An aquatic ecology assessment for the Project undertaken by Niche (Niche 2018) similarly concluded that, given the above, the quality and quantity of available aquatic habitat in the Bargo River is unlikely to be impacted by the Project.
Creeks	Creeks in the Subsidence Study Area include Dog Trap Creek, Hornes Creek, Teatree Hollow,Tributary 1 to Dog Trap Creek, Tributary 2 to Dog Trap Creek, Tributary to Teatree Hollow. MSEC (2018) notes that the streams have controlling features along their alignments	**Potential for increased levels of ponding, scouring or desiccation due to mining tilt** Change in the grade of a stream has the potential to lead to increased ponding, scouring, desiccation. MSEC (2018) states: 'Mining can potentially result in increased levels of ponding in locations where the mining induced tilts oppose and are greater than the natural stream gradients that exist before mining. Mining can also potentially result in an increased likelihood of scouring of the stream beds in the locations where the mining induced tilts considerably increase the natural stream gradients that exist before mining'. MSEC (2018) state that there is a predicted reversal of grade along a naturally flat section of Dog Trap Creek, upstream of the tailgate of Longwall 103. Hence there is increased potential for	Increased ponding may result in a change to microhabitats (debris, riffles, etc.) that may impact upon existing amphibian habitat along the creeks within the Study Area, in particular along Dog Trap creek. This may decrease habitat for amphibians that are sensitive to changes to microhabitats. However it is noted that MSEC predicts that such changes to be relatively minor.

Type	Description of natural feature	Subsidence impact	Potential biodiversity impact
	including rockbars, riffles, knick points and debris accumulations.	ponding upstream of this location, which is estimated to be up to 0.2 metres deep and 150 metres long. It is possible that there could be localised areas along the streams which could experience small increases in the levels of ponding, where the predicted maximum tilts occur in the locations where the natural gradients are low. As the predicted changes in grade are typically less than 1 %, however, any localised changes in ponding are expected to be minor and not result in adverse impacts on these streams. The streams flow predominantly over Hawkesbury Sandstone, which has a high resilience to scouring. As discussed in the report by Fluvial Systems (2013), mud was commonly found in the channel bed with soft knickpoints in small streams on the plateau. The predicted maximum increases in grade are up to 1.2 %, which are relatively small compared to the natural gradients and, therefore, the potential for increased scouring is not expected to be substantial. Further discussions on the potential changes in ponding and flooding along the streams and the impacts, consequences and implications of the changes are provided by the specialist surface water consultant in the report by Hydro Engineering and Consulting (2018a).	
		Potential for fracturing and surface water flow diversion in the streams MSEC (2018) states that 'Where the longwalls mine directly beneath the streams it is considered likely that fracturing could result in surface water flow diversions. Upsidence and compressive strains due to valley closure are expected to be of sufficient magnitude to cause the underlying strata to buckle and induce cracking at the surface at some locations. This can lead to the diversion of water from the stream beds into the dilated strata beneath it'. It is unlikely, however, that there would be any net loss of water from the catchment since any redirected flow would not intercept any flow path that would allow the water to be diverted into deeper strata or the mine. If substantial fracturing were to occur, partial or complete diversion of surface water and drainage of pools could occur at locations and times where the rate of flow diversion is greater than the rate of incoming surface water. The majority of the streams are ephemeral and so water typically flows during and for a period of time after each rain event. In times of heavy rainfall, most of the runoff would flow over the beds of the streams and would not be diverted into the dilated strata below the stream beds. In times of low flow, however, some or all of the water could be diverted into the strata below the stream beds for those sections of the streams that are located over the mined panels. Based on the previous experience of mining beneath streams at Tahmoor Mine, it is likely that fracturing and surface flow diversions will occur in the sandstone bedrock along the streams,	The fracturing and changes to surface water flow may result in a decrease in the number of existing pools along the creeks in the Study Area. This may impact upon pools which amphibians rely on for breeding and lifecycle development. Whilst, not all pools are predicted to be impacted and impacts are likely to be relatively minor and localised, during times of low rainfall may see breeding amphibian pools dry limiting habitat.

Type	Description of natural feature	Subsidence impact	Potential biodiversity impact
		particularly for streams that are located directly above the proposed longwalls. In some of these locations, the fracturing could impact the holding capacity of the standing pools, particularly those located directly above the proposed longwalls'.	
		Potential water quality changes due to subsidence The following has been extracted from HEC (2018): ▪ Liberation of contaminants can occur from subsidence induced fracturing in watercourses, causing localised and transient increases in iron concentrations and other constituents due to flushing of freshly exposed fractures in the sandstone rocks which contain iron and other mineralisation. This sort of impact has the potential to affect Tea Tree Hollow, Dog Trap Creek, and Eliza Creek, Cow Creek and Carters Creek and downstream watercourses. Fracturing of bed rock is predicted to occur and upsidence related buckling of stream beds is predicted along some sections of these creeks. Based on past experience in the Southern Coalfields, including experience at Tahmoor North, it is expected that upsidence induced fracturing may lead to releases of aluminium, iron, manganese and zinc. It is likely these will be seen as transient spikes in the concentration of these and possibly other metals which would be relatively localised. The extent of these impacts is expected to be similar to impacts observed in similar streams in the Southern Coalfield i.e. iron staining and flocs in pools and localised and transient spikes in iron, manganese and aluminium in waterways previously undermined. Changes to chemical characteristics of surface flows can also occur as a result of changes in baseflow. One of the effects of longwall subsidence on watercourses commonly reported is the emergence of ferruginous springs. These concentrated (point) inflows have a distinctive orange to red/brown colouration caused by enhanced groundwater inflows and oxidation of iron commonly present in shallow groundwater in the area. This is often accompanied by iron flocs, staining of the bed, increased turbidity and the build-up of iron rich slimes. Changes can also occur to the chemical composition of surface flows due to either increased or decreased groundwater fed baseflow.	The potential changes to water quality through subsidence are predicted to be localised (HECONS 2018) MSEC 2018). This may have an impact to local amphibians if they were to occupy a pool that has had a change in water quality.

Type	Description of natural feature	Subsidence impact	Potential biodiversity impact
		Contamination of surface waters by gas drainage Drainage of strata gas and expression to the surface through surface water has occurred to varying degrees in the Southern Coalfields. It is most readily detectable in permanent slow moving pools. Studies of the phenomena have shown that the gas flow does not affect the quality of surface waters that it drains through, due to the very low solubility of methane and the short residence time in the water column however there have been rare instances of reported vegetation die back. It has not been reported as an issue at Tahmoor North, most likely due to the relative absence of perennial water bodies. It is considered likely there will be enhanced strata gas emissions generated as a result of the Tahmoor South Project and that some of these may be visible as bubbling in more persistent pools in overlying watercourses (HECONS, 2018b). While not affecting water quality per se, the gas expression associated with release of strata gas has the potential to cause vegetation dieback in the vicinity of the gas release point.	Gas emission has the potential to result in localised die back of vegetation where the vegetation occurs immediately adjacent. However, as noted in MSEC (2018), these occurrence are rare and localised.
		Potential for gas emissions and changes to water quality MSEC (2018) states gas emissions from the sandstone strata have been previously observed above and adjacent to mining areas in the Southern Coalfield, and some gas emissions have also been observed in water bores. Analyses of gas compositions indicate that the Bulli Seam is not the direct and major source of the gas and that the most likely source is the Hawkesbury Sandstone (APCRC, 1997). It is likely that gas emissions will occur as a result of the mining of the longwalls. Gas is often released into rivers and streams as these areas form topographical low points in the landscape. Where these gas releases occur into the water column there is insufficient time for any significant amount of gas to dissolve into the water. The majority of the gas is released into the atmosphere and is unlikely to have an adverse impact on water quality. As mentioned above, however, it is possible for substantial gas emissions at the surface to cause localised vegetation die-back. This is a rare event and has only occurred previously on one occasion at Tower Mine, over small areas in the base of the Cataract Gorge that had been directly mined beneath by Longwalls 10 and 14. These impacts were limited to small areas of vegetation, local to the points of emission, and when the gas emissions declined, the affected areas were successfully restored.	As discussed above, the potential for localised vegetation die-back is possible, and unlikely to result in substantial impacts. This is discussed further in section 7.4.2.
Cliffs	MSEC (2018) states that a total of 24 cliffs are located within the Subsidence Study Area. A	According to MSEC (2018), a total of 24 cliffs are located within the Subsidence Study Area. The cliffs are generally located within the valleys of the Dog Trap Creek and the lower reaches of	Some fauna species are dependent on the specialised habitat of the cliff faces/ rock

Type	Description of natural feature	Subsidence impact	Potential biodiversity impact
	cliff has been defined as a continuous rockface having a maximum height greater than 10 metres, a minimum length of 20 metres and a minimum slope of 2 in 1, i.e. having a minimum angle to the horizontal of 63degrees. The cliffs within the Study Area are generally located within the valleys Bargo River, Dog Trap Creekand Lower Reaches of Hornes Creek	Hornes Creek. The cliffs are commonly between 10 and 20 metres in height and less than 100 metres in length. The great majority of cliffs within the Subsidence Study Area, i.e. for 23 out of a total of 24, will not be directly mined beneath by the proposed development. These include the cliffs along the Bargo River and Hornes Creek, which are all located outside the extents of the proposed basecase longwalls at minimum distances of 1070 metres and 625 metres, respectively. There are also some cliffs located along Dog Trap Creek that will not be directly mined beneath by the proposed development. It is noted by MSEC (2018) that it is extremely difficult to assess the likelihood of cliff instabilities based upon predicted ground movements. The likelihood of a cliff becoming unstable is dependent on a number of factors which are difficult to fully quantify. These factors include jointing, inclusions, weaknesses within the rock mass, groundwater pressure and seepage flow behind the rockface. Even if these factors could be determined, it would still be difficult to quantify the extent to which these factors influence the stability of a cliff naturally or when it is exposed to mine subsidence movements. It is possible, therefore, that cliff instabilities may occur during mining that may be attributable to either natural causes, mine subsidence, or both. The likelihood of cliff instabilities along the Nepean River, Bargo River and Hornes Creek has been assessed by MSEC (2018) using case studies where previous longwall mining has occurred close to but not directly beneath cliffs. The case studies have indicated that very minor rock falls have been observed outside the extracted goaf areas of longwall mining in the Southern Coalfield, however there have been no recorded large cliff instabilities. Based on this previous experience of mining at Tahmoor, Appin and Tower Collieries, it is unlikely that cliffs beyond the extent of the longwall mining area will experience large instabilities. It is possible that isolated rock falls could occur, particularly at those that have weathered to be marginally stable naturally and at those located closest to previously extracted longwall panels and the proposed longwall mining area. Any impacts are expected to represent less than 0.5 % of the total face area of the cliffs. The cliffs along Hornes Creek and Bargo River will not be directly mined beneath by the proposed Tahmoor South longwalls. The cliffs that occur above longwalls include: • One cliff along Dog Trap Creek (55 metres in length, 10 metres in height) As discussed in MSEC (2018), previously experience in the southern coalfield have indicated that cliffs which are directly mined beneath may exhibit instabilities It is expected that these cliffs could experience the full range of predicted subsidence movements and based on previous experience in the southern coalfields, there is a moderate to	ledges and overhangs for survival. This habitat has the potential to support habitat for reptile species, and microbat species for roosting. Potential impacts to threatened fauna as a result of impacts to cliffs within the Study Area are addressed in 7.5.

Type	Description of natural feature	Subsidence impact	Potential biodiversity impact
		likely probability that rock falls and cliff instabilities will occur somewhere along the cliff lines which are directly mined beneath, including those along Dog Trap. MSEC (2018) states that any impacts to the cliffs that are directly mined beneath, are expected to affect between 3% to 5 % of the total length of cliffs that are directly mined beneath.	
Steep slopes and rocky outcrops	MSEC (2018) states that a steep slope has been defined as an area of land having a gradient greater than 1 in 3 (33% or 18.3º). The locations of the steep slopes within the Study Area are detailed in MSEC (2018) however encompass: a) Steep slopes on the sides of valleys b) Steep slopes along part of the Nepean Fault at the northern end of the Study Area from the Bargo River alongside Sugarloaf Gully c) Batters of road and railway embankments and cuttings d) Farm dams e) Tahmoor Colliery mine infrastructure, including spoil heaps, coal piles and dams f) Wollondilly Shire Council waste disposal area	Potential impacts on steep slopes would generally result from the down slope movement of soils, causing tension cracks to appear at the tops of the slopes and compression ridges to form at the bottoms of the slopes. If tension cracks were left untreated it is possible that erosion could occur. The steep slopes on the sides of valleys are predominantly found in Hawkesbury Sandstone and consist of a mixture of cliffs and rock outcrops, which are stable at vertical to overhanging, and screed slopes with rocky soils and loose rock fragments. The majority of slopes are stabilised, to some extent, by natural vegetation. There is extensive experience of mining beneath steep slopes in the Southern Coalfield. These include steep slopes along the Cataract, Nepean, Bargo and Georges Rivers and streams such as Myrtle Creek and Redbank Creek above Tahmoor Colliery Longwalls 22 to 27. No large-scale slope failures have been observed along these slopes, even where longwalls have been mined directly beneath them. Minor rock falls along cliff lines or rock outcrops have been observed, for example, during the mining of Appin Longwalls 301 and 302 adjacent to the Cataract River. While in most cases impacts to slopes are likely to consist of surface cracking, there remains a low probability of large-scale slope slippage. The probability is assessed to be very low for slopes that will not be directly mined beneath by the longwalls. Experience indicates that the probability of mining-induced large-scale slippages is extremely low due to significant depth of cover.	Slippage of earth and rocks down steep slopes and rock falls have the potential to directly impact (destroy/smother) vegetation, flora and fauna habitat as well as directly injure or kill native fauna. Biodiversity more likely to be impacted are those species dependant on rocky outcrops and ledges, and include microbats, reptiles and some mammals. While the probability of rock falls and large-scale slippages is considered to be very low, the potential impact on threatened biodiversity that may be impacted is discussed throughout section 7.

7.3 Native vegetation

7.3.1 Impact from surface infrastructure

The Project would result in the direct impact to approximately 49.2 hectares of native vegetation associated with the clearing for surface infrastructure. Approximately 0.1 hectares of which is made up of planted vegetation.

The vegetation to be cleared includes:

- 43.4 hectares of HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin
- 5.7 hectares of HN564 Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin.
- 0.1 hectares of planted vegetation that does not align to a PCT.

As discussed in section 5.3, HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest aligns to Shale Sandstone Transition Forest as listed as a CEEC under the BC Act and EPBC Act.

The impact to native vegetation has been discussed in the offset strategy for the Project (section 11).

7.3.2 Impact from subsidence

Subsidence from the Project may result in the following impacts to native vegetation:

- Vegetation die-back around strata gas emission/drainage sites within creeks.
- Changes to the floristic composition of vegetation communities immediately adjacent to creeks/ponds where fracturing may result in changes to water flow and water retention periods.
- Destruction/smothering of vegetation/tree fall by rock falls and/or slippage of earth and rocks down steep slopes.

Each of these subsidence related impacts are discussed below.

Strata gas emissions and vegetation dieback

The release of gas emissions from fracturing of sandstone strata may occurs as a result of subsidence. Gas may be released into rivers and streams as these areas form topographical low points in the landscape.

The Tahmoor South Project may result in enhanced strata gas emissions within some of these emissions visible as bubbling in more persistent pools in overlying watercourses (HECONS 2018b; MSEC 2018). While not affecting water quality per se, the gas expression associated with release of strata gas has the potential to cause vegetation dieback in the vicinity of the gas release point.

MSEC (2018) states that vegetation dieback as result of gas emissions is a rare event and has only occurred previously on one occasion at Tower Mine, over small areas in the base of the Cataract Gorge that had been directly mined beneath by Longwalls 10 and 14 (Eco Logical Australia, 2004 in TEC 2007), and small localised changes to riparian vegetation along a section of the Waratah Rivulet (HC 2007). These impacts were short term impacts, and limited to small areas of vegetation, local to the points of emission, and when the gas emissions declined, the affected areas were successfully restored. No similar impacts have been reported during the mining of Tahmoor North.

PCTs that occur along the riparian zones of the Study Area includes HN586 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest. It is possible that some localised die back from gas emissions may occur to this PCT where plants immediately occur above or adjacent to the point of gas emission. Given MSEC (2018) has not predicted any significant gas emission releases along any of the water courses within the Study Area, it is therefore similarly expected that any impacts to the PCT as a result of gas emissions from Tahmoor South would be limited in extent and temporal in nature, and that, as for the sites previously affected by gas emissions, if it was to occur, the vegetation would regenerate once the gas emissions declined. As such, it is unlikely that gas emissions from subsidence would result in a decrease in the extent of the PCT and habitat within the Study Area.

Changes to riparian floristic composition due to increased levels of ponding, scouring or desiccation

Changes in the grade of a stream as a result of subsidence has the potential to lead to increased ponding, scouring and/or desiccation. MSEC (2018) states 'It is possible that there could be very localised areas along the streams which could experience small increases in the levels of ponding, where the predicted maximum tilts occur in the locations where the natural gradients are low. However, as the predicted changes in grade are typically less than 1%, any localised changes in ponding are expected to be minor and not result in adverse impacts on these streams. Predicted maximum increases in grade (which may lead to scouring) are relatively small compared with natural grades and the potential increase for scouring is not expected to be significant'.

Vegetation communities which are independent of ground-water and not closely associated with the water levels and hydrology of the creeks are unlikely to be impacted by subsidence due to underground mining.

The localised changes to ponding are predicated by MSEC (2018) to be relatively minor and not result in adverse impacts on the streams. It is similarly expected that any potential impacts to riparian vegetation that may affect the floristic composition of the community would be subtle, and highly localised to the area adjacent to the water source. In the Southern Coalfield, previous impacts to riparian vegetation as a result of subsidence have been minor in occurrence, and mostly attributed from gas release causing relatively short term damage to the vegetation, rather than changes to hydrological regimes (as mentioned above).

To date, no impacts to riparian vegetation have been observed at Tahmoor Mine. The creeks within the Study Area are all ephemeral in nature with many being consistently dry throughout the years of survey there. It is highly likely that the vegetation along the watercourses is accustomed to periodically dry conditions. Given the vegetation is not solely reliant upon ground-water for its survival, and given the dry conditions vegetation along much of the watercourses currently experience, should water diversion occur as a result of subsidence, it is unlikely to result in significant alterations to the composition of the community or vegetation die back. As such, it is considered unlikely that subsidence would result in any extensive or significant impact to native riparian vegetation within the Study Area. Should any impact occur, it is likely to be highly localised with only some subtle changes to species composition likely depending on interaction of that species with the change in watercourse. It is highly unlikely that potential impacts as a result of a predicted change to stream hydrology, would decrease the area of PCTs or vegetative habitat that currently occurs along the creeklines of the Study Area.

Destruction of vegetation/tree fall by rock falls and earth slippages

The steep slopes on the sides of valleys are predominantly found in Hawkesbury Sandstone and consist of a mixture of cliffs and rock outcrops, which are stable at vertical to overhanging, and screed slopes with rocky soils and loose rock fragments. Steep slopes have been mapped by MSEC (2018) (Figure 4) as occurring along all creeklines within the Study Area. The majority of the slopes are stabilised, to some extent, by natural vegetation (MSEC 2018).

Slippage of earth and rocks down steep slopes and rock falls have the potential to directly impact (destroy/smother) vegetation, flora and fauna habitat as well as directly injure or kill native fauna.

Subsidence may result in the downslope movement of soils, causing tension cracks to appear at the tops of the slopes, and compression ridges to form at the bottoms of the slopes, which in turn has the potential to cause erosion (MSEC 2018). However, as indicated by MSEC (2018), there is a low probability of large-scale slope slippage as a result of the Project. The probability is assessed to be very low for slopes that will not be directly mined beneath by the longwalls.

MSEC (2018) further supports this prediction due to the following:

- Experience in the Southern Coalfield indicates that the probability of mining-induced large-scale slippages is extremely low due to significant depth of cover.
- There is extensive experience of mining beneath steep slopes in the Southern Coalfield. These include steep slopes along the Cataract, Nepean, Bargo and Georges Rivers and streams such as Myrtle Creek and Redbank Creek above Tahmoor Colliery Longwalls 22 to 27. No large-scale slope failures have been observed along these slopes, even where longwalls have been mined directly beneath them.
- Minor rock falls along cliff lines or rock outcrops have been observed, for example, during the mining of Appin Longwalls 301 and 302 adjacent to the Cataract River. These have resulted in minor and localised rock collapses.

As such, it is considered likely that any impacts to vegetation as a result of earth and rock-face instability will be highly localised and relatively minor in nature. Large-scale impacts to vegetation as a result of large-scale slope failures are highly unlikely based on the predication of MSEC (2018). The potential impact to PCTs along creeklines are therefore likely to be so small and localised to be relatively insignificant.

7.3.3 Impacts to EPBC Act listed Threatened Ecological Communities

The Project would result in an impact to 43.4 hectares of Shale Sandstone Transition Forest (HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin), which is listed as Critically Endangered under the EPBC Act.

A detailed discussion on the occurrence, distribution and impacts to Shale Sandstone Transition Forest has been provided in section 8.2.1. An Assessment of Significance has been also been completed in Appendix 8 for the impacts to Shale Sandstone Transition Forest. The assessment concluded that a significant impact to the TEC is likely.

A biodiversity offset for the impact to Shale Sandstone Transition Forest has been proposed in section 11.

7.4 Threatened flora

7.4.1 Clearing of habitat for surface infrastructure

The Project would result in the clearing of the following threatened flora that occur within the area proposed for surface infrastructure:

- *Grevillea parviflora* subsp. *parviflora*: a total of 2,324 individuals to be removed
- *Persoonia bargoensis*: 100 individuals to be cleared.

No other threatened flora would be directly impact by clearing for surface infrastructure.

A biodiversity offset for each of these impacted threatened flora has been discussed in section 10.2.

7.4.2 Subsidence related impacts to threatened flora

Subsidence impacts toward threatened flora may occur as a result of the following:

- Die-back of threatened flora that occurs immediately adjacent to a strata gas emission/drainage event.
- Loss of threatened flora and its habitat as a result of a change hydrological regime.
- Damage or loss of threatened flora from rock falls and/or slippage of earth and rocks down steep slopes.

These impacts are generally centred on habitat types along riparian areas, immediately above and below cliff lines and steep slopes. Vegetation and habitat that occurs on the flat terrain of the Study Area are located away from areas that may be prone to subsidence related impacts.

Of the threatened flora recorded, only *Pomaderris brunnea* was recorded within the gully habitat of the Study Area. The remainder of the threatened flora were located away from the subsidence sensitive areas. Threatened flora records obtained from bionet also indicate that most of the threatened flora occur away from these areas (Figure 13).

Pomaderris brunnea

As discussed in section 1.1.1, the population of *Pomaderris brunnea* was recorded along Tea Tree Hollow Creek. For the most part, the population typically occurred on the mid-bank to higher banks of the creek, away from the creek bed. The creek was dry for much of its traverse during the survey and monitoring years, with intermittent shallow pools occurring in the area where the majority of the population resided. As such, it could reasonably assumed that there is a disconnection of *Pomaderris brunnea* to the water within the creek given the species persistence during periods where water in the creek was absent. The drying of pools, or predicted changes to the hydrological regime as a result of subsidence is therefore unlikely to result in die back of the *Pomaderris brunnea* population.

Similarly, as discussed in section 7.3.2 gas emissions as a result of subsidence are predicted to be rare. If gas emissions were to occur along the portion of Tea Tree Hollow Creek where *Pomaderris brunnea* resides, it may be reasonable to assume that given the plants position away from the lowest points in the topography, that die back would largely be avoided.

Furthermore, the chances of a rock fall or steep slope collapse occurring directly above the population of *Pomaderris brunnea* resulting in the loss of individuals within the population seems quite unlikely given such events are predicted by MSEC (2018) to be minor in occurrence, and no cliffs occur within this portion of Tea Tree Hollow Creek.

Based on the above reasons, we have concluded that potential subsidence related impacts to threatened flora, in particular *Pomaderris brunnea* are highly unlikely.

7.4.3 Impacts to EPBC Act listed threatened flora

Assessments of Significance have been completed for those threatened flora that have a moderate to high likelihood of occurrence within the Study Area (Appendix 8).

The Assessments of Significance have concluded a significant impact to *Persoonia bargoensis* is likely as a result of the Project. The DoEE has also regarded a significant impact to *Grevillea parviflora* subsp. *parviflora* and *Pomaderris brunnea* is likely.

Biodiversity offsets for *Persoonia bargoensis* and *Grevillea parviflora* subsp. *parviflora* have been proposed in section 10.2. No offset has been proposed for *Pomaderris brunnea* as the species will not be impacted by the Project. A slight design change in the surface development footprint after the submission of the Commonwealth Referral has avoided the need to clear 40 individuals of the species and potential habitat for the species. As such, *Pomaderris brunnea* would not be significantly impacted by the Project (Appendix 8).

Given *Leucopogon exolasius* has been nominated by DoEE as potentially being impacted by the Project, an Assessment of Significance has been completed for the species on a precautionary basis despite having a low likelihood of occurrence within the Study Area. The assessment concluded that a significant impact was unlikely given the species is unlikely to have habitat with the area proposed for surface infrastructure, and subsidence is unlikely to result in a loss to any important population given the species occur on the creek banks not within the riparian zone of creek. Thus any hydrological change from subsidence is unlikely to impact upon *Leucopogon exolasius.* Furthermore, as discussed in section 7.3.2 gas emissions as a result of subsidence are predicted to be rare, and given the species is known to occur on rock hill slopes, that die back from gas emission would largely be avoided. The species has therefore unlikely to be significantly impacted by the Project.

7.5 Threatened fauna

The Project may result in impacts to threatened fauna as a result of clearing of habitat for the surface infrastructure, or via subsidence which is predicted to have impacts on cliffs and watercourses in the Study Area.

For those species credits fauna recorded, or with moderate to high likelihood of occurrence within the Study Area (section 6.3.2), the impact associated with each species has been provided below.

7.5.1 Koala

Whilst there is no evidence of Koala was detected during the field surveys (observations of animals, scats or scratches on trees), the Koala has been assigned a high likelihood of occurrence within the Study Area given previous nearby records in the locality. These records have been provided in Figure 16.

Within the area proposed for surface infrastructure, Koala feed trees (*Eucalyptus punctata*, with the occasional *Eucalyptus tereticornis*) were recorded, both of which are listed as Schedule 2 feed trees on the State Environment Planning Policy 44 Koala Protection (SEPP 44). These trees are associated with PCT HN564 Red Bloodwood - Grey Gum woodland and HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest, both of which will be directly impacted.

Despite the presence of the feed trees, it is considered unlikely that Koalas would occur regularly within the area proposed for surface infrastructure, given there were no Koala scats, or scratches identified on trees within the Study Area, despite targeted spotlighting and Koala SAT plots. However, whilst the Koala was not detected, given the records for the species in the locality, the area to be cleared for the surface infrastructure would result in the loss of potential Koala habitat.

The expansion of the existing REA and ventilation shaft sites would increase fragmentation of potential Koala habitat along Tea Tree Hollow Creek corridor. However, given the absence of historic records along Tea Tree Hollow Creek, and the lack of any evidence supporting regular use of the Koala in the area, the fragmentation of potential habitat is considered unlikely to impede Koala movement. However, this assessment notes the importance of habitat for the Koala in the locality, and as such, the removal of 43.5 hectares comprising of the moderate/good and moderate/good_medium condition classes of PCTs HN564 and HN556 would require a biodiversity offset (Section 11).

Subsidence as a result of the Project is unlikely to have an impact upon the Koala. Subsidence is unlikely to result in the loss of Koala feed trees, or native vegetation loss that would restrict Koala movement. Furthermore, it is highly unlikely that steep slope slippage or rock fall would result in the death of a Koala.

7.5.2 Large-eared Pied Bat

Although the Large-eared Pied Bat was not detected during the survey, records for the species exist along the Nepean River immediately outside the Study Area. It is likely given the proximity of records, that the species may utilise the Study Area for foraging habitat.

The OEH Bionet atlas notes that foraging habitat within close proximity to cliffs is important for the species. No cliffs occur within close proximity to the area being cleared for surface infrastructure. The closest cliff is greater than 500 meters away from surface infrastructure occurring along the Bargo River. As such, no important foraging habitat would be cleared for the Project.

The Large-eared Pied Bat may utilise caves and rocky crevices for roosting and breeding habitat. According to MSEC (2018), a total of 24 cliffs are located within the Study Area. The cliffs may provide roosting habitat for the species. The cliffs are generally located within the valleys of the Bargo River, Dog Trap Creek and Hornes Creek.

As detailed in MSEC (2018), most of the cliffs (23 out of a total of 24), will not be directly mined beneath. These include the cliffs along the Bargo River and Hornes Creek, which are all located outside the extents of the proposed longwalls. The cliffs that occur outside of the area directly above longwalls, are predicted by MSEC (2018) to experience very low levels of vertical subsidence, and are not expected to experience any substantial conventional tilts, curvatures or strains. The likelihood of cliff instabilities along the Bargo River and Hornes Creek has been assessed by MSEC (2018) using case studies where previous longwall mining has occurred close to but not directly beneath cliffs. The case studies have indicated that very minor rock falls have been observed outside the extracted goaf areas of longwall mining in the Southern Coalfield, although there have been no recorded large cliff instabilities. These case studies are supported by previous impacts from mining at Tahmoor, Appin and Tower Collieries, which have not experienced any large instabilities beyond the extent of the longwall mining area (MSEC 2018).

Based on the MSEC predications and previous experience in the Southern Coalfields, it is unlikely that potential roosting habitat for the Large-eared Pied Bat within the cliffs to be directly mined beneath would be impacted by large scale instabilities which may destroy this potential habitat.

As discussed in MSEC (2018), previous experience in the Southern Coalfield has indicated that cliffs which are directly mined beneath may exhibit instabilities. The one cliff that occurs above the longwalls and may exhibit instabilities:

- One cliff along Dog Trap Creek (55 metres long, 10 metres high)

There is the potential for the cliffs to support roosting habitat for the Large-eared Pied Bat. It is predicted by MSEC (2018) that these cliffs could experience the full range of predicted subsidence movements, and based on previous experience in the southern coalfields that there is a moderate to likely probability that rock falls and cliff instabilities would occur somewhere along these cliff lines. MSEC (2018) states that any impacts to the cliffs that are directly mined beneath, are expected to affect between 3-5 % of the total length of the cliffs. Based on this prediction, the length of the cliff along Dog Trap Creek that may be impacted by subsidence is relatively small.

Given the relatively small length of the cliff line that would potentially be impacted by subsidence, the probability that roosting habitat would be impacted is very low. Even more unlikely is that subsidence would result in impacts to a crevice in which a roosting population of Large-eared Pied is present, particularly given no caves are known to occur above the longwalls.

As such, despite the Large-eared Pied Bat having a high likelihood of occurrence within the Study Area, it is unlikely that the species would be impacted by subsidence related impacts or vegetation clearing.

7.5.3 Large-footed Myotis

The Large-footed Myotis was recorded within the surface area footprint of the REA during targeted surveys. The Large-footed Myotis is regarded as species credit fauna given its dependence on habitat surrounding waterways for roosting.

The OEH Bionet database notes that hollow-bearing trees, bridges, caves or artificial structures within 200 metres of a riparian zone are areas of important habitat for the species. Portions of the proposed surface infrastructure for the REA contain hollow-bearing trees that are within 200 metres of Tea Tree Hollow Creek. The portion of habitat within 200 metres of a riparian zone that would be removed is 7.4 hectares. As such, the removal of this area of habitat would require an offset as detailed in Section 11. The removal of vegetation for the remainder of the surface works will avoid hollow-bearing trees within 200 metres of riparian areas and, as such, would not require an offset.

As for the Large-eared Pied Bat, it is unlikely that subsidence would impact on roosting habitat for the Large-footed Myotis. Predictions by MSEC (2018) indicate that cliff lines that are not directly mined beneath are unlikely to result in any large scale rock fall or instabilities. As discussed for the Large-eared Pied Bat, given the very small length of the cliff line that would potentially be impacted by subsidence (4.35 to 7.25 metres) the probability that roosting habitat would be impacted is very low. Furthermore, no bridges or culverts within the Study Area that provide roosting habitat for the Large-footed Myotis are likely to be impacted by subsidence. As such, roosting habitat for the species is unlikely to be impacted by the Project.

The Large-footed Myotis is known to forage over streams and pools catching insects and small fish by raking their feet across the water surface. The length of watercourse in the Study Area that provide potential foraging habitat exceeds 20 kilometres.

Subsidence has the potential to result in the loss or decrease in some potential foraging pools within the watercourses of the Study Area. HECONS (2018b) has indicated that subsidence from the Project may result in the reduced frequency of pools overflowing, lowering of pool water levels and periodic loss of interconnection between pools during dry weather. Streams or sections of streams located away from the proposed longwalls, are less likely to have fracturing and surface flow diversions, compared to stream sections located directly above the proposed longwalls.

As noted in HECONS (2018b), it is not possible to predict the precise locations where diversion of surface flow induced fracturing will occur, or to predict the flow capacity of the subsurface fracture networks that could form following subsidence. It is therefore difficult to determine the extent of impact, if any, on potential foraging habitat pools for the Large-footed Myotis. However, mapping of pools by HECONS (2018b) in combination with subsidence predictions by MSEC (2018) have indicated the following:

- Most of the 14 pools mapped in Tea Tree Hollow Creek are located in areas where there is a low risk of impact to water holding capacity. However, two pools are located in an area of moderate risk of impact to flow holding capacity.

- The largest number of pools (in excess to 70) were mapped on Dog Trap Creek. Fourteen of these are located in areas of either moderate or high risk of loss of water holding capacity.

Based on the mapping, a total of 16 pools may exhibit a moderate to high degree of loss in pool water holding capacity during drier conditions. The remainder of pools within the Study Area that may provide foraging habitat for the Large-footed Myotis are unlikely to be impacted.

Whilst there may be some loss in potential foraging habitat, according to MSEC (2018) a change in the grade of a stream has the potential to lead to increased ponding. MSEC (2018) states: 'that there is a predicted reversal of grade along a naturally flat section of Dog Trap Creek... There is increased potential for ponding upstream of this location, which is estimated to be up to 0.2 metres deep and 150 metres long'. MSEC (2018) also states that it is 'possible that there could be very localised areas along the streams which could experience small increases in the levels of ponding,… however any localised changes in ponding are expected to be minor and not result in adverse impacts on these streams'.

The potential for ponding may therefore increase the availability of foraging habitat for the Large-footed Myotis. As discussed in Niche (2018), increased ponding is likely to provide localised increase in available habitat for aquatic macroinvertebrates and if there is stream connectivity in the area of ponding, it may also provide additional habitat for fish and macrophytes.

Whilst there may be changes to water capacity during dry periods at up to 14 pools, there is also potential that ponding will occur following subsidence that creates foraging habitat for the Large-footed Myotis. Furthermore, not all foraging pools within the watercourse of the Study Area would be impacted or completely drained and, as such, the potential impacts to 26 pool may not disrupt the life cycle of the species such that the population would decline. Based on these reasons, a biodiversity offset for impacts as a result of subsidence has therefore not been proposed.

7.5.4 Eastern Cave Bat

The Eastern Cave Bat was recorded within the surface infrastructure development area during targeted surveys.

The species is known to have breeding habitat identified by the presence of rocky areas containing caves, or overhangs or crevices or escarpments, old, tunnels or culverts.

The OEH Bionet database regards important habitat for this species to occur within two kilometres of rocky areas containing caves, overhangs, escarpments, outcrops, crevices or boulder piles, or within two kilometres of old mines, tunnels, old buildings or sheds. This definition of important habitat means the entire Study Area contains potential habitat. However, it is noted in the Bionet Atlas that 'clearing and isolation of dry eucalypt forest and woodland, particularly about cliffs and other areas containing suitable roosting and maternity sites' is a key threat to the species.

Although the vegetation to be cleared for the Project occurs within two kilometres of overhangs, old building and sheds, the site does not occur within close proximity to any known maternity or roost site. The closest cliff which could potentially contain a roosting site for the species occurs in Dog Trap Creek, approximately 600 metres to the east of REA 2 where the species was recorded.

Furthermore, the Eastern Cave Bat was only recorded at one Anabat on one night. The Anabat was located in the far east of REA 2. If a breeding colony was nearby, a greater detection of the species on the Anabat would be likely. As such, this assessment does not regard the vegetation to be cleared for the surface works to contain important foraging or breeding habitat for the species.

As for the Large-eared Pied Bat and Large-footed Myotis, the likelihood of subsidence impacting upon a roosting site is very low. Predictions by MSEC (2018) indicate that cliff lines that are not directly mined beneath are unlikely to result in any large scale rock fall or instabilities. Given the very small length of the cliff lines that would potentially be impacted by subsidence (4.35 to 7.25 metres) the probability that roosting habitat would be impacted is very low. Furthermore, no sheds or old buildings are predicted by MSEC (2018) to collapse. As such, roosting habitat for the species is unlikely to be impacted by the Project.

7.5.5 Red-crowned Toadlet

A population of the Red-crowned Toadlet was recorded within the Study Area at Hornes Creek during the Tahmoor South Project Terrestrial Ecology Monitoring Program. The Red-crowned Toadlet was not recorded within any other riparian areas within the Study Area and surrounds, including Dog Trap Creek, Tea Tree Hollow Creek, Bargo River and its tributaries, Eliza Creek, Cow Creek, Dry Creek and Carter Creek.

The Red-crowned Toadlet is known to occur within periodically wet drainage lines below sandstone ridges, sheltering under rocks and amongst masses of dense vegetation or thick piles of leaf litter. Such features occur in all the catchments within the Study Area. However, during the Amphibian Monitoring Program, these environments were more often found to be inhabited by the common Bibron's Toadlet (*Pseudophryne bibronii*), a close relative of the Red-crowned Toadlet. *Pseudophryne spp.* often do not occupy the same locations (e.g. White 1993, Dewaly *et al.* 2015), which may explain why the Red-crowned Toadlet was absent from the remaining creeks within the Study Area.

It is noted that the species has not been recorded breeding in waters that are mildly polluted or with a pH outside the range 5.5 to 6.5 (DEC 2005). For many of the creeks in the Study Area, impacts from the surrounding rural and residential area has resulted in iron floc , which is clearly evident by the orange staining of rocks and sediment. It is thus possible that the absence of the Red-crowned Toadlet within the majority of watercourses within the Study Area could be also be attributed to the presence of pollutants in the water. Hornes Creek, where the species was recorded, is situated amongst bushland with less pollution influences from nearby rural and residential developments.

The vegetation clearing associated with the Project would not impact the Red-crowned Toadlet, given the species was not detected within Tea Tree Hollow Creek or Dog Trap Creek.

Subsidence associated with the Project has the potential to result in a reduced frequency of pools overflowing, lower pool water levels and periodic loss of interconnection between pools during dry weather (HECONS 2018b). However, it is noted that streams or sections of streams located away from the proposed longwalls, are less likely to have fracturing and surface flow diversions compared to stream sections located directly above the proposed longwalls (HECONS 2018b).

The section of Hornes Creek where the Red-crowned Toadlet was recorded, occupies a length of approximately 1.5 kilometres within the limits of subsidence. The width of Hornes Creek in this area ranges from one metre to approximately 10 metres.

The species is likely to occupy a further 2 kilometres downstream. And two kilometres upstream of Hornes Creek which occurs outside of the Study Area and would not be impacted by subsidence. No longwalls are proposed directly under the portion of Hornes Creek (or upstream) where the population of Red-crowned Toadlet occurs. As such, based on the predictions of MSEC (2018), the likelihood for the standing capacity of pools to be reduced or lost along this section of Hornes Creek are very low. HECONS (2018b) do not specifically report on any impacts to the pool capacity or the risk of impact to the water holding capacity of Hornes Creek. This is likely due to the creek not occurring above the proposed longwalls.

Contamination of the water bodies may also arise from subsidence due to releases of aluminium, iron, manganese and zinc from the sandstone strata (MSEC 2018). It is likely these would be seen as transient spikes in the concentration of these and possibly other metals which would be relatively localised. The extent of these impacts is expected to be similar to impacts observed in similar streams in the Southern Coalfield (i.e. iron staining and flocs in pools and localised and transient spikes in iron, manganese and aluminium in waterways previously undermined). Such an impact may affect the suitability of the pools as breeding habitat for the species given the Red-crowned Toadlet is sensitive to water chemistry. However, no changes to water chemistry have been specified in the specialist water quality assessment for the Project.

Given that impacts, if any, as a result of subsidence to the Red-crowned Toadlet are considered to be relatively low, no offset for the species has been proposed.

7.6 Impact to EPBC Act listed Fauna

Assessments of Significance have been completed for those threatened fauna that have a moderate to high likelihood of occurrence within the Study Area (Appendix 8).

The Assessments of Significance have concluded a significant impact to threatened fauna listed on the EPBC Act is unlikely. Of particular note, a significant impact to the Koala and Greater Glider is unlikely to occur. Both these species were noted by DoEE to potentially be impacted by the Project (section 2.1.2).

The potential impacts to the Koala have been discussed in section 7.5.1, and regardless of a non-significant impact to the Koala, the species would subsequently be offset in accordance with the FBA (section 10.2).

The Greater Glider on the other hand, has only a moderate likelihood of occurrence within the Study Area (6.3.3, Appendix 1). The species was unlikely to utilise the habitat features of the surface infrastructure footprint given the species was not detected during targeted survey across differing months. As such, the removal of native vegetation for surface infrastructure is unlikely to impact upon the species. Subsidence is unlikely to impact upon tree hollows which the species may utilise. Similarly, subsidence is unlikely to result in a decline in the availability of foraging habitat for the species, as no large-scale vegetation die back events are likely (section 7.3.2). As such, no significant impact to the Greater Glider is likely.

7.7 Impact to conservation areas

The Project is unlikely to result in an impact to Conservation Reserves or known BioBank sites due to vegetation clearing.

The Study Area does slightly occur within the Upper Nepean Conservation Area and Metropolitan Special Area to the far south as shown in Figure 2. A BioBank site is also known to occur to the west of Remembrance Drive opposite Tahmoor Colliery. Subsidence is unlikely to result in an impact to these conservation areas as no cliffs or watercourses are contained within these sites within the Study Area. As discussed in section 7.3.2, cracking of soil within dry sclerophyll forest and woodland habitat is unlikely to result in any adverse impacts to the flora or structure of that PCT. As such, it is highly unlikely that the Project would result in any impact to conservation areas due to subsidence.

7.8 Impact to Thirlmere Lakes

The Thirlmere Lakes lies to the west of the existing Tahmoor Mine (approximately 3km from the subsidence area), in the upper reaches of Blue Gum Creek, which ultimately flows to Lake Burragorang (Warragamba Dam). Thirlmere Lakes lie within the Thirlmere Lakes National Park which is part of the Greater Blue Mountains World Heritage Area. The Lakes are a series of five interconnected Lakes (in order from most upstream to downstream): Gandangarra, Werri Berri, Couridjah, Baraba and Nerrigorang (refer Figure 2). The nearest Tahmoor Mine longwall panels to the Thirlmere Lakes were mined between 1996 and 2002 and were located approximately 600 m from Lake Couridjah.

In order to assess any potential impacts from the Project on the Thirlmere Lakes, specialist groundwater and surface water studies were undertaken by HydroSimulations (2018) and HECONS (2018b). The assessment included an investigation into the potential for project-related impacts to occur to the Thirlmere Lakes using a calibrated lake water balance model.

Key predictions from the modelling by HECONS (2018b) and HydroSimulations (2018) include:

- The model predicts a negligible increase (approximately 2%) in groundwater recharge from the Lakes as a result of the project, and a negligible decrease (also about 2%) in outflows to Blue Gum Creek; changes which will both be imperceptible.
- The magnitude of this change in recharge/discharge would be very small compared to natural variability in downstream catchment conditions, and in the context of the potential impacts on inflow to downstream Lake Burragorang (Warragamba Dam), it would be imperceptible.
- Average Lake water levels would decrease by between 0.01 m and 0.06 m. The predicted average number of weeks per decade that the Lakes were without any discernible ponded water increases by between 3 and 5.2 weeks.

HECONS (2018) have regarded that the magnitude of change water levels to be imperceptible and very small compared to natural variability and are therefore considered negligible.

Hydro Simulations (2018) have indicated a gradual recovery in groundwater impacts following completion of mining. Therefore the above changes would decrease with time following the end of mining.

Based on the relatively imperceptilble impacts to the Thirlmere Lakes concluded in HyrdoSimulations (2018) and HECONS (2018b) toward changes in groundwater and surface water, it is highly unlikely that the terrestrial biodiversity values of the Thirlmere Lakes system would be impacted in a manner that would result in loss of vegetation and habitat or die back of vegetation. As stated in HECONS (2018b) compared to natural variability, any change would so minor to be negigble and essentially unquantifiable toward biodiversity. As such, it is highly unlikely that the biodiversity values of the Thirlmere Lakes would be impacted by the Project. A field survey of the biodiversity values of Thirlmere Lakes was therefore not required as part of the scope of this assessment.

8. Impacts requiring further consideration

Under section 9.2 of the FBA, the assessor is required to identify impacts on biodiversity values that require further consideration.

Impacts on biodiversity values that require further consideration are:

(a) impacts on landscape features, being:

> (i) impacts that will reduce the width of vegetation in the riparian buffer zone bordering significant streams and rivers, important wetlands or estuarine areas in accordance with Subsection 9.2.3, or
>
> (ii) impacts that will prevent species movement along corridors that have been identified as providing significant biodiversity linkages across the state in accordance with Subsection 9.2.3, and

(b) impacts on native vegetation that are likely to cause the extinction of an EEC/CEEC from an IBRA subregion or significantly reduce its viability in accordance with Subsection 9.2.4, and

(c) impacts on critical habitat or on threatened species or populations that are likely to cause the extinction of a species or population from an IBRA subregion or significantly reduce its viability in accordance with Subsection 9.2.5.

Biodiversity values identified in the SEARs as requiring further consideration include:

- River-flat Eucalypt Forest on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions (EEC)
- Shale Sandstone Transition Forest in the Sydney Basin Bioregion (CEEC)
- Southern Highlands Shale Woodlands (CEEC)
- Cumberland Plain Woodland in the Sydney Basin Bioregion (CEEC)
- *Persoonia bargoensis* (Bargo Geebung)
- *Persoonia glaucescens* (Mittagong Geebung)
- *Persoonia hirsuta* (Hairy Geebung)
- *Haplocephalus bungaroides* (Broad-headed Snake)

Each of these values is discussed below in relation to the requirements of the FBA.

8.1 Impact on landscape features

8.1.1 Riparian buffers

Under section 9.2.3 of the FBA, impacts that will reduce the width of vegetation in the riparian buffer zone bordering significant streams and rivers, important wetlands or estuarine areas are to be assessed.

The Project would not result in the clearing of native vegetation of within:

- 20 m either side of a 4th and 5th order stream
- 50 m either side of a 6th order stream or higher, or
- 50 m around an estuarine area.

The clearing associated with the surface infrastructure will not result in the clearing of native vegetation within the riparian buffer of Tea Tree Hollow Creek. The clearing will occur approximately 80 metres from the outside edge of the riparian buffer of Tea Tree Hollow Creek which is a 3rd order stream. Mitigation measures detailed in section 9.2 would be employed to avoid indirect impacts.

The impacts to native vegetation associated with subsidence are unlikely to result in a substantial or significant impact to riparian vegetation. As discussed in section 7.3.1, the likelihood for gas emissions to result in vegetation die back is low. Furthermore, if such impacts were to occur, they would be relatively temporary and highly localised.

The project therefore does not impact the width of native vegetation within any riparian buffers in the Study Area.

8.1.2 Impacts on important wetlands

No wetlands occur within the Study Area. The Project will therefore not have an impact upon any important wetland.

8.1.3 Impacts on species movement along corridors

This includes any impact of development on areas of native vegetation on land that is mapped or defined as a state significant biodiversity link, and where the impact:

1. creates a gap greater than 100 m between two areas of moderate to good condition native vegetation with a patch size greater than 1 ha (30 m for non-woody ecosystems), or
2. removes over-storey cover and mid-storey cover vegetation within the state significant biodiversity link to create a gap in over-storey cover and mid-storey cover vegetation greater than 100 m between two areas of moderate to good condition vegetation with a patch size greater than 1 ha (30 m for non-woody ecosystems), or
3. creates a hostile barrier, such as a dual carriageway, wider highway, or similar hostile barrier within the state significant biodiversity link.

No regional or state biodiversity links have been mapped as occurring with the Study Area. As such, the Project will not have any impact upon any state significant biodiversity link.

8.2 Impact on native vegetation

Impacts on native vegetation that require further consideration include impacts on:

(a) any CEEC, unless the CEEC is specifically excluded by the SEARs

(b) an EEC specifically nominated in the SEARS as an EEC that is likely to become extinct or have its viability significantly reduced in the IBRA subregion if it is impacted on by development.

TECs nominated in the SEARs include:

- Shale Sandstone Transition Forest in the Sydney Basin Bioregion (CEEC)
- River-flat Eucalypt Forest on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions (EEC)
- Southern Highlands Shale Woodlands (CEEC)
- Cumberland Plain Woodland in the Sydney Basin Bioregion (CEEC).

Each of these TECs are discussed below in relation to the requirements of section 9.2.4.2 of the FBA.

8.2.1 Shale Sandstone Transition Forest

(a) the area and condition of the CEEC or EEC to be impacted directly and indirectly by the proposed development

A total 43.4 hectares of Shale Sandstone Transition Forest (HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin) would be directly impacted by the Project. The extent of this community is shown on Figure 10.

The area to be cleared consists of three different condition classes which are detailed in Appendix 6.

Three different condition classes recorded within the surface infrastructure footprint include:

- Moderate/Good_good condition: minimal weeds with high resilience with stratum layers typically intact. It is the best condition of the TEC recorded on site. Approximately 26.0 hectares will be directly impacted for the surface infrastructure.
- Moderate/Good_medium: shrub dominated vegetation condition consisting predominantly of Acacia parramattensis and Kunzea ambigua. Approximately 11.8 hectares of this condition class will be directly impacted by the surface infrastructure.
- Moderate/Good_derived: area of moderate resilience which has been largely cleared of canopy and mid-storey species. Canopy trees and shrubs are relatively isolated. Regenerating eucalypts and shrubs are occasional. Weeds were recorded throughout with a low to moderate occurrence of native species. Approximately 5.6 hectares of this condition class would be directly impacted by the Project.

Indirect impacts to the remaining Shale Sandstone Transition Forest would be avoided by carrying out weed control, pest control, demarcating 'no go' areas, and contractor education. Details regarding these are provided in section 9.2.

(b) the extent and overall condition of the CEEC or EEC within an area of 1000 ha and then 10,000 ha surrounding the proposed development footprint.

The mapped occurrence of Shale Sandstone Transition Forest based on OEH (2013) surrounding the development footprint is as follows:

- 1,000 ha = < 1 hectare (this is an error in the mapping – validated vegetation mapping by Niche indicates that approximately 43.4 hectares of the TEC occurs within the 1,000 ha circle)
- 10,000 ha = 889.6 hectares.

The condition of Shale Sandstone Transition Forest within both the 1,000 ha and 10,000 hectares circles is likely to be predominately in a low to moderate condition, given the urban and rural pressure and historic clearing of the area. It is highly likely that weeds would occupy portions of the lower stratums.

The largest patches of Shale Sandstone Transition Forest have been mapped (Figure 10) include:

- A patch greater than 20 hectares immediately to the east of the REA within Crown Land. This patch borders Dog Trap Creek and Charlies Point Road. It is known based on other field surveys by Niche to be in a relatively good condition.
- A patch within Minnamurra Nature Reserve which extends north along Tea Tree Hollow Creek. The patch is greater than 10 hectares in size.
- A large patch greater than 15 hectares occurring north of Anthony Road to the west of Dog Trap Creek.
- Nepean State Conservation Area immediately off Avon Dam Road is known to contain Shale Sandstone Transition Forest in a benchmark condition. This patch is greater than 20 hectares in size.

(c) an estimate of the extant area and overall condition of the CEEC or EEC remaining in the IBRA subregion after the impact of the proposed development has been taken into consideration

The Project occurs in the Cumberland IBRA subregion. Approximately 1,100 hectares of Shale Sandstone Transition Forest has been mapped as occurring with the IBRA region based on OEH (2013) It is highly likely that given the urban and rural pressures within the region, that the condition of Shale Sandstone Transition Forest is likely to be degraded, with patches of the mapped occurrence to be dominated by weeds.

The Project will reduce the extent of Shale Sandstone Transition Forest by 43.4 hectares. This equates to 5 percent of the mapped occurrence of Shale Sandstone Transition Forest within the Cumberland IBRA region.

(d) the development proposal's impact on:

(i) abiotic factors critical to the long-term survival of the CEEC or EEC. For example, will the impact lead to a reduction of groundwater levels or substantial alteration of surface water patterns?

The Project will result in the loss to 43.4 hectares of Shale Sandstone Transition Forest due to direct clearing for surface infrastructure. As discussed in section 1.1, Shale Sandstone Transition Forest is unlikely to be impacted by subsidence as a result of the Project. Furthermore, mitigation measures will prevent any indirect impacts to neighbouring patches of the community.

The patch of Shale Sandstone Transition Forest to be impacted is quite large in comparison to other ground-truthed patches of the community in the locality. However, the removal of the patch will not result in the loss of abiotic features that will result in the decline of the remaining patches.

(ii) characteristic and functionally important species through impacts such as, but not limited to, inappropriate fire/flooding regimes, removal of understorey species or harvesting of plants

The Project will not result in inappropriate fire and flooding regimes that would impact upon surrounding patches of Shale Sandstone Transition Forest. A Fire Management Plan would be developed as part of the Project to minimise any potential fire ignition from the site, and to ensure that recommended fire management is carried out. Flooding as a result of the Project is unlikely to result in an impact to Shale Sandstone Transition Forest. The community is typically located away from the lower lying areas of the landscape. As discussed previously, subsidence will not result in an impact to the community.

(iii) the quality and integrity of an occurrence of the CEEC or EEC through threats and indirect impacts including, but not limited to, assisting invasive flora and fauna species to become established or causing regular mobilisation of fertilisers, herbicides or other chemicals or pollutants which may harm or inhibit growth of species in the CEEC or EEC.

The removal of 43.4 hectares of Shale Sandstone Transition Forest opens the surrounding patches to edge effects. Edge effects include the invasion of weeds, erosion and sedimentation. Mitigation measures to be undertaken as part of the project include: weed control, pest control, demarcating 'no go' areas, and contractor education. Details regarding these are provided in section 9.2.

(e) direct or indirect fragmentation and isolation of an important area of the CEEC or EEC

Given Shale Sandstone Transition Forest is listed as Critically Endangered, all areas containing this community are important, particularly larger patches.

The removal of Shale Sandstone Transition Forest for REA 1 and REA 2 will result in fragmentation of the community surrounding the existing REA.

The clearing associated with REA 1 would result in an isolated of a patch of Shale Sandstone Transition Forest to the immediately south, which would be bordered by Charlies Point Road. This patch of Shale Sandstone Transition Forest would still be connected to native vegetation along Tea Tree Hollow Creek.

The clearing associated with REA 2 would also result in fragmentation of Shale Sandstone Transition Forest to the immediate north and east. The clearing would remove a strip of the community to the direct west of Charlies Point Road.

The construction of the ventilation shaft sites would also fragment portions of Shale Sandstone Transition Forest along Charlies Point Road.

(f) the measures proposed to contribute to the recovery of the CEEC or EEC in the IBRA subregion.

The Project will require a like-for-like offset to satisfy the requirements of the FBA and EPBC Act. As such, this will result in the establishment of a conservation area that will protect and enhance Shale Sandstone Transition Forest. Given Shale Sandstone Transition Forest is quite limited in its range, much of the land the community occupies is in the Cumberland IBRA region, and as such, there is a level of confidence that the conservation area would be established there, and thus contribute to the recovery of the CEEC within the IBRA subregion.

8.2.2 River-flat Eucalypt Forest on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions (EEC), Southern Highlands Shale Woodlands (CEEC), and Cumberland Plain Woodland in the Sydney Basin Bioregion (CEEC).

(a) the area and condition of the CEEC or EEC to be impacted directly and indirectly by the proposed development

The Project will not have a direct or indirect impact upon: River-flat Eucalypt Forest, Southern Highlands Shale Woodlands, or Cumberland Plain Woodland. All three of these vegetation communities do not occur within the area proposed for vegetation clearing, and are unlikely to be impacted by subsidence.

Mapping by OEH (2013) has indicated that approximately 2.9 hectares of River-flat Eucalypt Forest (HN526 Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats) occurs within the Study Area. The patch of this community occurs at the very upstream portion of Eliza Creek surrounded by rural land. This area could not be surveyed during the field survey given it occurred within private property. When looking at this patch on the latest aerial imagery, the patch is quite open, indicating historic clearing. As such, it is highly likely the patch would be quite disturbed and contain weeds in the lower stratums.

Cumberland Plain Woodland has not been mapped by OEH (2013) mapping or by Niche as occurring within the Study Area. However, given the expanse of the Study Area across private properties, the field survey was limited to accessible areas. As such, it is possible that Cumberland Plain Woodland may occur as small patches within some private properties on relatively flat terrain throughout the Study Area.

Similarly, Southern Highlands Shale Woodlands has not been mapped by OEH (2013) within the Study Area. Mapping by Tozer et al (2006) has indicated that a 6.4 hectare patch occurs toward the far west of the Study Area within private property. Given access was not available, field validation was not possible, however based on aerial interpretation, the patch has been impacted by previous clearing, and it is likely to be with a degraded condition given the surrounding rural/residential land.

Subsidence could possibly cause cracks in the soil of all three vegetation communities, however an impact upon the floristics, structure and viability as a result is likely to be negligible. There is no evidence in the Southern Coalfield to suggest that cracking of the soils within forest and woodland vegetation communities would result in any impact to the flora within that community.

Vegetation die back as a result of gas emissions within each of the vegetation communities is also highly unlikely. Gas emissions are likely to occur within the lowest point of the topography as discussed in MSEC (2018). The three TECs do not occur along gullies of the Study Area and are therefore away from potential gas emission impacts. Furthermore, no changes to natural hydrology as a result of subsidence have been predicted to occur within any of the areas to which these vegetation communities have been mapped.

(b) the extent and overall condition of the CEEC or EEC within an area of 1000 ha and then 10,000 ha surrounding the proposed development footprint.

The mapped occurrence of River-flat Eucalypt Forest, Southern Highlands Shale Woodland and Cumberland Plain Woodland based on OEH (2013) and Tozer et al (2006) is provided in the table below.

Threatened Ecological Community	River-flat Eucalypt Forest	Southern Highlands Shale Woodland	Cumberland Plain Woodland
OEH (2013)			
1,000 ha	0.0	0.0	0.0
10,000 ha	2.9	0.0	0.0
Tozer et al (2006)			
1,000 ha	0.0	0.0	0.0
10,000 ha	2.2	6.4	0.0

The condition of all three vegetation communities across both the 1,000 and 10,000 hectare areas is likely to be in a moderate to low condition, given the urban and rural pressure and historic clearing of the area. It is highly likely that weeds would occupy portions of the lower stratums.

(c) an estimate of the extant area and overall condition of the CEEC or EEC remaining in the IBRA subregion after the impact of the proposed development has been taken into consideration

The Project would not reduce the extent of River-flat Eucalypt Forest, Southern Highlands Shale Woodland and Cumberland Plain Woodland within the Cumberland IBRA subregion. None of the TECs would be subjected to direct or indirect impacts as a result of clearing, nor be impacted by subsidence.

(d) the development proposal's impact on:

(i) abiotic factors critical to the long-term survival of the CEEC or EEC. For example, will the impact lead to a reduction of groundwater levels or substantial alteration of surface water patterns?

The Project will not result in a change to abiotic factors that are critical to the long-term survival of River-flat Eucalypt Forest, Southern Highlands Shale Woodland and Cumberland Plain Woodland. As discussed previously, direct and indirect impacts from the vegetation clearing associated with the Project would not impact on the TECs. Furthermore, the likelihood for any subsidence related impact upon the TECs is relatively low. MSEC (2018) and HECONS (2018b) have not predicted any significant hydrology change in areas supporting these vegetation communities.

(ii) Characteristic and functionally important species through impacts such as, but not limited to, inappropriate fire/flooding regimes, removal of understorey species or harvesting of plants

As discussed above, the Project will not result in an impact to River-flat Eucalypt Forest, Southern Highlands Shale Woodland and Cumberland Plain Woodland.

A Fire Management Plan would be developed as part of the Project to minimise any potential fire ignition from the site, and to ensure that recommended fire management and prevention is carried out.

All three vegetation communities are mapped as occurring away from the lower lying areas of the landscape. As such, if flooding were to occur as a result of the Project, it would not result in an impact to any of the TECs.

(iii) the quality and integrity of an occurrence of the CEEC or EEC through threats and indirect impacts including, but not limited to, assisting invasive flora and fauna species to become established or causing regular mobilisation of fertilisers, herbicides or other chemicals or pollutants which may harm or inhibit growth of species in the CEEC or EEC.

The Project will not result in an impact to quality and integrity of River-flat Eucalypt Forest, Southern Highlands Shale Woodland and Cumberland Plain Woodland. Clearing associated with the Project does not occur adjacent to any of the TECs. Furthermore, a Biodiversity Management Plan would be prepared and mitigation measures employed as detailed in section 9.2 to further reduce the potential for any indirect impacts in the locality.

(e) direct or indirect fragmentation and isolation of an important area of the CEEC or EEC

The Project would not result in the fragmentation or isolation of River-flat Eucalypt Forest, Southern Highlands Shale Woodland and Cumberland Plain Woodland.

(f) the measures proposed to contribute to the recovery of the CEEC or EEC in the IBRA subregion.

The Project would not result in direct or indirect impacts toward River-flat Eucalypt Forest, Southern Highlands Shale Woodland and Cumberland Plain Woodland. As such, the Project would not result in a net loss of the TECs within the Cumberland IBRA region.

8.3 Impact on threatened species

Impacts on threatened species that require further consideration include impacts on:

(a) on any critically endangered species, unless the critically endangered species is specifically excluded in the SEARs

(b) on a threatened species or population that is specifically nominated in the SEARS as a species or population that is likely to become extinct or have its viability significantly reduced in the IBRA subregion if it is impacted on by the development, or

(c) where the survey or expert report undertaken in Section 6.6 confirms that a threatened species is present on the proposed development site, and the threatened species has not previously been recorded in the IBRA subregion according to records in the NSW Wildlife Atlas.

Threatened species identified in the SEARs requiring further consideration include:

- *Persoonia bargoensis* (Bargo Geebung)
- *Persoonia glaucescens* (Mittagong Geebung)
- *Persoonia hirsuta* (Hairy Geebung)
- *Haplocephalus bungaroides* (Broad-headed Snake).

8.3.1 *Persoonia bargoensis*

Where the impacts of the proposed development meet these criteria, the assessor is required to provide the following further information in the BAR:

The size of the local population directly and indirectly impacted by the development

The proposed development would result in the loss of 100 known individuals as a result of the clearing required for the proposed works. The remaining population, a further 592 plants, is considered viable and not likely to decline over time as a result of the proposed development.

The species is unlikely to be impacted by subsidence given it is recorded away from cliffs, steep slopes and watercourses.

Mitigation measures detailed in section 9.2 would be employed to reduce the impact toward the remaining population.

(b) the likely impact (including direct and indirect impacts) that the development will have on the habitat of the local population, including but not limited to:

(i) an estimate of the change in habitat available to the local population as a result of the proposed development

The Project would result in the removal of approximately 49.1 hectares of habitat.

(ii) the proposed loss, modification, destruction or isolation of the available habitat used by the local population,

At present, the local population of *Persoonia bargoensis* extends around the existing REA and to the east of Charlies Point Road as shown on Figure 15. The population is currently fragmented by Charlies Point Road and the existing REA operations. The proposed development would result in increased distances between individuals of this species within the population which occurs along Charlie's Point Road.

(iii) modification of habitat required for the maintenance of processes important to the species' life cycle (such as in the case of a plant – pollination, seed set, seed dispersal, germination), genetic diversity and long-term evolutionary development.

The proposed development would result in the removal of approximately 100 plants within the population. This is a reduction of 14 percent of the known population. The remaining 86 percent of the population would not be impacted by the Project and therefore would not result in extinction of the population. The remaining population is likely to maintain the seed capacity of the species within the surrounding area.

Based on previous mapping (Tozer et al 2006), the area of potential habitat in the locality is approximately 10,653 hectares, comprising of Sydney Hinterland Transition Woodland (2698.70 hectares) and Cumberland Shale Sandstone Transition Forest (573 hectares). The proposed development would result in the removal of approximately 0.3 per cent of potential habitat in the locality.

How the proposal is likely to affect the ecology and biology of any residual plant population that will remain post development including where information is available on: pollination cycle, seedbanks, recruitment and interactions with other species (e.g. pollinators, host species, mycorrhizal associations)

The remaining 86 percent of the population of *Persoonia bargoensis* is likely to remain viable despite the loss of 100 individuals within the population. Information regarding pollinators is very limited, but it is likely that the species is primarily pollinated by native bees (Bernhardt and Weston 1996). Pollinators are unlikely to result in significant declines given 86 percent of the population would remain intact.

d) a description of the extent to which the local population will become fragmented or isolated as a result of the proposed development

As discussed previously, the local population of *Persoonia bargoensis* extends around the existing REA and to the east of Charlies Point Road as shown on Figure 15. The population is currently fragmented by Charlies Point Road and the existing REA operations. The proposed development would result in increased distances between individuals of this species within the population which occurs along Charlie's Point Road to the individuals to the north of the existing REA.

(e) the relationship of the local population to other population/populations of the species. This must include consideration of the interaction and importance of the local population to other population/populations for factors such as breeding, dispersal and genetic viability/diversity, and whether the local population is at the limit of the species' range

The population to be impacted is within the central range for *Persoonia bargoensis*. The species has a range which is restricted to a small area south-west of Sydney on the western edge of the Woronora Plateau and the northern edge of the Southern Highlands. The historical limits are Picton and Douglas Park (northern), Yanderra (southern), Cataract River (eastern) and Thirlmere (western). It is possible given the species relatively small range, given that all smaller populations are of the same genetic make-up. Given 86 percent of the population would remain intact it seems unlikely that other populations in the region would be impacted by the Project.

(f) the extent to which the proposed development will lead to an increase in threats and indirect impacts, including impacts from invasive flora and fauna, that may in turn lead to a decrease in the viability of the local population

The Project is likely to result in edge effects in the form of weed invasion, sedimentation and erosion within habitat for *Persoonia bargoensis* immediately adjacent to the areas being cleared. However, mitigation measures detailed in section 9.2 would be employed to reduce the impact of edge effects occurring on habitat for the remaining population.

(g) the measure/s proposed to contribute to the recovery of the species in the IBRA subregion.

The Project will require a like-for-like offset to satisfy the requirements of the FBA. As such, this will result in the establishment of a conservation area that will protect and enhance *Persoonia bargoensis*. Given *Persoonia bargoensis* is quite limited in its range, much of the land the community occupies is in the

Cumberland IBRA region, and as such, there is a level of confidence that the conservation area would be established there, and thus contribute to the recovery within the IBRA subregion.

8.3.2 *Persoonia glaucescens* and *Persoonia hirsuta*

Where the impacts of the proposed development meet these criteria, the assessor is required to provide the following further information in the BAR:

The size of the local population directly and indirectly impacted by the development

Persoonia glaucescens and *P. hirsuta* were not recorded during the current survey within areas proposed for surface infrastructure, nor within areas that are sensitive to subsidence related impacts. The proposed development would therefore not result direct or indirect impacts to *Persoonia glaucescens* and *P. hirsuta.*

(b) the likely impact (including direct and indirect impacts) that the development will have on the habitat of the local population, including but not limited to:

(i) an estimate of the change in habitat available to the local population as a result of the proposed development

The Project would result in the removal of approximately 49.1 hectares of potential habitat for both species. However, it should be noted that neither species was recorded within the area to be impacted by the Project.

(ii) the proposed loss, modification, destruction or isolation of the available habitat used by the local population,

The Project will not result in the loss or destruction of any known habitat. The Project will impact upon 49.1 hectares of potential habitat for both species.

(iii) modification of habitat required for the maintenance of processes important to the species' life cycle (such as in the case of a plant – pollination, seed set, seed dispersal, germination), genetic diversity and long-term evolutionary development.

Approximately 49.1 hectares of potential habitat for both species would be removed for the Project. However, despite targeted survey, *Persoonia glaucescens* and *P. hirsuta* were not recorded. As such the proposed development would not result in the removal of any known individuals.

It is therefore unlikely that any pollinators or seed bank would be impacted and result in a decline in the genetic diversity or long-term evolutionary development for both species.

How the proposal is likely to affect the ecology and biology of any residual plant population that will remain post development including where information is available on: pollination cycle, seedbanks, recruitment and interactions with other species (e.g. pollinators, host species, mycorrhizal associations)

The Project will not result in an impact to any residual *Persoonia glaucescens or P. hirsuta* population post development.

d) a description of the extent to which the local population will become fragmented or isolated as a result of the proposed development

No local population of *Persoonia glaucescens or P. hirsuta* would be impacted by the Project.

(e) the relationship of the local population to other population/populations of the species. This must include consideration of the interaction and importance of the local population to other population/populations for factors such as breeding, dispersal and genetic viability/diversity, and whether the local population is at the limit of the species' range

No local population of *Persoonia glaucescens or P. hirsuta* would be impacted by the Project.

(f) the extent to which the proposed development will lead to an increase in threats and indirect impacts, including impacts from invasive flora and fauna, that may in turn lead to a decrease in the viability of the local population

The Project is likely to result in edge effects in the form of weed invasion, sedimentation and erosion within area of potential habitat for *Persoonia glaucescens and P. hirsuta* immediately adjacent to the areas being cleared.

(g) the measure/s proposed to contribute to the recovery of the species in the IBRA subregion.

The Project will not result in direct or indirect impacts to *Persoonia glaucescens or P. hirsuta*. An offset for *Persoonia bargoensis* would be required for the Project. *Persoonia bargoensis* has similar habitat requirements to that of *Persoonia glaucescens and P. hirsuta*. It is quite likely that any conservation area established for *Persoonia bargoensis* would conversely offer protection of potential habitat for both *Persoonia glaucescens and P. hirsuta*.

8.3.3 Broad-headed Snake

The size of the local population directly and indirectly impacted by the development

The Broad-headed Snake has not been recorded in the Study Area during current surveys, nor has the species previously been recorded within the Study Area. No known local population of the Broad-headed Snake are therefore known to occur within the Study Area.

The closest records obtained from bionet is a record approximately 4 kilometres to the west of the Study Area along the ridgeline of the Bargo River, and a record 6 kilometres to the south along Avon River. These areas differ from the Study Area as they contain extensive deep incised gullies and cliff lines. These areas are also within conservation lands managed by NSW NPWS and WaterNSW respectively.

Given the species was not detected during targeted surveys, and the absence of records, it is highly unlikely that habitat exists within the surface area footprint. Furthermore, the habitat to be cleared is situated away from rocky outcrops which the species is known to occupy, so movement into the surface infrastructure footprint to use hollow-bearing trees is unlikely.

Potential habitat for the species is also quite limited within the Study Area. The Broad-headed Snake is known to be selective in its selection of rock outcrops for habitat. The Broad-headed Snake is known to occupy ridgelines facing north or west, as the species relies upon specific thermal conditions that are only attained in such ridgelines. These outcrops must have limited to no shading from the woodland canopy, again to allow penetration of high levels of sunlight. Finally, the outcrop must also include suitable rock exfoliations, which take the form of thin layers of rock resting directly on larger rock and without sand or debris between the layers (Pringle et al. (2003), Webb and Shine (1994) and Webb and Shine (1998a, 1998b & 1998c). Within the Study Area, suitable potential habitat is rather limited to a number of cliff line habitats along the valleys of the, the Bargo River, Dog Trap Creek and Hornes Creek. However, based on traverses throughout these areas during the field survey, areas of suitable rock exfoliation are quite limited.

As discussed in section 7.4.2 MSEC (2018) predict that a small number of cliffs may be subjected to the impacts of subsidence, which are more likely to be impacted if directly mined beneath. MSEC (2018) states that any impacts to the cliffs that are directly mined beneath, are expected to affect between 3% to 5 % of the total length of the cliffs. One cliff in the Study Area would be mined beneath. Based on this prediction, the length of the cliffs along Dog Trap Creek that may be impacted by subsidence equates to a length of approximately 2 metres.

Whilst there is always the possibilities that the rocky outcrops of the cliff habitat could be potential habitat for the species, the likelihood of suitable exfoliating rock habitat to occur within this relatively small range of cliff line, is quite low. Furthermore, the changes of subsidence to impact the precise exfoliating rock habitat for which a Broad-headed Snake resides is also quite low.

As such, it seems unlikely that the Broad-headed Snake would be impacted by subsidence related impacts or vegetation clearing.

(b) the likely impact (including direct and indirect impacts) that the development will have on the habitat of the local population, including but not limited to:

(i) an estimate of the change in habitat available to the local population as a result of the proposed development

The Project would not result in an impact to a local population of the Broad-headed Snake. A local population is unlikely to occur in the Study Area. If a population was to occur, only a very small area of cliff line (detailed above) may be impacted.

(ii) the proposed loss, modification, destruction or isolation of the available habitat used by the local population,

The Project will not result in the loss or destruction of any known habitat.

As discussed above, the area to be cleared does not contain any areas of rocky outcrops. Given the Broad-headed Snake was not detected during targeted surveys, and the absence of records, it is highly unlikely that habitat exists within the surface area footprint. Furthermore, the habitat to be cleared is situated away from rocky outcrops which the species is known to occupy.

Potential habitat for the species is also quite limited within the Study Area. As discussed previously, suitable potential habitat is rather limited to a number of cliff line habitats and areas of suitable rock exfoliation are quite limited to non-existent within these areas.

It is estimated that a small amount of cliffs may be subjected to the impacts of subsidence. Whilst there is always the possibility that the rocky outcrops of the cliff habitat could be potential habitat for the species, the likelihood of suitable exfoliating rock habitat to occur within this relatively small range of cliff line, is quite low. Furthermore, the chances of subsidence to impact the precise exfoliating rock habitat for which a Broad-headed Snake resides is also quite low.

As such, it seems unlikely that the Project would result in the destruction, loss or isolation of available habitat for the species.

(iii) modification of habitat required for the maintenance of processes important to the species' life cycle (such as in the case of a plant – pollination, seed set, seed dispersal, germination), genetic diversity and long-term evolutionary development.

The following is known about the breeding cycle of the Broad-headed Snake (DEC 2005):

- Preferred habitat is centred on the communities occurring on the Triassic sandstone of the Sydney Basin.
- The sites where they occur are typified by exposed sandstone outcrops and benching and in these locations the vegetation is mainly woodland, open woodland and/or heath.
- Seasonally occupies distinctive microhabitats within these broader habitat types. They utilise rock crevices and exfoliating sheets of weathered sandstone during the cooler months and tree hollows during summer.
- Nocturnal to crepuscular (active at dusk) and is an 'ambush predator', preying predominantly on lizards, particularly Lesueurs Velvet Geckos, at least during the cooler months.
- During this time the species can be found frequenting exposed sandstone ridgetops where it refuges under exfoliating sheets of sandstone resting on naked rock or within crevices. These refuges often have a predominantly west to north westerly aspect. This aspect effect is thought to provide thermoregulatory advantage and maximises temperature levels for the peak feeding periods of early evening.
- During the warmer months of the year they become arboreal frequenting tree hollows and undergo a presumed dietary shift to small mammals, although crepuscular arboreal skinks (Eulamprus tenuis) have also been reported in the diet of summer captured individuals (G. Turner 1998 unpublished).
- They give birth to live young (ovoviviparous).

The proposed development is unlikely to disrupt the breeding cycle of an important population due to the following:

- The species has not been previously recorded in the Study Area.
- The species was not recorded during current surveys to date.
- Whilst there is always the possibility that the rocky outcrops of the cliff habitat could provide some habitat for the species, the likelihood of suitable exfoliating rock habitat to occur within this relatively small range of cliff line, is quite low.
- Not all potential habitat is likely to be impacted by the proposed development.
- Hollow bearing trees would not be impacted by subsidence.
- Food sources are unlikely to be impacted by the proposed development.

As discussed above, the Broad-headed Snake is unlikely to be present within the Study Area. The Project is unlikely to result in the modification of habitat required for the species life cycle.

(c) the likely impact on the ecology of the local population. At a minimum, address the following: breeding, foraging, roosting, and dispersal or movement pathways

As previously discussed, the Broad-headed Snake is unlikely to be present within the Study Area.

The area to be cleared for surface infrastructure is located away from rocky outcrops, and thus it is highly unlikely that foraging habitat would be impacted by the vegetation clearing associated with the Project.

The movement of the Broad-headed Snake if it were to occur within the Study Area is unlikely to be impacted by Project. Subsidence is only predicted to have minor impacts upon cliff lines. The likelihood of suitable exfoliating rock habitat to occur within this relatively small range of cliff line is quite low. Furthermore, the chances of subsidence to impact the precise exfoliating rock habitat for which a Broad-headed Snake resides is also quite low.

d) a description of the extent to which the local population will become fragmented or isolated as a result of the proposed development

No local population of Broad-headed Snake would be impacted by the Project.

(e) the relationship of the local population to other population/populations of the species. This must include consideration of the interaction and importance of the local population to other population/populations for factors such as breeding, dispersal and genetic viability/diversity, and whether the local population is at the limit of the species' range

No local population of Broad-headed Snake would be impacted by the Project.

(f) the extent to which the proposed development will lead to an increase in threats and indirect impacts, including impacts from invasive flora and fauna, that may in turn lead to a decrease in the viability of the local population

The Project is unlikely to result in edge effects in the form of weed invasion, sedimentation and erosion within areas of potential habitat for the Broad-headed Snake. However, mitigation measures detailed in section 9.2 would be employed to reduce the impact of edge effects occurring on areas of native vegetation surrounding the proposed surface infrastructure.

(g) the measure/s proposed to contribute to the recovery of the species in the IBRA subregion.

The Project will not result in direct or indirect impacts to Broad-headed Snake. The Project will therefore not interfere with the recovery of the species within the Cumberland IBRA subregion.

8.4 Impact on Critical Habitat

The Project will not impact upon areas of land that the Minister for the Environment has declared 'critical habitat' in accordance with section 47 of the BC Act and that are listed on the Register of Critical Habitat.

9. Avoidance and mitigation

9.1 Avoidance of direct impacts

In accordance with the NSW Biodiversity Offsets Policy for Major Projects and the FBA, proponents must demonstrate the measures employed to avoid, mitigate and offset impacts of a Project on biodiversity values. This section of the report outlines the avoidance, management and mitigation measures that Tahmoor Coal has incorporated into the Project design or will employ during construction, operation and completion of the Project to reduce impacts on biodiversity values. Section 11 of this report describes the offset strategy for the Project to account for residual impacts that cannot be avoided or mitigated.

9.1.1 Site selection and design considerations

Site selection for the infrastructure location was undertaken during a risk assessment process. The process involved identifying areas of high constraints, such as threatened flora and fauna records, potential habitat and areas of TEC which may be impacted by subsidence or impacted by the proposed development. Where possible these areas were avoided or impacts minimised to reduce any potential significant impacts. The following design considerations were incorporated into the Project:

- The REA was redesigned to minimise the potential impacts on Shale Sandstone Transition Forest, *Persoonia bargoensis* and *Grevillea parviflora* subsp. *parviflora*, and be moved away from Tea Tree Hollow Creek and the population of *Pomaderris brunnea*.
- The longwalls in the north of the Study Area have been designed to stand back from the Bargo River and Nepean River. This design maximises the protection of the natural features within these rivers and reduces any potential for the Project to impact the biodiversity values associated with those two rivers.
- The longwalls in the south of the Study Area have been re-designed to stand back from the Nepean State Conservation Area, and avoid impacts to Cow Creek. This will also avoid impacts to the Giant Burrowing Frog which was recorded during previous surveys by Niche along Cow Creek.
- The longwall panels originally proposed in the 'Eastern Domain' have also been removed from the Project. This has resulted in the avoidance of potential subsidence impacts, including Eliza Creek.

9.2 Mitigation and management of construction impacts

Impacts arising from the construction will primarily relate to vegetation clearing. The mitigation and management actions to be implemented by Tahmoor Coal during construction are detailed below. The cost associated with the implementation of mitigation measures in relation to biodiversity have been provided in Cadence Economics (2018) Economic Impact Assessment, which considers the cost of mitigation measures in the economic modelling of the project.

9.2.2 Fencing and signposting

Fencing and/or the use of highly visible rope or tape boundaries will be used to delineate the boundary of vegetation clearing at the edge of the area to be cleared.

Signposting will be used to inform Project personnel and site visitors of areas of conservation value to restrict entry and/or inform behaviour that will reduce incidental interactions with threatened species - e.g. speed limits along access roads to reduce potential for fauna vehicle strikes.

9.2.1 Employee Education and General Environmental Controls

Employees and contractors would be educated on, and required to implement the following controls, to avoid or at least minimise potential environmental impacts associated with the construction of the southern overburden emplacement.

- Minimise dust generation by minimising the extent and time that bare soil is exposed and by appropriate dust suppression.
- Procedures for the management of hydrocarbon and/or chemical spills throughout the Study Area including the requirements for vehicles to carry spill kits.
- Ensuring vehicles remain on designated roads and tracks and abide by site speed limits, through use of signposting and driver education during the induction process and in on-going Project discussions.
- Management and removal of all rubbish from the Study Area.

9.2.2 Vegetation Clearing

Vegetation Clearance Protocol

A vegetation clearing protocol would be included in a Biodiversity Management Plan. This Plan is to include the following:

- Prior to clearing of native vegetation, ecologists are to survey for ground-dwelling fauna and to remove any fauna/fauna habitat (nests or hollow logs) to adjacent habitat that would not be further disturbed.
- Prior to clearing all hollow-bearing trees are to be marked. Underscrubbing would then take place within the vegetation surrounding the hollow-bearing trees.
- After a 24 hour period, in the presence of an ecologist, the hollow-bearing trees would be gently felled.
- Any fauna displaced during clearing are to be captured where possible and relocated to previously identified, safe areas (fauna to be captured and handled only by personnel trained to do so).
- In an event that fauna are injured during clearing, the NSW Wildlife Information, Rescue and Education Service (WIRES) will be contacted to handle and collect for appropriate care and rehabilitation.

9.2.3 Rehabilitation

All surface infrastructure would be progressively rehabilitated in accordance with a Landscape and Rehabilitation Management Plan, to create a stable landform that does not result in sediment laden runoff or fugitive dust emissions, blends well with the adjacent natural landscapes and re-establishes a native bushland.

9.2.4 Biodiversity Management Plan

Tahmoor Coal currently has a Tahmoor Environmental Management System (EMS), which includes a series of Environmental Management Plans (EMPs) that outline the mitigation and management programs for key environmental aspects at the mine. An outline of this plan is provided in the main body of the EIS for the Project.

Operations at Tahmoor will continue to be managed in accordance with the EMS and associated EMPs, which will be revised and updated to incorporate the additional environmental management requirements as outlined in the EIS for the Tahmoor South Project. This will include biodiversity management measures associated with the construction and operation of the Project in order to protect and manage important biodiversity values.

All management plans will be prepared to the satisfaction of relevant State and Commonwealth agencies. The plans will also be prepared/updated in consultation with the relevant NSW government agency, which will be outlined in the conditions of Project Approval, should the project be approved.

Pest and weed management

The Biodiversity Management Plan would include a section relating to pest and weed management activities of the Project and will include:

- Management protocols for feral animals such as foxes, rabbits and cats within the rehabilitation area.

- Management protocols for the identification of noxious or significant environmental weeds within areas to be cleared (in order to avoid transporting the weeds to rehabilitation areas or other parts of the site).

Fire management

Tahmoor currently have a Bushfire Management Plan for their operations. Fire prevention and suppression are detailed within the Plan including emergency protocols should a fire occur. This Plan would be updated where required to reflect the Project.

9.2.5 Extraction Plan

An Extraction Plan would be developed for the Project, which will include biodiversity management measures associated with potential subsidence related impacts in order to protect and manage important biodiversity values.

9.3 Indirect impacts

Indirect impacts associated with the Project will largely occur during the construction of the REA expansion areas and will be minimised where possible through management procedures. A range of indirect impacts are likely to, or could, occur as a result of the Project including:

- Increased noise and dust.
- Erosion or sedimentation in the drainage lines downslope toward Tea Tree Hollow Creek.
- Increased spreading of weed propagules.
- Increased edge-effects on the adjacent woodlands.

The indirect impacts described above are variable in terms of the distance they may extend from the surface infrastructure footprint, and in many cases, due to mitigation measures, indirect impacts will be completely contained within the direct disturbance area. Indirect impacts are unlikely to extend into areas of native vegetation due to the following:

- Active weed management would occur along the boundaries of the surface infrastructure work during construction and operation.
- A buffer of stockpile and the adjacent woodland areas has been incorporated into the REA expansion area design.
- Mitigations measures are proposed to minimise noise and dust emissions, the introduction and spread of weeds and erosion and sedimentation of downstream drainage systems.

Indirect impacts on the biodiversity values of areas surrounding the proposed disturbance footprint, along with recommended mitigation measures to minimise identified impacts, are discussed in Table 22.

Table 22. Indirect impacts

Indirect impact	Likely impact from the Project	Mitigation measure
Edge effects	The establishment of surface infrastructure would result in the creation of new edges adjacent to areas of existing native vegetation, however these edges have been incorporated within the disturbance footprint. The new edges could facilitate the establishment and spread of introduced plant species, however appropriate monitoring and control measures would be implemented during and after construction, to assist in preventing weed invasion. The surface infrastructure would be progressively rehabilitated and will eventually be entirely revegetated to a native, open woodland community, which will recreate fauna habitat.	Fencing and/or the use of highly visible rope or tape boundaries will be used to delineate the boundary of vegetation clearing at the edge of the emplacement. Signposting and education will also be used to inform Project personnel of no-go areas. Weed management and monitoring to be included in Biodiversity Management Plan.
Weeds	Weeds have the opportunity to establish themselves in areas of disturbed vegetation. The greatest establishment of weeds are in areas already disturbed or subject to agricultural land use. This is mainly toward the south of the study area. The Project has the potential to increase or lead to the establishment of weed species where they do not currently exist through the operation of machinery during construction. New weed species can potentially be introduced as a result of the movement of construction vehicles and materials into the study area. Areas more likely to be exposed to weed increases are areas of native vegetation that occur to the east and south of the study area as these areas, unlike the study area, are in better condition and contain less introduced species. However, weeds will be controlled during and after construction in accordance with the Biodiversity Management Plan and thus indirect impacts from weeds is likely to be minor within the adjacent woodland areas.	Weed management and monitoring to be implemented in accordance with the Biodiversity Management Plan.
Erosion and sedimentation	Erosion of soils and associated sedimentation associated with the proposed development may involve the following: • Alteration of soil structure beneath haul roads. • The increase of surface water flow from the study area during rain events into the woodland areas to the east and south may result in erosion. The deposition of soil particulates in drainage lines and remnant vegetation along the toe of the emplacement areas.	Sediment basins have been designed to attenuate stormwater runoff and capture sediment from the overburden emplacement. Stormwater management measures will be implemented in accordance with the recommendations in the Project's Water Management Plan.
Dust	Dust will be generated from the construction and operating hours. Through accumulation with existing dust generated from existing operations, dust generated during construction of the Project has the potential to impact upon the health of plants and vegetation particularly in those areas of dense native woodland immediately adjacent to the site. Research shows that the impacts of dust on vegetation can have both positive and negative impacts, however the impacts of increased levels of dust on animals are unknown (Farmer 1993). Farmer (1993) anticipated that dust may increase the susceptibility of plants and vegetation to secondary stresses, such as drought, insects and pathogens, or allow penetration of toxic metals or phytotoxic gaseous pollutants.	Dust impacts will be mitigated through the onsite use of water suppression and the progressive rehabilitation of the overburden emplacement. Further, vegetation clearing protocols for the Project will seek to minimise exposed areas with the potential to generate dust by completing vegetation clearing as close to the commencement of overburden emplacement as practical.
Noise	Noise will be generated from the construction and the extended in-pit operating hours. Although relevant research is limited, studies have found that traffic noise can mask the important contact calls of certain birds such as the Budgerigar, Canary, and Zebra Finch, (Lohr et al. 2003). Parris and Schneider (2008) found that it was increased volumes of	Tahmoor will continue to manage site operations in accordance with the existing noise restrictions and commitments.

Indirect impact	Likely impact from the Project	Mitigation measure
	noise and not increased volumes of traffic that were important. Various studies have indicated that changes in bird calls in response to traffic noise are twofold, either the birds change the characteristics of their call to avoid interaction of the sound of the call with the created sounds or they limit calling to periods when the levels of noise are reduced. The Project is unlikely to result in any additional noise impacts on local fauna as the hours of operation would be similar to that occurring at present.	
Fire	Historically, rural bushfires tend to be associated with a proficient growth of native grasses following large rain events. During summer, following rain events, dry swards of grasses pose a bushfire hazard when placed near a source of ignition. Vehicles driven through long grass with hot exhausts may cause a fire particularly during the hotter months of the year.	Tahmoor Coal will continue to manage site operations in accordance with the existing Bushfire Management Plan.
Light	Lighting within the areas proposed for surface infrastructure may consist of low intensity directional lighting. There is some night lighting at the REA and ventilation shafts; however this is limited to small directional lights (ie no flood lighting). The light that is likely to be generated by the surface works is unlikely to result in a significant change to fauna movement given the lighting would be directional toward the surface infrastructure. Furthermore, operation lighting (eg. from vehicle movement) will be restricted to hours of operation.	Tahmoor Coal will ensure lights are turned off at night if not required, and that the placement of lights for night work will be so that they are directed internally towards the work area to avoid/minimise light spill.

10. Thresholds for impacts and offsetting unavoidable impacts

10.1 Threshold impact criteria

The FBA lists threshold impact criteria for landscape features, native vegetation, and threatened species in order to determine when an offset or further consideration by consent authorities is required due to a Project's impacts. The impacts are classed according to the following criteria:

a. impacts that the assessor is required to identify for further consideration by the consent authority
b. impacts for which the assessor is required to determine an offset
c. impacts for which the assessor is not required to determine an offset
d. impacts that do not require further assessment by the assessor.

The impacts associated with biodiversity considered for further consideration has been detailed in section 8.

This offset strategy quantifies the required offsets for the Project in accordance with both the BC Act and EPBC Act, through the use of the FBA methodology.

The Project meets criteria b, *impacts for which the assessor is required to determine an offset* due to the following:

- Impacts on approximately 43.4 hectares of Shale Sandstone Transition Forest TEC
- Impacts on approximately 5.7 hectares of native vegetation that is not listed as a TEC
- Impacts to *Persoonia bargoensis and Grevillea parviflora* subsp*. parviflora.*
- Impacts to 43.5 hectares of potential Koala habitat.
- Impacts to 7.4 hectares of potential Large-footed Myotis habitat.

10.2 Quantifying offset of impacts

The FBA identifies the BioBanking Credit Calculator (BBCC) as the appropriate tool for quantifying the precise nature of the offsets required in both ecosystem species credit terms. The major Project function of the BBCC is used under the FBA to quantify the number of credits required for the development.

A calculation of the nature and extent of offset credits required due to the biodiversity impacts associated with the Project was undertaken using Version 4.0 of the BBCC.

Details of the BBCC inputs have been discussed in sections 4 to 6. Appendix 9 includes the full output printout of the BBCC for the Project which defines the ecosystem and species credits required to offset the impacts of the Project on biodiversity in accordance with the NSW Biodiversity Offsets Policy for Major Projects.

10.2.1 Summary of credits required

Offsets required for vegetation disturbance as a result of the Project are shown in Table 23, and offsets required for species are provided in Table 24.

Table 23. Ecosystem credits required for the Project

PC type code	Plant community type name	Condition	Management zone area (ha)	Ecosystem credits required	Total credits
HN556	Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion	Moderate/good _derived	5.7	210	2,246
		Moderate/good	26.0	1,437	
		Moderate/good _medium	11.8	599	
HN564	Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion	Moderate/good	5.7	287	287

Table 24. Species credits required for the Project

Threatened species	No. impacted	Credits required
Persoonia bargoensis	100	7,700
Grevillea parviflora subsp. *parviflora*	2,324	32,536
Large-footed Myotis	7.4 ha	163
Koala	43.5 ha	1,131

11. Biodiversity offset strategy

The Biodiversity offset strategy forms Stage 3 of the FBA.

11.1 Introduction

The NSW Biodiversity Offsets Policy for Major Projects (OEH 2014) states that biodiversity offsets provide benefits to biodiversity to compensate for the adverse impacts of an action. Biodiversity offsets assist in achieving long-term conservation outcomes while providing development proponents with the ability to undertake actions that have unavoidable impacts on biodiversity.

Unavoidable impacts to biodiversity are those impacts that are residual (i.e. impacts that remain after impact avoidance, management and mitigation measures are employed to reduce the type or magnitude of biodiversity impacts). Section 9 of this report outlines the design changes that Tahmoor Coal has implemented through the feasibility and pre-feasibility stages of the Project in order to avoid and reduce impacts to biodiversity values. Section 9 and Section 9.2 of this report outline the management and mitigation actions that Tahmoor Coal will employ to further reduce direct and indirect impacts to biodiversity values as a result of this Project.

This section of the report describes the approach to biodiversity offsetting proposed for the Project in accordance with the NSW Biodiversity Offsets Policy for Major Projects.

11.1.1 NSW Biodiversity Offsets Policy for Major Projects

The Project requires an offset for the removal of 49.2 hectares of native vegetation, of which 43.4 hectares aligns to the TEC Shale Sandstone Transition Forest; and impacts to 100 *Persoonia bargoensis* plants, 2,324 *Grevillea parviflora* subsp. *parviflora* plants, 7.4 hectares of Large-footed Myotis habitat and 43.5 hectares of Koala habitat.

To offset the impacts, the proposed off strategy must be implemented in accordance with the NSW Biodiversity Offsets Policy for Major Projects.

The policy:

1. Establishes a set of offsetting principles for Major Projects.
2. Defines key thresholds for when offsetting is required.
3. Adopts an assessment methodology to quantify and describe the offset required.
4. Defines mechanisms required to establish offset sites.
5. Provides a range of flexible options that can be used in lieu of providing offsets, including rehabilitation actions and supplementary measures.

The NSW Biodiversity Offsets Policy for Major Projects contains within it provision for the establishment of an offset fund into which proponents may contribute financially an amount which otherwise would be equal to the cost of establishing independent offset sites.

11.1.2 Offset to satisfy the Commonwealth Offset Requirements

The DoEE have accepted the Project be assessed under the Bilateral Agreement (section 2.1.2).

As discussed in section 2.1.2, the Project has been regarded as a controlled action by DoEE based on significant impact to the following:

- Shale Sandstone Transition Forest (SSTF)
- *Persoonia bargoensis*
- *Grevillea parviflora* subsp. *parviflora*
- *Pomaderris brunnea*

The above entities, with the exception of *Pomaderris brunnea,* are proposed to be offset accordingly using the FBA. No impacts to *Pomaderris brunnea* would occur as a result of the Project, and thus no offset has been proposed.

The Project would also offset for impact to approximately 43.5 hectares of Koala habitat.

No other Commonwealth entities have been proposed to be offset.

11.2 Proposed offset strategy

The formalisation of the offset proposed in section 11.3 will satisfy both the NSW and Commonwealth offset requirement. Table 25 outlines the approach that will be taken by Tahmoor Coal to develop a suitable biodiversity offset in accordance with the key offsetting policy principles.

The approach to the development of the future biodiversity offset package is presented below.

The formalisation of the offset for the Project will be done in a manner to satisfy the Commonwealth offset requirement as per the Bilateral Agreement.

Table 25: Principles for developing biodiversity offsets under NSW and Commonwealth legislation

Offsetting principle	How principle will be addressed in the offset package
NSW Biodiversity Offsets Policy for Major Projects	
Principle 1: Before offsets are considered, impacts must first be avoided and unavoidable impacts minimised through mitigation measures. Only then should offsets be considered for the remaining impacts.	Impacts have been avoided where possible during the design of the Project. Management and mitigation measures for biodiversity values have been proposed for the Project. Impact avoidance, management and mitigation measures have been detailed in Section 9 to Section 9.3.
Principle 2: Offset requirements should be based on a reliable and transparent assessment of losses and gains.	BioBanking plot data and threatened species surveys within the Study Area have been undertaken in accordance with the FBA. The latest version of the BBCC has been used to determine the credits required to offset the impacts of the Project on PCTs and species credits. Accredited BioBanking assessors have conducted the field surveys and offset calculations. The proposed offset has been assessed in accordance with the requirements of the FBA, to determine the suitability and quantum of offsets for the Project.
Principle 3: Offsets must be targeted to the biodiversity values being lost or to higher conservation priorities.	The offset proposed would be in accordance with the rules of the FBA.
Principle 4: Offsets must be additional to other legal requirements.	The proposed offset will be additional to other legal obligations that the proposed offset site may have.

Offsetting principle	How principle will be addressed in the offset package
Principle 5: Offsets must be enduring, enforceable and auditable.	The biodiversity offset site will be formally secured in accordance with the permissible offset mechanisms of the NSW Biodiversity Offsets Policy for Major Projects.
Principle 6: Supplementary measures can be used in lieu of offsets.	The biodiversity offset site will be formally secured in accordance with the permissible offset mechanisms of the NSW Biodiversity Offsets Policy for Major Projects.
Commonwealth Offsetting Principles	
Deliver an overall conservation outcome that improves or maintains the viability of the protected matter	The offset package will deliver an overall conservation outcome that improves or maintains the viability of the protected matters that will be significantly impacted by the Project. The offset requirements will be calculated using the FBA. Offset sites will be managed appropriately to improve the condition of the protected matter. Details of the management will be contained in relevant management plans.
Be built around direct offsets but may include other compensatory measures	The offset requirements will be calculated using the FBA.
Be in proportion to the level of statutory protection that applies to the protected matter.	The application of the FBA will ensure that the final offset packages is adequately proportioned to account for the level of statutory protection that applies to the protected matters that will be significantly impacted by the Project.
Be of a size and scale proportionate to the residual impacts on the protected matter.	The application of the FBA will ensure that the final offset package adequately offsets the size and scale of the impacts of the Project on the protected matters.
Effectively account for and manage the risks of the offset not succeeding.	Offsets will be audited, monitored and managed appropriately to ensure success in compensating for the residual impacts of the action over a period of time.
Be additional to what is already required, determined by law or planning regulations, or agreed to under other schemes or programs.	The proposed offset will be additional to other legal obligations that the proposed offset site may have.
Be efficient, effective, timely, transparent, scientifically robust and reasonable.	The acquisition and protection of the proposed offsets will be staged in line with the staging of the action. The adequacy of the offsets would be determined using the FBA, which would be accompanied by a detailed report outlining the methodology and assumptions of the calculations.
Have transparent governance arrangements including being able to be readily measured, monitored, audited and enforced.	The proposed offset package will be subject to an offset management plan. The management plan will include prescribed monitoring and auditing commitments. The management plan will be developed through consultation with the DoEE and OEH.
In assessing the suitability of an offset, government decision-making will be: Informed by scientifically robust information and incorporate the precautionary principle in the absence of scientific certainty.	The adequacy of the offsets would be determined using the FBA, which would be accompanied by a detailed report outlining the methodology and assumptions of the calculations.

Offsetting principle	How principle will be addressed in the offset package
In assessing the suitability of an offset, government decision-making will be: Conducted in a consistent and transparent manner.	The FBA would be used to determine the offsets required. Preliminary calculations have been provided in this report.
Deliver an overall conservation outcome that improves or maintains the viability of the protected matter	The offset package will deliver an overall conservation outcome that improves or maintains the viability of the protected matters that will be significantly impacted by the Project. The offset requirements will be calculated using the FBA. Offset sites will be managed appropriately to improve the condition of the protected matter. Details of the management will be contained in relevant management plans.
Be built around direct offsets but may include other compensatory measures	The offset requirements will be calculated using the FBA

11.3 Approach to satisfying the offset requirement

Given vegetation clearing would be progressive, and would not all occur within the first few years of project commencement, it is proposed that the offsets for the project also be progressive, to match that of the vegetation and/or species being impacted.

Tahmoor Coal proposes a two stage offsetting approach over a 7 year period, within the first stage occurring in the first year of development (Figure 17).

The credits for each stage are detailed in Table 26.

In the first year of Project commencement the following would be offset:

- 790 credits for HN556
- 32,536 credits for *Grevillea parviflora* subsp. *parviflora*
- 308 credits for *Persoonia bargoensis*
- 403 credits for the Koala

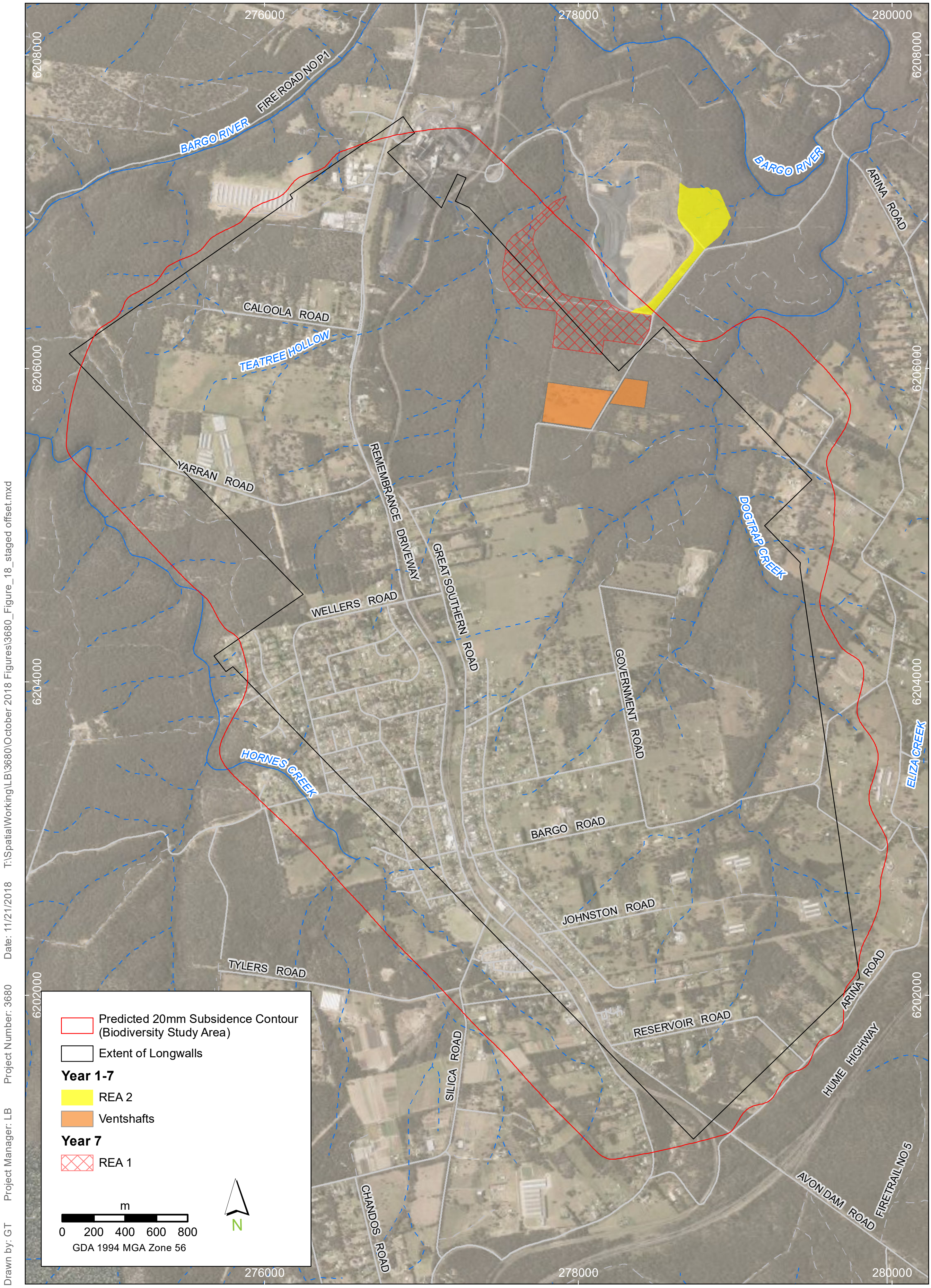
Tahmoor Coal propose to undertake a combination of the following offset mechanisms to offset the Project:

1. Establishment of Biodiversity Stewardship Agreement sites within Tahmoor Coal landholdings
2. Purchase of the required credits available on the Public Register (ensuring that the credits also meet the Commonwealth criteria for the threatened entity being offset)
3. Payment into the NSW Biodiversity Offsets Fund (to satisfy NSW offset liability).

Details regarding the approach to each of these are provided in the following sections.

Table 26. Staged offset approach – credit requirement

	HN556 credit requirement			HN564 credit requirement	Species credits required				
	Mod/good	Mod/good_med	Mod/good_derived	Mod/good	G. parviflora subsp. parviflora	P. bargoensis	Cumberland Plain Land Snail	Koala	Large-footed Myotis
Stage 1 – Year 0									
REA 2	360	-	-	-	22,775	7,392	-	317	-
Ventilation shafts	210	-	210	-		-	6	86	-
TOTAL	**570**	**-**	**210**	**-**	22,775	**7,392**	**6**	**403**	**-**
Stage 2 – Year 7									
REA1	867	599	0	287	9,761	308	-	728	163
TOTAL	**867**	**599**	**0**	**287**	9,761	**308**	**-**	**728**	**163**
TOTAL	**1,437**	**599**	**210**	**287**	**32,536**	**7,700**	**6**	**1,131**	**163**



Staged Offset

Tahmoor South Project Biodiversity Assessment Report

FIGURE 17

Imagery: (c) LPI 2013

11.4 Establishment of offset sites within Tahmoor Coal landholdings

Tahmoor Coal proposed to use areas of native vegetation within their existing landholdings[4] which have been assessed by Niche as potential offset sites for the Project.

Each of the proposed offset sites are listed in Table 27 and would be officially established as Biodiveristy Stewardship Agreement sites in accordance with the OEH (2016) Biodiversity Assessment Methodology (BAM). In order to demonstrate a comparison of the proposed offset sites to the offset liability associated with the Project, field and desktop data has been input into the BBCC rather than the BAM calculator as currently, there is no public credit conversion tool to convert the FBA credit liability associated with the Project to BAM credits. Each of the proposed offset sites, including the inputs in the BBCC are discussed below.

Table 27. Overview of proposed offset sites

Property Description	Address	Lot/ DP	Total native vegetation (ha)
Pit Top	2975 Remembrance Driveway, Bargo	Lot 162 DP1054184	29.9
Shaft 2	Rockford Road, Tahmoor	Lot 441 DP751270	6.0
Rockford Road	260 & 270 Rockford Road, Tahmoor	Lot 1 and Lot 2 DP1037712	24.6
Bargo Colliery land	Ashby Close & 76 Gwynn Hughes Street, Bargo	Lot 170 DP751250 and Lot 35 DP751250	270.0
Anthony Road	125 Anthony Road, Tahmoor	Lot 245 DP751250	10.3

11.4.1 Proposed Pit Top offset site

The proposed Pit Top offset site occurs immediately to the west of the REA within land owned by Tahmoor Coal (Figure 20).

The offset area consists of native vegetation which is part of a corridor of native vegetation which extends along Tea Tree Hollow Creek.

Overall, the condition of vegetation across the offset area (in particular the eastern side) was in relatively good condition – with all stratum layers intact and minimal weeds. Weeds tended to occur adjacent to existing tracks which border the proposed offset site.

Landscape Assessment

The proposed offset area occurs within the Hawkesbury Nepean IBRA region, and within the Cumberland IBRA subregion (Figure 21). This is the same IRBA region, and IBRA subregion as the Project.

One Mitchell landscape occurs across the study area: Picton Razorback Hills, which is also the same as the Project (Figure 21).

[4] The exact layout of each of the proposed Biodiversity Stewardship Agreement sites is being internally formalised by Tahmoor Coal.

GIS interrogation was used to determine the vegetation cover percentage as provided in Table 28.

Table 28. Native vegetation cover at the proposed Pit Top offset area

Native vegetation cover class (%)			
Before offset		**After offset**	
1,000 ha	**100 ha**	**1,000 ha**	**100 ha**
81-85%	81-85%	81-85%	81-85%

Connectivity

The proposed offset site occur on both sides of a third order stream (Tea Tree Hollow Creek). This was therefore entered into the BBCC.

Landscape score calculation

The landscape assessment resulted in a Landscape Score of 21.0 after a patch size of 2,000 hectares was entered for all of the vegetation zones.

Assessing native vegetation at the offset area

The vegetation of the offset site was validated during the most recent round of surveys for the Project. However, given changes in the design of the offset site and development areas, not all plots were completed within the offset site. This is seen as a minor limitation given the condition class of each of the vegetation types were consistent within and outside of the offset site. It is proposed that plots be completed in accordance of the FBA within the offset area during the formalisation and reporting process for the offset site after development consent has been issued.

Vegetation recorded during the survey included the following vegetation types:

- HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin
- HN564 Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin.
- HN586 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest in gullies of western Sydney, Sydney Basin sandstone.

The vegetation types along with equivalent PCT (and reference codes), Keith Class, Keith Formation, is provided in Table 29, and a description of each community provided below.

<u>HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest</u>

HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest, occurred to the far west of the proposed offset site. This community consisted was of an open forest structure, comprising of canopy species: *Eucalyptus punctata*, *E. fibrosa*, and *E. eugenioides*. Midstorey species included: *Allocasuarina littoralis*. The shrub layer contained *Acacia decurrens*, *Bursaria spinosa*, *Kunzea ambigua*, *Melaleuca thymifolia, Pultenaea villosa, Olearia microphylla,* and *Ozothamnus diosmifolius*. The grass layer was quite diverse and included: *Anisopogon avenaceus, Aristida ramosa, Aristida vagans, Entolasia stricta, Eragrostis brownii, Microlaena stipoides* and *Themeda australis.*

This vegetation community aligned to Shale Sandstone Transition Forest under both the BC Act and EPBC Act given the presence of diagnostic species for the TEC.

HN564 Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin.

HN564 Red Bloodwood - Grey Gum woodland occurred predominantly throughout the proposed offset site.

Dominant canopy species in this community included the following: *Corymbia gummifera, Eucalyptus eugenioides, Eucalyptus punctata* and *Eucalyptus racemosa.* A fairly dense shrub layer consisted of *Acacia ulicifolia, Acacia terminalis, Acacia linifolia, Banksia spinulosa* var. *spinulosa, Hakea sericea, Persoonia levis, Persoonia linearis* and *Leptospermum trinervium.* Ground cover species included the following: *Cyathochaeta diandra, Entolasia stricta, Microlaena stipoides, Poa sieberiana, Cheilanthes sieberi, Goodenia hederacea, Lomandra filiformis, Lomandra obliqua, Lomandra longifolia, Lepidosperma laterale, Phyllanthus hirtellus, Pimelea linifolia* subsp. *linifolia* and *Xanthosia tridentata.*

Two condition classes were attributed to the vegetation unit: A moderate/good condition class – which contained all stratum layers intact. And a moderate/good_high condition class – which was attributed to an area which had been previously disturbed and is fairly dense with shrubs (mainly *Acacia parramattensis*).

HN586 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest in gullies of western Sydney, Sydney Basin sandstone

This vegetation community occurs within the gullies of the proposed offset site. Dominant species of the community include the following canopy species: *Corymbia gummifera, Eucalyptus eugenioides, Eucalyptus piperita, Eucalyptus racemosa* and *Allocasuarina littoralis*. The shrub layer consisted of *Acacia terminalis, Banksia spinulosa var. spinulosa, Hakea sericea, Hovea purpurea, Kunzea ambigua, Persoonia linearis, Platysace linearifolia, Leptospermum trinervium* and *Xanthosia pilosa.* The ground layer comprised: *Cyathochaeta diandra, Entolasia stricta, Billardiera scandens, Cheilanthes sieberi, Lepidosperma laterale, Phyllanthus hirtellus, Pomax umbellata, Pteridium esculentum* and *Xanthosia tridentata.*

The community was observed to be high resilience with regenerating canopy species and a high percentage of native shrubs.

Table 29. Vegetation zones mapped in Pit Top offset area

Vegetation community	Plant Community Type (PCT)	Formation	Class	Condition	Area
Cumberland Shale Sandstone Transition Forest	HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin	Dry Sclerophyll Forests (Shrub/grass subformation)	Cumberland Dry Sclerophyll Forests	Moderate/ Good	2.0
Upper Georges River Sandstone Woodland	HN564 Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin.	Dry Sclerophyll Forests (Shrubby subformation)	Sydney Hinterland Dry Sclerophyll Forests	Moderate/ Good	17.8
				Moderate/good_high	4.5
Hinterland Sandstone Gully Forest	HN586 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest in gullies of western Sydney, Sydney Basin sandstone	Dry Sclerophyll Forests (Shrubby subformation)	Sydney Coastal Dry Sclerophyll Forests	Moderate/ Good	5.6
Total					**29.9**

Threatened flora survey

During the field survey, threatened flora encountered were recorded with a GPS and counted. The following threatened flora were recorded within the proposed offset site:

- *Persoonia bargoensis*: 77 plants
- *Epacris purpurascens* var. *purpurascens*: 5 plants
- *Pomaderris brunnea*: 141 plants
- *Grevillea parviflora* subsp. *parviflora*: one clump consisting of 21 plants.

Threatened flora survey

The offset site provides potential Koala habitat due to the presence of important feed trees – *Eucalyptus punctata.* Given an offset for the Koala is being proposed for the impacts to the REA expansion areas, and the Pit Top offset site occurs immediately adjacent, Koala credits for the preservation and enhancement of 29.9 hectares of potential habitat would be sought. Similarly, given the site occurs within 200 metres of a creek line and contains hollow-bearing trees, credits for 29.9 hectares of habitat for the Large-footed Myotis will also be generated.

Credits generated at the Pit Top offset site

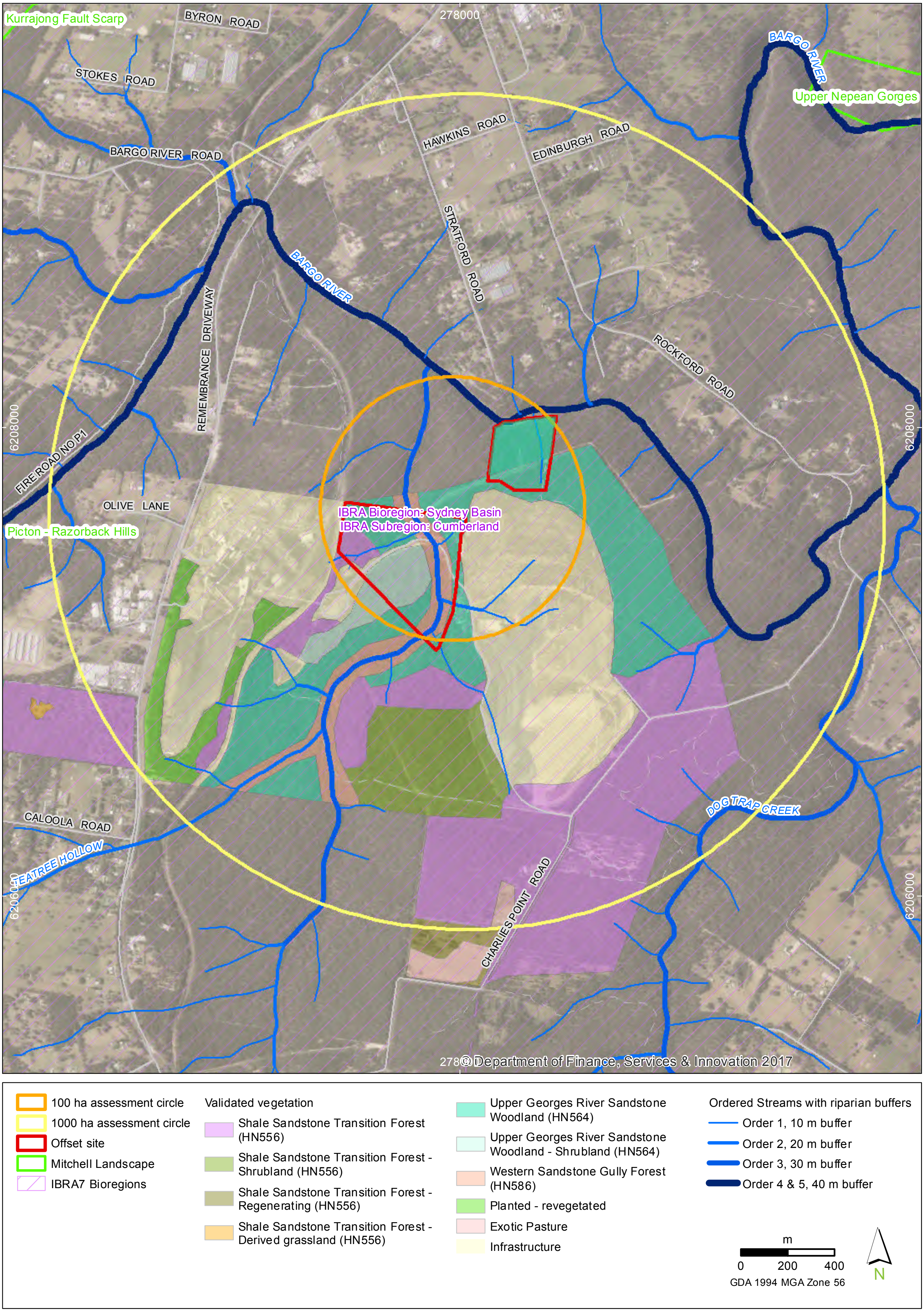
The credits that may be generated at the Pit Top offset site include those provided in Table 30 and Table 31.

Table 30. Ecosystem credits generated at the Pit Top offset site

Veg code	Vegetation name	Manage-ment zone	Manage-ment zone area (ha)	LandScape Value score	Current site value	Future site value	Gain in site value	Averted loss in site value	Number of ecosystem credits created
HN556	Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion	1	2	21.00	50	75.85	25.85	5.44	**26**
HN564	Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion	2	17.8	21.00	58.70	73.43	14.73	5.62	**184**
HN564	Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion	3	4.5	21.00	56.52	86.23	29.71	5.13	**63**
HN586	Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney, Sydney Basin Bioregion	4	5.6	21.00	57.97	72.22	14.25	5.44	**57**

Table 31. Species credits generated at the Pit Top offset site

Scientific name	Common name	Number of species credits created
Persoonia bargoensis	Bargo Geebung	**547**
Pomaderris brunnea	Brown Pomaderris	**1001**
Epacris purpurascens subsp. purpurascens	Epacris purpurascens subsp. purpurascens	**36**
Grevillea parviflora subsp. parviflora	Small-flower Grevillea	**149**
Phascolarctos cinereus	Koala	**212**
Myotis macropus	Large-footed Myotis	**212**



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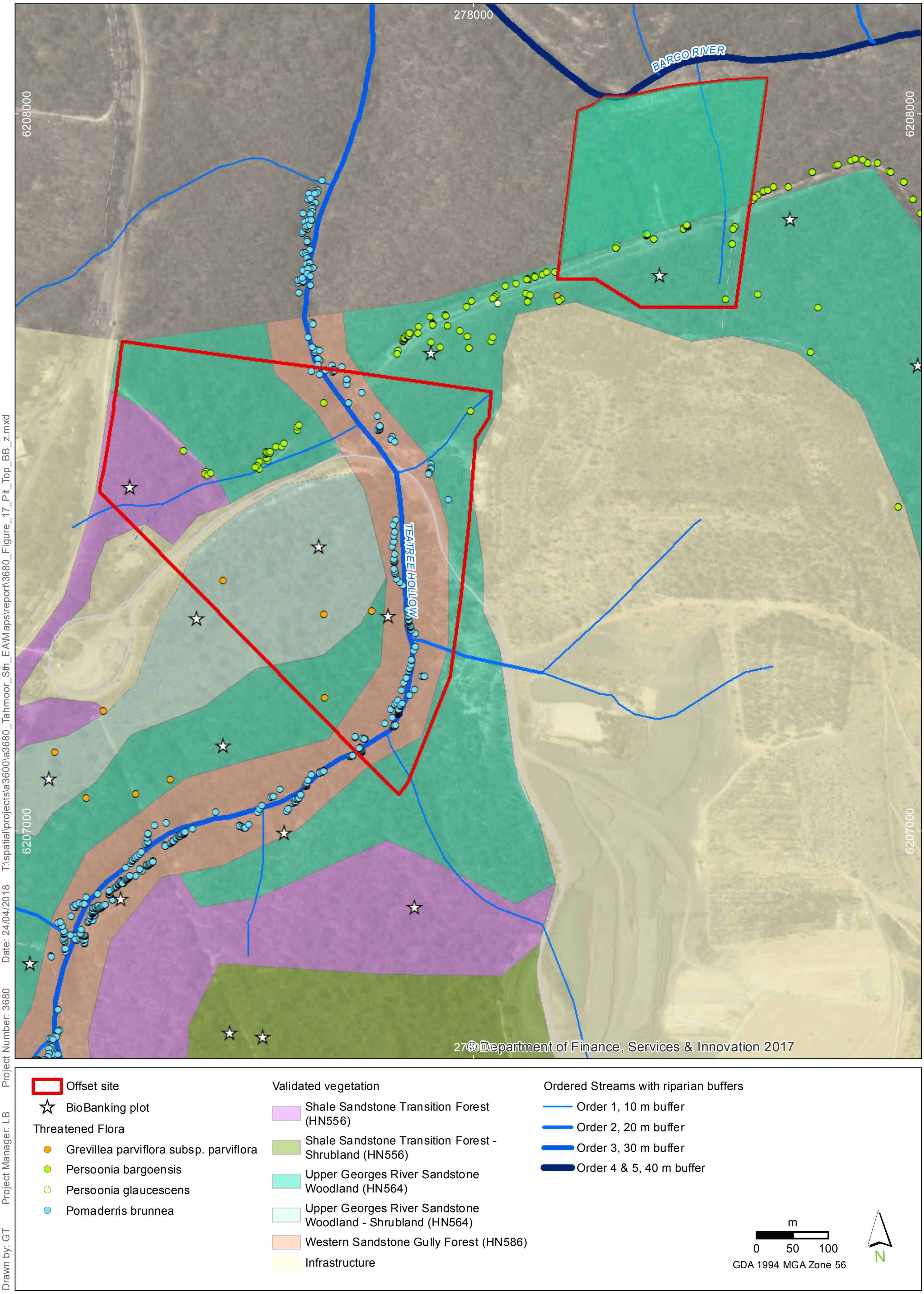
Pit Top Offset site

Tahmoor South Project Biodiversity Assessment Report

FIGURE 18

Imagery: (c) LPI 2013



Pit Top Offset site

Tahmoor South Project Biodiversity Assessment Report

FIGURE 19

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Imagery: (c) LPI

11.4.2 Proposed Rockford Road offset site

The proposed Rockford Road offset site occurs immediately to the north-east of the REA within land owned by Tahmoor Coal. Mining has previously been undertaken beneath the location of the proposed offset site and would require signing off internally to remove the mining lease over the portion containing the offset site (Figure 20).

The offset area consists of native vegetation which is part of a corridor of native vegetation which extends along the Bargo River.

Overall, the condition of vegetation across the offset area was in relatively good condition, with all stratum layers intact and minimal weeds. Weeds tended to occur adjacent to the existing paddock areas.

Landscape assessment

The offset area occurs within the Hawkesbury Nepean IBRA region, and within the Cumberland IBRA subregion (Figure 21). This is the same IRBA region, and IBRA subregion as the Project.

One Mitchell landscape occurs across the study area: Picton Razorback Hills, which is also the same as the Project (Figure 21).

GIS interrogation was used to determine the vegetation cover percentage as provided in Table 32

Table 32. Native vegetation cover at the proposed Rockford Road offset area

Native vegetation cover class (%)			
Before offset		After offset	
1,000 ha	100 ha	1,000 ha	100 ha
71-75%	81-85%	71-75%	81-85%

Connectivity

The proposed offset site occurs on one side of a 4th order stream (Bargo River). This was therefore entered into the BBCC.

Landscape score calculation

The landscape assessment resulted in a Landscape Score of 24.0 after a patch size of 2,000 hectares was entered for all of the vegetation zones.

Assessing native vegetation at the offset area

The vegetation of the offset site was validated during a site visit to the site on the 24th July 2014. Plot data from the site visit has been used for this assessment. Additional plot data would be collected when finalising the offset site as there was a two plot shortfall for both HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum, and HN586 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest in gullies. We do not anticipate the credits would change significantly.

Vegetation recorded during the survey included the following vegetation types:

- HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin
- HN586 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest in gullies of western Sydney, Sydney Basin sandstone.

The vegetation categories along with equivalent PCT (and reference codes), Keith Class, Keith Formation, is provided in Table 33, and a description of each community provided below.

HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest

HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest, occurred throughout the flatter terrain of the proposed offset site. This community consisted was of an open forest structure, comprising of canopy species: *Eucalyptus punctata, E. fibrosa,* and *E. eugenioides*. The shrub layer contained *Acacia parramattensis, Kunzea ambigua, Persoonia linearis, Melaleuca thymifolia,* and *Ozothamnus diosmifolius*. The grass layer was quite diverse and included: *Anisopogon avenaceus, Aristida ramosa, Aristida vagans, Entolasia stricta, Eragrostis brownii, Microlaena stipoides* and *Themeda australis.*

This vegetation community aligned to Shale Sandstone Transition Forest under both the BC Act and EPBC Act given the presence of diagnostic species for the TEC.

HN586 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest in gullies of western Sydney, Sydney Basin sandstone

This vegetation community occurs within the gullies of the proposed offset site. Dominant species of the community include the following canopy species: *Corymbia gummifera, Eucalyptus eugenioides, Eucalyptus piperita, Eucalyptus racemosa* and *Allocasuarina littoralis*. The shrub layer consisted of: *Acacia terminalis, Banksia spinulosa var. spinulosa, Hakea sericea, Hovea purpurea, Kunzea ambigua, Persoonia linearis, Platysace linearifolia, Leptospermum trinervium* and *Xanthosia pilosa*. The ground layer comprised: *Cyathochaeta diandra, Entolasia stricta, Billardiera scandens, Cheilanthes sieberi, Lepidosperma laterale, Phyllanthus hirtellus, Pomax umbellata, Pteridium esculentum* and *Xanthosia tridentata*.

Table 33. Vegetation zones mapped in Rockford Road offset area

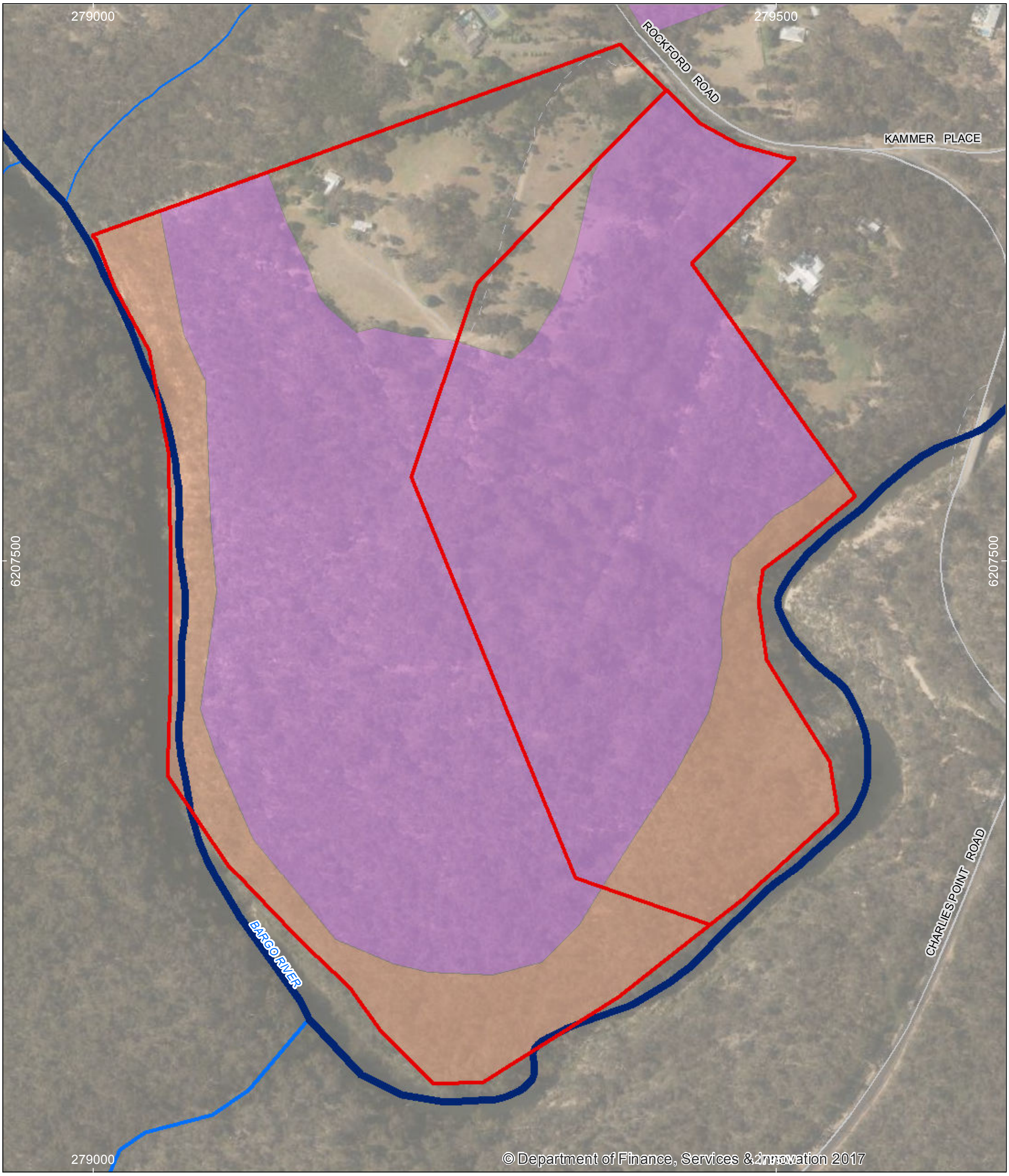
Vegetation community	Plant Community Type (PCT)	Formation	Class	Condition	Area
Shale Sandstone Transition Forest	HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin	Dry Sclerophyll Forests (Shrub/grass subformation)	Cumberland Dry Sclerophyll Forests	Moderate/ Good	20.4
Hinterland Sandstone Gully Forest	HN586 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest in gullies of western Sydney, Sydney Basin sandstone	Dry Sclerophyll Forests (Shrubby subformation)	Sydney Coastal Dry Sclerophyll Forests	Moderate/ Good	4.2
Total					**24.6**

Credits generated at the Rockford Road offset site

The credits that may be generated at the Rockford Road offset site include those provided in Table 34.

Table 34. Ecosystem credits generated at the Rockford Road offset site

Veg code	Vegetation name	Manage-ment zone	Manag-ement zone area (ha)	LandScape Value score	Current site value	Future site value	Gain in site value	Averted loss in site value	Number of ecosystem credits created
HN556	Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion	1	20.4	24.00	75.85	91.06	15.21	7.37	**238**
HN586	Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney, Sydney Basin Bioregion	2	4.2	24.00	69.81	85.99	16.18	6.16	**49**



Offset site
Shale Sandstone Transition Forest (HN556)
Western Sandstone Gully Forest (HN586)

Ordered Streams with riparian buffers
Order 1, 10 m buffer
Order 2, 20 m buffer
Order 4 & 5, 40 m buffer

m
0 20 40 60 80
GDA 1994 MGA Zone 56
N

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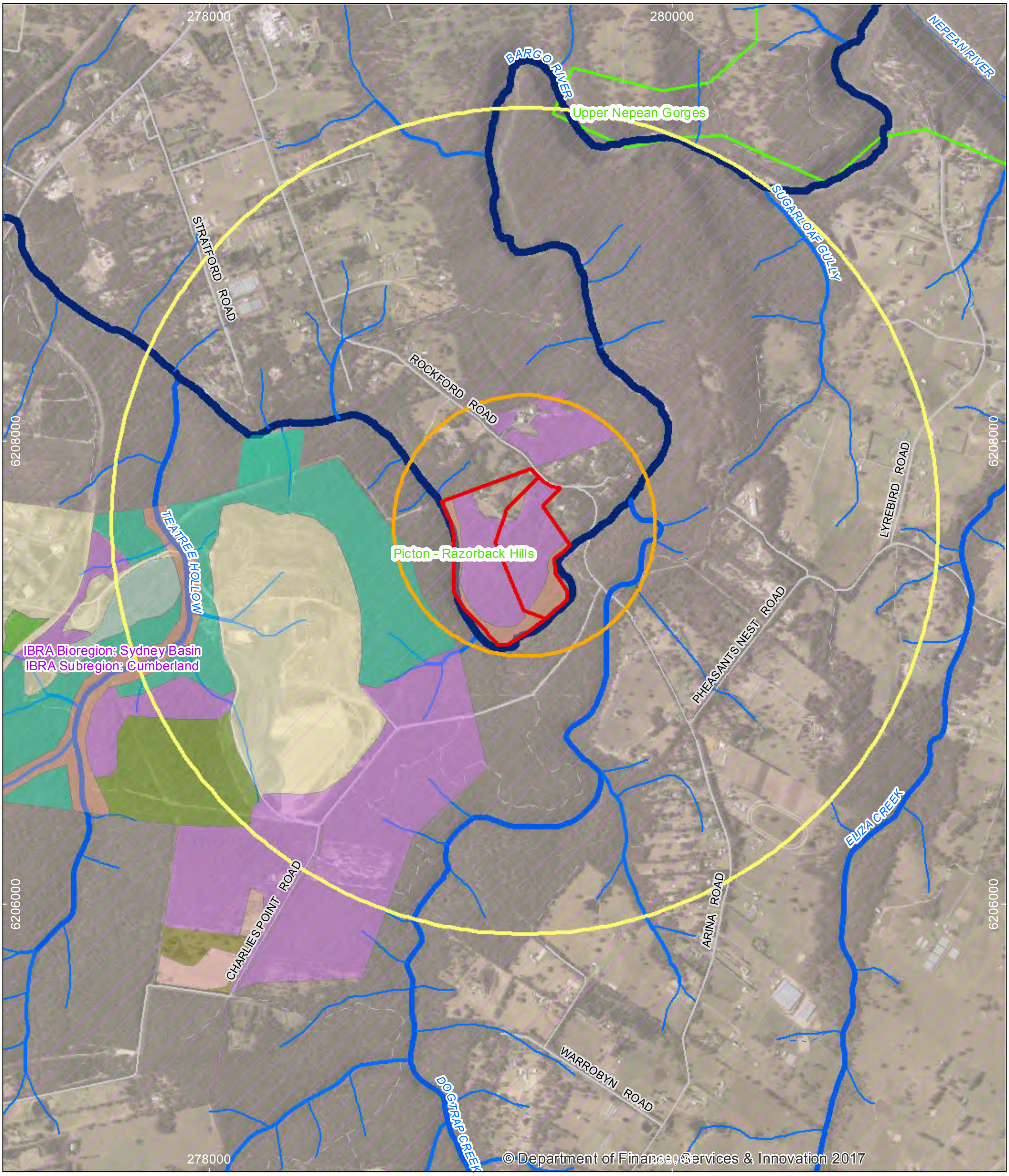
Rockford Road Offset site

Tahmoor South Project Biodiversity Assessment Report

FIGURE 20

Imagery: (c) LPI 2013



Project Number: 3680 Date: 24/04/2018 T:\spatial\projects\a3600\a3680_Tahmoor_Sth_EA\Maps\report\3680_Figure_20_Rockford_BB.mxd

- 100 ha assessment circle
- 1000 ha assessment circle
- Offset site
- Mitchell Landscape
- IBRA7 Bioregions

Validated vegetation

- Shale Sandstone Transition Forest (HN556)
- Shale Sandstone Transition Forest - Shrubland (HN556)
- Shale Sandstone Transition Forest - Regenerating (HN556)
- Upper Georges River Sandstone Woodland (HN564)
- Upper Georges River Sandstone Woodland - Shrubland (HN564)
- Western Sandstone Gully Forest (HN586)
- Planted - revegetated
- Exotic Pasture
- Infrastructure

Ordered Streams with riparian buffers

- Order 1, 10 m buffer
- Order 2, 20 m buffer
- Order 3, 30 m buffer
- Order 4 & 5, 40 m buffer

m
0 200 400
GDA 1994 MGA Zone 56
N

Drawn by: GT Project Manager: LB

Rockford Road Offset site

Tahmoor South Project Biodiversity Assessment Report

FIGURE 21

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Imagery: (c) LPI 201

11.4.3 Proposed Ventshaft No 2. offset site

The proposed Ventshaft No. 2 offset site occurs immediately to the north-east of the REA within land owned by Tahmoor Coal (Figure 22). The positioning of the proposed offset site occurs around the existing ventilation shaft No 2. Infrastructure, and would require signing off internally to remove the mining lease over the portion containing the offset site.

Overall, the condition of vegetation across the offset area was in relatively good condition with all stratum layers intact and minimal weeds. Weeds tended to occur adjacent to the existing fenceline.

Landscape Assessment

The offset area occurs within the Hawkesbury Nepean IBRA region, and within the Cumberland IBRA subregion (Figure 23). This is the same IRBA region, and IBRA subregion as the Project.

One Mitchell landscape occurs across the study area: Picton Razorback Hills, which is also the same as the Project (Figure 23).

GIS interrogation was used to determine the vegetation cover percentage as provided in Table 35.

Table 35. Native vegetation cover at the proposed Ventshaft No. 2 offset area

Native vegetation cover class (%)			
Before offset		After offset	
1,000 ha	100 ha	1,000 ha	100 ha
71-75%	81-85%	71-75%	81-85%

Connectivity

The proposed offset site does not occur within a strategic location as defined in the BBAM.

Therefore, an assessment of the primary connecting link (i.e. connectivity width and condition) is required as per the requirement of the BBAM. The assessment has indicated that there would be no change in connectivity due to the establishment in the offset. The limiting connectivity width is 30 to 100 metres and is within a benchmark condition.

Landscape score calculation

The landscape assessment resulted in a Landscape Score of 12.0 after a patch size of 2,000 hectares was entered for all of the vegetation zones.

Assessing native vegetation at the offset area

The vegetation of the offset site was validated during the current assessment on the 21st September 2017. This entailed the collection of four plots/transects and a random meander for threatened flora. All threatened flora observed were recorded with a handheld GPS and counted.

Vegetation recorded during the survey included HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin.

The vegetation along with equivalent PCT (and reference codes), Keith Class, Keith Formation, is provided in Table 36.

HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest

HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest, occurred throughout the flatter terrain of the proposed offset site. This community consisted was of an open forest structure, comprising of canopy species: *Eucalyptus punctata, E. fibrosa,* and *E. eugenioides*. The shrub layer contained *Acacia parramattensis, Kunzea ambigua, Persoonia linearis, Melaleuca thymifolia,* and *Ozothamnus diosmifolius.* The grass layer was quite diverse and included: *Anisopogon avenaceus, Aristida ramosa, Aristida vagans, Entolasia stricta, Eragrostis brownii*, *Microlaena stipoides* and *Themeda australis.*

This vegetation community aligned to Shale Sandstone Transition Forest under both the TSC Act and EPBC Act given the presence of diagnostic species for the TEC.

Threatened flora survey

During the field survey, the location of threatened flora encountered was recorded with a handheld GPS and all individuals counted. The following threatened flora were recorded within the proposed offset site:

- *Persoonia bargoensis*: 1 plant
- *Grevillea parviflora* subsp. *parviflora*: 20 plants.

Table 36. Vegetation zones mapped at the Ventshaft No. 2 offset area

Vegetation community	Plant Community Type (PCT)	Formation	Class	Condition	Area
Shale Sandstone Transition Forest	HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin	Dry Sclerophyll Forests (Shrub/grass subformation)	Cumberland Dry Sclerophyll Forests	Moderate/ Good	6.0
Total					**6.0**

Credits generated at the Ventshaft No. 2 offset site

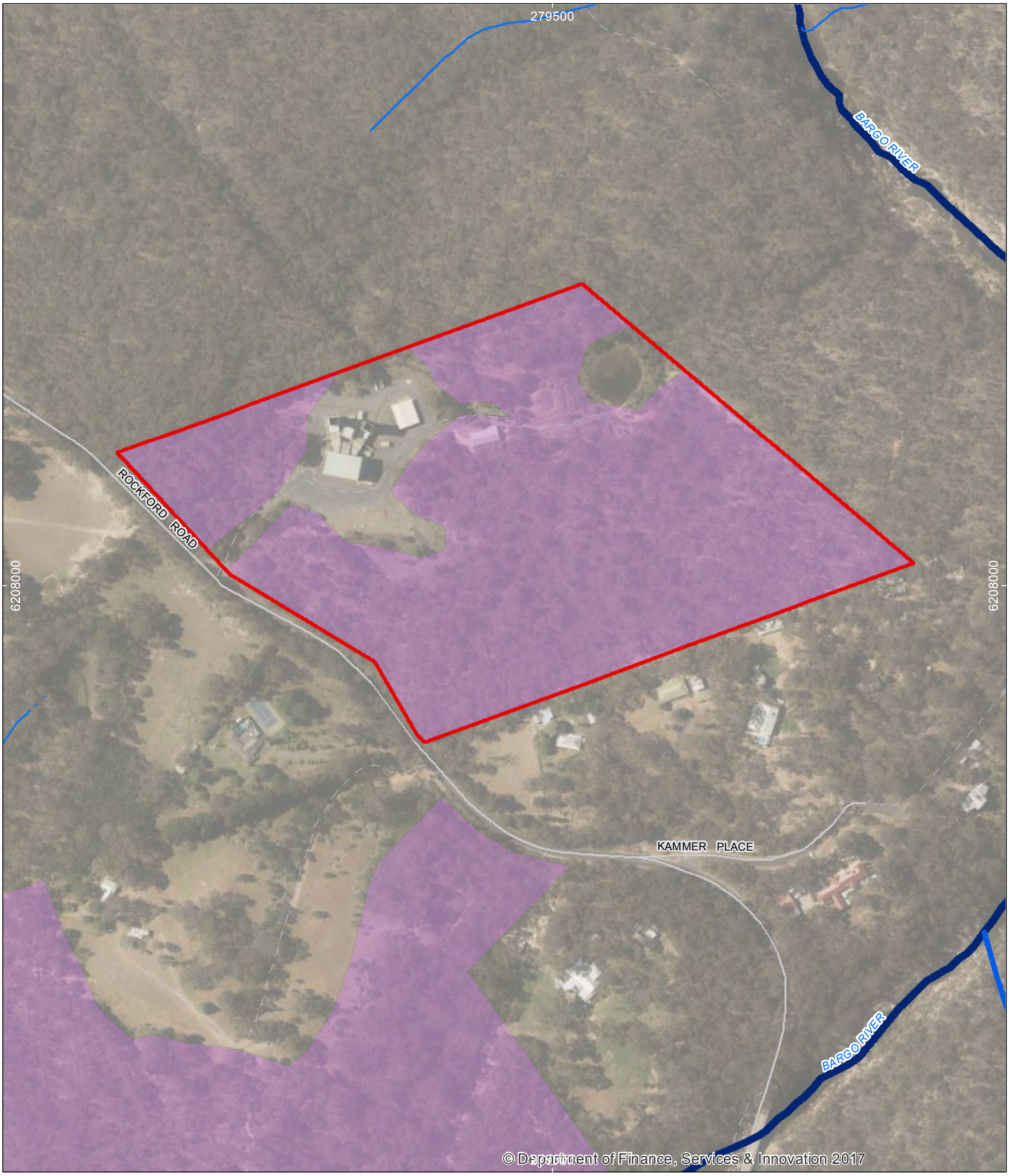
The credits that may be generated at the Ventshaft No. 2 offset site include those provided in Table 37.

Table 37. Ecosystem credits generated at the Ventshaft No. 2 offset site

Veg code	Vegetation name	Manage-ment zone	Manage-ment zone area (ha)	LandScape Value score	Current site value	Future site value	Gain in site value	Averted loss in site value	Number of ecosystem credits created
HN556	Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion	1	6	12.00	55.80	83.82	28.02	5.62	**68**

Table 38. Species credits generated at the Ventshaft No.2 offset site

Scientific name	Common name	Number of species credits created
Persoonia bargoensis	Bargo Geebung	**7**
Grevillea parviflora subsp. *supplicans*	*Grevillea parviflora* subsp. *parviflora*	**71**



Offset site

Shale Sandstone Transition Forest (HN556)

Ordered Streams with riparian buffers

- Order 1, 10 m buffer
- Order 3, 30 m buffer
- Order 4 & 5, 40 m buffer

m
0 20 40 60 80
GDA 1994 MGA Zone 56
N

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Vent Shaft No.2 Offset site

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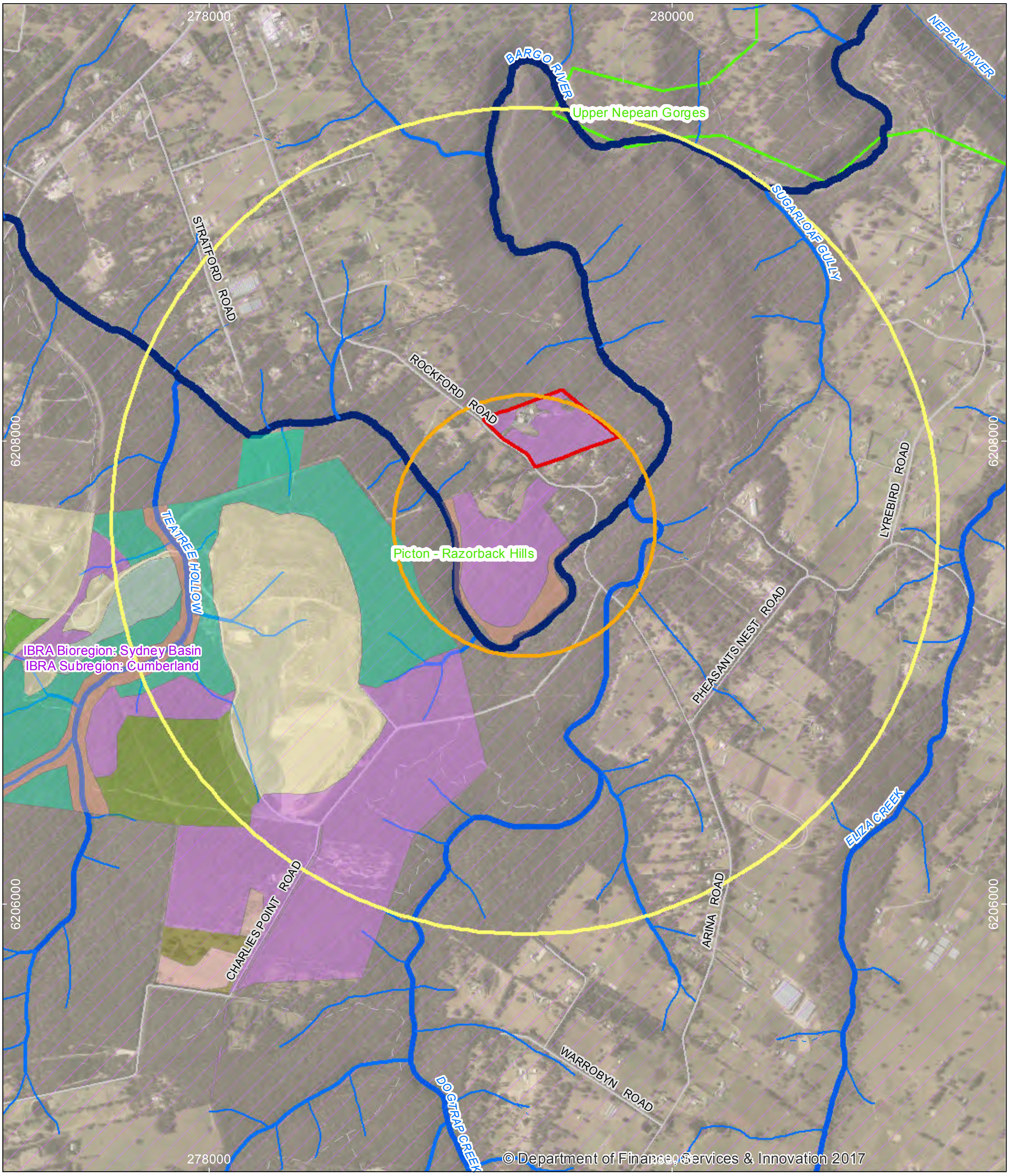
FIGURE 22

Imagery: (c) LPI 2013



100 ha assessment circle
1000 ha assessment circle
Offset site
Mitchell Landscape
IBRA7 Bioregions

Validated vegetation
Shale Sandstone Transition Forest (HN556)
Shale Sandstone Transition Forest - Shrubland (HN556)
Shale Sandstone Transition Forest - Regenerating (HN556)
Upper Georges River Sandstone Woodland (HN564)
Upper Georges River Sandstone Woodland - Shrubland (HN564)
Western Sandstone Gully Forest (HN586)
Planted - revegetated
Exotic Pasture
Infrastructure

Ordered Streams with riparian buffers
Order 1, 10 m buffer
Order 2, 20 m buffer
Order 3, 30 m buffer
Order 4 & 5, 40 m buffer

m
0 200 400
GDA 1994 MGA Zone 56
N

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Vent Shaft No.2 Offset site

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FIGURE 23

Imagery: (c) LPI 2013

11.4.4 Proposed Bargo Colliery offset site

The proposed Bargo Colliery offset site occurs to the immediate west of the Study Area, within land owned by Tahmoor Coal. It is located as two separate lots, comprising Lot 170 DP751250 and Lot 35 DP751250 (Figure 24).

The Bargo Colliery offset site is part of an extensive corridor of vegetation extending north along the Bargo River, west into Bargo State Conservation Area, and south into Upper Nepean State Conservation Area.

The size of the proposed offsite site is 276 hectares in area which contains a range of fauna habitat features.

Given there is a current mining lease on the site, it would require signing off internally to remove the mining lease over the portion containing the offset site.

Landscape assessment

The offset area occurs within the Hawkesbury Nepean IBRA region, and within the Burragorang IBRA subregion (Figure 25).

The Picton Razorback Hills Mitchell landscape occupies much of the proposed offset site and has therefore been entered into the BBCC.

GIS interrogation was used to determine the vegetation cover percentage as provided in Table 39.

Table 39. Native vegetation cover at the proposed Bargo Colliery offset area

Native vegetation cover class (%)			
Before offset		After offset	
1,000 ha	100 ha	1,000 ha	100 ha
91-95%	96-100%	91-95%	96-100%

Connectivity

The proposed offset site occurs on one side of a 4th/5th order stream (Hornes Creek). This was therefore entered into the BBCC.

Landscape score calculation

The landscape assessment resulted in a Landscape Score of 27.0 after a patch size of 2,000 hectares was entered for all of the vegetation zones.

Assessing native vegetation at the offset area

The vegetation of the offset site was validated during the current field survey from the 19th to 21st of September 2017. Plot data from the site visit has been used for this assessment.

Vegetation recorded during the survey included the following vegetation types within a moderate/good condition class:

- HN566 Red Bloodwood - scribbly gum heathy woodland on sandstone plateaux, Sydney Basin

- HN586 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest in gullies of western Sydney, Sydney Basin sandstone.

The vegetation communities along with equivalent PCT (and reference codes), Keith Class, Keith Formation, is provided in Table 40 and vegetation descriptions are provided below.

HN566 Red Bloodwood - scribbly gum heathy woodland on sandstone plateaux, Sydney Basin

This vegetation community occurs within flat and gentle terrain of the proposed offset site on sandy soils. Dominant species of the community included the following canopy species: *Eucalyptus sclerophylla, E. sparsifolia,* and *E. sieberi*. The shrub layer typically comprised *Kunzea ambigua, Lambertia formosa, Banksia spinulosa* var. *spinulosa, Hakea sericea, Persoonia linearis, Platysace linearifolia* and *Xylomelum pyriforme.* The ground layer comprised: *Phyllanthus hirtellus, Cyathochaeta diandra, Entolasia stricta, Anisopogon avenaceus* and *Lomandra obliqua.*

HN586 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest in gullies of western Sydney, Sydney Basin sandstone

This vegetation community occurs within the gullies of the proposed offset site. Dominant species of the community included the following canopy species: *Eucalyptus piperita, Eucalyptus racemosa* and *Allocasuarina littoralis*. The shrub layer consisted of *Acacia terminalis, Banksia spinulosa* var. *spinulosa, Hakea sericea, Persoonia linearis, Platysace linearifolia, Leptospermum trinervium* and *Xanthosia pilosa.* The ground layer comprised: *Phyllanthus hirtellus, Cyathochaeta diandra, Entolasia stricta, Billardiera scandens, Lepidosperma laterale, Pomax umbellata, Pteridium esculentum* and *Xanthosia tridentata.*

Table 40. Vegetation zones mapped in Bargo Colliery offset area

Vegetation community	Plant Community Type (PCT)	Formation	Class	Condition	Area
Coastal Sandstone Ridgetop Woodland	HN566 Red Bloodwood - scribbly gum heathy woodland on sandstone plateaux, Sydney Basin	Dry Sclerophyll Forests (Shrubby subformation)	Sydney Coastal Dry Sclerophyll Forests	Moderate/ Good	248.0
Hinterland Sandstone Gully Forest	HN586 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest in gullies of western Sydney, Sydney Basin sandstone	Dry Sclerophyll Forests (Shrubby subformation)	Sydney Coastal Dry Sclerophyll Forests	Moderate/ Good	19.8
Total					**270.0**

Assessing threatened flora at the offset area

The following threatened flora were recorded during the current survey within the proposed offset site:

- *Acacia bynoeana* = 32 plants
- *Grevillea parviflora* subsp. *parviflora* = 31,917 plants
- *Persoonia bargoensis* = 168 plants
- *P. glaucescens,* = 56 plants

- *P. hirsuta* = 145 plants
- *Pomaderris brunnea* = approximately 45 plants.

Given the large population of *Grevillea parviflora* subsp. *parviflora* present throughout the eastern portion of the proposed offset site, it was not possible to count each plant. As such, a population estimate was generated by undertaking the following:

- Traversing the disturbance area to determine the extent of the species and differential between core habitat and isolated occurrences.
- Where isolated individuals were encountered, their location was recorded with a handheld GPS and individuals counted.
- Where extensive clumps were located, these were also recorded with a GPS and flagged as being a part of the 'core' population.
- Within the core population area (covering and area of approximately 20 hectares), four transects (100 metres long by 15 metres wide – 0.15 hectares) were traversed with all individuals along the transect counted by two botanists.
- The count within the four traverses were then extrapolated to the area of 'core' habitat.

The results of the population count are provided in the Table 41, which conclude that a total of 31,917 *Grevillea parviflora* subsp. *parviflora* plants were estimated to occur within the 'core' habitat area.

Table 41. Grevillea parviflora subsp. parviflora population count

Transect		Transect start (AMG Zone56)	Transect end(AMG Zone56)	No. recorded per 0.15 ha
Transect 1	Core habitat	275990/ 6203117	276011/ 6203036	198
Transect 2	Core habitat	275763/ 6203112	275835/ 6203134	210
Transect 3	Core habitat	275896/ 6203691	275911/ 6203016	171
Transect 4	Core habitat	275780/ 6203058	275799/ 6202977	187
Total				**766**
Average per 0.15 ha				191.5 (1,277 plants per ha)
No. recorded within 25 ha of core habitat				**31,917 plants**

Assessing threatened fauna at the offset area

No targeted threatened fauna survey have been completed at the proposed offset site. However, given the records obtained by Bionet, it is highly likely that the site contains 270 hectares of Koala habitat. Furthermore, Hornes Creek occupies a length of over 1.5 kilometres throughout the site, and thus is highly likely to generate Large-footed Myotis credits due to the presence of foraging habitat, and Red-crowned Toadlet credits given the species is known to occur downstream of Hornes Creek.

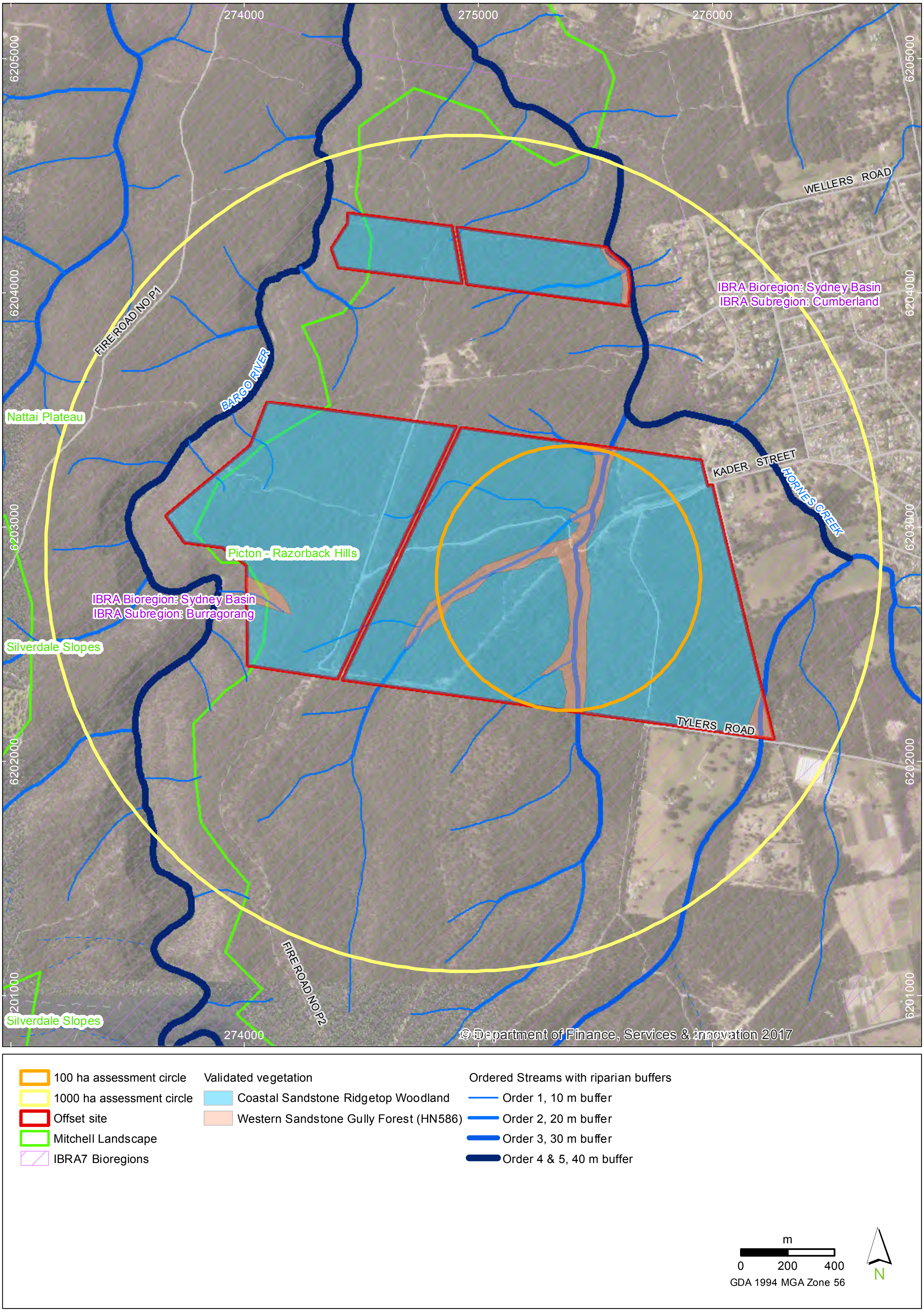
Credits generated at the Bargo Colliery offset site

Table 42. Ecosystem credits generated at the Bargo Colliery offset site

Veg code	Vegetation name	Manage-ment zone	Manage-ment zone area (ha)	LandScape Value score	Current site value	Future site value	Gain in site value	Averted loss in site value	Number of ecosystem credits created
HN566	Red Bloodwood - scribbly gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion	1	248	27.00	55.73	86.11	30.38	5.08	3,873
HN586	Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney, Sydney Basin Bioregion	2	19.8	27.00	68.60	84.30	15.70	6.16	242

Table 43. Species credits generated at the Bargo Colliery offset site

Scientific name	Common name	Number of species credits created
Persoonia bargoensis	Bargo Geebung	1,193
Pomaderris brunnea	Brown Pomaderris	320
Acacia bynoeana	Bynoe's Wattle	227
Persoonia hirsuta	Hairy Geebung	1,030
Persoonia glaucescens	Mittagong Geebung	398
Grevillea parviflora subsp. parviflora	Small-flower Grevillea	226,611
Pseudophryne australis	Red-crowned toadlet (based on approximately 2.7 ha)	19
Phascolarctos cinereus	Koala (based on 270 hectares of habitat)	1,917
Myotis macropus	Large-footed Myotis (based on 30 hectares of habitat – 200 metres buffer along Hornes Creek)	213



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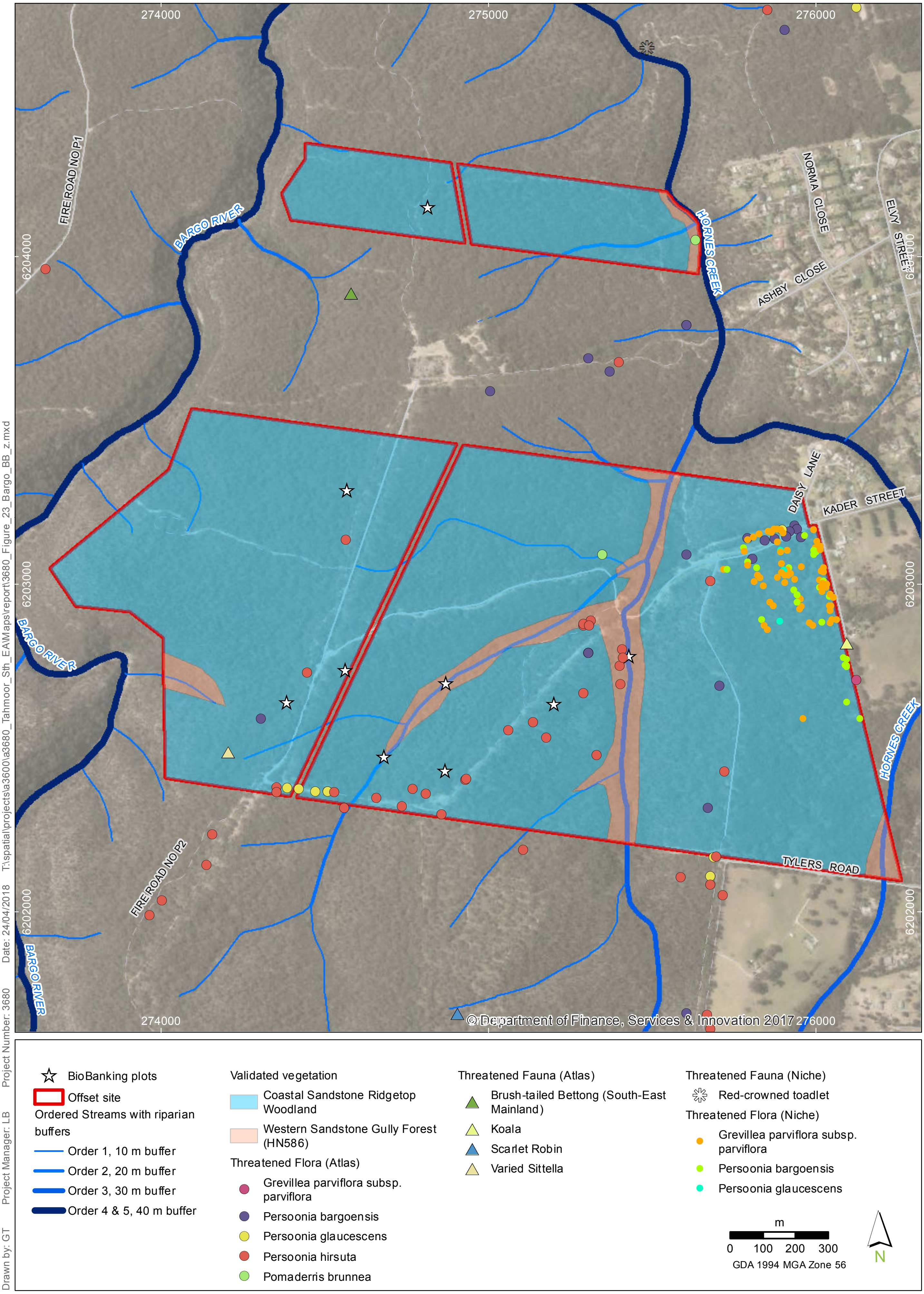
Bargo Colliery Offset site

Tahmoor South Project Biodiversity Assessment Report

FIGURE 24

Imagery: (c) LPI 2013



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Bargo Colliery Offset site

Tahmoor South Project Biodiversity Assessment Report

FIGURE 25

Imagery: (c) LPI 2013

11.4.5 Proposed Anthony Road offset site

The proposed Anthony Road offset site occurs within land owned by Tahmoor Coal. It is located as one Lot 245 DP751250 (Figure 26) occupying an area of 10.2 ha.

Given there is a current mining lease on the site, it would require signing off internally to remove the mining lease over the portion containing the offset site.

Landscape assessment

The offset area occurs within the Hawkesbury Nepean IBRA region, and within the Burragorang IBRA subregion (Figure 25).

The Picton Razorback Hills Mitchell landscape occupies much of the proposed offset site and has therefore been entered into the BBCC.

GIS interrogation was used to determine the vegetation cover percentage as provided in Table 39.

Table 44. Native vegetation cover at the proposed Anthony Road offset area

Native vegetation cover class (%)			
Before offset		After offset	
1,000 ha	100 ha	1,000 ha	100 ha
65-70%	70-75%	65-70%	70-75%

Connectivity

The proposed offset site does not occur within a riparian buffer. It would not increase the width of connecting link.

Landscape score calculation

The landscape assessment resulted in a Landscape Score of 12.0 after a patch size of 2,000 hectares was entered for all of the vegetation zones.

Assessing native vegetation at the offset area

The vegetation of the offset site was validated during the current field survey in 2013. Plot data from the site visit has been used for this assessment.

Vegetation recorded during the survey included the following condition classes of HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest.

Table 45. Vegetation zones mapped in Anthony Road offset area

Vegetation community	Plant Community Type (PCT)	Formation	Class	Condition	Area
Shale Sandstone Transition Forest	HN556 Narrow-leaved Ironbark - Broad-leaved	Dry Sclerophyll	Sydney Coastal	Regenerating	3.8

Vegetation community	Plant Community Type (PCT)	Formation	Class	Condition	Area
	Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin	Forests (Shrubby subformation)	Dry Sclerophyll Forests	Derived	2.4
Non-native	Non-native	-	-	-	3.9
Total					**10.1**

Assessing threatened flora at the offset area

No threatened flora occur at the offset site. However, should future surveys result in detected of threatened flora, then additional flora species credits may be applied for.

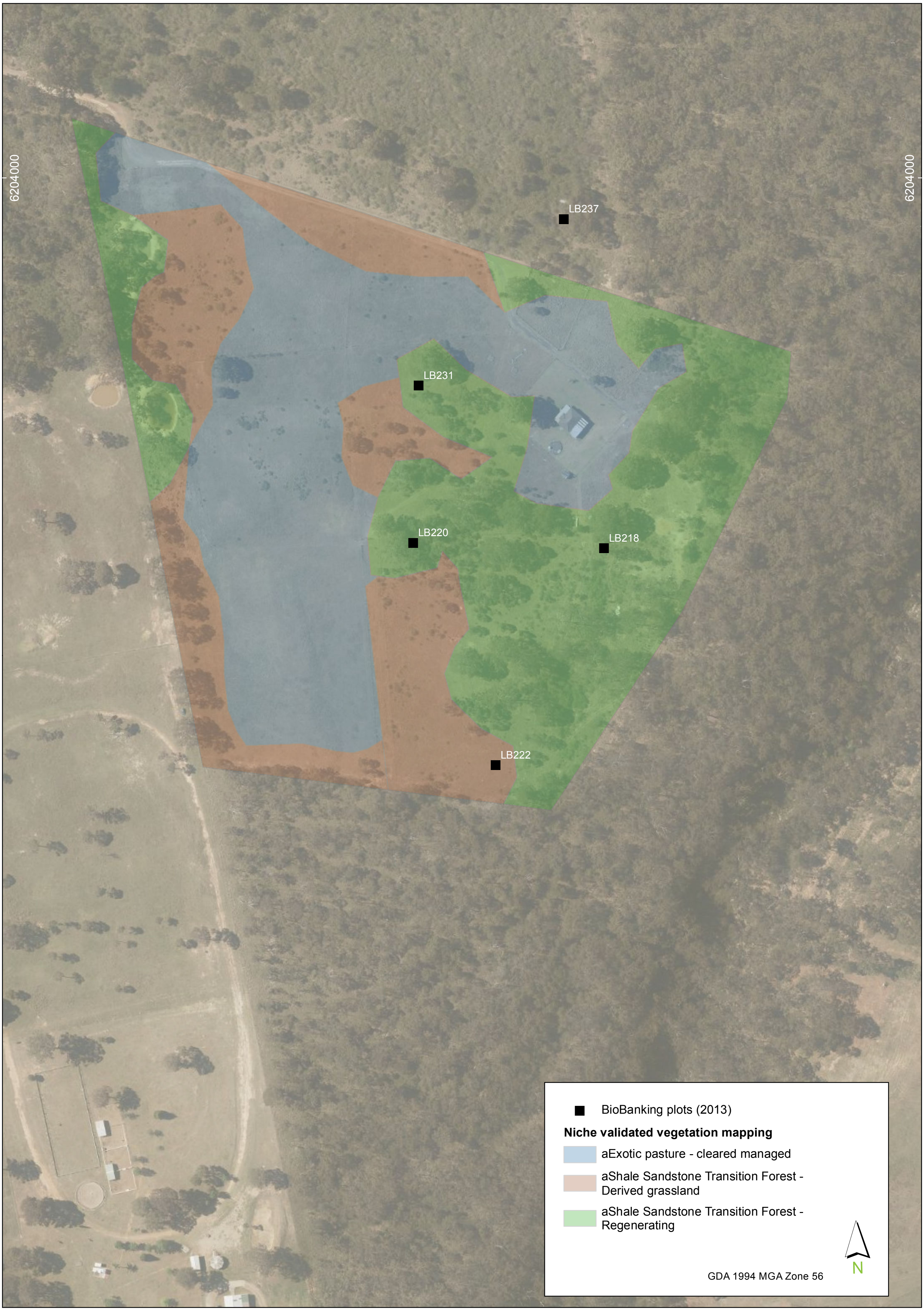
Assessing threatened fauna at the offset area

No targeted threatened fauna surveys have been completed at the proposed offset site. However, future surveys may result in threatened fauna generating species credits.

Credits generated at the Anthony Road offset site

Table 46. Ecosystem credits generated at the Anthony Road offset site

Veg code	Vegetation name	Manage-ment zone	Manage-ment zone area (ha)	LandScape Value score	Current site value	Future site value	Gain in site value	Averted loss in site value	Number of ecosystem credits created
HN556	Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion	1	3.8	12.00	55.80	83.82	28.02	5.62	43
HN556	Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion	2	2.4	12.00	32.85	57.49	24.64	3.14	24



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Proposed Anthony Road Offset Site

Tahmoor South Project Biodiversity Assessment Report

FIGURE 26

Imagery: (c) LPI 2013

11.5 Credits generated from proposed offsets

Details regarding the credits generated from the proposed offset sites, compared to that of the offset liability for the Project are provided in Table 47.

The credits that may be generated from the proposed offset sites, would satisfy the offset requirement for *Grevillea parviflora* subsp. *parviflora,* Koala and Large-footed Myotis.

However, there would be a shortfall for the following:

- Shortfall of 1,847 credits for HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion
- Shortfall of 45 credits for HN564 Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion
- Shortfall of 5,953 credits for *Persoonia bargoensis*.

In relation to stage 1 for the offset liability, the credits generated from the proposed offset would satisfy the offset requirement for *Grevillea parviflora* subsp. *parviflora,* Koala and Large-footed Myotis. However, there would be a shortfall for the following:

- Shortfall of 381 credits for HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion
- Shortfall of 5,645 credits for *Persoonia bargoensis.*

Tahmoor would explore a number of options for meeting the credit deficit in accordance with the requirements of the FBA. The options for approaching the credit deficit are discussed in sections 11.6 and 11.7.

Table 47. Credits generated from proposed offset sites compared to credit liability for the Project

Vegetation type	Proposed offset sites – with credits generated					Total credits generated	Credits required	Credit shortfall
	Pit Top	Rockford Road	Ventshaft No. 2	Bargo Colliery land	Anthony Road			
HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion	26	238	68	-	67	399	2,246	**1,847**
HN564 Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion	247	-	-	-	-	247	287	**40**
HN586 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney, Sydney Basin Bioregion	57	49	-	242	-	348	0	**0**
HN566 Red Bloodwood - scribbly gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion	-	-	-	3,873	-	3,873	0	**0**
Species credits								
Acacia bynoeana	-	-	-	227	-	227	0	**0**
Epacris purpurascens var. *purpurascens*	36	-	-	-	-	36	0	**0**
Grevillea parviflora subsp. *parviflora*	149	-	71	226,611	-	226,831	32,536	**0**
Persoonia bargoensis	547	-	7	1,193	-	1,747	7,700	**5,953**
Persoonia glaucescens	-	-	-	398	-	398	0	**0**
Persoonia hirsuta	-	-	-	1,030	-	1,030	0	**0**
Pomaderris brunnea	1,001	-	-	320	-	320	0	**0**
Large-footed Myotis	212	-	-	213	-	-	163	**0**
Red-crowned Toadlet	-	-	-	19	-	-	0	**0**
Koala	212	-	-	1,917	-	-	1,131	**0**
Cumberland Plain Land Snail	-	-	-	-	-	-	6	**6**

Table 48. Credits generated from proposed offset sites compared to credit liability for Stage 1

Vegetation type	Proposed offset sites – with credits generated					Total credits generated	Credits required for Stage 1 impact	Credit shortfall
	Pit Top	Rockford Road	Ventshaft No. 2	Bargo Colliery land	Anthony Road			
HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion	26	238	68	-	67	399	780	**381**
HN564 Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion	247	-	-	-		247	0	**0**
Species credits								
Grevillea parviflora subsp. *parviflora*	149	-	71	226,611	-	226,831	32,536	**0**
Persoonia bargoensis	547	-	7	1,193	-	1,747	7,392	**5,645**
Koala	212	-	-	1,917	-	-	403	**0**

11.6 Purchase of credits available on the public register

Tahmoor Coal would purchase the shortfall, or the entire offset liability, should it become available on the Biodiversity credit market.

In order to satisfy the Commonwealth offset requirement for Shale Sandstone Transition Forest, only credits that meet the threshold criteria for the TEC as defined in the EPBC Act Approved Conservation Advice (including listing advice) for Shale Sandstone Transition Forest of the Sydney Basin Bioregion, would be purchased.

11.7 Payment into the Biodiversity Conservation Trust Fund (BCT)

Tahmoor Coal, through consultation with OEH and DoEE would seek the opportunity to pay into the Biodiversity Conservation Trust Fund to satisfy the offset for the Project.

11.8 The final Biodiversity Offset Package

The current investigation demonstrates the ecosystem credit availability within Tahmoor Coal's landholdings, and the process by which Tahmoor Coal would satisfy the offset liability.

The formalisation of the proposed sites to a Biodiversity Stewardship Agreement site, and the purchasing of credits/payment into the fund would occur following approval, and would be progressive in two stages to match the impact to vegetation and threatened flora throughout the life of the mine.

Following Project approval, the following tasks would be completed by Tahmoor Coal:

1. Purchase of credits that are available on the public register. Note that the credits purchased to satisfy the Shale Sandstone Transition Forest requirement would meet the EPBC listing criteria.
2. Final layout of offset areas to be defined by Tahmoor Coal and formally established as a Biodiversity Stewardship Agreement site.
3. Consultation with OEH regarding the establishment of Biodiversity Stewardship Agreement sites, application and management actions.
4. If required - seek variation criteria through consultation with OEH and DoEE.
5. Optional - Payment into the Biodiversity Conservation Trust Fund through consultation with OEH and DoEE.

12. Conclusion

This report provides a biodiversity assessment to address the potential impacts associated with the Project.

The Project will result in the disturbance of 49.2 hectares of native vegetation and potential for subsidence related impacts. Indirect impacts may include dust, noise, erosion and sedimentation which will be mitigated by measures provided in section 9.3 of this report.

During the field survey one TEC – Shale Sandstone Transition Forest was found to occur within the Study Area. Three condition classes were attributed to the TEC. The Project will result in disturbance to approximately 43.4 hectares of the TEC listed under the BC Act and EPBC Act. This TEC would be offset according to the requirements of the FBA.

The Project would result in the following impacts to threatened flora:

- Removal of 100 individuals of *Persoonia bargoensis*
- Removal of an estimated 2,324 individuals of *Grevillea parviflora* subsp. *parviflora.*

In terms of species credit fauna, this assessment has identified impacts to the following:

- Removal of 43.5 hectares of potential Koala habitat
- Removal of 7.4 hectares of Large-footed Myotis habitat.

This assessment concludes that threatened flora or species credit fauna are unlikely to be impacted by subsidence associated with the Project.

Mitigation measures associated with indirect impacts have been proposed through the revision and implementation of new and existing management plans.

The Ecosystem credits required to offset the Project equate to the following:

- 2,246 credits for the impacts to HN556 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion
- 287 credits for the impacts to Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion.

The Species credits required to offset the Project equate to the following:

- 7,700 credits for the removal of 100 *Persoonia bargoensis* plants
- 32,536 credits for the removal of 2,324 *Grevillea parviflora* subsp. *parviflora* plants.
- 163 credits for the removal of 7.4 hectares of Large-footed Myotis habitat.
- 1,131 credits for the removal of 43.5 hectares of potential Koala habitat

Tahmoor Coal propose to undertake a combination of the following offset mechanisms to offset the Project:

1. Establishment of Biodiversity Stewardship Agreement sites within Tahmoor Coal landholdings
2. Purchase of the required credits available on the Public Register
3. Payment into the NSW Biodiversity Conservation Trust Fund.

Given vegetation clearing would be progressive, and would not all occur within the first few years of project commencement, Tahmoor Coal has proposed that the offsets for the project be in two stages, to match the timing of the vegetation clearing and/or threatened flora being impacted.

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Appendix 1. Likelihood of occurrence of threatened flora and fauna within the Study Area

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Flora						
Acacia bynoeana Bynoe's Wattle	*A. bynoeana* occurs mainly in heath and dry sclerophyll forest (Morrison & Davies 1991). The substrate is typically sand and sandy clay, often with ironstone gravels and is usually very infertile and well-drained. The species seems to prefer open, sometimes slightly disturbed sites such as trail margins, edges of roadside spoil mounds.	**NSW:** Vulnerable **Commonwealth:** Vulnerable	Known	Moderate	There are known records for this species within the Study Area. Despite extensive surveys this species was not recorded within the surface works development footprint but habitat for this species does occur within this area. This species does not occur within and/or is not likely to be reliant on the vegetation communities or habitats that may be adversely impacted by subsidence.	Species
Acacia flocktoniae	Grows in dry sclerophyll forest on sandstone. The Flockton Wattle is found only in the Southern Blue Mountains (at Mt Victoria, Megalong Valley and Yerranderie).	**NSW:** Vulnerable **Commonwealth:** Vulnerable	Low	Low	No previous records in Study Area or locality. Not detected during field survey. Not considered further.	Species
Acacia gordonii	Restricted to the north-west of Sydney, it has a disjunct distribution occurring in the lower Blue Mountains in the west, and in the Maroota/Glenorie area in the east. This species is known from only a few locations and current information suggests the total number of individuals may be less than 2000, with only one population supporting greater than 400 individuals. A relatively large proportion of individuals (approximately 850) occur on conservation reserve within Blue Mountains National Park. This species is found within the Hawkesbury, Blue Mountains and Baulkham Hills local government areas.	**NSW:** Endangered **Commonwealth:** Endangered	Low	Low	No previous records in Study Area or locality. Not detected during field survey. Not considered further.	Species

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Acacia pubescens	Concentrated around the Bankstown-Fairfield-Rookwood area and the Pitt Town area, with outliers occurring at Barden Ridge, Oakdale and Mountain Lagoon.	**NSW:** Vulnerable **Commonwealth:** Vulnerable	Low	Low	No previous records in Study Area or locality. Not detected during field survey. Not considered further.	Species
Allocasuarina glareicola	This species is restricted to a few small populations in and around Castlereagh, north-east of Penrith, NSW.	**NSW:** Endangered **Commonwealth:** Endangered	Low	Low	No previous records in Study Area or locality. Not detected during field survey. Not considered further.	Species
Asterolasia elegans	Occurs north of Sydney, in the Baulkham Hills, Hawkesbury and Hornsby local government areas. Also likely to occur in the western part of Gosford local government area. Known from only seven populations, only one of which is wholly within a conservation reserve.	**NSW:** Endangered **Commonwealth:** Endangered	Low	Low	No previous records in Study Area or locality. Not detected during field survey. Not considered further.	Species Species
Caladenia tesselata Tessellated Spider Orchid	The Tessellated Spider Orchid is found in grassy sclerophyll woodland on clay loam or sandy soils, though the population near Braidwood is in low woodland with stony soil. Known from the Sydney area (old records), Wyong, Ulladulla and Braidwood in NSW. Populations in Kiama and Queanbeyan are presumed extinct.	**NSW:** Endangered **Commonwealth:** Vulnerable	Low	Low	No previous records in Study Area or locality. Unlikely to be present due to lack of potential habitat. Not considered further.	Species
Commersonia prostrata Dwarf Kerrawang	Occurs on sandy, sometimes peaty soils in a wide variety of habitats: Snow gum woodland at Rose Lagoon; Blue-leaved Stringybark open forest at Tallong; and in Brittle Gum low open woodland at Penrose; Scribbly Gum - Swamp Mahogany ecotonal forest at Tomago.	**NSW:** Endangered **Commonwealth:** Endangered	Low	Low	No previous records in Study Area or locality. Unlikely to be present due to lack of potential habitat. Not considered further.	Species

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Cryptostylis hunteriana Leafless Tongue Orchid	Grows in swamp-heath on sandy soils, chiefly in coastal districts, south from the Gibraltar Range.	**NSW:** Vulnerable **Commonwealth:** Vulnerable	Low	Low	No previous records in Study Area or locality. Unlikely to be present due to lack of potential habitat. Not considered further.	Species
Cynanchum elegans White-flowered Wax Plant	Recorded from rainforest gullies scrub and steep slopes from the Gloucester district to the Wollongong area and inland to Mt Dangar.	**NSW:** Endangered **Commonwealth:** Endangered	Low	Low	No previous records in Study Area or locality. Unlikely to be present due to lack of potential habitat. Not considered further.	Species
Darwinia biflora	Recorded in Ku-ring-gai, Hornsby, Baulkham Hills and Ryde local government areas. The northern, southern, eastern and western limits of the range are at Maroota, North Ryde, Cowan and Kellyville, respectively. Occurs on the edges of weathered shale-capped ridges, where these intergrade with Hawkesbury Sandstone. The vegetation structure is usually woodland, open forest or scrub-heath.	**NSW:** Vulnerable **Commonwealth:** Vulnerable	Low	Low	No previous records in Study Area or locality. Unlikely to be present due to lack of potential habitat. Not considered further.	Species
Darwinia peduncularis	Occurs as local disjunct populations in coastal NSW with a couple of isolated populations in the Blue Mountains. It has been recorded from Brooklyn, Berowra, Galston Gorge, Hornsby, Bargo River, Glen Davis, Mount Boonbourwa and Kings Tableland. Usually grows on or near rocky outcrops on sandy, well drained, low nutrient soil over sandstone.	**NSW:** Vulnerable **Commonwealth:** Not listed	Low	Low	No previous records in Study Area or locality. Not detected during field survey. Not considered further.	Species
Dillwynia tenuifolia population	The core distribution is the Cumberland Plain from Windsor and Penrith east to Dean Park near Colebee. Other populations in western Sydney are recorded from Voyager Point and Kemps Creek in the Liverpool LGA, Luddenham in the Penrith LGA and South Maroota in the Baulkham Hills Shire. Disjunct localities outside the Cumberland Plain include the Bulga Mountains at Yengo in the north, and Kurrajong Heights and Woodford in the Lower Blue Mountains.	**NSW:** Endangered population **Commonwealth:** Not listed	None	None	Not considered – located outside of Study Area	Species

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Epacris purpurascens var. purpurascens	Found in a range of habitat types, most of which have a strong shale soil influence. Recorded from Gosford in the north, to Narrabeen in the east, Silverdale in the west and Avon Dam vicinity in the south.	**NSW:** Vulnerable **Commonwealth:** Not listed	Known	Known	Individuals of *Epacris purpurascens* var. *purpurascens* have been recorded within the Study Area.	Species
Eucalyptus camfieldii Heart-leaved Stringybark	Restricted distribution in a narrow band with the most northerly records in the Raymond Terrace Area south to Waterfall. Poor coastal country in shallow sandy soils overlying Hawkesbury sandstone. Coastal heath mostly on exposed sandy ridges. Occurs mostly in small scattered stands near the boundary of tall coastal heaths and low open woodland of the slightly more fertile inland areas.	**NSW:** Vulnerable **Commonwealth:** Vulnerable	Low	Low	No previous records in Study Area or locality. Unlikely to be present due to lack of potential habitat. Not considered further.	Species
Eucalyptus sp. cattai	Occurs in the area between Colo Heights and Castle Hill, northwestern Sydney, with historical records from central Sydney. Occurs as a rare emergent tree in scrub, heath and low woodland on sandy soils, usually as isolated individuals or occasionally in small clustered groups. The sites at which it occurs are generally flat and on ridge tops. Associated soils are laterised clays overlying sandstone. There are no known populations occur in conservation reserves.	**NSW:** Vulnerable **Commonwealth:** Vulnerable	None	None	No previous records in Study Area or locality. Unlikely to be present due to lack of potential habitat. Not considered further.	Species
Genoplesium baueri	Grows in sparse sclerophyll forest and moss gardens over sandstone. The species has been recorded from locations between Ulladulla and Port Stephens.	**NSW:** Vulnerable **Commonwealth:** Not listed	Low	Low	No previous records in Study Area or locality. Unlikely to be present due to lack of potential habitat. Not considered further.	Species

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Grevillea parviflora subsp. *parviflora* Small-flower Grevillea	Grows in sandy or light clay soils usually over thin shales. Occurs in a range of vegetation types from heath and shrubby woodland to open forest. Often occurs in open, slightly disturbed sites such as along tracks. Sporadically distributed throughout the Sydney Basin with the main occurrence centred on Picton, Appin and Bargo (and possibly further south to the Moss Vale area).	**NSW:** Vulnerable **Commonwealth:** Vulnerable	Known	Known	There are known records for this species within the Study Area. This species does not occur within and/or is not likely to be reliant on the vegetation communities or habitats that may be adversely impacted by subsidence.	Species
Haloragis exalata subsp. Exalata Square Raspwort	Occurs in 4 widely scattered localities in eastern NSW. It is disjunctly distributed in the central coast, south coast and north-western slopes botanical subdivisions of NSW. The species appears to require protected and shaded damp situations in riparian habitats.	**NSW:** Vulnerable **Commonwealth:** Vulnerable	Low	Low	No previous records in Study Area or locality. Unlikely to be present due to lack of potential habitat. Not considered further.	Species
Hibbertia superans	Occurs from Baulkham Hills to South Maroota in the northern outskirts of Sydney, where there are currently 16 known sites, and at one locality at Mount Boss, inland from Kempsey. No populations are known from a formal conservation reserve.	**NSW:** Endangered **Commonwealth:** **Not listed**	None	None	No previous records in Study Area or locality. Unlikely to be present due to lack of potential habitat. Not considered further.	Species
Lasiopetalum joyceae	The species has a restricted range occurring on lateritic to shaley ridgetops on the Hornsby Plateau south of the Hawkesbury River. It is currently known from 34 sites between Berrilee and Duffys Forest. Seventeen of these are reserved, though many are situated at the reserve edge and subject to subsequent edge effects such as nutrient enrichment and weed encroachment.	**NSW:** Vulnerable **Commonwealth:** **Not listed**	None	None	No previous records in Study Area or locality. Unlikely to be present due to lack of potential habitat. Not considered further.	Species

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Leucopogon exolasius Woronora Beard-heath	The Woronora Beard-heath is restricted to Woronora and Grose Rivers (in the Blue Mountains), Stokes Creek and Georges River. It is found in the Holsworthy Military Reserve and in Heathcote and Royal National Parks (Commonwealth land). The species is endemic to the Sydney region and central coast of New South Wales (NSW) occurring within the Sydney Metro and Hawkesbury-Nepean Natural Resource Management Regions. The Woronora Beard-heath inhabits woodland on sandstone (and sandy alluvium) and prefers rocky hillsides along creek banks.	**NSW:** Vulnerable **Commonwealth:** Vulnerable	Low	Low	Despite extensive surveys this species was not recorded within the surface facility development footprint nor along the creeklines of the Study Area.	Species
Leucopogon fletcheri subsp. fletcheri	Restricted to north-western Sydney between St Albans in the north and Annangrove in the south, within the local government areas of Hawkesbury, Baulkham Hills and Blue Mountains. Occurs in dry eucalypt woodland or in shrubland on clayey lateritic soils, generally on flat to gently sloping terrain along ridges and spurs. Flowers August to September. Fruit produced October. Evidence suggests the species responds slowly to fire. The species is an obligate seeder and slow growing with a maturation period likely to exceed 5 years.	**NSW:** Endangered **Commonwealth:** Not listed	None	None	No previous records in Study Area. Not detected during field survey. Study Area not within known habitat. Not considered further.	Species
Marsdenia viridiflora subsp. viridiflora - endangered population	Recent records are from Prospect, Bankstown, Smithfield, Cabramatta Creek and St Marys. Previously known north from Razorback Range. Grows in vine thickets and open shale woodland.	**NSW:** Endangered population **Commonwealth:** Not listed	None	None	No previous records in Study Area. Not detected during field survey. Study Area not within known habitat. Not considered further.	Species

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Melaleuca biconvexa Biconvex Paperbark	Biconvex Paperbark generally grows in damp places, often near streams or low-lying areas on alluvial soils of low slopes or sheltered aspects. Scattered and dispersed populations found in the Jervis Bay area in the south and the Gosford-Wyong area in the north.	**NSW:** Vulnerable **Commonwealth:** Vulnerable	Low	Low	No previous records in Study Area. Not detected during field survey. Study Area not within known habitat. Not considered further.	Species
Melaleuca deanei Dean's Melaleuca	The species grows in heath on sandstone. Occurs in two distinct areas, in the Ku-ring-gai / Berowra and Holsworthy / Wedderburn areas respectively	**NSW:** Vulnerable **Commonwealth:** Vulnerable.	Low	Low	No previous records in Study Area. Not detected during field survey. Study Area not within known habitat. Not considered further.	Species
Pelargonium sp. Striatellum	The species is known to occur in habitat usually located just above the high water level of irregularly inundated or ephemeral lakes. During dry periods, the species is known to colonise exposed lake beds. In New South Wales Pelargonium sp. is currently known to occur at four localities in the Southern Tablelands, at altitudes ranging from 680-1030 m a.s.l.	**NSW:** Endangered **Commonwealth:** Endangered	Low	Low	No previous records in Study Area. Not detected during field survey. Study Area not within known habitat. Not considered further.	Species
Persicaria elatior Tall Knotweed	This species normally grows in damp places, especially beside streams and lakes. Occasionally in swamp forest or associated with disturbance. Only recorded from 8 locations in NSW. Closest record is Picton Lakes.	**NSW:** Vulnerable **Commonwealth:** Vulnerable	Low	Low	No previous records in Study Area. Not detected during field survey. Study Area not within known habitat. Not considered further.	Species
Persoonia acerosa Needle Geebung	Occurs in dry sclerophyll forest, scrubby low-woodland and heath on low fertility soils. Recorded only on the central coast and in the Blue Mountains, from Mt Tomah in the north to as far south as Hill Top where it is now believed to be extinct. Mainly in the Katoomba, Wentworth Falls, Springwood area.	**NSW:** Vulnerable **Commonwealth:** Vulnerable	Low	Low	No previous records in Study Area. Not detected during field survey. Study Area not within known habitat. Not considered further.	Species

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Persoonia bargoensis	The Bargo Geebung occurs in woodland or dry sclerophyll forest on sandstone and on heavier, well drained, loamy, gravely soils.	**NSW:** Endangered **Commonwealth:** Vulnerable	Known	Known	There are known records for this species within the Study Area. This species does not occur within and/or is not likely to be reliant on the vegetation communities or habitats that are may be adversely impacted by subsidence. A large population of this species was recorded within the REA development footprint. It is estimated that over 96 plants will be removed as a result of the proposed development.	Species
Persoonia glaucescens	The Mittagong Geebung grows in woodland to dry sclerophyll forest on clayey and gravely laterite. The preferred topography is ridge-tops, plateaux and upper slopes. Aspect does not appear to be a significant factor.	**NSW:** Endangered **Commonwealth:** Vulnerable	Known	Known	There are known records for this species within the Study Area. Despite extensive surveys this species was not recorded within the surface facility development footprint but habitat for this species does occur within this area. This species has been assessed on the basis of the presence of suitable habitat which will be removed for the development of the proposed surface facilities. This species does not occur within and/or is not likely to be reliant on the vegetation communities or habitats that may be adversely impacted by subsidence.	Species
Persoonia hirsuta	The Hairy Geebung is found in sandy soils in dry sclerophyll open forest, woodland and heath on sandstone.	**NSW:** Endangered **Commonwealth:** Endangered	High	High	There are known records for this species within the Study Area. Despite extensive surveys this species was not recorded within the surface facilities development footprint but habitat for this species does occur within this area. This species has been assessed on the basis of the presence of suitable habitat which will be removed for the proposed surface facilities. This species does not occur within and/or is not likely to be reliant on the vegetation communities or habitats that may be adversely impacted by subsidence.	Species

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Persoonia mollis subsp. maxima	Highly restricted, known from the Hornsby Heights-Mt Colah area north of Sydney in the Sydney Basin Bioregion. Occurs in three populations (described on a catchment basis) located over an approximate north-south range of 5.75 km and east-west distance of 7.5 km. Additional locations may exist outside the current distribution.	**NSW:** Endangered **Commonwealth:** Endangered	Low	Low	No previous records in Study Area. Not detected during field survey. Study Area not within known habitat. Not considered further.	Species
Pimelea curviflora var. curviflora	Confined to the coastal area of Sydney between northern Sydney in the south and Maroota in the north-west. Former range extended south to the Parramatta River and Port Jackson region including Five Dock, Bellevue Hill and Manly. Occurs on shale-lateritic soils over sandstone and shale-sandstone transition soils on ridgetops and upper slopes amongst woodlands.	**NSW:** Vulnerable **Commonwealth:** Vulnerable	Low	Low	No previous records in Study Area or locality. Unlikely to be present due to lack of potential habitat. Not considered further.	Species
Pimelea spicata	Pimelea spicata has a relatively scattered distribution in two disjunct areas: the Cumberland Plain area of western Sydney; and the Illawarra Region near Wollongong, NSW. In western Sydney, the distribution extends from Camden in the south to Maraylya in the north and from Horsley Park east to Bankstown. In the Illawarra, the species is associated with coastal headlands and hill tops from Mount Warrigal to Gerroa. The western Sydney/Cumberland Plain populations occur on undulating to hilly country in remnant bushland on Wianamatta shales.	**NSW:** Endangered **Commonwealth:** Endangered	Low	Low	No previous records in Study Area. Not detected during field survey. Study Area not within known habitat. Not considered further.	Species
Pomaderris brunnea	The species has been found in association with *Eucalyptus amplifolia*, *Angophora floribunda, Acacia parramattensis, Bursaria spinosa* and *Kunzea ambigua*. Brown Pomaderris is found in a very limited area around the Colo, Nepean and Hawkesbury Rivers, including the Bargo area. It also occurs at Walcha on the New England tablelands and in far eastern Gippsland in Victoria.	**NSW:** Vulnerable **Commonwealth:** Vulnerable	Known	Known	There are known records for this species within the Study Area. This species does occur within the Study Area. A large population was recorded along Tea TreeHollow Creek during the field survey. It has been considered further in the impact assessment for this project.	Species

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Pterostylis saxicola Sydney Plains Greenhood	Restricted to western Sydney between Freemans Reach in the north and Picton in the south. Most commonly found growing in small pockets of shallow soil in depressions on sandstone rock shelves above cliff lines. The vegetation communities above the shelves where *Pterostylis saxicola* occurs are sclerophyll forest or woodland on shale/sandstone transition soils or shale soils.	**NSW:** Endangered **Commonwealth:** Endangered	Low	Low	No previous records in Study Area. Not detected during field survey. Study Area not within known habitat. Not considered further.	Species
Pultenaea glabra Smooth Bush-pea	Grows in swamp margins, hillslopes, gullies and creekbanks and occurs within dry sclerophyll forest and tall damp heath on sandstone. Restricted to the higher Blue Mountains.	**NSW:** Vulnerable **Commonwealth:** Vulnerable	Low	Low	No previous records in Study Area. Not detected during field survey. Study Area not within known habitat. Not considered further.	Species
Pultenaea pedunculata	Matted Bush-pea is widespread in Victoria, Tasmania, and south-eastern South Australia. In NSW however, it is represented by just three disjunct populations, in the Cumberland Plains in Sydney, the coast between Tathra and Bermagui and the Windellama area south of Goulburn (where it is locally abundant). The Cumberland Plain occurrences were more widespread (Yennora, Canley Vale and Cabramatta were lost to development) and is now found at Villawood and Prestons, and north-west of Appin between the Nepean River and Devines Tunnel number 2 (Upper Sydney Water Supply Canal).	**NSW:** Endangered **Commonwealth:** Not listed	Low	Low	No previous records in Study Area. Not detected during field survey. Study Area not within known habitat. Not considered further.	Species
Rulingia prostrata	Occurs on sandy, sometimes peaty soils in a wide variety of habitats: Snow Gum (*Eucalyptus pauciflora*) Woodland at Rose Lagoon; Blue leaved Stringybark (*E. agglomerata*) Open Forest at Tallong; and in Brittle Gum (*E. mannifera*) Low Open Woodland at Penrose; Scribbly Gum (*Eucalyptus haemastoma*)/ Swamp Mahogany (*E. robusta*) Ecotonal Forest at Tomago.	**NSW:** Endangered **Commonwealth:** Endangered	Low	Low	No previous records in Study Area. Not detected during field survey. Study Area not within known habitat. Not considered further.	Species

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Streblus pendulinus	On the Australian mainland, Siah's Backbone is found in warmer rainforests, chiefly along watercourses. The altitudinal range is from near sea level to 800 m above sea level. The species grows in well-developed rainforest, gallery forest and drier, more seasonal rainforest	**NSW:** Not listed **Commonwealth:** Endangered	None	None	No previous records in Study Area. Not detected during field survey. Study Area not within known habitat. Not considered further.	Species
Syzygium paniculatum Magenta Lilly Pilly	Found only in NSW, in a narrow, linear coastal strip from Bulahdelah to Conjola State forest. On the south coast the species occurs on grey soils over sandstone, restricted mainly to remnant stands of littoral rainforest. On the central coast it occurs on gravels, sands, silts and clays in riverside gallery rainforests and remnant littoral rainforest communities.	**NSW:** Endangered **Commonwealth** Vulnerable	Low	Low	No previous records in Study Area or locality. Unlikely to be present due to lack of potential habitat. Not considered further.	Species
Tetratheca glandulosa	Restricted to the following Local Government Areas: Baulkham Hills, Gosford, Hawkesbury, Hornsby, Ku-ring-gai, Pittwater, Ryde, Warringah, and Wyong. There are approximately 150 populations of this plant ranging from Sampson's Pass (Yengo NP) in the north to West Pymble (Lane Cove NP) in the south. The eastern limit is at Ingleside (Pittwater LGA) and the western limit is at East Kurrajong (Wollemi NP). There are historical collections of this species south to Manly, Willoughby and Mosman, however these populations are now extinct.	**NSW:** Vulnerable **Commonwealth:** Vulnerable	Low	Low	No previous records in Study Area. Not detected during field survey. Study Area not within known habitat. Not considered further.	Species
Thelymitra sp. Kangaloon Kangaloon Sun Orchid	Recorded from shallow black peaty soil in coastal heath on sandstone. *Thelymitra* sp. Kangaloon is a terrestrial orchid endemic to New South Wales, and is known from three locations near Robertson in the Southern Highlands.	**NSW:** Not listed **Commonwealth:** Critically Endangered	None	None	No previous records in Study Area. Not detected during field survey. Study Area not within known habitat. Not considered further.	Species

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Thesium australe Austral Toadflax	Austral Toad-flax is found in very small populations scattered across eastern NSW, along the coast, and from the Northern to Southern Tablelands. It is also found in Tasmania and Queensland and in eastern Asia. Occurs in grassland or grassy woodland. Often found in damp sites in association with Kangaroo Grass (*Themeda australis*). A root parasite that takes water and some nutrient from other plants, especially Kangaroo Grass.	**NSW:** Vulnerable **Commonwealth:** Vulnerable	Low	Low	No previous records in Study Area. Not detected during field survey. Study Area not within known habitat. Not considered further.	Species
Wahlenbergia multicaulis - endangered population	In NSW, W. *multicaulis* grows mainly in the coastal and tableland districts south from Sydney and the Blue Mountains, and west along the Murray River to Mathoura. This includes the following botanical subdivisions: the Central Coast, South Coast, Central Tablelands, Southern Tablelands, South Western Slopes, and South Western Plains. There are very few records from the Central Coast botanical subdivision. Early collections from Hornsby, Ashfield, and Punchbowl, may now be extinct. The occurrence in the local government areas of Auburn, Bankstown, Strathfield and Canterbury, is likely to be the only known population remaining in the Sydney area and in the Central Coast botanical subdivision	**NSW:** Endangered population **Commonwealth:** Not listed	None	None	No previous records in Study Area. Not detected during field survey. Study Area not within known habitat. Not considered further.	Species
Zieria involucrata	Disjunct distribution north and west of Sydney, in the Baulkham Hills, Hawkesbury, Hornsby and Blue Mountains local government areas. Recent records for the species come from 22 populations in the catchments of the Macdonald, Colo and Hawkesbury Rivers between Melon Creek and Mogo Creek in the north to Little Cattai Creek (Hillside) and Wheeny Creek (Colo) in the south and from a single population in the upper Blue Mountains north of Katoomba. In addition, historical records exist for at least two other localities in the eastern Blue Mountains: south of Springwood Valley Heights and north-west of Kurrajong.	**NSW:** Endangered **Commonwealth:** Vulnerable	None	None	No previous records in Study Area. Not detected during field survey. Study Area not within known habitat. Not considered further.	Species

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Fauna						
Birds						
Actitis hypoleucos Common Sandpiper	Utilises a wide range of coastal wetlands and some inland wetlands, mostly found around muddy margins or rocky shores. Forages in shallow water and on soft mud, roosts on rocks or vegetation such as mangroves. Northern hemisphere breeding.	**NSW:** Not listed **Commonwealth:** Migratory	Low	Low	The species may occur from time to time in the Study Area but is not likely to be reliant on the Study Area for breeding or foraging. No wetland occur within the Study Area. Habitat is unlikely to be impacted by subsidence. The species was not detected in the surface infrastructure disturbance area.	-
Apus pacificus Fork-tailed Swift	The Fork-tailed Swift is almost exclusively aerial, flying from less than 1 m to at least 300 m above ground and probably much higher. It occurs over various inland habitats. There are no significant threats to the Fork-tailed Swift in Australia. Potential threats include habitat destruction and predation by feral animals.	**NSW:** Not listed **Commonwealth:** Migratory	Moderate	Moderate	Due to the wide range of the species and its aerial habits, the species may occur on occasion in the Study Area. The species was not detected during the field survey and is unlikely to be present within the surface infrastructure area.	-
Ardea alba Great Egret	Terrestrial wetlands, estuarine and littoral habitats and moist grasslands. Inland, prefer permanent waterbodies on floodplains; shallows of deep permanent lakes (either open or vegetated), semi-permanent swamps with tall emergent vegetation and herb dominated seasonal swamps with abundant aquatic flora. Also regularly use saline habitats including mangrove forests, estuarine mudflats, saltmarshes, bare saltpans, shallows of salt lakes, salt fields and offshore reefs. Breeding requires wetlands with fringing trees in which to build nests including mangrove forest, freshwater lakes or swamps and rivers.	**NSW:** Not listed **Commonwealth:** Migratory	Low - moderate	Low	The species may occur from time to time in the Study Area but is not likely to be reliant on the Study Area for breeding or foraging. Habitat is unlikely to be impacted by subsidence. The species was not detected in the surface infrastructure disturbance area.	-

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Ardea ibis Cattle Egret	The Cattle Egret occurs in tropical and temperate grasslands, wooded lands and terrestrial wetlands. It has occasionally been seen in arid and semi-arid regions however this is extremely rare. High numbers have been observed in moist, low-lying poorly drained pastures with an abundance of high grass; it avoids low grass pastures. It has been recorded on earthen dam walls and ploughed fields. It is commonly associated with the habitats of farm animals, particularly cattle, but also pigs, sheep, horses and deer. The Cattle Egret is known to follow earth-moving machinery and has been located at rubbish tips. It uses predominately shallow, open and fresh wetlands including meadows and swamps with low emergent vegetation and abundant aquatic flora. They have sometimes been observed in swamps with tall emergent vegetation. http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=59542	**NSW:** Not listed **Commonwealth:** Migratory	Low/moderate	Low	The species may occur from time to time in the Study Area but is not likely to be reliant on the Study Area for breeding or foraging. Habitat is unlikely to be impacted by subsidence. The species was not detected in the surface infrastructure disturbance area.	-
Artamus cyanopterus cyanopterus Dusky Woodswallow	Often reported in woodlands and dry open sclerophyll forests, usually dominated by eucalypts, including mallee associations. It has also been recorded in shrublands and heathlands and various modified habitats, including regenerating forests; very occasionally in moist forests or rainforests.	**NSW:** Vulnerable **Commonwealth:** Not listed	Low	Low	Margin habitat occurs in the Study Area. There are no records within the locality.	Ecosystem
Botaurus poiciloptilus Australasian Bittern	The species is widespread in NSW and Victoria. In NSW, it occurs along the coast and is frequently recorded in the Murray-Darling Basin, notably in floodplain wetlands of the Murrumbidgee, Lachlan, Macquarie and Gwydir Rivers.	**NSW**: Endangered **Commonwealth:** Endangered	Low	Low	Marginal habitat occurs in the Study Area. There are no records within the locality.	Species

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Burhinus grallarius Bush Stone-curlew	The Bush Stone-curlew is found throughout Australia except for the central southern coast and inland, the far south-east corner, and Tasmania. Only in northern Australia is it still common however and in the south-east it is either rare or extinct throughout its former range. Inhabits open forests and woodlands with a sparse grassy ground layer and fallen timber.	**NSW**: Vulnerable **Commonwealth:** Not listed	Low	Low	Marginal habitat occurs in the Study Area. There are no records within the locality. Not detected during field surveys. Unlikely to be present in surface infrastructure disturbance area.	Ecosystem
Calidris acuminata Sharp-tailed Sandpiper	Prefers muddy edges of shallow or brackish wetlands, with inundated or emergent sedges, saltmarsh or other low vegetation. Also found foraging in sewage ponds and flooded paddocks. Northern hemisphere breeding.	**NSW:** Not listed **Commonwealth:** Migratory	Low	Low	Marginal habitat occurs in the Study Area. There are no records within the locality. Not detected during field surveys. Unlikely to be present in surface infrastructure disturbance area.	-
Calidris ferruginea Curlew Sandpiper	It occurs along the entire coast of NSW, particularly in the Hunter Estuary, and sometimes in freshwater wetlands in the Murray-Darling Basin. It generally occupies littoral and estuarine habitats, and in New South Wales is mainly found in intertidal mudflats of sheltered coasts. It also occurs in non-tidal swamps, lakes and lagoons on the coast and sometimes the inland. Northern hemisphere breeding.	**NSW:** Endangered **Commonwealth:** Critically endangered, Migratory	Low	Low	Marginal habitat occurs in the Study Area. There are no records within the locality. Not detected during field surveys. Unlikely to be present in surface infrastructure disturbance area.	Ecosystem
Calidris melanotos Pectoral Sandpiper	Prefers shallow fresh to saline wetlands, found at coastal lagoons, estuaries, bays, swamps, inundated grasslands, saltmarshes and artificial wetlands. Northern hemisphere breeding.	**NSW:** Not listed **Commonwealth:** Migratory	Low	Low	Marginal habitat occurs in the Study Area. There are no records within the locality. Not detected during field surveys. Unlikely to be present in surface infrastructure disturbance area.	-
Callocephalon fimbriatum Gang-gang Cockatoo	In summer, generally found in tall mountain forests and woodlands, particularly in heavily timbered and mature wet sclerophyll forests. In winter, may occur at lower altitudes in drier more open eucalypt forests and woodlands, and often found in urban areas.	**NSW:** Vulnerable **Commonwealth:** Not listed	High	Moderate	The species has a high likelihood of occurrence within the Study Area. Its habitat is unlikely to be impacted by subsidence. It was not detected during the survey within the surface infrastructure areas.	Species

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Calyptorhynchus lathami Glossy Black Cockatoo	Inhabits open forest and woodlands of the coast and the Great Dividing Range up to 1000 m in which stands of she-oak species, particularly Black She-oak (*Allocasuarina littoralis*), Forest She-oak (*A. torulosa*) or Drooping She-oak (*A. verticillata*) occur.	**NSW:** Vulnerable **Commonwealth:** Endangered only in South Australia Population	Known	Known	Recorded immediately adjacent to the REA during surveys and is almost certain to be present as suitable feed trees are present, although large hollow-bearing trees suitable for nesting are not present within the disturbance areas for surface infrastructure.	Ecosystem (but species for Riverina pop)
Climacteris picumnus victoriae Brown Treecreeper	Found in eucalypt woodlands (including Box-Gum Woodland) and dry open forest of the inland slopes and plains inland of the Great Dividing Range; mainly inhabits woodlands dominated by stringybarks or other rough-barked eucalypts, usually with an open grassy understorey, sometimes with one or more shrub species; also found in mallee and River Red Gum (*Eucalyptus camaldulensis*) Forest bordering wetlands with an open understorey of acacias, saltbush, lignum, cumbungi and grasses; usually not found in woodlands with a dense shrub layer; fallen timber is an important habitat component for foraging; also recorded, though less commonly, in similar woodland habitats on the coastal ranges and plains.	**NSW:** Vulnerable **Commonwealth:** Not listed	High (Previously recorded by OEH).	High	A record for this species occurs within the Study Area. It may use the surface infrastructure on occasion. Habitat types are unlikely to be impacted by subsidence.	Ecosystem
Cuculus optatus Oriental Cuckoo	Mainly inhabits coniferous, deciduous and mixed forests. Breeds in northern hemisphere. Brood parasite, laying eggs in nests of other birds.	**NSW:** Not listed **Commonwealth:** Migratory	Low	Low	Marginal habitat occurs in the Study Area. There are no records within the locality. Not detected during field surveys. Unlikely to be present in surface infrastructure disturbance area.	-

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Daphoenositta chrysoptera Varied Sittella	The Varied Sittella is sedentary and inhabits most of mainland Australia except the treeless deserts and open grasslands, with a nearly continuous distribution in NSW from the coast to the far west. It inhabits eucalypt forests and woodlands, especially rough-barked species and mature smooth-barked gums with dead branches, mallee and *Acacia* woodland. The Varied Sittella feeds on arthropods gleaned from crevices in rough or decorticating bark, dead branches, standing dead trees, and from small branches and twigs in the tree canopy. It builds a cup-shaped nest of plant fibres and cobweb in an upright tree fork high in the living tree canopy, and often re-uses the same fork or tree in successive years.	**NSW:** Vulnerable **Commonwealth:** Not listed	Known	Known	This species was recorded within the Study Area during this assessment.	Ecosystem
Dasyomis brachypterus Eastern Bristlebird	The Eastern Bristlebird inhabits low dense vegetation in a broad range of habitat types including sedgeland, heathland, swampland, shrubland, sclerophyll forest and woodland, and rainforest. Within NSW, populations of Eastern Bristlebirds are isolated, fragmented and small. Disjunct populations occur in the north-east, the Illawarra region and the south-east of the state.	**NSW:** Endangered **Commonwealth:** Endangered	Low	Low	No previous records in Study Area. No known populations in Study Area. Not recorded during field surveys. Not considered further.	Species
Erythrotriorchris radiatus Red Goshawk	The Red Goshawk occurs in coastal and sub-coastal areas in wooded and forested lands of tropical and warm-temperate Australia. Riverine forests are also used frequently. Such habitats typically support high bird numbers and biodiversity, especially medium to large species which the goshawk requires for prey. The Red Goshawk nests in large trees, frequently the tallest and most massive in a tall stand, and nest trees are invariably within one km of permanent water. In NSW favoured habitat is mixed subtropical rainforest and Melaleuca forest along coastal rivers, often in rugged terrain. http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=942	**NSW:** Critically Endangered **Commonwealth:** Endangered	Low	Low	No previous records in Study Area. No known populations in Study Area. Not recorded during field surveys. Not considered further.	Species

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Falco subniger Black Falcon	Widely, but sparsely, distributed in NSW, mostly occurring in inland regions. In NSW there is assumed to be a single population that is continuous with a broader continental population, given that falcons are highly mobile, commonly travelling hundreds of kilometres. The Black Falcon inhabits woodland, shrubland and grassland in the arid and semi-arid zones, especially wooded watercourses and agricultural land with scattered remnant trees.	**NSW:** Vulnerable **Commonwealth:** Not listed	Low	Low	Marginal habitat occurs in the Study Area. There are no records within the locality. Not detected during field surveys. Unlikely to be present in surface infrastructure disturbance area.	Ecosystem
Gallinago hardwickii Latham's Snipe	In Australia, Latham's Snipe occurs in permanent and ephemeral wetlands up to 2000 m above sea-level. They usually inhabit open, freshwater wetlands with low, dense vegetation (e.g. swamps, flooded grasslands or heathlands, around bogs and other water bodies). However, they can also occur in habitats with saline or brackish water, in modified or artificial habitats, and in habitats located close to humans or human activity. http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=863	**NSW:** Not listed **Commonwealth:** Migratory	Low	Low	No previous records in Study Area. No known populations in Study Area. Not recorded during field surveys. Not considered further.	-
Glossopsitta pusilla Little Lorikeet	Forages primarily in the canopy of open Eucalyptus forest and woodland, yet al.so finds food in Angophoras, Melaleucas and other tree species. Riparian habitats are particularly used, due to higher soil fertility and hence greater productivity. Isolated flowering trees in open country, e.g. paddocks, roadside remnants and urban trees also help sustain viable populations of the species.	**NSW:** Vulnerable **Commonwealth:** Not listed	Moderate	Moderate	The habitat present in the Study Area is suitable for use by this species. The species may also use the habitat of the surface infrastructure disturbance footprint on occasion. Habitat features of the Study Area are unlikely to be impacted by subsidence.	Ecosystem
Grantiella picta Painted Honeyeater	The Painted Honeyeater is nomadic and occurs at low densities throughout its range. The greatest concentrations of the bird and almost all breeding occurs on the inland slopes of the Great Dividing Range in NSW, Victoria and southern Queensland. During the winter it is more likely to be found in the north of its distribution. Inhabits boree, brigalow and box-gum woodlands and box-ironbark forests.	**NSW:** Vulnerable **Commonwealth:** Vulnerable	Low	Low	The habitat present in the Study Area is unlikely to be suitable for use by this species on a regular basis given the lack of potential habitat.	Ecosystem

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Haliaeetus leucogaster White-bellied Sea-eagle	A migratory species that is resident to Australia. Found in terrestrial and coastal wetlands; favouring deep freshwater swamps, lakes and reservoirs; shallow coastal lagoons and salt marshes.	**NSW:** Not listed **Commonwealth:** Migratory	Low	Low	Not considered further.	-
Hieraaetus morphnoides Little Eagle	Occupies open eucalypt forest, woodland or open woodland. Sheoak or acacia woodlands and riparian woodlands of interior NSW are also used. Nests in tall living trees within a remnant patch, where pairs build a large stick nest in winter.	**NSW:** Vulnerable **Commonwealth:** Not listed	Known	Known	This species was observed immediately adjacent to the REA and the habitat in the REA is suitable for foraging and nesting.	Ecosystem
Hirundapus caudacutus White-throated Needletail	An aerial species found in feeding concentrations over cities, hilltops and timbered ranges). There appear to be few threats to the populations of White-throated Needletails. When in Australia, there is the constant threat of collision with overhead wires, windows and lighthouses, though, as this affects only a few individuals, it is not a threat to the species overall.	**NSW:** Not listed **Commonwealth:** Migratory	Low	Low	No previous records in Study Area. No known populations in Study Area. Not recorded during field surveys. Not considered further.	-
Lathamus discolor Swift Parrot	On the mainland they occur in areas where eucalypts are flowering profusely or where there are abundant lerp (from sap-sucking bugs) infestations. Favoured feed trees include winter flowering species such as Swamp Mahogany *Eucalyptus robusta*, Spotted Gum *Corymbia maculata*, Red Bloodwood *C. gummifera*, Mugga Ironbark *E. sideroxylon*, and White Box *E. albens*.	**NSW:** Endangered **Commonwealth:** Endangered	High	Low	The habitat present in the Study Area is suitable for use by this species. The species has marginal habitat within the surface infrastructure disturbance footprint. Habitat features of the Study Area are unlikely to be impacted by subsidence.	Ecosystem
Leipoa ocellata Malleefowl	In New South Wales, it typically occurs west of the Great Dividing Range. Its distribution extends from Pilliga south-west to the districts of Griffith and Wentworth, although the species is absent from the southern parts of the Riverina region.	**NSW**: Vulnerable **Commonwealth:** Vulnerable, Migratory	None	None	No previous records in Study Area. No known populations in Study Area. Not recorded during field surveys. Not considered further.	Ecosystem

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Lophoictinia isura Square-tailed Kite	Typically inhabits coastal forested and wooded lands of tropical and temperate Australia. In NSW it is often associated with ridge and gully forests dominated by woollybutt, spotted gum, river peppermint or gully gum. Individuals appear to occupy large hunting ranges of more than 100km². They require large living trees for breeding, particularly near water with surrounding woodland -forest close by for foraging habitat. Nest sites are generally located along or near watercourses, in a tree fork or on large horizontal limbs.	**NSW:** Vulnerable **Commonwealth:** Not listed	Low	Low	No previous records in Study Area. No known populations in Study Area. Habitat marginal. Not recorded during field surveys. Not considered further.	Ecosystem
Melanodryas cucullata cucullata Hooded Robin	Prefers lightly wooded country, usually open eucalypt woodland, acacia scrub and mallee, often in or near clearings or open areas. Requires structurally diverse habitats featuring mature eucalypts, saplings, some small shrubs and a ground layer of moderately tall native grasses.	**NSW**: Vulnerable **Commonwealth:** Not listed	Moderate	Moderate	The habitat present in the Study Area is suitable for use by this species. The species may also use the habitat of the surface infrastructure disturbance footprint on occasion. Habitat features of the Study Area are unlikely to be impacted by subsidence.	Ecosystem
Melithreptus gularis gularis Black-chinned Honeyeater	Occupies mostly upper levels of drier open forests or woodlands dominated by box and ironbark eucalypts, especially Mugga Ironbark (*Eucalyptus sideroxylon*), White Box (*E. albens*), Inland Grey Box (*E. microcarpa*), Yellow Box (*E. melliodora*) and Forest Red Gum (*E. tereticornis*). Also inhabits open forests of smooth-barked gums, stringybarks, ironbarks and tea-trees.	**NSW:** Vulnerable **Commonwealth:** Not listed	High (Previously recorded by OEH).	High	Previously recorded in Study Area.	Ecosystem
Merops ornatus Rainbow Bee-eater	Usually occurs in open or lightly timbered areas, often near water (Higgins, 1999). The species occurs in a variety of habitat types throughout Australia. In Australia the nest is located in an enlarged chamber at the end of long burrow or tunnel that is excavated, by both sexes, in flat or sloping ground, in the banks of rivers, creeks or dams, in roadside cuttings, in the walls of gravel pits or quarries, in mounds of gravel, or in cliff-faces. http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=670	**NSW:** Not listed **Commonwealth:** Migratory	Moderate	Moderate	This species could occasionally be present in the Study Area.	-

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Monarcha melanopsis Black-faced Monarch	A migratory species found during the breeding season in damp gullies in temperate rainforests. Disperses after breeding into more open woodland. The Black-faced Monarch mainly occurs in rainforest ecosystems, including semi-deciduous vine-thickets, complex notophyll vine-forest, tropical (mesophyll) rainforest, subtropical (notophyll) rainforest, mesophyll (broadleaf) thicket/shrubland, warm temperate rainforest, dry (monsoon) rainforest and (occasionally) cool temperate rainforest http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=609	**NSW:** Not listed **Commonwealth:** Migratory	Low	Low	No previous records in Study Area. No known populations in Study Area. Habitat marginal. Not recorded during field surveys. Not considered further.	-
Motacilla flava Yellow Wagtail	Breeds in temperate Europe and Asia. The Yellow Wagtail is a regular wet season visitor to northern Australia. Increasing records in NSW suggest this species is an occasional but regular summer visitor to the Hunter River region. The species is considered a vagrant to Victoria, South Australia and southern Western Australia. Habitat requirements for the Yellow Wagtail are highly variable, but typically include open grassy flats near water. Habitats include open areas with low vegetation such as grasslands, airstrips, pastures, sports fields; damp open areas such as muddy or grassy edges of wetlands, rivers, irrigated farmland, dams, waterholes; sewage farms, sometimes utilise tidal mudflats and edges of mangroves.	**NSW:** Not listed **Commonwealth:** Migratory	Low	Low	No previous records in Study Area. No known populations in Study Area. Habitat marginal. Not recorded during field surveys. Not considered further.	-

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Myiagra cyanoleuca Satin Flycatcher	Migratory species that occurs in coastal forests, woodlands and scrubs during migration. Breeds in heavily vegetated gullies. Satin Flycatchers are mainly recorded in eucalypt forests, especially wet sclerophyll forest, often dominated by eucalypts such as Brown Barrel, *Eucalypt fastigata*, Mountain Gum, *E. dalrympleana*, Mountain Grey Gum, Narrow-leaved Peppermint, Messmate or Manna Gum, or occasionally Mountain Ash, *E. regnans*. Such forests usually have a tall shrubby understorey of tall acacias, for example Blackwood, *Acacia melanoxylon*. In higher altitude Black Sallee, *E. stellulata*, woodlands, they are often associated with tea-trees and tree-ferns. They sometimes also occur in dry sclerophyll forests and woodlands, usually dominated by eucalypts such as Blakely's Red Gum, *E. blakelyi*, Mugga Ironbark, *E. sideroxylon*, Yellow Box, White Box, *E. albens*, Manna Gum or stringybarks, including Red Stringybark, *E. macrorhyncha* and Broad-leaved Stringybark, usually with open understorey. http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=612	**NSW:** Not listed **Commonwealth:** Migratory	Moderate	Moderate	The habitat present in the Study Area may be suitable for this species.	-
Neophema pulchella Turquoise Parrot	Lives on the edges of eucalypt woodland adjoining clearings, timbered ridges and creeks in farmland.	**NSW:** Vulnerable **Commonwealth:** Not listed	Moderate	Moderate	The habitats present in the Study Area may be suitable for this species. Limiting resources for this species are unlikely to be impacted by the proposed development. This species is generally highly mobile, and are likely to utilise potential habitat immediately adjacent to the proposed surface infrastructure.	Ecosystem
Ninox connivens Barking Owl	Generally found in open forests, woodlands, swamp woodlands and dense scrub. Can also be found in the foothills and timber along watercourses in otherwise open country.	**NSW:** Vulnerable **Commonwealth:** Not listed	High	High	The habitat present in the Study Area may be suitable for this species.	Ecosystem

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Ninox strenua Powerful Owl	The Powerful Owl inhabits a range of vegetation types, from woodland and open sclerophyll forest to tall open wet forest and rainforest. The Powerful Owl requires large tracts of forest or woodland habitat but can occur in fragmented landscapes as well. The species breeds and hunts in open or closed sclerophyll forest or woodlands and occasionally hunts in open habitats. It roosts by day in dense vegetation comprising species such as Turpentine *Syncarpia glomulifera*, Black She-oak *Allocasuarina littoralis*, Blackwood *Acacia melanoxylon*, Rough-barked Apple *Angophora floribunda*, Cherry Balart *Exocarpus cupressiformis* and a number of eucalypt species.	**NSW:** Vulnerable **Commonwealth:** Not listed	Known	Known	Previously recorded in Study Area and recorded during surveys.	Ecosystem
Petroica boodang Scarlet Robin	The Scarlet Robin is primarily a resident in forests and woodlands, but some adults and young birds disperse to more open habitats after breeding. The Scarlet Robin lives in dry eucalypt forests and woodlands. The understorey is usually open and grassy with few scattered shrubs. This species lives in both mature and regrowth vegetation. It occasionally occurs in mallee or wet forest communities, or in wetlands and tea-tree swamps. Scarlet Robin habitat usually contains abundant logs and fallen timber: these are important components of its habitat. The Scarlet Robin breeds on ridges, hills and foothills of the western slopes, the Great Dividing Range and eastern coastal regions; this species is occasionally found up to 1000 metres in altitude. In autumn and winter many Scarlet Robins live in open grassy woodlands, and grasslands or grazed paddocks with scattered trees.	**NSW:** Vulnerable **Commonwealth:** Not listed	Known	Known	Previously recorded in Study Area and the habitat in the REA area is suitable for the species.	Ecosystem

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Pyrrholaemus saggitatus Speckled Warbler	The Speckled Warbler lives in a wide range of Eucalyptus dominated communities that have a grassy understorey, often on rocky ridges or in gullies. Typical habitat would include scattered native tussock grasses, a sparse shrub layer, some eucalypt regrowth and an open canopy. Large, relatively undisturbed remnants are required for the species to persist in an area.	**NSW:** Vulnerable **Commonwealth:** Not listed	Moderate	Moderate	The woodlands present represent relatively suitable habitat for this species although the Study Area contains large areas of disturbed habitat. Limiting resources for this species are unlikely to be impacted by the proposed development.	Ecosystem
Rhipidura rufifrons Rufous Fantail	In east and south-east Australia, mainly inhabits wet sclerophyll forests, often in gullies dominated by eucalypts such as Tallow-wood (*Eucalyptus microcorys*), Mountain Grey Gum (*E. cypellocarpa*), Narrow-leaved Peppermint (*E. radiata*), Mountain Ash (*E. regnans*), Alpine Ash (*E. delegatensis*), Blackbutt (*E. pilularis*) or Red Mahogany (*E. resinifera*); usually with a dense shrubby understorey often including ferns. They also occur in subtropical and temperate rainforests; for example near Bega in south-east NSW, where they are recorded in temperate Lilly Pilly (*Acmena smithii*) rainforest, with Grey Myrtle (*Backhousia myrtifolia*), Sassafras (*Doryphora sassafras*) and Sweet Pittosporum (*Pittosporum undulatum*) subdominants. They occasionally occur in secondary regrowth, following logging or disturbance in forests or rainforests. When on passage, they are sometimes recorded in drier sclerophyll forests and woodlands, including Spotted Gum (*Eucalyptus maculata*), Yellow Box (*E. melliodora*), ironbarks or stringybarks, often with a shrubby or heath understorey. They are also recorded from parks and gardens when on passage. In north and north-east Australia, they often occur in tropical rainforest and monsoon rainforests, including semi-evergreen mesophyll vine forests, semi-deciduous vine thickets or thickets of Paperbarks (*Melaleuca* spp.)	**NSW:** Not listed **Commonwealth:** Migratory	Low	Low	No previous records in Study Area. No known populations in Study Area. Habitat marginal. Not recorded during field surveys. Not considered further.	Ecosystem

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Rostratula australis Australian Painted Snipe	Generally inhabits shallow terrestrial freshwater (occasionally brackish) wetlands, including temporary and permanent lakes, swamps and claypans. They also use inundated or waterlogged grassland or saltmarsh, dams, rice crops, sewage farms and bore drains (DoEE).	**NSW**: Endangered **Commonwealth:** Vulnerable	Low	Low	No previous records in Study Area. No known populations in Study Area. Habitat marginal. Not recorded during field surveys. Not considered further.	Ecosystem
Stagonopleura guttata Diamond Firetail	Feeds exclusively on the ground, on ripe and partly-ripe grass and herb seeds and green leaves, and on insects (especially in the breeding season). Found in grassy eucalypt woodlands, including Box-Gum Woodlands and Snow Gum *Eucalyptus pauciflora* Woodlands. Also occurs in open forest, mallee, Natural Temperate Grassland, and in secondary grassland derived from other communities. Often found in riparian areas (rivers and creeks), and sometimes in lightly wooded farmland.	**NSW:** Vulnerable **Commonwealth:** Not listed	High (Previously recorded by OEH).	High	Previously recorded in Study Area. Likely to use the Study Area on occasion.	Ecosystem
Sterna fuscata Sooty Tern	Flocks can be seen soaring, skimming and dipping but seldom plunging in off shore waters. Breeds in large colonies in sand or coral scrapes on offshore islands and cays including Lord Howe and Norfolk Islands.	**NSW:** Vulnerable **Commonwealth:** Not listed	None	None	Previously recorded however was an isolated incident of a lost vagrant individual and the Study Area contains no suitable habitat for this marine species. It is not considered further.	Ecosystem
Tringa nebularia Common Greenshank	Variety of inland wetlands and sheltered coastal habitats of varying salinity. Found on mudflats, saltmarsh, mangroves in embayments, harbours, deltas and lagoons. Breeds in northern hemisphere.	**NSW**: Not listed **Commonwealth:** Migratory	Low	Low	No previous records in Study Area. No known populations in Study Area. Habitat marginal. Not recorded during field surveys. Not considered further.	-
Tyto novaehollandiae Masked Owl	Pairs have a large home-range of 500 to 1000 hectares. Lives in dry eucalypt forests and woodlands from sea level to 1100 m. A forest owl, but often hunts along the edges of forests, including roadsides. The typical diet consists of tree-dwelling and ground mammals, especially rats. Roosts and breeds in moist eucalypt forested gullies, using large tree hollows or sometimes caves for nesting.	**NSW:** Vulnerable **Commonwealth:** Not listed	High	High	The habitat present in the Study Area is suitable for this species.	Ecosystem

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Tyto tenebricosa Sooty Owl	Occurs in rainforest, including dry rainforest, subtropical and warm temperate rainforest, as well as moist eucalypt forests. Roosts by day in the hollow of a tall forest tree or in heavy vegetation; hunts by night for small ground mammals or tree-dwelling mammals such as the Common Ringtail Possum (*Pseudocheirus peregrinus*) or Sugar Glider (*Petaurus breviceps*). Nests in very large tree-hollows.	**NSW:** Vulnerable **Commonwealth:** Not listed	Known	Known	Recorded during the field survey.	Ecosystem

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Anthomyza phrygia Regent Honeyeater	A semi-nomadic species occurring in temperate eucalypt woodlands and open forests. Most records are from box-ironbark eucalypt forest associations and wet lowland coastal forests (NPWS, 1999) (Pizzey, 1997).	**NSW**: Endangered **Commonwealth:** Endangered, Migratory	Moderate	Low	As state in the OEH Bionet description, 'the species is a dual credit species, mapped important areas are a species credit, these areas do not require survey and any impact from development could be potentially serious and irreversible. Ecosystem credit are areas that are unlikely to be potential serious and irreversible impacts.' The habitats present in the Study Area may be suitable for this species on an occasional basis (fly in or over the Study Area). The survey did not detect the species, nor have there been any previous records or and known breeding populations in the Study Area. Limiting resources for this species are unlikely to be impacted by the proposed development. This species is generally highly mobile. Furhtermore, subsidence is unlikely to impact the dry sclerophyll forest and woodand habitat that the species may occasionally use.	The species is a dual credit species, mapped important areas are a species credit, these areas do not require survey and any impact from development could be potentially serious and irreversible. Ecosystem credit are areas are unlikely to be potential serious and irreversible impacts.
Fish						

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Macquaria australasica Macquarie Perch	Macquarie perch are found in the Murray-Darling Basin (particularly upstream reaches) of the Lachlan, Murrumbidgee and Murray rivers, and parts of south-eastern coastal NSW, including the Hawkesbury and Shoalhaven. Macquarie perch are found in both river and lake habitats, especially the upper reaches of rivers and their tributaries.	**NSW:** Endangered **Commonwealth:** Endangered	None	None	No habitat present in Study Area.	-
Amphibians						
Heleioporus australiacus Giant Burrowing Frog	Breeding habitat of this species is generally soaks or pools within first or second order streams. They are also commonly recorded from 'hanging swamp' seepage lines and where small pools form from the collected water. Around the Sydney Basin they are associated with Triassic Sandstones. South of the Sydney Basin they have been recorded from a wide range of habitat including heath, woodlands and dry and wet sclerophyll forests, but not cleared lands. Adults move 50-200m from the breeding site during non-breeding times.	**NSW:** Vulnerable **Commonwealth:** Vulnerable	Low	Low	No known populations in Study Area. Habitat marginal. Lack of deep pools and suitable habitat. Not recorded during field surveys or amphibian monitoring within the Study Area. Not considered further.	Species
Litoria aurea Green and Golden Bell Frog	Inhabits marshes, dams and stream-sides, particularly those containing bullrushes (*Typha* spp.) or spikerushes (*Eleocharis* spp.). Optimum habitat includes water-bodies that are un-shaded, free of predatory fish such as Plague Minnow (*Gambusia holbrooki*), have a grassy area nearby and diurnal sheltering sites available. This frog is also a “pioneering” species that invades newly disturbed habitats and most of the sites it remains extant at are highly disturbed human created environments.	**NSW:** Endangered **Commonwealth:** Vulnerable	Low. Habitat is of low quality only (no open shallow water bodies with emergent vegetation) and the species is probably extinct in region.	Low	No known populations in Study Area. Habitat marginal. Not recorded during field surveys or amphibian monitoring. Not considered further.	Species

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Litoria littlejohni Littlejohn's Tree Frog	Occurs in wet and dry sclerophyll forests associated with sandstone outcrops between 280 and 1000 m on the eastern slopes of the Great Dividing Range. The species has been located calling around a range of water bodies including rocky flowing streams, semi-permanent and permanent dams, upland swamps and temporary pools. Individuals forage and shelter both in the tree canopy and on the ground. It is not known from coastal or completely cleared habitats.	**NSW:** Vulnerable **Commonwealth:** Vulnerable	Low	Low	No known populations in Study Area. Habitat marginal at best. Not recorded during field surveys or amphibian monitoring. Not considered further.	Species
Mixophyes balbus Stuttering Frog	This species is associated with mountain streams in wet mountain forests and rainforests. Adults and juveniles are regularly recorded hundreds of metres from the banks of the permanent forest streams that form their breeding sites. Eggs are deposited in leaf litter or gravel/sand within the stream bed in nests hollowed out by the female. The tadpoles enter the stream proper when they are large enough to break free of the nesting hollow or when they are washed out by rains.	**NSW:** Endangered **Commonwealth:** Vulnerable	Low. Habitat is poor and species is almost certainly extinct in region	Low	No known populations in Study Area. Lack of suitable habitat in Study Area. Not recorded during field surveys or amphibian monitoring. Not considered further.	Species
Pseudophryne australis Red-crowned Toadlet	Red-crowned Toadlets are quite a localised species that appear to be largely restricted to the immediate vicinity of suitable breeding habitat. Red-crowned Toadlets are usually found as small colonies scattered along ridges coinciding with the positions of suitable refuges near breeding sites. Due to this tendency for discrete populations to concentrate at particular sites, a relatively small localised disturbance may have a significant impact on a local population if it occurs on a favoured breeding or refuge site. Occurs in open forests, mostly on Hawkesbury and Narrabeen Sandstones.	**NSW:** Vulnerable **Commonwealth:** Not listed	Known	Low	Recorded at Hornes Creek within the Study Area. Unlikely to be present within the area proposed for surface infrastructure and thus unlikely to be impacted by works in that area. There is the potential for subsidence impacts to results in loss of pools which could support a population of the species along Hornes Creek. This species is considered further in the impact assessment of this report.	Species
Reptiles						

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Hoplocephalus bungaroides Broad-headed Snake	Shelters in rock crevices and under flat sandstone rocks on exposed cliff edges during autumn, winter and spring, requiring very specific types of rock shelters that may be used year after year. Moves from the sandstone rocks to shelters in hollows in large trees within 200 m of escarpments in summer.	**NSW:** Endangered **Commonwealth:** Vulnerable	Low	Low	The Broad-headed Snake is unlikely to occur within the Study Area due to the following: - It was not detected during targeted field survey - No known records occur within the Study Area. - Most of the records occur greater than 3.5 km to the south of the Study Area within land managed by WaterNSW. - The broad-headed snake is known to occur sandstone ridgetops to which the snakes are known to prefer sites with a west to north-west aspect. Such habitat features are quite restricted in the Proejct Area, occurring along the portions of Dog Trap Creek, Tea TreeHollow Creek, Dry Creek, Eliza Creek and the Nepean River. The restricted habitat, coupled with the lack of records and distance from known populations, indicates a low likelihood fo the species to occur within the Study Area.	Species
Varanus rosenbergi Rosenberg's Goanna	Found in heath, open forest and woodland. Terrestrial termite mounds are a critical habitat component for this species as is uses them as nesting sites. Rock outcrops are also important as shelter sites.	**NSW:** Vulnerable **Commonwealth:** Not listed	Low	Low	The species is unlikely to occur within the Study Area due to the following: - It was not detected during targeted field survey despite targeted trapping - No known records occur within the Study Area. - Records occur greater than 3.5 km to the south of the Study Area within land managed by WaterNSW.	Species
Invertebrates						

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Meridolum corneovirens Cumberland Plain Land Snail	Lives in a very small area on the Cumberland Plain west of Sydney, from Richmond and Windsor south to Picton and from Liverpool west to the Hawkesbury and Nepean Rivers at the base of the Blue Mountains. Primarily inhabits Cumberland Plain Woodland. This community is a grassy, open woodland with occasional dense patches of shrubs. Lives under litter of bark, leaves and logs, or shelters in loose soil around grass clumps. Occasionally shelters under rubbish.	**NSW:** Endangered **Commonwealth:** Not listed	Low	Loq	Not detected during target surveys within area proposed for surface disturbance. Lack of Cumbelrand Plain Woodland throughout the Study Area.	Species
Mammals						
Cercartetus nanus Eastern Pygmy-possum	Inhabits rainforest through to sclerophyll forest and tree heath. Banksias and myrtaceous shrubs and trees are a favoured food source. Will often nest in tree hollows, but can also construct its own nest. Because of its small size it is able to utilise a range of hollow sizes including very small hollows. Individuals will use a number of different hollows and an individual has been recorded using up to 9 nest sites within a 0.5ha area over a 5 month period.	**NSW:** Vulnerable **Commonwealth:** Not listed	Low	Low	No previous records in Study Area. No known populations in Study Area. The species was not recorded during the field survey. Furthermore, the habitat type associated with this species are highly unlikely to be impacted by subsidence.	Species
Chalinolobus dwyeri Large-eared Pied Bat	Roosts in caves (near their entrances) and overhangs, crevices in cliffs, old mine workings and in the disused, bottle-shaped mud nests of the Fairy Martin (*Hirundo ariel*), frequenting low to mid-elevation dry open forest and woodland close to these features. Females have been recorded raising young in maternity roosts (c. 20-40 females) from November through to January in roof domes in sandstone caves. They will return to the same cave over many years.	**NSW:** Vulnerable **Commonwealth:** Vulnerable	Moderate	Moderate	There are no known caves within the Study Area, however sandstone overhangs and cliffs do occur. There is also suitable foraging habitat present. Considered further in impact assessment.	Ecosystem & Species
Dasyurus maculatus Spotted-tailed Quoll	Recorded across a range of habitat types, including rainforest, open forest, woodland, coastal heath and inland riparian forest, from the sub-alpine zone to the coastline.	**NSW:** Vulnerable **Commonwealth:** Endangered	Low	Low	No previous records in Study Area. No known populations in Study Area. Habitat marginal. Not recorded during field surveys. Not considered further.	Ecosystem

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Falsistrellus tasmaniensis Eastern False Pipistrelle	Generally roosts in eucalypt hollows, but has also been found under loose bark on trees or in buildings. Occurs at higher altitudes.	**NSW:** Vulnerable **Commonwealth:** Not listed	Known	Known	Previously recorded in Study Area.	Ecosystem
Isoodon obesulus Southern Brown Bandicoot	Prefers sandy soils with scrubby vegetation and/or areas with low ground cover that are burn from time to time. A mosaic of post fire vegetation is important for this species.	**NSW:** Endangered **Commonwealth:** Endangered	Low	Low	No previous records in Study Area. No known populations in Study Area. Habitat marginal. Not recorded during field surveys. Not considered further.	Species
Miniopterus schreibersii oceanensis Eastern Bent- wing Bat	Caves are the primary roosting habitat, but also use derelict mines, storm-water tunnels, buildings and other man-made structures. Critical habitat are its maternity roosts where very large numbers of female bats congregate. These are scattered throughout Australia.	**NSW:** Vulnerable **Commonwealth:** Not listed	Known	Known	Previously recorded in Study Area.	Ecosystem & Species
Miniopterus australis Little Bent-wing–Bat	East coast and ranges of Australia from Cape York in Queensland to Wollongong in NSW. Critical habitat are its maternity roosts where very large numbers of female bats congregate. These are scattered throughout Australia.	**NSW:** Vulnerable **Commonwealth:** Not listed	Low	Low	This species is at very edge of possible range and is unlikely to be present. It is also a cave-roosting bat and would not be reliant on any habitats within the Study Area. It is not considered further.	Ecosystem & Species
Mormopterus norfolkensis Eastern Freetail-Bat	Occur in dry sclerophyll forest, woodland, swamp forests and mangrove forests east of the Great Dividing Range. Roosts mainly in tree hollows but will also roost under bark or in man-made structures.	**NSW:** Vulnerable **Commonwealth:** Not listed	Known	Known	Previously recorded in Study Area.	Ecosystem
Myotis macropus Large-footed Myotis	Generally roost in groups of 10 - 15 close to water in caves, mine shafts, hollow-bearing trees, storm water channels, buildings, under bridges and in dense foliage. Uses water courses as primary foraging habitat.	**NSW:** Vulnerable **Commonwealth:** Not listed	Known	Known	Recorded in the Study Area.	Ecosystem & Species
Pseudomys novaehollandiae New Holland Mouse	Coastal heath and dry sclerophyll forest and woodland. Across the species' range, the New Holland Mouse is known to inhabit the following types of habitat; open heathland; open woodland with a heathland understorey; vegetated sand dunes.	**NSW:** Not listed **Commonwealth:** Vulnerable	Low	Low	No previous records in Study Area. No known populations in Study Area. Habitat marginal. Not recorded during field surveys. Not considered further.	Ecosystem

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Petaurus australis Yellow-bellied Glider	Occur in tall mature eucalypt forest generally in areas with high rainfall and nutrient rich soils. Forest type preferences vary with latitude and elevation; mixed coastal forests to dry escarpment forests in the north; moist coastal gullies and creek flats to tall montane forests in the south.	**NSW:** Vulnerable **Commonwealth:** Not listed	Low	Low	No previous records in Study Area. No known populations in Study Area. Habitat marginal. Not recorded during field surveys. Not considered further.	Ecosystem
Petaurus norfolcensis Squirrel Glider	Inhabits mature or old growth Box, Box-Ironbark woodlands and River Red Gum forest west of the Great Dividing Range and Blackbutt-Bloodwood forest with heath understorey in coastal areas.	**NSW:** Vulnerable **Commonwealth:** Not listed	Low	Low	No previous records in Study Area. No known populations in Study Area. Habitat marginal. Not recorded during field surveys. Not considered further.	Species
Petrogale penicillata Brush-tailed Rock-wallaby	Occupy rocky escarpments, outcrops and cliffs with a preference for complex structures with fissures, caves and ledges facing north.	**NSW:** Endangered **Commonwealth:** Vulnerable	None	None	No previous records in Study Area. No known populations in Study Area. Not recorded during field surveys. Not considered further.	Species
Phascolarctos cinereus Koala	Inhabit eucalypt woodlands and forests.	**NSW:** Vulnerable **Commonwealth:** Vulnerable	High (Previously recorded by OEH).	Low	Previously been recorded in the Study Area, however was not recorded within the surface infrastructure area during targeted surveys. It is therefore unlikely the species would use the area proposed for surface infrastructure for important foraging habitat. Considered further in impact assessment.	Species
Potorous tridactylus Long-nosed Potoroo	Inhabits coastal heath and wet and dry sclerophyll forests. Generally found in areas with rainfall greater than 760 mm. Requires relatively thick ground cover where the soil is light and sandy (Johnston, 1995).	**NSW:** Vulnerable **Commonwealth:** Vulnerable	Low	Low	No previous records in Study Area. No known populations in Study Area. Habitat marginal. Not recorded during field surveys. Not considered further.	Ecosystem
Pteropus poliocephalus Grey-headed Flying-fox	This species is a canopy-feeding frugivore and nectarivore of rainforests, open forests, woodlands, melaleuca swamps and banksia woodlands. Bats commute daily to foraging areas, usually within 15 km of the day roost (Tidemann 1995) although some individuals may travel up to 70 km (Augee 1999).	**NSW:** Vulnerable **Commonwealth:** Vulnerable	High	High	Habitat for this species occurs within the Study Area. Considered further in impact assessment.	Ecosystem & Species

Threatened species	Habitat requirements	Conservation status	Likelihood of occurrence in Study Area	Likelihood of occurrence in surface works area	Consideration in this assessment	Species Credit or Ecosystem Credit species
Scoteanax rueppellii Greater Broad-nosed Bat	Utilises a variety of habitats from woodland through to moist and dry eucalypt forest and rainforest, though it is most commonly found in tall wet forest. Although this species usually roosts in tree hollows, it has also been found in buildings. This species tends to occur at lower altitudes.	**NSW:** Vulnerable **Commonwealth:** Not listed	High (Previously recorded by OEH).	High	Likely present within the Study Area. The species may utilise the disturbance footprint for surface infrastructure for foraging.	Ecosystem
Vespadelus troughtoni Eastern Cave Bat	Very little is known about the biology of this uncommon species. A cave-roosting species that is usually found in dry open forest and woodland, near cliffs or rocky overhangs; has been recorded roosting in disused mine workings, occasionally in colonies of up to 500 individuals. Occasionally found along cliff-lines in wet eucalypt forest and rainforest. Little is understood of its feeding or breeding requirements or behaviour. The Study Area is the southern edge of the species range	**NSW:** Vulnerable **Commonwealth:** Not listed	Known	Known	This species is known to occur within the Study Area.	Ecosystem & Species
Petauroidies volans Greater Glider	The Greater Glider occurs in eucalypt forests and woodlands along the east coast of Australia from north east Queensland to the Central Highlands of Victoria. Feeds exclusively on eucalypt leaves, buds, flowers and mistletoe. Shelter during the day in tree hollows and will use up to 18 hollows in their home range. Occupy a relatively small home range with an average size of 1 to 3 ha.	**NSW:** Vulnerable **Commonwealth:** Not listed	Moderate	Low	No previous records in Study Area. No known populations in Study Area. Habitat marginal. Not recorded during field surveys. Records approximately 300 metres to the north of the Study Area along Bargo River.	NA

Appendix 2. Threatened Ecological Community likelihood of occurrence

Threatened Ecological Community	Description	TSC Act Status	EPBC Act Status	Likelihood of occurrence within Study Area
Bangalay Sand Forest of the Sydney Basin and South East Corner bioregions	Bangalay Sand Forest typically comprises a relatively dense or open tree canopy, an understorey of mesophyllous or sclerophyllous small trees and shrubs, and a variable groundcover dominated by sedges, grasses or ferns. The most common tree species include *Eucalyptus botryoides* (Bangalay) and *Banksia integrifolia* subsp. *integrifolia* (Coast Banksia). It occurs on deep, freely draining to damp sandy soils on flat to moderate slopes within a few km of the sea and at altitudes below 100 m. It is currently known from parts of the Local Government Areas of Sutherland, Wollongong, Shellharbour, Kiama, Shoalhaven, Eurobodalla and Bega Valley but may occur elsewhere in these bioregions.	Endangered	-	None – out of distribution range for this community.
Blue Gum High Forest in the Sydney Basin Bioregion	A moist, tall open forest community, with dominant canopy trees of Sydney Blue Gum (*Eucalyptus saligna*) and Blackbutt (*E. pilularis*). Forest Oak (*Allocasuarina torulosa*) and Sydney Red Gum (*Angophora costata*) also occur. Species adapted to moist habitat such as Lilly Pilly (*Acmena smithii*), Sandpaper Fig (*Ficus coronata*), Rainbow Fern (*Calochleana dubia*) and Common Maidenhair (*Adiantum aethiopicum*) may also occur. The remnants mainly occur in the Lane Cove, Willoughby, Ku-ring-gai, Hornsby, Baulkham Hills, Ryde and Parramatta local government areas. An example of Blue Gum High Forest can be seen at the Dalrymple-Hay Nature Reserve, St Ives.	Endangered	Critically Endangered	None – out of distribution range for this community.
Blue Mountains Shale Cap Forest in the Sydney Basin Bioregion	Characteristic tree species of this ecological community are Mountain Blue Gum (*Eucalyptus deanei*), Monkey Gum (*E. cypellocarpa*) and Turpentine (*Syncarpia glomulifera*). Other tree species include Sydney Red Gum (*Angophora costata*), Rough-barked Apple (*A. floribunda*), Mountain Mahogany (*E. notabilis*), Sydney Peppermint (*E. piperita*) and Grey Gum (*E. punctata*). Tree species composition varies between sites depending on geographical location and local conditions (e.g. topography, rainfall exposure). Known from the local government areas of Blue Mountains and Hawkesbury, both within the Sydney Basin Bioregion. It may occur elsewhere in the Bioregion, and communities within Wollondilly LGA certainly show similarities to this community.	Endangered	Critically Endangered	Low – not recorded during vegetation survey, or previously mapped by Tozer et al. (2006) within the Study Area.
Castlereagh Scribbly Gum and Agnes Banks Woodland in the Sydney Basin Bioregion	Agnes Banks Woodland is a low woodland dominated by *Eucalyptus sclerophylla* and *Angophora bakeri* with a diverse understorey of sclerophyllous shrubs species including *Banksia oblongifolia*, *Conospermum taxifolium, Leptospermum trinervium, Dillwynia sericea, Monotoca scoparia,Persoonia nutans*, and ground stratum species including *Lepidosperma urophorum, Platysace ericiodes, Pimelea linifolia, Mitrasacme polymorpha, Trachymene incisa* and *Stylidium graminifolium.* Agnes Banks Woodland is restricted to small areas of sand dunes overlying Tertiary Alluvium at Agnes Banks on the east bank of the Hawkesbury River. In low-lying, poorly drained areas it grades into Castlereagh Ironbark Forest. #	Vulnerable/ Critically Endangered	Endangered	None – out of distribution range for this community.

Threatened Ecological Community	Description	TSC Act Status	EPBC Act Status	Likelihood of occurrence within Study Area
Coastal Saltmarsh in the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	Coastal Saltmarsh occurs in the intertidal zone on the shores of estuaries and lagoons that are permanently or intermittently open to the sea. It is frequently found as a zone on the landward side of mangrove stands. Characteristic plants include *Baumea juncea*, Sea Rush (*Juncus krausii* subsp. *australiensis*), Samphire (*Sarcocornia quinqueflora* subsp. *quinqueflora*), Marine Couch (*Sporobolus virginicus*), Streaked Arrowgrass (*Triglochin striata*), Knobby Club-rush (*Ficinia nodosa*), Creeping Brookweed (*Samolus repens*), Swamp Weed (*Selliera radicans*), Seablite (*Suaeda australis*) and Prickly Couch (*Zoysia macrantha*). Occasionally mangroves are scattered through the saltmarsh. Tall reeds may also occur, as well as salt pans. This community occurs in the intertidal zone along the NSW coast.	Endangered	Vulnerable	None – out of distribution range for this community.
Coastal Upland Swamp in the Sydney Basin Bioregion	The Coastal Upland Swamp in the Sydney Basin Bioregion includes open graminiod heath, sedgeland and tall scrub associated with periodically waterlogged soils on the Hawkesbury sandstone plateaux. The Coastal Upland Swamp is generally associated with soils that are acidic and vary from yellow or grey mineral sandy loams with a shallow organic horizon to highly organic spongy black peat soils with pallid subsoils. The vegetation of the Coastal Upland Swamp may include tall open scrubs, tall closed scrubs, closed heaths, open graminoid heaths, sedgelands and fernlands. Larger examples may include a complex of these structural forms. The flora comprising the upland swamp is diverse there are 73 plant species listed as characterising the ecological community.The total species list is much greater and is likely to exceed 200 species of vascular plants.	Endangered	Endangered	None – no upland swamps previously mapped within the Study Area. Furthermore, aerial photography interpretation has not identified any potential upland swamps.
Cooks River/Castlereagh Ironbark Forest in the Sydney Basin Bioregion	Ranges from open forest to low woodland, with a canopy dominated by Broad-leaved Ironbark (*Eucalyptus fibrosa*) and Paperbark (*Melaleuca decora*). The canopy may also include other eucalypts such as Woolybutt (*E. longifolia*). The dense shrubby understorey consists of Prickly-leaved Paperbark (*Melaleuca nodosa*) and Peach Heath (*Lissanthe strigosa*), with a range of 'pea' flower shrubs, such as *Dillwynia tenuifolia*, Hairy Bush-pea (*Pultenaea villosa*) and Gorse Bitter Pea (*Daviesia ulicifolia*) (can be locally abundant). The sparse ground layer contains a range of grasses and herbs. Contains many more species and other references should be consulted to identify these. Occurs in western Sydney, and the extent of intact remnants is now reduced to 1011 hectares, with the most extensive stands occurring in the Castlereagh and Holsworthy areas.	Endangered	Critically Endangered	Low – not recorded during surveys, nor previously mapped as occurring in Study Area.

Threatened Ecological Community	Description	TSC Act Status	EPBC Act Status	Likelihood of occurrence within Study Area
Cumberland Plain Shale Woodlands and Shale Gravel Transition Forest	Has an open forest structure with a canopy dominated by Broad-leaved Ironbark *Eucalyptus fibrosa*, with Grey Box *E. moluccana* and Forest Red Gum *E. tereticornis* occurring less frequently. Paperbark *Melaleuca decora* is common in the small tree layer. A sparse shrub layer is usually present which includes Blackthorn *Bursaria spinosa, Daviesia ulicifolia* and Peach Heath *Lissanthe strigosa*. Contains many more species and other references should be consulted to identify these. Mainly found in the northern section of the Cumberland Plain, western Sydney, in the Richmond, Marsden Park and Windsor districts. Also appears in the Liverpool/ Holsworthy area, and there are small occurrences at Bankstown, Yennora and Villawood and the Kemps Creek area.	Critically Endangered	Critically Endangered	Possible however detailed vegetation mapping by Niche did not record this TEC during field surveys, no has vegetation mapping by Tozer et al. (2006) mapped any within the study area.
Elderslie Banksia Scrub Forest in the Sydney Basin Bioregion	A scrub community dominated by Coastal Banksia *Banksia integrifolia* subsp. *integrifolia*. Other canopy species include Broad-leaved Apple *Angophora subvelutina*. The shrubby understorey is diverse and includes species that usually occur in sandstone areas, such as Wedding Bush *Ricinocarpus pinifolius,* Riceflower *Pimelea linifolia* subsp. *linifolia* and Daphne Heath *Brachyloma daphnoides*. Contains many more species and other references should be consulted to identify these. Occurs only in the Elderslie area, near Camden, in Sydney's south-west. Remaining remnants are 15 ha in total.	Endangered	-	None – out of range for this TEC.
Freshwater Wetlands on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	Associated with coastal areas subject to periodic flooding and in which standing fresh water persists for at least part of the year in most years. Typically occurs on silts, muds or humic loams in low-lying parts of floodplains, alluvial flats, depressions, drainage lines, backswamps, lagoons and lakes but may also occur in backbarrier landforms where floodplains adjoin coastal sandplains. Generally occur below 20 m elevation on level areas. They are dominated by herbaceous plants and have very few woody species. The structure and composition of the community varies both spatially and temporally depending on the water regime: Those that lack standing water most of the time are usually dominated by dense grassland or sedgeland vegetation, often forming a turf less than 0.5 metre tall and dominated by amphibious plants including *Paspalum distichum* (water couch), *Leersia hexandra* (swamp rice-grass), *Pseudoraphis spinescens* (mud grass) and *Carex appressa* (tussock sedge). Known from along the majority of the NSW coast. However, it is distinct from Sydney Freshwater Wetlands which are associated with sandplains in the Sydney Basin bioregion. Extensively cleared and modified.	Endangered	-	Low – not recorded during vegetation survey, or previously mapped by Tozer et al. (2006) or OEH (2012) within the Study Area.

Threatened Ecological Community	Description	TSC Act Status	EPBC Act Status	Likelihood of occurrence within Study Area
Littoral Rainforest in the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	Littoral Rainforest is generally a closed forest, the structure and composition of which is strongly influenced by its proximity to the ocean. The plant species of this community are predominantly rainforest species. Several species have compound leaves, and vines may be a major component of the canopy. These features differentiate littoral rainforest from forest or scrub, but while the canopy is dominated by rainforest species, scattered emergent individuals of sclerophyll species, such as *Angophora costata*, *Banksia integrifolia*, *Eucalyptus botryoides* and *Eucalyptus tereticornis* occur in many stands. There is considerable floristic variation between stands and in particular areas, localised variants may be recognised. The Sutherland Shire Littoral Rainforest Endangered Ecological Community which was listed previously as an endangered ecological community is included within this community.	Endangered	Critically Endangered	Low – not recorded during vegetation survey, or previously mapped by Tozer et al. (2006) within the Study Area.
Montane Peatlands and Swamps of the New England Tableland, NSW North Coast, Sydney Basin, South East Corner, South Eastern Highlands and Australian Alps bioregions	Montane Peatlands and Swamps comprises a dense, open or sparse layer of shrubs with soft-leaved sedges, grasses and forbs. It is the only type of wetland that may contain more than trace amounts of Sphagnum spp., the hummock peat-forming mosses. Small trees may be present as scattered emergents or absent. The community typically has an open to very sparse layer of shrubs, 1-5 m tall, (eg. *Baeckea gunniana*, *B. utilis, Callistemon pityoides, Leptospermum juniperinum, L. lanigerum, L. myrtifolium, L. obovatum, L. polygalifolium).* Species of *Epacris (*eg. *E. breviflora, E. microphylla, E. paludosa)* and *Hakea microcarpa* are also common shrubs. In some peatlands and swamps, particularly those with a history of disturbance to vegetation, soils or hydrology, the shrub layer comprises dense thickets of Leptospermum species. In other peatlands and swamps with a history of grazing by domestic livestock, the shrub layer may be very sparse or absent.	Endangered	Endangered	None – not recorded during vegetation survey, Study Area out of known range and not previously mapped by within the Study Area.
O'Hares Creek Shale Forest	Occurs on small outcrops of Hawkesbury shale in the Darkes Forest area of the Woronora Plateau. The community is dominated by *Eucalyptus piperita* (Sydney Peppermint), *E. globoidea* (White Stringybark) and *Angophora costata* (Smooth-barked Apple), with the latter species sometimes being the dominant canopy species. The shrub layer is variable in density and height but is characterised by *Acacia binervata, A. longifolia* subsp. *longifolia, Leucopogon lanceolatus var. lanceolatus* and *Banksia spinulosa* var. *spinulosa*. The groundcover is often the distinguishing feature of the community with an impressive cushion of ferns, lilies, grasses and rushes that include species such as *Calochlaena dubia, Pteridium esculentum, Doryanthes excelsa, Dianella caerulea, Lomandra longifolia, Blechnum cartilagineum, Entolasia stricta* and *Imperata cylindrica* var. *major*. O'Hares Creek Shale Forest is a component of Red Bloodwood - Smooth Barked Apple shrubby forest on shale or ironstone of coastal plateau, Sydney Basin. The community occupies approximately 286 ha within the local government areas of Campbelltown, Wollondilly and Wollongong between the Cataract Special Area and Appin Road to Helensburgh.	Endangered	-	None – not recorded during vegetation survey, Study Area out of known range and not previously mapped by within the Study Area.

Threatened Ecological Community	Description	TSC Act Status	EPBC Act Status	Likelihood of occurrence within Study Area
River-Flat Eucalypt Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	As the name suggests, this EEC is found on the river flats of the coastal floodplains. It has a tall open tree layer of eucalypts, which may exceed 40 m in height, but can be considerably shorter in regrowth stands or under conditions of lower site quality. While the composition of the tree stratum varies considerably, the most widespread and abundant dominant trees include *Eucalyptus tereticornis* (forest red gum), E. *amplifolia* (cabbage gum), *Angophora floribunda* (rough-barked apple) and *A. subvelutina* (broad-leaved apple). *Eucalyptus baueriana* (blue box), *E. botryoides* (bangalay) and *E. elata* (river peppermint) may be common south from Sydney, *E. ovata* (swamp gum) occurs on the far south coast, *E. saligna* (Sydney blue gum) and *E. grandis* (flooded gum) may occur north of Sydney, while *E. benthamii* is restricted to the Hawkesbury	Endangered	-	Moderate – previously mapped occurred on the far upper reaches of Eliza Creek. The existing mapping could be incorrect. Validated of the mapping could not be undertaken given location within private property.
Shale Sandstone Transition Forest	Occurs at the edges of the Cumberland Plain, where clay soils from the shale rock intergrade with earthy and sandy soils from sandstone, or where shale caps overlay sandstone. The boundaries are indistinct, and the species composition varies depending on the soil influences. The main tree species include Forest Red Gum (*Eucalyptus tereticornis*), Grey Gum (*E. punctata*), stringybarks (*E. globoidea, E. eugenioides*) and ironbarks (*E. fibrosa* and *E. crebra*). Areas of low sandstone influence (more clay-loam soil texture) have an understorey that is closer to Cumberland Plain Woodland. Shale Sandstone Transition Forest in the Sydney Basin Bioregion contains many more species than described for the canopy (above) and other references should be consulted to identify these. Only 9,950 ha remains intact (22.6% of its original extent) and the bulk of this occurs in the Hawkesbury, Baulkham Hills, Liverpool, Parramatta, Penrith, Campbelltown and Wollondilly local government areas. Good examples can be seen at Gulguer Nature Reserve, in the Wilton area and in the Sackville - Maroota area.	Critically Endangered	Critically Endangered	Known – vegetation validation has confirmed the precence of the TEC within area proposed for surface infrastructure.
Southern Highlands Shale Woodlands in the Sydney Basin Bioregion	Southern Highlands Shale Woodland is confined to a small area in the Southern Highlands. It occurs roughly within an area bounded by the Illawarra Escarpment in the east, Burrawang and Bundanoon in the south, Canyonleigh in the west and Berrima and Colo Vale in the north. Occurs in the Wingecarribee local government area, but may occur elsewhere in the Sydney Basin Bioregion. Southern Highlands Shale Woodland is a variable community in terms of both structure and composition. The community may exist as tall open forest, grassy woodland or scrub; though it originally existed as woodland. The dominant canopy species vary across the distribution of the community. Common species throughout much of the community's range are Mountain Grey Gum *Eucalyptus cypellocarpa*, Sydney Peppermint *E. piperita*, Swamp Gum *E. ovata*, Narrow-leafed Peppermint *E. radiata* and White Stringybark *E. globoidea*. Brittle Gum *E. mannifera*, Snow Gum *E. pauciflora*, Cabbage Gum *E. amplifolia* and Rough-barked Apple *Angophora floribunda* are less common.	Endangered	Critically Endangered	Low – not recorded during vegetation survey. More likely to occur south of Study Area near Colo Vale.

Threatened Ecological Community	Description	TSC Act Status	EPBC Act Status	Likelihood of occurrence within Study Area
Southern Sydney sheltered forest on transitional sandstone soils in the Sydney Basin Bioregion	Southern Sydney sheltered forest on transitional sandstone soils in the Sydney Basin Bioregion has an open forest structure, although disturbance may result in local manifestations as woodland or scrub. The community is typically associated with sheltered heads and upper slopes of gullies on transitional zones where sandstone outcrops may exist, but where soils are influenced by lateral movement of moisture, nutrients and sediment from more fertile substrates, such as shale/ironstone caps or dolerite dykes, in adjacent areas. Southern Sydney sheltered forest on transitional sandstone soils is an open forest dominated by eucalypts with scattered subcanopy trees, a diverse shrub layer and well-developed groundcover of ferns, herbs and graminoids. Some stands may take on structural forms of woodland or scrub, as disturbance associated with past clearing has resulted in reduced density and/or dense regrowth of the tree stratum. The dominant trees include *Angophora costata*, *Eucalyptus piperita* and occasionally *E. pilularis*, particularly around Helensburgh. *Corymbia gummifera* occurs frequently within the community, although generally at lower abundance than the other eucalypts. An open subcanopy includes *Allocasuarina littoralis, Ceratopetalum gummiferum* and occasionally *Elaeocarpus reticulatus* and *Pittosporum undulatum*.	Endangered	-	Low – not recorded during vegetation survey, or previously mapped by Tozer et al. (2006) within the Study Area.
Swamp Oak Floodplain Forest of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	This community is found on the coastal floodplains of NSW. It has a dense to sparse tree layer in which *Casuarina glauca* (swamp oak) is the dominant species northwards from Bermagui. Other trees including *Acmena smithii* (lilly pilly), *Glochidion* spp. (cheese trees) and *Melaleuca* spp. (paperbarks) may be present as subordinate species, and are found most frequently in stands of the community northwards from Gosford. Tree diversity decreases with latitude, and *Melaleuca ericifolia* is the only abundant tree in this community south of Bermagui. The understorey is characterised by frequent occurrences of vines, *Parsonsia straminea, Geitonoplesium cymosum* and *Stephania japonica* var. *discolor*, a sparse cover of shrubs, and a continuous groundcover of forbs, sedges, grasses and leaf litter.	Endangered	-	Low – not recorded during vegetation survey, or previously mapped by Tozer et al. (2006) within the Study Area.
Swamp Sclerophyll Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	This swamp community has an open to dense tree layer of eucalypts and paperbarks although some remnants now only have scattered trees as a result of partial clearing. The trees may exceed 25 m in height, but can be considerably shorter in regrowth stands or under conditions of lower site quality where the tree stratum is low and dense. For example, stands dominated by *Melaleuca ericifolia* typically do not exceed 8 m in height. The community also includes some areas of fernland and tall reedland or sedgeland, where trees are very sparse or absent. The most widespread and abundant dominant trees include *Eucalyptus robusta* (swamp mahogany), *Melaleuca quinquenervia* (paperbark) and, south from Sydney, *Eucalyptus botryoides* (bangalay) and Eucalyptus longifolia (woollybutt). Other trees may be scattered throughout at low abundance or may be locally common at few sites, including *Callistemon salignus* (sweet willow bottlebrush), *Casuarina glauca* (swamp oak) and *Eucalyptus resinifera* subsp. *hemilampra* (red mahogany), *Livistona australis* (cabbage palm) and *Lophostemon suaveolens* (swamp turpentine).	Endangered	-	Low – not recorded during vegetation survey, or previously mapped by Tozer et al. (2006) within the Study Area.

Threatened Ecological Community	Description	TSC Act Status	EPBC Act Status	Likelihood of occurrence within Study Area
Sydney Freshwater Wetlands in the Sydney Basin Bioregion	A complex of vegetation types largely restricted to freshwater swamps in coastal areas. These also vary considerably due to fluctuating water levels and seasonal conditions. Characteristic species include sedges and aquatic plants such as Baumea species, *Eleocharis sphacelata*, Gahnia species, *Ludwigia peploides* subsp. *montevidensis* and Persicaria species. Areas of open water may occur where drainage conditions have been altered and there may also be patches of emergent trees and shrubs. Characteristic species are listed in the final determination - see links box. Occurs on sand dunes and low-nutrient sandplains along coastal areas in the Sydney Basin bioregion. It is known from the Lake Macquarie, Wyong, Gosford, Pittwater, Warringah, Woollahra, Waverley, Botany, Rockdale, Randwick, Sutherland and Wollongong local government areas, but is likely to occur elsewhere within the bioregion. Has been extensively cleared and filled and remnants are often small and disturbed.	Endangered	-	Low – no freshwater wetlands are known to occur within the Study Area
Tableland Basalt Forest in the Sydney Basin and South Eastern Highlands Bioregions	Tableland Basalt Forest is dominated by an open eucalypt canopy of variable composition. *Eucalyptus viminalis, E. radiata, E. dalrympleana subsp. dalrympleana* and *E. pauciflora* may occur in the community in pure stands or in varying combinations. The community typically has an open canopy of eucalypts with sparse mid-story shrubs (e.g. *Acacia melanoxylon* and *A. dealbata*) and understory shrubs (e.g. *Rubus parvifolius*) and a dense groundcover of herbs and grasses, although disturbed stands may lack either or both of the woody strata. The structure of the community varies depending on past and current disturbances, particularly fire history, clearing and grazing. Contemporary tree-dominated stands of the community are largely relics or regrowth of originally taller forests and woodlands, which are likely to have had scattered shrubs and a largely continuous grassy groundcover. At some sites, mature trees may exceed 30 m tall, although regrowth stands may be shorter than 10 m tall. Tableland Basalt Forest is currently found in the Eastern Highlands and Southern and Central Tablelands, covering the local government areas of Bathurst Regional, Goulburn Mulwaree, Oberon, Palerang, Shoalhaven, Upper Lachlan and Wingecarribee. The community, however, may be found elsewhere within the designated bioregions.	Endangered	-	Low – not recorded during vegetation survey, or previously mapped by Tozer et al. (2006) within the Study Area.

Threatened Ecological Community	Description	TSC Act Status	EPBC Act Status	Likelihood of occurrence within Study Area
Tablelands Snow Gum, Black Sallee, Candlebark and Ribbon Gum Grassy Woodland in the South Eastern Highlands, Sydney Basin, South East Corner and NSW South Western Slopes Bioregions	This community, commonly referred to as Tablelands Snow Gum Grassy Woodland, occurs as an open-forest, woodland or open woodland. This community may also occur as a secondary grassland where the trees have been removed, but the groundlayer remains. The main tree species are *Eucalyptus pauciflora* (Snow Gum), *E. rubida* (Candlebark), *E. stellulata* (Back Sallee) and *E. viminalis* (Ribbon Gum), either alone or in various combinations. Other eucalypt species may occur. A shrub layer may be present and sub-shrubs are common. The most common shrubs include Melicytus sp. 'Snowfileds' (Gruggly-bush) and *Melichrus urceolatus* (Urn Heath). The ground layer is grassy, with the most common species including *Themeda australis* (Kangaroo Grass), Poa spp. (snow-grasses), Austrostipa spp. (spear-grasses) and Rytidosperma spp. (wallaby-grasses). Sites in high condition have a range of forb (wildlfower) species, including *Leptorhynchos squamatus* (Scaly-buttons), *Chrysocephalum apiculatum* (Common Everlastings) and *Asperula conferta* (Native Woodlruff). Many threatened flora and fauna species have been recorded in this community.	Endangered	Critically Endangered	None – out of distribution range for this community.
Themeda grassland on seacliffs and coastal headlands in the NSW North Coast, Sydney Basin and South East Corner Bioregions	Themeda Grassland on seacliffs and coastal headlands is found on a range of substrates in the NSW North Coast, Sydney Basin and South East Corner bioregions. Stands on sandstone are infrequent and small. Larger stands are found on old sand dunes above cliffs, as for example at Cape Banks and Henry Head in Botany Bay National Park, and on metasedimentary headlands, as for example at McCauleys Headland in Coffs Coast Regional Park, Look-at-me-now Headland, Dammerels Head and Bare Bluff in Moonee Beach Nature Reserve and Wilson's Headland in Yuraygir National Park. Individual stands of the community are often very small, a few square metres, but at some sites larger stands of up to several hectares or tens of hectares occur. Overall, the community has a highly restricted geographic distribution comprising small, but widely scattered patches.	Endangered	-	None – out of distribution range for this community.

Threatened Ecological Community	Description	TSC Act Status	EPBC Act Status	Likelihood of occurrence within Study Area
Turpentine Ironbark Forest in the Sydney Basin Bioregion	Open forest, with dominant canopy trees including Turpentine *Syncarpia glomulifera*, Grey Gum *Eucalyptus punctata*, Grey Ironbark *E. paniculata* and Thin-leaved Stringybark *E. eugenoides*. In areas of high rainfall (over 1050 mm per annum) Sydney Blue Gum *E. saligna* is more dominant. The shrub stratum is usually sparse and may contain mesic species such as Sweet Pittosporum *Pittosporum undulatum* and Elderberry Panax *Polyscias sambucifolia*. Contains many more species and other references should be consulted to identify these. A similar form of the community occurs more widely (particularly in the Wollondilly and Hawkesbury areas) but this is outside the nominated councils that are included in the determination (Ashfield, Auburn, Canterbury, Concord, Drummoyne, Leichhardt, Marrickville, Bankstown, Ryde, Hunters Hill, Baulkham Hills, Ku-ring-gai, Hornsby, Parramatta, Bankstown, Rockdale, Kogarah, Hurstville and Sutherland). This form could be equated to Blue Mountains Shale Cap Forest, although the correlation is less strong for Wollondilly (which is not mentioned in that determination).	Endangered	Critically Endangered	Low – not recorded during vegetation survey, or previously mapped by Tozer et al. (2006) or OEH (2013) within the Study Area.
Upland Basalt Eucalypt Forests of the Sydney Basin Bioregion	The ecological community typically occurs as an open to tall open forest with a sparse to dense layer of shrubs and vines, and a diverse understorey of native grasses, forbs, twiners and ferns (Keith, 2004). However, the structure of the ecological community may vary from tall open forest with trees up to and above 30 m tall with a projected foliage cover of 30–70% (e.g. *Eucalyptus fastigata* forest on basalt near Sassafras in and around Morton National Park) to woodland with trees 10–30 m tall, with a projected foliage cover of 10–30% (e.g. exposed woodland on rocky microsyenite at Mt Jellore) depending on aspect, slope, soil conditions, soil depth, and previous clearing and disturbance (Fisher et al., 1995; NPWS & SCA, 2003; Eco Logical Australia, 2003; NSW Scientific Committee, 2001a, 2001b).	Endangered	Endangered	Low – not recorded during vegetation survey, or previously mapped by Tozer et al. (2006) within the Study Area.
Western Sydney Dry Rainforest and Moist Woodland on Shale	The canopy of the Moist Shale Woodland generally has trees of *Eucalyptus tereticornis* and *Eucalyptus moluccana,* with *Eucalyptus crebra* and *Corymbia maculata* occurring occasionally. There is often a small tree stratum including species such as *Acacia implexa* or *Acacia parramattensis* subsp. *parramattensis.* A sparse shrub stratum is usually present, and commonly *includes Breynia oblongifolia, Clerodendrum tomentosum, Bursaria spinosa* and *Olearia viscidula.* Ground layer species include *Desmodium varian, Cyperus gracilis, Galium propinquum, Cayratia clematidea, Glycine clandestina, Brunoniella australis, Desmodium brachypodum, Dichondra repens, Microlaena stipoides* var. *stipoides, Sigesbeckia orientalis* subsp. *orientalis* and *Solanum prinophyllum.* Moist Shale Woodland usually occurs on soils derived from Wianamatta Shale on higher country in the southern half of the Cumberland Plain. Moist Shale Woodland is found in very similar environments to Western Sydney Dry Rainforest, but tends to occupy upper slopes while Western Sydney Dry Rainforest is often found on lower slopes and in gullies.	Endangered	Critically Endangered	Low – not recorded during vegetation survey, or previously mapped by Tozer et al. (2006) within the Study Area.

Threatened Ecological Community	Description	TSC Act Status	EPBC Act Status	Likelihood of occurrence within Study Area
White Box Yellow Box Blakely's Red Gum Woodland	Box-Gum Woodland is found from the Queensland border in the north, to the Victorian border in the south. It occurs in the tablelands and western slopes of NSW. White Box Yellow Box Blakely's Red Gum Woodland (commonly referred to as Box-Gum Woodland) is an open woodland community (sometimes occurring as a forest formation), in which the most obvious species are one or more of the following: White Box *Eucalyptus albens*, Yellow Box *E. melliodora* and Blakely's Red Gum *E. blakelyi*. Intact sites contain a high diversity of plant species, including the main tree species, additional tree species, some shrub species, several climbing plant species, many grasses and a very high diversity of herbs. The community also includes a range of mammal, bird, reptile, frog and invertebrate fauna species.	Endangered	Critically Endangered	None – out of distribution range for this community.

Appendix 3. Vegetation and threatened flora survey effort

Site	Activity	Date	Total hours threatened flora survey	Staff
Surface infrastructure (2018)	Seven BioBanking quadrats, threatened flora survey.	12/09/18 – 15/09/18, 18/09/18	32 hours	Ciaro Forrest, Alex Christie
Surface infrastructure (2017)	Four quadrats, threatened flora survey, *Grevillea parviflora* subsp. *parviflora* population count	13/09/17, 14/09/17, 15/09/17, 16/09/17, 17/09/17	24 hours	Luke Baker, Matthew Stanton, Cairo Forrest
REA Survey (2013)	43 quadrats, Threatened flora targeted survey, population counts for *Grevillea parviflora* subsp. *parviflora*, *Persoonia bargoensis* and *Pomaderris brunnea*.	15/9/12, 16/9/12, 20/9/12, 22/9/12, 16/10/12, 17/10/12, 18/10/12, 22/10/12, 23/10/12, 15/11/12, 18/6/13	100 hours	Luke Baker, Nathan Smith, Anna Senior
Ventilation shaft TSC1 (2013) – site no longer part of Project.	One quadrat, random meander, rapid data points	6/09/13	10 hours	Luke Baker, Anna Senior
Ventilation shaft TSC2 (2013) site no longer part of Project.	Seven quadrats, random meander	18/6/13	10 hours	Luke Baker, Anna Senior
Ventilation shaft TSC3 (2013) site no longer part of Project.	Seven quadrats, random meander	19/6/13	10 hours	Luke Baker, Anna Senior
Transmission line (2013) site no longer part of Project.	Two quadrats, random meander, threatened species counts	21/6/13	10 hours	Luke Baker, Anna Senior, Frank Lemckert
Haul Road (2013) site no longer part of Project.	Random meander, threatened flora counts	20/6/13	6 hours	Anna Senior, Chris McEvoy

Site	Activity	Date	Total hours threatened flora survey	Staff
Riparian vegetation monitoring (2012-2013) (Niche 2013)	30 quadrats and threatened flora random meanders	18/6/12, 19/6/12, 20/6/12, 21/6/12, 22/6/12, 5/12/12, 6/12/12, 7/12/12, 10/12/12, 11/12/12, 12/12/12, 13/12/12.	80 hours	Luke Baker, Anna Senior, Simon Tweed, Daniella Binder
Riparian vegetation monitoring (2013-2014) (Niche 2014)	30 quadrats and threatened flora random meanders	3/6/13, 4/6/13, 5/6/13, 6/6/13, 10/6/13, 11/6/13, 12/6/13, 13,6/13, 14/6/13, 15/6/13	80 hours	Luke Baker, Anna Senior.
Tahmoor South Pilot study (Niche 2012)	Habitat assessment. Rapid data points and random meander	5/12/11, 6/12/11, 7/12/12, 8/12/11, 11/4/12, 16/4/12	6 hours	Luke Baker, Frank Lemckert, Kristy McQueen

Appendix 4. Fauna survey effort

Table 49. Surface infrastructure survey effort

Area (Surface infrastructure)	Method	Survey effort (hours/trap nights)	Total hours	Dates	Staff
Ventilation shaft sites	Camera traps	10 traps over 10 nights	2,400 hours	12/09/18 to 22/09/2018	Cairo Forrest and Alex Christie
Ventilation shaft sites	Call play-back	3 hours over three nights	3 hours	12/09/18, 13/09/18,	Cairo Forrest and Alex Christie
Ventilation shaft sites	Spotlighting	12 hours over 2 nights	12 hours	12/09/18, 13/09/18,	Cairo Forrest and Alex Christie
Ventilation shaft sites	Bird surveys (morning)	Three mornings	2.5 hours	13/09/18, 17/09/18, 18/09/18	Cairo Forrest and Alex Christie
Ventilation shaft sites	Koala SAT searches	6 hours total	6 hours	18/09/18	Cairo Forrest and Alex Christie
Ventilation shaft sites	Cumberland Plain Land Snail Searches	24 hours total	24 hours	13/09/18, 17/09/18, 18/09/18	Cairo Forrest and Alex Christie
Ventilation shaft sites	Songmeter	3 nights one location	68 hours	14/09/18, 15/09/18, 16/09/18	Cairo Forrest and Alex Christie
Hornes Creek	Songmeter	3 nights one location	72 hours	14/09/18, 15/09/18, 16/09/18	Cairo Forrest and Alex Christie
REA	Camera traps	29 traps over 10 nights	6,980 hours	13/09/17	Matthew Stanton, Cairo Forrest
REA	Call play-back	3 hours over three nights	3 hours	13/09/17, 14/09/17, 15/09/17, 16/09/17, 17/09/17	Matthew Stanton, Cairo Forrest
REA	Spotlighting	24 hours over three nights	24 hours	13/09/17, 14/09/17, 16/09/17,	Matthew Stanton, Cairo Forrest

Area (Surface infrastructure)	Method	Survey effort (hours/trap nights)	Total hours	Dates	Staff
REA	Koala scat searches	6 hours	6 hours	17/09/17	Luke Baker, Cairo Forrest
REA	Frog searches (Dog Trap Creek, Tea Tree Hollow Creek, Eliza Creek)	3 days and 2 nights	24 hours	13/09/17, 14/09/17	Matthew Stanton, Cairo Forrest, Frank Lemckert
REA	Camera traps	7 nights (3 traps)	252 hours	20th -27th March, 2013	Matthew Stanton, Frank Lemckert
REA	Koala scat searches	10 hours (2 day)	10 hours	26th-27th March, 2013	Matthew Stanton, Anna Senior
REA	Spotlighting/stag watch	4 hours	4 hours	20th -27th March, 2013	Matthew Stanton, Frank Lemckert, Anna Senior
REA	Call playback	8 hours	8 hours	20th -27th March, 2013	Matthew Stanton, Frank Lemckert, Anna Senior
REA	Frog searches	6 hours	6 hours	20th -27th March, 2013	Matthew Stanton, Frank Lemckert, Anna Senior
REA	Songmeters	5 days (one location)	60 hours	20th -27th March, 2013	Matthew Stanton, Frank Lemckert
REA	Harp traps	2 nights in two locations	48 hours	20th -27th March, 2013	Matthew Stanton, Frank Lemckert
REA	Songmeters	9 nights (in three locations)	324 hours	5th - 14th Nov, 2013	Simon Tweed, Anna Senior, Frank Lemckert
REA	Camera traps	9 nights (3 locations)	1620 hours	5th - 14th Nov, 2013	Simon Tweed, Anna Senior, Frank Lemckert
REA	Call playback	16 hours	16 hours	5th - 14th Nov, 2013	Simon Tweed, Anna Senior, Frank Lemckert
REA	Spotlighting/stag watch	12 hours	12 hours	5th - 14th Nov, 2013	Simon Tweed, Anna Senior, Frank Lemckert
REA	Frog searches	6 hours	6 hours	5th - 14th Nov, 2013	Simon Tweed, Anna Senior, Frank Lemckert
REA	Arboreal cage traps	150 trap nights	1800 hours	5th - 14th Nov, 2013	Simon Tweed, Anna Senior, Frank Lemckert
REA	Harp traps	3 nights in 2 locations	72 hours	5th - 14th Nov, 2013	Simon Tweed, Anna Senior, Frank Lemckert
REA	Hair tubes	9 nights	6480 hours	5th - 14th Nov, 2013	Simon Tweed, Anna Senior, Frank Lemckert
REA	Reptile spotlighting	4 hours	4 hours	5th - 14th Nov, 2013	Simon Tweed, Anna Senior, Frank Lemckert
REA	Reptile habitat search	4 hours	4 hours	5th - 14th Nov, 2013	Simon Tweed, Anna Senior, Frank Lemckert
REA	Diurnal Bird searches	20 minutes each site (6) with two people + opportunistic	5 hours	5th - 14th Nov, 2013	Simon Tweed, Anna Senior, Frank Lemckert

Area (Surface infrastructure)	Method	Survey effort (hours/trap nights)	Total hours	Dates	Staff
REA	Habitat search	2 hours	2 hours	16th Oct, 2012	Simon Tweed, Anna Senior
REA	Koala scat searches	2 hours	2 hours	16th Oct, 2012	Simon Tweed, Anna Senior
Ventilation shaft TSC1	Habitat assessment	4 hours	4 hours	6/09/13	Luke Baker, Anna Senior
Ventilation shaft TSC2	Habitat assessment	8 hours	8 hours	18/6/13	Luke Baker, Anna Senior
Original ventilation shaft TSC3	Habitat assessment	8 hours	8 hours	19/6/13	Luke Baker, Anna Senior

Table 50. Amphibian monitoring survey effort 2012 season

		Autumn 2012				Spring 2012			
Site	**Activity**	**Date**	**Staff**	**Time**	**Effort (mins/per person)**	**Date**	**Staff**	**Time**	**Effort (mins/per person)**
Dog Trap Creek 1	Transect	3/7	LB, ST	17.00	45	4/12	LB, FL	20.00	25
Dog Trap Creek 1	Day tadpole search	20/6	LB, ST	9.00	15	-	LB, FL	-	-
Dog Trap Creek 1	Songmeter	-	LB, ST	-	-	4/12	LB, FL	-	4nights
Dog Trap Creek 2	Transect	3/7	LB, ST	18.05	40	4/12	LB, FL	20.45	30
Dog Trap Creek 3	Transect	3/7	LB, ST	19.00	45	4/12	LB, FL	21.30	30
Cow Creek 1	Transect	28/6	LB, ST	16.20	40	26/11	LB, FL	19.30	50
Cow Creek 1	Day tadpole search	28/6	LB, ST	16.00	20	-	LB, FL	-	-
Cow Creek 1	Songmeter	-	LB, ST	-	-	26/11	LB, FL	-	8nights
Cow Creek 2	Transect	28/6	LB, ST	17.10	55	26/11	LB, FL	20.20	40
Cow Creek 3	Transect	28/6	LB, ST	18.20	45	26/11	LB, FL	21.15	35
Carter Creek 1	Transect	3/7	LB, ST	16.30	20	11/12	LB, FL	11.15	20
Carter Creek 1	Tadpole search	13/6	LB, ST	10.3	10	-	LB, FL	-	-
Carter Creek 2	Transect	3/7	LB, ST	17.00	25	11/12	LB, FL	12.10	20
Carter Creek 3	Transect	3/7	LB, ST	17.3	20	11/12	LB, FL	12.50	22
Tea Tree Hollow 1	Transect	4/7	LB, ST	16.00	45	4/12	LB, FL	22.15	30
Tea Tree Hollow 1	Day tadpole search	21/6	LB, ST	15.30	25	5/12	LB, FL	9.30	10
Tea Tree Hollow 1	Songmeter	21/6	LB, ST	-	3nights	-	LB, FL	-	-
Tea Tree Hollow 2	Transect	4/7	LB, ST	17.10	50	4/12	LB, FL	22.45	30
Tea Tree Hollow 3	Transect	4/7	LB, ST	18.05	40	4/12	LB, FL	23.20	30
Washhouse Gully 1	Transect	28/6	LB, ST	19.45	30	26/11	LB, FL	22.00	35
Washhouse Gully 2	Transect	28/6	LB, ST	20.25	40	26/11	LB, FL	22.45	35
Washhouse Gully 3	Transect	28/6	LB, ST	21.00	40	26/11	LB, FL	23.25	35

		Autumn 2012				Spring 2012			
Site	Activity	Date	Staff	Time	Effort (mins/per person)	Date	Staff	Time	Effort (mins/per person)
Hornes Creek D 1	Transect	5/7	LB, ST	17.00	55	28/11	LB, FL	20.00	40
Hornes Creek D 1	Songmeter	5/7	LB, ST	-	3nights	-	LB, FL	-	-
Hornes Creek D 2	Transect	5/7	LB, ST	18.00	30	28/11	LB, FL	21.00	25
Hornes Creek D 3	Transect	5/7	LB, ST	19.00	45	28/11	LB, FL	21.35	30
Hornes Creek U 1	Transect	5/7	LB, ST	10.30	45	28/11	LB, FL	22.25	30
Hornes Creek U 2	Transect	5/7	LB, ST	9.30	40	28/11	LB, FL	23.00	20
Hornes Creek U 3	Transect	5/7	LB, ST	20.30	30	28/11	LB, FL	23.30	20
Moore Creek 1	Transect	29/6	LB, ST	16.15	50	27/11	LB, FL	-	-
Moore Creek 1	Songmeter	-	LB, ST	-	-	27/11	LB, FL	-	4nights
Moore Creek 1	Day tadpole search	29/6	LB, ST	15.30	20	27/11	LB, FL	8.30	10
Moore Creek 2	Transect	29/6	LB, ST	17.30	40	-	LB, FL	-	-
Moore Creek 2	Day tadpole search	-	LB, ST	-	-	27/11	LB, FL	9.10	13
Moore Creek 2	Songmeter	-	LB, ST	-	-	-	LB, FL	-	4nights
Moore Creek 3	Transect	29/6	LB, ST	18.55	40	-	LB, FL	-	-
Moore Creek 3	Songmeter	-	LB, ST	-	-	27/11	LB, FL	-	4nights
Moore Creek 3	Day tadpole search	-	LB, ST	-	-	13/12	LB, FL	-	14
Unnamed Bargo Tributary 1	Transect	29/6	LB, ST	20.00	45	-	LB, FL	-	-
Unnamed Bargo Tributary 1	Day tadpole search	5/7	LB, ST	13.00	10	13/12	LB, FL	12.00	15
Unnamed Bargo Tributary 2	Transect	29/6	LB, ST	20.55	40	-	LB, FL	-	-
Unnamed Bargo Tributary 2	Day tadpole search	5/7	LB, ST	14.00	15	13/12	LB, FL	13.00	15
Unnamed Bargo Tributary 3	Transect	29/6	LB, ST	-	-	-	LB, FL	-	-
Unnamed Bargo Tributary 2	Day tadpole search	5/7	LB, ST	15.20	20	13/12	LB, FL	13.40	15
Eliza Creek 1	Transect	3/7	LB, ST	20.30	45	27/11	LB, FL	22.00	30

		Autumn 2012				Spring 2012			
Site	**Activity**	**Date**	**Staff**	**Time**	**Effort (mins/per person)**	**Date**	**Staff**	**Time**	**Effort (mins/per person)**
Eliza Creek 1	Day tadpole search	19/6	LB, ST	11.30	20	-	LB, FL	-	-
Eliza Creek 2	Transect	3/7	LB, ST	21.30	40	27/11	LB, FL	22.45	30
Eliza Creek 3	Transect	3/7	LB, ST	22.20	45	27/11	LB, FL	23.20	30
Dry Creek 1	Transect	4/7	LB, ST	19.30	45	27/11	LB, FL	19.30	30
Dry Creek 2	Transect	4/7	LB, ST	20.15	45	27/11	LB, FL	20.00	45
Dry Creek 3	Transect	4/7	LB, ST	21.10	45	27/11	LB, FL	20.55	35
Woodhouse Creek 1	Transect	6-Jul	LB, ST	10.30	20	7/12	LB, AS	9.30	22
Woodhouse Creek 2	Transect	6-Jul	LB, ST	11.30	22	7/12	LB, AS	10.15	19
Woodhouse Creek 3	Transect	6-Jul	LB, ST	12.40	18	7/12	LB, AS	11	25
Bargo River 1	Transect	21-June	LB, ST	15.00	20	7/12	LB, AS	14.25	12
Bargo River 2	Transect	21-June	LB, ST	15.30	25	7/12	LB, AS	14.55	15
Bargo River 3	Transect	21-June	LB, ST	16.10	18	7/12	LB, AS	15.20	13

Table 51. Amphibian monitoring 2013 season

		Autumn 2013			Spring 2013		
Site	**Activity**	**Date**	**Time**	**Effort (mins/per person)**	**Date**	**Time**	**Effort (mins/per person)**
Dog Trap Creek 1	Transect	30-Apr	18:30	60	11-Sep	17:25	30
Dog Trap Creek 2	Transect	30-Apr	19:49	46	11-Sep	18:00	40
Dog Trap Creek 3	Transect	30-Apr	20:57	31	11-Sep	18:45	30
Cow Creek 1	Transect	2-May	18:03	52	12-Sep	17:25	18
Cow Creek 2	Transect	2-May	19:12	40	12-Sep	18:00	20
Cow Creek 3	Transect	2-May	20:49	35	12-Sep	18:45	32
Carter Creek 1	Transect	30-May	18:30	45	29-Oct	19:50	18
Carter Creek 2	Transect	30-May	19:12	36	29-Oct	20:30	16
Carter Creek 3	Transect	30-May	20:05	32	29-Oct	20:55	20
Tea Tree Hollow 1	Transect	30-Apr	22:26	63	11-Sep	19:40	15
Tea Tree Hollow 2	Transect	30-Apr	23:32	30	11-Sep	20:00	25
Tea Tree Hollow 3	Transect	30-Apr	0:10	49	11-Sep	20:30	26
Washhouse Gully 1	Transect	2-May	22:24	24	12-Sep	19:40	15
Washhouse Gully 2	Transect	2-May	22:54	28	12-Sep	20:00	18
Washhouse Gully 3	Transect	2-May	23:29	46	12-Sep	20:30	16
Hornes Creek D 1	Transect	1-May	17:32	32	30-Oct	19:45	32
Hornes Creek D 2	Transect	1-May	18:15	45min	30-Oct	20:55	25
Hornes Creek D 3	Transect	1-May	19:52	80	30-Oct	21:35	18
Hornes Creek U 1	Transect	1-May	22:19	51	30-Oct	22:30	18
Hornes Creek U 2	Transect	1-May	23:10	26	30-Oct	23:05	18
Hornes Creek U 3	Transect	1-May	0:34	62	30-Oct	23:35	18
Moore Creek 1	Transect	23-May	18:30	26	31-Oct	19:50	25
Moore Creek 2	Transect	23-May	19:08	48	31-Oct	20:40	20

		Autumn 2013			Spring 2013		
Site	**Activity**	**Date**	**Time**	**Effort (mins/per person)**	**Date**	**Time**	**Effort (mins/per person)**
Moore Creek 3	Transect	23-May	20:36	37	31-Oct	21:18	18
Unnamed Bargo Tributary 1	Transect	23-May	22:10	26	31-Oct	22:10	16
Unnamed Bargo Tributary 2	Transect	23-May	22:58	19	31-Oct	22:38	17
Unnamed Bargo Tributary 3	Transect	23-May	23:35	25	31-Oct	23:00	15
Eliza Creek 1	Transect	8-May	18:30	23	28-Oct	19:00	25
Eliza Creek 2	Transect	8-May	19:05	31	28-Oct	19:30	27
Eliza Creek 3	Transect	8-May	19:55	23	28-Oct	20:15	21
Dry Creek 1	Transect	8-May	21:00	23	28-Oct	21:15	22
Dry Creek 2	Transect	8-May	21:42	20	28-Oct	21:55	18
Dry Creek 3	Transect	8-May	22:16	40	28-Oct	22:17	16

Table 52. Weather condition during current field survey

Date	Min temp	Max temp	Rainfall	Max wind speed km/h	Direction
13-Sep-17	4.2	33.3	0mm	74	WNW
14-Sep-17	9.9	17.4	0mm	76	W
15-Sep-17	10.7	20.9	0mm	61	SW
16-Sep-17	8	22.8	0mm	69	WNW
17-Sep-17	0.4	20	0mm	31	ENE
18-Sep-17	0.2	27.2	0mm	31	NNW
19-Sep-17	3.8	22.2	0mm	52	WSW
20-Sep-17	2.4	21.2	0mm	28	NNW
21-Sep-17	3.2	26.9	0mm	22	NE

22-Sep-17	3.8	30	0mm	20	NNE

Table 53. Weather conditions during 2012/2013 field survey

Date	Min temp	Max temp	Rainfall	Max wind speed km/h	Direction
16-Oct-12	9	32	24.5mm in preceding 4 days	39	NW
5-Nov-12	11.7	33.6	1.2mm in preceding 2 days	54	N
6-Nov-12	17.1	33.6	0mm	35	ENE
7-Nov-12	18.4	25.3	0.8mm	20	ENE
8-Nov-12	16.1	29.8	1.8mm	35	ENE
9-Nov-12	16.2	30.7	0.6mm	41	WSW
10-Nov-12	13.2	19.9	0mm	35	S
11-Nov-12	9.3	23.3	0mm	37	ESE
12-Nov-12	6.3	29.1	0mm	37	NNE
13-Nov-12	10.5	24.3	0mm	35	SSE
14-Nov-12	13.4	21.1	1.0mm	30	NE
20-Mar-13	10.3	26.3	0mm	31	NE
21-Mar-13	11.7	28.7	0mm	37	NNE
22-Mar-13	14.8	31.7	0mm	35	NNW
23-Mar-13	19.6	30.2	0mm	33	ENE
24-Mar-13	17.2	31.2	0mm	22	N
25-Mar-13	10.9	29.5	0mm	24	SE
26-Mar-13	13.8	28.4	0mm	24	NNE
27-Mar-13	17.8	30.1	0mm	28	NE
28-Mar-13	16.5	32	0mm	44	SW

Appendix 5. Flora species list and plot data

Table 54. Flora species list

Score: 1 = present but common, 2 = <5% and common, 3 = 6-20%, 4 = 21-50%, 5 = 51-75%, 6 = >75

	Quadrat name																																								
Botanical name	003	012	017	033	034	054	056	065	088	124	134	135	136	137	138	153	157	161	163	164	174	175	176	281	384	582	591	244	245	246	247	253	255	256	257	258	259	260	263	264	280
Acacia baileyana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia brownii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	1	0	0	0	0	0
Acacia decurrens	0	0	0	0	0	2	0	0	0	1	0	3	0	0	1	1	0	2	3	0	0	0	0	2	5	2	0	0	0	0	0	0	0	0	0	2	2	0	3	3	3
Acacia falcata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia fimbriata	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia linifolia	2	1	0	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	4	0	3	0	2	0	0	0	0	0	0	0	0	0
Acacia longifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	2	0	0	0	0
Acacia obtusifolia	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia terminalis	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	2	0	0	0
Acacia ulicifolia	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	2	0	0	0	0	0	0	0	2	0	0	0	0
Acianthus fornicatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0
Allocasuarina littoralis	0	0	1	0	0	2	0	3	0	0	3	3	0	2	0	0	0	0	0	1	3	2	0	0	0	0	2	2	3	0	2	2	0	0	0	2	0	0	5	2	2
Anisopogon avenaceus	4	4	4	3	4	2	0	5	4	3	0	0	4	4	0	0	0	0	0	0	2	3	0	0	0	0	3	2	2	4	4	4	2	2	2	3	0	0	0	0	2
Aristida ramosa	3	0	3	0	0	0	4	2	0	3	0	4	4	3	3	3	2	2	0	0	0	2	2	0	0	0	3	2	0	0	0	0	3	2	0	0	0	0	0	0	2
Aristida vagans	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	2	2	0	2	2	2
Aristida warburgii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	2	0
Astroloma humifusum	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
Austrodanthonia racemosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Austrodanthonia spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Austrodanthonia tenuior	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0

	Quadrat name																																								
Botanical name	003	012	017	033	034	054	056	065	088	124	134	135	136	137	138	153	157	161	163	164	174	175	176	281	384	582	591	244	245	246	247	253	255	256	257	258	259	260	263	264	280
Austrostipa pubescens	0	0	0	0	0	2	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Axonopus compressus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Banksia serrata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Banksia spinulosa	0	1	0	0	0	0	0	2	3	0	0	3	0	0	0	0	0	0	0	0	2	3	3	0	0	0	0	2	2	3	3	3	3	0	2	3	3	0	0	0	0
Bauera rubioides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bidens pilosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Billardiera scandens	2	1	2	0	0	1	0	3	2	0	0	0	0	3	2	0	0	0	0	1	2	2	2	2	0	0	2	0	2	0	0	0	2	0	1	0	2	0	2	0	0
Blechnum spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Boronia ledifolia	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Boronia polygalifolia	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bossiaea obcordata	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2	0	0	0
Bossiaea prostrata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Brachyloma daphnoides	0	0	2	0	0	0	0	2	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachyscome angustifolia	3	2	2	0	3	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bromus catharticus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brunoniella australis	0	1	0	1	0	0	0	1	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Burchardia umbellata	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Callistemon linearifolius	0	0	0	0	3	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Callistemon linearis	0	0	0	0	0	0	0	0	0	0	0	1	2	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Calochilus paludosus	0	0	0	0	0	1	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Calytrix tetragona	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Cassinia aculeata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cassytha glabella	1	0	0	0	0	0	0	2	0	0	1	0	0	2	0	0	0	0	0	2	1	0	0	0	0	0	0	1	1	2	2	0	2	0	0	0	0	0	1	1	0
Cassytha pubescens	0	2	2	1	2	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	2	0	1	0	0	1	0	0	0
Centaurium tenuiflorum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	Quadrat name																																							
Botanical name	003	012	017	033	034	054	056	065	088	124	134	135	136	137	138	153	157	161	163	164	174	175	176	281	384	582	591	244	245	246	247	253	255	256	257	258	259	260	263	264	280
Centella asiatica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cheilanthes sieberi	0	0	0	0	2	2	0	0	0	1	0	2	2	2	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2	2	2
Cirsium vulgare	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Clematis aristata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	0	0	0	0
Conyza bonariensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	1	2	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Conyza sumatrensis	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
Coronidium scorpioides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0
Correa reflexa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Corymbia gummifera	0	2	0	0	0	0	0	3	0	0	0	0	0	0	0	0	2	0	0	2	0	3	2	0	0	0	0	2	2	2	2	3	0	0	3	2	3	0	0	0	0
Cyanicula caerulea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Cyathochaeta diandra	4	3	5	2	5	0	4	5	3	0	2	0	2	4	2	0	0	1	0	3	3	4	2	2	0	0	3	3	3	3	4	4	0	3	3	0	0	3	0	2	3
Cymbopogon refractus	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Cynodon dactylon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
Daviesia acicularis	0	0	2	2	0	0	3	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Daviesia corymbosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Daviesia squarrosa	1	0	0	0	2	0	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Daviesia ulicifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Desmodium brachypodum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dianella caerulea	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	2	1	1	0	0	1	2	0	0	0	0	0	0	2	1	0	2	0	0	0	0
Dianella revoluta	1	4	2	3	2	2	1	0	2	2	2	3	3	2	3	0	0	0	0	0	0	1	0	2	2	0	0	1	0	0	0	1	2	1	0	1	0	0	2	1	2
Dichelachne micrantha	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Dichondra repens	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dillwynia retorta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Dillwynia rudis	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dillwynia sieberi	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	Quadrat name																																							
Botanical name	003	012	017	033	034	054	056	065	088	124	134	135	136	137	138	153	157	161	163	164	174	175	176	281	384	582	591	244	245	246	247	253	255	256	257	258	259	260	263	264	280
Diuris arenaria	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diuris sulphurea	0	0	1	1	0	0	1	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
Drosera peltata	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Echinopogon caespitosus	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	3	0	1
Einadia hastata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Entolasia marginata	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Entolasia stricta	2	4	3	3	3	3	3	4	3	4	3	4	4	4	4	0	0	0	0	2	4	3	3	3	0	2	4	3	3	0	3	3	3	2	0	2	2	3	3	2	3
Epacris microphylla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Eragrostis brownii	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	2	0
Eragrostis leptocarpa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eragrostis leptostachya	0	4	1	2	0	0	0	0	0	0	0	0	3	2	3	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eriostemon australasius	0	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	0	0	0	3	2	3	3	0	0	0	3	0	2	3	0	0	3	3	2	2	2	3	0	0	0
Eucalyptus crebra	0	3	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus eugenioides	0	0	0	3	5	3	4	0	0	4	2	3	4	4	4	0	0	0	0	0	0	3	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus fibrosa	3	0	3	4	2	4	4	0	0	5	0	5	4	1	4	0	0	0	0	0	2	0	0	3	0	1	0	0	0	3	3	3	0	0	0	0	0	0	2	3	3
Eucalyptus globoidea	3	3	3	0	0	0	0	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	3	3	3	2	2	2	0	0	0	0	0	3
Eucalyptus piperita	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	3	0	0	0	0	0	0	0	0	0	3	0	3	3	4	0	0	0	0
Eucalyptus punctata	3	2	4	0	3	3	0	2	0	3	2	0	3	3	0	0	2	0	0	1	0	3	0	0	0	2	2	3	2	2	3	2	0	2	0	2	0	0	2	0	0
Eucalyptus racemosa	0	3	0	0	0	0	0	4	4	0	0	0	0	0	0	0	3	0	0	3	3	4	2	0	0	0	5	2	3	0	0	0	3	3	2	3	3	4	0	3	2
Eucalyptus saligna	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus seeana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euryomyrtus ramosissima	0	0	0	0	0	0	0	0	2	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eustrephus latifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
Exocarpos cupressiformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	2	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
Facelis retusa	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	Quadrat name																																							
Botanical name	003	012	017	033	034	054	056	065	088	124	134	135	136	137	138	153	157	161	163	164	174	175	176	281	384	582	591	244	245	246	247	253	255	256	257	258	259	260	263	264	280
Gahnia aspera	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Galium propinquum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Glycine clandestina	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Glycine tabacina	0	0	0	0	0	0	0	0	0	2	0	0	0	1	2	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Gompholobium glabratum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Gompholobium minus	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	1	0	0
Gonocarpus tetragynus	1	2	2	1	2	0	0	0	0	0	0	0	2	3	0	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	2	2	2	2	0	0	2	0	0	1
Goodenia bellidifolia	2	0	1	0	3	0	0	0	0	0	0	0	2	2	2	2	0	2	0	2	2	1	0	0	0	0	0	0	2	2	2	2	2	0	0	2	0	2	0	2	2
Goodenia hederacea	0	2	0	1	3	2	2	2	0	3	0	2	2	3	1	0	0	0	0	0	0	2	0	0	0	0	0	1	1	1	1	2	3	2	1	0	0	2	0	0	1
Goodenia stelligera	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grevillea mucronulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grevillea parviflora	2	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grevillea robusta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grevillea sphacelata	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	0	1	0	0	0	0	0	0	3	0	0	0
Hakea dactyloides	2	1	0	0	2	1	0	3	3	0	0	0	0	3	0	0	0	0	0	1	1	3	2	0	0	0	0	2	2	3	2	2	0	0	0	0	0	0	0	0	0
Hakea sericea	2	0	3	0	0	3	0	0	0	0	0	0	0	2	0	0	0	0	0	1	1	0	2	0	0	0	0	2	1	3	0	0	2	2	0	2	0	0	1	1	0
Hardenbergia violacea	2	1	1	1	0	1	1	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	2	0	0	0	2	0	1	0
Hibbertia aspera	0	0	0	0	0	2	3	0	0	3	0	0	3	0	0	0	0	0	1	0	2	0	1	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0
Hibbertia bracteata	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hibbertia cistiflora subsp. cistiflora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hibbertia diffusa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Hibbertia empetrifolia subsp. empetrifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Hibbertia fasciculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Hibbertia obtusifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0

	Quadrat name																																							
Botanical name	003	012	017	033	034	054	056	065	088	124	134	135	136	137	138	153	157	161	163	164	174	175	176	281	384	582	591	244	245	246	247	253	255	256	257	258	259	260	263	264	280
Hibbertia riparia	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hibbertia spp.	2	1	0	0	0	0	0	3	1	0	0	2	1	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	2	1	1	0	0	0	0	0	0
Hovea linearis	2	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	2	2	0	0	0	0	0	2	0	0	1	1	0	0	0	0	2	0	0	0	0
Hovea longifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hovea purpurea	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	1	0	1	0	0	0	0
Hybanthus monopetalus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrocotyle pedicellosa	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hypericum gramineum	0	0	0	0	0	0	0	0	0	1	0	0	2	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hypochaeris radicata	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	2	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Imperata cylindrica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0	0	2	0	0	3	0	3	2	0
Isopogon anemonifolius	0	0	2	0	0	0	0	3	3	0	0	0	0	0	0	0	0	0	0	1	2	2	1	0	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0
Joycea pallida	0	0	0	4	0	3	4	0	0	3	3	0	2	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juncus spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kunzea ambigua	0	0	2	0	3	0	4	0	0	2	3	3	0	2	0	1	0	0	2	0	3	0	2	0	0	0	0	3	0	0	0	0	0	2	0	3	0	0	4	1	3
Lagenophora stipitata	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	1	2	0	1	0	0	0	0	0	0	0
Lambertia formosa	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	4	4	3	1	0	0	0	0	0	0	0	0	0	2	2	0	0	2	3	0	0	0
Lasiopetalum ferrugineum	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3	2	2	0	0	0	0	0	0	1	2	1	0	0	0	0	1	0	0	0	0	0
Laxmannia gracilis	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidosperma forsythii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Lepidosperma laterale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidosperma spp.	2	0	3	3	3	3	5	4	0	4	3	4	5	4	4	0	0	0	0	3	0	2	0	0	0	0	0	0	0	0	4	4	0	0	2	0	0	2	1	2	3
Leptomeria acida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
Leptospermum continentale	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptospermum parvifolium	0	3	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptospermum polyanthum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0

	Quadrat name																																							
Botanical name	003	012	017	033	034	054	056	065	088	124	134	135	136	137	138	153	157	161	163	164	174	175	176	281	384	582	591	244	245	246	247	253	255	256	257	258	259	260	263	264	280
Leptospermum polygalifolium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0	0	2	3	2	3	2	0	2	0	0	0	2	0	0	0
Leptospermum trinervium	0	3	0	0	0	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	3	0	0	0	0	0	0	0	1	0
Lepyrodia scariosa	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Leucopogon appressus	1	2	2	2	0	1	0	0	0	0	2	2	3	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Leucopogon ericoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Leucopogon lanceolatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	2	1	0
Ligustrum sinense	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Lindsaea linearis	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	1	1	1	1	2	0	0	0
Lissanthe strigosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	2	0	0	2	2	0	0	2	2	1
Lomandra cylindrica	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	2	0	0	2	0	0	0	0	2	1	2	2	2	0	0	0	0	0	0	0	0	2
Lomandra filiformis	2	0	2	3	0	1	1	3	0	2	3	1	3	3	3	0	0	0	0	0	2	0	0	0	0	0	3	1	0	0	0	0	3	0	0	2	3	2	0	2	2
Lomandra fluviatilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Lomandra gracilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Lomandra longifolia	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	2	0	0	2	2	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Lomandra multiflora subsp. multiflora	2	1	2	2	2	2	3	3	0	4	2	0	0	0	0	0	0	2	0	0	2	2	0	2	0	0	2	1	0	2	2	0	2	0	0	2	2	0	2	2	1
Lomandra obliqua	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Lomandra spp.	3	4	2	0	3	0	2	3	2	0	0	0	4	3	3	0	0	0	0	2	2	3	2	0	0	0	1	3	2	3	2	2	3	2	2	2	0	3	2	0	0
Lomatia silaifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	3	2	0	0	3	2	0	0	0
Lycium ferocissimum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melaleuca linariifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melaleuca thymifolia	0	0	0	2	0	0	0	0	0	0	0	0	1	2	1	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Melichrus procumbens	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melichrus urceolatus	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Microlaena stipoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Micromyrtus minutiflora	0	0	0	0	0	2	0	0	0	3	0	5	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	0	2	1	1	2	2

	Quadrat name																																								
Botanical name	003	012	017	033	034	054	056	065	088	124	134	135	136	137	138	153	157	161	163	164	174	175	176	281	384	582	591	244	245	246	247	253	255	256	257	258	259	260	263	264	280
Mirbelia rubiifolia	4	3	3	1	3	0	0	3	1	0	0	0	3	2	0	0	0	2	0	2	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	2	0	1	0
Monotoca scoparia	2	0	0	0	0	0	0	3	1	0	1	0	0	1	0	0	0	0	0	1	0	2	2	0	0	0	2	1	1	2	2	2	0	1	1	2	2	0	0	0	0
Olearia microphylla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Olearia viscidula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Opercularia diphylla	2	0	2	1	0	0	1	2	0	2	0	2	3	2	2	1	0	0	0	2	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0
Opercularia hispida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Oplismenus aemulus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1
Oplismenus imbecillis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Ozothamnus diosmifolius	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Panicum simile	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paspalum dilatatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	2	3	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Patersonia glabrata	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	2	0	0	0	0	0	0	0	0	0	0
Patersonia sericea	2	0	2	0	3	0	0	3	0	2	0	0	3	2	0	0	0	0	0	1	2	1	0	0	0	0	2	2	2	2	2	2	2	2	2	2	0	0	0	0	0
Pennisetum clandestinum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Persoonia bargoensis	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
Persoonia levis	0	2	0	0	0	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	1	3	1	0	0	0	0	2	2	2	3	2	3	2	2	0	0	2	0	0	0
Persoonia linearis	2	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	2	3	0	1	0	0	0	2	3	0	0	1	2	3	0	2	0	2	3	0	1	0
Persoonia pinifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0
Petrophile pulchella	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Petrophile sessilis	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2	2	0	0	0	0	1	0	0	0	0	0	0
Phyllanthus hirtellus	2	2	2	0	2	0	3	3	2	3	1	2	0	2	2	2	0	0	0	2	2	2	1	0	0	0	0	2	0	2	2	2	2	2	0	1	2	2	2	0	0
Pimelea linifolia	2	0	2	0	2	0	2	3	2	1	1	0	0	2	0	0	0	0	0	1	2	0	0	0	0	0	0	2	2	2	3	0	0	0	0	0	0	2	0	2	2
Pittosporum undulatum	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantago lanceolata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Platysace linearifolia	0	0	0	0	0	0	0	3	3	0	0	0	0	0	0	0	0	0	0	3	2	3	2	0	0	0	2	0	2	0	0	0	2	2	0	0	0	3	0	0	0

	Quadrat name																																							
Botanical name	003	012	017	033	034	054	056	065	088	124	134	135	136	137	138	153	157	161	163	164	174	175	176	281	384	582	591	244	245	246	247	253	255	256	257	258	259	260	263	264	280
Poa sieberiana	2	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	2	2	2	0	0	0	0	0	0
Podolobium scandens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pomaderris andromedifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
Pomaderris brunnea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Pomaderris elliptica subsp. elliptica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pomaderris ferruginea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0
Pomax umbellata	2	2	2	1	2	3	2	2	1	2	1	2	2	2	1	2	0	0	0	1	2	0	2	0	0	0	2	0	2	2	2	0	2	2	2	2	0	2	2	1	1
Poranthera ericifolia	0	2	3	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
Pratia purpurascens	0	0	0	1	0	2	0	1	0	2	1	2	4	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	1
Pseuderanthemum variabile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	1	0	0	1	0	1	0	0	0	0	0
Pteridium esculentum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
Pterostylis concinna	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	3	0	0	0	3	3	0	0	0
Pterostylis spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Ptilothrix deusta	0	0	0	0	1	2	0	0	3	2	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Pultenaea hispidula	0	0	0	1	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pultenaea mollis	0	0	1	0	0	0	0	0	0	2	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pultenaea tuberculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Pultenaea villosa	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2
Rhytidosporum procumbens	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	1	1	0	0	0	0	0	0
Rumex crispus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sannantha pluriflora	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Schoenus apogon	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Schoenus brevifolius	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Senecio madagascariensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Setaria parviflora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	Quadrat name																																							
Botanical name	003	012	017	033	034	054	056	065	088	124	134	135	136	137	138	153	157	161	163	164	174	175	176	281	384	582	591	244	245	246	247	253	255	256	257	258	259	260	263	264	280
Sida rhombifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solanum nigrum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solanum prinophyllum	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Solanum pungetium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Sphaerolobium vimineum	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Sporobolus creber	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stackhousia viminea	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stypandra glauca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thelymitra spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	1	1
Themeda australis	0	0	3	3	2	3	0	0	0	2	0	0	3	2	2	3	2	3	4	0	0	0	0	3	0	0	0	0	0	0	0	0	2	0	1	0	0	0	1	3	2
Trifolium repens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Verbena bonariensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viola hederacea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Wahlenbergia communis	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wahlenbergia gracilis	0	0	0	0	1	1	0	0	0	1	0	0	0	1	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Xanthorrhoea minor subsp. minor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0
Xanthosia pilosa	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Xerochrysum bracteatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Xylomelum pyriforme	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 55. Transect attribute data (development)

PlotName	NPS	NOS	NMS	NGCG	NGCS	NGCO	EPC	NTH	OR	FL	Easting	Northing	Zone
SSTF Good													
1311 LB017	38	32.5	2.5	88	12	78	0	1	1	6	278852	6206854	56
1311 LB054	40	23	0	82	6	66	0	0	1	3	278398	6206313	56
1311 LB056	27	21	18	80	14	58	0	2	1	11	278052	6206126	56
1311 LB124	41	27	1.5	80	2	60	0	2	1	29	277889	6206184	56
CF_01	20	12.5	1.5	100	22	68	0	0	1	10	278047	6206264	56
3680 CF02	21	17.4	0	45	0	43	0	0	1	17	278402	6205829	56
3690 cf03	28	15	0	38	0	37	0	0	1	18	278270	6205788	56
SSTF Med													
1311MR263	32	8	6.5	56	26	0	0	0	1	102	277705	6206713	56
1311MR264	36	12	6.5	66	4	8	0	0	1	78	277660	6206719	56
1311MR280	42	14	2	94	10	12	0	0	1	8	278114	6206347	56
CF_02	12	29	2	80	14	14	0	0	1	0	277699	6206641	56
SSTF low													
3680cf01	15	14.3	0	10	0	8	6	0	1	74	277870	6205792	56
3690cf05	12	6.5	11	44	0	0	0	0	1	0	278015	6205857	56
3690cf04	10	0	4	44	0	2	0	0	1	0	278109	6205702	56
UGRSW													
1311MR253	51	12	1	76	0	16	0	2	1	45	278821	6207051	56
1311MR246	45	8	2	76	0	14	0	2	1	43.5	278751	6207484	56
1311MR247	56	11	0	98	16	12	0	1	1	23	278804	6207216	56

Table 56. Transect attribute data (offset sites)

PlotName	NPS	NOS	NMS	NGCG	NGCS	NGCO	EPC	NTH	OR	FL	Easting	Northing	Zone
Pit Top - Shale Sandstone Transition Forest (HN556) – moderate/good													
1311MR257	39	8	0.5	52	8	22	0	0	1	57	277518	6206583	56
1311MR281	24	8	2	46	10	10	1	0	1	48	278043	6206499	56
Pit Top - Upper Georges River Sandstone Woodland (HN564) – moderate/good													
1311LB088	39	12.5	0.5	30	16	76	0	2	1	23	277941	6207668	56
1311MR244	57	12	0.5	46	2	16	0	0	1	63	278259	6207776	56
1311MR245	51	8	4.5	90	22	22	0	0	1	49	278441	6207854	56
Pit Top - Upper Georges River Sandstone Woodland (HN564) – moderate/good_high													
CF01	26	8	40	20	20	40	0	0	1	4	277407	6207073	56
CF02	22	9	30	18	16	20	0	0	1	8	277613	6207297	56
CF03	26	8	25	30	22	22	0	0	1	10	277784	6207397	56
Pit Top - Hinterland Sandstone Gully Forest (HN586) – moderate/good													
1311MR255	58	8	1	8	4	54	1	0	1	58	277431	6206667	56

1311MR259	40	16	2	20	16	14	0	2	1	56	277508	6206906	56
1311MR260	45	10.5	2	44	46	6	0	4	1	12	277736	6206997	56
Rockford - Hinterland Sandstone Gully Forest (HN586) – moderate/good													
RF003	40	18	8	20	20	44	0	1	1	15	279379	6207235	56
Rockford - Shale Sandstone Transition Forest (HN556) – moderate/good													
RF001	38	12	2	44	8	22	0	0	1	9	279177	6207575	56
RF002	37	8	4	26	6	6	1	0	1	5	278043	6206499	56
Ventshaft No.2 - Shale Sandstone Transition Forest (HN556) – moderate/good													
VS02	37	8	4	26	6	6	2	0	1	5	279527	6208046	56
VS03	30	6	6	32	8	16	2	0	1	6	279246	6208086	56
VS02	37	8	4	26	6	6	2	0	1	5	279527	6208046	56
Bargo Colliery Land – Exposed Sandstone Scribbly Gum Woodland (HN566)													
BC01	32	16	2	8	24	44	0	1	1	8	275199	6202636	56
Bc02	41	10	0	16	20	48	0	1	1	22	274866	6202430	56
BC03	46	8	0	12	20	38	0	1	1	28	274383	6202640	56
BC04	38	16	4	6	34	36	0	0	1	44	274563	6202737	56
BC05	28	10	6	18	32	28	0	0	1	26	274567	6203286	56
BC06	34	14	0	12	18	32	0	2	1	10	274813	6204150	56
Bargo Colliery Land - Hinterland Sandstone Gully Forest (HN586) – moderate/good													
BC07	42	18	8	20	20	44	0	1	1	15	274679	6202475	56
BC08	44	20	8	18	44	40	0	1	1	28	274870	6202699	56
BC09	38	24	10	12	38	56	0	1	1	30	275427	6202782	56

Appendix 6. Vegetation descriptions

Vegetation community descriptions and PCT alignment

HN556: Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest

HN556: Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest is the dominant vegetation community within the study area.

Dominant species of the community include the following:

Trees: *Eucalyptus punctata, E. fibrosa, E. eugenioides, Allocasuarina littoralis,* and *A. torulosa.*

Shrubs: *Acacia decurrens, Bursaria spinosa, Exocarpos cupressiformis, Indigofera australis, Kunzea ambigua, Melaleuca thymifolia, Pultenaea villosa, Olearia microphylla,* and *Ozothamnus diosmifolius.*

Grasses: *Anisopogon avenaceus, Aristida ramosa, Aristida vagans, Entolasia stricta, Eragrostis brownii, Microlaena stipoides* and *Themeda australis*.

Ground Covers: *Billardiera scandens, Cheilanthes sieberi, Einadia hastata, Lomandra filiformis, Lomandra obliqua, Lepidosperma laterale, Phyllanthus hirtellus, Pratia purpurascens,* and *Solanum prinophyllum.*

NSW PCT: This vegetation type is most closely aligned to HN556: Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest, as is evident from the dominant species listed above and forest structure.

Condition: Three different condition classes were recorded within the study area:

Moderate/Good_good condition – minimal weeds with high resilience

Moderate/Good_medium – shrub dominated vegetation condition consisting predominantly of Acacia parramattensis and Kunzea ambigua.

Moderate/Good_derived – area of moderate resilience which has been largely cleared of canopy and mid-storey species. Canopy trees and shrubs are relatively isolated. Regenerating eucalypts and shrubs are occasional. Weeds were recorded throughout with a low to moderate occurrence of native species.

Conservation status

EPBC Act status: Critically Endangered Ecological Community.

BC Act status: Critically Endangered Ecological Community.

This vegetation community in all condition classes aligns to the NSW TSC Act Shale Sandstone Transition Forest TEC (CEEC) and EPBC Act listed CEEC. How the vegetation community fits the TEC listing as detailed in Scientific Determination (2014) and DoEE (2014) is provided in Table 57.

Table 57. Shale Sandstone Transition Forest TEC alignment

Condition	Description	How it meets the TSC Act Determination	How it meets the EPBC Act Determination
Good	▪ The presence of diagnostic mature trees including *Eucalyptus punctata, E. eugenioides, E. fibrosa* in an open woodland formation. ▪ Presence of diagnostic groundcover plant species including some important species (excluding grasses). ▪ Presence of regenerating over-storey species.	▪ Characterised by the presence or prior occurrence of Eucalyptus eugenioides, E. punctata. ▪ A small tree stratum is present in high resilience and intact area consisting of Eucalyptus spp., with *Allocasuarina* littoralis and *Acacia decurrens* present. ▪ A shrub layer dominated by *Bursaria spinosa* is present. ▪ The understorey in intact areas is characterised by native grasses and a high diversity of herbs ▪ Characteristic species are present as identified in the Scientific Determination ▪ Occurs within the known range of the TEC.	▪ Diagnostic species present. ▪ Predominantly native understorey. ▪ Mature trees and natural regeneration of eucalypts is present. ▪ Meets the moderate condition class threshold. ▪ Patch is greater than 0.5 hectares. ▪ Great than 30 percent of understorey is made up of native species ▪ The patch is contiguous with a native vegetation remnant (any native vegetation where cover in each layer present is dominated by native species) >1ha in area ▪ The patch has at least one tree with hollows.
Medium	▪ Sparse canopy layer. Isolated trees comprising of predominantly *Eucalyptus eugenioides* ▪ Shrub dominated vegetation unit due to historic disturbance ▪ Relatively low diversity groundcover plant species ▪ Regenerating over storey species. ▪ Moderate to high occurrence of exotic plant species.	▪ Characterised by the presence or prior occurrence of characteristic overstorey species. ▪ Resilience is observed through regeneration of Bursaria spinosa and diagnostic native grasses including *Aristida ramosa, A. vagans, Themeda australis,* and *Entolasia stricta.* ▪ Shrubs are generally sparse or absent, though they may be locally common. ▪ Characteristic species are present as identified in the Scientific Determination. ▪ Occurs within the known range of the TEC.	▪ Diagnostic species present. ▪ Predominantly native understorey. ▪ Mature trees and natural regeneration of eucalypts is present. ▪ Meets the moderate condition class threshold. ▪ Patch is greater than 0.5 hectares. ▪ Great than 30 percent of understorey is made up of native species ▪ The patch is contiguous with a native vegetation remnant (any native vegetation where cover in each layer present is dominated by native species) >1ha in area ▪ The patch has at least one tree with hollows.

Condition	Description	How it meets the TSC Act Determination	How it meets the EPBC Act Determination
Derived	▪ No canopy structure ▪ Regenerating eucalypts present in areas. ▪ Areas of regenerating native shrubs characteristic of SSTF. ▪ Relatively low diversity groundcover plant species. ▪ Regenerating over storey species. ▪ Moderate to high occurrence of exotic plant species. ▪ A history of grazing.	▪ Characterised by the presence or prior occurrence of characteristic overstorey species. ▪ Resilience is observed through regeneration of Bursaria spinosa and diagnostic native grasses including *Aristida ramosa, A. vagans, Themeda australis,* and *Entolasia stricta.* ▪ Shrubs are generally sparse or absent, though they may be locally common. ▪ Characteristic species are present as identified in the Scientific Determination. ▪ Occurs within the known range of the TEC.	▪ Diagnostic species present. ▪ Meets the moderate condition class threshold. ▪ Patch is greater than 0.5 hectares. ▪ Great than 30 percent of understorey is made up of native species ▪ The patch is contiguous with a native vegetation remnant (any native vegetation where cover in each layer present is dominated by native species) >1ha in area

Photo 1. Shale Sandstone Transition Forest (HN556) moderate/good_good

Photo 2. Shale Sandstone Transition Forest (HN556) moderate/good_medium

Photo 3. Shale Sandstone Transition Forest (HN556) moderate/good_derived condition

HN564 Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin

HN564 Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin was recorded to the north of REA Area 1 and to the west of the REA.

Dominant species of the community include the following:

Trees: *Corymbia gummifera, Eucalyptus eugenioides, Eucalyptus punctata* and *Eucalyptus racemosa*.

Shrubs: *Acacia ulicifolia, Acacia terminalis, Acacia linifolia, Banksia spinulosa var. spinulosa, Hakea sericea, Persoonia levis, Persoonia linearis, Leptospermum trinervium.*

Grasses: *Anisopogon avenaceus, Aristida ramosa, Cyathochaeta diandra, Entolasia stricta, Microlaena stipoides, Poa sieberiana,* and *Themeda australis*.

Ground Covers: *Billardiera scandens, Cheilanthes sieberi, Goodenia hederacea, Lomandra filiformis, Lomandra obliqua, Lomandra longifolia, Lepidosperma laterale, Phyllanthus hirtellus, Pimelea linifolia subsp. linifolia* and *Xanthosia tridentata.*

The community was observed to be highly resilient with all recognised layers of the vegetation community being intact. A minimal number of weeds were recorded in this vegetation community and natural regeneration was observed to be occurring at a number of sites.

NSW PCT: This vegetation type is most closely aligned to NSW PCT: HN564 Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin.

Condition: One condition classes was recorded within the study area:

Moderate/Good_good condition – minimal weeds with high resilience

Conservation status

EPBC Act status: Not listed.

BC Act status: Not listed.

Photo 4. Upper Georges River Sandstone Woodland (HN564) moderate/good_good

HN586 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney, Sydney Basin Bioregion

HN586 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney, Sydney Basin Bioregion was recorded along Tea Tree Hollow Creek.

Dominant species of the community include the following:

Trees: *Corymbia gummifera, Eucalyptus eugenioides, Eucalyptus piperita, Eucalyptus racemosa* and *Allocasuarina littoralis*.

Shrubs: Acacia terminalis, *Banksia spinulosa var. spinulosa, Hakea sericea, Hovea purpurea, Kunzea ambigua, Persoonia linearis, Platysace linearifolia, Leptospermum trinervium* and *Xanthosia pilosa.*

Grasses: *Anisopogon avenaceus, Cyathochaeta diandra, Entolasia stricta, Microlaena stipoides, Poa sieberiana* and *Themeda australis*.

Ground Covers: *Billardiera scandens, Cheilanthes sieberi, Dianella caerulea, Goodenia hederacea, Lomandra obliqua, Lomandra longifolia, Lepidosperma laterale, Phyllanthus hirtellus, Pomax umbellata, Pteridium esculentum* and *Xanthosia tridentata.*

The community was observed to be of high resilience with regenerating canopy species and a high percentage of native shrubs.

NSW PCT: This vegetation type is most closely aligned to NSW PCT: HN586 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney, Sydney Basin Bioregion.

Condition: One condition class (moderate/good_good) was assigned to this PCT in the study area.

Conservation status

EPBC Act status: Not listed.

BC Act status: Not listed.

Photo 5. Western Sandstone Gully Forest (HN586) moderate/good

Appendix 7. Fauna species list

Table 58. Fauna recorded during the current survey

Group	Scientific name	Common name	Date and time of record	No. recorded
Amphibia	*Crinia signifera*	Clicking Froglet	18/09/2017 20:07	2
Amphibia	*Crinia signifera*	Clicking Froglet	21/09/2017 10:51	3
Amphibia	*Litoria lesueurii*	Stoney Creek Frog	21/09/2017 15:23	1
Aves	*Aegotheles cristatus*	Australian Owlet-nightjar	18/09/2017 20:16	3
Aves	*Aegotheles cristatus*	Australian Owlet-nightjar	20/09/2017 19:35	1
Aves	*Artamus cyanopterus*	Dusky Woodswallow	19/09/2017 16:56	2
Aves	*Artamus cyanopterus*	Dusky Woodswallow	20/09/2017 17:28	2
Aves	*Climacteris erythrops*	Red-browed Treecreeper	14/09/2017 13:09	2
Aves	*Daphoenositta chrysoptera*	Varied Sittella	20/09/2017 15:08	2
Aves	*Daphoenositta chrysoptera*	Varied Sittella	20/09/2017 15:38	2
Aves	*Daphoenositta chrysoptera*	Varied Sittella	21/09/2017 13:40	2
Aves	*Lichenostomus melanops*	Yellow-tufted Honeyeater	20/09/2017 15:44	1
Aves	*Ninox novaeseelandiae*	Southern Boobook	20/09/2017 19:32	1
Aves	*Origma solitaria*	Rockwarbler	21/09/2017 15:40	1
Aves	*Petroica boodang*	Scarlet Robin	19/09/2017 15:34	1
Aves	*Podargus strigoides*	Tawny Frogmouth	20/09/2017 20:23	1
Mammalia	*Macropus giganteus*	Eastern Grey Kangaroo	14/09/2017 20:40	2
Mammalia	*Macropus giganteus*	Eastern Grey Kangaroo	15/09/2017 12:37	5
Mammalia	*Myotis macropus*	Large-footed Myotis	21/09/2017 16:04	15
Mammalia	*Petaurus breviceps*	Sugar Glider	14/09/2017 21:18	2
Mammalia	*Petaurus breviceps*	Sugar Glider	18/09/2017 20:53	1
Mammalia	*Petaurus breviceps*	Sugar Glider	18/09/2017 21:50	1
Mammalia	*Petaurus breviceps*	Sugar Glider	18/09/2017 23:19	1
Mammalia	*Petaurus breviceps*	Sugar Glider	18/09/2017 23:32	2
Mammalia	*Petaurus breviceps*	Sugar Glider	20/09/2017 20:10	1
Mammalia	*Pseudocheirus peregrinus*	Common Ringtail Possum	14/09/2017 20:48	1
Mammalia	*Pseudocheirus peregrinus*	Common Ringtail Possum	14/09/2017 20:57	1
Mammalia	*Pseudocheirus peregrinus*	Common Ringtail Possum	18/09/2017 19:56	1
Mammalia	*Pseudocheirus peregrinus*	Common Ringtail Possum	18/09/2017 21:05	1
Mammalia	*Pseudocheirus peregrinus*	Common Ringtail Possum	18/09/2017 21:32	1
Mammalia	*Pseudocheirus peregrinus*	Common Ringtail Possum	18/09/2017 22:11	1
Mammalia	*Pseudocheirus peregrinus*	Common Ringtail Possum	18/09/2017 22:42	2
Mammalia	*Pseudocheirus peregrinus*	Common Ringtail Possum	18/09/2017 23:06	1
Mammalia	*Pseudocheirus peregrinus*	Common Ringtail Possum	20/09/2017 19:14	1
Mammalia	*Pseudocheirus peregrinus*	Common Ringtail Possum	20/09/2017 19:15	1
Mammalia	*Pseudocheirus peregrinus*	Common Ringtail Possum	20/09/2017 19:26	1
Mammalia	*Pseudocheirus peregrinus*	Common Ringtail Possum	20/09/2017 19:38	2

Group	Scientific name	Common name	Date and time of record	No. recorded
Mammalia	*Pseudocheirus peregrinus*	Common Ringtail Possum	20/09/2017 19:53	1
Mammalia	*Pseudocheirus peregrinus*	Common Ringtail Possum	20/09/2017 20:05	1
Mammalia	*Pseudocheirus peregrinus*	Common Ringtail Possum	20/09/2017 20:40	1
Mammalia	*Trichosurus vulpecula*	Common Brushtail Possum	14/09/2017 20:53	1
Mammalia	*Trichosurus vulpecula*	Common Brushtail Possum	20/09/2017 20:25	2
Mollusca	*Meridolum sheai*	Land Snail	14/09/2017 10:25	0
Aves	*Aegotheles cristatus*	Australian Owlet-nightjar	18/09/2017 20:16	3
Aves	*Aegotheles cristatus*	Australian Owlet-nightjar	20/09/2017 19:35	1
Aves	*Artamus cyanopterus*	Dusky Woodswallow	19/09/2017 16:56	2
Aves	*Artamus cyanopterus*	Dusky Woodswallow	20/09/2017 17:28	2
Aves	*Climacteris erythrops*	Red-browed Treecreeper	14/09/2017 13:09	2
Aves	*Lichenostomus melanops*	Yellow-tufted Honeyeater	20/09/2017 15:44	1
Aves	*Ninox novaeseelandiae*	Southern Boobook	20/09/2017 19:32	1
Aves	*Origma solitaria*	Rockwarbler	21/09/2017 15:40	1
Aves	*Petroica boodang*	Scarlet Robin	19/09/2017 15:34	1
Aves	*Podargus strigoides*	Tawny Frogmouth	20/09/2017 20:23	1
Aves	*Coturnix ypsilophora*	Brown Quail	17/09/2018	1
Aves	*Phaps chalcoptera*	Common Bronzewing	17/09/2018	1
Aves	*Sturnus tristis*	Common Myna	17/09/2018	1
Aves	*Platycercus eximius*	Eastern Rosella	17/09/2018	1
Aves	*Cacomantis flabelliformis*	Fan-tailed Cuckoo	17/09/2018	1
Aves	*Lichenostomus fuscus*	Fuscous Honeyeater	17/09/2018	1
Aves	*Anthochaera chrysoptera*	Little Wattlebird	18/09/2018	1
Aves	*Anas superciliosa*	Pacific Black Duck	21/09/2018	1
Aves	*Strepera graculina*	Pied Currawong	17/09/2018	1
Aves	*Lichenostomus melanops*	Yellow-tufted Honeyeater	18/09/2018	1
Aves	*Sericornis frontalis*	White-browed Scrubwren	17/09/2018	1
Aves	*Acanthiza nana*	Yellow Thornbill	17/09/2018	1
Aves	*Aegotheles cristatus*	Australian Owlet-nightjar	17/09/2018	1
Aves	*Dacelo novaeguineae*	Laughing Kookaburra	18/09/2018	1
Mammalia	*Macropus giganteus*	Eastern Grey Kangaroo	17/09/2018	2
Mammalia	*Macropus giganteus*	Eastern Grey Kangaroo	20/09/2018	1
Mammalia	*Trichosurus vulpecula*	Common Brushtail Possum	20/09/2018	1
Mammalia	*Trichosurus vulpecula*	Common Brushtail Possum	17/09/2018	2
Mollusca	*Meridolum corneovirens*	Cumberland Plain Land Snail	21/09/2018	2

Table 59. Survey effort results during 2013 survey

Family	Species	Scientific name	Status	REA 1								REA 2							Area surrounding REA			
				Survey Technique																		
				Call playback	Cage trap	Incidental	Amphibian	Spotlighting	Diurnal/bird	Hair tubes	Anabat	Amphibian	Diurnal/bird	Spotlighting	Hair tubes	Call playback	Incidental	Anabat	Incidental	Amphibian	Hair tubes	Anabat
Amphibia																						
Hylidae	Bleating Tree Frog	*Litoria dentata*					O					H					H					
Hylidae	Lesueur's Frog	*Litoria lesueurii*						O														
Hylidae	Peron's Tree Frog	*Litoria peronii*					H (>50)					H				O				H		
Hylidae	Tyler's Tree Frog	*Litoria tyleri*					H (4)					H								H		
Myobatrachidae	Common Eastern Froglet	*Crinia signifera*				H	H (>100)	H (>20)				H				O				H		
Myobatrachidae	Eastern Banjo Frog	*Limnodynastes dumerilii*										O/H										
Myobatrachidae	Smooth Toadlet	*Uperoleia laevigata*							O			O/H			O					H	O	
Myobatrachidae	Striped Marsh Frog	*Limnodynastes peronii*						O														
Aves																						
Phasianidae	Brown Quail	*Coturnix ypsilophora*															O					
Columbidae	Common Bronzewing	*Phaps chalcoptera*				H			H				H									
Sturnidae	Common Myna	*Sturnus tristis*																	O			
Psittaculidae	Eastern Rosella	*Platycercus eximius*							O													
Cuculidae	Fan-tailed Cuckoo	*Cacomantis flabelliformis*							H													
Apodidae	Fork-tailed Swift	*Apus pacificus*							>10H													
Meliphagidae	Fuscous Honeyeater	*Lichenostomus fuscus*																	O			
Meliphagidae	Little Wattlebird	*Anthochaera chrysoptera*							H													
Accipitridae	Little Eagle	*Hieraaetus morphnoides*	TSC Act: V									O										
Anatidae	Pacific Black Duck	*Anas superciliosa*							O													
Artamidae	Pied Currawong	Strepera graculina															H					
Meliphagidae	Yellow-tufted Honeyeater	Lichenostomus melanops				O			O,H													
Acanthizidae	White-browed Scrubwren	*Sericornis frontalis*											O									
Acanthizidae	Yellow Thornbill	*Acanthiza nana*											O									
Aegothelidae	Australian Owlet-nightjar	*Aegotheles cristatus*										H										
Alcedinidae	Laughing Kookaburra	*Dacelo novaeguineae*											O/H									
Alcedinidae	Sacred Kingfisher	*Todiramphus sanctus*				H			H				O									
Artamidae	Australian Magpie	*Cracticus tibicen*											H				H		O			
Artamidae	Grey Butcherbird	*Cracticus torquatus*							H				H						H			
Cacatuidae	Glossy Black-Cockatoo	*Calyptorhynchus lathami*	TSC Act: *V*										H									
Campephagidae	Black-faced Cuckoo-shrike	*Coracina novaehollandiae*							O, H								H					
Climacteridae	White-throated Treecreeper	*Cormobates leucophaea*							O				H									
Corvidae	Australian Raven	*Corvus coronoides*															O		O,H			
Cuculidae	Brush Cuckoo	*Cacomantis iediolosus*											H									
Cuculidae	Channel-billed Cuckoo	*Scythrops novaehollandiae*											H									
Cuculidae	Pallid Cuckoo	*Cacomantis pallidus*							H				H				O,H					
Maluridae	Variegated Fairy-wren	*Malurus lamberti*											O									
Meliphagidae	Eastern Spinebill	*Acanthorhynchus tenuirostris*				O, H			H				O									

Family	Species	Scientific name	Status	REA 1								REA 2							Area surrounding REA			
				Survey Technique																		
				Call playback	Cage trap	Incidental	Amphibian	Spotlighting	Diurnal/bird	Hair tubes	Anabat	Amphibian	Diurnal/bird	Spotlighting	Hair tubes	Call playback	Incidental	Anabat	Incidental	Amphibian	Hair tubes	Anabat
Meliphagidae	Noisy Friarbird	*Philemon corniculatus*							H				H				O,H					
Meliphagidae	Red Wattlebird	*Anthochaera carunculata*				O, H			H				O									
Meliphagidae	White-eared Honeyeater	*Lichenostomus leucotis*											O						O			
Meliphagidae	Yellow-faced Honeyeater	*Lichenostomus chrysops*							H				O				H, O					
Monarchidae	Restless Flycatcher	*Myiagra inquieta*																				
Neosittidae	Varied Sittella	*Daphoenositta chrysoptera*	TSC Act: V EPBC: V										O									
Pachycephalidae	Grey Shrike-thrush	*Colluricincla harmonica*											H									
Pachycephalidae	Rufous Whistler	*Pachycephala rufiventris*				H			H				O				O,H		H			
Pardalotidae	Spotted Pardalote	*Pardalotus punctatus*							H				IO/H									
Pardalotidae	Striated Pardalote	*Pardalotus striatus*											H									
Petroicidae	Eastern Yellow Robin	*Eopsaltria australis*				O, H			H				O				O,H		O			
Petroica	Scarlet Robin	*Petroica boodang*	TSC Act: V			O																
Psittacidae	Crimson Rosella	*Platycercus elegans*				O			O				H				H					
Psophodidae	Eastern Whipbird	*Psophodes olivaceus*				O, H							H						H			
Rhipiduridae	Grey Fantail	*Rhipidura albiscapa*							O				O				O,H		O,H			
Strigidae	Powerful Owl	*Ninox strenua*	TSC Act: V	O																		
Tytonidae	Sooty owl	*Tyto tenebricosa*	TSC Act: V													O						
Mammalia																						
Vespertilionidae	Gould's wattled bat	*Chalinolobus gouldii*																				
Vespertilionidae	Long-eared bat	*Nyctophilus sp.*									O											O
Vespertilionidae	Southern Myotis	*Myotis macropus*	TSC Act: V															H				
Vespertilionidae	Eastern Free-tail Bat	*Mormopterus norfolkensis*	TSC Act: V															H				
Vespertilionidae	Eastern Bent-wing Bat	*Miniopterus schreibersii oceanensis*	TSC Act: V															H				
Vespertilionidae	Eastern false Pipistrelle	*Falsistrellus tasmaniensis*	TSC Act: V															H				
Vespertilionidae	Eastern Cave Bat	*Vespadelus troughtoni*	TSC Act: V															H				
Vespertilionidae	Southern forest bat	*Vespadelus regulus*									O											O
Molossidae	White-striped freetail bat	*Tadarida australis*																				
Macropodidae	Eastern Grey Kangaroo	*Macropus giganteus*											O									
Macropodidae	Swamp Wallaby	*Wallabia bicolor*											O									
Muridae	Bush Rat	*Rattus fuscipes*			O																	
Petauridae	Sugar Glider	*Petaurus breviceps*										O										
Phalangeridae	Common Brushtail Possum	*Trichosurus vulpecula*						O	O	O					O						O	
Pseudocheiridae	Common Ringtail Possum	*Pseudocheirus peregrinus*				O		O				O		O								
Vespertilionidae	Eastern cave Bat	*Vespadelus troughtoni*																				
Vespertilionidae	White-striped Mastiff Bat	*Tadarida australis*														H						
Reptilia																						

Family	Species	Scientific name	Status	REA 1								REA 2							Area surrounding REA			
				Survey Technique																		
				Call playback	Cage trap	Incidental	Amphibian	Spotlighting	Diurnal/bird	Hair tubes	Anabat	Amphibian	Diurnal/bird	Spotlighting	Hair tubes	Call playback	Incidental	Anabat	Incidental	Amphibian	Hair tubes	Anabat
Chelidae	Long-necked Turtle	*Chelodina longicollis*				O																
Agamidae	Jacky Lizard	*Amphibolurus muricatus*											O									
Gekkonidae	Leaf tailed gecko	*Saltuarius swaini*				O																
Gekkonidae	Stone Gecko	*Diplodactylus vittatus*				O											O					
Scincidae	Coppertail Skink	*Ctenotus taeniolatus*							O								O					
Scincidae	Eastern Water Skink	*Eulamprus quoyii*							O													
Scincidae	Pale-flecked Garden Sunskink	*Lampropholis guichenoti*							O				O				O		O			
Typhlopidae	Blackish Blind Snake	*Rhamphotyphlops nigrescens*							O													

Appendix 8. MNES Assessments of Significance

Matters for Assessment

Assessments of Significance are presented for the following MNES in relation to the Project:

- Threatened Ecological Communities
  - Shale Sandstone Transition Forest.
- Threatened flora
  - *Acacia bynoeana*
  - *Grevillea parviflora subsp. parviflora*
  - *Leucopogon exolasius*
  - *Persoonia bargoensis*
  - *Persoonia glaucescens*
  - *Persoonia hirsuta*
  - *Pomaderris brunnea*.
- Threatened Fauna
  - Broad-headed Snake (assessment undertaken as a precautionary approach).
  - Large-eared Pied Bat
  - Koala
  - Grey-headed Flying-fox
  - Greater Glider
  - Birds (grouped): Swift Parrot, Regent Honeyeater, Cattle Egret, Great Egret, Fork-tailed Swift, Rainbow Bee-eater, and Satin Flycatcher.

Descriptions in regards to the lifecycle for the species have been taken from the relevant Commonwelath Conservation Advice unless otherwise stated.

Shale Sandstone Transition Forest	
Critically Endangered Ecological Community	Significant Assessment Criteria
An action is likely to have a significant impact on a critically endangered or endangered ecological community if there is a real chance or possibility that it will:	
Reduce the extent of an ecological community	The proposed development would involve the removal of approximately 43.4 hectares of Shale Sandstone Transition Forest (SSTF) as a result of clearing required for the Project. Subsidence as a result of the proposed development may cause cracking of the soil within the community, however SSTF occurs within drier soils and is not solely dependent on groundwater interaction that may be impacted by surface cracking. Previous vegetation mapping by Tozer et al. 2006 has mapped approximately 2,947 hectares as occurring within 10km of the study area. The Project will therefore result in reducing the extent of the SSTF in the locality by approximately 2 per cent.
Fragment or increase fragmentation of an ecological community, for example by clearing vegetation for roads or transmission lines	Approximately 43.4 hectares of SSTF would be impacted by the required clearing for the proposed development. The proposed development would result in the following fragmentation: ▪ Clearing within REA Area 1 would result in fragmenting a strip of SSTF to the immediate west. ▪ Clearing within REA Area 2 would result increased fragmentation of SSTF along Charlies Point Road to the immediate south-east. ▪ Clearing of SSTF for vent shaft TS2 would result in a reduction of connectivity width of vegetation along Dog Trap Creek. ▪ Clearing for vent shaft TS1 would result in a reduction in connectivity along Charlies Point Road. The proposed development is likely to result in the isolation of currently interconnecting or proximate areas of habitat for SSTF in the long-term.
Adversely affect habitat critical to the survival of an ecological community	The habitat for SSTF that would be impacted within the Study Area consist of approximately 43.4 hectares which equates to approximately 2 per cent of SSTF within the locality (2947 hectares has been mapped by Tozer et al. 2006 as occurring within 10km of the study area). Much of the remaining SSTF within the locality is scattered within private lots, and crown land that are not formally protected under conservation agreements. Within the locality, SSTF is informally protected within Upper Nepean State Conservation Area, WaterNSW Special Area, and Wirrimburra Sanctuary Bargo. None of these areas would be impacted by the proposed development. When compared to the amount of SSTF within the locality and priority conservation lands, the component of the CEEC that would be impacted by the proposed development is unlikely to adversely affect habitat critical to the survival of the community.
Modify or destroy abiotic (non-living) factors (such as water, nutrients, or soil) necessary for an ecological community's	The proposed development would involve the clearing of approximately 43.4 hectares of SSTF, and therefore destroy abiotic factors necessary for the CEEC survival within the impact footprint.

Shale Sandstone Transition Forest	
Critically Endangered Ecological Community	Significant Assessment Criteria
survival, including reduction of groundwater levels, or substantial alteration of surface water drainage patterns	The proposed development would not result in the removal of all SSTF within the locality: over 2,947 hectares has been mapped by Tozer et al. 2006 in the locality. As such, the SSTF to be cleared would not adversely affect all abiotic factors critical to the survival of the community within the locality.
Cause a substantial change in the species composition of an occurrence of an ecological community, including causing a decline or loss of functionally important species, for example through regular burning or flora or fauna harvesting	The proposed development would result in the clearing of approximately 43.4 hectares of SSTF. As stated above, the proportion of the community not impacted directly by the proposed development would remain viable. The proposed development is not likely to cause changes to the remainder of the CEEC within the locality that would lead to the decline or loss of functionally important species.
Cause a substantial reduction in the quality or integrity of an occurrence of an ecological community, including, but not limited to; assisting invasive species, that are harmful to the listed ecological community, to become established, or causing regular mobilisation of fertilisers, herbicides or other chemicals or pollutants into the ecological community which kill or inhibit the growth of species in the ecological community, or	The proposed development would result in the reduction of SSTF within the Study Area through the clearing of approximately 43.4 hectares of the CEEC. The Project would involve the implementation of mitigation measures such as a weed management plan. Through implementing this plan it is unlikely that an increase in invasive species would occur within bushland surrounding the surface infrastructure footprint. The proposed development is not likely to increase the mobilisation of fertilisers, herbicides or other chemicals or pollutants into the CEEC which would impact on the species composition. Any use of herbicides as part of a weed management plan would be undertaken using industry best practice.
Interfere with the recovery of an ecological community.	An approved recovery plan exists for SSTF as part of the recovery plan for the Cumberland Plain (DECCW 2010). The main recovery objectives of this recovery plan include (DECCW 2010): ▪ To build a protected area network, comprising public and private lands, focused on the priority conservation lands ▪ To deliver best practice management for threatened biodiversity across the Cumberland Plain, with a specific focus on the priority conservation lands and public lands where the priority management objectives are compatible with biodiversity conservation ▪ To develop and understanding and enhanced awareness in the community of the Cumberland Plain's threatened biodiversity, the best practice standards for its management and the recovery program

Shale Sandstone Transition Forest	
Critically Endangered Ecological Community	Significant Assessment Criteria
	▪ To increase knowledge of the threats to the survival of the Cumberland Plain's threatened biodiversity, and thereby improve capacity to manage these in a strategic and effective manner. The proposed development is likely to interfere with the recovery of SSTF, as the Study Area has been identified as part of a priority conservation land in the Cumberland Plain Recovery Plan (DECW 2010). Of the 9,642 hectares of SSTF remaining (as mapped by NPWS 2002, Tozer 2003 and NSW Scientific Committee and Simpson 2008, referenced in DECCW 2010), approximately 3,145 hectares (33%) have been mapped as priority conservation lands (DECCW 2010). The 43.4 hectares that would be removed as part of the proposed development represents 1.5% of the area of SSTF mapped as part of a priority conservation lands (DECCW 2010).
Conclusion	The Project is **likely** to result in a significant impact to SSTF due to the following: ▪ The Project would result in the direct clearing of approximately 43.4 identified in the Cumberland Plain Recovery Plan (DECW 2010). ▪ The Project would result in fragmentation of SSTF due to direct clearing. ▪ The Project would reduce the extent of the CEEC.

Acacia bynoeana	
Vulnerable species	**Address of Criteria**
Background	*Acacia bynoeana* occurs in heath or dry sclerophyll forest on sandy soils. The species seems to prefer open, sometimes slightly disturbed sites such as trail margins, edges of roadside spoil mounds and in recently burnt patches (NPWS 1999). A population of *Acacia bynoeana* was recorded during the current survey along an existing Fire Trail off Ashby Close, within Bargo. The population does not occur within the Study Area and would therefore not be impacted by the Project. Within the Study Area, no individuals for *Acacia bynoeana* were recorded despite targeted survey. Whilst no individuals were recorded, it is noted that the proposed development would result in impacts to approximately 49.1 hectares of potential habitat for *Acacia bynoeana* through vegetation clearing. Potential habitat to be directly impacted includes Shale Sandstone Transition Forest, and Upper Georges Sandstone Woodland. Given the species occurs within a heath and Dry Sclerophyll Forest habitat typically occurring away from sensitive environmental features that may be impacted by subsidence (ie. Watercourses, edges of ridges) subsidence is unlikely to impact upon the species.
Is this population an important population?	Given the species was not recorded in the Study Area despite targeted searches, the proposed development footprint is not likely to support an important population of the species.
An action is likely to have a significant impact on a critically endangered or endangered species if there is a real chance or possibility that it will:	
Lead to a long-term decrease in the size of an important population of a species	*Acacia bynoeana* occurs in heath or dry sclerophyll forest on sandy soils. The species seems to prefer open, sometimes slightly disturbed sites such as trail margins, edges of roadside spoil mounds and recently burnt patches (NPWS 1999). *Acacia bynoeana* was not recorded during the current survey within the disturbance footprint, as such, no important population would be impacted. Furthermore, the species is not considered likely to be impacted by subsidence, as it is unlikely that cracking of soils within areas of potential habitat would lead to vegetation die back, or significant vegetation composition changes. Given no important population was recorded in the proposed surface facility areas, and the species is unlikely to be impacted by subsidence, the proposed development is unlikely to result in a long-term decrease in the size of a population.
Reduce the area of occupancy of an	The proposed development would not reduce the area of occupancy of the species as no individuals were recorded in the proposed surface facility footprint.

Acacia bynoeana	
Vulnerable species	**Address of Criteria**
important population	It is unlikely that subsidence would result in the modification of habitat given the species is reliant upon dry sclerophyll forest habitats that are not solely reliant or groundwater. Furthermore, no important population was recorded within the Study Area.
Fragment an existing important population into two or more populations	The proposed development would not result in the fragmentation of an existing population.
Adversely affect habitat critical to the survival of a species	The proposed development is unlikely to adversely affect habitat critical to the survival of the species as: ▪ No individuals are likely to be impacted by the proposed development. ▪ The species is relatively conspicuous and is unlikely to have remained undetected during the field survey if present. It is therefore likely the species is not present within the proposed footprint of the surface facility sites. ▪ Subsidence is unlikely to impact the species given it is reliant upon dry sclerophyll forest habitats.
Disrupt the breeding cycle of an important population	The following is known about the lifecycle of *Acacia bynoeana* (NPWS 1999): ▪ Plants are generally very small and produce few flowers. ▪ Flowers from September until March and the fruit matures November to January with the peak fruit maturation occurring in November. ▪ Seeds are shed at maturity. Seed production is considered to be minimal and seedlings are rare. There is apparently little local dispersal of seed. ▪ The plant has a woody rootstock and it is likely the species is able to re-sprout from this rootstock after fire. ▪ The species maintains a long-term soil-stored seedbank. ▪ Plants may not always be apparent and appear periodically, perhaps in response to local disturbance. The proposed development is unlikely to have an adverse impact on Acacia bynoeana such that the breeding cycle of an important population would be disrupted, due to the following: ▪ The proposed development would not impact upon any known individuals of *Acacia bynoeana*. ▪ The proposed development is unlikely to result in the loss of any known pollinators of the species.

Acacia bynoeana	
Vulnerable species	**Address of Criteria**
	▪ No important population was recorded within the Study Area. Given the species is relatively conspicuous, and is therefore unlikely to remain undetected during the field survey, it is likely that no individuals would be impacted by the proposed development. Furthermore, subsidence as a result of the proposed development is unlikely to impact the species as it occurs within dry sclerophyll vegetation.
Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline	The proposed development would result in the removal of approximately 49.1 ha of potential habitat. Based on previous vegetation mapping (Tozer 2006), the area of potential habitat in the locality is approximately >20,000 hectares, comprising of Sydney Hinterland Transition Woodland (7,705 hectares), Coastal Sandstone Ridgetop Woodland (11,239 hectares), and Cumberland Shale Sandstone Transition Forest (2,947 hectares). This vegetation would not be impacted by the proposed development. Given the species was not recorded during the current survey, and given the large extent of potential habitat, it is unlikely the proposed development would modify, destroy, remove or isolate the availability of quality of habitat to the extent that the species is likely to decline.
Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat	There is the potential for the proposed development to result in an increase in invasive species that may occur within areas of potential habitat. However, mitigation measures such as the implementation of a weed management plan would be undertaken as part of the Project. This would reduce the potential for any impacts on the habitat of *Acacia bynoeana*.
Introduce disease that may cause the species to decline, or	There is the potential for machinery to result in the spread of *Phytophthora cinnamomi*. However, mitigation measures such as vehicle wash downs would be undertaken to reduce the potential for any impacts to Acacia bynoeana.
Interfere substantially with	The proposed development is unlikely to interfere substantially with the recovery of the species as the species was not recorded during the current survey, no known populations should be impacted by the Project and potential habitat is relatively extensive in the locality.

Acacia bynoeana	
Vulnerable species	**Address of Criteria**
the recovery of the species.	
Conclusion	The proposed development is unlikely to significantly impact the *Acacia bynoeana* as : • the species was not recorded during the current survey • Potential habitat is relatively extensive in the locality. • No known populations should be impacted by the Project. • Mitigation measures such as weed management would be implemented to reduce impacts to potential habitat.

Grevillea parviflora* subsp. *parviflora	
Vulnerable Species	Significant Assessment Criteria
Background	*Grevillea parviflora* subsp. *parviflora* was recorded during the currently survey, and previously surveys by Niche at the following locations within the Study Area: ▪ Within proposed REA 1 and REA 2 ▪ Immediately surrounding the boundary of both REA 1 and REA 2 ▪ Bushland to the east of Charlies Point Road ▪ Within the Anthony Road property owned by Tahmoor Coal ▪ At the site of the ventilation shafts ▪ Along Fire Road 5 in the Upper Nepean State Conservation Area. It is likely that the records within the REA, and area immediately surrounding the REA and to the east of Charlies Point Road are part of the same population give proximity of all records and occupancy within similar habitat. In summary, the total estimated count of *Grevillea parviflora* subsp. *parviflora* recorded during the current survey that would be directly impacted by the Project is 2,324 individuals. The REA population extends to the east of Charlies Point Road and is likely to include an additional 10,000 plants based on approximately 20.0 hectares.

Grevillea parviflora subsp. *parviflora*	
	Furthermore, it should be noted that another site containing a population of the species within the tens of thousands was recorded within land owned by Tahmoor Coal located off Ashby Close, Bargo. This population would not be impacted by the Project.
Is this population an important population?	The population recorded within the development footprint of the REA and immediately surrounds, should be regarded as an 'important population' as: 1. It is a key source population for breeding or dispersal. It is likely that the population is a key source population for breeding and dispersal given the size of the population and the extensive distribution in the locality. Sites of particular significance for *Grevillea parviflora* subsp. *parviflora* would include any population with greater than 50 plants; a population with a varied age structure including active recruitment of seedlings; and an area of intact habitat away from high disturbance areas (SEWPaC 2013). The population recorded fits this description. 2. It is a population that is necessary for maintaining genetic diversity. The population is very large and likely to contain a significant proportion of the genetic diversity of the species. It is likely that this population has distinct genetic differentiation from the northern populations of the species in the Hunter Valley. 3. The population is near the limit of the species range. The population is at or near the southern limit of the range for the species which is identified as Bargo (SEWPaC 2013). Given its size and distribution, the population of *Grevillea parviflora* subsp. *parviflora* in the locality is considered to be an important population.
An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	
Lead to a long-term decrease in the size of an important population of a species	*Grevillea parviflora* subsp. *parviflora* is unlikely to be impacted by subsidence, as the species does not occur within areas that are sensitive to subsidence related impacts (eg. bed of watercourses, ridgelines). The habitat within Dry Sclerophyll Forest vegetation may be exposed to subsidence cracking of the soil, however such an impact is unlikely to result in significant changes to floristics and composition that may impact upon *Grevillea parviflora* subsp. *parviflora*. In total, the proposed development would impact approximately 5.1 hectares of known habitat and approximately 2,324 individuals of *Grevillea parviflora* subsp. *parviflora*. During the field survey, *Grevillea parviflora* subsp. *parviflora* was also recorded to the east of Charlies Point Road which occurs outside of the development footprint. The individuals recorded to the east of Charlies Point Road are likely to be of the same population to those recorded at the REA. The area of potential habitat mapped to the east of Charlies Point Road is approximately 20 hectares, and based on population counts equates to approximately 10,000 individuals of *Grevillea parviflora* subsp. *parviflora*. The proposed development would impact upon 25 per cent of the localised distribution of this species which is considered to be part of a much larger (important) population of *Grevillea parviflora* subsp. *parviflora*. Despite the losses that would occur from the proposed development, the remaining population is considered viable and not likely to decline over time as a result of the proposed development. Furthermore, a larger population
Reduce the area of occupancy of an	The proposed development would reduce the area of occupancy of an important population by approximately 25 percent.

Grevillea parviflora subsp. parviflora	
important population	
Fragment an existing important population into two or more populations	At present, the local distribution of this species is already fragmented by Charlies Point Road and the existing REA operations. The proposed development footprint surrounding the existing REA would result in increased distances between individuals within the population.
Adversely affect habitat critical to the survival of a species	The proposed development is unlikely to adversely affect habitat critical to the survival of the species as: ▪ The proposed development would result in the removal of approximately 5.1 hectares of known habitat. A further 20 hectares of known habitat (supporting an estimated 10,000 individuals) on the east of Charlies Point Road would not be impacted by the proposed development. ▪ A larger population of *Grevillea parviflora* subsp. *parviflora* that occurs outside of the Study Area within land owned by Tahmoor Coal would not be impacted by the Project. This population is likely to be in the tens of thousands. ▪ A population within the Wirrimbirra Reserve in Bargo is informally protected, and Niche has recorded a population within the Nepean State Conservation Area off Avon Dam Road. Both these populations occur within the locality and would not be impacted by the proposed development.
Disrupt the breeding cycle of an important population	The following is known about the breeding cycle of *Grevillea parviflora* subsp. *parviflora*: ▪ Biology and ecology of the species is poorly known, though it is believed that the species lives between 25–60 years (D. Keith pers.comm. cited in Benson and McDougall 2000). ▪ Flowering occurs in April, May and between July and December. The flowers are insect pollinated. One to two seeds are released at maturity (Benson & McDougall 2000) but have limited seed dispersal, probably of less than 2 m (DSEWPaC 2013) ▪ Plants are capable of suckering or regenerating from a rootstock (NSW DECC 2005p). Sucker stems usually occur in patches close to the parent plant (DSEWPaC 2013). ▪ After fire or other disturbance, regeneration can occur from both the rhizomes and seed in the soil seedbank. However, after fire, adult plants are killed and seedling recruitment is uncommon (Benson & McDougall 2000). ▪ Little is known about the production and viability of seed, seed predation or germination rates and requirements. Much of the current knowledge of *Grevillea parviflora* subsp. *parviflora* is based on general observations (DSEWPaC 2013). It is unlikely the proposed development would affect the lifecycle of the remaining population due to the following: ▪ The proposed development would remove approximately 2,324 individuals from the local population. The remaining 9,240 plants within the population would not be impacted by the proposed development. ▪ The proposed development would impact upon 25 percent of the important population. The remaining 75 percent of the population is considered viable and not likely to decline over time as a result of the proposed development. ▪ The proposed development is unlikely to result in the loss of any known pollinators of the species.

Grevillea parviflora subsp. parviflora	
	▪ A large population recorded within the Upper Nepean State Conservation Area would not be impacted by the proposed development. A population count has not been conducted, but it likely to exceed over a thousand individuals. Similarly the population recorded within Tahmoor Coal owned land off Ashby Close in Bargo would not be impacted. ▪ Subsidence is unlikely to cause any significant impact to the species. *Grevillea parviflora* subsp. *parviflora* is located within the dry sclerophyll forests away from creek and watercourses. It is unlikely subsidence would impact all areas that the species occupies.
Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline	The proposed development would impact approximately 5.1 hectares of known habitat. The species is common within the Shale Sandstone Transition Forest in the locality which covers a much larger area (2,947 hectares). This is supported by the large populations within the Upper Nepean State Conservation Area near Avon Dam Road, and the Bargo Colliery Land off Ashby Close, Bargo. Overall, the proposed development would lead to a decline in the total number of plants within the population and a reduction in the total available habitat for the species. The proportion of the estimated population that would not be affected by the proposed development is substantial. It is unlikely that the proposed development would lead to a decline in the overall species.
Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat	There is the potential for the proposed development to result in an increase in invasive species that may occur within areas of potential habitat. However, mitigation measures such as the implementation of a weed management plan would be undertaken as part of the Project. This would reduce the potential for any impacts on the habitat of *Grevillea parviflora* subsp. *parviflora.*
Introduce disease that may cause the species to decline, or	There is the potential for machinery to result in the spread of *Phytophthora cinnamomi*. However, mitigation measures such as vehicle wash downs would be undertaken to reduce the potential for any impacts to *Grevillea parviflora* subsp. *parviflora*.
Interfere substantially with the recovery of the species.	The proposed development would result in the loss of 25 percent of the important population. However, the species is relatively common within the locality, with populations in the tens of thousands recorded within the Nepean State Conservation Area and land owned by Tahmoor Coal located to the west of Bargo. These populations would not be impacted by the Project.
Conclusion	The Project is unlikely to result in a significant impact to *Grevillea parviflora* subsp. *parviflora* as: ▪ The proposed disturbance would result in direct impacts to 2,324 plants within an important population, however over 10,000 plants would not be impacted by the Project and would remain viable.

Grevillea parviflora subsp. parviflora	
	▪ Larger populations within the tens of thousands of plants would not be impacted by the Project. The populations located within the Nepean State Conservation Area and within Tahmoor Coal land to the west of Bargo would not be directly impacted. ▪ The species is unlikely to be impacted by subsidence. ▪ Mitigation measures proposed would reduce indirect impacts to the important population that would not be able to be cleared.

Persoonia bargoensis	
Vulnerable Species	Significant Assessment Criteria
Background	*Persoonia bargoensis* was recorded at various locations during the field survey including: ▪ A total of 692 individuals of *Persoonia bargoensis* were recorded within and adjacent to the REA. The bulk of the population occurs along the transmission line easement to the north of REA Area 2, and along the south-east boundary of REA Area 2. ▪ Individuals recorded along Anthony Road ▪ Individuals recorded along Fire Roads off Ashby Close in Bargo Approximately 100 individuals of *Persoonia bargoensis* would be directly impacted by the proposed development, including approximately 46.9 hectares of potential habitat. Potential habitat includes: Shale Sandstone Transition Forest and Upper Georges Sandstone Woodland.
Is this population an important population?	The population (being defined as the broader local population, not just those individuals recorded within the Study Area) should be regarded as an 'important population' if: 1. It is a key source population for breeding or dispersal - Given that the species is restricted in distribution to a very small area, it is likely that the 692 individuals form part of a population of this species which is a key source, and perhaps the only source, population for breeding and dispersal of this species. 2. It is a population that is necessary for maintaining genetic diversity - Again, given that the species is restricted in its entire distribution to a very small areas it is likely that the 692 individuals recorded form part of a population that is necessary for maintaining genetic diversity for the species. 3. The population is near the limit of the species range - The population is at the limit of the range for the species which is identified above with northern, southern, eastern and western limits at Picton and Douglas Park, Yanderra, Cataract River and Thirlmere. Given its size and distribution, the local population of Persoonia bargoensis is considered to be an important population.
An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	
Lead to a long-term decrease in the size of an important population of a species	Approximately 49.6 hectares of potential habitat would be impacted by the proposed development. Potential habitat includes Upper Georges River Sandstone Woodland and Shale Sandstone Transition Forest. *Persoonia bargoensis* is unlikely to be impacted by subsidence, as the species does not occur along ridgelines or close to waterways. The woodland and forest environments that it inhabits are not water dependent, and therefore subsidence is unlikely to impact the species. The proposed development would result in the loss of 100 known individuals as a result of the clearing required for the proposed works. Despite the losses that would occur from the proposed development, the remaining population, a further 592 plants, is considered viable and not likely to decline over time as a result of the proposed development.

Persoonia bargoensis	
Vulnerable Species	Significant Assessment Criteria
Reduce the area of occupancy of an important population	The proposed development would directly impact approximately 100 individuals of *Persoonia bargoensis* for the Project. This is approximately 14 per cent of the important population.
Fragment an existing important population into two or more populations	At present, the local distribution of this species is fragmented by Charlies Point Road and the existing REA operations. The proposed development would result in increased distances between individuals of this species within the population which occurs along Charlie's Point Road.
Adversely affect habitat critical to the survival of a species	The proposed development is unlikely to adversely affect habitat critical to the survival of the species as: ▪ The proposed development would result in the removal of approximately 100 plants within the population. This is a reduction of 18 percent of the important population. The remaining 86 percent of the population would not be impacted by the Project and therefore would not result in extinction of the population. ▪ Based on previous mapping (Tozer 2006), the area of potential habitat in the locality is approximately 10,653 hectares, comprising of Sydney Hinterland Transition Woodland (2698.70 hectares) and Cumberland Shale Sandstone Transition Forest (573 hectares) (Tozer et al. 2006). The proposed development would result in the removal of approximately 0.3 per cent of potential habitat in the locality.
Disrupt the breeding cycle of an important population	The following is known about the life cycle of *Persoonia bargoensis* (DEC 2005): ▪ Grows in woodland to dry sclerophyll forest, on sandstone and clayey laterite on heavier, well-drained, loamy, gravelly soils of the Hawkesbury Sandstone and Wianamatta Shale in the catchments of the Cataract, Cordeaux and Bargo Rivers. ▪ Local populations are very small (mostly less than eight plants) and scattered, with a total population likely to be less than 250 (in 1999). The species appears to be associated with disturbance margins such as the edge of fire trails, possibly because of more light, less root competition, factors regulating the breaking of dormancy, or a factor relating to dispersal agents. The species is fire-sensitive and appears to need a minimum fire frequency of 10-15 years between fires. ▪ The longevity of *Persoonia bargoensis* is likely to be approximately 20 years. ▪ Flowering occurs mainly in summer (Blombery and Maloney 1992) but can extend into autumn (Douglas pers. obs.). ▪ Primarily pollinated by native bees (Bernhardt and Weston 1996). ▪ Plants are likely to be killed by fire and recruitment is solely from seed. ▪ Like most Geebungs this species seems to benefit from the reduced competition and increased light available on disturbance margins including roadsides.

Persoonia bargoensis	
Vulnerable Species	Significant Assessment Criteria
	The proposed development is likely to result in a disruption to the breeding cycle of the species, given 18 percent of the population would be removed. This would therefore result in changes to the seed bank for the population in the long-term. However, it is noted that the remaining 82 percent of the population would provide seed source which would not lead to extinction of the species within the locality.
Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline	As described above, the proposed development would result in the loss of approximately 14 percent of the population. The proposed development would not isolate or decrease the availability or quality of the remaining habitat for this species to the extent that the species is likely to decline.
Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat	There is a limited potential for the proposed development to result in an increase in invasive species within the REA and elsewhere where any surface infrastructure would be developed or exploration activities would be undertaken. However, the proposed development also involves the implementation of good environmental practice including vehicle hygiene and development of a weed management plan. Further, the current REA activities and the exploration activities undertaken to date have not resulted in high number of invasive species establishing within the habitat for this vulnerable species.
Introduce disease that may cause the species to decline, or	There is the potential for machinery to result in the spread of *Phytophthora cinnamomi*. However, mitigation measures such as vehicle wash downs would be undertaken to reduce the potential for any impacts to Persoonia bargoensis.
Interfere substantially with the recovery of the species.	The proposed development would result in the loss of a relatively large number of individuals of this species and also 49.6 hectares of known habitat. The impact of the proposed development on the important population would not extend beyond the Study Area and would therefore not interfere with the recovery of the species elsewhere in the locality.
Conclusion	The Project is **likely** to result in a significant impact to *Persoonia bargoensis* based on the following: ▪ The important population would be reduced by 14 percent based on the removal of 100 plants.

Persoonia bargoensis	
Vulnerable Species	Significant Assessment Criteria
	▪ The species has a relatively limited distribution. The population to be impacted occurs within the limits of distribution. ▪ Fragmentation of the population would occur as a result of the proposed disturbance. ▪ Given 14 percent of the population would be removed, the seed bank would likely be impacted.

Persoonia glaucescens	
Vulnerable Species	Significant Assessment Criteria
Background	*Persoonia glaucescens* was not recorded during the current field surveys. A record of the species, obtained from the OEH Atlas of NSW Wildlife, has been mapped as occurring within the southern portion of proposed REA Area 2. This individual was not detected during the current survey at the coordinates obtained from OEH. Approximately 49.1 hectares of potential habitat would be removed as part of the disturbance associated with the Project. Potential habitat includes Shale Sandstone Transition Forest and Upper Georges River Sandstone Woodland.
Is this population and important population?	No population has been mapped as occurring within the proposed development footprint.
An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	
Lead to a long-term decrease in the size of an important population of a species	The proposed development would not impact upon an important population.
Reduce the area of occupancy of an important population	The proposed development would not impact upon an important population. Approximately 49.1 hectares of potential habitat would be impacted by the proposed development. Potential habitat includes Shale Sandstone Transition Forest and Upper Georges Sandstone Woodland., approximately 14,000 hectares of similar potential habitat is mapped as occurring within the locality (Tozer et al. 2006). The proposed development would reduce the area of potential habitat within the locality by approximately <1 percent.
Fragment an existing important population into two or more populations	The proposed development would not impact any known individuals of Persoonia glaucescens. The proposed development may result in some fragmentation of potential habitat as a result of the REA development footprint. Two corridors of vegetation that currently link areas of vegetation east and west of the REA development footprint would be removed. However, the vegetated links representing habitat for Persoonia glaucescens would still occur to the north and south of the REA development footprint post clearing. Subsidence is unlikely to result in fragmentation of habitat for Persoonia glaucescens.
Adversely affect habitat critical to the survival of a species	The proposed development is unlikely to adversely affect habitat critical to the survival of the species as: ▪ Persoonia glaucescens was not recorded within the development footprint during the current survey. ▪ Subsidence is unlikely to impact on potential habitat for the species, as the species does not occur within habitat types that are sensitive to changes due to subsidence (eg. creek beds, groundwater dependent ecosystems etc.).

Persoonia glaucescens	
Vulnerable Species	Significant Assessment Criteria
Disrupt the breeding cycle of an important population	The threatened species profile lists the following about the lifecycle of Persoonia glaucescens: ▪ Grows in woodland to dry sclerophyll forest on clayey and gravely laterite. ▪ Preferred topography is ridge-tops, plateaux and upper slopes. Aspect does not appear to be a significant factor. ▪ Within its habitat, Persoonia glaucescens is generally rare and the populations are linear and fragmented. Under ideal circumstances, the species can be locally common, though such conditions are very rare. ▪ Plants are killed by fire and recruitment is solely from seed. ▪ Like most Persoonia species this species seems to benefit from the reduced competition and increased light available on disturbance margins including roadsides. ▪ The proposed development is unlikely to have an adverse impact on the breeding cycle of Persoonia glaucescens due to the following: ▪ The proposed development would not impact upon any known individuals of Persoonia glaucescens. ▪ No important population was recorded. The proposed development is unlikely to result in the loss of any known pollinators of the species. The species does not occur within and/or is not likely to be reliant on the vegetation communities or habitats that may be adversely impacted by subsidence.
Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline	The proposed development would impact approximately 49.6 hectares of potential habitat. Based on previous mapping (Tozer 2006), the area of potential habitat in the locality is approximately 14,000 hectares, comprising of Cumberland Shale Sandstone Transition Forest and Upper Georges River Sandstone Woodland. The proposed development would result in the removal of approximately 1 per cent of potential habitat in the locality. Given the species was not recorded within the development footprint during the current survey, and the extent of potential habitat is relatively extensive, it is unlikely the proposed development would modify, destroy, remove or isolate the availability of quality of habitat to the extent that the species is likely to decline.
Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat	There is a limited potential for the proposed development to result in an increase in invasive species within the REA and elsewhere where any surface infrastructure would be developed or exploration activities would be undertaken. However, the proposed development also involves the implementation of good environmental practice including vehicle hygiene and development of a weed management plan. Further, the current REA activities and the exploration activities undertaken to date have not resulted in high number of invasive species establishing within the habitat for this vulnerable species.

Persoonia glaucescens	
Vulnerable Species	Significant Assessment Criteria
Introduce disease that may cause the species to decline, or	There is the potential for machinery to result in the spread of Phytophthora cinnamomi. However, mitigation measures such as vehicle wash downs would be undertaken to reduce the potential for any impacts to Persoonia bargoensis.
Interfere substantially with the recovery of the species.	No known individuals of this species would be removed by the proposed development. Approximately 50 hectares of potential habitat would be removed by proposed surface infrastructure. The impact of the proposed development would not extend beyond the Study Area and would therefore not interfere with the recovery of the species elsewhere in the locality.
Conclusion	The Project would not result in an impact to Persoonia glaucescens due to the following: ▪ No individuals of Persoonia glaucescens was recorded within the disturbance area. ▪ Persoonia glaucescens does not occur within habitat that would be impacted by subsidence. ▪ The habitat for Persoonia glaucescens is relatively extensive within the locality.

Persoonia hirsuta	
Vulnerable Species	Significant Assessment Criteria
Background	During the current field survey, no records for *Persoonia hirsuta* were recorded. The species is relatively conspicuous and unlikely to remain undetected during the current and previous field surveys. Approximately 49.1 hectares of potential habitat would be removed as part of the disturbance associated with the Project. Potential habitat includes Shale Sandstone Transition Forest and Upper Georges River Sandstone Woodland.
Is this population and important population?	No population has been mapped as occurring within the proposed development footprint.
An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	
Lead to a long-term decrease in the size of an important population of a species	The proposed development would not impact upon an important population.
Reduce the area of occupancy of an important population	The proposed development would not impact upon an important population. Approximately 49.1 hectares of potential habitat would be impacted by the proposed development. Potential habitat includes Shale Sandstone Transition Forest and Upper Georges Sandstone Woodland, approximately 14,000 hectares of similar potential habitat is mapped as occurring within the locality (Tozer et al. 2006). The proposed development would reduce the area of potential habitat within the locality by approximately <1 percent.
Fragment an existing important population into two or more populations	The proposed development would not impact any known individuals of *Persoonia hirsuta*. The proposed development may result in some fragmentation of potential habitat as a result of the REA development footprint. Two corridors of vegetation that currently link areas of vegetation east and west of the REA development footprint would be removed. However, the vegetated links representing habitat for *Persoonia hirsuta* would still occur to the north and south of the REA development footprint post clearing. Subsidence is unlikely to result in fragmentation of habitat for *Persoonia hirsuta*.
Adversely affect habitat critical to the survival of a species	The proposed development is unlikely to adversely affect habitat critical to the survival of the species as: ▪ *Persoonia hirsuta* was not recorded within the development footprint during the current survey. ▪ Subsidence is unlikely to impact on potential habitat for the species, as the species does not occur within habitat types that are sensitive to changes due to subsidence (eg. creek beds, groundwater dependent ecosystems etc.).
Disrupt the breeding cycle of an important population	The threatened species profile lists the following about the lifecycle of *Persoonia hirsuta*: ▪ The Hairy Geebung is found in sandy soils in dry sclerophyll open forest, woodland and heath on sandstone. ▪ It is usually present as isolated individuals or very small populations. ▪ Plants are killed by fire and recruitment is solely from seed.

Persoonia hirsuta	
Vulnerable Species	Significant Assessment Criteria
	The proposed development is unlikely to have an adverse impact on the breeding cycle of *Persoonia hirsuta* due to the following: ▪ The proposed development would not impact upon any known individuals of *Persoonia hirsuta*. ▪ No important population was recorded. ▪ The proposed development is unlikely to result in the loss of any known pollinators of the species. ▪ The species does not occur within and/or is not likely to be reliant on the vegetation communities or habitats that may be adversely impacted by subsidence.
Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline	The proposed development would impact approximately 49.1 hectares of potential habitat. Based on previous mapping (Tozer 2006), the area of potential habitat in the locality is approximately 14,000 hectares, comprising of Cumberland Shale Sandstone Transition Forest and Upper Georges River Sandstone Woodland. The proposed development would result in the removal of approximately 1 per cent of potential habitat in the locality. Given the species was not recorded within the development footprint during the current survey, and the extent of potential habitat is relatively extensive, it is unlikely the proposed development would modify, destroy, remove or isolate the availability of quality of habitat to the extent that the species is likely to decline.
Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat	There is a limited potential for the proposed development to result in an increase in invasive species within the REA and elsewhere where any surface infrastructure would be developed, or exploration activities would be undertaken. However, the proposed development also involves the implementation of good environmental practice including vehicle hygiene and development of a weed management plan. Further, the current REA activities and the exploration activities undertaken to date have not resulted in a high number of invasive species establishing within habitat of this vulnerable species.
Introduce disease that may cause the species to decline, or	There is the potential for machinery to result in the spread of *Phytophthora cinnamomi*. However, mitigation measures such as vehicle wash downs would be undertaken to reduce the potential for any impacts to *Persoonia hirsuta*.
Interfere substantially with the recovery of the species.	No known individuals of this species would be removed by the proposed development. Approximately 50 hectares of potential habitat would be removed by proposed surface infrastructure. The impact of the proposed development would not extend beyond the Study Area and would therefore not interfere with the recovery of the species elsewhere in the locality.
Conclusion	The Project would not result in an impact to *Persoonia hirsuta* due to the following:

Persoonia hirsuta	
Vulnerable Species	Significant Assessment Criteria
	▪ No individuals of *Persoonia hirsuta* were recorded within the disturbance area. ▪ *Persoonia hirsuta* does not occur within habitat that would be impacted by subsidence. ▪ The habitat for *Persoonia hirsuta* is relatively extensive within the locality.

Pomaderris brunnea	
Vulnerable Species	Significant Assessment Criteria
Background	A population of *Pomaderris brunnea* was recorded along Tea Tree Hollow Creek during the current survey. Over 300 individuals were recorded within the gully environment of Tea Tree Hollow Creek. The species has also been previously recorded in creeklines at Wirrimbirra Sanctuary (Bargo) (SEWPAC 2013). The Wirrimbirra population contained 900 plants in the late 1980s (SEWPAC 2013). Together, these local records are likely to form a local population of the species totalling at least 1235 individuals. Whilst *Pomaderris brunnea* occurs within a gully environment adjacent to Tea Tree Hollow Creek, it is highly unlikely subsidence would result in die back of the population due to the following: Tea Tree Hollow Creek undergoes extensive periods of dryness, thus the species unlikely to be affected by any potential creek surface cracking or changes to groundwater as a result of subsidence. Much of the population was recorded on the top of middle banks of Tea Tree Hollow Creek and not within areas inundated with water. Thus any changes to the water regime are unlikely to result in impacts to the population. Die back of vegetation from gas emissions may occur as a result of the proposed development, however based on previous experience in the Southern Coalfields, the likelihood of this occurring is low, and any impacts would be isolated and localised. Given the population does not occur within the bed of the creek, and is largely positioned away from the lower banks, die back from gas emissions is unlikely.
Is this population an important population?	The population (being defined as the broader local population, not just those individuals recorded within the Study Area) should be regarded as an 'important population' if: It is a key source population for breeding or dispersal: The individual plants within Tea Tree Hollow Creek, Dog Trap Creek and Hornes Creek are likely to form part of a broader population within the Wirrimbirra Nature Sanctuary. Together this population is likely to be locally important for dispersal and breeding. It is a population that is necessary for maintaining genetic diversity: The population is likely to contain a significant proportion of the genetic diversity of the species within the locality. It is likely that this population has distinct genetic differentiation from other populations of this species. The population is near the limit of the species range: The local records of this species are not at the limit of the species range. The population of Pomaderris brunnea recorded within Tea Tree Hollow is considered to be part of an important population for the species.
An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	

Pomaderris brunnea	
Vulnerable Species	Significant Assessment Criteria
Lead to a long-term decrease in the size of an important population of a species	The proposed development footprint would not result in the removal of any plants from the important population. Subsidence is unlikely to results in a decrease in the population of the species as: ▪ Pomaderris brunnea is not a strictly water dependent species. It does not occur in the watercourse. It occurs in moist forest communities and gullies often near water. ▪ Tea Tree Hollow Creek experiences periods of dryness. Whilst it is a possibility that subsidence can result in loss of water from watercourses, the population of Pomaderris brunnea in the Study Area is already exposed to such conditions. ▪ Tea Tree Hollow Creek has been previously mined beneath. No declines in the population have been previously observed. ▪ Any vegetation die back from gas emissions is likely to be isolated and localised. Based on previous experience in the Southern Coalfields, it is unlikely that any gas emissions would cause significant impact to the vegetation. The proposed development is therefore unlikely to result in a long-term decrease in size of an important population.
Reduce the area of occupancy of an important population	The proposed development footprint would not reduce the important population through clearing. Mitigation measures would prevent indirect impacts to the important population.
Fragment an existing important population into two or more populations	The proposed development would not result in fragmentation of the important population. The proposed development would occur to the immediate east of the population.
Adversely affect habitat critical to the survival of a species	The proposed development is unlikely to adversely affect habitat critical to the survival of the species as: No known individuals would be impacted by the development. Mitigation measures proposed would prevent indirect impacts to the population. Potential habitat for the species is unlikely to be significantly impacted by the proposed development and associated subsidence. The species is found within the Wirrimbirra Sanctuary which occurs within the locality (SEWPaC 2013). This population is unlikely to be impacted by the proposed development.

Pomaderris brunnea	
Vulnerable Species	Significant Assessment Criteria
Disrupt the breeding cycle of an important population	The following is known about the breeding cycle of Pomaderris brunnea: ▪ The species is expected to live for 10-20 years, while the minimum time to produce seed is estimated to be 4-6 years ▪ Grows in moist woodland or forest on clay and alluvial soils of flood plains and creek lines. ▪ Flowers appear in September and October. The proposed development is unlikely to disrupt the breeding cycle of an important population as: ▪ None of the important population would be cleared. ▪ Mitigation measures would prevent indirect impacts. ▪ Proposed development is unlikely to impact known dispersal or reproduction mechanisms. ▪ Proposed development is unlikely to result in changes to the fire regime for the species as appropriate fire regimes will be implemented in the Tahmoor Coal Bushfire Management Plan.
Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline	The species occurs in the Sydney region of the Central Coast of NSW, east of Tamworth on the Northern Tablelands of NSW, and in the East Gippsland region of Victoria. In NSW, the species was originally considered endemic to the Sydney Hawkesbury Sandstone region. It is found on the Colo River, the Nepean River floodplain at Menangle, in creeklines at Wirrimbirra Sanctuary (Bargo) and on the Hawkesbury River. The distribution may extend into the southern section of Yengo National Parks along major creeklines and floodplains. The Wirrimbirra population contained 900 plants in the late 1980s. (source: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=16845) The Project is unlikely to result in such a decrease in habitat that the species is likely to decline. The important population would not be cleared, and as such, a viable seedbank would be maintained.
Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat	There is the potential for the proposed development to result in an increase in invasive species that may occur within areas of potential habitat. However, mitigation measures such as the implementation of a weed management plan would be undertaken as part of the Project. This would reduce the potential for any impacts on the habitat of Pomaderris brunnea.
Introduce disease that may cause the species to decline, or	There is the potential for machinery to result in the spread of Phytophthora cinnamomi. However, mitigation measures such as vehicle wash downs would be undertaken to reduce the potential for any impacts to Pomaderris brunnea.

Pomaderris brunnea	
Vulnerable Species	Significant Assessment Criteria
Interfere substantially with the recovery of the species.	A National Recovery Plan for Pomaderris brunnea was developed in 2011. The overall objective of recovery is to minimise the probability of extinction of Pomaderris brunnea in the wild and to increase the probability of populations becoming self-sustaining in the long term. The proposed development would not result in direct impacts to the population. Furthermore, mitigation measures are proposed to minimise and prevent impacts to the species. It is unlikely that the direct impacts to Pomaderris brunnea as a result of the proposed development would interfere substantially with the recovery of the species.
Conclusion	The Project is unlikely to result in a significant impact to Pomaderris brunnea

Leucopogon exolasius	
Vulnerable Species	Significant Assessment Criteria
Background	During the current field survey, no records for *Leucopogon exolasius* were recorded. The species is relatively conspicuous when not in flower and was unlikely to remain undetected during targeted surveys within the disturbance footprint. Furthermore, the species is unlikely to be impacted by subsidence given the species occurs within the following vegetation communities: Shale Sandstone Transition Forest and Upper Georges River Sandstone Woodland, Western Sandstone Gully Forest and Sydney Hinterland Transition Woodland. These vegetation communities are not reliant solely on groundwater dependency, and any surface cracking within the communities is unlikely to result in measurable species composition changes to areas of potential habitat for *Leucopogon exolasius.* Furthermore, the species typically occurs on the slopes of gullies away from the riparian zone of creeks. Thus any subsidence related impacts to hydrology are unlikely to impact habitat for the species.
Is this population and important population?	No population has been mapped as occurring within the proposed development footprint.
An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	
Lead to a long-term decrease in the size of an important population of a species	The proposed development would not impact upon an important population.
Reduce the area of occupancy of an important population	The proposed development would not impact upon an important population.
Fragment an existing important population into two or more populations	The proposed development would not impact any known individuals of *Leucopogon exolasius.* The proposed development would not impact an important population.
Adversely affect habitat critical to	The proposed development is unlikely to adversely affect habitat critical to the survival of the species as: ▪ *Leucopogon exolasius* was not recorded within the development footprint during the current survey.

Leucopogon exolasius	
Vulnerable Species	Significant Assessment Criteria
the survival of a species	▪ Subsidence is unlikely to impact on potential habitat for the species, as the species does not occur within habitat types that are sensitive to changes due to subsidence (eg. creek beds, groundwater dependent ecosystems etc.).
Disrupt the breeding cycle of an important population	No important population occurs within the Study Area, as such, the breeding cycle would not be impacted.
Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline	Based on previous mapping (Tozer 2006), the area of potential habitat in the locality is over 20,000 hectares, comprising of Cumberland Shale Sandstone Transition Forest, Western Sandstone Gully Forest, Upper Georges River Sandstone Woodland and Sydney Hinterland Transition Woodland. The proposed development would result in the removal of less than 1 per cent of potential habitat in the locality. However it should be noted that this habitat is marginal at best given the species was not recorded. Given the species was not recorded within the development footprint during the current survey, and the extent of potential habitat is relatively extensive, it is unlikely the proposed development would modify, destroy, remove or isolate the availability of quality of habitat to the extent that the species is likely to decline.
Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat	There is a limited potential for the proposed development to result in an increase in invasive species within the REA and elsewhere where any surface infrastructure would be developed or exploration activities would be undertaken. However, the proposed development also involves the implementation of good environmental practice including vehicle hygiene and development of a weed management plan. Further, the current REA activities and the exploration activities undertaken to date have not resulted in high number of invasive species establishing within the habitat for this vulnerable species.
Introduce disease that may cause the species to decline, or	There is the potential for machinery to result in the spread of *Phytophthora cinnamomi*. However, mitigation measures such as vehicle wash downs would be undertaken to reduce the potential for any impacts to *Leucopogon exolasius*.
Interfere substantially with the recovery of the species.	No known individuals of this species would be removed by the proposed development. Approximately 77 hectares of potential habitat would be removed by proposed surface infrastructure. The impact of the proposed development would not extend beyond the Study Area and would therefore not interfere with the recovery of the species elsewhere in the locality.

Leucopogon exolasius	
Vulnerable Species	Significant Assessment Criteria
Conclusion	The Project would not result in an impact to *Leucopogon exolasius* due to the following: ▪ No individuals of *Leucopogon exolasius* was recorded within the disturbance area. ▪ *Leucopogon exolasius* does not occur within habitat that would be impacted by subsidence. ▪ The habitat for *Leucopogon exolasius* is relatively extensive within the locality.

Hoplocephalus bungaroides Broad-headed Snake	
Criteria (Vulnerable Species)	Address of Criteria
An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it would:	
Lead to a long-term decrease in the size of an important population of a species	The Broad-headed Snake was not recorded during the current survey. Potential breeding and foraging habitat for this species occurs on ridge lines – particularly around sandstone outcrops within the Study Area, around Dog Trap Creek, and Hornes Creek. The proposed vegetation clearing associated with the Project it is unlikely to impact upon the species due to the lack of potential habitat occurring within the disturbance footprint. Furthermore, trees to be cleared are largely free of hollows. However, subsidence has the potential to cause cracking of rock outcrops and shelters which the species may utilize. Based on mine subsidence predication, it is likely that the proposed development would result in minor, isolated rock falls and cracking, and thus any impact to habitat is likely to be relatively minor. Furthermore, rock falls and cracking may create habitat for the species. Given the lack of records in the Study Area, and the relatively minor nature of predicted subsidence impacts, it is unlikely that a long-term decrease in the species would occur as a result of the proposed development. Furthermore, no important population is known from the Study Area.
Reduce the area of occupancy of an important population	Subsidence impacts as a result of the proposed development are likely to cause some minor and isolated rock falls and cracking. This may impact only a minimal area of potential habitat for the species. Tree hollows which the species utilises would not be impacted by the proposed development. It is highly unlikely isolated/minor subsidence impacts would reduce the area of occupancy of an important population.
Fragment an existing important population into two or more populations	Based on previous mine subsidence predictions, subsidence impacts associated within the proposed development could cause rock falls and surface cracking. Given the species has not been recorded during the current surveys and only one previous record occurs in the locality, it is unlikely fragmentation of an important population would occur.
Adversely affect habitat critical to the survival of a species	No critical habitat has been listed for the species on the EPBC Act Register of Critical Habitat. Given that the species has not been recorded in the Study Area despite targeted surveys and the lack of previous records in the locality, the Study Area is not likely to support habitat critical to the survival of the Broad-headed Snake.
Disrupt the breeding cycle of an important population	The following is known about the breeding cycle of the Broad-headed Snake (DEC 2005): ▪ Preferred habitat is centred on the communities occurring on the Triassic sandstone of the Sydney Basin. ▪ The sites where they occur are typified by exposed sandstone outcrops and benching and in these locations the vegetation is mainly woodland, open woodland and/or heath. ▪ Seasonally occupies distinctive microhabitats within these broader habitat types. They utilise rock crevices and exfoliating sheets of weathered sandstone during the cooler months and tree hollows during summer.

Hoplocephalus bungaroides Broad-headed Snake	
Criteria (Vulnerable Species)	Address of Criteria
	▪ Nocturnal to crepuscular (active at dusk) and is an 'ambush predator', preying predominantly on lizards, particularly Lesueurs Velvet Geckos, at least during the cooler months. ▪ During this time the species can be found frequenting exposed sandstone ridgetops where it refuges under exfoliating sheets of sandstone resting on naked rock or within crevices. These refuges often have a predominantly west to north westerly aspect. This aspect effect is thought to provide thermoregulatory advantage and maximises temperature levels for the peak feeding periods of early evening. ▪ During the warmer months of the year they become arboreal frequenting tree hollows and undergo a presumed dietary shift to small mammals, although crepuscular arboreal skinks (Eulamprus tenuis) have also been reported in the diet of summer captured individuals (G. Turner 1998 unpublished). ▪ They give birth to live young (ovoviviparous) The proposed development is unlikely to disrupt the breeding cycle of an important population due to the following: ▪ Subsidence impacts are likely to be minimal and isolated. Only small scale impacts to surface rock and potential habitat are assumed. ▪ The species has not been previously recorded in the Study Area. ▪ The species was not recorded during current surveys to date. ▪ Not all potential habitat is likely to be impacted by the proposed development. ▪ Hollow bearing trees would not be impacted by subsidence. ▪ Food sources are unlikely to be impacted by the proposed development.
Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline	It is unlikely that the proposed development would result in the loss of habitat to the extent that the species is likely to decline. Based on previous subsidence predictions localised and isolated rock falls and surface cracking may occur. This is unlikely to significantly reduce the extent and quality of potential habitat such that the species is likely to decline.
Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat	It is unlikely the proposed development would introduce invasive species that are harmful to the species habitat. The potential habitat for the species is located away from proposed surface works.
Introduce disease that may cause the species to decline, or	It is unlikely the proposed development would introduce disease that is harmful to the species. The potential habitat for the species is located away from proposed surface works.
Interfere substantially with the recovery of the species.	The proposed development is unlikely to substantially interfere with the recovery of the species. Degradation of breeding habitat through subsidence impacts is likely to be isolated and insignificant when compared to the availability of potential habitat in the Study Area.
Conclusion: The proposed action is unlikely to have a significant impact on the Broad-headed Snake due to the following:	

Hoplocephalus bungaroides Broad-headed Snake	
Criteria (Vulnerable Species)	Address of Criteria
The species was not recorded during targeted survey.	

- An important population is unlikely to be present within the Study Area given the lack of records, and non-detection during survey.
- Clearing associated with the surface infrastructure is unlikely to result in a decline of important habitat for the species.
- Subsidence related impacts to habitat are likely to be minor and isolated.

Phascolarctos cinereus (Koala	
Criteria (Vulnerable Species)	Address of Criteria
An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	
Lead to a long-term decrease in the size of a population	The Koala was not recorded during the current field survey despite targeted surveys including spotlighting and scat surveys. However, a record of the Koala by OEH exist within the Study Area. Potential habitat in the Study Area is widespread through the Study Area, however is likely to be more concentrated toward the far west of the Study Area within vegetation land that is extensive along the Bargo River. Approximately 49.6 hectares of potential foraging habitat would be cleared for the surface infrastructure. Given the species has not been detected during targeted surveys, and no populations are known in the area, it is unlikely that a population exists within the Study Area. Furthermore, habitat for the Koala is unlikely to be significantly impacted by subsidence mechanisms. Therefore it is unlikely the proposed development would affect a population in the long-term.
Reduce the area of occupancy of the species	It is unlikely that the proposed development would reduce the area of occupancy of the Koala as: ▪ Subsidence impacts within the Study Area are anticipated to be localised and minor and unlikely to impact any potential habitat for the Koala ▪ No populations of the Koala are known to occur within the Study Area ▪ No populations of the Koala are known to occur within area to be disturbed by the Project ▪ Potential habitat for the Koala is relatively extensive within the Locality. The Locality includes the Nepean State Conservation Area, vegetation corridors along the Bargo River to the west of the Study Area, and land managed by Water NSW.
Fragment an existing population into two or more populations	It is unlikely that the proposed development would fragment an existing population of the Koala as: ▪ Subsidence impacts within the Study Area are anticipated to be localised and minor and unlikely to impact any potential habitat for the Koala ▪ No populations of the Koala are known to occur within the Study Area ▪ No populations of the Koala are known to occur within area to be disturbed by the Project ▪ Fragmentation of the surface works will result in some fragmentation of habitat, however the species has not been recorded during targeted fauna survey completed by Niche.
Adversely affect habitat critical to the survival of a species	No critical habitat has been listed for the species on the EPBC Act Register of Critical Habitat. The Study Area is not likely to support habitat critical to the survival of the Koala given the species is more likely to utilise the extensive vegetation west and south of the Study Area which adjoins the Nepean State Conservation Area, Conservation land managed by Water NSW and vegetation along the Bargo River.

Phascolarctos cinereus (Koala	
Criteria (Vulnerable Species)	Address of Criteria
Disrupt the breeding cycle of a population	The following is known about the breeding cycle of the Koala (DEC 2005): ▪ Home range size varies with quality of habitat, ranging from less than 2 ha to several hundred hectares in size. ▪ Generally solitary, but have complex social hierarchies based on a dominant male with a territory overlapping several females and sub-ordinate males on the periphery. ▪ Animals reach sexual maturity at two years and although breeding can occur yearly, this does not generally occur (DECC 2008). ▪ Diet is primarily comprised of eucalypt leaves. Koalas have been observed to feed on 70 eucalypt and 30 non-eucalypt species. However, in any one area, koalas feed almost exclusively on a small number of preferred species which vary widely on a regional, local and possibly seasonal basis (DECC 2008). ▪ Some groundcover vegetation and other features such as hollow logs, are also useful to provide shelter while on the ground and refuge in extreme weather conditions (DECC 2008). ▪ Studies have shown that koala activity was greater in structurally diverse forest with the majority of trees 25.5-80 diameter at breast height (dbh), or 50–80 cm dbh. (DECC 2008) ▪ The recovery plan (DECC 2008) lists koala food species for different regions. None of the primary food tree species listed for the central coast management area were recorded in the area to be disturbed for surface infrastructure. However secondary food tree species E. eugenioides and -supplementary food species E. globoidea were recorded in the Study Area. The proposed development is unlikely to have an adverse effect on the species ability to breed successfully due to the following: ▪ Subsidence impacts to potential habitat would be localised and minor and unlikely to result in impacts to the Koala habitat. ▪ Habitat features within the Study Area are likely to be extensive and not all areas of potential habitat would be impacted by the proposed development. ▪ No known population occur within the Study Area. ▪ No population were recorded within the area to be disturbed for surface infrastructure.
Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline	The species has not been previously recorded in the surface area footprint. Approximately 49.6 hectares of potential habitat would be impacted by surface infrastructure. Habitat is unlikely to be impacted by subsidence. It is unlikely that the proposed development would result in the loss of habitat to the extent that the species is likely to decline as over >20,000 hectares of potential foraging/breeding habitat has been mapped by Tozer et al (2006) as occurring within the locality (including: Shale Sandstone Transition Forest, Upper Georges River Sandstone Woodland, Western Sandstone Gully Forest).
Result in invasive species that are harmful to a critically endangered or endangered species becoming	The Project would implemented a biodiversity management plan which would propose weed control measures to minimise impacts to adjacent bushland. It is unlikely that the Project would result in an increase in feral pest activity that may impact potential Koala habitat.

Phascolarctos cinereus (Koala	
Criteria (Vulnerable Species)	Address of Criteria
established in the critically endangered or endangered species' habitat	
Introduce disease that may cause the species to decline, or	It is unlikely that the proposed development would result in the introduction of a disease that may cause the species to decline.
Interfere substantially with the recovery of the species.	The proposed development is unlikely to interfere substantially with the recovery of the species as: ▪ A population is unlikely to occur within the surface infrastructure footprint where loss of habitat through native vegetation clearing would occur. ▪ Habitat is unlikely to be impacted by subsidence given the species may utilise a range of vegetation. Furthermore, feed trees are unlikely to be significantly impacted as a result of subsidence.

Conclusion: The proposed action is unlikely to have a significant impact on the Koala due to the following:

- The species was not recorded in the Study Area despite targeted trapping survey.
- No important populations are known to occur within the Study Area.
- Habitat to be removed is relatively extensive throughout the locality.
- Subsidence is unlikely to result in impacts to potential habitat for the species.

Chalinolobus dwyeri (Large-eared Pied Bat)	
Criteria (Vulnerable Species)	Address of Criteria
An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	
Lead to a long-term decrease in the size of a population	The Large-eared Pied Bat was not recorded during the current field survey, however recorded by OEH exist within the Study Area. Potential habitat in the Study Area is widespread through the Study Area, however is likely to be more concentrated occurs within gullies and adjacent vegetation of Dog Trap Creek, Tea Tree Hollow, and Hornes Creek. Approximately 49.6 hectares of potential foraging habitat would be cleared for the surface infrastructure. Given the species has not been detected during the current survey, and no populations are known in the area, it is unlikely that a population exists within the Study Area. Furthermore, whilst the Large-eared Pied Bat *may* use small caves, rock crevices, boulder fields and rocky-cliff faces as den sites, it is unlikely that all these habitat features would be impacted by subsidence related impacts. Such impacts, should they occur, are predicated to be localised and of a minor scale. Therefore it is unlikely the proposed development would affect a population in the long-term.
Reduce the area of occupancy of the species	It is unlikely that the proposed development would reduce the area of occupancy of the Large-eared Pied Bat as: ▪ Subsidence impacts within the Study Area are anticipated to be localised and minor. ▪ Not all potential habitat within the Study Area would be impacted by subsidence and clearing associated with the Project. ▪ Not all habitat features are likely to be impacted by subsidence e.g. logs, tree hollows.
Fragment an existing population into two or more populations	It is unlikely that the proposed development would fragment an existing population of the Large-eared Pied Bat as: ▪ Subsidence impacts within the Study Area are anticipated to be localised and minor; ▪ The species is relatively mobile and vegetation clearing is unlikely to significantly fragment habitat.
Adversely affect habitat critical to the survival of a species	No critical habitat has been listed for the species on the EPBC Act Register of Critical Habitat. The Study Area is not likely to support habitat critical to the survival of the Large-eared Pied Bat given the species is more likely to utilise the extensive deeper gullies of the Bargo River.
Disrupt the breeding cycle of a population	The following is known about the breeding cycle of the Large-eared Pied Bat (DEC 2005): ▪ Roosts in caves (near their entrances), crevices in cliffs, old mine workings and in the disused, bottle-shaped mud nests of the Fairy Martin (Petrochelidon ariel), frequenting low to mid-elevation dry open forest and woodland close to these features. Females have been recorded raising young in maternity roosts (c. 20-40 females) from November through to January in roof domes in sandstone caves and overhangs. They remain loyal to the same cave over many years. ▪ Found in well-timbered areas containing gullies. ▪ The relatively short, broad wing combined with the low weight per unit area of wing indicates manoeuvrable flight. This species probably forages for small, flying insects below the forest canopy.

<table>
<tr><th colspan="2">Chalinolobus dwyeri (Large-eared Pied Bat)</th></tr>
<tr><th>Criteria (Vulnerable Species)</th><th>Address of Criteria</th></tr>
<tr><td></td><td>▪ Likely to hibernate through the coolest months.
It is uncertain whether mating occurs early in winter or in spring. The proposed development is unlikely to have an adverse effect on the species ability to breed successfully due to the following:
▪ Subsidence impacts to potential habitat would be localised and minor.
▪ Habitat features within the Study Area are likely to be extensive and not all areas of potential habitat would be impacted by the proposed development.
▪ Not all habitat features are likely to be impacted by subsidence e.g. logs, tree hollows.</td></tr>
<tr><td>Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline</td><td>The species has not been previously recorded in the surface area footprint. Approximately 49.6 hectares of potential habitat would be impacted by the REA development footprint. Subsidence impacts to potential habitat are likely to be minor and isolated. It is unlikely that the proposed development would result in the loss of habitat to the extent that the species is likely to decline as over >20,000 hectares of potential foraging/breeding habitat has been mapped by Tozer et al (2006) as occurring within the locality (including: Shale Sandstone Transition Forest, Upper Georges River Sandstone Woodland, Western Sandstone Gully Forest).</td></tr>
<tr><td>Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the critically endangered or endangered species' habitat</td><td>The Project would implemented a biodiversity management plan which would propose weed control measures to minimise impacts to adjacent bushland. It is unlikely that the Project would result in an increase in feral pest activity that may impact potential Large-eared Pied Bat habitat.</td></tr>
<tr><td>Introduce disease that may cause the species to decline, or</td><td>It is unlikely that the proposed development would result in the introduction of a disease that may cause the species to decline.</td></tr>
<tr><td>Interfere substantially with the recovery of the species.</td><td>The proposed development is unlikely to interfere substantially with the recovery of the species as:
▪ An important population is unlikely to occur within the surface infrastructure footprint where loss of habitat through native vegetation clearing would occur.
▪ Impact as a result of subsidence toward potential habitat is likely to be isolated rock falls, and surface rock cracking. As such, all habitat is unlikely to be impacted by the Project.</td></tr>
<tr><td colspan="2">Conclusion: The proposed action is unlikely to have a significant impact on the Large-eared Pied Bat due to the following:
▪ The species was not recorded in the Study Area despite targeted trapping survey.
▪ No important populations are known to occur within the Study Area.
▪ Habitat to be removed is relatively extensive throughout the locality.
▪ Subsidence related impacts are likely to be relatively isolated and minor in nature.</td></tr>
</table>

Petauroides volans (Greater Glider)	
Criteria (Vulnerable Species)	Address of Criteria
An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	
Lead to a long-term decrease in the size of a population	The Greater Glider was not recorded during the current field survey despite targeted survey, however the species has been recorded along the Bargo River approximately 1.3 km to the north of the Study Area. Potential habitat in the Study Area occurs along the gullies of the Bargo River River. No known habitat for the species would be impacted by the proposed surface infrastructure, and thus would not lead to a long-decrease of a population of the species. Furthermore, subsidence would not result in the loss of hollow bearing trees, nor decrease the amount of suitable eucalypt forest habitat that a population could utilise. Thus, subsidence would not result in a long-term decrease in the size of any potential population.
Reduce the area of occupancy of the species	It is unlikely that the proposed development would reduce the area of occupancy of the Greater Glider as: ▪ The species does not occur within the area proposed to be cleared for surface infrastructure. ▪ Subsidence is unlikely to impact upon habitat for this species eg. tree hollows, tall eucalypt forest.
Fragment an existing population into two or more populations	It is unlikely that the proposed development would fragment an existing population of the Greater Glider as: ▪ Subsidence impacts within the Study Area are anticipated to be localised and minor. These potential impacts would not result in fragmentation of potential habitat. ▪ The species does not occur within the area proposed to be cleared for surface infrastructure, and thus unlikely to result in fragmentation of an important habitat.
Adversely affect habitat critical to the survival of a species	No critical habitat has been listed for the species on the EPBC Act Register of Critical Habitat. The Study Area is not likely to support habitat critical to the survival of the Greater Glider given the species is more likely to utilise the extensive deeper gullies of the Bargo River.
Disrupt the breeding cycle of a population	The following is known about the breeding cycle of the Greater Glider (Threatened Species Scientific Committee 2016): ▪ The Greater Glider is an arboreal nocturnal marsupial, largely restricted to eucalypt forests and woodlands. ▪ It is primarily folivorous, with a diet mostly comprising eucalypt leaves, and occasionally flowers ▪ During the day it shelters in tree hollows, with a particular selection for large hollows in large, old trees ▪ Home ranges are typically relatively small (1−4 ha) ▪ Females give birth to a single young from March to June. ▪ Sexual maturity is reached in the second year. ▪ Longevity has been estimated at 15 years, so generation length is likely to be 7−8 years. ▪ The relatively low reproductive rate may render small isolated populations in small remnants prone to extinction

Petauroides volans (Greater Glider)	
Criteria (Vulnerable Species)	Address of Criteria
	The proposed development is unlikely to have an adverse effect on the species ability to breed successfully due to the following: ▪ Subsidence impacts to potential habitat are highly unlikely. ▪ Habitat features within the Study Area are likely to be extensive and not all areas of potential habitat would be impacted by the proposed development. ▪ The Project would not result in the clearing of likely habitat for the species.
Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline	The species has not been previously recorded in the surface infrastructure footprint despite targeted survey. The Greater Glider was not recorded during the current field survey despite targeted survey, however the species has been recorded along the Bargo River approximately 1.3 km to the north of the Study Area. Potential habitat in the Study Area occurs along the gullies of the Bargo River and Nepean River. No known habitat for the species would be impacted by the proposed surface infrastructure. Furthermore, subsidence would not result in the loss of hollow bearing trees, nor decrease the amount of suitable eucalypt forest habitat that a population could utilise. Thus, the Project is unlikely to reduce the habitat utilise by a population to an extent that the species would decline.
Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the critically endangered or endangered species' habitat	The Project would implemented a biodiversity management plan which would propose weed control measures to minimise impacts to adjacent bushland. It is unlikely that the Project would result in an increase in feral pest activity that may impact potential Greater Glider habitat.
Introduce disease that may cause the species to decline, or	It is unlikely that the proposed development would result in the introduction of a disease that may cause the species to decline.
Interfere substantially with the recovery of the species.	The proposed development is unlikely to interfere substantially with the recovery of the species as: ▪ An important population is unlikely to occur within the surface infrastructure footprint where loss of habitat through native vegetation clearing would occur. ▪ Habitat for the species is unlikely to be impacted by subsidence.
Conclusion: The proposed action is unlikely to have a significant impact on the Greater Glider due to the following: ▪ The species was not recorded in the Study Area despite targeted survey. ▪ No important populations are known to occur within the Study Area. ▪ Habitat to be removed for the surface infrastructure is unlikely to be utilized by the Greater Glider. ▪ Subsidence related impacts are likely to be relatively isolated and minor in nature. Subsidence would not impact habitat available for the species.	

Grey-headed Flying-fox	
Criteria (Vulnerable Species)	Address of Criteria
An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:	
Lead to a long-term decrease in the size of a population	The Grey-headed Flying-fox was not recorded during the current field survey, however it is likely the species would utilised the Study Area for foraging habitat. No known camp sites exist within the area proposed for surface infrastructure or within the Study Area. Approximately 49.6 hectares of potential foraging habitat would be cleared for the surface infrastructure, however potential habitat is widespread throughout the locality. Given the species has not been detected during the current survey, and no populations are known in the area, it is unlikely that an important population exists within the Study Area. Furthermore, habitat features for the Grey-headed Flying-fox are unlikely to be impacted by subsidence.
Reduce the area of occupancy of the species	It is unlikely that the proposed development would reduce the area of occupancy of the Grey-headed Flying-fox as: ▪ Subsidence within the Study Area are unlikely to impact upon habitat for the species. ▪ No known camp sites occur within the Study Area. ▪ An important population does not occur within the Study Area.
Fragment an existing population into two or more populations	It is unlikely that the proposed development would fragment an existing population of the Grey-headed Flying-fox as: ▪ Subsidence impacts within the Study Area are anticipated to be localised and minor. ▪ The species is relatively mobile and vegetation clearing is unlikely to significantly fragment habitat.
Adversely affect habitat critical to the survival of a species	No critical habitat has been listed for the species on the EPBC Act Register of Critical Habitat.
Disrupt the breeding cycle of a population	The following is known about the breeding cycle of the Grey-headed Flying-fox (DEC 2005): ▪ Occur in subtropical and temperate rainforests, tall sclerophyll forests and woodlands, heaths and swamps as well as urban gardens and cultivated fruit crops. ▪ Roosting camps are generally located within 20 km of a regular food source and are commonly found in gullies, close to water, in vegetation with a dense canopy. ▪ Individual camps may have tens of thousands of animals and are used for mating, and for giving birth and rearing young. ▪ Annual mating commences in January and conception occurs in April or May; a single young is born in October or November. ▪ Site fidelity to camps is high; some camps have been used for over a century. ▪ Can travel up to 50 km from the camp to forage; commuting distances are more often <20 km.

Grey-headed Flying-fox	
Criteria (Vulnerable Species)	Address of Criteria
	▪ Feed on the nectar and pollen of native trees, in particular Eucalyptus, Melaleuca and Banksia, and fruits of rainforest trees and vines. ▪ Also forage in cultivated gardens and fruit crops. It is uncertain whether mating occurs early in winter or in spring. The proposed development is unlikely to have an adverse effect on the species ability to breed successfully due to the following: ▪ Subsidence is unlikely to impact habitat for the Grey-headed Flying Fox. ▪ Habitat features within the Study Area are likely to be extensive and not all areas of potential habitat would be impacted by the proposed development.
Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline	The species has not been previously recorded in the surface area footprint. Approximately 49.2 hectares of potential foraging habitat would be impacted by the REA development footprint. Habitat is relatively extensive throughout the locality. Subsidence is unlikely to result in impacts to foraging habitat. The species is unlikely to decline due to the Project.
Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the critically endangered or endangered species' habitat	The Project would implemented a biodiversity management plan which would propose weed control measures to minimise impacts to adjacent bushland which is foraging habitat for the species. It is unlikely that the Project would result in an increase in feral pest activity that may impact potential Grey-headed Flying-fox.
Introduce disease that may cause the species to decline, or	It is unlikely that the proposed development would result in the introduction of a disease that may cause the species to decline.
Interfere substantially with the recovery of the species.	The proposed development is unlikely to interfere substantially with the recovery of the species as: ▪ An important population is unlikely to occur within the surface infrastructure footprint where loss of habitat through native vegetation clearing would occur. ▪ Impact to habitat as a result of subsidence is unlikely.
Conclusion: The proposed action is unlikely to have a significant impact on the Grey-headed Flying-fox due to the following: ▪ The species was not recorded in the Study Area despite targeted trapping survey. ▪ No important populations are known to occur within the Study Area. ▪ Habitat to be removed is relatively extensive throughout the locality. ▪ Habitat would not be impacted by subsidence.	

BIRDS Endangered species: Swift Parrot (*Lathamus discolor*) and Regent Honeyeater (*Xanthomyza phrygia)*	
Criteria (Critically Endangered and Endangered Species)	Address of Criteria
An action is likely to have a significant impact on a critically endangered or endangered species if there is a real chance or possibility that it will:	
Lead to a long-term decrease in the size of a population	Neither of these species were recorded during the current survey, nor have they been previously recorded in the Study Area. It is unlikely subsidence associated with the proposed development would impact potential habitat associated with these species. Furthermore, the proposed surface infrastructure would remove approximately 49.6 hectares of native vegetation. Despite the loss of this native vegetation, the proposed development is unlikely to lead to a long-term decrease in the size of a population due to the following: ▪ It is unlikely a population of either of these species exist in the Study Area, as neither of the species were recorded during the current or previous surveys. ▪ Extensive potential habitat surrounding the Study Area would not be impacted by the proposed development.
Reduce the area of occupancy of the species	The impact of the proposed development may reduce native vegetation by 49.6 hectares. Potential habitat immediately adjacent to the Study Area is extensive which extends into Nepean State Conservation Area, and Conservation Lands managed by Water NSW. It is unlikely that the loss of native vegetation as a result of surface infrastructure associated with the Project would reduce the area of occupancy of either of these bird species. Furthermore, no populations of these species have been recorded in the Study Area.
Fragment an existing population into two or more populations	Neither of the species are likely to have populations reliant upon the Study Area. Whilst the proposed development would result in some fragmentation, the species are mobile and therefore unlikely to be impacted by fragmentation.
Adversely affect habitat critical to the survival of a species	No critical habitat has been listed for these species on the EPBC Act Register of Critical Habitat. As these species have not been recorded in the Study Area, the potential habitat within the Study Area is not likely to represent habitat critical to the survival of these species.
Disrupt the breeding cycle of a population	The proposed development is unlikely to disrupt the breeding cycle of a population as: ▪ Neither of these species are likely to have populations reliant upon the Study Area. ▪ The species have not been recorded in the Study Area. Thus a population of these species is unlikely to occur. ▪ The species are mobile and likely to move to other areas of potential habitat. ▪ Potential habitat immediately adjacent to the Study Area is extensive.

BIRDS Endangered species: Swift Parrot (*Lathamus discolor*) and Regent Honeyeater (*Xanthomyza phrygia)*	
Criteria (Critically Endangered and Endangered Species)	Address of Criteria
Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline	The proposed development would remove and decrease approximately 49.6 hectares of native vegetation associated with the surface works for the Project. It is unlikely that the proposed development would result in the loss of habitat to the extent that the species is likely to decline as extensive potential habitat occurs within the locality.
Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the critically endangered or endangered species' habitat	There is the potential for the proposed development to result in an increase in invasive species such as introduced weeds into adjacent habitat. However, mitigation measures such as the implementation of a weed management plan would be carried out. This would reduce the potential for any impacts of the habitat of these species.
Introduce disease that may cause the species to decline, or	It is unlikely the proposed development would introduce disease that would cause these species to decline.
Interfere substantially with the recovery of the species.	The proposed development is unlikely to substantially interfere with the recovery of the species as neither have been recorded in the Study Area. No known habitat for these species occurs in the Study Area.
Conclusion: The proposed action is unlikely to have a significant impact on Swift Parrot (*Lathamus discolor*) and Regent Honeyeater (*Xanthomyza phrygia).*	

BIRDS Migratory species: Cattle Egret, Great Egret, Fork-tailed Swift, Regent Honey Eater, Rainbow Bee-eater, Satin Flycatcher.	
Criteria (Migratory Species)	Address of Criteria
An action is likely to have a significant impact on a migratory species if there is a real chance or possibility that it will:	
Substantially modify (including by fragmenting, altering fire regimes, altering nutrient cycles or altering hydrological cycles), destroy or isolate an area of important habitat for a migratory species	The impact of the proposed development may reduce potential habitat by 49.6 hectares. Potential habitat immediately adjacent to the Study Area is extensive and is part of a corridor of vegetation along the Bargo River, Nepean State Conservation Area and land managed by Water NSW. It is unlikely that the loss of potential habitat within the Study Area would reduce the area of a population of any of these bird species. Whilst the proposed development would result in some fragmentation, the species are mobile and therefore unlikely to be impacted by fragmentation. It is unlikely that the proposed development would result in the loss of habitat to the extent that the species are likely to decline as over 20,000 hectares of potential habitat occurs within the locality.
Result in an invasive species that is harmful to the migratory species becoming established in an area of important habitat for the migratory species, or	There is the potential for the proposed development to result in an increase in invasive species such as introduced weeds into adjacent habitat. However, mitigation measures such as the implementation of a weed management plan would be implemented. This would reduce the potential for any impacts of the habitat of the species.
Seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.	The proposed development is unlikely to disrupt the breeding cycle of an important population as: ▪ None of these species are likely to have ecologically significant proportions of the population reliant upon the Study Area; ▪ The species have not been recorded in the Study Area. Thus an ecologically significant proportion of the population of any of these species is unlikely to occur. ▪ The species are mobile and likely to move to other areas of potential habitat. ▪ Potential habitat immediately adjacent to the Study Area is extensive.
Conclusion: The proposed action is unlikely to have a significant impact on Cattle Egret, Great Egret, Fork-tailed Swift, Regent Honey Eater, Rainbow Bee-eater, and Satin Flycatcher.	

Appendix 9. Credit profile for development

Biodiversity credit report

This report identifies the number and type of biodiversity credits required for a major project.

Date of report: 21/11/2018 Time: 3:23:00PM Calculator version: v4.0

Major Project details

Proposal ID:	0112/2017/4587MP
Proposal name:	3680 Tahmoor South Project (October)
Proposal address:	
Proponent name:	
Proponent address:	
Proponent phone:	
Assessor name:	
Assessor address:	
Assessor phone:	
Assessor accreditation:	0112

Summary of ecosystem credits required

Plant Community type	Area (ha)	Credits created
Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion	43.40	2,246.00
Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion	5.70	287.00
Total	49.10	2,533

Credit profiles

1. Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion, (HN556)

Number of ecosystem credits created	2,036
IBRA sub-region	Cumberland - Hawkesbury/Nepean

Offset options - Plant Community types	Offset options - IBRA sub-regions
Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion, (HN556)	Cumberland - Hawkesbury/Nepean and any IBRA subregion that adjoins the IBRA subregion in which the development occurs

2. Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion, (HN556)

Number of ecosystem credits created	210
IBRA sub-region	Cumberland - Hawkesbury/Nepean

Offset options - Plant Community types	Offset options - IBRA sub-regions
Broad-leaved Ironbark - Melaleuca decora shrubby open forest on clay soils of the Cumberland Plain, Sydney Basin Bioregion, (HN513) Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion, (HN604) Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion, (HN556)	Cumberland - Hawkesbury/Nepean and any IBRA subregion that adjoins the IBRA subregion in which the development occurs

3. Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion, (HN564)

Number of ecosystem credits created	287
IBRA sub-region	Cumberland - Hawkesbury/Nepean

Offset options - Plant Community types	Offset options - IBRA sub-regions
Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion, (HN564) Yellow Bloodwood - ironbark shrubby woodland of the dry hinterland of the Central Coast, Sydney Basin Bioregion, (HN612)	Cumberland - Hawkesbury/Nepean and any IBRA subregion that adjoins the IBRA subregion in which the development occurs

Summary of species credits required

Common name	Scientific name	Extent of impact Ha or individuals	Number of species credits created
Bargo Geebung	Persoonia bargoensis	100.00	7,700
Small-flower Grevillea	Grevillea parviflora subsp. parviflora	2,324.00	32,536
Koala	Phascolarctos cinereus	43.50	1,131
Southern Myotis	Myotis macropus	7.40	163
Red-crowned Toadlet	Pseudophryne australis	2.40	31
Cumberland Plain Land Snail	Meridolum corneovirens	0.50	6

Environment and Heritage

Niche Environment and Heritage

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Environment and Heritage

Tahmoor South Project

Aquatic Ecology Impact Assessment

Prepared for Tahmoor Coal Pty Ltd

2018

Document control

Project no.:	3806
Project client:	Tahmoor Coal Pty Ltd
Project office:	Wollongong
Document description:	Aquatic ecology impact assessment for the proposed Tahmoor South Project.
Project Director:	Matthew Richardson
Project Manager:	Matthew Russell
Authors:	Dr Kristy McQueen and Matthew Russell
Internal review:	Bruce Blunden, David Cummings, Radika Michniewicz
Document status:	Final
Local Government Area:	Wollondilly and Wingecarribee, NSW

Document revision status

Author	Revision number	Internal review	Date issued
Matthew Russell, Kristy McQueen	D1, D2	Bruce Blunden, David Cummings, Radika Michniewicz	November
Radika Michniewicz	D3		
Matthew Russell	D4,		
Matthew Russell	R0		04/05/2018
Matthew Russell	R1		02/11/2018

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Locations

Sydney

Central Coast

Illawarra

Armidale

Newcastle

Mudgee

Port Macquarie

Brisbane

Cairns

Cover photograph: Eliza Creek in Project Area (Niche Environment and Heritage)

Executive summary

Context

Tahmoor Coal Pty Ltd (Tahmoor Coal) owns and operates the Tahmoor Mine, an underground coal mine approximately 80 km south-west of Sydney in the Southern Coalfields of NSW. Tahmoor Coal is seeking approval for the Tahmoor South Project (the Project). The Project involves the extension of underground coal mining at Tahmoor Mine, to the south and east of the existing Tahmoor Mine surface facilities area.

Niche Environment and Heritage (Niche) was commissioned by Tahmoor Coal to undertake the aquatic ecology impact assessment component of the Environmental Impact Assessment (EIS) for the Project. Specifically this report assesses whether the proposed development is likely to have a significant impact on aquatic ecological communities and specific threatened species listed on the NSW*, Fisheries Management Act 1994* (FM Act) and the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Key results

AUSRIVAS water quality sampling results indicated that reaches of some of the ephemeral/lower order streams such as Dry Creek, Carters Creek and Eliza Creek have EC levels above ANZECC guidelines. High salinity in intermittent or more permanently flowing lower order streams may indicate low surface flow and groundwater influence. High salinities in Tea Tree Hollow are influenced by mine water discharge from Licensed Discharge Point LDP1. All streams within the Project Area recorded low dissolved oxygen during monitoring, indicating poor connectivity or stream flow and aquatic ecological health at the time of sampling. The pH of Cow Creek and many of the control sites was low, indicating a slightly acidic environment typical of the surrounding sandstone geology. At Carters Creek and Tea Tree Hollow (below the mine water discharge point), pH was high, indicating a more alkaline environment associated with the outgassing of carbon dioxide and presence of carbonate minerals in the mine discharge water.

AUSRIVAS macroinvertebrate bands showed variable results between sampling times and seasons, however in general, macroinvertebrate fauna recorded at the majority of monitoring sites within the Project Area were generally comparable to reference condition. SIGNAL scores indicated that most sites within the Project Area were subject to moderate to severe pollution. These scores however are based upon the pollution tolerance of macroinvertebrate fauna that inhabit these semi-permanent/ephemeral streams and do not necessarily indicate anthropogenic pollution.

Quantitative sampling showed that most streams, including ephemeral streams/semi-permanent lower order streams and the Bargo River, have macroinvertebrate assemblages dominated by pollution sensitive Leptophlebiidae (may fly) and pollution tolerant Chironomidae (non-biting midges) larvae. This appeared to be the case for all sites in the Project Area. Bargo River sites were differentiated from lower order streams by greater abundance of Elmidae, Leptoceridae, Calamaceridae, and Ecnomidae. Mine water discharge control and impact sites were differentiated by reductions in Leptophlebiidae, Oligochaeta, Elmidae and increases in Chironominae and Caenidae in sites downstream of the discharge point. However changes in these fauna could not be directly related to the impact of mine water discharge.

Bait fish trapping results showed that exotic Mosquito Fish were recorded from all waterways surveyed within the Project Area with the exception of Cow Creek. Native fish recorded include Firetail Gudgeons *Hypseleotris galii* caught in Dry Creek, Common Jollytail *Galaxias maculatus* in Bargo River and Eliza Creek, Australian Smelt *Retropinna semoni* in Bargo River, Mountain Galaxias *Galaxias olidus* in Hornes Creek and

Empire Gudgeon *Hypseleotris compressa* caught at Stonequarry Creek. Freshwater yabbies *Cherax destructor* and common freshwater shrimp *Paratya australiensis* were caught in abundance from all creeks within the Project Area. Freshwater crayfish *Euastacus spinifer* were observed at sites on Hornes Creek and three were captured in bait traps at control sites on Moore Creek.

No threatened macroinvertebrates were identified from the baseline monitoring program or targeted surveys. No threatened fish (i.e. Macquarie Perch) have been identified in two years of baseline monitoring and the habitat assessment determined that the Project Area does not contain suitable habitat for this species.

Impact assessment

Subsidence related impacts

The ground movements induced by longwall mining can potentially have indirect impacts on aquatic biota through the diversion of surface water flows to the dilated substrata, increased levels of ponding and changes in water quality. Based on mine subsidence predictions (MSEC 2018), there will be little to no impact on aquatic habitat and biota in the Nepean and Bargo Rivers, however streams within the Project Area that occur directly over the proposed longwalls will experience fracturing, resulting in surface water flow diversion and potential changes in water chemistry. In times of heavy rainfall, the majority of the runoff would flow over the beds of the streams and would not be diverted into the dilated strata below the stream beds. In times of low flow however, some or all of the surface flow could be diverted into the strata below the stream beds. Where loose materials occur in the substrate upstream of fracturing, it is possible that fracturing in the bedrock would not be seen at the surface as the fractures may be filled with soil during subsequent flow events (MSEC 2018). Strata cracking may also cause a degradation of water quality, typically a lower pH, elevated EC, increase in dissolved metals and precipitation of iron flocs.

Fracturing and the partial or total loss of water could result in loss of aquatic habitat in sections of Dog Trap Creek and Tea Tree Hollow, and subsequently loss of aquatic biota inhabiting pools. Native fish recorded in these waterways may be subject to desiccation and a range of macroinvertebrates will also suffer mortalities in areas where pools are drained while hardier species such as freshwater yabbies *Cherax destructor* and freshwater crayfish *Euastacus spinifer* may be able to relocate to other areas of aquatic habitat or retreat into their burrows.

All creeks discussed above have substrate consisting of sand, mud and cobbles upstream of the areas of impact and as such, there may be some natural infilling during subsequent flow events that will return some aquatic habitat over time. There is expected to be some recovery of stream fauna once pool holding capacity and habitat is re-established.

Mine water discharge

Tahmoor Coal Pty Ltd are licensed to release treated water from their water management system in accordance with Environmental Protection Licence (EPL) release limits. Under the current licence there is also a requirement to enhance treatment of water prior to release via Pollution Reduction Program (PRP22) which involves the development and commissioning of a water treatment plant to reduce the concentrations of arsenic, nickel and zinc in mine water released from the consolidated Licensed Discharge Point 1 (LDP1). A barium precipitate was observed in Tea Tree Hollow (TTH12a) which is thought to be impacting benthic macroinvertebrates by smothering of the substrate. The lack of interstitial spaces and covering of organic matter are thought to be limiting macroinvertebrate habitat and food supply. Completion of that program would see enhanced water quality through reduced heavy metals and barium precipitate in Tea Tree Hollow and the Bargo River downstream. This assessment assumes no significant increase in salinity/electrical conductivity (EC) levels. Salinity levels were investigated under PRP23. The study (Cardno 2016) concluded the desalination of discharge water was not a suitable measure to mitigate against elevated EC and recommended that EC discharge limits for LDP1 currently listed in the Tahmoor Environment Protection Licence remain unchanged. It was recommended that an aquatic ecology monitoring program be established aimed at identifying any future changes in aquatic health due to the discharge from LDP1.

Results of predictive modelling of the water management system over the remaining mine life indicate that total discharges and spill from the pit top of the combined existing Tahmoor North operation and the proposed Tahmoor South Project are unlikely to increase significantly from current levels. On the basis of the above, it is not expected that the Tahmoor South Project would result in additional adverse water quality impacts due to releases and spills from the site water management system (HEC 2018c).

Recommendations

Subsidence

- It is recommended that subsidence monitoring of macroinvertebrates be conducted for a baseline period two years prior to longwall extraction. The monitoring program may require the addition or relocation of sites according to the final mine plan, and should use the same sampling methods employed in the aquatic monitoring conducted to date.
- It is recommended that a BACI (Before After Control Impact) designed monitoring program be implemented to compliment the baseline information collected and to assess monitoring impacts in an adaptive management framework.

Mine water discharge

- It is recommended that the requirements of PRP22 are implemented and the heavy metal water treatment plant be commissioned and measures outlined in section 2.4 be implemented to improve the water quality of the mine water discharge. The expected measures are scheduled for completion by November 2018.
- It is recommended that an investigation of Tea Tree Hollow downstream of LDP1 be undertaken to determine potential remediation methods to remove the impacts of the black precipitate on the aquatic habitat. Benthic macroinvertebrates, periphyton and the precipitate itself should be monitored.
- It is recommended that EC discharge limits for LDP1 currently listed in the Tahmoor Environment Protection Licence remain unchanged and that an aquatic ecology monitoring program that aims at identifying any future changes in aquatic health due to the discharge from LDP1 be established.

Glossary

Term	Definition
Annual Recurrence Interval (ARI)	Used to describe the frequency or probability of floods occurring (e.g. a 100 year ARI flood is a flood that occurs or is exceeded on average once every 100 years).
ANZECC	Australian and New Zealand Environment and Conservation Council National water quality management strategy and assessment guidelines: Australian guidelines for fresh and marine water quality
Aquifer	Geologic formation, group of formations, or part of a formation capable of transmitting and yielding quantities of water.
Arterial roads	The main or trunk roads of the State road network.
Bed	Stratum of coal or other sedimentary deposit.
Bore	A cylindrical drill hole sunk into the ground from which water is pumped for use or monitoring.
Borehole	A hole produced in the ground by drilling for the investigation and assessment of soil and rock profiles.
Bulli seam	Shallowest coal horizon in the Illawarra Coal Measures in the Southern Coalfield. The Bulli coal seam is a primary source of coking coal, located in the Illawarra and Southern Coalfields of New South Wales.
Catchment	The area from which a surface watercourse or a groundwater system derives its water.
CEMP	Construction Environmental Management Plan. A site specific plan developed for the construction phase of a project to ensure that all contractors and sub-contractors comply with the environmental conditions of approval for the project and that environmental risks are properly managed.
Clearing	The removal of vegetation or other obstacles at or above ground level.
Coal handling and preparation plant (CHPP)	Treatment by screening to give coal of various sizes to meet a purchasers requirements and treatment by one or more processes to reduce the amount of waste (ash) present in the coal.
Compressive strain	Compressive strains decrease in the distance between two points and may cause shear cracking, steps, or concave curvatures at the ground surface.
Cover	The overburden above the coal resource.
Critical habitat	A critical habitat as defined under the *Biodiversity Conservation Act 2016* (BC Act) includes, the whole or any part or parts of the area or areas of land comprising the habitat of an endangered species, population or ecological community or critically endangered species or ecological community that is critical to the survival of the species, population or ecological community.
Cumulative impacts	Combination of individual effects of the same kind due to multiple actions from various sources over time.
Development	The operations involved in preparing a mine for extraction, including cutting roadways and headings. Also includes tunnelling, sinking, crosscutting, drifting, and raising.
Discharge	A release of water from a particular source.
Drainage	Natural or artificial means for the interception and removal of surface or subsurface water.
Ecology	The study of the relationship between living things and the environment.
Ecologically sustainable development (ESD)	As defined by the *Protection of the Environment Administration Act 1991*, requires the effective integration of economic and environmental considerations in decision making processes including: The precautionary principle. Inter-generational equity. Conservation of biological diversity and ecological integrity. Improved valuation, pricing and incentive mechanisms (includes polluter pays, full life cycle costs, cost effective pursuit of environmental goals).
Ecosystem	As defined in the *Environment Protection and Biodiversity Conservation Act 1999*, an ecosystem is a 'dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.'
Endangered Ecological Community (EEC)	An ecological community identified by the *Threatened Species Conservation Act 1995* that is facing a very high risk of extinction in New South Wales in the near future, as determined in accordance with criteria prescribed by the regulations, and is not eligible to be listed as a critically endangered ecological community.

Term	Definition
Edge effects	A change in species composition, physical conditions or other ecological factors at the boundary between two ecosystems or the ecological changes that occur at the boundaries of ecosystems (including changes in species composition, gradients of moisture, sunlight, soil and air temperature, wind speed and other factors).
Environmental Management Plan (EMP)	A plan used to manage environmental impacts during each phase of project development. It is a synthesis of proposed mitigation, management and monitoring actions, set to a timeline with defined responsibilities and follow up actions.
Environmental management system (EMS)	A quality system that enables an organisation to identify, monitor and control its environmental aspects. An EMS is part of an overall management system, which includes organisational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy.
Environment	As defined within the *Environmental Protection & Assessment Act, 1979*, all aspects of the surroundings of humans, whether affecting any human as an individual or in his or her social groupings.
Ephemeral	Existing for a short duration of time.
EPL	Environment Protection Licence. EPLs are issued by EPA under the *Protection of the Environment Operations Act 1997.* EPLs with respect to scheduled development work or scheduled activities or non-scheduled activities may regulate all forms of pollution (including water pollution) resulting from that work or those activities. EPLs authorising or controlling an activity carried on at any premises may also regulate pollution resulting from any other activity carried on at the premises to which the licence applies. .
Existing Tahmoor Approved Mining Area	Shown on Figure 1. Encompasses all existing approved mining areas associated with the Tahmoor Mine, including the Surface Facilities Area.
Fault	Break in the continuity of a coal seam or rock strata.
Greenhouse gases	Gases with the potential to cause climate change (e.g. methane, carbon dioxide and others listed in the *National Greenhouse and Energy Reporting Act 2007*). Expressed in terms of carbon dioxide equivalent.
Groundwater	Water located within an aquifer that is, held in the rocks and soil beneath the earth's surface.
Habitat	The place where a species, population or ecological community lives (whether permanently, periodically or occasionally).
Hydrogeology	The study of subsurface water in its geological context.
Hydrology	The study of rainfall and surface water runoff processes.
Impact	Influence or effect exerted by a project or other activity on the natural, built and community environment.
Key threatening process	As defined under the *Threatened Species Conservation Act 1994*, a key threatening process is any listed process under the Act that adversely affects threatened species, populations or ecological communities, or that could cause species, populations or ecological communities that are not threatened to become threatened.
Longwall	A system of coal mining, where the coal seam is extracted from on a broad front or long face.
Overburden	The geological units and material above the coal seam proposed or being mined.
Perched Water	Unconfined groundwater held above the water table by a layer of impermeable rock or sediment.
Pollutant	Any matter that is not naturally present in the environment.
Project Area	Shown on Figure 2. Encompasses 4,743 ha. It is determined as a 600 m buffer around the proposed mine plan and includes a section of Bargo River to incorporate the receiving waters of mine water discharge
Proposed development	Extension of underground coal mining and associated activities at Tahmoor Mine within the Project Area. Referred to as The Tahmoor South Project, as described in Section 4 of this EIS.
Riparian	Relating to the banks of a natural waterway.
Run-off	The portion of water that drains away as surface flow.
Seam	Layer or bed of coal.
Strain	The change in horizontal distance between two points at the surface after mining, divided by the pre-mining distance between the points and usually expressed in mm/m.
Subsidence	The vertical lowering, sinking or collapse of the ground surface.
Surface Facilities Area	Comprises surface land containing mining and non-mining infrastructure.
Surface water	Water flowing or held in streams, rivers and other wetlands in the landscape.
Tensile strain	The relative increase in the distance between two points on the surface.

Term	Definition
Tributary	A river or stream flowing into a larger river or lake.
Upsidence	A surface phenomenon associated with mining and subsidence and occurs where workings pass beneath a gorge or similar surface feature causing a concentration of horizontal stress in the strata between the bottom of the feature and the top of any goaf cavity. This increased stress may cause strata beds close to the surface to bend upwards and possibly fracture
Vulnerable	As defined under the *Threatened Species Conservation Act 1995*, a species that is facing a high risk of extinction in New South Wales in the medium-term future.
Water table	The surface of saturation in an unconfined aquifer at which the pressure of the water is equal to that of the atmosphere.
Waterway	Any flowing stream of water, whether natural or artificially regulated (not necessarily permanent).

Acronyms

Acronym	Term/Definition
AHD	Australian Height Datum
AEIA	Aquatic Ecology Impact Assessment
ANZECC	Australian and New Zealand Environment and Conservation Council
AUSRIVAS	Australian River Assessment System
BC Act	Biodiversity Conservation Act 2016
CCL	Consolidated Coal Lease
CHPP	Coal Handling & Preparation Plant
DGRs	Director-General's requirements
DP&I	Department of Planning and Infrastructure
DTIRIS	NSW Department of Trade and Investment, Regional Infrastructure and Services
EEC	Endangered Ecological Community
EIS	Environmental Impact Statement
EPA	NSW Environment Protection Authority
EP&A Act	*Environmental Planning and Assessment Act 1979* (NSW)
EPBC Act	*Environment Protection and Biodiversity Act 1999* (Cth)
EPL	Environment Protection Licence
Ha	Hectare/s
GHG	Greenhouse gas
LGA	Local Government Area
LoS	Level of service
mg/L	Milligrams per litre
micron	One millionth of a metre (abbreviation µ)
Mining SEPP	*State Environment Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007*
mL	Millilitre
ML	Mining Lease
MNES	Matters of National Environmental Significance).
PEA	Preliminary Environmental Assessment
pH	A measure of acidity or alkalinity of a solution. The potential of hydrogen.
PRP	Pollution Reduction Program
REA	Rejects Emplacement Area. Can also be called refuse emplacement area.
RMZ	Risk Management Zone
SEPP	State Environmental Planning Policy
SEPP 44	*State Environmental Planning Policy 44 – Koala Habitat Protection*
SEWPaC	Former Commonwealth Department of Sustainability, Environment, Water, Population and Communities
SIMPER	Similarity percentages
TSC Act	*Threatened Species Conservation Act 1995* (NSW)
Wingecarribee LEP 2010	*Wingecarribee Local Environmental Plan 2010*
WinSC	Wingecarribee Shire Council
Wollondilly LEP 2011	*Wollondilly Local Environmental Plan 2011*
WSC	Wollondilly Shire Council

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1. Introduction

1.1 Tahmoor South Project

1.1.1 Overview

Tahmoor Coal Pty Ltd (Tahmoor Coal) owns and operates the Tahmoor Mine, an underground coal mine approximately 80 km south-west of Sydney in the Southern Coalfields of NSW (Figure 1). Tahmoor Coal produces up to two million tonnes per annum of product coal from its existing operations at the Tahmoor Mine, and undertakes underground mining under existing development consents, licences and the conditions of relevant mining leases.

Tahmoor Coal is seeking approval for the extension of underground coal mining to the south of the existing Tahmoor Mine surface facilities area. The extended underground coal mining area will continue to be accessed via the existing surface facilities at Tahmoor Mine, located between the towns of Tahmoor and Bargo. The extension of these mining facilities encompasses the Tahmoor South Project.

The Tahmoor South Project (the Project) seeks to extend the life of underground mining at Tahmoor Mine until approximately 2035. The Project will enable mining to be undertaken within the southern portion of Tahmoor's existing lease areas and permit continued operations and employment of the current workforce for approximately a further 13 years.

The Project will extend mining within the Project Area using longwall methods, with the continued use of ancillary infrastructure at the existing Tahmoor Mine surface facilities area. The Project Area is shown in Figure 2 and comprises an area adjacent to, and to the south of, the existing Tahmoor approved mining area. It also overlaps a small area of the existing Tahmoor approved mining area comprising the surface facilities area, historical workings and other existing mine infrastructure.

1.1.2 Project timeframes

The Tahmoor South Project seeks to extend the life of underground mining at Tahmoor Mine beyond the forecast completion of mining at Tahmoor North in approximately 2022, which is dependent upon geological and mining conditions. Longwall mining is proposed to commence in the Central Domain once mining is completed at Tahmoor North, and is expected to be completed in the Central Domain by approximately 2035, depending upon geological and mining conditions. Surface works, rehabilitation and mine closure would occur after this time.

A number of pre-mining activities (outlined in Section 2.1) are required to be completed prior to commencement of longwall mining for the Tahmoor South Project. These pre-mining activities need to begin in 2019 and are anticipated to take approximately three years to complete before longwall mining can commence in the Central domain.

1.1.3 Legislative framework

Legislation, policies, guidelines and criteria relevant to this assessment are described in Table 1 below.

Table 1 Legislation, policy and guidelines relevant to the assessment

Relevant legislation/policy/ guideline	Relationship to this assessment
Legislation	
Commonwealth	

Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)	The Commonwealth EPBC Act requires the proposed development to be assessed in terms of potential impact upon Matters of National Environmental Significance (MNES). MNES currently listed under the EPBC Act are: • World Heritage properties • Natural heritage places • wetlands of international importance • Threatened species and ecological communities • Migratory species • Commonwealth marine areas • Nuclear actions (including uranium mining). • A water resource, in relation to coal seam gas development and large coal mining development. The EPBC Act applies to the Project for commonwealth threatened species and ecological communities. All commonwealth threatened species and ecological communities recorded or predicted to occur within the Project Area require an assessment to be undertaken to determine if a referral is required to the Department of Environment (DoEE) who will in turn determine if the proposal is a Controlled Action under the EPBC Act. The decision on the referral was determined as a controlled action on 12 January 2018.
NSW	
*NSW Environmental Planning & Assessment Act 1979 (*EP&A Act*)*	Note: The Project is to be assessed under the transitional legislative arrangements of the NSW biodiversity legislation reforms, i.e. the new assessment methodologies now required under the *Biodiversity Conservation Act 2016* (BC Act) do not apply to the Project. The main law regulating land use in NSW is the Environmental *Planning and Assessment Act 1979* (EP&A Act). The assessment of the proposed development has been carried out for approval under the provision for State Significant Development (SSD) within Part 4, Division 4.1 of the EP&A Act. Under the provisions of Part 4 of the EP&A Act, SSD applications require an Environmental Impact Statement to be prepared in accordance with Secretary's Environment Assessment Requirements (SEARs) (DPI 2011). The consent authority for SSD is the NSW Department of Planning and Infrastructure. Part 5A (now repealed) of the EP&A Act lists seven factors which are used to assess the likely impact of a development on threatened species, populations (including their habitats) or EECs. A Species Impact Statement (SIS) is not required for SSD applications; however the SEARs require biodiversity issues to be assessed by applicants (DPI 2011).
*NSW Fisheries Management Act 1994 (*FM Act*)*	The main objectives of the NSW *Fisheries Management Act 1994* (FM Act) are to conserve, develop and share the fishery resources of NSW for the benefit of present and future generations, and in particular: • To conserve fish stocks and key fish habitats. • To conserve threatened species, populations and ecological communities of fish and marine vegetation. • To promote ecologically sustainable development, including the conservation of biological diversity, and, be consistent with these objectives. • To promote quality recreational fishing opportunities. • To appropriately share fisheries resources between the users of those resources. • To provide social and economic benefits for the wider community of NSW. • To recognise the spiritual, social and customary significance to Aboriginal persons of fisheries resources and to protect, and promote the continuation of, Aboriginal cultural fishing. The waterways within the Project Area fall within the definition of 'key fish habitats' based on DPI policy and guidelines (Fairfull 2013) and key fish habitat mapping (DPI 2017c). To meet the primary objectives, Part 7 of the FM Act deals with the protection of aquatic habitats and Part 7A deals with threatened species conservation. Part 7 commonly applies to "integrated development" proposals as defined by the EP&A Act. The FM Act applies within the Project Area for state listed threatened species, populations and ecological communities. Impacts of the proposed development on threatened species, populations and ecological communities known or considered to have suitable habitat in the Project Area are required to be assessed to determine if significant impacts are likely to occur. As stated above, a Species Impact Statement (SIS) is not required for SSD applications; however the SEARs require biodiversity issues to be assessed by applicants (DPI 2011).
Policy/Guidelines	
Policy and Guidelines for fish habitat, conservation and management (Fairfull 2013)	This document outlines policies and guidelines aimed at maintaining and enhancing fish habitat for the benefit of native fish species, including threatened species in marine, estuarine and freshwater environments. The document aims to help developers, their consultants and government and non-government organisations to ensure compliance with legislation, policies and guidelines as they relate to fish habitat conservation and management. Assessment of waterways within the Project Area (Section 3.5) were based on definitions described in this document.
National water quality management	The main objective of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality is to provide an authoritative guide for setting water quality objectives required to sustain current or likely future environmental values for natural and semi-natural water resources in Australia and New Zealand.

strategy and assessment guidelines: Australian and New Zealand guidelines for fresh and marine water quality (ANZECC/ARMCANZ)	These guidelines provide a framework for water resource management, state specific water quality guidelines for each environmental value and the context within which they should be applied, and guidelines for monitoring of aquatic ecosystems. The ecological monitoring design is consistent with these guidelines uses default trigger values to interpret water quality.
The Threatened Species Assessment Guideline – The Assessment of Significance (DPI, 2008)	Threatened species assessment is an integral part of environmental impact assessment. The Assessment of Significance Guidelines has been prepared to help applicants and/or proponents of a development or activity to interpret and apply the factors of assessment. These are the factors that need to be considered when assessing whether an action, development or activity is likely to significantly affect threatened species, populations or ecological communities, or their habitats. The guidelines clarify the specific terminology of the relevant legislation and provide clear interpretations of the factors of assessment. The Assessments of Significance undertaken as part of the impact assessment for the proposed development in this document have been undertaken in a manner consistent with these guidelines.

1.2 Aquatic ecology impact assessment relevance

1.2.1 The Project

The Project would use longwall mining to extract coal from the Bulli seam within the bounds of CCL 716 and CCL 747 (Figure 2). Coal extraction of up to 4 million tonnes of ROM coal per annum is proposed as part of the development. Once the coal has been extracted and brought to the surface, it would be processed at Tahmoor Mine's existing Coal handling and Preparation Plant (CHPP), and then transported via the existing rail loop, the Main Southern Railway and the Moss Vale to Unanderra Railway to Port Kembla for export to domestic and international markets. A detailed description of the Project is provided in Section 2 of this report, however, briefly, the Project involves:

- Mine development including pit bottom redevelopment, vent shaft construction, pre-gas drainage and service connection.
- Longwall mining in the Central and Eastern Domains.
- Upgrades to the existing surface facilities area including:
    - Upgrades to the Coal Handling and Preparation Plant (CHPP).
    - Expansion of the existing Rejects Emplacement Area (REA).
    - Additional mobile plant for coal handling.
    - Additions to the existing bathhouses, stores and associated access ways.
    - Upgrades to onsite and offsite service infrastructure, including electrical supply.
- Rail transport of product coal to Port Kembla and Newcastle (from time to time).
- Mine closure and rehabilitation.
- Environmental monitoring and management.

The components of the Project that relate to the aquatic ecology impact assessment are detailed below.

1.2.2 Surface infrastructure development

Infrastructure upgrades

During construction, appropriate erosion and sediment control will need to be in place to ensure run-off does not impact on receiving waters.

Increased mining rates

The Tahmoor South Project will result in increased mining and processing rates, and an extension to the approved mine life. Extension of the REA will also be required to accommodate the rejected material that would be produced over the mine life. These changes will entail the following potential impacts to water management:

- Water supply reliability and increased requirement for external supply.
- Changes and potential for increased risk of loss of containment of site contaminated water.
- Increased requirements for controlled releases of contaminated water and risk of non-compliance with licensed discharge conditions.
- Increased risk of release of disturbed area runoff from expanded Rejects Emplacement Area (HEC 2018c).

To maintain a safe and efficient underground mine environment, water entering the underground workings needs to be managed. Mine water would be collected in underground sumps and pumped from the mine to the existing water management system at the surface facilities area for treatment. Treated mine water will be either reused underground for non-potable uses or discharged at the surface via the existing Licensed Discharge Point (LDP1) into Tea Tree Hollow Creek.

Mine water contains elevated concentrations of dissolved salts and metals and can pose environmental risks to aquatic biota. In times of low rainfall however, mine water may be the only source of water for creeks, although at other times, the water may be diluted by other sources of runoff, in which case the potential effects of the discharge decrease with increasing distance from the source. Many factors, including the chemical composition of discharged water, conductivity, volume and periodicity of flow and habitat characteristics, combine to determine the abundance and composition of aquatic biota which, in turn, determines ecosystem viability (CEL 2011).

1.2.3 Underground mining (subsidence)

Underground mining operations have the potential to result in a number of subsidence related impacts on waterways within the Project Area, including geomorphic responses that would constitute an environmental impact with possible implications for ecological processes. The potential geomorphic responses to mining which need to be assessed and considered include:

- Irreversible changes in stream type.
- Change of alignment of the channel.
- Reduction of existing in-channel pool volume.
- Formation of new in-channel pools or a deepening of existing pools.
- Migration of soft knickpoint upstream at a faster than natural rate.
- Increased sediment supply to channel.
- Changes in water chemistry.
- Increased sediment accumulation in channel.
- Increased sediment scouring in channel.
- Increased cover (density) of vegetation on channel bed (baseflow shift from high depth of water to shallow depth).
- Decreased cover (density) of vegetation on channel bed (baseflow shift from shallow depth of water to dry, or from shallow to deep).
- Increased rockfall frequency above natural rate (Fluvial Systems 2013).

While there are established conceptual links between mining related causes and geomorphic responses, confident predictions cannot be made of geomorphic response for a given level of subsidence or change in stream flow. The likelihood of the risk occurring relative to the level of threat offered by the mining related change has been categorised in the geomorphology technical report (Fluvial Systems 2013).

The geomorphic responses listed above would potentially impact the aquatic habitat and biota in waterways within the Project Area. The level of impact would directly relate to the scale of the geomorphic responses. This is considered in the impact assessment section of this report.

In addition to the above geomorphic responses, subsidence movements have the potential to impact surface water quality through increased concentrations of metals and solutes liberated from subsidence induced cracking (HEC 2018).

1.3 Purpose of this Report

1.3.1 Agency requirements

This report presents the Aquatic Ecology Impact Assessment (AEIA) undertaken for the Tahmoor South Project as the aquatic component of the Tahmoor South Project Environmental Impact Statement, which has been prepared in accordance with Part 4 Division 4.1 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). In preparing this aquatic ecology assessment, the Secretary's Environmental Assessment Requirements (SEARs) issued for the Tahmoor South Project (SSD 17_8445) on 9 July 2017 have been addressed as required. The key matters raised by the Secretary for consideration in the aquatic ecology impact assessment and where and how they are addressed in this report are outlined in Table 2.

Table 2: Secretary Environmental Assessment Requirements – Aquatic ecology

Key agency requirements		Section of report
NSW Department of Primary Industries		
Aquatic habitat assessment and Aquatic Fauna assessment	The AEIA uses aquatic baseline monitoring of 'key fish habitat' conducted in 2012/2013. The data includes: • Two years (autumn and spring) quantitative sampling of macroinvertebrates in BACI monitoring design. • Two years (autumn and spring) AUSRIVAS sampling of macroinvertebrates, water quality variables and habitat attributes. • Threatened dragonfly (macroinvertebrate) targeted sampling. • Macrophyte sampling as part of AUSRIVAS. • Physiochemical water quality sampling as part of AUSRIVAS. • Two years of seasonal fish sampling. • Aquatic habitat monitoring. • Photo point monitoring. Threatened dragonfly and Macquarie Perch potential habitat mapping and assessment were also conducted. Hydrological and monthly water quality data was conducted by surface water impact assessment.	Sections 3, 5 and 6.
NSW Environment Protection Authority		
The EIS should determine whether environmental value for the Bargo River are being met downstream of the discharges or will be met following full commission of the plant. *The EIS should integrate the results of the aquatic health study in the Bargo River (PRP23) as well as previous aquatic studies undertaken by the mine.*	The AEIA used the findings from PRP23 to determine whether the aquatic ecological values are being met downstream. The AEIA integrates the findings from the comprehensive baseline monitoring conducted in 2012/2013 as well as recent mine water discharge studies (PRP 23).	Section 4.4.2.
NSW Office of Environment and Heritage		

Effects of downstream fauna to water dependent flora and fauna. *Impacts to natural processes and functions within rivers, wetlands, estuaries and floodplains that affect river system and landscape health such as nutrient flow aquatic connectivity and access to habitat for spawning and refuge (e.g. river benches)*	The AEIA assesses the impact to water dependent downstream flora and fauna, processes and functions, aquatic connectivity, spawning and refuge habitat. This is achieved through appraisal of baseline monitoring data which describes the existing environment and interpreting impacts from predicted water quality and hydrological changes due to mine water discharge and subsidence. Water quality results and hydrological impacts are provided by the surface water assessment (HEC 2018c).	Section 6.

1.3.2 Objectives

The aim of the AEIA is to assess the potential impacts of the proposed development on stream ecology and aquatic threatened species, populations, communities or their habitats. The assessment addresses the impacts of subsidence from underground coal mining as well as mine water discharge generated from surface facilities.

The assessment required two years of baseline monitoring to account for natural variation and provide the before component of a BACI (Before After Control Impact) study for the quantitative macroinvertebrate monitoring design. AUSRIVAS data was also collected at potential impact sites and compared to modelled reference sites to infer current stream health.

The specific objectives are to:

- Describe the natural/pre-mine development characteristics of stream ecology through quantitative and qualitative monitoring of macroinvertebrates as well as monitoring of fish, macrophytes, aquatic habitat and water quality in the Project Area.
- Identify or determine the likelihood of occurrence of threatened species, populations, habitat and/or communities with in the Project Area.
- Determine the subsidence and mine water discharge impacts that could affect stream ecology.
- Assess whether these impacts will cause significant adverse effects to stream ecology.
- Determine whether these impacts will significantly impair threatened species, populations, habitat or communities.
- Recommend mitigation measures to minimise potential impacts to stream ecology, in particular threatened aquatic species, populations and communities.

1.4 Report structure

This report is structured as follows:

- Section 1: Introduction – outlines the Project and presents the purpose of the report.
- Section 2: Proposed Development – provides a detailed description of the Project.
- Section 3: Methods – describes the methods employed for the aquatic ecology impact assessment.
- Section 4: Existing Environment – outlines the existing environment relevant to aquatic ecology.
- Section 5: Survey Results – describes the results of the aquatic ecology surveys.
- Section 6: Potential Impacts – describes the monitoring results, and the potential impacts of subsidence and mine water discharge on aquatic ecology and threatened species.
- Section 7: Safeguards and Management - provides a summary of environmental mitigation, management and monitoring responsibilities in relation to aquatic ecology management.
- Section 8: Conclusion.
- Section 9: Figures.

2. Tahmoor South Project

The Tahmoor South Project Area is operationally divided into three different mining domains based on geological complexity and mining potential. The mining domains are the Central Domain, Eastern Domain and Southern Domain.

The Project seeks to undertake longwall mining of the Bulli seam within the Central Domain only, at a depth of between approximately 375 and 430 metres below ground level.

During the mine planning process, a constraints analysis, risk assessment and detailed fieldwork were undertaken to identify sensitive natural surface features (such as waterways, cliffs, and Aboriginal heritage sites) and to develop risk management zones (RMZs). Following the completion of the risk assessment process, the proposed longwall layout was modified to minimise significant subsidence impacts to natural features. Although the longwall layout will continue to be refined during the detailed design phase of the proposed development, the maximum extent of the proposed mine is shown in Figure 2.

2.1 Mine development

A number of pre-mining activities are required to be completed prior to commencement of longwall mining of the Central Domain, including:

- Recovery of existing underground development roadways.
- Redevelopment of the underground pit bottom.
- Pre-mining gas drainage.
- Longwall development including establishment of gate roads.
- Installation of electrical, water and gas management networks.
- The purchase and installation of equipment.

An additional 50 - 175 personnel would be required for the Tahmoor South Project development works, which may occur concurrently with the ongoing mining operations at Tahmoor North. Additional site amenities, including bathhouses and additional onsite car parks would be required to accommodate the increased workforce during the transition period from mining operations at Tahmoor North and the Tahmoor South Project's development works.

Other site infrastructure required for longwall mining at Tahmoor South includes construction of the first new mine ventilation shafts... These and the pre-mining activities are detailed below.

2.1.1 Mine ventilation

The Project would make use of three existing vent shafts currently being used for the operations at Tahmoor North, being one upcast (T2) and two downcast shafts (T1 and T3).Two new ventilation shafts would be required to provide reliable and adequate supply of ventilation air to personnel in the mine, consisting of:

- Central Domain:
  - TSC1: an upcast ventilation shaft located on Tahmoor Coal's Charlies Point Road property.
  - TSC2: a downcast ventilation shaft located on Crown Land adjacent to Tahmoor Coal's Charlies Point Road property.

The construction of the ventilation shafts would entail a disturbance footprint of between four to six hectares at each location. Access to TSC1 and TSC2 will be from the existing road network... The construction of each of the proposed ventilation shafts would involve the following:

- Construction of internal roads for construction and operational maintenance vehicles access.
- Establishment of the construction site to allow sufficient space for stockpiling of shaft liners for TSC1 and TSC2, temporary spoil emplacement for TSC1 and TSC2 (spoil from TSC1 and TSC2 will be stockpiled at the REA), water management, storage and safe movement on-site during construction activities.
- Establishment of the ventilation shaft site involving:
  - Installation of environmental controls such as silt fences, fencing and a lockable gate, as well as display of appropriate signage relating to restricted entry.
  - Clearing of vegetation and stripping of topsoil. Topsoil will be temporarily stockpiled for rehabilitation post construction.
  - Excavation and construction of a temporary hardstand area for operation of drilling equipment.

The hardstand footprint would be determined by the size and number of liner pieces to be manufactured and excavated to a depth of approximately 0.2 metres. The temporary hardstand areas would include:

- Road base surrounding the site compound area and drill rig slab for site facilities.
- Laydown areas and a levelled hardstand area for storage of the ventilation shaft liners.
- A stable access way between the liner storage area and the shaft to facilitate transport of the cured liner segments on purpose built trailers.
- A 20 x 15 metre concrete pad constructed around the top of the shaft as a foundation for the drill rig and to provide a clean work area.
- Connection of 66 kV electrical power and establishment of electrical substations at ventilation shaft sites.
- Sinking of the shaft using blind boring methods, and lining of the shafts using a composite concrete and steel liner.
- Construction of fan buildings and installation of ventilation fans within fan buildings. The upcast shaft site’s fan buildings will also incorporate a fan outlet stack, approximately 30 metres high, to control odour discharge from the mine.

The shaft construction sites would incorporate water treatment sedimentation controls, with the final water treatment from the ventilation shaft being pumped via overland pipeline to a final sedimentation pond at the surface facilities area for further treatment and discharge.

Following the construction phase, the footprint of the operational area of each ventilation shaft would be reduced to approximately two to four hectares, plus the internal vent shaft access road. The area immediately surrounding the ventilation shaft would be rehabilitated following the construction phase. The ventilation fans would operate for the life of the proposed development.

2.1.2 Gas drainage operations

The coal seams within the Southern Coalfields are generally known to be gassy, with methane and CO_2 released from the goaf and surrounding strata during mining. Gas in the underground mine would be managed by gas drainage operations including:

- Pre-mining gas drainage, whereby gas would be drawn from the coal seam and surrounding strata prior to longwall mining.
- Gas extraction via the mine ventilation system, which would occur throughout mining.
- Post-drainage of gas, whereby gas would be drawn from the goaf.

Gas management would continue to use the existing infrastructure, including the Tahmoor Mine Gas Plant, Gas Plant Vent and Flare Plant, as well as the WCMG Power Plant. Some components of the existing gas management infrastructure may need to be upgraded throughout the life of the Project.

2.1.3 Pre-mining gas drainage: underground and surface

The purpose of pre-mining gas drainage is to reduce gas volumes in the coal seams prior to mining, with the Bulli, Wongawilli and Balgownie seams targeted for pre-mining gas drainage at Tahmoor Mine. Pre-mining gas drainage of the gas levels in the seams is required to facilitate the timely commencement and progression of mining as well as to reduce the demands on the mine ventilation system for the purpose of gas dilution during operations.

Pre-mining gas drainage activities are undertaken underground, via drilling and drainage from the roadways developed for longwall panels. Underground pre-mining gas drainage works at Tahmoor Mine would drain gas following development of the mine roadways and prior to longwall development. Gas would be drawn from the coal seam by vacuum and piped to the Gas Plant at the surface facilities area via the underground pipe network. Underground gas drainage of the coal seam would continue ahead of longwall development for the duration of mining.

Gas from the coal seam would be drained using pumps, collected at the surface and piped to the existing Gas Plant at the Tahmoor Mine surface facilities area to be used in the WCMG Power Plant or Gas Fare Plant.

2.1.4 Post- mining gas-drainage

Post-mining gas drainage would be required as strata relaxation caused by the retreating underground longwall face will liberate volumes of gas into the mine workings from the underlying Wongawilli seam and from overlying strata, released due to fracturing of the goaf. To capture this gas during the proposed development, cross-measure boreholes are proposed to be drilled from the mine workings into the Wongawilli seam. These boreholes would be designed to collect the gas at its source or to intercept gas before it migrates into the mine workings. At the conclusion of mining from each panel, the panel would be sealed and gas drawn from the sealed areas as part of the post-mining gas drainage operations. The gas collected from the in-seam and cross-measure boreholes would be drawn by vacuum via the underground pipe network to the Gas Plant located at the surface facilities area. Post-mining gas drainage would not result in surface disturbance.

2.1.5 Ventilation

The ventilation system would deliver fresh air into the mine from the existing and proposed downcast vent shafts and would extract stale air from the mine via the existing and proposed upcast vent shaft. Similar to the existing operations, the ventilation system would carry the remaining diluted gases out of the mine via the upcast mine vent shafts.

2.1.6 Mining method and equipment

Underground mining would be undertaken via conventional longwall development using continuous miners. Longwall development refers to the mining of a series of roadways (gate roads) and cut-through, to form pillars of coal that support the overlying strata during the extraction of coal. Longwalls would be up to 300 metres wide, measured as the distance between gate road centrelines. Gate roads would be approximately 5.2 metres wide and up to 3.0 metres high. Coal would be cut from the coal face by the longwall shearer, loaded onto the armoured face conveyor and transported to the surface facilities area via a series of underground conveyors. The longwall retreats as coal is mined and the overlying rock strata collapses into the void left by the coal extraction, forming the goaf.

Tahmoor Coal would continue to investigate improved or alternate mining methods and technology throughout the life of the Project. Improved methods would be employed where available to allow for the efficient and economically viable extraction of the coal resource. Tahmoor Coal would ensure that the resulting environmental and social impacts of improved or alternate methods are consistent with those predicted in this AEIA.

2.1.7 Mine access (underground)

The Project would use the existing infrastructure at Tahmoor Mine for employee and material access to the mine. Access to the Central Domain would be via the existing Tahmoor Mine surface facilities area, the existing drift, and men and materials travel lift installed within the T3 downcast shaft. The T3 vertical men and material travel lift has a capacity for 70 persons and approximately 12 tonnes of materials.

2.1.8 Coal logistics

The Project would use existing coal logistics to manage movement of coal from the site to market. No further surface development is required to facilitate coal logistics for the Project.

2.1.9 Mine dewatering

Mine water would be collected in underground sumps and pumped from the mine to the existing water management system at the surface facilities area for treatment. Treated mine water would be either reused underground for non-potable uses or discharged at the surface via the existing Licensed Discharge Point. Groundwater inflows during the earlier years of mining are predicted to be around 3.0 ML per day and peak groundwater inflows of approximately 6.8 ML of groundwater per day are not predicted to occur until the late 2030s.

This volume represents an increase of around 1.8 ML of groundwater per day from the existing operations when comparing peak inflows. A site water balance assessment undertaken for the Project (HEC 2018a) indicated that simulated releases of treated water to Tea Tree Hollow via LDP1 over the life of the Project were all compliant with the current EPL daily volumetric limits. An application would be made to vary the EPL in the instance that discharge volumes at the mine increase beyond this estimate.

Water quality impacts associated with the mine dewatering have been considered in Section 6.6.7 of this assessment.

2.2 Surface facilities area

The existing surface facilities and infrastructure at the Tahmoor Mine surface facilities area, operating within surface CCL 716 and Mining Lease 1642, would be used for the Project. Upgrades to some aspects of the surface facilities area would be required and are associated with the increase in annual coal production for the proposed development. Upgrades to existing surface infrastructure would be undertaken within the footprint of the existing Tahmoor Mine surface lease (Mining Lease 1642) and additional surface lease areas required for the Project.

2.2.1 Coal handling and preparation plant

The existing CHPP would be upgraded, including the installation of:

- A new coarse rejects screen.
- Additional belt press filter capacity.

- An increase in thickener capacity.

The existing CHPP and existing ROM stockpile area would be used for the Project. During peak production ROM coal may be trucked from the ROM stockpile to the coal product stockpiles and re-trucked back to the ROM stockpile when required. Reject material generated from the coal washing process at the CHPP would be transported to the expanded REA via the existing reject conveyor to the reject bin for disposal, then transported by haul truck to the REA.

2.2.2 Rejects management

The existing REA would be expanded into adjacent areas to accommodate the reject material associated with the Project. The expansion area is anticipated to cover up to an additional 80 hectares, providing an additional emplacement capacity of approximately 12 million tonnes for the rejects generated during the operation of the Project.

Construction and maintenance of new internal haul roads would be required to and around the REA to cater for the REA expansion. The stormwater management system and infrastructure at the existing REA would be augmented with the construction of additional sedimentation dams, drains and a pumping station.

The expansion of the REA and associated infrastructure would result in vegetation disturbance, which has been considered in the terrestrial impact assessment.

2.2.3 Site amenities, Tahmoor Mine site access and parking areas

The existing site amenities at the Tahmoor Mine surface facilities area would be used for the Project. Additional bathhouses would be required to accommodate the additional workforce. Bathhouses would be constructed adjacent to the existing amenities and would consist of prefabricated modular buildings.

A new all-weather covered pathway and pedestrian bridge over the rail loop is proposed to be constructed from the new car parking area to the mine amenities, muster area and T3 man lift. The proposed development would also require minor upgrades of the existing services such as onsite firefighting, water reticulation and power supply systems.

2.3 Rehabilitation and mine closure

Rehabilitation of the proposed development would be undertaken using a staged approach, comprising:

- Progressive rehabilitation of the REA over the life of the Project. This process would involve capping the reject material with topsoil and revegetating. Annual monitoring would be undertaken to determine the success of revegetation and to inform ongoing management of the rehabilitated areas.
- Mine closure and rehabilitation of the surface facilities area and ventilation shafts.

2.4 Environmental management

Environmental management at Tahmoor Mine is currently governed by the Environmental Management System Strategy and Framework. The Project would be managed within this Framework and in line with existing procedures. Where required, the existing procedures and management plans would be updated to reflect the specific details of the Project.

In addition, a Mine Operations Plan (MOP) would be prepared to meet the requirements of the Mining Act 1992 and Mining Regulation 2010. The Division of Mineral Resources and Energy would be consulted to ensure that the MOP is prepared in accordance with the current guidelines at the time.

2.4.1 Subsidence monitoring and management

Tahmoor Mine currently manages and monitors subsidence as part of the existing operations at Tahmoor North. The systems and programmes currently in place to monitor and manage subsidence would continue during the proposed development and would be augmented to monitor the effects of mining within the Central Domain.

Specifically, subsidence would be managed through implementation of a series of Extraction Plans (EPs) in consultation with stakeholders. The management plans would describe measures to be undertaken to monitor surface subsidence and physical changes that are predicted to occur during mining. Measures detailed in the management plans would include:

- The requirements for inspection regimes for natural and built surface features.
- The layout of monitoring points and parameters to be measured.
- Monitoring methods and accuracy.
- The timing and frequency of surveys and inspections.
- Processes for recording and reporting of monitoring results.

2.4.2 Water management

Surface water runoff from operational areas and stockpiles would continue to be captured by the existing stormwater treatment dams at the surface facilities area. Following treatment, the water would continue to be discharged to Tea Tree Hollow at LDP1.

Potable water supply for use at the surface facilities area and underground would be drawn from the town water main, and non-potable supply sourced from the recycled water treatment plant at the surface facilities area. Mine water would be treated and recycled for non-potable underground use, or pass through the stormwater treatment dams and be discharged via LDPs.

Pollution Reduction Program 22 (PRP 22)

Under PRP 22, a Waste Water Treatment Plant (WWTP) was constructed at Tahmoor Underground Mine in June 2015. The treatment objectives were set by a Pollution Reduction Program (PRP) on the Environmental Protection Licence (EPL). The purpose of the plant is to treat up to 6 ML/d of mine water to reduce the concentrations of arsenic (As), nickel (Ni) and zinc (Zn) in the water discharged from the mine to below the following levels:

- As: 0.013 mg/L
- Ni: 0.011 mg/L
- Zn: 0.008 mg/L

The plant is scheduled for completion in November 2018.

Licensed Discharge Point

The Project would collect water underground in sumps and pump this water via underground pipes to the surface. As per the existing operations, the Project would continue to discharge a portion of the stormwater and treated mine water via Licensed Discharge Point LDP1 under EPL 1389.

Site water balance

The major components of the mine water balance for the proposed development would be:

- Inflows from surface runoff, direct rainfall onto dam surfaces, potable water draw and groundwater inflows to the underground operations.
- Outflows including discharges to the Bargo River catchment via LDPs to Tea Tree Hollow, evaporation from dam surfaces, and water loss to product coal and coarse rejects.

Site water management plan

Water management during operation of the proposed development would be governed by the water management plan currently in place at the Tahmoor Mine. The water management plan would be augmented to encompass the operations of the Project and would be implemented in line with the following objectives:

- Use available surface water runoff for use as process water.
- Minimise instances of licensed discharge.
- Minimise the magnitude of licensed discharge.
- The quality and quantity of water discharged is to be in accordance with relevant water quality criteria.

3. Methods

The aquatic ecology impact assessment methods were structured to specifically reflect relevant legislation, specific guidelines, and advice from local, state, and federal agency stakeholders, and to address the Secretary's Environmental Assessment Requirements (SEARs). The methods outline the monitoring design and impact assessment criteria.

3.1 Project Area

The Project Area includes all watercourses that occur within the extent of the longwall area. The New South Wales Department of Planning (NSW DoP 2008) defined "Risk Management Zones (RMZ's)" as streams within the mine subsidence area of 3rd order or above, under the Strahler (1952) stream classification scheme. The RMZ is defined from the outside extremity of the surface feature, either by a 40° angle from the vertical down to the coal seam that is proposed to be extracted, or by a surface lateral distance of 400 metres, whichever is the greater (NSW DoP 2008). However, closure and upsidence movements in the Southern Coalfields have been detected more than 500 metres from the edges of longwalls (Kay et al. 2006) and as such, the Project Area is defined as a buffer distance of 600 metres from the mine plan extent for the purpose of this assessment (Figure 2). The Subsidence Study Area is a conservative region investigated for potential subsidence impacts, whereas the 20 millimetre subsidence contour taken from the subsidence assessment (MSEC 2018) defines the limit of actual subsidence impacts (Figure 2). The study area includes the Project Area and areas outside the project area including downstream water courses and control streams.

As mine water is discharged at the surface via the existing LDP1 into Tea Tree Hollow Creek, the Project Area also includes the receiving waters of Tea Tree Hollow Creek that occur outside of the 600 metre mine extent buffer and the Bargo River from its confluence with the Nepean River, for the assessment of mine water discharge. The Project Area covers an area of approximately 7,128 hectares.

3.2 Literature and data review

A number of resources were used to undertake the AEIA, a complete reference list is provided in Section 10. Primary resources include:

- AECOM (2012) Tahmoor South Project Preliminary Environmental Assessment, prepared for Tahmoor Coal August 2012.
- Niche (2012) Tahmoor South Pilot Study, Prepared for Tahmoor Coal.
- Niche (2013) Tahmoor South Aquatic Ecology Monitoring Project Year 2012-2013.
- DOP (2008) Impacts of Underground Coal Mining on Natural Features in the Southern Coalfields - Strategic Review. State of NSW through the Department of Planning, 2008 (commonly referred to as the Southern Coalfields Inquiry).
- PAC (2009) The Metropolitan Coal Project Review Report. State of NSW through the NSW Planning Assessment Commission, 2009.
- PAC (2010) Review of the Bulli Seam Operations Project. State of New South Wales through the NSW Planning Assessment Commission, 2010.
- Bioanalysis (2009). Part 3A Bulli Seam Aquatic Ecology Impact Assessment.
- NPWS (2003) Native Vegetation of the Woronora, O'Hare's and Metropolitan Catchments.
- OEH Atlas of NSW Wildlife (accessed October 2017).
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3.3 Threatened species

3.3.1 Threatened species search

Threatened native fish and aquatic invertebrate species, populations and ecological communities are protected by the NSW *Biodiversity Conservation Act 1995* (BC Act), FM Act and Commonwealth EPBC Act (note that the transitional arrangements tests of significance under the former *Threatened Species Conservation Act 1995* (TSC Act) apply to this assessment rather than the new assessment methodologies now required under the BC Act). A list of threatened aquatic species, populations and ecological communities (subject species) that occur or could potentially occur within the Project Area were identified by a database search from the following databases in June 2013, and updated in October 2017:

- The Office of Environment and Heritage BioNet Atlas of NSW Wildlife records for aquatic threatened species and/or endangered ecological communities listed under the BC Act which have been recorded within the locality (10 km area search co-ordinates: N: -34.1551; E: 150.7012; S: -34.3353; W: 150.4836).
- The Department of Environment and Energy (DoEE) Protected Matters Search Tool for Matters of National Environmental Significance (MNES) listed under the EPBC Act that may occur in the Project Area (10 km point search co-ordinates: -34.25069,150.57968).
- The Department of Primary Industries (DPI) list of threatened species under the FM Act that have been recorded within the Hawkesbury-Nepean CMA and/or recorded in the Wollondilly LGA using DPI Threatened Species Profile Viewer and DPI Spatial Data portal.

3.3.2 Determining affected species

In order to adequately determine the relevant level of assessment to apply to subject species, a further analysis of the likelihood of occurrence within the Project Area was undertaken. Diagram 1 provides a representation of the hierarchy of decision making employed to determine which species, populations, ecological communities or MNES were considered further for impact assessment.

Five categories for 'likelihood of occurrence' (Table 3) were attributed to species after consideration of criteria such as known records, presence or absence of important habitat features on the subject site, results of the field surveys and professional judgement. Species considered further in formal assessments of significance pursuant to relevant legislation were those in the 'Known' to 'Moderate' categories and where impacts for the species could reasonably occur from the development.

Diagram 1: Hierarchical process to determine species

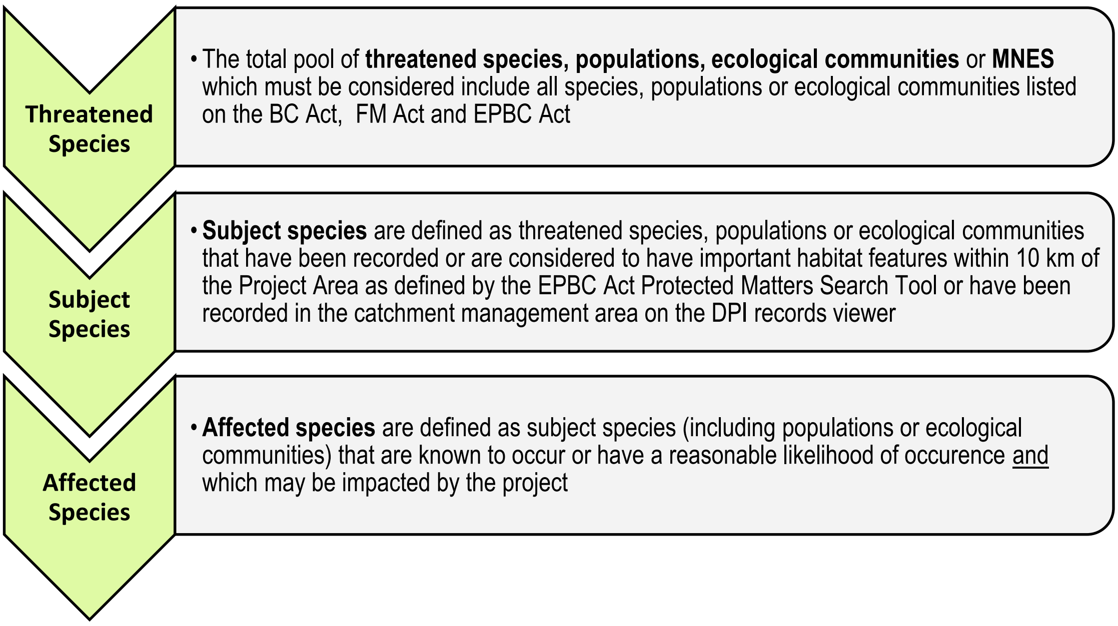


Table 3: Likelihood of occurrence criteria.

Likelihood rating	Threatened macrophyte criteria	Threatened aquatic fauna criteria	Likelihood rating
Known	The species has been observed within the Project Area	The species has been observed within the Project Area	Known
High	It is likely that a species occurs within the Project Area	It is likely that a species inhabits or utilises habitat within the Project Area	High
Moderate	Potential habitat for a species occurs on the site. Adequate field survey would determine if there is a 'high' or 'low' likelihood of occurrence for the species within the Project Area	Potential habitat for a species occurs on the site and the species may occasionally utilise that habitat. Species unlikely to be wholly dependent on the habitat present within the Project Area	Moderate
Low	It is unlikely that the species inhabits the Project Area	It is unlikely that the species inhabits the Project Area.	Low
None	The habitat within the Project Area is unsuitable for the species.	The habitat within the Project Area is unsuitable for the species	None

3.4 Site selection for baseline monitoring

Scoping surveys were undertaken prior to monitoring using 1:25,000 Topographic Map Series, (Bargo 9029-3N and Picton 9029-4S sheets, Land and Property Information NSW Government) combined with field surveys to select monitoring sites that were representative of the creeks in terms of physical appearance and that were accessible. Where appropriate, access through private property to the creek lines was arranged by Tahmoor Coal.

Site locations were selected in an effort to capture the spatial variability of aquatic biota within streams (two sites per stream) and between streams (sampling of each stream in Project Area). Effort was also made to capture the variability of aquatic biota within sites through sample replication and following AUSRIVAS sampling methodology.

The baseline monitoring program was based on surveys of aquatic ecological indicators within the Tahmoor South Project Area. Within the Project Area, 1st order streams were observed to have relatively small catchments, lower energy (and sediment transport), few pools (if any) and fewer areas of exposed bedrock features. As such, they were of lower interest to the assessment of geomorphic risk compared with 2nd order streams and higher (Fluvial Systems 2013), and the risk to aquatic habitat and biota would also be lower. For the purpose of aquatic ecological assessment, monitoring points were therefore selected in streams of 2nd order or above.

3.4.1 Subsidence impact monitoring locations

Four potential impact watercourses were selected for monitoring within the Project Area and eight ecologically comparable creeks outside of the Project Area were selected as control watercourses, with two sampling sites at each location. These potential impact and control locations (creeks) are detailed in Table 4 and shown in Figure 3. Note that because of mine layout changes, sites at Cow Creek, Eliza Creek, Dry Creek and Carters Creek that were previously monitored as potential impact sites are now considered as control locations.

Table 4: Subsidence monitoring locations

Watercourse	Sampling site names	Strahler's (1952) Stream Order
Potential impact locations		
Dog Trap Creek	DTC9, DTC10	3
Tea Tree Hollow	TTH11, TTH12	3
Hornes Creek	HC13, HC14	4
Bargo River	BR15, BR16	5
Control locations		
Cow Creek	CWC1, CWC2	3
Carters Creek	CC3, CC4	3
Dry Creek	DC5, DC6	2
Eliza Creek	EC7, EC8	2
Bargo River tributary	CBR1, CBR2	2
Moore Creek	CMC3, CMC4	3
Cedar Creek	CCC5, CCC6	4
Stonequarry Creek	CSQ7, CSQ8	3

3.4.2 Mine water discharge impact monitoring locations

Mine water is currently discharged into Tea Tree Hollow Creek via mine discharge point LDP1, which flows into Bargo River. One^ impact monitoring site was selected downstream in Tea Tree Hollow Creek and two impact locations (two sampling sites at each location) downstream of the confluence point in Bargo River. One control monitoring site was selected upstream of mine discharge point LDP4 in Tea Tree Hollow Creek and two control locations (two sampling sites at each location) upstream of the confluence point in Bargo River. These potential impact and control locations are detailed in Table 5 and shown in Figure 4.

Subsidence monitoring sites TTH11, TTH12 and Sites BR15 and BR16 were used for this monitoring program. Additional Bargo River mine water discharge monitoring sites SBR3 to SBR8 were monitored for one year only. The monitoring was complimented by an aquatic health investigation (CEL 2016) which was incorporated as part of the impact assessment.

^At the commencement of the monitoring program (June 2012), the upstream (control) site on Tea Tree Hollow Creek (TTH11) was selected above the mine discharge point LDP4 and the downstream (impact) site (TTH12) was selected at a point below mine discharge point LDP4 and above discharge point LDP1. However, following 1.5 years of monitoring, discharge point LDP4 was converted to a high flow discharge only. As such, the downstream monitoring location on Tea Tree Hollow was relocated to downstream of the main discharge point at LDP1 (TTH12a).

Table 5: Discharge monitoring locations

Location	Sampling site names
Potential impact locations	
Tea Tree Hollow Creek - downstream	TTH12 (2012 – 2013), TTH12a (2013)
Bargo River – downstream	SBR5, SBR6, SBR7, SBR8
Control locations	
Tea Tree Hollow Creek - upstream	TTH11
Bargo River - upstream	SBR1 (BR15), SBR2 (BR16), SBR3, SBR4

3.5 Field surveys

The aquatic monitoring program is in accordance with the NSW Department of Planning's "Strategic Review of Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield" (NSW DoP 2008), hereafter referred to as the Strategic Review.

Specific recommendations within the Strategic Review that are relevant to aquatic ecological investigations include:

- Streams within the mine subsidence area of 3rd order or above, under the Strahler stream classification scheme are to be considered as Risk Management Zones (RMZs).
- A minimum of 2 years of baseline data, collected at appropriate frequency and scale should be provided for significant natural features.
- Monitoring of mine subsidence impacts should allow for back analysis and comparison of actual versus predicted effects and impacts, in order to review the accuracy and confidence levels of the prediction techniques used i.e. The use of Before, After, Control, Impact (BACI) design ecological studies (Underwood 1981).

Monitoring began in autumn 2012, prior to the commencement of longwall mining and upgrades of surface mine infrastructure. Sampling of sites occurred in autumn and spring for two years (see Appendix C for dates), survey effort for each component is provided in Table 6 with survey details for each component provided below. Survey timing and meteorology is provided in Appendix C.

Note that AUSRIVAS utilises modelled reference stream for comparison of macroinvertebrate fauna, and therefore control sites were not used as part of this component of the monitoring program.

Table 6: Aquatic survey effort.

Method	Sampling effort	Subsidence monitoring schedule	Mine water discharge monitoring schedule
Habitat monitoring	One sample at each site. Two sampling sites in each stream. At impact sites and control sites Eliza	Two sampling occasions in: autumn 2012, spring 2012, autumn 2013 and spring 2013.	One sampling occasion in spring 2012 and autumn 2013 combined with

	Creek, Dry Creek, Carters creek and Cow Creek.		selected subsidence monitoring sites.
Photo point monitoring	One sample at each site. 2 sampling sites in each stream. At impact and control sites.	Two sampling occasions in: autumn 2012, spring 2012, autumn 2013 and spring 2013.	One sampling occasion in spring 2012 and spring 2013 combine with selected subsidence monitoring sites.
Water quality sampling	One sample at each site (average of 3 samples). Two sampling sites in each stream. At impact and control sites.	Two sampling occasions in: autumn 2012, spring 2012, autumn 2013 and spring 2013 for impact sites. Control sites were sampled on one occasion per season during quantitative macroinvertebrate sampling.	One sampling occasion in spring 2012 and spring 2013 combined with selected subsidence monitoring sites.
Fish sampling – bait traps	Four bait traps set at each site. Two sites in each stream at impact and control sites. Combined with fish caught in dip nets (AUSRIVAS sampling).	One sampling occasion in: autumn 2012, spring 2012, autumn 2013 and spring 2013.	One sampling occasion in spring 2012 and spring 2013 combined with selected subsidence monitoring sites.
Macrophyte sampling - AUSRIVAS	One sample at each site. Two sampling sites in each stream. At impact sites only and control sites Eliza Creek, Dry Creek, Carters creek and Cow Creek...	Two sampling occasions in: autumn 2012, spring 2012, autumn 2013 and spring 2013.	One sampling occasion in spring 2012 and spring 2013 combined with selected subsidence monitoring sites.
Macroinvertebrates - AUSRIVAS	One 10 metre dip net sweep at each site. Two sampling sites in each stream. At impact sites and control sites Eliza Creek, Dry Creek, Carters creek and Cow Creek.	Two sampling occasions in: autumn 2012, spring 2012, autumn 2013 and spring 2013.	One sampling occasion in spring 2012 and spring 2013 combined with selected subsidence monitoring sites.
Macroinvertebrates -Quantitative sampling	Three benthic samples at each site. Two sites in each stream at impact sites and controls.	Artificial collectors: autumn 2012. Benthic suction sampler: one sampling occasion in spring 2012, autumn 2013 and spring 2013.	One sampling occasion in spring 2012 and spring 2013 combined with selected subsidence monitoring sites.
Targeted survey			
Targeted surveys	Sydney Hawk dragonfly: 29 sites sampled using modified AUSRIVAS edge sampling technique.	One sampling occasion (5 days) in July/August 2013.	-

3.5.1 Aquatic habitat descriptions and monitoring

A qualitative description of the aquatic habitats at each site was made based on the following attributes:

- Topography.
- Extent and condition of riparian vegetation.
- Stream level and width.
- Instream features such as sequence of pools, runs and riffles.
- Presence and extent and type of aquatic vegetation.
- Stream substratum.
- Presence of fish habitat, including snags, bank undercuts and aquatic plants.

In addition to the above habitat descriptors, the Riparian, Channel and Environmental Inventory (RCE) assessment was undertaken at each site (Chessman et al. 1997; Appendix B). This assessment produces a score for each site based on a series of observations relating to the natural characteristics and degree of disturbance evident at each site and allows comparison between sites and over time.

A photo record point was also established at each site. Photographs were taken from the upstream point, the centre and the downstream point of the 100 m reach. At each photo point, an upstream and downstream photograph was taken (see Niche 2013).

3.5.2 Water quality

Surface water quality was measured *in situ* using a Yeo-kal 611 water quality probe, with three readings taken at subsidence monitoring sites and mine water discharge monitoring sites. The following variables were recorded:

- Temperature (°C)
- Salinity/conductivity (µS/cm)
- pH/alkalinity
- Oxidation – Reduction Potential (ORP) (mV)
- Dissolved Oxygen (% saturation and mg/L)
- Turbidity (ntu).

Water quality data were compared with the ANZECC (2000) default trigger values of physical and chemical stressors for the protection of slightly disturbed aquatic ecosystems in south-eastern Australia.

3.5.3 Fish sampling

Fish sampling was undertaken at subsidence and surface works monitoring sites (Appendix F and Appendix G). Fish surveys using bait traps were undertaken at each sample site once per season (Plate 1). Four bait traps were deployed in slow flowing pools at each site for two continuous hours. Additionally, fish at each site collected as part of the AUSRIVAS macroinvertebrate sampling were identified and counted. All captured fish and large crustaceans were immediately transferred to a bucket of water for identification and release. Fish were identified in the field using Field Guide to the Freshwater Fishes of Australia (Allen et al. 2002). Any individuals that could not be identified were preserved using 70% ethanol for later identification.

Fish sampling was done in accordance with an Animal Research Authority (Fauna Surveys: Terrestrial and Aquatic) and a Scientific Collection Permit (No. P10/0027-3.0) issued by the NSW Department of Primary Industries.

3.5.4 Macrophytes

The presence/absence of macrophytes within a 100 metre reach at each sample site was recorded. All macrophytes observed at surveys sites were identified to species.

3.5.5 Aquatic macroinvertebrate sampling

Aquatic macroinvertebrates were collected using both the AUSRIVAS protocol for NSW streams (Turak et al. 2004), and the quantitative sampling method for surveying macroinvertebrates.

AUSRIVAS sampling

The AUSRIVAS methods of sampling both pools and riffles were modified as no suitable in-stream riffle features were present. Samples were collected from pool edges for a distance of 10 metre either as a continuous line or in disconnected segments. Sampling in segments was often undertaken to ensure the sampling of sub-habitats such as macrophyte beds, bank overhangs, submerged branches and root mats.

Segmented sampling was also employed where pool length was short and it was logistically difficult to sample in a continuous line (e.g. in-stream logs). A 250 µm dip net was drawn through the water with short sweeps towards the bank to dislodge benthic fauna while scraping submerged rocks and debris, sides of the stream bank and the bed substrate. Further sweeps in the water column targeted the suspended fauna. In many of the pools where it was difficult to scrape the substrate with the net (e.g. due to obstacles), the substrate was disturbed using a kicking motion and the net moved through the water column to collect specimens.

Each sample was rinsed from the net onto a white sorting tray from which animals were picked using forceps, pipettes and or paint brushes. Each tray was picked for a minimum period of forty minutes, after which they were picked at ten minute intervals for either a total of one hour or until no new specimens had been found. Care was taken to collect cryptic and fast moving animals in addition to those that were conspicuous or slow. Specimens were placed into a labelled jar containing 70% ethanol. In accordance with the AUSRIVAS protocol, samples were sorted under a binocular microscope (at 40 X magnification), identified to family or sub-order level.

The chemical and physical variables required for running the AUSRIVAS predictive model were also recorded. Alkalinity, modal depth and width of the river, percentage bedrock, boulder or cobble and latitude and longitude of each site were recorded in the field, whilst distance from source, altitude, land-slope and rainfall were determined in the laboratory.

Quantitative sampling

The Before monitoring component of a BACI (Before After Control Impact) monitoring design was implemented to assess the potential impacts of mining subsidence on aquatic ecology, provided that similar assessments are made during and/or after mining (Underwood 1991, 1992, 1993, 1994; Downes et al. 2002).

Artificial collectors

At the beginning of the autumn 2012 AUSRIVAS seasons, four replicate artificial collector units providing habitat structure for aquatic macroinvertebrates were deployed at each site. The collectors consisted of 24 centimetre long x 3 centimetre diameter bundles of nine wooden chopsticks held together with plastic cable ties (Plate 2). The four collectors were attached to nylon twine and submerged 1 metre apart at the edge of pools in approximately 0.5 metres of water. Collectors were anchored using concrete weights or tied to vegetation along the bank. The collectors were retrieved during the second survey, approximately six weeks after being deployed. During retrieval the collectors were carefully cut away from their anchors, placed into plastic bags, labelled and preserved in 70% ethanol for subsequent laboratory identification and analysis. This method is based on a modified technique used by Cardno Ecology Lab (CEL 2010b). Artificial collecting sticks were rinsed using 70% ethanol onto a 250 µm mesh sieve and examined in the laboratory using a binocular microscope. Macroinvertebrates (adults, juveniles, larvae, pupae) were identified to family level except for Oligochaeta (to class), Polychaeta (to class), Ostracoda (to subclass), Nematoda (to phylum), Nemertea (to phylum), Acarina (to order) and Chironomidae (to subfamily).

The collectors were set in autumn 2012 and retrieved early June. Due to logistical constraints the artificial collectors were replaced with the suction sampler quantitative technique (Brooks 1994) for the remainder of the monitoring program. The data assessed in this report includes three seasons of benthic suction sampling and artificial collector data has been excluded from the analyses. Data collected with artificial collectors is provided in Tahmoor South Aquatic Monitoring Report (Niche 2012).

Benthic suction sampler

Macroinvertebrates were sampled from three random pool edges at each site. Pool-edge samples were collected from depths of 0.2 - 0.5 metre within 2 metres of the bank. A suction sampler described by Brooks (1994) (Plate 2) was placed over the substrate and operated for one minute at each sampling location. The sample was washed thoroughly over a 500 µm mesh sieve. All material retained on the 500 µm mesh sieve was preserved in 70% ethanol for laboratory sorting. Samples were subsampled in a 100 cell Marchant box (Marchant 1989) and 35% (35 cells) of the sample were randomly extracted. Samples that contained few invertebrates were not subsampled. All macroinvertebrates (except for segmented and unsegmented worms, Acarina and Chironomidae) were identified to family level. The segmented worms were identified to class (Oligochaeta) and unsegmented worms to phylum, except for flatworms which were identified to order (Tricladida). Acarina were identified to order and Chironomidae to subfamily. Small crustaceans Ostrocoda, Copapoda and Cladocera were not identified.

3.5.6 Targeted surveys

Targeted surveys were undertaken for the threatened Sydney Hawk Dragonfly (*Austrocordulia leonardi*) on 24 - 26 July and 31st July - 2 August, 2013. A conservative approach was adopted in implementing the targeted surveys to ensure that threatened fauna are not present in areas affected by subsidence within the Project Area. The survey primarily targeted the tributaries to the Bargo River and Nepean River, particularly since Austrocorduliidae (the Sydney Hawk dragonfly family) were observed in Eliza Creek in baseline monitoring samples. Bargo River sites within the Project Area were adequately sampled (eight sites) within the baseline monitoring program. Potential habitat for these dragonflies was based on geomorphology mapping prepared by Fluvial Systems (2013) and modelled using ArcGIS mapping software.

Sydney Hawk Dragonfly

All pools with a predominantly boulder and/or cobble substrate were defined as containing potential habitat. Within the Project Area, a total of 30 sites were identified (Figure 6) and subsequently surveyed for Sydney Hawk Dragonfly using a modified AUSRIVAS technique, whereby cobbles and boulders were actively lifted and the substrate stirred followed by sampling the water column using a 250 µm dip net in a continuous sweeping motion.

Sample processing and picking for the species followed AUSRIVAS protocol. Dragonflies were identified to family *in situ*. If they were not from Austrocorduliidae they were returned to the habitat from where they were collected. Dragonfly from the family Austrocorduliidae were kept for further identification.

3.6 Data analysis

3.6.1 AUSRIVAS samples

Samples collected using the AUSRIVAS protocol were analysed using the predictive spring and autumn models for NSW pool edge habitats. The AUSRIVAS model predicts the aquatic macroinvertebrate fauna expected to occur at a site in the absence of environmental stress, such as pollution or habitat degradation, and generates a number of indices, which are detailed below.

The Observed to Expected ratio (OE50)

OE50 is the ratio of the number of invertebrate families observed (NTC50) at a site to the number of families expected (NTE50) at that site. Only macroinvertebrate families with a greater than 50% predicted probability of occurrences are used by the model. OE50 provides a measure of biological impairment at the test site. The OE50 ratios are divided into bands representing the following different levels of impairment:

- Band X represents a more biologically diverse community than reference.
- Band A is considered similar to reference.
- Band B represents sites significantly impaired.
- Band C represents sites in a severely impaired condition.
- Band D represents sites that are extremely impaired.

Stream Invertebrate Grade Number Average Level (SIGNAL)

SIGNAL is a simple biotic index for river macroinvertebrates, developed initially for application to eastern Australia (Chessman 1995). The SIGNAL method uses ecological patterns to measure water quality using waterbugs. The SIGNAL score of a site can be calculated to form an objective opinion about river health. Table 7 provides a broad guide for interpreting the health of the site according to the SIGNAL score of the site.

Table 7: Guide to interpreting SIGNAL scores

SIGNAL Score	Habitat quality
Greater than 6	Healthy habitat
Between 5 and 6	Mild pollution
Between 4 and 5	Moderate pollution
Less than 4	Severe pollution

(Source: Gooderham J and Tsyrlin E 2002)

3.6.2 General sample analyses

Other analyses performed on the data to indicate stream health and aquatic macro-invertebrate diversity include taxa richness, EPT richness and EPT ratio, also detailed below.

Taxa richness

The richness of macroinvertebrate families (or class/orders if not identified to family level) was calculated as an indicator of stream health. The higher the number, the healthier the aquatic ecosystem.

EPT richness and EPT ratio

The EPT (Ephemeroptera, Plecoptera and Tricoptera) index is based on the insect orders that contain a majority of pollution sensitive taxa (Lenat 1988). All genera of Ephemeroptera, Plecoptera and Tricoptera were identified and the number of distinct taxa were counted as an indicator of ecosystem health. The higher the number, the healthier the aquatic ecosystem. The ratio of EPT to the number of taxa was also calculated as another measure of ecosystem health.

3.6.3 Quantitative macroinvertebrate data analysis

To estimate the original family densities per $0.21m^2$ (i.e. area of benthic suction sampler) any samples subsampled (35% subsampled) in the laboratory were multiplied by 100/35. Analysis of benthic invertebrate data was done using Primer v6.

Univariate mean family richness and density univariate data was graphed. Multivariate data was 4th root-transformed for the calculation of Bray-Curtis Similarity measure to reduce difference in scale among variables, but still retain information regarding relative abundances.

Non-metric multidimensional scaling nMDS (Clarke 1993) was undertaken to visualise patterns among the macroinvertebrate assemblage. In addition a nMDS plot was also performed on averaged sites to reduce the stress value and provide a better representation of the collected data. The Similarity Percentages Procedure (SIMPER) was performed to identify the main taxa contributing to differences in similarity of the assemblages observed in the nMDS.

3.7 Assumptions and limitations

This report combines two years of baseline aquatic monitoring data (2012 – 2013) with previous research carried out by MSEC (subsidence), HECON (surface water) and Fluvial Systems (geomorphology). The following assumptions have been made and limitations encountered during this assessment:

- While efforts were made to ensure macroinvertebrate sites are representative of the streams ecosystem, temporally and spatially, it is not possible to encompass the full extent of stream diversity in the Project Area.
- Suitable habitat for Sydney Hawk Dragonfly was identified using GIS mapping based on geomorphological mapping (Fluvial Systems 2013). Targeted field surveys of these areas were limited for a number of reasons:
    - Access was unavailable through private property.
    - All small streams were not surveyed as some streams may have been characterised as similar based on aerial photography and terrain data.
    - Parts of Bargo River and the Nepean River were too deep to safely navigate and cross on foot.
- The weather in 2012 was cool and wet at the start of the year, and warm and dry in the latter half of the year, with rainfall and temperature close to the historical average. The year 2013 was the warmest year on record for NSW maximum temperatures, and the third-warmest for mean temperatures. Rainfall was above average along the coast, with several heavy rainfall events, but below average in inland NSW and across the Murray Darling Basin (BOM 2013). While weather can influence the abundance and diversity of aquatic biota recorded during surveys, it is considered that the weather experienced during the monitoring period was fairly typical for the area, and that low flows and the drying out of some pools (i.e. sample sites on Dog Trap Creek), is consistent with the ephemeral nature of the creeks within the Project Area. As such, it is assumed that the weather experienced during monitoring did not alter the diversity and abundance of species recorded from what would typically occur.

4. Existing environment

4.1 Project Area summary

The Project Area is located approximately 80 kilometres south-west of Sydney, in the vicinity of the townships of Tahmoor and Bargo, in the Southern Coalfield and is encompassed by CCL 747 and CCL 716 (Figure 2), on the south western edge of the Sydney Basin, situated on the western extent of the Woronora Plateau. The Project Area occurs within the boundaries of Wollondilly and Wingecarribee Local Government Areas (LGA), with the western and southern areas located in Wingecarribee LGA and northern and eastern areas in Wollondilly LGA.

Most of the area to the east of the Project Area consists of rural residential development, whilst the western portion consists primarily of vegetated land privately held but mainly undeveloped and a large tract of Crown Land. Topography varies within the Project Area with the eastern portion situated on gently undulating flats, the south east with moderately inclined side slopes and the western portion comprising steep incised gullies with exposed Hawkesbury Sandstone.

The Bargo River is the main natural feature within the Project Area, located on the western side of CCL 747. A number of unnamed 1st and 2nd order tributaries flow into Bargo River. Other significant creeks within the Project Area include: Hornes Creek, Dog Trap Creek, Eliza Creek, Tea Tree Hollow Creek, Dry Creek, Carters Creek and Cow Creek. Sections of these creeks (3^{rd} order and above) are mapped as Key Fish Habitat (DPI 2017c). The Tahmoor South Project have 3rd Streams and above that contain both highly sensitive Key Fish Habitat (Type1) “Freshwater habitats that contain in-stream gravel beds, rocks greater than 500 mm in two dimensions, snags greater than 300 mm in diameter or 3 metres in length, or native aquatic plants” and minimal Key Fish Habitat (Type 3) “Ephemeral aquatic habitat not supporting native aquatic or wetland vegetation” (DPI 2013).

4.2 Key characteristics of the area

The following landscape information is summarised from NSW DoP (2008) and is a generalised description of the land encompassed by the Southern Coalfields.

4.2.1 Topography

The essential landscape feature which has determined the valley forms and cliff lines of the Southern Coalfields is the Hawkesbury Sandstone, which is highly resistant to weathering. The weathering and erosion caused by the concentration of moving water along the networks of faults and joints, which occur naturally in this rock as the result of stresses imposed during geologic time, has led to the development of a system of deeply incised river gorges that drain the plateaus. The river valleys, particularly the downstream sections as they approach the Hawkesbury River Valley, are often narrow with steep sides and stream beds largely composed of the sandstone bedrock, with rock bars and boulder-strewn channels. These steep-sided valleys, may take the form of a gorge, with imposing sandstone cliffs on one or both sides of the river. An example is the Bargo River Gorge, located between Pheasants Nest and Tahmoor (NSW DoP 2008), which is within the boundary of CCL 747.

Further upstream in most catchments, the rivers are less incised and their valleys are broader and more open in form although the sandstone bedrock still remains the key geomorphological determinant. Stream beds are still generally composed of exposed sandstone bedrock, with rock bars and channels strewn with smaller boulders and cobbles. The sandstone bedrock becomes a drainage surface (either at the base of swampy vegetation draping the landscape or below the regolith), which sheds groundwater towards the streams. The groundwater provides base flow for the streams and supports the generally perennial character of the larger streams and rivers (NSW DoP 2008).

4.2.2 Geomorphology

The following geomorphic characterisation is taken from the geomorphology technical report prepared for the Tahmoor South Project (Fluvial Systems 2013).

In terms of landscape scale characteristics, the majority of the proposed development is underlain by Hawkesbury Sandstone, with a smaller portion underlain by Wianamatta Group. The soils in this region are characterised by generally weakly developed soils on sandstone and shale. Some of the soils are highly susceptible to erosion by concentrated water flow, which is expected of weakly developed soils in steep environments. The susceptibility of the soils to water erosion is part of the natural process of delivery of sediment to streams. Some of the soils are high in iron content and can be responsible for release of dissolved iron to stream water.

The streams comprise small headwater streams on relatively low gradient plateau landscapes and streams eroded into rocky gorges. The gorges are rimmed by cliffs of various lengths and heights, with densely vegetated talus slopes below the cliffs. These cliffs, and the talus slopes below them, are relatively stable.

A wide range of channel bed materials was observed over the Project Area. Mud was more prevalent in small streams on the plateau, but it was also occasionally present in the lower reaches of tributary streams. Sand, gravel, cobble and bedrock were commonly found throughout the Project Area. Exposed bedrock was commonly observed in streams throughout the Project Area. Streams with particularly frequent bedrock features in their beds were Lower Eliza Creek and [two tributaries to the Bargo River]. The frequency of bedrock features was also high in Dog Trap Creek, Cow Creek and Dry Creek, but less so in Carters Creek, Hornes Creek and Tea Tree Hollow. The observed frequency of bedrock features in the bed of Bargo River was an underestimate because at the time of sampling, for most of its length the water was too deep to permit observation of the bed.

In-channel pools are common in streams within the Project Area, particularly in Dog Trap Creek, Dry Creek and Cow Creek. Tea Tree Hollow has a lower frequency of pools compared to other creeks. Boulders are the most common type of hydraulic control on pools, with 47% being boulders, 33% rock bars, 12% high points of cohesive material, 8% gravel, cobble or sand bars, and 1% artificial material. As the channels are bedrock controlled, they are naturally resilient to geomorphic change.

The continuity of riparian vegetation and level of tree cover was within the natural range of undisturbed sites and as such, provides geomorphic stability of streams in the Project Area. Grass cover on the low flow channel was found on all of the small headwater streams of the creeks in the Project Area, but it was uncommon in 2nd order streams and higher. Dry Creek was an exception, but with a small catchment area it is a relatively low energy stream.

Knickpoints were common in streams within the Project Area and soft knickpoints were found mainly on small, plateau streams running through both cleared and uncleared land. Hard knickpoints were found in steeper streams.

Ferruginous seeps in rocks close to stream channels were uncommon in the Project Area. One seep was observed on Dog Trap Creek, and one on Carters Creek. The seep on Dog Trap Creek covered a very small area of a few square centimetres, while the seep on Carters Creek was more substantial. The seep on Carters Creek was clearly related to emergence of water to the creek that had seeped through the wall of a farm dam located immediately upstream. The creek water downstream of this ferruginous seep was not discoloured.

The majority of streams are defined as being in a stable, close to natural geomorphic condition. Some streams were impacted by factors that marginally reduced their condition. These factors included clearance of riparian trees, licensed discharges, incision, mobile knick-points, and filamentous algae. Some streams were affected by loss of water to the subsurface over short reaches, and others were impacted by ferruginous seeps and suspended colloids. These factors do not have strong implications for geomorphic condition, but they could have relevance for ecological condition. A few isolated major culverts were judged to be in poor condition, as these were an unnatural stream type.

4.2.3 Catchments

The Project Area is part of Bargo River/Nepean catchment and consists of a number of smaller sub-catchments including Hornes Creek, Tea Tree Hollow, Dog Trap Creek, Dry Creek, Cow Creek, Carters Creek and Eliza Creek.

The upland areas, including the Bargo Township, are drained by headwater streams of Hornes Creek, Tea Tree Hollow, Dog Trap Creek and Eliza Creek. The central domain of the Project Area is drained predominantly by Tea Tree Hollow and Dog Trap Creek which flow generally north and eastward toward the Bargo River. A small area on the south western side of the central domain is drained by headwater tributaries of Hornes Creek which flows into the Bargo River at Picton Weir (HEC 2018a).

The eastern Project Area is predominantly drained by Eliza Creek which flows generally northward to the Nepean River. A small part of the eastern Project Area is also drained by Cow Creek and Carters Creek, which flows north-eastward to the Nepean River (HEC 2018a).

Thirlmere Lakes

The Thirlmere Lakes lie to the west of the existing Tahmoor Mine (approximately 3 kilometres from the subsidence area) (Figure 3), in the upper reaches of Blue Gum Creek, which ultimately flows to Lake Burragorang (Warragamba Dam). Thirlmere Lakes lie within the Thirlmere Lakes National Park which is part of the Greater Blue Mountains World Heritage Area and is mapped as 'Key Fish Habitat' (DPI 2017c). The Lakes are a series of five interconnected Lakes (in order from most upstream to downstream): Gandangarra, Werri Berri, Couridjah, Baraba and Nerrigorang. The nearest Tahmoor Mine longwall panels to the Thirlmere Lakes were mined between 1996 and 2002 and were located approximately 600 metres from Lake Couridjah.

4.2.4 Hydrology

Catchment modelling was undertaken in the Surface Water Baseline Study (HECON 2018a) using deterministic models, which are configured to simulate catchment characteristics important to the environmental assessment. The modelling results suggest that there may be a transmission loss in the Dog Trap Creek catchment and perhaps in Eliza Creek. The base flow makes a substantial less contribution to flow in Dog Trap Creek the Bargo River Upstream. The rate that groundwater drains out of storage and into the Bargo River upstream is substantially slower than in Dog Trap or Eliza Creek. Stream flow characteristics of each creek have been described in the Surface Water Baseline Study (HEC 2018a).

4.2.5 Watercourses

The type of topography described above usually provides a series of pools and riffle sections in 1st and 2nd order creeks, which provide important macro-invertebrate habitat and fish refuge. The higher order streams are typically broader and provide habitat for larger fish species (NSW DoP 2008). Within the

Project Area there are eight named creeks ranging from1st order to 4th order creeks (using Strahlers' 1952 stream order system).

Bargo River is the main watercourse within the Project Area and is located on the western side of the Project Area. Bargo River is a tributary of the Nepean River and falls within the Bargo River sub-catchment, which is the smallest sub-catchment (130.70 km^2) of the Hawkesbury Nepean catchment. It contains two reaches separated by the Bargo reservoir. Reach one, Bargo R1, is considered to be in near natural condition, while Bargo R2 is experiencing some degradation from mining activity impacts and exhibits poor riparian zone condition. In addition, Picton Weir upstream is also having a negative effect on this reach (HNCMA 2006) as it affects the natural flow of the river downstream.

Following its confluence with Bargo River, the Nepean River continues to flow north, through the Nepean River sub-catchment, eventually flowing into the Hawkesbury River which enters the Pacific Ocean. Both the Bargo River and Upper Nepean River sub-catchments form part of the Western Sydney Region of the Hawkesbury-Nepean Catchment Management Authority (CMA).

4.2.6 Vegetation

The riparian vegetation around Bargo River is dominated by Hinterland Sandstone Gully Forest. This vegetation community also occurs around Hornes Creek, Dog Trap Creek and Cow Creek. Cumberland Shale Sandstone Transition Forest is mapped along parts of Eliza Creek, Dry Creek and Carters Creek, while areas of Sydney Hinterland Transition Woodland occur predominantly along Eliza Creek and Dog Trap Creek (Tozer 2010). Spiny-head Mat-rush *Lomandra longifolia* is very common along creeks, and has extensively colonised the low-level areas of all potential impact streams within the Project Area.

4.3 Water quality

4.3.1 Baseline watercourse monitoring

Water quality monitoring was conducted by Tahmoor Coal at all baseline stream flow monitoring sites in the Project Area from early 2012 to June 2015 and reported by Hydro and Engineering Consulting (HEC 2018a). Water quality parameters tested include aluminium, arsenic, barium, cadmium, chromium, copper, iron, lead, mercury, selenium, magnesium, sodium, potassium, arsenic, sulphate, zinc, pH, electrical conductivity, turbidity, chloride and calcium carbonate hardness. The baseline water quality data was assessed against ANZECC guideline (ANZECC 2000) trigger levels for the protection of Aquatic Ecosystems and Recreational Uses in accordance with the perceived principal beneficial uses of the surface water resources in the area. A summary of the major findings of the baseline water quality monitoring program for each watercourse presented in HEC 2018a are provided below.

Cow Creek

At the Cow Creek monitoring site there have been twenty exceedances of the aquatic ecosystem guideline trigger value for zinc and three for copper. There have also been exceedances of both the aquatic ecosystem and recreational use guideline trigger values for aluminium, cadmium and pH. The median concentrations of aluminium and zinc have exceeded the guideline trigger values for protection of aquatic ecosystems. All other parameters were below guideline trigger values.

Carters Creek

At the Carters Creek monitoring site there have been twenty nine exceedances of the aquatic ecosystem trigger for zinc and nine for copper. There have also been exceedances of both the aquatic ecosystem and recreational use triggers for aluminium, pH, turbidity and cadmium. The median concentrations of aluminium and zinc exceeded the trigger values for protection of aquatic ecosystems. All other parameters were below guideline trigger values.

Dry Creek

At the Dry Creek monitoring site, there have been twenty seven exceedances of the aquatic ecosystem guideline trigger value for zinc, two for lead and nine for copper. There have also been exceedances of both the aquatic ecosystem and recreational use guideline trigger values for aluminium. The median concentrations of aluminium and zinc both exceeded the guideline trigger values for protection of aquatic ecosystems. All other parameters were below guideline trigger values.

Eliza Creek

At the Eliza Creek monitoring site, there have been thirty four exceedances of the aquatic ecosystem guideline trigger value for zinc, four for lead and seventeen for copper. There have been exceedances of the recreational guideline value for chloride and iron. There have also been exceedances of both the aquatic ecosystem and recreational use guideline trigger values for aluminium. The median concentrations of copper and zinc have exceeded the guideline trigger values for protection of aquatic ecosystems. All other parameters' median values were below the guideline trigger values. Compared to the other monitoring sites, the concentrations of sodium and chloride in Eliza Creek have been elevated.

Dog Trap Creek

At the Dog Trap Creek Downstream there have been twenty two exceedances of the aquatic ecosystem guideline trigger for zinc and six for copper. There have been seven exceedances of the iron guideline trigger value for recreational use. There have also been exceedances of both the aquatic ecosystem and recreational use guideline trigger values for aluminium. The median concentrations of aluminium and zinc have exceeded the guideline trigger values for both protection of aquatic ecosystems and recreational use. All other parameters were within guideline trigger values.

Water quality at the Dog Trap Creek upstream site was generally similar to the downstream site. There have been thirty one exceedances of the aquatic ecosystem trigger value for zinc and seven for copper. There have been nine exceedances of the iron guideline trigger value for recreational use. There have also been exceedances of both the aquatic ecosystem and recreational use trigger guideline values for aluminium. The median concentrations of aluminium and zinc have both exceeded the guideline trigger values for protection of aquatic ecosystems. All other parameters were below guideline trigger values.

Tea Tree Hollow

At the Tea Tree Hollow monitoring site, which is downstream of the Tahmoor Mine licenced discharge point LDP 1, there have been twenty six exceedances of the aquatic ecosystem guideline trigger value for zinc, twenty six for selenium, eight for lead, twenty six for arsenic and twenty for copper. There have also been exceedances of both the aquatic ecosystem and recreational use guideline trigger values for aluminium, arsenic and selenium. The median concentrations of aluminium, arsenic, copper, selenium, pH and zinc exceeded the guideline trigger values or ranges for protection of aquatic ecosystems. Compared to the other monitoring sites the concentrations of sodium and bicarbonate have been elevated.

Hornes Creek

All but two of the samples collected from Hornes Creek exceeded the guideline trigger value for protection of aquatic ecosystems for zinc. There were five exceedances of the guideline trigger value for protection of aquatic ecosystems for cadmium and eight for copper. There were sixteen exceedances of the iron guideline trigger value for recreational use. There were sixteen exceedances of the aquatic ecosystem guideline trigger range for pH and five exceedances of the turbidity guideline trigger value. There have also been exceedances of both the aquatic ecosystem and recreational use guideline triggers for aluminium and selenium. The median concentration of aluminium and zinc exceeded the guideline trigger values for protection of aquatic ecosystems.

Bargo River

All but two of the samples collected at the Bargo River Upstream exceeded the zinc guideline trigger for protection of aquatic ecosystems. There were fifteen exceedances of the iron guideline trigger for recreational use and one for barium. There have also been exceedances of both the aquatic ecosystem and recreational use guideline trigger values for aluminium, arsenic and cadmium. The median concentrations of aluminium and zinc exceeded the guideline trigger values for protection of aquatic ecosystems.

The concentrations of bicarbonate and sodium at the Bargo River at Rockford Bridge, were noticeably higher than at the upstream sites on the Bargo River. It is presumed that this reflects the effects of licensed releases from LDP1 at the Tahmoor pit top via Tea Tree Hollow. All but one of the samples collected exceeded the guideline trigger for protection of aquatic ecosystems for zinc. There were twelve exceedances of the guideline trigger for protection of aquatic ecosystems for arsenic, six for copper and four for lead. There were eighteen exceedances of the guideline trigger for recreational use for bicarbonate, seventeen for sodium, and twenty three for barium. There have also been exceedances of both the aquatic ecosystem and recreational use guideline trigger values for aluminium, arsenic and selenium. The median concentrations of aluminium, arsenic, selenium, zinc and pH have exceeded the guideline trigger values for protection of aquatic ecosystems.

Temporal water quality monitoring

A history of key water quality indicators were recorded by Hydro and Engineering Consulting (HEC 2018a) at Tea Tree Hollow, Dog Trap Creek (downstream) and Eliza Creek monitoring sites. The following specific observations were presented in HEC 2018a:

- Electrical conductivity (an indication of salinity) has been significantly higher and more variable at the Eliza Creek monitoring site than at other sites.
- pH values have been within or close to the ANZECC guideline range (6.5 to 8.5) - at all three monitoring sites. Relatively higher values have been recorded at Tea Tree Hollow and relatively lower values have been recorded at the Eliza Creek monitoring site.
- Turbidity has been consistently relatively low at the Dog Trap Creek monitoring site. Relatively elevated levels have been recorded at the Eliza Creek monitoring site.
- Sulphate has been consistently low at Tea Tree Hollow and higher and more variable at the Dog Trap and Eliza Creek monitoring sites.
- Aluminium concentrations have been highly variable at all three monitoring sites.
- Arsenic concentrations have been low at the Dog Trap and Eliza Creek monitoring sites but occasionally elevated and highly variable at the Tea Tree Hollow monitoring site.
- Iron concentrations have been low at the Tea Tree Hollow and Eliza Creek monitoring sites and occasionally elevated at the Dog Trap Creek monitoring site.
- Manganese concentrations have been highly variable but uncorrelated between monitoring sites. More persistent elevated concentrations have been recorded at the Eliza Creek monitoring site.

Results of water quality monitoring data collected as part of the baseline aquatic assessment for this report is discussed in Section 5.3.

4.4 Mine water discharge – water quality and aquatic ecology

4.4.1 PRP 22 – Mine water treatment plant

PRP 22 states: *"The treatment process must reduce concentrations of arsenic, nickel and zinc to levels below the default 95%ile trigger values for protection of aquatic ecosystems specified in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000) in the Bargo River downstream of the confluence with Tea Tree Hollow."*

The completion of construction under the Waste Water Treatment Plant was achieved during July 2015, however as outlined in Section 2.4.2, improvements are required for the plant to operate efficiently. The upgrades are expected to be implemented by November 2018, and are expected to reduce concentrations of arsenic, nickel and zinc to acceptable limits.

4.4.2 PRP 23 - Aquatic ecology investigation

PRP 23 states: "*The Licensee must conduct an aquatic health monitoring investigation in Tea Tree Hollow and the Bargo River. The main objective of the investigation will be to define site specific trigger values for electrical conductivity in the Bargo River, and recommend suitable discharge concentration limits for electrical conductivity at Licensed Discharge Point.*"

The results from the PRP 23 investigation (Cardno 2016) found that there is an apparent effect of the discharge on aquatic ecology in Tea Tree Hollow and Bargo River with a reduction in pollution sensitive invertebrates and an increase in pollution tolerant invertebrates downstream of the Discharge Point. However, the report found that the impairment was not excessive, in the context of a system modified by other anthropogenic land uses. The results of the field study suggest that the effect of the discharge on aquatic ecology appears localised to within a few kilometres downstream of the Discharge Point that includes Tea Tree Hollow and the Bargo River.

Based on conclusions for CEL (2016), there is no strong justification for the need to improve ecological health by further reductions in EC levels. While there was evidence of an effect of the discharge on the aquatic ecology of Tea Tree Hollow and at locations on the Bargo River, these effects appear to be localised to areas immediately downstream of the Discharge Point in the Bargo River and elevated levels are not likely in the Nepean River. The study found that:

- *"While EC experienced at LDP1 is elevated, levels are not considered to be excessive. Current EC levels in the Bargo are also not considered to be excessively high with respect to the reported tolerances of many aquatic biota present in Tea Tree Hollow and the Bargo River. Previous studies have indicated that the Bargo River and Tea Tree Hollow support functioning aquatic ecosystems as indicated by the presence of aquatic macroinvertebrates that are relatively sensitive to elevated EC. Furthermore, once water from the Bargo River enters the Nepean River a few kilometres downstream from Tea Tree Hollow, EC values would further reduce following dilution. The effect of the mine water discharge (due to elevated EC at least), if any, would likely be limited to the lower reaches of the Bargo River only, and would be very unlikely to affect the wider catchment.*
- *Measures to reduce EC at LDP1 would likely result in reduced flow in Tea Tree Hollow and the Bargo, as discharge water would likely be re-used on site. Discharge from LDP1 constitutes a substantial proportion of flow in the Bargo, and any reduction in flow would likely have consequences on aquatic ecology, such as reductions in habitat area and connectivity. Thus, there may be no net benefit of reducing EC to aquatic ecology given if it resulted in reduced flow (and habitat connectivity) in Tea Tree Hollow and the Bargo River.*
- *The results of the modelling indicate that EC at LDP1 has less influence on EC levels on the Bargo River than flow at LDP1 and background levels of EC and flow in the Bargo. The amount of variation present in these predictors, and thus the relatively large range of EC levels required at LDP1 to achieve the PC80*

on the Bargo, could make implementing a suitable EC limit at LDP1 problematic, unless a very conservative level of EC at LDP1 was implemented."

5. Results

5.1 Threatened species searches

A search of Fisheries NSW Spatial Data Portal (DPI 2017b) showed one species, the Macquarie Perch, having indicative distribution in the Hawkesbury/Nepean Catchment. The EPBC protected matters search tool also reported the Macquarie Perch within a 10 kilometre radius of the Project Area. Species listed under the FM Act with potential habitat within the Project Area that were not shown on the DPI database portal were also considered. NSW NPWS Wildlife database showed one threatened insect, the Giant Dragonfly with an aquatic larval stage, recorded within a 10 kilometre radius of the Project Area. As a result of the database searches, the following four species were included as Subject Species:

- Macquarie Perch,
- Giant Dragonfly,
- Sydney Hawk dragonfly, and
- Adam's Emerald dragonfly.

The likelihood of occurrence of these Subject Species within the Project Area based on habitat assessment and the known habitat requirements of each species is considered in Appendix A. Table 8 summarises the Subject Species and their likelihood of occurrence in the Project Area. Only the Sydney Hawk Dragonfly, is considered to have potential habitat within the Project Area.

Results of targeted surveys for this species are provided in Section 5.8 and the assessment of significance for this species is provided in Appendix I. It is considered unlikely that the Project will have a significant impact on the Sydney Hawk Dragonfly.

Table 8: Threatened aquatic species recorded within the locality and likelihood of occurrence

Scientific Name	Common Name	Status	Likelihood of occurrence rating
Austrocordulia leonardi	Sydney Hawk Dragonfly	Endangered FM Act	Moderate. Potential habitat occurs in the Bargo/Nepean River
Archaeophya adamsi	Adam's Emerald Dragonfly	Endangered FM Act	Low. Only one potential riffle habitat located which will not be impacted by the proposal.
Petalura gigantea	Giant Dragonfly	Endangered BC Act	Low. No suitable swamp habitat.
Macquaria australasica	Macquarie perch	Endangered EPBC Act, FM Act	Low. Potential habitat occurs in the Bargo/Nepean River outside of the Project Area.

5.2 Habitat monitoring

Subsidence monitoring sites are shown in Figure 3 and mine water discharge monitoring sites in Figure 4

5.2.1 Subsidence monitoring sites

Table 9 details the habitat at each monitoring site.

Potential impact sites

The majority of the creeks within the Project Area had a lower stratum riparian zone dominated by Spiny-headed Mat-rush (*Lomandra longifolia*) and had a high percentage of bedrock and boulders instream. Habitat attributes within these creeks included pools with bank overhang and trailing bank vegetation, rock bars, small waterfalls and sections of dry bed dominated by Spiny-headed Mat-rush and boulders. Hornes

Creek and Tea Tree Hollow had an obvious orange discolouration of the water, iron flocs and algae present... Macrophytes were uncommon (Table 9). Many of the creeks contained freshwater yabbies *Cherax destructor*, freshwater shrimp *Paratya australiensis* and the Mosquito Fish *Gambusia holbrooki*.

Control sites

Filamentous algae and orange discolouration was typical of some sections of Bargo River, Cedar Creek, Stonequarry Creek, Carters Creek and Eliza Creek. Alkalinity of the water was low at the majority of the control sites and appeared to be a natural condition. Moore Creek, Eliza Creek, Dry Creek, Carters Creek and Cow Creek control sites, had similar vegetation and bed characteristics to many of the potential impact sites. Both Cedar Creek and Stonequarry Creek control sites did have some similarities in bed structure, however the riparian zones were comprised of different vegetation communities and had greater exotic species coverage.

Table 9: Subsidence monitoring sites: habitat

Watercourse	Site names	Habitat description
Potential impact locations		
Dog Trap Creek	DTC9, DTC10	Dog Trap Creek is a 3rd order stream with a catchment area of 13.6 km^2 at its confluence with the Bargo River. It drains the eastern part of the Central Domain. The catchment consists of rural residential areas with mixed farming. Dog Trap Creek flows into Bargo River approximately 1 km upstream of Mermaids Pool and is characterised by areas of very steep sided valleys. The creek is dominated by bedrock and ranges in width from 1 - 7 metres with a modal width of approximately 4 metres. Habitat features include pools, small waterfalls, undercut banks, trailing vegetation, snags and boulder dominated rapid sections. The riparian vegetation has been mapped as Sydney Hinterland Transition Woodland (Tozer 2010). The canopy was observed to consist mostly of Grey Gum (*Eucalyptus punctata*) and Sydney Peppermint (*E. piperita)*, with the middle stratum dominated by *Melaleuca* sp*., Leptospermum* sp*., Acacia* sp., and Black Wattle *Callicoma serratifolia*. The lower stratum was dominated by Spiny-headed Mat-rush. At both survey sites, the banks are characterised by native forest however there are rural properties upstream. The upstream survey site (DTC9) is located in a valley to the east of Charlies Point Road off a fire trail. During monitoring, a visual assessment of the water quality indicated some minor disturbance with slightly turbid waters and the instream habitat indicated some disturbance through the presence of Mosquito fish. The riparian zone showed evidence of flood damage, with large deposits of debris along the bank. The downstream survey site (DTC10) is located off a fire trail on Charlies Point Road and has similar attributes to the upstream location, however the sides of the creek are steeper with some escarpment sections. During monitoring, a visual assessment of disturbance related to human activities indicated there was minor disturbance to water quality, with a light film on the surface of the water. Instream disturbance included flood debris and there was little evidence of weed invasion. Dog Trap Creek was unable to be sampled during spring 2012 surveys as the creek was dry at sample sites and for much of the creek.
Tea Tree Hollow	TTH11, TTH12	Tea Tree Hollow is a 3rd order stream with a catchment area of 6.8 km^2 which drains the western part of the Central Domain. Tea Tree Hollow flows into Bargo River approximately 4 kilometres upstream of Mermaids Pool and the catchment contains Tahmoor Mine. The Tahmoor Mine discharges water from mine discharge point LDP1, along Tea Tree Hollow Creek. It is considered that without this discharge the creek would likely be a dry gully (CEL 2009). The riparian vegetation community at both sites along Tea Tree Hollow has been mapped as Sydney Hinterland Transition Woodland (Tozer 2010). The dominant canopy species recorded were Sydney Peppermint and Scribbly Gum *E. sclerophylla*, while the middle stratum was dominated by Black Wattle, *Melaleuca* sp., *Leptospermum* sp., *A. longifolia*, *Hakea* sp*., Pomaderris* sp., and *Lambertia formosa*. Spiny-headed Mat-rush dominated the lower stratum, with some ferns, exotic grasses and exotic herbs also present. The bed of the creek was highly influenced by the mine operations, with unnatural sediment deposits (barium precipitate) present. Habitat attributes include pools with undercut banks and trailing vegetation, riffle sections, snags and small drop offs. The upstream survey site (TTH11) is located downstream of a cleared track that crosses the creek. The site is upstream of mine discharge point LDP4 and access along this track is through the mine site. During monitoring, a visual assessment of disturbance related to human activities indicated some influence from the mine water discharge entering downstream, with slightly turbid waters observed. Water flow at this site was minimal. Instream evidence of disturbance included the presence of Mosquito fish, filamentous algae, gravel and dirty coloured sediments. There was also evidence of moderate weed invasion from Crofton Weed in the riparian vegetation. The original downstream survey site (TTH12) is located downstream of LDP4. During monitoring, the creek was observed to be flowing on all monitoring occasions (from mine water discharge) and the waters appeared turbid and some foam was present on the surface of the water. Instream evidence of disturbance included the presence of Mosquito fish, filamentous algae, gravel and dirty coloured sediments. There was also evidence of disturbance of the riparian vegetation, with some walking tracks in the vegetation and exotic grasses. As discussed in Section 3.4.2, the modification of mine discharge site LDP4 to a high flow discharge point only in mid-2013 necessitated a change in the downstream monitoring site to below the main mine water discharge LDP1 (TTH12a). The downstream site on Tea Tree Hollow Creek (TTH12a) is located downstream of LDP1. During monitoring, a visual assessment of disturbance related to human activities reported clear water however the instream environment had been highly compromised, with extensive development of a dark-coloured crystalline precipitate over the substrate (Plate 3). Samples of the deposit were collected for

		Tahmoor Coal. The subsequent laboratory analysis by ALS indicated that the deposit was high in barium, iron, aluminium and manganese. The high level of heavy metals is due to the precipitation from the discharged mine water over the extended 30 years of operation of the Tahmoor Mine, with the heavy metals in the mine water most likely derived from the leaching of coal (Singh et al. 1998).
Hornes Creek	HC13, HC14	Hornes Creek is a 4th order stream with a total catchment of 19.5 km^2. Approximately 3% (0.585km^2) of its catchment lies within the Project Area. The catchment consists of native bushland (owned by the mine) and a portion of the township of Bargo. Hornes Creek flows into Bargo River approximately 100 metres upstream of the Picton Weir. The bed is dominated by bedrock and habitat features include bank overhang, trailing bank vegetation, snags and small waterfalls. The upstream monitoring site on Hornes Creek (HC13) is a 3rd order stream and is located upstream of the Ashby Close road crossing. The riparian vegetation has been mapped as Sydney Hinterland Transition Woodland (Tozer 2010). The dominant canopy species consisted of large smooth barked eucalypt species with a middle stratum dominated by Black Wattle, *Melaleuca* sp., *Leptospermum* sp., *A. longifolia*, *Hakea* sp., *Pomaderris* sp. and *Banksia* sp. The lower stratum was dominated by Spiny-headed Mat-rush, *Banksia spinosa* and native sedges *S. melanostachys* with some ferns. During monitoring, a visual assessment of disturbance related to human activities indicated moderate disturbance in water quality, with orange discolouration. Instream disturbance was also observed with filamentous algae and Mosquito Fish present. Only minor disturbance to the riparian zone was observed. The downstream monitoring site (HC14) is located in a remote section of Hornes Creek and is accessible via a fire trail PC2. The riparian vegetation at this site has been mapped as Hinterland Sandstone Gully Forest (Tozer 2010) and the canopy is dominated by Sydney Peppermint and Scribbly Gum, while the middle stratum is dominated by Black Wattle, *Melaleuca* sp., *Leptospermum* sp., *A. longifolia* and *Hakea* sp. Spiny-headed Mat-rush dominated the lower stratum, with some ferns, exotic grasses and herbs and *Lambertia formosa* also present. During monitoring, a visual assessment of disturbance related to human activities indicated slight disturbance through the presence of orange discoloration in the water column, Mosquito Fish, and some plastic bottles in the stream, along with some evidence of flood damage to the riparian zone.
Bargo River	BR15, BR16	Bargo River is a tributary of the Nepean River; however it and its watercourses fall within the Bargo River sub-catchment, which is the smallest sub-catchment (130.70 km^2) of the Hawkesbury Nepean catchment. It contains two reaches separated by the Picton Weir. Reach one (Bargo R1) is considered to be in near intact condition, while the second reach downstream (Bargo R2) is experiencing some degradation from mining activity impacts and damage from local access to the riparian zone. Picton Weir itself is also having a negative effect on this reach (HNCMA 2006). The Bargo River is a 5th order perennial stream. The river commences near the townships of Hill Top and Yerrinbool, flows to the west of the proposed longwalls, to where it drains into the Nepean River approximately 1.1 kilometres north-west of the proposed LW202. Approximately 450 metres of the Bargo River is located just inside the Project Area. The surface water flows in this section of the Bargo River are controlled by the Picton Weir (also called the Bargo Weir) and licensed discharge from Tahmoor Mine, which enters the river via Tea Tree Hollow. Reports by Fluvial Systems (2013) and Hydro and Engineering Consulting (HEC 2018a) further describe this river. The Bargo River valley within the Project Area is typically between 20 and 40 metres high, comprising cliffs, rock outcrops and talus slopes in a number of locations. The river bed consists of a series of pools, rock bars, riffles and boulder fields. The average natural gradient of this section of the river is around 20 millimetres/metre (i.e. 2 %, or 1 in 50). The riparian vegetation in this section of the Bargo River has been mapped as Hinterland Sandstone Gully Forest (Tozer 2010) and is characterised by rainforest species. Habitat features include bedrock bars and pools, boulders, overhanging bank, trailing vegetation, snags and riffle sections. Water was flowing from the Weir at the time of all monitoring occasions. The upstream monitoring location on Bargo River (BR15) is located in a steep valley approximately 1 kilometre downstream of Picton Weir, where it is a 4th order stream. The width of this section of river is from 7 - 15 metres with a modal width of approximately 7 metres. During surveys, a visual assessment of disturbance related to human activities indicated only little disturbance to the water quality and instream habitat, with moderate disturbance of the riparian zone through the proximity of a fire trail and the presence of the Weir itself altering natural flows and depths. The downstream monitoring location (BR16) is located approximately 1.7 kilometres downstream of the Picton Weir, again in a steep-sided valley. The width at this point is 2 - 12 metres with a modal width of 5 metres. During surveys, a visual assessment of disturbance related to human activities indicated a more moderate level of disturbance to the water quality with foam observed on the surface of the water. Presence of Mosquito Fish indicated some instream disturbance and the riparian zone has been considerably modified through the construction of a fire trail and changes to the water flows following construction of the Weir.
Control locations		
Bargo River tributary	CBR1, CBR2	The control sites on Bargo River are located downstream of the Picton Weir, upstream of the Project Area and within a steep-sided gorge. Both locations are mapped as Hinterland Sandstone Gully Forest (Tozer 2010). The upstream control site (CBR1) is located approximately 400 metres downstream of the Weir. At this point, the river is wide, ranging from 4 - 14 metres with a modal width of 10 metres within the 100 metre reach. The middle stratum species were dominated by *Cyperus* sp. and *Melaleuca* sp., while the lower stratum contained sedges *S. melanostachys* and *L. laterale*, with some Bracken Fern (*P. esculentum*) and Coral Fern (*Gleichenia microphylla*). Emergent macrophytes contributed 30% of the surface water area at this site. The water was deep and the substrate consisted of silt and clay. During monitoring, a visual assessment of disturbance related to human activities indicated a moderate level of disturbance to the water quality with turbidity observed. Instream environment contained some rubbish and the riparian zone was impacted by changes to the natural hydrology (Picton Weir), the proximity of the fire trail and the presence of rubbish. The second control site (CBR2) is located on a 3rd order tributary that joins with Bargo River approximately 600 metres downstream of Picton Weir. The creek is characterised by bedrock and boulders, with a smaller percentage of cobbles and smaller substrate. The riparian vegetation at this site consists of tall eucalypts and she-oaks with some rainforest species. The width of the stream ranged from 1 - 4 metres with a mode of 3 metres. Both sides of the creek at this location are characterised by native forest. A visual assessment of

		the water quality and riparian zone indicated slight disturbance to the water quality, with an oily film present. The instream environment had been impacted by the constructed fire trail crossing at the creek and there was evidence of weed invasion in the riparian zone.
Moore Creek	CMC3, CMC4	Moore Creek is located outside the Project Area, to the west of the railway line and within Bargo State Recreation Area. It flows into Little River which flows north into Lake Burragorang which merges with the Nepean River. The first control site on Moore Creek (CMC3) is located in a steep valley to the south west of the town of Balmoral. Access to the site is via Bolan Road fire trail. As with many of the potential impact sites, the canopy vegetation is dominated by Sydney Peppermint and Grey Gum, however the middle and lower stratum vegetation differed at this site as Spiny-headed Mat-rush was not dominant. Present were Hop Bush (*Dodonea triquetra*) and Tea Tree (*Leptospermum* sp.) and Devils Twine (*Cassytha* sp.), along with sedges *S.melanostachys* and Bracken Fern. The creek bed comprises large amounts of detritus, with some boulders. Habitat attributes include pools with trailing bank vegetation and some rock bars and associated drops and a lot of snags. During monitoring, a visual assessment of disturbance related to human activities indicated no disturbance to water quality, however there were large amounts of detritus and some exotics species present in the riparian zone near the fire trail. Alkalinity test kits were unable to provide a measure at this site and further testing is required. This site was dry during spring 2012 surveys and, as a result, a site 200 m upstream of CMC4 was selected for future sampling spring surveys. The vegetation type and site characteristics resembled CMC4. The second control site on Moore Creek (CMC4) is located approximately 500 metres upstream of its confluence with Little River where it is a 3rd order stream. Access into Bargo State Recreation Area is via foot through a locked gate. The site is a steep valley and is characterised primarily by bedrock. The riparian vegetation consists of a canopy of Sydney Peppermint and Scribbly Gum with middle stratum species such as Tea Tree., *Acacia* sp., *Callistemon* sp. and *Hakea* sp. The lower stratum was dominated by sedges *S. melanostachys*, Cone Sticks (*Petrophile* sp.) and Coral Fern. Some macrophytes were present and the width of the stream ranged from 0.5 - 6 metres with a mode of 3 metres. Both sides of the bank are characterised by native forest. A visual assessment of the water quality and riparian zone indicated no evidence of disturbance however there was some filamentous algae present. Moore Creek has similar habitat attributes to many of the potential impact locations as it is dominated by bedrock, with low shrub riparian vegetation.
Cedar Creek	CCC5, CCC6	Cedar Creek is located approximately 7 kilometres north of the northern boundary of the Project Area. It flows into Stonequarry Creek which eventually flows into the Nepean River at a point approximately 4 kilometres downstream of the Bargo River and Nepean River confluence. Both control sites on Cedar Creek (CCC5 and CC6) are located downstream of the Cedar Creek Road bridge. The sites are in a broad valley with a catchment area dominated by rural residential properties and orchards. The width of the stream ranged from 1 - 12 metres with a mode of 7 metres. The riparian vegetation has a canopy of Grey Gum and Stringybark species with a middle stratum of Hop Bush, *Melaleuca* sp., Cherry Ballarat (*Exocarpus cupressiformis*), *A. longifolia*, *Ozothamnus diosmifolium* and a lower stratum consisting of *Juncus kraussi*i along with exotic grasses and herbs. A visual assessment of the water quality and instream habitat indicated a moderate level of disturbance, with turbid looking water, orange discolouration, filamentous algae, *Typha* sp. and Mosquito fish present along with rubbish and weeds in the riparian zone.
Stonequarry Creek	CSQ7, CSQ8	Stonequarry Creek flows into the Nepean River at a point approximately 4 kilometres downstream of the Bargo River and Nepean River confluence. Its catchment area consists of rural residential areas and farmland. The upstream control site (CSQC7) is located in a newly developed rural estate, the stream exhibiting steep banks. The riparian vegetation has a canopy of *Allocasuarina* sp*.* and *E. grandis*, while the middle stratum was dominated by Cheese Tree (*Glochidion ferdinandi var ferdinandi*), Hop Bush, *Melaleuca* sp*.* and *Acacia* sp. The lower stratum consists of ferns and a large percentage of exotic species. The bed consists of boulder and bedrock with habitat attributes such as pools and riffles and some emergent macrophytes (*Persicaria decipiens*). The water was flowing at the time of survey despite a long period of dry weather. A visual assessment of the water quality and instream habitat indicated a high level of disturbance, with turbid, orange water with oily films, foam and iron flocks. The instream disturbance consisted of considerable amounts of filamentous algae and the riparian vegetation contained exotic grasses and Lantana *camara*. The downstream control site on Stonequarry Creek (CSQC8) is located under the Mulhollands Road Bridge. The riparian vegetation at this site was very different to other sites, and consisted primarily of Mahoganys in the canopy and exotics such as Privet (*Ligustrum lucidum*) in the middle stratum. The lower stratum contained some Spiny-headed Mat-rush and maiden hair ferns. The bed consisted primarily of bedrock, with some bank overhang and trailing bank vegetation. The water was flowing at the time of surveys despite a long period of dry weather. A visual assessment of the water quality and instream habitat indicated a high level of disturbance, with turbid, orange water and a considerable amount of filamentous algae in the instream environment. The riparian vegetation contained exotic weeds such as Privet and Wandering Jew (*Tradescantia fluminensis*).
Cow Creek	CWC1, CWC2	Cow Creek is a 3rd order stream at the Project Area boundary and has a catchment area of 10.1 km^2 at its confluence with the Nepean River, some 18% of which is within the Project Area. The upper reaches of Cow Creek drain a small area (Figure 3) on the south-eastern side of the Project Area at the southern end of the Central Domain. The majority of the Cow Creek catchment falls within the Sydney Water Catchment Area (SCA). Cow Creek feeds into the Nepean River approximately 5.5 kilometres upstream of the Nepean River's confluence with the Cordeaux. Cow Creek has a high frequency of exposed bedrock features in its bed and in-channel pools were common compared to other creeks within the Project Area. Habitat features such as pools, small waterfalls, undercut banks, trailing vegetation, snags and boulder-dominated rapid sections were characteristic of this creek. The bed substrate primarily consisted of a thin sediment layer over bedrock. As it flows through undisturbed forested land, it also had a relatively high frequency of in-stream wood and plant detritus/debris. Surface flow loss was observed in Cow Creek during geomorphology field surveys and was presumed to be a natural situation (Fluvial Systems 2013). At monitoring sites within Cow Creek, the riparian vegetation has been mapped as Hinterland Sandstone Gully Forest (Tozer 2010). The dominant trees observed included Stringybark species and Sydney Peppermint. The middle stratum consisted of *Melaleuca* sp*.*, *Leptospermum* sp., *Banksia* sp. and *Persoonia* sp., while the lower stratum was dominated by Bracken Fern and *Blechum* sp. The width of the creek varied from 0.5 to 8 metres, with the modal width being ~ 3 metres.

		The upstream site CWC1 is at a junction where the creek becomes a 3rd order stream. This junction is in close proximity to a proposed longwall and represents a catchment area of approximately 220 hectares, all of which occurs within the Project Area. During monitoring, visual assessments of disturbance related to human activities indicated some turbidity in the water column, and the creek bed contained fallen debris from previous floodwaters, however there was no evidence of in-stream disturbance or disturbance to the riparian zone either through weed invasion or clearing. The second site CWC2 is located outside of the Project Area and further downstream where other first order tributaries (that are sourced within the Project Area) have entered the creek. At this point, the catchment area is approximately 325 hectares, of which is within the Project Area. During monitoring, there was no evidence of disturbance to the water quality, instream habitat or riparian zone.
Carters Creek	CC3, CC4	Carters Creek is a 3rd order stream at the Project Area boundary. It drains a total area of 6.4 km^2 at its confluence with the Nepean River, some 35% of which is within the Project Area. The upper reaches of Carters Creek drain a small area (Figure 3) on the south-eastern side of the Project Area, near the southern end of the Eastern Domain. The catchment of this creek consists mostly of rural residential properties and mixed rural agricultural properties. Along much of Carters Creek in the rural areas the riparian zone remained intact. Carters Creek feeds into the Nepean River approximately 2.5 kilometres downstream of the Nepean/Cordeaux River confluence. The width of the creek varied from 0.5 to 8 metres, with the modal width being ~ 3 metres. Habitat features such as pools, small waterfalls, undercut banks, trailing vegetation, snags and boulder-dominated rapid sections were characteristic of this creek. The bed substrate primarily consisted of bedrock. A substantial ferruginous seep was observed on Carters Creek and was thought to be associated with water that had seeped through the wall of a farm dam located immediately upstream (Fluvial Systems 2013). At monitoring sites within Carters Creek, the vegetation was unmapped (Tozer 2010). The dominant canopy species observed at both survey sites included Grey Gum and Sydney Peppermint, while middle stratum was dominated by *Allocasuarina littoralis* at CC3 and *Melaleuca* sp., *Acacia longifolia* at CC4. The lower stratum was dominated by Spiny-headed Mat-rush at both sites, with some ferns (Bracken Fern and *Adiantum aethiopicum*) present. The upstream monitoring site (CC3) is located just below the junction where the creek becomes a 3rd order stream. The catchment area at this site is approximately 244 hectares, which is wholly within the Project Area. During monitoring, a visual assessment of disturbance related to human activities indicated there was moderate disturbance of water quality, with an oily film observed on the surface and orange discolouration and some iron flocs observed in the water. Filamentous algae and the introduced Mosquito Fish were also observed instream indicating moderate disturbance. The riparian vegetation showed no evidence of clearing, bank destabilisation or serious weed infestation, however, Crofton Weed (*Ageratina adenophora*), which is a Class 4 noxious weed under the *NSW Noxious weeds Act 1993*, was present. The second survey site (CC4) is downstream of the Mockingbird Road bridge overpass, outside of the Project Area. This site encompasses the northern arm of Carters Creek, which is also within the Project Area. Some sections of the creek appeared to have little to no water, with the drainage line defined only by a high density of Spiny-headed Mat-rush. Disturbance to water quality at this site was evident by minor orange colouration of the water. There was some rubbish instream along with Mosquito Fish, and walking tracks occurred throughout the riparian vegetation. Smaller amounts of Crofton Weed was observed along with some exotic grasses.
Dry Creek	DC5, DC6	Dry Creek is a 2nd order stream at the Project boundary and is located in the eastern portion of the Project Area with all of its catchment within the Project Area (Figure 3). The proposed longwall runs under a length of nearly 2 kilometres of the creek bed. The catchment of this creek consists mostly of rural residential properties with some mixed farming e.g. poultry and hobby farms. Dry Creek feeds into the Nepean River approximately 1.7 kilometres upstream of its confluence with the Bargo River. Habitat features such as pools, small waterfalls, undercut banks, trailing vegetation, snags and boulder dominated rapid sections were characteristic of this creek. The bed substrate primarily consisted of bedrock. The creek was dominated by little to no water flow, where the creek bed was defined only by a high density of Spiny-headed Mat-rush. At the upstream monitoring site on Dry Creek (DC5), the riparian vegetation was mapped as Cumberland Shale Sandstone Transition Forest while the downstream site (DC6) was unmapped (Tozer 2010). The canopy at both survey sites was dominated by Grey Gum, Sydney Peppermint and Stringybark species. DC6 also had some Ironbark species present. The middle stratum was dominated by *Melaleuca* sp., *Leptospermum* sp. and *A. littoralis*. The lower stratum was dominated by Spiny-headed Mat-rush, with only a small percentage cover of ferns, vines and native sedges (*Schoenus melanostachys*). The width of the creek varied from 0.5 to 8 metres, with the modal width being ~ 1 metre. The upstream survey site (DC5) is located on a section of creek that is a 2nd order stream, upstream of the Pheasants Nest Road Bridge. At this point, the catchment area is approximately 184 hectares. During monitoring, a visual assessment of disturbance related to human activities indicated there was evidence of disturbance to water quality, with orange colouration resulting in very turbid looking water. The instream habitat was also disturbed, with some rubbish evident and Mosquito Fish present along with influence from the Pheasants Nest Road Bridge in the form of structural changes to the creek in this area (rubble and revetment). The downstream site (DC6) is located close to its confluence with the Nepean River and as such, the catchment at this site encompasses nearly the entire Dry Creek catchment area. Disturbance at this site was less evident; however there was still some orange coloration and iron flocs present along with some instream rubbish. There was some evidence of walking tracks or exotic weeds within the riparian zone.
Eliza Creek	EC7, EC8	Eliza Creek is a 2nd order stream with a catchment area of 4.9 km^2 at its confluence with the Bargo River. It drains the bulk of the Eastern Domain. The longwalls are proposed both under and to run roughly parallel to Eliza Creek for a portion of its length (Figure 3). Eliza Creek feeds into the Nepean River approximately 1.4 kilometres upstream of the Nepean/Bargo River confluence. The lower reach of Eliza Creek had a high amount of exposed bedrock in the form of rock bars and rock slabs. Habitat features such as pools, small waterfalls, undercut banks, trailing vegetation, snags and boulder dominated rapid sections were observed along the creek. In some areas, the riparian vegetation along this creek had a high percentage of exotic species. A failed dam was observed on Eliza Creek during geomorphology surveys and directly upstream a deposit of fine sediment of unknown origin which appeared to contain ferruginous material was observed. Below this deposit, the creek had an orange discolouration (Fluvial

		Systems 2013). The ferruginous colloids suspended in the water and filamentous algae were observed downstream of the deposit. The deposit and failed dam occur between EC7 and EC8. At the upstream monitoring site (EC7), the riparian vegetation has been mapped as Sydney Hinterland Transition Woodland (Tozer, 2010). The upper canopy at this site was dominated by Grey Gum, Sydney Peppermint, and Blue Gum (*E. saligna*), while the middle stratum contained *A. littoralis*, *Acacia* sp., *M. nodosa*, *P. linearis* and *Leptospermum* sp. The lower stratum was the dominant layer and was dominated almost entirely by Spiny-headed Mat-rush, with occasional sedges (*S. melanostachys*) and ferns (Bracken Fern *and A. aethiopicum*). The width of the creek ranged from 1 – 5 metres, with a modal width of approximately 2 metres. The EC7 site has a catchment area of approximately 234 hectares which consists of farmland with grazing cattle and sheep. During monitoring, a visual assessment of disturbance related to human activities indicated that there was little evidence of disturbance at this site, with some turbidity in the water column, Mosquito Fish were present and there was minor presence of weeds and disturbance in the riparian zone. The creek bed was dominated by boulders, with areas of dry creek bed marked only by Spiny-headed Mat-rush. The downstream site (EC8) is located off Lyrebird Road, approximately 1 kilometres upstream of its confluence with the Nepean River. The riparian vegetation at this site has been mapped as Hinterland Sandstone Gully Forest (Tozer 2010). The upper stratum was dominated by Grey Gum and Sydney Peppermint, while the middle stratum consisted *of A. littoralis* and *Leptospermum* sp. Spiny-headed Mat-rush was the dominant species along the creek, with some *S. melanostachys*. The creek bed at this site was dominated by bedrock. During monitoring, a visual assessment of disturbance related to human activities indicated that the water quality at this site was highly disturbed, with a strong orange colouration, an oily film and foam on the surface. Instream habitat was also highly disturbed, with filamentous algae present and *Typha* sp. Some exotic species were also observed in the riparian zone.

5.2.2 Mine water discharge monitoring sites

Table 10 details the habitat at each monitoring site.

Table 10: Mine water discharge monitoring sites: habitat

Location	Site names	Habitat description
Potential impact locations		
Tea Tree Hollow Creek - downstream	TTH12 (2012 – 2013), TTH12a (2013)	The mine discharge monitoring sites in Tea Tree Hollow are the same as those used for subsidence monitoring (TTH11, TTH12 and TTH12a) and have been described in Table 9. Tea Tree Hollow is an ephemeral tributary which flows naturally only after significant localised rainfall. Mine water discharged into the creek therefore constitutes most of the flow and also contributes a large proportion of flow to the Bargo River downstream of the confluence with Tea Tree Hollow. In the absence of mine discharge, Tea Tree Hollow and the Bargo River would become a series of isolated pools during drought periods (CEL 2011).
Bargo River – downstream	SBR5, SBR6, SBR7, SBR8	Survey site SBR5 is located approximately 350 metres downstream of the Tea Tree Hollow confluence and SBR6 is located a further 500 metres downstream. At both sites, the river width ranges from 4 - 12 metres with a modal width of 6 metres. The substrate is mainly bedrock with some boulder riffle sections between pools. The valley is steep with moderate shading of the river from riparian vegetation. A visual assessment of disturbance related to human activities taken during surveys indicates little disturbance to the quality of the water and instream habitat. The riparian zone was mostly intact. Survey sites SBR7 and SBR8 are near Rockford Bridge, approximately 2.5 kilometres downstream of the Tea Tree Hollow confluence. At this point along the Bargo River, the width ranges from 5 - 20 metres with a modal width of 10 metres. The valley is steep sided, with low-moderate shading along the river from riparian vegetation and the substrate was mostly bedrock. A visual assessment of disturbance related to human activities taken during surveys indicated little disturbance to the quality of the water and instream habitat. The riparian zone was mostly intact. There was moderate instream disturbance in the form of bridge piers and artificial substrate at Rockford Bridge.
Control locations		
Tea Tree Hollow Creek - upstream	TTH11	The mine discharge monitoring sites in Tea Tree Hollow are the same as those used for subsidence monitoring (TTH11, TTH12 and TTH12a) and have been described in Table 9.
Bargo River - upstream	SBR1, SBR2, SBR3, SBR4	Survey sites SBR1 and SBR2 are located downstream of Picton Weir and are described in Table 9 as Bargo River (sites BR15 and BR16). This location was within the Project Area boundary and as such considered as a potential impact site for subsidence analysis, however as there will be no subsidence impacts on this location, it is considered suitable as a control location for the analysis of potential surface works impacts. Survey sites SBR3 and SBR4 are located immediately upstream of Remembrance Driveway. Here the river is located in a broad valley with a lower level of shading from riparian vegetation. The width at this point ranges from 10 – 20 metres with a modal width of 12 metres. The substrate was mainly bedrock. A visual assessment of disturbance related to human activities taken during surveys indicates little disturbance to the quality of the water, with some orange discolouration present, moderate instream disturbance based on the presence of filamentous algae, exotic Mosquito Fish and some instream rock construction at SBR4. The riparian zone was moderately to highly disturbed, with a cleared grassy reserve on the left bank and a 60 metre wide riparian strip separating the river from Remembrance Driveway on the right bank.

5.3 Water quality monitoring (AUSRIVAS)

Default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems (upland rivers) are available for pH, DO%, salinity (conductivity (µS/cm)) and turbidity (NTU) (ANZECC, 2000).

5.3.1 Subsidence monitoring sites

Water quality field data for subsidence monitoring sites is provided in Appendix D. Table 11 shows monitoring events where water quality parameters were triggered for each site.

pH and Alkalinity

No distinct patterns were observed for pH with most sites experiencing fluctuations below, within and above ANZECC trigger values. However site TTH12 (downstream of the mine water discharge) was consistently elevated above ANZECC trigger values. Alkalinity levels varied throughout the sampling period. However were consistently low during sampling in autumn 2012, spring 2012 and autumn 2013 at the control locations: Bargo River, Moore Creek and Cedar Creek (Appendix D). Low alkalinity means that there is less buffering capacity against changes in pH.

Dissolved oxygen

Generally, dissolved oxygen was depressed among all streams falling below ANZECC trigger values with exception of sampling in June 2012 (Table 11, Appendix D). Low dissolved oxygen is expected in streams, particularly those of low order, in times of low or no visible flow.

Electrical Conductivity/Salinity

During two years of monitoring, EC exceeded the ANZECC trigger values consistently at a number of sites within the Project Area particularly at the Tea Tree Hollow downstream sites , which exceeded trigger values by four times and reached concentrations greater than 1000 µS/cm. Of the control sites, Stonequarry Creek and Eliza Creek consistently exceeded trigger levels. It is thought that groundwater is contributing to the higher concentration in Eliza and Stonequarry Creeks whereas Tea Tree Hollow is the result of mine water discharge.

Turbidity

Generally turbidity was quite low among all streams, however there were occasions, notably in November 2012, and October 2013, when trigger values were exceeded (Table 11, Appendix D). The turbidity results were expected for streams in the area and likely related rainfall and subsequent flow. There were no obvious sites that had significantly high turbidity.

Table 11: Triggered water quality parameters per site – Subsidence sites

Site	Autumn May 2012				Autumn June 2012				Spring Oct 2012				Spring Nov 2012				Autumn March 2013				Autumn April 2013				Spring Sept 2013				Spring Oct 2013			
	A	D	S	T	A	D	S	T	A	D	S	T	A	D	S	T	A	D	S	T	A	D	S	T	A	D	S	T	A	D	S	T
PIS																																
DTC9								✓	x	x	x	x	x	x	x	x										✓						✓
DTC10		✓						✓	x	x	x	x	x	x	x	x	✓	✓			✓	✓				✓				✓		✓
TTH11		✓							✓	✓	✓			✓	✓	✓		✓		✓	✓	✓				✓				✓	✓	✓
TTH12 (12a)	✓		✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓		✓		✓	
HC13		✓						✓						✓		✓	✓	✓			✓	✓	✓			✓			✓	✓	✓	✓

Site	Autumn May 2012				Autumn June 2012				Spring Oct 2012				Spring Nov 2012				Autumn March 2013				Autumn April 2013				Spring Sept 2013				Spring Oct 2013			
	A	D	S	T	A	D	S	T	A	D	S	T	A	D	S	T	A	D	S	T	A	D	S	T	A	D	S	T	A	D	S	T
HC14		✓	✓		✓			✓		✓				✓				✓				✓				✓			✓	✓	✓	
BR15		✓							✓	✓				✓				✓			✓	✓			✓	✓			✓	✓		✓
BR16		✓							✓	✓				✓				✓				✓				✓						
CS																																
CWC1	✓	✓				✓				✓			✓	✓		✓	✓	✓			✓	✓			✓	✓				✓		
CWC2		✓				✓				✓			✓	✓			✓	✓			✓	✓			✓	✓				✓		
CC3		✓			✓													✓			✓	✓				✓				✓	✓	
CC4	✓		✓		✓		✓			✓	✓	✓		✓	✓	✓	✓	✓			✓	✓				✓	✓			✓	✓	✓
DC5		✓	✓			✓	✓		✓	✓		✓		✓		✓	✓	✓			✓	✓			✓	✓				✓	✓	✓
DC6			✓			✓	✓		✓	✓	✓			✓		✓	✓	✓			✓	✓				✓	✓			✓	✓	✓
EC7		✓				✓	✓	✓		✓		✓		✓		✓	✓	✓		✓	✓	✓				✓		✓		✓		✓
EC8			✓				✓			✓	✓			✓	✓				✓	✓						✓	✓	✓			✓	✓
CBR1		✓								✓			x	x	x	x	✓	✓			x	x	x	x		✓			x	x	x	x
CBR2		✓							✓	✓			x	x	x	x	✓	✓			x	x	x	x		✓			x	x	x	x
CMC3	✓	✓			✓				✓	✓			x	x	x	x	✓	✓			x	x	x	x	✓	✓			x	x	x	x
CMC4	✓	✓			✓				x	x	x	x	x	x	x	x	✓	✓			x	x	x	x	✓	✓			x	x	x	x
CCC5	✓	✓	✓		✓					✓			x	x	x	x		✓			x	x	x	x					x	x	x	x
CCC6		✓	✓		✓					✓			x	x	x	x		✓			x	x	x	x		✓			x	x	x	x
CSQC7			✓		✓		✓		✓	✓	✓		x	x	x	x		✓			x	x	x	x	✓		✓		x	x	x	x
CSQC8		✓	✓		✓		✓		✓	✓	✓		x	x	x	x		✓			x	x	x	x		✓	✓	✓	x	x	x	x

PIS = Potential impact sites, CS = control sites, A = pH, D = percentage dissolved oxygen S = salinity/electrical conductivity, T = turbidity, ✓ = trigger value reached, x = no samples.

5.3.2 Mine water discharge monitoring sites

Water quality field data for subsidence monitoring sites is provided in Appendix E. Table 12 shows monitoring events where water quality parameters were triggered for each mine water discharge site

Salinity and pH were above ANZECC trigger values in 2012 at monitoring sites on the Bargo River that were located downstream of its confluence with Tea Tree Hollow (i.e. SRB5, SBR6, SBR7 & SBR8), however these same sites were below trigger values in 2013. The saline, alkaline water is a result of the existing coal wash discharge from Tea Tree Hollow. The dissolved oxygen was below the guidelines at the majority of monitoring sites. Further studies (CEL 2016) have been conducted to assess stream health and determine appropriate EC trigger values of mine water discharge.

Table 12: Triggered water quality parameters per site – mine water discharge sites

Site	Autumn May 2012				Autumn June 2012				Spring Oct 2012				Spring Nov 2012				Autumn March 2013				Autumn April 2013				Spring Sept 2013				Spring Oct 2013			
	A	D	S	T	A	D	S	T	A	D	S	T	A	D	S	T	A	D	S	T	A	D	S	T	A	D	S	T	A	D	S	T
PIS																																
TTH12 (12a)	✓		✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓		✓		✓	
SBR5	x	x	x	x	x	x	x	x	✓	✓	✓		x	x	x	x					x	x	x	x	x	x	x	x	x	x	x	x
SBR6	x	x	x	x	x	x	x	x	✓		✓		x	x	x	x					x	x	x	x	x	x	x	x	x	x	x	x
SBR7	x	x	x	x	x	x	x	x	✓	✓	✓		x	x	x	x					x	x	x	x	x	x	x	x	x	x	x	x

Site	Autumn May 2012				Autumn June 2012				Spring Oct 2012				Spring Nov 2012				Autumn March 2013				Autumn April 2013				Spring Sept 2013				Spring Oct 2013			
	A	D	S	T	A	D	S	T	A	D	S	T	A	D	S	T	A	D	S	T	A	D	S	T	A	D	S	T	A	D	S	T
SBR8	x	x	x	x	x	x	x	x	✓		✓		x	x	x	x					x	x	x	x	x	x	x	x	x	x	x	x
CS																																
TTH11		✓							✓	✓	✓			✓	✓	✓		✓		✓	✓	✓				✓				✓	✓	✓
SBR1		✓							✓	✓				✓				✓			✓	✓			✓	✓			✓	✓		✓
SBR2		✓							✓	✓				✓				✓				✓				✓						
SBR3	x	x	x	x	x	x	x	x		✓			x	x	x	x	✓				x	x	x	x	x	x	x	x	x	x	x	x
SBR4	x	x	x	x	x	x	x	x		✓			x	x	x	x		✓			x	x	x	x	x	x	x	x	x	x	x	x

PIS = Potential impact sites, CS = control sites, A = pH, D = percentage dissolved oxygen S = salinity, T = turbidity, ✓ = trigger value reached, x = no samples.

5.4 Fish monitoring

5.4.1 Subsidence monitoring sites

Field data for bait traps and dip nets are presented in Appendix F. Table 13 combines all monitoring data and summarises the species captured at each site. Bait traps were deployed once per season however there was an additional deployment in autumn 2012 and spring 2013. Fish caught using the dip net method used for AUSRIVAS sampling (two samples per season only at potential impact sites) were also identified and quantified.

Nine species were detected during bait trap and dip net surveys. The most commonly caught species included the yabby (*Cherax destructor*), common freshwater shrimp (*Paratya australiensis*) and the Mosquito Fish (*Gambusia holbrooki*). Mosquito Fish were recorded from all waterways surveyed within the Project Area with the exception of Cow Creek.

Freshwater yabbies were caught during all sampling occasions at all creeks within the Project Area with the exception of Bargo River.

Table 13: Fish monitoring summary: subsidence monitoring sites

	Yabby *Cherax destructor*	Common Freshwater Shrimp *Paratya australiensis*	Mosquito Fish *Gambusia holbrooki*	Australian Smelt *Retropinna semoni*	Firetail Gudgeon *Hypseleotris galii*	Common Jollytail *Galaxias maculatus*	Mountain Galaxias *Galaxias olidus*	Spiny Crayfish *Euastacus spinifer*	Empire Gudgeon *Hypseleotris compressa*
PIS									
DTC9	55	17	5						
DTC10	67	26	2						
TTH11	26	5	12						
TTH12 (12a)	22		20						
HC13	1		119						
HC14	1	26	11			2	1		
BR15		18	27	3					
BR16	1	26	9	8					
CS									
CWC1	41	40							
CWC2	60	63							

CC3	54	85	378						
CC4	2	98	31						
DC5	74	11	17		3				
DC6	48		5		1				
EC7	68	1	24						
EC8	3	4	9			4			
CBR1									
CBR2									
CMC3	2					5		4	
CMC4						9		6	
CCC5			1						
CCC6			2						
CSQC7									
CSQC8									1

5.4.2 Mine water discharge monitoring sites

Field data for bait traps and dip nets are presented in Appendix G. Table 14 combines all monitoring data and summarises the species captured at each site. The dip net method used for AUSRIVAS sampling was employed at both potential impact and control sites for mine water discharge monitoring sites.

Four species, yabby, common freshwater shrimp, Mosquito Fish and Australian Smelt (*Retropinna semoni*) were detected at the mine water discharge monitoring sites, with all four detected at the control sites and only three (Common Freshwater Shrimp absent) at the potential impact sites. Mosquito Fish were detected at all monitoring sites, and the Common Freshwater Shrimp only at control sites.

Table 14: Fish monitoring summary: mine water discharge monitoring sites

	Yabby ***Cherax destructor***	**Common Freshwater Shrimp** ***Paratya australiensis***	**Mosquito Fish** ***Gambusia holbrooki***	**Australian Smelt** ***Retropinna semoni***
PIS				
TTH12 (12a)	22		20	
SBR5	1		12	28
SBR6			13	19
SBR7			3	25
SBR8	1		7	12
CS				
TTH11	26	5	12	
SBR1		1	24	3
SBR2	1	4	8	2
SBR3		20	20	
SBR4		10	3	10

5.4.3 Threatened fish

Based on likelihood of occurrence (Appendix A) and historic records, the Project Area does not contain habitat for any threatened fish species listed on the FM Act, BC Act or EPBC Act. It is considered unlikely that Macquarie Perch inhabit the Bargo River and tributaries within the Project Area. This is based on lack of recorded occurrences of Macquarie Perch above Mermaid Falls, which acts as a barrier to fish passage and the lack of suitable habitat and numerous barriers to fish passage to creeks below Mermaid Falls within the Project Area, as mapped by Fluvial Systems (2013). Macquarie Perch are however known from the Nepean River, upstream of the Bargo River confluence (Figure 5). There would be no reduction in the quality of the water in Bargo River below Mermaid Falls (where there is potential Macquarie Perch habitat) as a result of the Project (HEC 2018c).

5.5 Macrophytes

Field data for macrophyte surveys are presented in Appendix H. The abundance, diversity and distribution of macrophytes recorded during aquatic monitoring surveys in the Project Area was low, with only some sites (CC4, EC8, TTH11, TTH12b, HC13 and HC14) consistently recording macrophytes. Submerged and floating macrophytes generally require permanent water however they can, in time, recolonise dry areas if and when water levels return.

At impact monitoring sites, sedges and rushes such as Spiny-headed Mat-rush, *S. melanostachys*, Saw Sedge (*G. clarkei*), *C. appressa* and *C. gracilis* were common and in some cases very dominant along creeks, however the abundance and diversity of aquatic macrophytes was low. Floating Pond Weed (*Potamogeton sulcatus*) was recorded at sample sites CC4, *Typha orientalis* at TTH12, EC7 and EC8, Slender Knotweed (*Persicaria decipiens*) at EC7 and EC8 and Tall Spikerush (*Eleocharis sphacelata*) at EC8, HC13 and HC14. Macrophytes recorded at BR15 (SBR1) included Tall Spikerush, Jointed Twig Rush (*Baumea articulate*) and *Typha domingensis* (Appendix H).

5.6 Macroinvertebrates (AUSRIVAS)

AUSRIVAS macroinvertebrates data are presented in Table 15 and Appendix J.

5.6.1 Subsidence AUSRIVAS monitoring

Table 15 presents the AUSRIVAS scores and other calculated health indicator data for each subsidence monitoring site.

Macroinvertebrate fauna recorded at subsidence monitoring sites within the Project Area were generally comparable to modelled reference sites (Band A). Throughout the baseline monitoring period sites such as Bargo River, Tea Tree Hollow, and Hornes Creek scores lowered to Band B, possibly indicating impairment to macroinvertebrate communities at this time. Some sites consistently recorded SIGNAL scores below 4 indicating that the sites were subject to severe pollution (Table 7). However it must be noted that low SIGNAL scores are reflective of the dominance of pollution tolerant species and can occur with the absence of pollution if the waterway is subject to natural environmental stressors (e.g. low rainfall/flow). Bargo River consistently recorded higher SIGNAL scores, indicating only moderate pollution. The EPT richness was generally low (ranging from 2-8) over the two years of sampling indicating a degree of impairment, however it must be noted that these indices are not rated and were also observed in control streams. As such, the low EPT richness index scored by these streams could be a reflection of natural macroinvertebrate assemblages.

Table 15: AUSRIVAS macroinvertebrate results at subsidence monitoring sites

Summary of Taxa and EPT richness and ratio, AUSRIVAS results and SIGNAL score for macroinvertebrate assemblages collected using AUSRIVAS techniques in autumn 2012, spring 2012, autumn 2013 and spring 2013 at subsidence monitoring sites.

Autumn 2012: May and June combined data																
LOCATION	**Cow Ck**		**Carters Ck**		**Dry Ck**		**Eliza Ck**		**Dog Trap Ck**		**Tea Tree Hollow**		**Hornes Ck**		**Bargo R.**	
SITE	CWC1	CWC2	CC3	CC4	DC5	DC6	EC7	EC8	DTC9	DTC10	TTH11	TTH12a	HC13	HC14	BR15	BR16
Taxon richness (Family level)	16	22	31	30	22	22	22	34	22	24	26	28	27	36	20	25
Abundance	181	275	227	310	147	213	282	370	318	287	263	321	266	253	287	186
EPT richness	4	3	4	3	3	4	4	7	5	5	3	4	3	5	2	4
EPT ratio	0.25	0.14	0.13	0.10	0.14	0.18	0.18	0.21	0.23	0.21	0.12	0.14	0.11	0.14	0.10	0.16
OE50	0.96	0.99	0.96	0.98	0.99	1	0.93	0.99	0.95	1	0.93	0.94	1.06	1	1.01	0.97
O0Signal	4.5	4.23	3.98	4.02	4.09	4.23	4.11	4.24	4.23	4.15	4.29	4.18	3.98	3.74	4.58	4.7
Band	A	A	A	X	A	A	A	B	A	A	A	A	A	A	B	B
SIGNAL	4.19	3.55	3.32	3.50	3.41	3.77	3.18	3.79	3.55	3.29	3.31	3.68	3.32	3.31	4.30	4.32

Spring 2012: October and November combined data																
LOCATION	**Cow Ck**		**Carters Ck**		**Dry Ck**		**Eliza Ck**		**Dog Trap Ck**		**Tea Tree Hollow**		**Hornes Ck**		**Bargo R.**	
SITE	CWC1	CWC2	CC3	CC4	DC5	DC6	EC7	EC8	DTC9	DTC10	TTH11	TTH12a	HC13	HC14	BR15	BR16
Taxon richness (Family level)	17	19	20	38	15	19	25	23	28	24	21	27	30	25	17	19
Abundance	190	233	122	298	80	182	190	183	316	114	191	184	259	230	190	233
EPT richness	3	2	3	5	2	2	2	4	3	4	2	3	6	7	3	2
EPT ratio	0.18	0.11	0.15	0.13	0.13	0.11	0.08	0.17	0.11	0.17	0.10	0.11	0.20	0.28	0.18	0.11
OE50	0.92	1.04	1.04	1.25	0.77	0.84	0.92	0.56	1.17	0.88	0.67	0.96	0.93	1	0.92	1.04
O0Signal	3.71	4	3.84	3.97	3.86	3.63	3.59	4.53	3.89	4.09	3.72	3.89	4.39	4.96	3.71	4
Band	A	A	A	X	B	A	A	B	X	A	B	A	A	A	A	A
SIGNAL	4.00	4.00	4.20	4.13	3.80	3.63	3.40	4.52	3.82	4.08	3.86	3.89	4.27	5.16	4.00	4.00

Autumn 2013: March and April combined data																
LOCATION	**Cow Ck**		**Carters Ck**		**Dry Ck**		**Eliza Ck**		**Dog Trap Ck**		**Tea Tree Hollow**		**Hornes Ck**		**Bargo R.**	
SITE	CWC1	CWC2	CC3	CC4	DC5	DC6	EC7	EC8	DTC9	DTC10	TTH11	TTH12a	HC13	HC14	BR15	BR16
Taxon richness (Family level)	14	18	30	21	15	20	30	25	18	16	16	26	31	20	31	14
Abundance	148	102	293	110	159	146	172	167	209	123	101	333	299	222	230	148
EPT richness	3	4	5	3	3	3	6	4	4	3	3	4	4	6	8	3
EPT ratio	0.21	0.22	0.17	0.14	0.20	0.15	0.20	0.16	0.22	0.19	0.19	0.15	0.13	0.30	0.26	0.21
OE50	0.87	1.11	1.05	1.01	0.92	0.83	0.96	0.99	1.11	0.83	0.74	0.85	0.92	1.2	0.65	1.07
O0Signal	4.27	3.82	4.05	3.81	3.89	4.38	3.83	4.37	3.96	4.37	3.5	3.72	3.36	3.84	4.41	4.66
Band	A	A	A	A	A	A	A	A	A	A	B	A	A	X	B	A
SIGNAL	4.27	3.59	4.05	3.56	3.41	3.76	3.33	4.68	3.96	4.37	3.50	3.72	3.44	3.88	4.64	4.67

Spring 2013: September and October combined data																
LOCATION	**Cow Ck**		**Carters Ck**		**Dry Ck**		**Eliza Ck**		**Dog Trap Ck**		**Tea Tree Hollow**		**Hornes Ck**		**Bargo R.**	
SITE	CWC1	CWC2	CC3	CC4	DC5	DC6	EC7	EC8	DTC9	DTC10	TTH11	TTH12a	HC13	HC14	BR15	BR16
Taxon richness (Family level)	16	21	24	28	22	20	22	32	26	25	26	29	24	32	27	29
Abundance	198	158	193	258	178	172	187	214	219	206	217	209	331	292	168	202
EPT richness	2	3	5	4	3	3	3	6	5	5	4	6	3	5	7	7
EPT ratio	0.13	0.14	0.21	0.14	0.14	0.15	0.14	0.19	0.19	0.20	0.15	0.21	0.13	0.16	0.26	0.24
OE50	0.84	0.88	0.88	1.17	0.86	1.01	1.01	0.98	1.04	1.1	1.01	0.88	0.82	1.11	0.97	1.06
O0Signal	4.19	4.19	4.04	3.71	3.82	3.8	4	4.13	4.04	3.92	3.8	4.11	3.75	3.9	4.35	4.61
Band	A	A	A	X	A	A	A	A	A	A	A	A	B	A	A	A
SIGNAL	4.19	4.19	4.04	3.71	3.82	3.80	4.00	4.28	4.08	3.92	3.65	4.14	3.96	3.78	4.19	4.62

5.6.2 Mine water discharge AUSRIVAS monitoring

Table 16 presents the AUSRIVAS scores and other calculated health indicator data for each mine water discharge monitoring site.

The macroinvertebrate fauna at the majority of sites along the Bargo River were defined as significantly impaired (Band B) with two sites defined as comparable to reference condition (Band A). SIGNAL scores ranged between 4.16 and 5.56, and, as all sites were above 4, were classed as being moderately polluted. One site (SBR2) recorded a SIGNAL score above 5 indicating only mild pollution at this monitoring site (Table 16).

During autumn 2013 monitoring surveys, taxon richness ranged between 12 and 26, abundance ranged between 72 and 159 and EPT richness between 2 and 6. The macroinvertebrate fauna at the majority of sites along the Bargo River were defined as significantly impaired (Band B) with one site defined as comparable to reference condition (Band A). SIGNAL scores ranged between 3.84 and 4.80. One site recorded a SIGNAL score below 4, indicating severe pollution, while the remaining seven monitoring sites recorded SIGNAL scores between 4 and 5 indicating moderate pollution (Table 16).

The quality of the water and the macroinvertebrate fauna present was lower in the autumn 2013 surveys compared to the spring 2012.

Table 16: AUSRIVAS macroinvertebrate results at mine water discharge monitoring sites

Summary of Taxa and EPT richness and ratio, AUSRIVAS results and SIGNAL score for macroinvertebrate assemblages collected using AUSRIVAS techniques in spring 2012 and autumn 2013 at mine water discharge monitoring sites.

Spring: October 2012								
LOCATION	**Bargo River Downstream of Picton Weir**		**Bargo River Remembrance Driveway**		**Bargo River Tea Tree Hollow Confluence**		**Bargo River Rockford Bridge**	
SITE	**SBR1**	**SBR2**	**SBR3**	**SBR4**	**SBR5**	**SBR6**	**SBR7**	**SBR8**
Taxon richness (Family level)	27	23	26	28	21	23	30	26
Abundance	151	129	128	132	114	55	128	102
EPT richness	6	5	6	7	4	4	6	5
EPT ratio	0.25	0.29	0.23	0.25	0.19	0.17	0.20	0.19
OE50	1.1	1.17	0.8	0.73	0.8	0.73	1.13	0.86
O0Signal	4.67	5.35	4.11	4.57	4.06	4.5	4.19	4.21
Band	A	B	B	B	B	B	A	A
SIGNAL	4.74	5.56	4.29	4.48	4.16	4.56	4.21	4.27

Autumn: March 2013								
LOCATION	**Bargo River Downstream of Picton Weir**		**Bargo River Remembrance Driveway**		**Bargo River Tea Tree Hollow Confluence**		**Bargo River Rockford Bridge**	
SITE	**SBR1**	**SBR2**	**SBR3**	**SBR4**	**SBR5**	**SBR6**	**SBR7**	**SBR8**
Taxon richness	22	31	13	26	15	16	12	15
Abundance	159	153	109	91	93	75	72	65

EPT richness	5	6	3	5	5	6	2	6
EPT ratio	0.23	0.19	0.23	0.19	0.33	0.38	0.17	0.40
OE50	0.58	1.01	0.64	0.81	0.77	0.71	0.56	0.59
O0Signal	4.42	4.44	4.38	4.07	4.47	4.25	4	4.8
Band	B	A	B	B	B	B	B	B
SIGNAL	4.09	3.84	4.38	4.15	4.47	4.25	4.00	4.80

5.7 Macroinvertebrates (quantitative sampling)

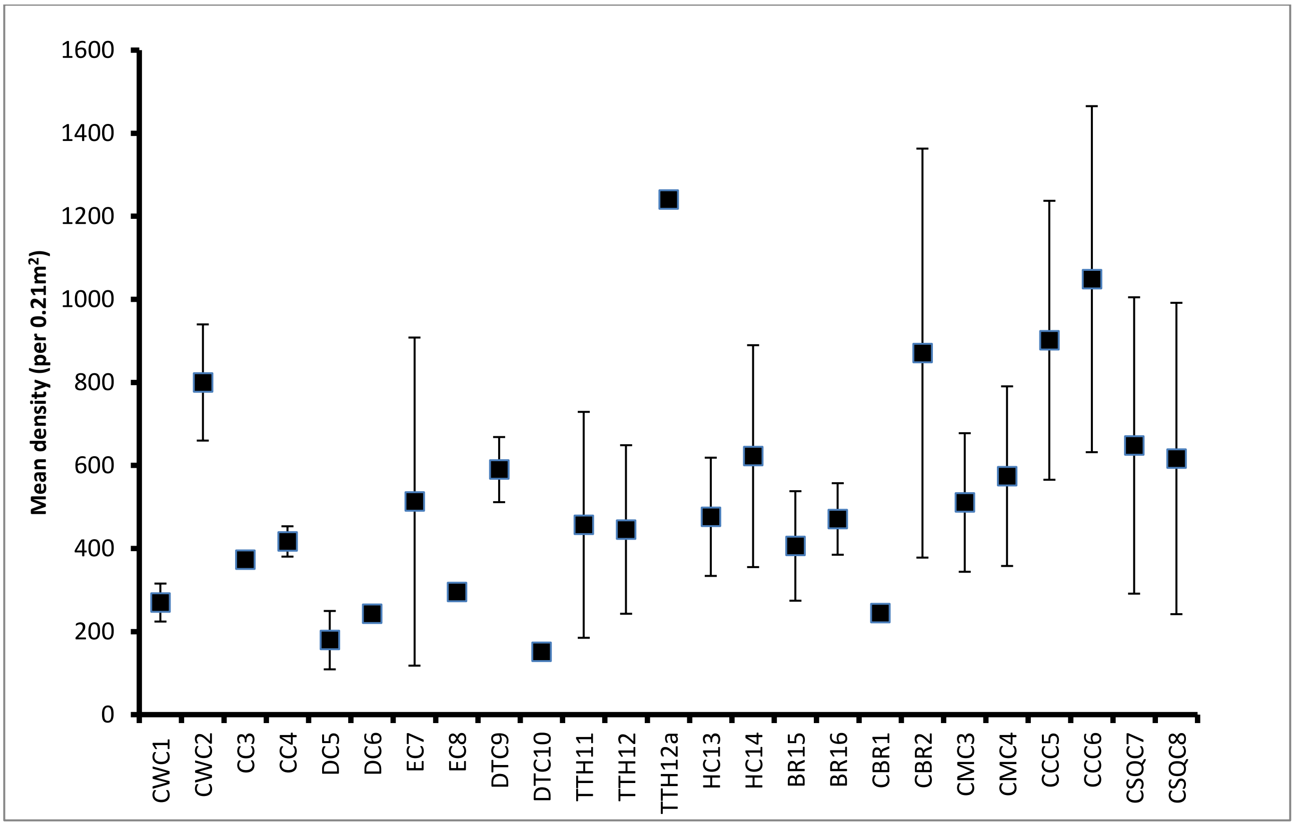
Average family densities at each site are presented in Appendix I. Subsidence monitoring site results include data from three sampling seasons, spring 2012, autumn 2013 and spring 2013. Autumn data 2012 was excluded from this analysis because of a necessary change in sampling method (discussed in Section 3.5.5). Analysis of autumn 2012 sampling season is provided in Tahmoor South Aquatic Monitoring Report, Niche 2013. Results are discussed in relation to the impact assessment in Section 6.

5.7.1 Subsidence monitoring sites

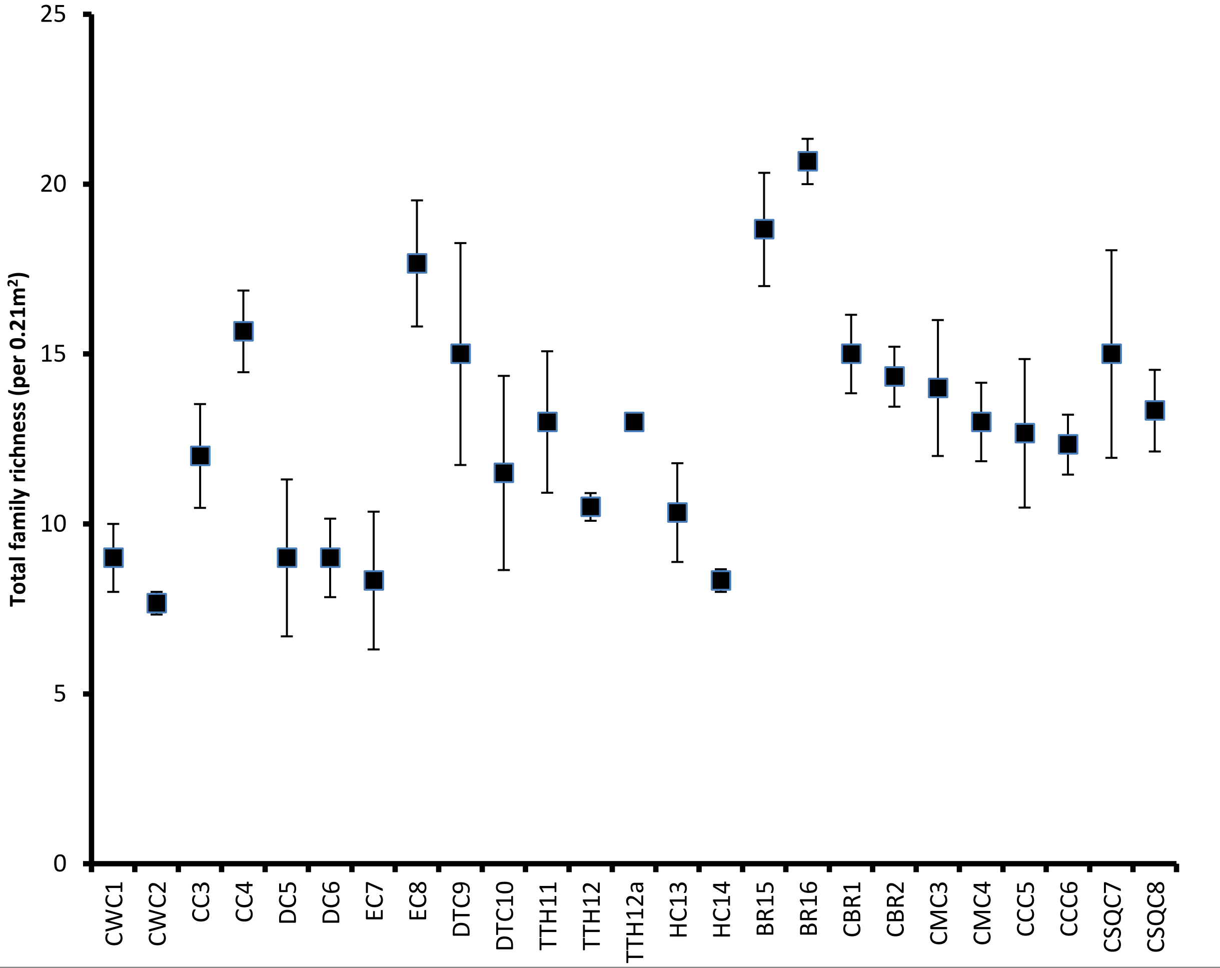
Univariate results

The average density over all sites and seasons sampled was 520.7 individuals per 0.21m^2.The highest mean density was recorded in Carters Creek (1048 individuals per 0.21m^2), although Tea Tree Hollow (TTH12a) recorded a total of 1240 individuals per 0.21m^2 (one sampling occasion only) (Graph 1)

There was an average of 12.8 (per 0.21m^2) families observed across all sites and seasons (Graph 2). The highest mean family richness was recorded in Bargo River (BR16) (20.7 families per 0.21m^2) and the lowest in Cow Creek (CWC2) (7.6 families per 0.21m^2).



Graph 1: Mean density of macroinvertebrates at subsidence monitoring sites (Error bars = +- S.E.).

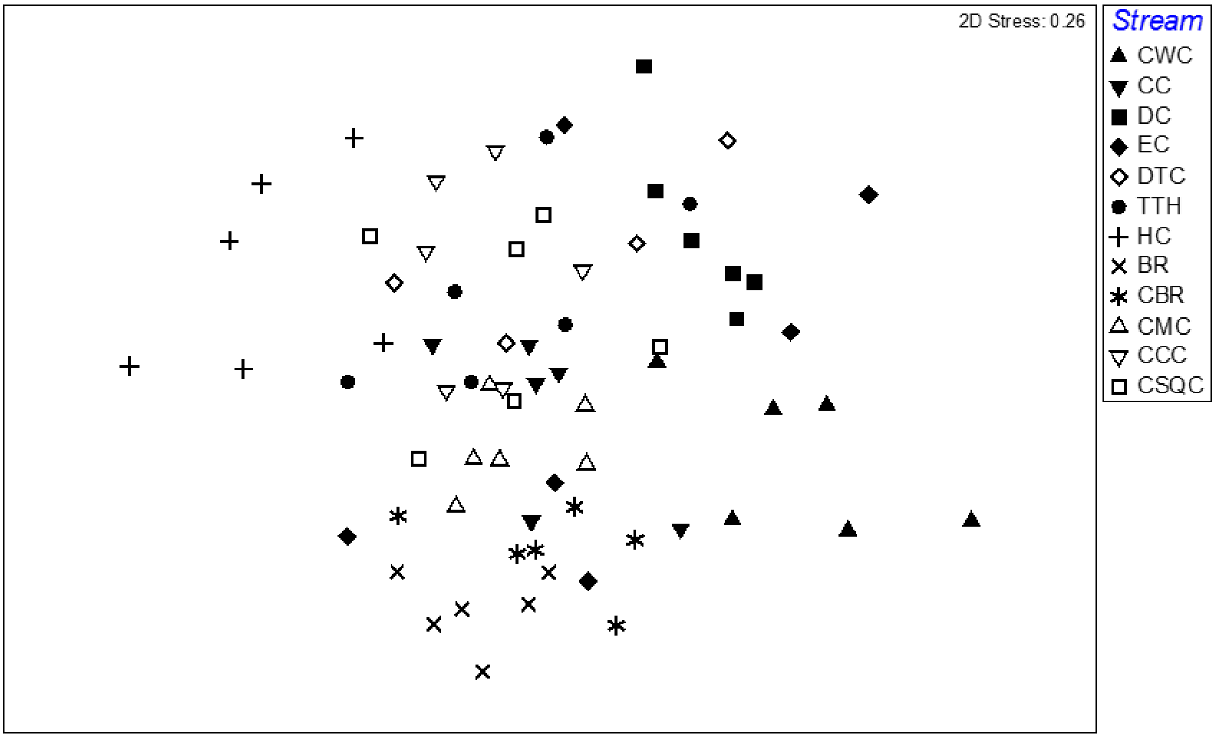


Graph 2: Mean family richness at subsidence monitoring sites (Error bars = +-S.E.)

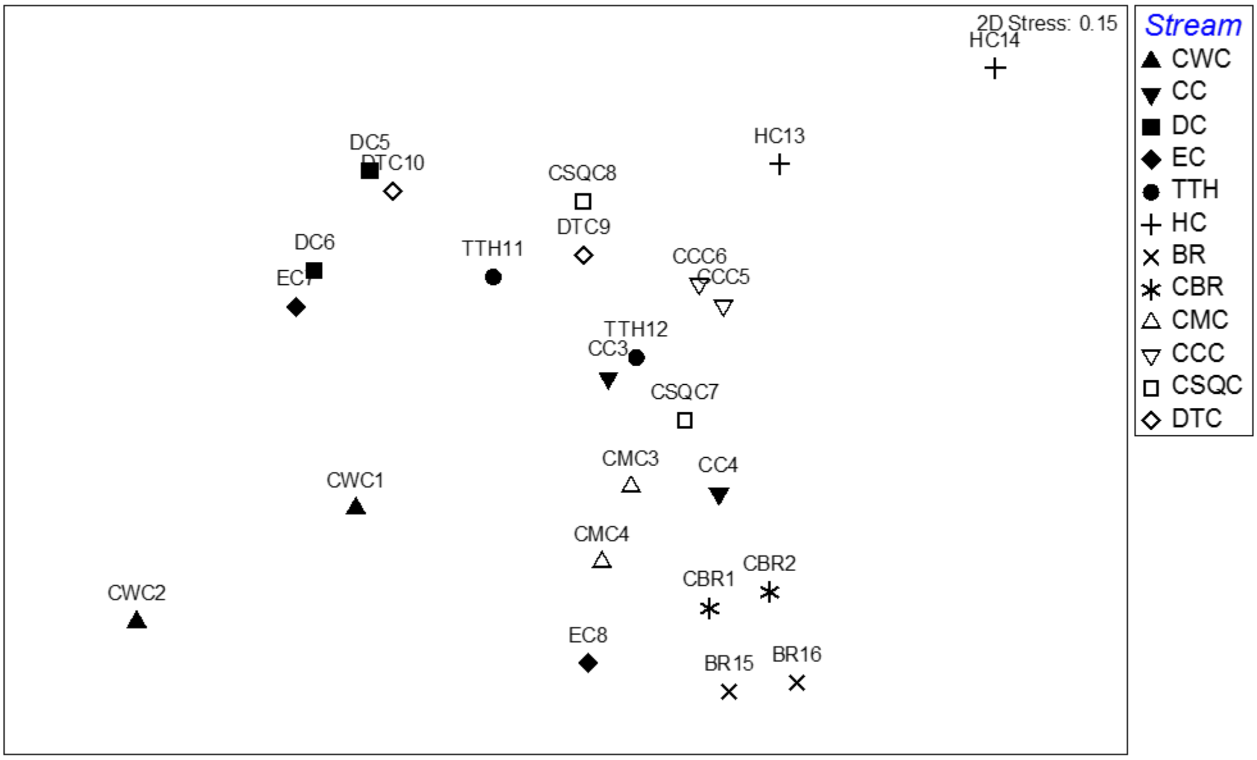
Multivariate results

There appears to be minor grouping of sites within streams (Graph 3 and Graph 4) e.g. Bargo River (BR15, BR16, CBR1, CBR2), however as with the case with Eliza Creek (EC7 and EC8) sites can be quite dispersed. The data in general is quite spread with no obvious groupings of different streams. Horne Creek and Cow Creek appear the most different from other sampling sites (Graph 3 and Graph 4).

SIMPER procedure (Appendix L) showed that sub-families, Chironominae, Orthocladinae and families Leptophlebiidae and Oligochaeta contributed most to the within stream similarity for all streams. This implies that these families occur at more consistent densities with in stream (that is at each site through time) than other taxa and that these families are common among streams. Differences between stream groups were variable. Differences in density of the most common taxa, previously listed, contributed to the dissimilarities between lower order semi-permanent streams. Bargo River sites (BR15, BR16, CBR1 and CBR2) were differentiated from the lower order streams consistently by the families Elmidae, Leptoceridae, Calamoceridae, and Ecnomidae.



Graph 3: MDS plot of subsidence monitoring sites showing each sampling occasion at each site



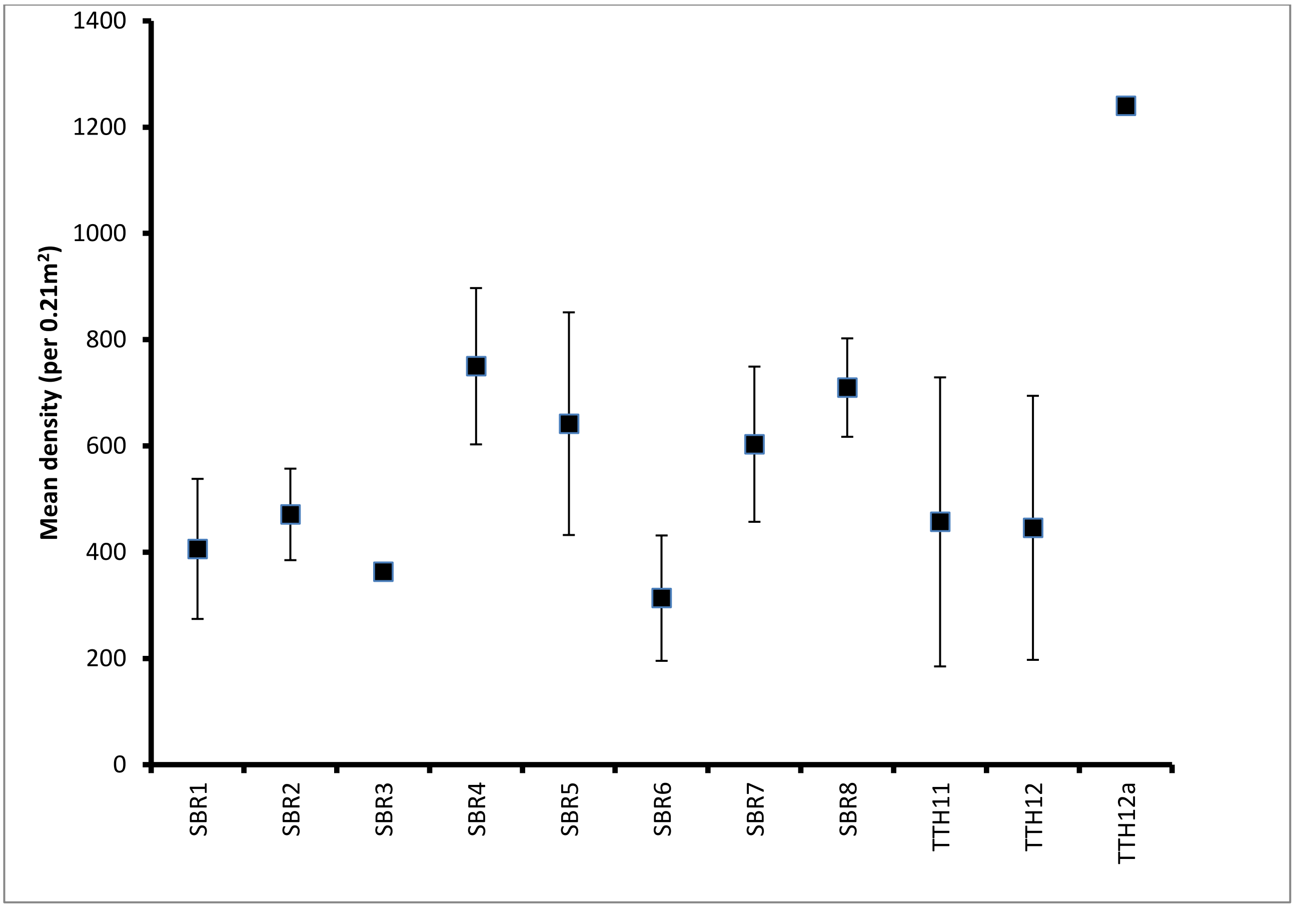
Graph 4: MDS plot of subsidence monitoring sites showing samples averaged across sites.

5.7.2 Mine water discharge monitoring

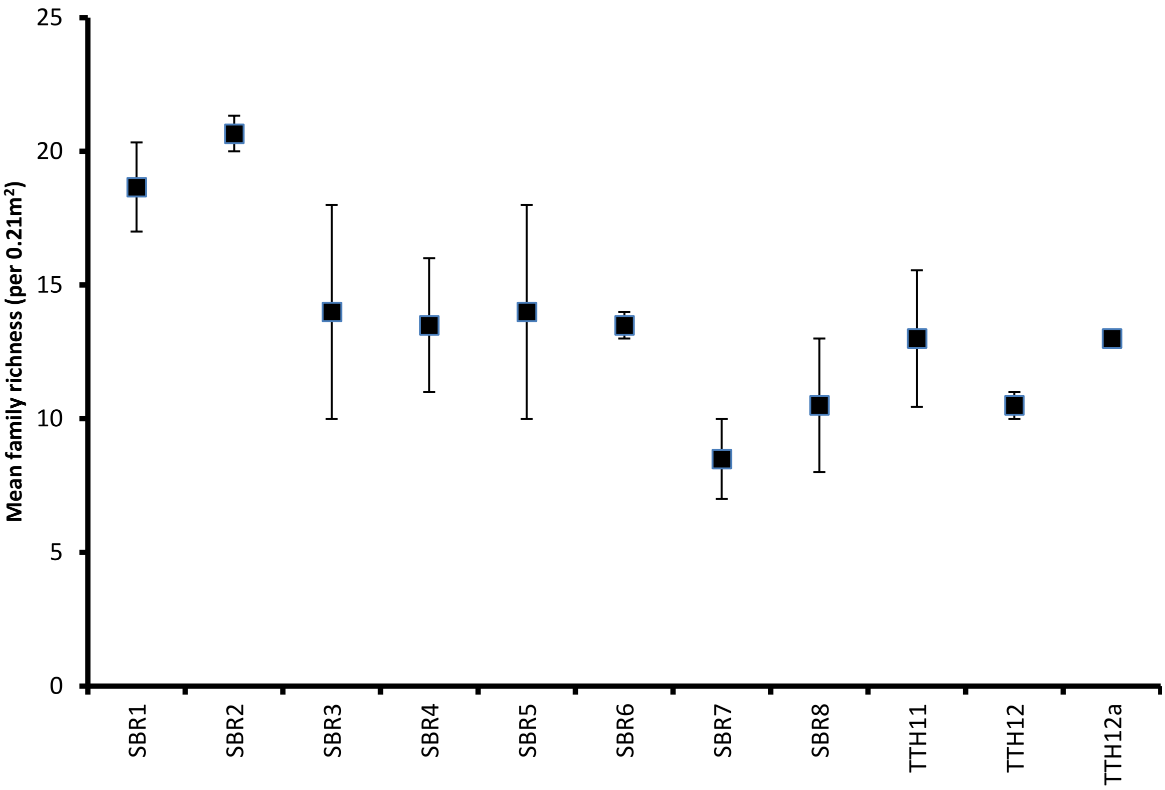
Univariate results

The average density over all sites and seasons sampled was 537.39 individuals per 0.21m^2.The highest mean density was recorded in Bargo River control site (SBR4) (750 individuals per 0.21m^2), although Tea Tree Hollow (TTH12a) recorded a total of 1240 individuals per 0.21m^2 (one sampling occasion only) (Graph 5). The lowest mean densities were recorded in Bargo River impact group (SBR6), (313.21 per 0.21m^2) (Graph 5).

There was on average 13.6 (per 0.21m^2) families observed across all sites and seasons. The highest mean family richness was recorded in Bargo River control sites (SBR1 and SBR2) (20.7 and 18.7 families per 0.21m^2 respectively) and the lowest in Bargo River impact group (SBR7) (8.5 families per 0.21m^2) (Graph 6).



Graph 5: Mean density of macroinvertebrates at mine water discharge monitoring sites (Error bar = +-S.E.)

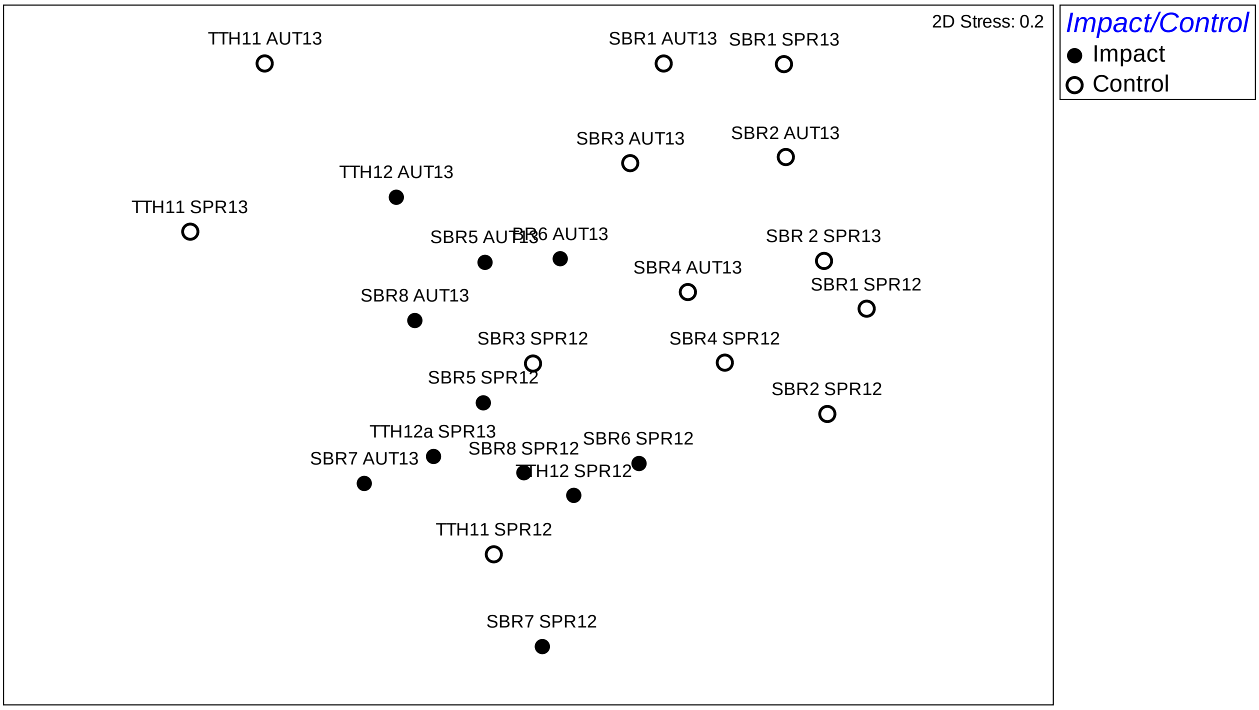


Graph 6: Mean family richness at mine water discharge monitoring sites (Error bars = ±S.E.)

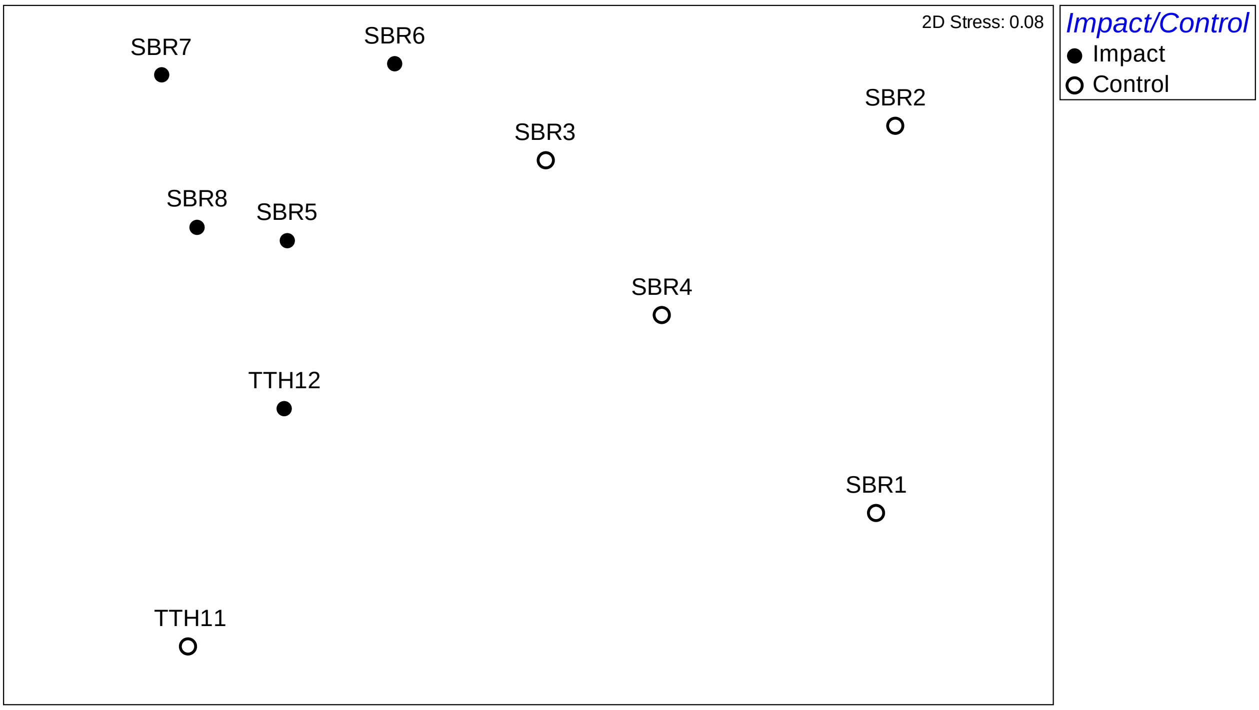
Multivariate results

There appears to be some grouping of impact and control sites particularly within Bargo River (SBR1, SBR2, SBR3, SBR4, SBR5, SBR6, SBR7, and SBR8) (Graph 7 and Graph 8).

SIMPER procedure (Appendix L) showed that within impact groups the sub-families, Chironominae, Tanypodinae, and family Caenidae contributed most to the within stream similarity. Chironominae, Tanypodinae, Leptophlebiidae and Oligochaeta contributed most to control group's similarity. Lower densities of Leptophlebiidae, Oligochaeta, Elmidae and increased densities of Chironominae and Caenidae in impact groups contributed most to the dissimilarity between impact and control groups. SIMPER performed on Tea Tree Hollow and Bargo River showed similar results however increased densities in Ecnomidae contributed to the difference between Tea Tree Hollow impact and control sites.



Graph 7: MDS plot mine water discharge monitoring sites showing each sampling occasion at each site.



Graph 8: MDS plot of mine water discharge sites averaged across site groups.

5.8 Targeted surveys

The Sydney Hawk Dragonfly is listed as endangered under the FM Act. Targeted surveys for this species and were conducted in July/August 2013 at sites within the Project Area. Areas of potential habitat were identified using geomorphology mapping (Fluvial Systems 2013) and habitat preferences for each species. For Sydney Hawk Dragonfly, all pools with a predominantly boulder and/or cobble substrate were defined as containing potential habitat. Within the Project Area, a total of 29 sites were identified and subsequently surveyed for this species. Of the 29 sites, 27 were sampled (two were dry), and seven sites recorded dragonflies from various families (Table 17).

The Sydney Hawk Dragonfly belongs to the family Austrocorduliidae. This family was observed at Eliza Creek on two sampling occasions and during targeted surveys. The specimens were sent to Sydney Water for identification to species level. Identification included consultation with dragonfly expert Gunther Theischinger (OEH). The specimens were confirmed as the non-threatened *Austrocorduliidae refracta*. This species is often found in similar habitats of deep and shady riverine pools with cooler water (DPI 2007) and rocky substrate. *A. refracta* can inhabit smaller streams whereas the Sydney Hawk Dragonfly is thought to be restricted to larger streams in coastal areas (Theischinger 2013). Therefore the presence of *A. refracta* does not necessarily imply suitable habitat for the Sydney Hawk Dragonfly. The Sydney Hawk Dragonfly has a moderate likelihood of occurrence as potential habitat may occur in Bargo River or in the Nepean River; areas unlikely to be impacted by the subsidence.

Table 17: Dragonfly targeted surveys

Site	Dragonfly Family	Count
SHD CWC4	Sythemistidae	1
EC8	Austrocorduliidae, (*Austrocordulia refracta*)	1
SHD DTC5	Aeshnidae	1
SHD TTH4	Gomphidae	1
SHD HC1	Libellulidae, Hemicordulidae	1, 2
SHD HC3	Libellulidae, Cordulephyidae	2, 1
SHD BR3	Telephlebiidae, Gomphidae	1, 1

6. Impact Assessment

6.1 Commonwealth

The EPBC protected matters search tool reported the Macquarie Perch within a 10 kilometre radius of the Project Area. The creeks within the Project Area were determined to contain a “None” to “Low Likelihood” of containing Macquarie Perch habitat. This is based on the highly fragmented habitat, with rock bars and other barriers to fish movement, along with the ephemeral nature of the 1st and 2nd order streams within the Project Area. The creeks also lack suitable spawning habitat. Whilst there are some sections on the Bargo River within the Project Area that contain suitable habitat for Macquarie Perch, they occur above Mermaid Falls and below Picton Weir. It is considered unlikely that a viable population of Macquarie Perch exists in this limited range and there are no recorded occurrences of this species within this section of the Bargo River despite surveys being conducted as part of this assessment and surveys by NSW DPI.

Figure 6 shows the quality of Macquarie Perch habitat in the broader area based on the likelihood of occurrence criteria described in Diagram 1. None of the creeks within the Project Area are defined as moderate or above and as such, this species is unlikely to occur within the Project Area.

6.2 State

The assessment of the Project has been carried out for approval under the provision for State Significant Development within Part 4, Division 4.1 of the EP&A Act. Threatened aquatic biodiversity as listed on the NSW BC Act and FM Act have been considered in this assessment. The Project is to be assessed under the transitional legislative arrangements of the NSW biodiversity legislation reforms, i.e. the new assessment methodologies now required under the *Biodiversity Conservation Act 2016* do not apply to the Project.

6.2.1 NSW BC Act and FM Act

Threatened species

Of those Subject Species identified within the Project Area, only the Sydney Hawk Dragonfly was considered to have potential habitat within the Project Area. The assessment of significance for this species is provided in Appendix I. It is considered unlikely that the Project will have a significant impact on the Sydney Hawk Dragonfly.

Key fish habitat

The Project may affect these key fish habitat at a number of locations, particularly in areas along Dog Trap Creek and Tea Tree Hollow (see section 6.4-6.6), and therefore some remediation measures may be required. If monitoring indicates this is the case, DPI Fisheries will be required to be consulted to determine the appropriate habitat rehabilitation measures or if environmental compensation is required. Any conditions will be incorporated into the monitoring and management of the waterways and key fish habitat. Further, as part of the development of the required Extraction Plan and associated management plans for the Project, a Trigger Action Response Plan (TARP) will be prepared, which will incorporate appropriate triggers, monitoring regimes and appropriate actions for key fish habitat in the Project Area.

All creeks within the Project Area have been mapped as ‘key fish habitat’ based on DPI key fish habitat mapping for Wollondilly LGA (DPI 2013c) or classified as ‘key fish habitat’ based on stream order (3rd order and above). Under this definition, significant environmental impacts (direct and indirect) on ‘key fish habitat’ are to have habitat rehabilitated or offset by environmental compensation. Compensation to offset fisheries resource or habitat losses will be considered only after it is demonstrated that the proposed loss is unavoidable, in the best interests of the community in general and is in accordance with the FM Act, Regulations and DPI (2013). Habitat replacement (as a compensation measure) will need to account for indirect as well as direct impacts of development to ensure that there is "no net loss" of key fish habitats.

Key threatening processes

A list of Key Threatening Processes (KTP) is maintained under the FM Act and is provided for by Part 7A, Division 2 of the FM Act. One KTP is considered relevant to the proposed development: human-caused climate change. The information regarding this KTP has been taken from the Final Determinations of the KTP and references therein. Key Threatening Processes listed under the BC Act are considered in the Terrestrial Ecology Report (Niche 2018).

Anthropogenic climate change

Climate change has occurred throughout geological history and has been a major force for evolution. It is now evident that in recent times (the so-called "Anthropocene"), 63% of greenhouse gases responsible for climate change originate from human-induced carbon dioxide and human-caused climate change is substantially affecting species, populations and communities of aquatic animals and vegetation throughout the world.

There is physical evidence that human-induced climate change is affecting biodiversity globally, in terrestrial, freshwater and marine systems. The International Panel on Climate Change (IPCC 2007) stated that "*observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature changes*".

Climate change is also predicted to have an impact on freshwater communities via changes in the seasonality of rainfall (increases and decreases) and the frequency and severity of storm events. Annually, the numbers of extreme warm events is likely to increase. The regional scenario for NSW freshwater aquatic systems is drying of aquatic areas, increased drought occurrence, higher water temperatures with diminished water flows, which will produce low oxygen levels and increased conductivity (salinity). Freshwater communities of fish and invertebrates in rivers, swamps and floodplains are likely to experience additional impacts as most species have specialised habitat and dietary requirements. Compared to the open estuaries and ocean waters, freshwater rivers are geographically constrained and limit the migratory options for aquatic plants, invertebrates and fish. Freshwater flows are a stimulus for breeding in many Australian freshwater fish species and thus the changes in volume and timing of spring floods are predicted to significantly impact fish recruitment. With low or reduced flow, freshwater river systems will shift towards lotic rather than lentic environments with a corresponding shift in the biological communities. In shallow freshwater rivers and lakes there is a balance between the phytoplankton communities (heterotrophy) and the bacterial biofilm (mostly autotrophs) on the substrate as the primary producers. Under some climate change scenarios a metabolic shift from heterotrophic communities to autotrophic communities is predicted.

Human-induced climate change is predicted to impact negatively on the survival and demography of aquatic ecosystems in NSW. Fisheries Scientific Committee is of the opinion that Human-induced Climate Change adversely affects threatened species and could cause species, populations or ecological communities that are not threatened to become threatened.

Coal extraction of up to 4 million tonnes of ROM coal per annum is proposed as part of the development. The Project's main sources of Green House Gas (GHG) emissions include fugitive methane from mine ventilation, pre- and post-drainage and flaring. Other emissions include diesel, unleaded petrol consumption, post-mining activities, electricity use and use of SF6 (sulphur hexafluoride gas) (Pacific Environment 2018). The GHG Assessment prepared for Tahmoor Coal found that the Project's contribution to the projected climate change and the associated impacts would be in proportion with its contribution to global GHG emissions. While the majority of the product coal will be combusted in other countries, the burning of coal is the largest contributor to CO_2 emissions and will contribute to climate change regardless of where it is burned.

Tahmoor Coal will employ a number of mitigation measures at the Project site to minimise the generation of GHG emissions. Such measures will include fugitive methane abatement such as the use of flares and recycling through a co-generation plant and Continuous Emissions Monitoring of fugitive emissions (Pacific Environment 2018).

6.3 Construction impacts

Direct impacts on the aquatic environment during construction would be minimal as there would be no direct works within waterways. There is potential for indirect impacts via run-off effects. The implementation of appropriate erosion and sediment control measures during construction would minimise the likelihood of these impacts.

6.4 Operational impacts

Potential operational impacts of the proposed development include the following:

- Changes in stream gradients.
- Increased levels of ponding, scouring and/or desiccation due to mining tilt.
- Fracturing and surface water flow diversion in the streams.
- Changes to water quality.

These operational impacts and how they relate to the ecology of the Project Area are discussed in more detail in the sections below.

6.4.1 Changes in stream gradients and increased levels of ponding, scouring or desiccation

Mining can potentially result in increased levels of ponding in locations where the mining induced tilts oppose and are greater than the natural stream gradients that exist before mining. Mining can also potentially result in an increased likelihood of scouring of the stream beds in the locations where the mining induced tilts considerably increase the natural stream gradients that exist before mining (MSEC 2018).

There is a predicted reversal of grade along a naturally flat section of Dog Trap Creek, upstream of the tailgate of LW103. There is increased potential for ponding upstream of this location, which is estimated to be up to 0.2 m deep and 150 m long (MSEC 2018).

Elsewhere, there are no other predicted reversals of grade due to the proposed mining. It is possible that there could be some localised areas along the streams which could experience small increases in the levels of ponding, where the predicted maximum tilts occur in the locations where the natural gradients are low. As the predicted changes in grade are typically less than 1 %, however, any localised changes in ponding are expected to be minor and not result in adverse impacts on these streams (MSEC 2018).

Stream gradients will increase where they flow into the predicted subsidence trough near the edges of the proposed longwalls. The streams flow predominantly over Hawkesbury Sandstone, which has a high resilience to scouring. As discussed in the report by Fluvial Systems (2013), mud was commonly found in the channel bed with soft knickpoints in small streams on the plateau. The predicted maximum increases in grade are up to 1.2 %, which are relatively small compared to the natural gradients and, therefore, the potential for increased scouring is not expected to be significant (MSEC 2018).

Further discussions on the potential changes in ponding and flooding along the streams are provided in the surface water impact assessment (HEC 2018b, c).

6.4.2 Fracturing and surface water flow diversion in the streams

Where the longwalls mine directly beneath the streams it is considered likely that fracturing resulting in surface water flow diversion would occur. Compressive strains due to closure are expected to be of sufficient magnitude to cause the underlying strata to buckle and induce cracking at the surface at some locations. This is likely to lead to the diversion of water from the stream beds into the dilated strata beneath it (MSEC 2018).

It is unlikely however that there would be any net loss of water from the catchment since any redirected flow would not intercept any flow path that would allow the water to be diverted into deeper strata or the mine (MSEC 2018).

If significant fracturing were to occur, partial or complete diversion of surface water and drainage of pools would occur at locations and times where the rate of flow diversion is greater than the rate of incoming surface water. The majority of the streams are ephemeral and so water typically flows during and for a period of time after each rain event. In times of heavy rainfall, the majority of the runoff would flow over the beds of the streams and would not be diverted into the dilated strata below the stream beds. In times of low flow, however, some or all of the water could be diverted into the strata below the stream beds (MSEC 2018).

The impacts of localised diversion of surface flow in upsidence induced subsurface fracture networks, include loss of water holding capacity of pools, reduced frequency of pools overflowing and periodic loss of interconnection between pools during dry weather within the affected reach. Potentially these sorts of impacts could occur in Tea Tree Hollow and Dog Trap Creek, (HEC 2018c).

While much of the channel beds are exposed bedrock, Fluvial Systems (2013) report that sand, gravel, cobble and mud were also commonly found in the channel beds throughout the Project Area. Where such loose materials occur, it is possible that fracturing in the bedrock would not be seen at the surface. In the event that fracturing of the bedrock occurs in these locations within the alignments of the streams, the fractures may be filled with soil during subsequent flow events (MSEC 2018). Where little sediment is present, the impacts are likely to remain for longer periods of time and remediation may be required after the completion of mining (MSEC 2018).

Based on the previous experience of mining beneath streams at Tahmoor Mine, it is likely that fracturing and surface flow diversions will occur in the sandstone bedrock along the streams, particularly for streams that are located directly above the proposed longwalls. In some of these locations, the fracturing could impact the holding capacity of the standing pools, particularly those located directly above the proposed longwalls. It is unlikely, however, that there would be any net loss of water from the catchment (MSEC 2018).

With respect to streams or sections of streams located away from the proposed longwalls, the likelihood of fracturing and surface flow diversions reduces substantially compared to stream sections located directly above the proposed longwalls. Minor and isolated fracturing could however occur outside the extent of the proposed longwalls (MSEC 2018).

Based on predicted closure values there areas along Tea Tree Hollow and Dog Trap Creek that have either moderate or high risk of impact to water holding capacity (HEC 2018c). There were 14 pools mapped in Tea Tree Hollow. Most pools are located in areas where there is a low risk of impact to water holding capacity. Two pools are however located in an area of moderate risk of impact to flow holding capacity. The largest number of pools (in excess to 70), were mapped on Dog Trap Creek. Of these some 14 are located in areas of either moderate or high risk of loss of water holding capacity.

Further discussions on the potential impacts of surface cracking and changes in surface water flows are provided in the reports by Hydro and Engineering Consulting (HEC 2018b, c).

6.4.3 Water quality

Subsidence impacts

Predicted subsidence impacts on waterways in the Project Area are based on specialist's reports (Fluvial Systems 2013; MSEC 2018 and HEC 2018c) and are discussed in Section 6.4 which considers the impact of the proposal on aquatic habitats. The following potential impacts of subsidence on water quality in overlying waterways is summarised from Hydro and Engineering Consulting (HEC 2018c).

Liberation of contaminants can occur from subsidence induced fracturing in watercourses, causing localised and transient increases in iron concentrations and other constituents due to flushing of freshly exposed fractures in the sandstone rocks which contain iron and other mineralisation. This sort of impact has the potential to affect Tea Tree Hollow and Dog Trap Creek and downstream watercourses. Fracturing of bedrock is predicted to occur and upsidence related buckling of stream beds is predicted along some sections of these creeks. Based on past experience in the Southern Coalfields, including experience at Tahmoor North, it is expected that upsidence induced fracturing may lead to releases of aluminium, iron, manganese and zinc. It is likely these will be seen as transient spikes in the concentration of these and possibly other metals which would be relatively localised. The extent of these impacts is expected to be similar to impacts observed in similar streams in the Southern Coalfield i.e. iron staining and flocs in pools and localised and transient spikes in iron, manganese and aluminium in waterways previously undermined.

Changes to chemical characteristics of surface flows

Changes to chemical characteristics of surface flows can also occur as a result of changes in base flow. One of the effects of longwall subsidence on watercourses commonly reported is the emergence of ferruginous springs. These concentrated (point) inflows have a distinctive orange to red/brown colouration caused by enhanced groundwater inflows and oxidation of iron commonly present in shallow groundwater in the area. This is often accompanied by iron flocs, staining of the bed, increased turbidity and the build-up of iron rich slimes. Changes can also occur to the chemical composition of surface flows due to either increased or decreased groundwater fed base flow contribution to watercourses (HEC 2018c).

These sorts of impacts have the potential to affect Tea Tree Hollow, Dog Trap Creek and downstream watercourses (HEC 2018c).

Contamination of surface waters by gas drainage

Drainage of strata gas and expression to the surface through surface water has occurred to varying degrees in the Southern Coalfields. It is most readily detectable in permanent slow moving pools. Studies of the phenomena have shown that the gas flow does not affect the quality of surface waters that it drains through, due to the very low solubility of methane and the short residence time in the water column, however there have been rare instances of vegetation die back reported.

It has not been reported as an issue at Tahmoor North, most likely due to the relative absence of perennial water bodies. It is considered likely there will be enhanced strata gas emissions generated as a result of the Tahmoor South Project and that some of these may be visible as bubbling in more persistent pools in overlying watercourses (HEC 2018c).

Mine water discharge

Tahmoor Coal are licensed to release treated water from their water management system in accordance with Environmental Protection Licence (EPL) release limits. Under the current licence there is also a requirement to enhance treatment of water prior to release via a Pollution Reduction Program (PRP 22), which involves the development and commissioning of a water treatment plant to reduce the concentrations of arsenic, nickel and zinc in mine water released from the consolidated Licensed Discharge Point 1.

The results of predictive modelling of the water management system over the remaining mine life indicate that total discharges and spill from the pit top of the combined existing Tahmoor North operation and the proposed Tahmoor South Project are unlikely to increase significantly from current levels.

Whilst not anticipated, accidental spills could also occur which could result in transient impacts to water quality. The risk of these occurring is not likely to increase as a result of the Project and would be managed as part of the site environmental management system (HEC 2018c).

6.5 Aquatic habitat

Habitat features are shown in Figure 7. Streams within the Project Area are base flow Groundwater Dependent Ecosystems (GDE's) and contain both surface and hyporheos habitats (Niche 2017b), and are supported (through the provision of base flow) by springs and seeps and associated wetland GDE habitat (this does not refer to threatened wetlands) (Niche 2017b). The habitats of these GDEs, particularly riverine aquatic habitats, are expected to exhibit some form of impact from subsidence. The ground movements associated with longwall mining can impact on the availability of aquatic habitats by changing the levels of ponding, flooding and scouring of banks along watercourses and altering surface water flows through the fracturing of river and stream beds. Changes to water quality would also impact the quality of the aquatic habitat available.

6.5.1 Nepean River

The maximum predicted subsidence along the Nepean River resulting from the extraction of the proposed longwalls is less than 20 mm. While the river could experience some very low levels of vertical subsidence, it is not expected to experience any significant conventional tilts, curvatures and strains. It is not expected, therefore, that the Nepean River would experience any adverse impacts resulting from the conventional subsidence movements (MSEC 2018).

As such, the quality and quantity of available aquatic habitat in the Nepean River is unlikely to be impacted by the proposal.

6.5.2 Bargo River

The Bargo River is not expected to experience any measurable subsidence or upsidence movements.

The river is predicted to experience small valley closure movements up to 30 mm; however, this would not be expected to be associated with any measurable compressive strains (i.e. less than the order of survey tolerance of 0.3 mm/m). It is extremely unlikely, therefore, that these low level movements would result in any adverse impacts on the river. This is supported by the fact that the furthest reported impact on a stream in the Southern Coalfield was a very minor and isolated fracture, at a distance of 415 m from mining, which did not affect the surface water flows or quality.

There has been a long history of over 30 years of mining directly beneath or near the Bargo River at Tahmoor Mine. While impacts have occurred when longwalls were mined directly beneath the river, no impacts have been observed when mining has been undertaken more than 500 m from the river. Based on this, it is extremely unlikely that the extraction of the proposed longwalls would result in any adverse impacts on the river. Even if the predictions and impact assessments were exceeded, the likelihood of pool drainage is considered extremely low given the water flows in the river.

Mermaid Pool is located on the Bargo River and no impacts were observed from previous extractions within 750 m of the pool, and as such, the likelihood of any impacts on the pool is extremely low given the large distance away from the proposed longwalls.

As such, the quality and quantity of available aquatic habitat in the Bargo River is unlikely to be impacted by the proposal.

6.5.3 Thirlmere Lakes

Modelling by HEC (2018) predict that:

- The magnitude of change in recharge/discharge would be very small compared to natural variability in downstream catchment conditions, and in the context of the potential impacts on inflow to downstream Lake Burragorang (Warragamba Dam), it would be imperceptible.
- Average Lake water levels would decrease by between 0.01 m and 0.06 m.
- The magnitude of change water levels would be imperceptible and very small compared to natural variability and are therefore considered negligible.
- Hydro Simulations (2018) have indicated a gradual recovery in groundwater impacts following completion of mining. Therefore the above changes would decrease with time following the end of mining.

Given the impacts stated above are likely to small in terms of quantity and relative to natural variability, it is unlikely that these change in water availability in likely to affect aquatic habitat and flora and fauna or key fish habitat.

6.5.4 Streams

Table 18 describes the main streams within the Project Area in relation to their proximity to the proposed longwalls and discusses the possible impacts.

The level of impact of the Project on streams that occur within the Project Area relates to the proximity of the longwalls to the streams. Where the longwalls mine directly beneath the streams it is considered likely that fracturing resulting in surface water flow diversion will occur. Compressive strains due to closure are expected to be of sufficient magnitude to cause the underlying strata to buckle and induce cracking at the surface at some locations. This is likely to lead to the diversion of water from the stream beds into the dilated strata beneath it. In some of these locations, MSEC (2018) expects that the fracturing could impact the holding capacity of the standing pools, particularly those located directly above the proposed longwalls. MSEC considers it unlikely that there would be any net loss of water from the catchment.

Where loose materials occur, it is possible that fracturing in the bedrock would not be seen at the surface. In the event that fracturing of the bedrock occurs in these locations within the alignments of the streams, the fractures may be filled with soil during subsequent flow events (MSEC 2018). Aquatic habitat features present in all of the streams within the Project Area include pools, small waterfalls, undercut banks, trailing vegetation, snags and boulder dominated rapids.

Table 18: Stream impacts

Location	Strahler Stream Order	Description	Discussion of impact
Dog Trap Creek	3rd Order	Located directly above the proposed LW101 to LW109, with a total length of 3.1 km directly mined beneath. LW12 and LW3 have been previously mined beneath a 1.0 km section downstream of LW109.	In addition, there are two tributaries of Dog Trap Creek, both located directly above the proposed LW101 to LW107, one with a total length of 2.6 km and one with a length of 2.4 km directly mined beneath. The substrate overlying the proposed longwall along these sections of Dog Trap Creek consists of mud, cobble, boulder and bedrock with numerous wet pools and rock knickpoints. During monitoring, a visual assessment of the water quality and instream habitat indicated only minor disturbance with slightly turbid waters and the presence of Mosquito fish. The largest numbers of pools mapped within the Project Area were on Dog Trap Creek (in excess of 70). Of these, 14 are located in areas of either moderate or high risk of loss of water holding capacity (HEC 2018c). Thus, there may be loss of aquatic pool habitat in up to 14 pools in Dog Trap Creek as a result of the proposal. In addition, there may be changes to the quality of the aquatic habitat through subsidence related impacts on water quality. It is possible however that cracking would be naturally infilled over time due to the nature of the substrate upstream of this area. The potential for erosion to occur is a balance between erosional forces (velocity) and erosional resistance of the bed and banks (bed shear stress). In general flow velocity is high in Dog Trap Creek due to the relatively steep bed gradient. The lowest velocities occur in the upper reaches where the drainage channel is flatter and the flows are more dispersed. Velocities increase as the creek gradient steepens and becomes more defined further downstream. Peak flow velocity is predicted to decrease in some areas and to increase in other areas. Significant increases in velocity (i.e. between 0.8 and 0.9 m/s) were predicted in isolated sections overlying longwalls 103 to 106. Relatively smaller increases in velocity (0.25 to 0.3 m/s) were predicted in areas overlying longwalls 101, 102 and 109 (HEC 2018c). The predicted changes in bed shear stress were generally small with increases generally between 10 and 50%. The higher increases occurred in isolated sections overlying and downstream of pillars between longwalls 105 and 106.
Tributary 1 to Dog Trap Creek	2nd Order	Located directly above the proposed LW101 to LW107, with a total length of 2.6 km directly mined beneath.	
Tributary 2 to Dog Trap Creek	2nd Order	Located directly above the proposed LW101 to LW107, with a total length of 2.4 km directly mined beneath.	
Hornes Creek	4th Order	Not directly mined beneath, located 360 m south-west of LW108 at its closest point to mining.	Subsidence related impacts in this creek are likely to be low based on their distance to longwalls (MSEC 2018). Thus, loss of water in pools and changes to water quality from subsidence related impacts are unlikely to impact the aquatic habitat in Hornes Creek.
Tea Tree Hollow	3rd Order	Located directly above the proposed LW101 to LW105, with a total length of 1.9 km directly mined beneath. LW1 and LW2 have been previously mined beneath a 0.5 km section downstream of LW101.	Tea Tree Hollow is located directly above the proposed LW101 to LW105, with a total length of 1.9 km directly mined beneath. LW1 and LW2 have been previously mined beneath a 0.5 km section downstream of LW101. In addition, a 3rd order tributary to Tea Tree Hollow is located directly above the proposed LW101 to LW106, with a total length of 2.4 km directly mined beneath The substrate overlying the proposed longwalls along these sections of creek consists of mostly mud, with some areas of bedrock and boulders. There are limited wet areas in the upper reaches as this creek is highly ephemeral and there are a number of rock knickpoints. During monitoring, the creek upstream of the discharge point was highly ephemeral in nature with flows only following rainfall. There was little visual evidence of human related disturbance in the upstream areas. Downstream of the Licensed Discharge Point was observed to be flowing on all monitoring occasions and the waters appeared turbid and some foam was present on the surface of the water. Instream evidence of disturbance included the presence of Mosquito Fish, filamentous algae, gravel and thick coating of a dark coloured precipitate over the substrate of unknown composition. There was also evidence of disturbance of the riparian vegetation, with some tracks in the vegetation and exotic grasses. There were 14 pools mapped in Tea Tree Hollow Creek within the Project area. Most of these pools are located in areas where there is a low risk of impact to water holding capacity. Two pools are however located in an area of moderate risk of impact to flow holding capacity (HEC 2018c). Thus, there may be loss of aquatic pool habitat in these two pools in Tea Tree Hollow as a result of the proposal. In addition, there may be changes to the quality of the aquatic habitat through subsidence related impacts on water quality. It is possible however that cracking would be naturally infilled over time due to the nature of the substrate upstream of this area. In general flow velocity in Tea Tree Hollow is high due to the relatively steep bed gradient. The lowest velocities occur in the upper reaches where the drainage channel is flatter and sections of the creek immediately upstream of main culvert constrictions beneath Remembrance Driveway and the railway line. Velocities are higher downstream of the culvert constrictions and in downstream reaches, which have steeper bed gradients. The highest simulated velocities were between 2.5 and 3.5 m/s in areas overlying LW104 and LW105. Peak flow velocity is predicted to decrease in some areas and increase in other areas. The most significant increases in velocity (i.e. between 0.4 and 0.6 m/s) are predicted in
Tributary to Tea Tree Hollow	3rd Order	Located directly above the proposed LW101 to LW106, with a total length of 2.4 km directly mined beneath.	

			isolated sections overlying longwalls 102 and 105 (HEC 2018c). The predicted changes to bed shear stress were generally small and less than 10% in most areas (HEC 2018c). The predicted changes in velocity and bed shear stress relate to erosion resistance.

6.6 Aquatic biota

6.6.1 Subsidence

The ground movements induced by longwall mining can have indirect impacts on aquatic biota through: the diversion of surface water flows to the dilated substrata, reducing water holding capacity of pools and stream connectivity, increased levels of ponding, and changes in water quality (DoP 2008). Drainage of pools resulting from mine subsidence in areas (discussed in Section 6.4.2) will impact aquatic biota inhabiting these pools, including macroinvertebrates and native fish, with high mortalities likely in areas of complete pool drainage. Areas of medium to high risk of impact on water holding capacity of pools include Tea Tree Hollow and Dog Trap Creek (HEC 2018c).

Hydro and Engineering Consulting (HEC 2018c) identified 16 pools likely to be impacted through reduced water holding capacity from longwall mining. While there may be loss of water (temporary or permanent) to sections of streams, the overall catchment yield is not expected to change (HEC 2018c; MSEC 2018). For invertebrates, while there will be loss of habitat in sections of streams, and changes to invertebrate composition, density and family richness where these impacts occur, it is unlikely that at a sub- catchment to catchment scale changes to overall assemblage and family richness will be measurable, however total biomass is likely to be reduced.

6.6.2 Localised short-term impacts

The sudden drainage of pools or rapid drop in stream flow due to subsidence are likely to have localised, significant impacts to aquatic biota, particularly on organisms that are unable to move to areas that are damp or submerged. Aquatic plants and sessile animals are particularly vulnerable to desiccation, because of their inability to move elsewhere to other available habitat. The survival of mobile organisms is difficult to predict, as it depends on a number of factors such as their tolerance and response to desiccation and rapid changes in water level, their ability to move, weather conditions, the underlying substratum and duration of exposure (Larned et al. 2010). Streams with soft sediment banks are likely to contain moisture with interstices which may prolong the survival of stranded animals. In the streams with a bedrock substrate where there are few natural refugia, with the exception of cracks and cavities, few organisms may survive complete pool drainage. The majority of freshwater fish species recorded in the Project Area are likely to asphyxiate when exposed to air.

6.6.3 Recovery potential of stream biota

There is capacity for recovery of some stream biota, particularly macroinvertebrate fauna. Ephemeral/ semi-permanent streams function as meta-communities (i.e. part of a larger community), with variable hydrological connectivity and multiple dispersal pathways (water, air, dry river bed) (Larned et al. 2010). Aquatic insects with aerial stages may be the most common migrants to and from disconnected aquatic habits. As well as those invertebrates that can persist for years as cysts, eggs, copodites, cocoons and dehydrated larvae and adults, and crayfish (*C. destructor* and *E. spinifer*), which retreat to their burrows or disperse overland. Most taxa identified are able to adapt to drying conditions and have the potential to recruit back to pools once and if pool holding capacity is re-established. Animals with long larval stages and limited distribution, are obligates to a particular habitat, or are poor dispersers will be most impacted. Fish may be limited in their capacity to re-establish if river connectivity is reduced. However surface flow will remain connected in higher flow periods (HEC 2018c) enabling movement of fish. Submerged and floating macrophytes generally require permanent water however they can, in time, recolonise dry areas if and when water levels return.

6.6.4 Long term impacts

Although there is potential for recovery, long term impacts may persist. Some pools may not self-heal; either being permanently dry; or have a permanently reduced holding capacity (of both volume and retention); and thus contribute to reduced stream connectivity. This could lead to permanent changes to stream biota within the affected pools and restrict recovery of animals that require stream connectivity e.g. fish.

6.6.5 Potential for increased levels of ponding

Mining can potentially result in increased levels of ponding and scouring of the stream beds. While the potential for increased scouring is not expected to be significant within the Project Area, there is a predicted reversal of grade along a naturally flat section of Dog Trap Creek, upstream of the tailgate of LW103, which results in increased potential for ponding in an area which is estimated to be up to 0.2 m deep and 150 m long.

Increased ponding is likely to provide localised increase in available habitat for aquatic macroinvertebrates and if there is stream connectivity in the area of ponding, it may also provide additional habitat for fish and macrophytes.

6.6.6 Changes in water quality

The potential impacts of subsidence on water quality in overlying waterways include the liberation of contaminants from subsidence induced fracturing in watercourses. This causes localised and transient increases in iron concentrations and other constituents due to flushing of freshly exposed fractures in the sandstone rocks which contain iron and other minerals. This sort of impact has the potential to affect biota in Tea Tree Hollow and Dog Trap Creek, and downstream watercourses (e.g. Bargo River). Changes to chemical characteristics of surface flows can also occur as a result of changes in base flow. One of the effects of longwall subsidence on watercourses commonly reported is the emergence of ferruginous springs, often accompanied by iron flocs (DoP 2008), staining of the bed, increased turbidity and the build-up of iron rich slimes. This furruginous deposition occurs within sandstone streams in the Sydney Basin and was particularly prevalent at Horne Creek potential impact site and Eliza Creek and Stonequarry Creek control sites.

Studies have shown considerable impact to flora and fauna from iron depositional related impacts (Wellnitz *et al*.1994; Johnson and Ritchie 2003). Invertebrate communities are impacted through a reduction in abundance, richness and changes to community composition (Johnson and Ritchie 2003; Wellnitz *et al*.1994; Rassmussan and Lindegaard 1988; Peters *et al*. 2011). It is thought that invertebrates are impacted through: reduction of habitat complexity, interference of holdfast mechanisms, affecting food supply, coating respiratory surfaces, and inhibiting ion exchange (Johnson and Ritchie 2003; Wellnitz *et al*. 1994). A commonly affected insect order is Mayflies, in particular the family Leptophlebiidae (SIGNAL 8) (Johnson and Ritchie 2003; Wellnitz *et al*.1994; Rassmussan and Lindegaard 1988; et al 2011). The sensitivity of Mayflies is likely to be related to the exposure of gills and the dependence on periphytic algae (Johnson and Richie 2003).

Leptophlebiidae was a common taxa found throughout most sites however they were depauperate in both Horne Creek sites but not in Eliza Creek. It is possible that increased iron precipitation in anoxic streams can impact macroinvertebrates through decrease in density, richness and changes to community composition.

Iron is known to precipitate on the gills of fish and eggs, prevent oxygen uptake (Peuranen *et al*. 1994) and also affect the food supply (Wellnitz *et al*.1994). Scouring of iron flocculent increases turbidity and suspended solids and may inhibit fish feeding (Peuranen *et al*.1994).

The degree of impact will be related to the alkalinity of the stream. Streams that are acidic (low pH) are likely to be impacted more than alkaline streams (Johnson and Ritchie 2003; Wellnitz *et al*.1994; Peters *et al.* 2011) that have greater buffering capacity. The impact of metals (iron, manganese, and zinc) is also expected to be localised and transient (HEC 2018c) and dependent upon stream flow. The impacts to stream fauna similarly are expected to be localised, and fauna are likely be able to recover from transient spikes in concentration. Localised long-term changes to fauna may occur if metal concentration is elevated for extended periods of time.

Drainage of strata gas and expression to the surface through surface water has occurred to varying degrees in the Southern Coalfields however it does not affect the quality of surface waters that it drains through, and therefore unlikely to impact aquatic biota (HEC 2018c) . Although gas emissions have been known to cause rare and isolated dieback of riparian vegetation in the Southern Coalfields (DoP 2008).

6.6.7 Mine water discharge impacts

Mine water contains elevated concentrations of dissolved salts and metals and can pose environmental risks to aquatic biota. In times of low rainfall however, mine water may be the only source of water for creeks, although at other times, the water may be diluted by other sources of runoff. The potential effects of the discharge decrease with increasing distance from the source.

Many factors, including the chemical composition of discharged water, conductivity, volume and periodicity of flow and habitat characteristics, combine to determine the abundance and composition of aquatic biota which, in turn, determines ecosystem viability (CEL 2011). There are three main impacts associated with mine water discharge at Tea Tree Hollow. These are: heavy metals and barium precipitate, increased salinity, and an altered hydrological regime.

Heavy metals and barium precipitate

Heavy metals have been shown to affect macroinvertebrate and algae composition (Niyogi 2002; Scheiring 1993; Holand *et al*. 1994; Pollard and Yuan 2006) through the reduction in abundance and diversity. Increases in heavy metals in mine water discharge are not predicted from the Tahmoor South Project (HEC 2018c) and it is expected that the commissioning of the heavy metal treatment plant will reduce the presence of heavy metals in the streams. Therefore future impacts from the development to aquatic ecology from heavy metals are unlikely.

A precipitate barium coal leachate present within Tea Tree Hollow downstream of LDP1 from the mine discharge has resulted in the benthos of Tea Tree Hollow being smothered by a hard black barium precipitate (Plate 3). The precipitate is likely to be impairing the benthic fauna and habitat. This precipitate consists of barium, iron, aluminium and manganese and is inert, however it is possible that the structural changes to the benthos are affecting the flora and fauna that use this habitat. The lack of interstitial spaces and covering of organic matter are thought to be limiting habitat and food supply. There is likely to be a reduction in the barium precipitate with the upgrade of the heavy metals water treatment plant required by PRP22 program. Completion of the program would most likely result in enhanced water quality in Tea Tree Hollow and the Bargo River downstream and thus improved habitat for primary producers and aquatic fauna.

Whilst not anticipated, accidental spills could also occur which could result in transient impacts to water quality. The risk of these occurring is not likely to increase as a result of the Project and would be managed as part of the site environmental management system (HEC 2018c).

Salinity

Previous studies conducted on Tea Tree Hollow Creek and the Bargo River observed that despite high conductivity levels as a result of mine water, AUSRIVAS analyses indicated that 68% of the expected number of taxa was present in Tea Tree Hollow Creek, but that upstream of the confluence, only 64% of the expected number was recorded (TEL 2005) suggesting that other factors were influencing the composition and abundance of macroinvertebrates (CEL 2010d). In salinity gradient studies, conductivity was observed to correlate weakly with macroinvertebrate abundance and number of taxa (CEL 2010d). Their studies concluded that factors other than the discharge from Tahmoor Mine are responsible for the smaller number of taxa than might be expected and that conductivity is not always the best, or even a good indicator of ecosystem "health" (CEL 2010d). A recent study conducted under PRP23 (CEL 2016) concluded that while there was evidence of an effect of the discharge on the aquatic ecology of Tea Tree Hollow and at locations on the Bargo River, these effects appear to be localised to areas immediately downstream of the Discharge Point in the Bargo River. The study recommended no further reductions in EC levels.

This assessment assumes that increases in salinity will not occur with the development of the Tahmoor South Project. Therefore it is expected that although the salinity of mine water discharge may still remain consistently elevated with respect to background levels, that no further impact to aquatic biota would be incurred if current levels are maintained.

Altered hydrology

The other impact to Tea Tree Hollow from mine water discharge is the impact of hydrology itself. The hydrology and its effect on fluvial geomorphology are inconsistent with streams in the area. The consistent flow of water differentiates the habitat present from the slow to no flow, poorly connected pools of other streams of similar size. Cardno Ecology Lab (CEL 2010d) found that physical conditions, such as water depth and substratum best "explained" the spatial distribution of invertebrates in Tea Tree Hollow. For this reason it is often difficult to ascertain whether the difference in faunal assemblages are the result of water quality or are the result of a constant flow of water that alters the flow dynamics, geomorphology, and thus habitat with in Tea Tree Hollow. Despite this, the discharge is providing habitat that would normally be dry and does contribute to flows in Bargo River.

The results of predictive modelling of the water management system over the remaining mine life indicate that total discharges and spill from the pit top of the combined existing Tahmoor North operation and the proposed Tahmoor South Project are unlikely to increase significantly from current levels. On the basis of the above, it is not expected that the Tahmoor South Project would result in adverse water quality impacts due to releases and spills from the site water management system (HEC 2018c).

6.7 Cumulative impacts

Cumulative impacts can be defined as the total impact on the environment that results from the incremental impacts of the action (in this case, the Project) added to other past, present, and future actions in a defined area and the interactions between these developments.

This assessment identified four major cumulative impacts to the aquatic environment. These are impacts to: water quality, stream connectivity, stream habitat and aquatic ecology and communities and threatened species.

6.7.1 Cumulative water quality impacts

It was concluded in section 6.4.3 that mine water discharge is unlikely to cause further adverse effects to the environment as there will be no negative change in discharge management. With the implementation of the heavy metals water treatment plant (under PRP 22) future cumulative impacts minewater discharge is considered neutral. However mine water discharge currently contributes to poor water quality in Bargo River and there is an interaction with past (water infrastructure developments), that is Picton Weir. This potentially has a cumulative effect to water quality as discharge is less diluted from upstream flow. This cumulative impact however is existing, and is partially offset by the potential habitat, and connectivity provided by mine water discharge from Tea Tree Hollow to Bargo River.

The combined water quality effects of the Project itself could be considered cumulative as discharge related impacts to water quality and subsidence water quality impacts can potentially contribute to increased poor water quality than would be experienced otherwise.

Land use from past and current activities contributes to poor water quality in streams in the Project Area. The main land use, agriculture (poultry, cattle, sheep, cropping), can contribute to point source (licensed discharges) and non-point source pollution through increased nutrients, sedimentation and other potential chemical inputs. Thus, combined impacts from existing and future agricultural landuse, with subsidence and discharge water quality impacts from the Project, are cumulative. Water extraction from these waterways for either agriculture or stock and domestic use, could also contribute to lower water level and exacerbate Project impacts through concentration of poor water quality.

6.7.2 Cumulative impacts to stream connectivity

Stream connectivity is naturally limited; however subsidence is likely to accentuate poor stream connectivity in the streams. In addition to this, Bargo River is disconnected from upstream reaches by Picton Weir and the Nepean dam disconnects the Nepean River. This is combined with other instream dams/weirs in some of the smaller water ways (e.g. Eliza Creek). Impacts to stream connectivity may particularly impact the movement of small fish with in the lower order streams and their overall distribution.

6.7.3 Cumulative impacts to loss of pool habitat

In general, temporary or permanent loss of pool habitat resulting from subsidence is not expected to change aquatic macroinvertebrate communities present in the river system at a sub-catchment to catchment scale. It is expected the same invertebrates will inhabit the streams where appropriate habitat is provided. However with the net loss of available habitat, there is likely to be less biomass in the system as a whole. The temporary or loss or alteration of pool habitat is in addition to the loss of pool habitat from current mining activities such as Tahmoor North (Redbank Creek and Myrtle Creek) and accentuated by degradation from agricultural land use (land clearing and sedimentation).

6.7.4 Cumulative impacts to aquatic ecology and communities

The aquatic ecology is affected by the combined influence of water quality, stream connectivity and habitat loss and is therefore susceptible to cumulative impacts to these environmental variables. The cumulative effects to ecology are difficult to predict and are likely to be spatially and temporally variable. Impacts may be localised (e.g. to a pool), transient (e.g. occur in prolonged low flow condition only), gradational impacts (e.g. downstream from a point source) and maybe triggered when one or more environmental thresholds are met. Impacts to stream and biological processes may alter aquatic communities through: localised reduced abundances of sensitive flora and fauna, increased abundance on tolerant flora and fauna, reduction of abundances of all aquatic flora and fauna, and a reduction of fauna richness. However there is potential for partial recovery of stream fauna as: Pollution Reduction Programs are to be implemented (e.g. PRP 22), and with re-establishment of aquatic communities following natural repair of some pool habitat.

7. Safeguards and management

During construction, management of drainage and sediment flows, in order to minimise sediment-laden scouring, run-off and subsequent deposition into adjoining areas are required.

7.1 Subsidence

It is recommended that subsidence monitoring of macroinvertebrates be conducted two years prior to longwall extraction. The monitoring program may require adding or relocating sites according to the final mine plan, and using the same sampling methods as used in this monitoring conducted thus far. It is recommended that a BACI (Before After Control Impact) designed monitoring program be implemented to compliment the baseline information collected and to assess potential impacts in an adaptive management framework.

It is also recommended that appropriate stream rehabilitation measures be applied to areas that undergo significant impacts due to subsidence.

7.2 Mine water discharge

It is recommended that:

- The requirements of PRP22 are implemented and the heavy metal water treatment upgrades discussed in section 2.4 be implemented to improve the water quality of the mine water discharge.
- An investigation of Tea Tree Hollow downstream of the LDP1 Licensed Discharge Point be undertaken to determine methods of potential remediation of the creek to remove the impacts of the black precipitate on the aquatic habitat.
- EC discharge limits for LDP1 currently listed in the Tahmoor Environment Protection licence remain unchanged and that an aquatic ecology monitoring program be established aimed at identifying any future changes in aquatic health due to the discharge from LDP1.
- It is recommended in light of field surveys and the previous studies (CEL 2010 a, b, c, d), that monitoring focuses upon the barium precipitate in Tea Tree Hollow, as EC as the measure of stream health and its correlation to invertebrate assemblages is poor. Although artificial sampling methods were used in Cardno Ecology Lab study (2010d), monitoring could include quantitative benthic suction sampling that specifically samples the benthos in situ such as used in this study. The artificial sampling (although provides a standard substrate) is likely to miss invertebrates that colonise the interstitial spaces of the benthos and as such may not be representative of habitat and or the impact affecting it. It is also subject to lengthy deployment making it susceptible to high flow events. Quantitative sampling of benthic algae in situ is also recommended, as well as the sampling of the inorganic benthic precipitate itself.

7.3 Aquatic habitat

In terms of general aquatic habitat, DPI (2013) enforces a ‘no net loss’ habitat policy for key fish habitat. There are two types of activity which can be used to mitigate damage to fish habitat, which are:

- Habitat rehabilitation - involves repairing damage caused by past activities.
- Environmental compensation - the creation or enhancement of fish habitats or fisheries resources in order to compensate for anticipated adverse or actual environmental effects of proposed developments. Environmental compensation may include:
    - Structures which represent an integral part of the development (e.g. groynes, pylons, artificial waterways).

- Works which are undertaken as compensation for disturbance of ecologically important habitats (e.g. transplanting vegetation, fishways, environmental flows, removal of barriers to fish passage, removal of polluted areas).
- Money to pay for the value of the habitat lost (DPI 2013).

Significant environmental impacts (direct and indirect) are to be offset by environmental compensation. Compensation to offset fisheries resource or habitat losses will be considered by DPI only after it is demonstrated that the proposed loss is unavoidable, in the best interest of the community in general and is in accordance with the FM Act, regulations and their policies and guidelines.

In addition, scientific research and monitoring programs should be established to quantify the impacts of development and the effectiveness of environmental mitigation and compensation measures. Management should be adaptive to incorporate the findings of these programs (DPI 2013).

Based on Key Fish Habitat mapping prepared for each local government area (i.e. Wollondilly), the following waterways within the Project Area have been mapped as Key Fish Habitat: Bargo River; Hornes Creek; Tea Tree Hollow; Dog Trap Creek; Eliza Creek; Carters Creek; and Cow Creek (DPI 2017c). First and second order streams are not classified as Key Fish Habitat under NSW legislation (DPI 2013), however 3rd order streams and above are. The Tahmoor South Project have 3rd Streams and above that contain both highly sensitive Key Fish Habitat (Type1) “Freshwater habitats that contain in-stream gravel beds, rocks greater than 500 mm in two dimensions, snags greater than 300 mm in diameter or 3 metres in length, or native aquatic plants” and minimal Key Fish Habitat (Type 3) “Ephemeral aquatic habitat not supporting native aquatic or wetland vegetation” (DPI 2013).

Section 6.6 discusses the likely loss of potential fish and macroinvertebrate pool habitat in the Project Area and the potential recovery with in these systems. While it is difficult to quantify the potential habitat loss and recovery, modelling by HEC (2018) and MSEC (2018) have predicted 16 pools with a high likelihood of suffering partial or total drainage from the proposed development. This is likely to affect both Type 1 and Type 3 habitat that occurs in the Project Area.

In addition, the quality of the water in the creeks within the Project Area will potentially be impacted by the liberation of contaminants from subsidence, changes to chemical characteristics of surface flows and contamination of surface waters by gas drainage (HEC 2018c) which are discussed further in Section 6.4.

Tahmoor Coal will negotiate with NSW DPI any rehabilitation and compensation measures that may be deemed necessary to ensure the longevity and ongoing management of Key Fish Habitat during and post coal extraction.

8. Conclusion

8.1 Subsidence Impacts

The following conclusions were made from the assessment of subsidence impacts:

- The dominant aquatic macroinvertebrates recorded in streams within the Project Area include Leptophlebiidae (may fly), Chironomidae, Tanypodinae, Othocladinae (non-biting midges), and Oligochaeta (worm) larvae. Other families such as Leptoceridae (caddis fly) were also common.
- Fracturing and loss of water would result in loss of aquatic habitat in sections of Dog Trap Creek and Tea Tree Hollow, and subsequently loss of aquatic biota inhabiting pools.
- Native fish recorded in the Project Area may be subject to desiccation and a range of macroinvertebrates would also suffer mortalities in areas where pools are drained.
- Migration of fish maybe limited by temporary or permanent changes to pool connectivity.
- There will potentially be localised changes to macroinvertebrate community assemblages, mean density and mean family richness.
- There is expected to be some recovery of aquatic fauna once pool holding capacity is re-established.
- At a catchment scale there is likely to be an overall reduction in faunal biomass, however, the overall catchment composition of macroinvertebrates is not expected to change.
- Increased iron floc precipitation from subsidence impacts may locally affect some macroinvertebrates such as Leptophlebiidae (mayfly) and has been known to affect fish.
- No threatened macroinvertebrates were identified with in the Project Area.
- There is potential habitat for Sydney Hawk dragonfly however it was concluded that it will not be impacted by the proposed development.
- No threatened fish or aquatic flora were identified as being affected by the Project within the streams in the Project Area.
- No impacts are expected for the Nepean and Bargo rivers.
- No impact to aquatic ecology is expected for Thirlmere Lakes.

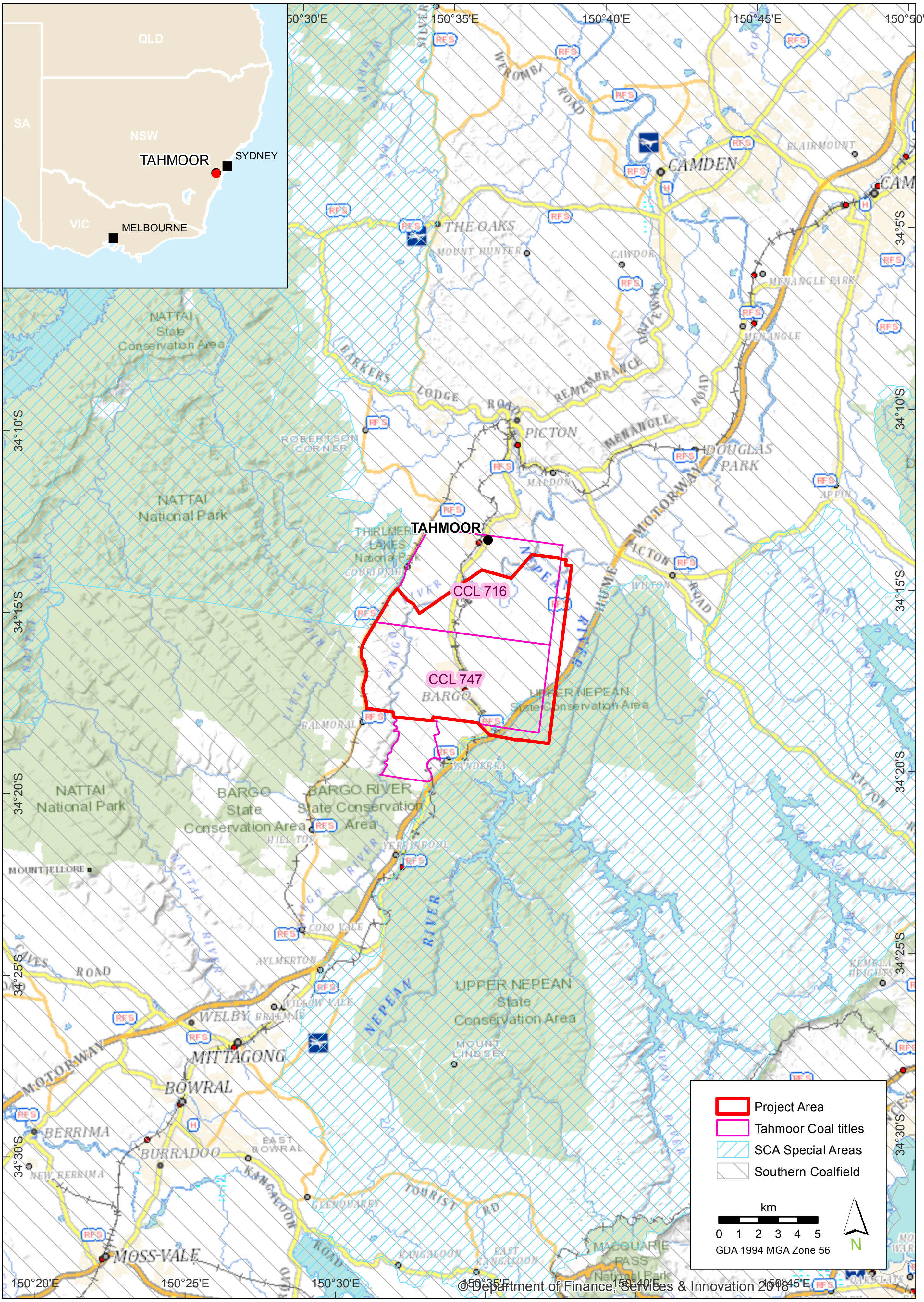
8.2 Mine water discharge Impacts

The following conclusions were made from the assessment of mine water discharge impact:

- There was significant difference between impact and control groups however this difference could not be directly related to mine water discharge impacts.
- These differences were reductions in Leptophlebiidae, Oligochaeta, Elmidae and increases in Chironominae and Caenidae in affected sites.
- Although no direct relationship could be established between faunal differences and mine water discharge, these taxa could be potentially useful indicators in a quantitative benthic monitoring program.
- A barium precipitate was identified as having a potential impact to benthic substrate and is thought to be impacting benthic processes and fauna.
- The implementation of a heavy metal treatment plant is likely to reduce heavy metal from mine water discharge and reduce barium precipitation.
- Studies of salinity from mine water discharge in the Southern Coalfield have not shown a direct linkage between salinity and effects on macroinvertebrates.
- Tea Tree hollow has an affected hydrology with the constant flow of water making it geomorphically different from other streams downstream of the discharge point LDP1.

- It is expected that no further impacts to aquatic ecology will occur with mine water discharge from Tahmoor South Project, as hydrology is not expected to differ significantly from the current regime, and with the commissioning of the heavy metals treatment plant water quality is expected to improve.
- It is expected that if salinity concentrations do not significantly change, no further impact to aquatic ecology will occur.

9. Figures



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Location map

Aquatic Ecology Impact Assessment

FIGURE 1

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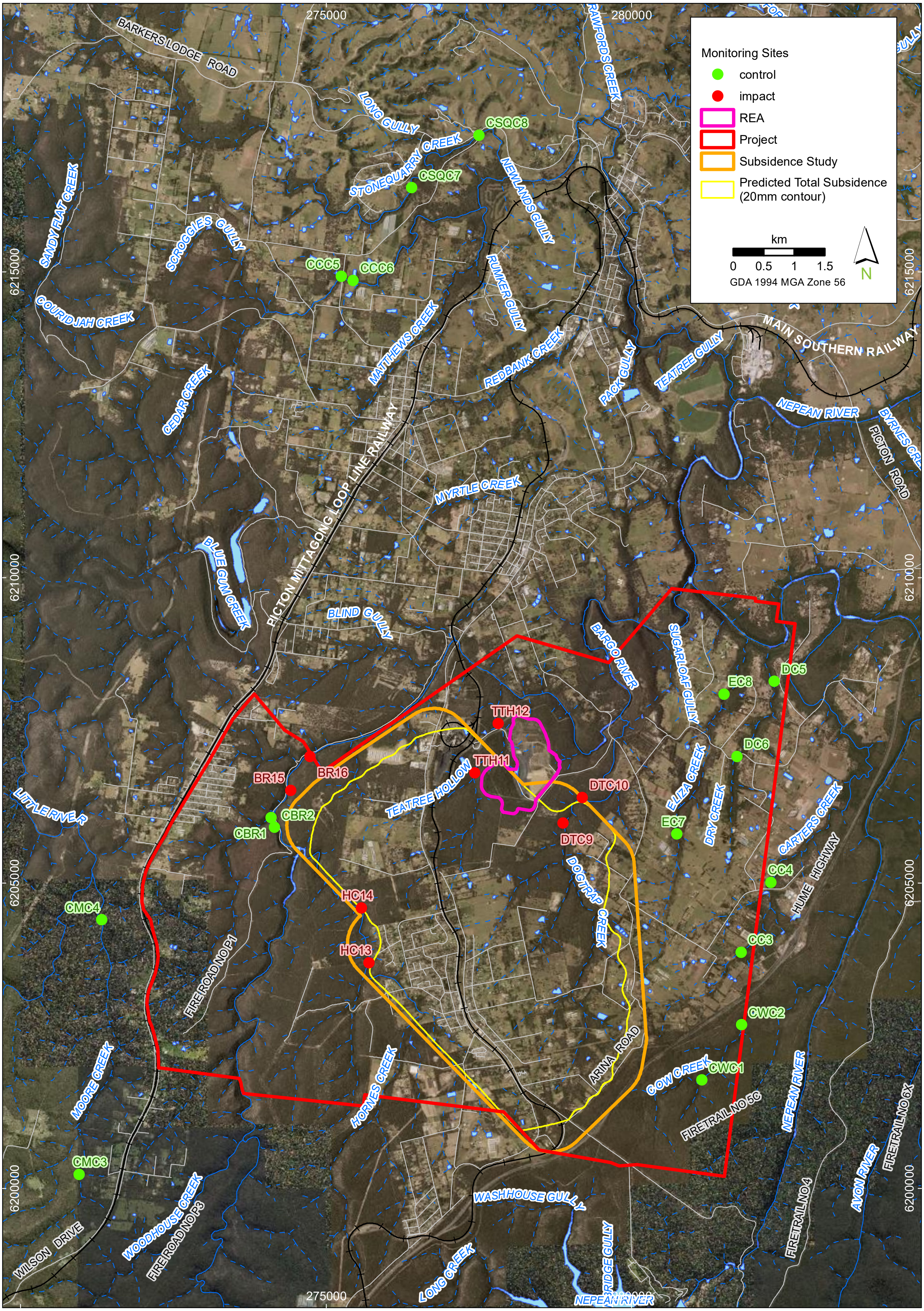
Project Area

Aquatic Ecology Impact Assessment

FIGURE 2

Imagery: (c) LPI 2016



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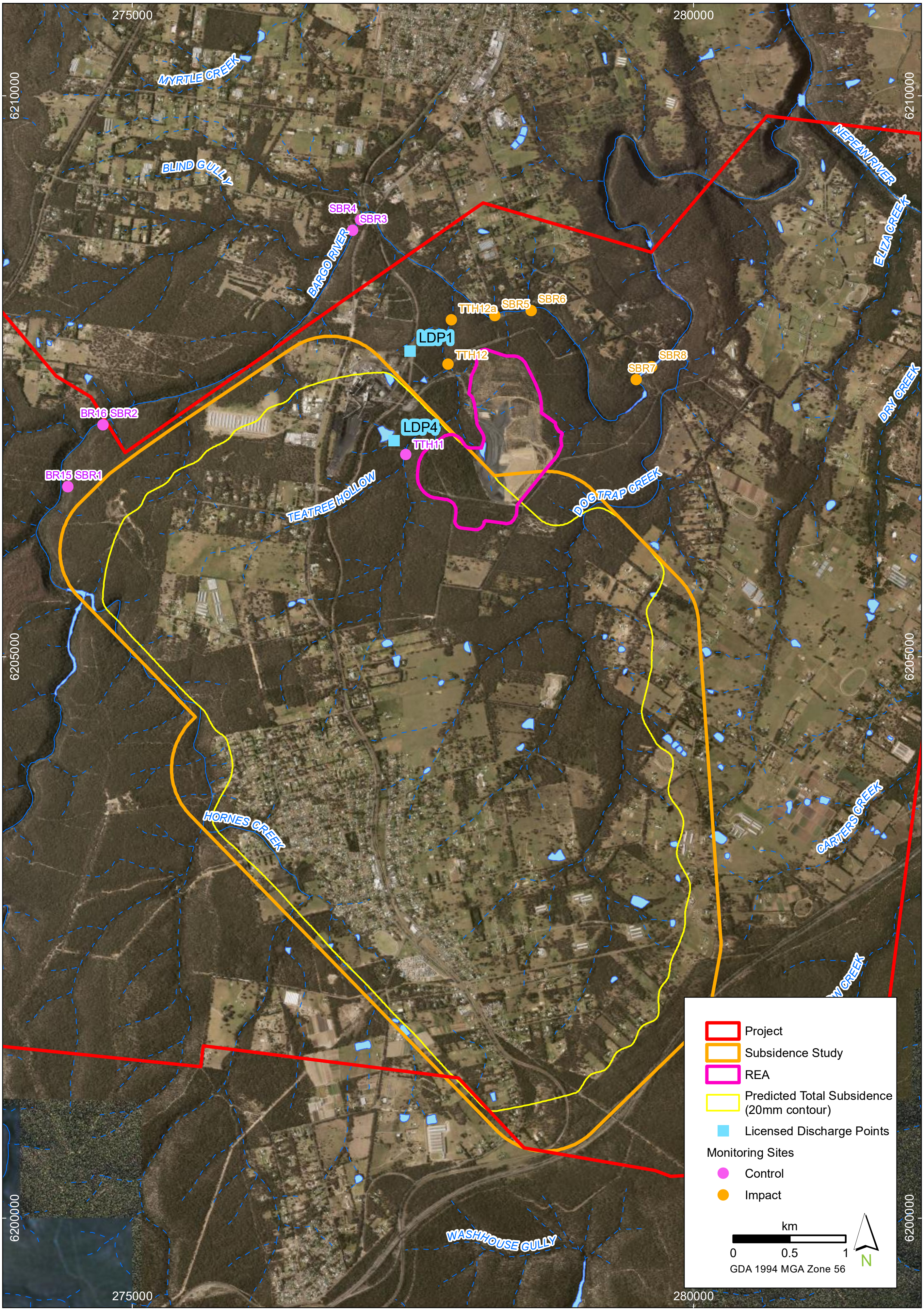
Monitoring sites - Subsidence

Aquatic Ecology Impact Assessment

FIGURE 3

Imagery: (c) LPI 2016-11-04



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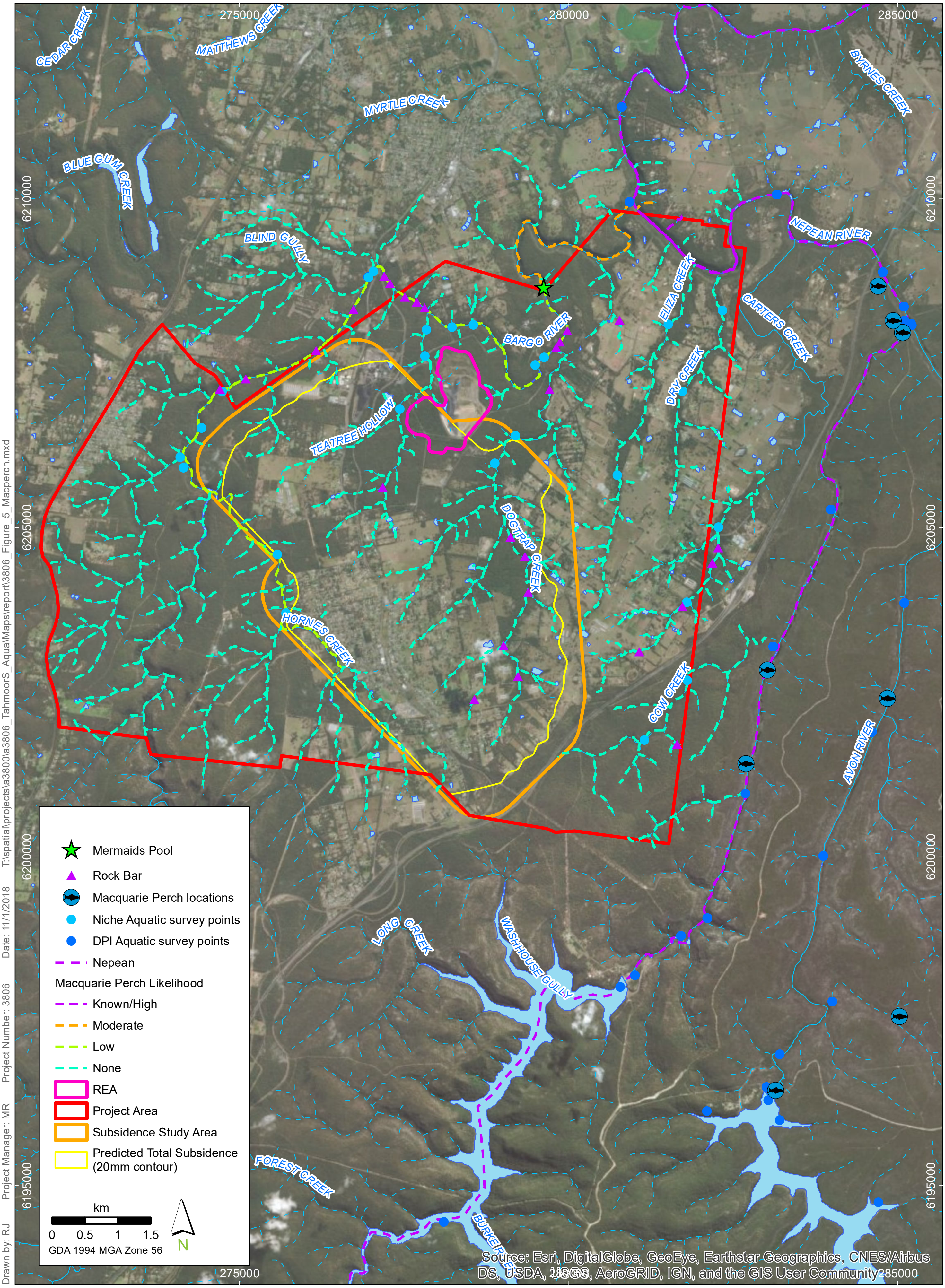
Monitoring sites - Discharge

Aquatic Ecology Impact Assessment

FIGURE 4

Imagery: (c) LPI 2016



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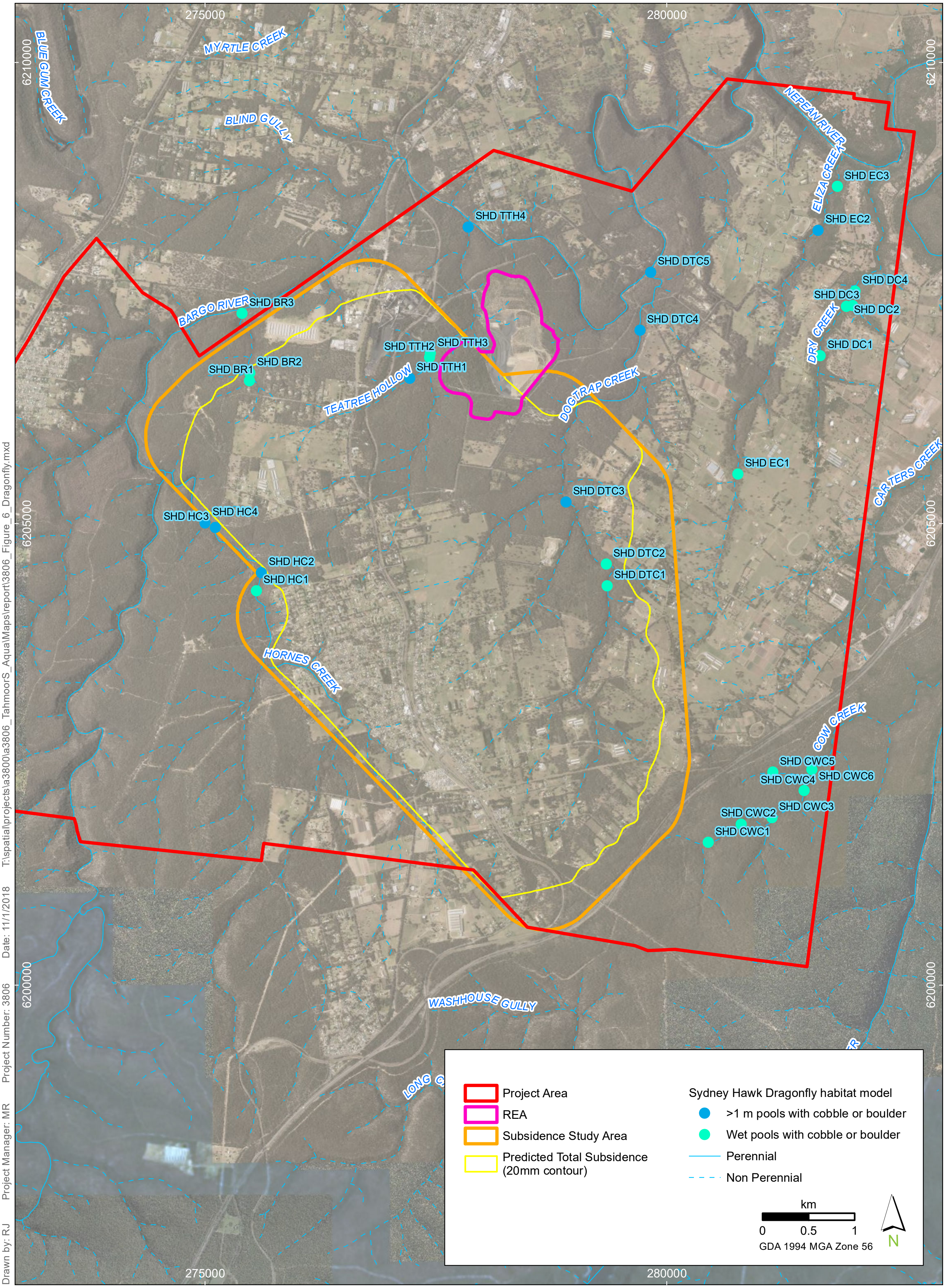
Macquarie Perch Habitat Analysis

Aquatic Ecology Impact Assessment

FIGURE 5

Imagery: (c) DigitalGlobe 2016



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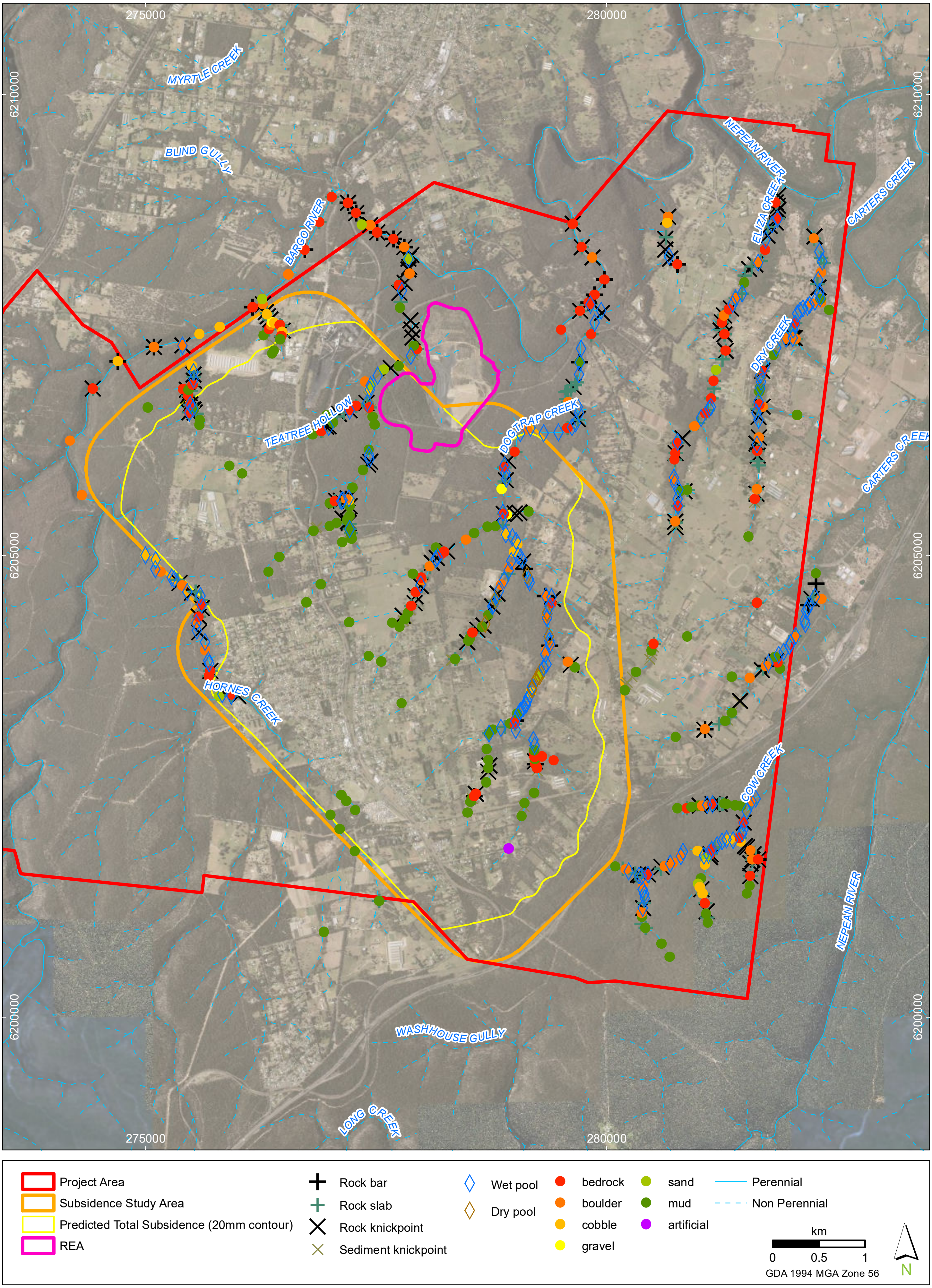
Threatened Dragonfly Habitat

Aquatic Ecology Impact Assessment

FIGURE 6

Imagery: (c) LPI 2016



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General Stream Geomorphology

Aquatic Ecology Impact Assessment

FIGURE 7

Imagery: (c) LPI 2016

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11. Plates

a)

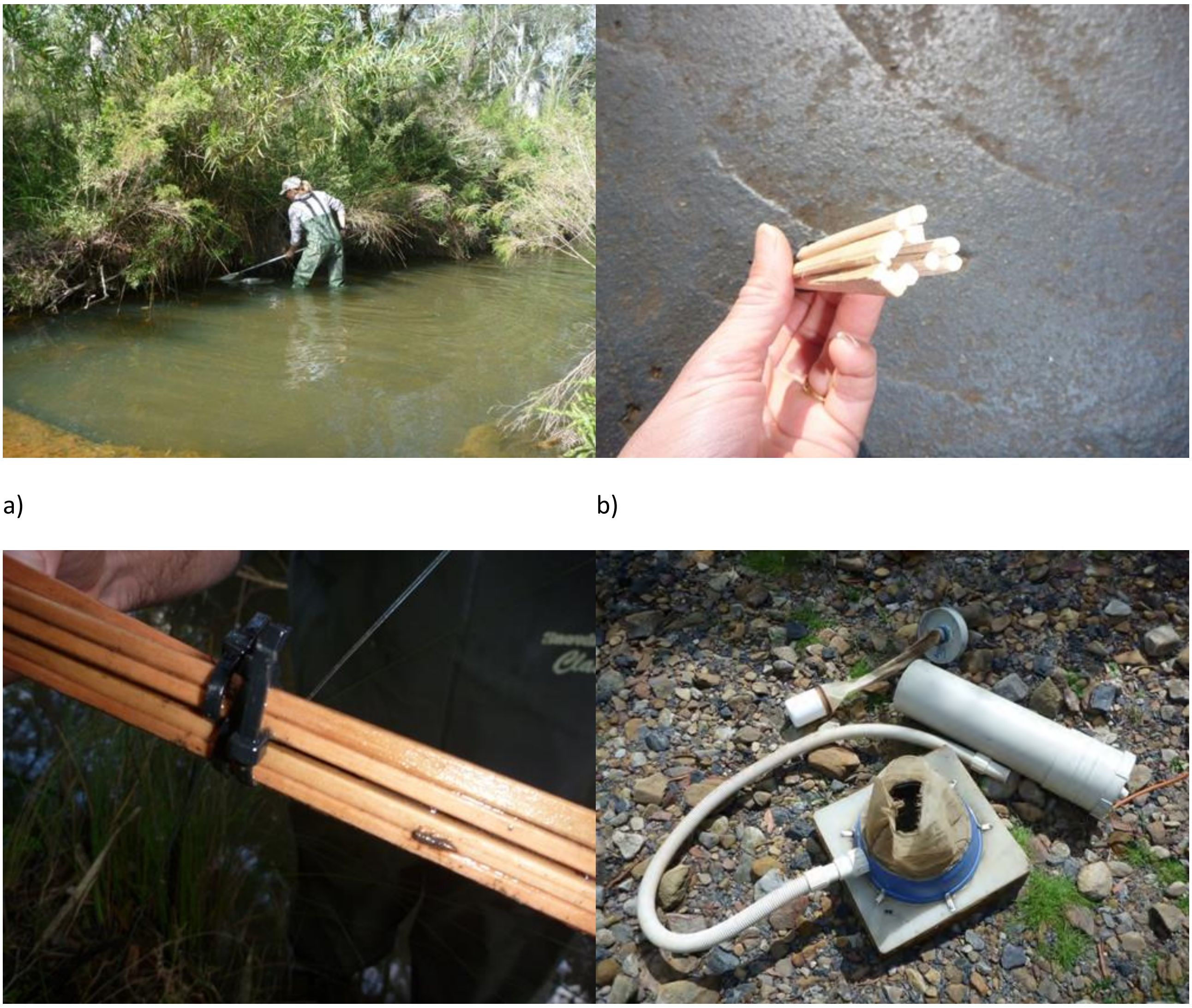
b)

c)

d)

Plate 1: Fish sampling techniques

Fish sampling techniques used in baseline surveys. a) Bait traps deployed at each site; b) dip netting for macroinvertebrate and fish sampling; (c) Yabby *Cherax destructor* caught in both bait traps and dip nets in creeks throughout the Project Area; and d) Firetail Gudgeon *Hypseleotris galii* caught in dip net at Dry Creek.



a) b) c) d)

Plate 2: Aquatic macroinvertebrate collecting techniques

Aquatic macroinvertebrate collecting techniques used in baseline surveys. a) AUSRIVAS macroinvertebrate edge sampling technique; b) macroinvertebrate artificial collector; c) macroinvertebrate artificial collector *in situ* and d) benthic suction sampler.

Plate 3: Barium precipitate sample

Barium precipitate sample collected from TTH12a in autumn 2013.

12. Appendices

Appendix A. Likelihood of occurrence of threatened aquatic fauna within the Project Area

Threatened species [1]	Habitat requirements[2]	Status	Likelihood occurrence in Project Area	Consideration in this assessment
Austrocordulia leonardi Sydney Hawk Dragonfly	The Sydney Hawk Dragonfly has a very restricted distribution. The known distribution of the species includes three locations in a small area south of Sydney, from Audley to Picton. The species is known from the Hawkesbury-Nepean, Georges River, Port Hacking and Karuah drainages. The Sydney Hawk dragonfly spends most of its life underwater as an aquatic larva, before metamorphosing and emerging from the water as an adult. Adults are thought to only live for a few weeks. All dragonflies are predatory. The larvae stalk or ambush their aquatic prey while the adults capture their prey on their wings. The Sydney Hawk Dragonfly has specific habitat requirements, and has only ever been collected from deep and shady riverine pools with cooler water. Larvae are found under rocks where they co-exist with *Austrocordulia refracta* (NSW DPI, 2011a).	E FM Act	Moderate	While there are limited recorded occurrences of this species, they are known from the Hawkesbury-Nepean river catchment and the Project Area does contain habitat where this species is known to occur (deep and shady riverine pools). Targeted surveys were conducted at sites defined as having suitable habitat based on geomorphology mapping (Fluvial Systems, 2013, Figure 7) and failed to locate any specimens. An assessment of significance has been prepared for this species (see Appendix I).
Archaeophya adamsi Adam's Emerald Dragonfly	Adam's Emerald Dragonfly is one of Australia's rarest dragonflies. Only five adults have ever been collected, and the species is only known from a few sites in the greater Sydney region: Somersby Falls and Floods Creek in Brisbane Waters National Park near Gosford, Berowra Creek near Berowra and Hornsby; Bedford Creek in the Lower Blue Mountains; and Hungry Way Creek in Wollemi National Park (Fisheries Scientific Committee, 2008). Larvae have been found in small creeks with gravel or sandy bottoms, in narrow, shaded riffle zones with moss and rich riparian vegetation. The larvae live for approximately 7 years and undergo various moults before metamorphosing into adults. Adults probably live for a few months at most. Adult dragonflies generally fly away from the water to mature before returning to breed. Males congregate at breeding sites and often guard a territory. Females probably lay their eggs into the water. All dragonflies are predatory and the larvae stalk or ambush their aquatic prey while the adults capture their prey on the wing. This species seem to have a low natural rate of recruitment and limited dispersal abilities (NSW DPI, 2011a).	E FM Act	Low	There are no records of Adam's Emerald Dragonfly occurring within the Bargo or Upper Nepean sub-catchments. Based on the known habitat requirements of this species, only one area of suitable habitat (i.e. a riffle section) occurs within the Project Area. Identification of suitable habitat was based on aquatic field surveys and geomorphology mapping (Fluvial Systems, 2013; Figure 7) conducted as part of this proposal. The riffle section is located on the Bargo River which will not be impacted by the Proposal (MSEC, 2018). Targeted surveys were conducted at this site however no specimens were recorded.

[1] Threatened species identified for inclusion in this assessment based on the EPBC Act Protected Matters Search Tool. Accessed April 2013.

[2] Unless otherwise stated information for the threatened species habitat requirements have been sourced from the Office of Environment and Heritage – threatened species website: http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/index.aspx. Additional information has been sourced from the SEWPAC EPBC Act web page http://www.environment.gov.au/biodiversity/ . Each individual reference has not been reproduced in this report.

				Not considered further.
Petalura gigantean Giant Dragonfly	The Giant Dragonfly is found along the east coast of NSW from the Victorian border to northern NSW. It is not found west of the Great Dividing Range. There are known occurrences in the Blue Mountains and Southern Highlands, in the Clarence River catchment, and on a few coastal swamps from north of Coffs Harbour to Nadgee in the south. Giant Dragonfly live in permanent swamps and bogs with some free water and open vegetation. Adults emerge from late October and are short-lived, surviving for one summer after emergence. The adults spend most of their time settled on low vegetation on or adjacent to the swamp. They hunt for flying insects over the swamp and along its margins. Females lay eggs into moss, under other soft ground layer vegetation, and into moist litter and humic soils, often associated with groundwater seepage areas within appropriate swamp and bog habitats. The species does not utilise areas of standing water wetland, although it may utilise suitable boggy areas adjacent to open water wetlands. Larvae dig long branching burrows under the swamp. Larvae are slow growing and the larval stage may last 10 years or more. It is thought that larvae leave their burrows at night and feed on insects and other invertebrates on the surface and also use underwater entrances to hunt for food in the aquatic vegetation (OEH 2012).	E BC Act	Low	The Project Area has no suitable habitat (i.e. absence of swamps and bogs) for this species. Not considered further.
Macquaria australasica Macquarie Perch	Macquarie perch are found in the Murray-Darling Basin (particularly upstream reaches) of the Lachlan, Murrumbidgee and Murray rivers, and parts of south-eastern coastal NSW, including the Hawkesbury and Shoalhaven catchments. The conservation status of the different populations is not well known, but there have been long-term declines in their abundance. Macquarie Perch are found in both river and lake habitats, especially the upper reaches of rivers and their tributaries. They are quiet, furtive fish that feed on aquatic insects, crustaceans and molluscs. Sexual maturity occurs at two years for males and three years for females. Macquarie Perch spawn in spring or summer in shallow upland streams or flowing parts of rivers and females produce around 50,000-100,000 eggs which settle among stones and gravel of the stream or river bed. Populations from the eastward-flowing Shoalhaven and Hawkesbury rivers are genetically distinct and may represent an undescribed species (Allen et al., 2002).	E FM Act; EPBC Act	Low	The creeks within the Project Area have None to Low Likelihood of containing Macquarie Perch habitat. This is based on the highly fragmented habitat, with rock bars and other barriers to fish movement, along with the ephemeral nature of the 1st and 2nd order streams within the Project Area. The creeks also lack suitable spawning habitat. Whilst there are some sections on the Bargo River within the Project Area that contain suitable habitat for Macquarie Perch, they occur above Mermaid Falls and below Picton Weir. It is considered unlikely that a viable population of Macquarie Perch exists in this limited range and there are no recorded occurrences of this species within this section of the Bargo River despite surveys being conducted as part of this assessment and surveys by NSW DPI. Figure 6 shows the quality of Macquarie Perch habitat in the broader area based on the likelihood of occurrence criteria described in

				Diagram 1. None of the creeks within the Project Area are defined as moderate or above and as such, this species is unlikely to occur within the Project Area. There are recorded occurrences of Macquarie Perch downstream in the Nepean River. The proposed water treatment plant (refer Section 5.3.2.1) will improve water quality to receiving waters and will not adversely impact the quality of the habitat for this species. Not considered further.

Key: CE = Critically Endangered; E, E1 = Endangered; EP = Endangered Population; V = Vulnerable.

Appendix B. Site descriptors used to calculate RCE Scores (after Chessman et al, 1997)

Descriptor	Category	Score
1. Landuse pattern beyond the immediate riparian zone	Undisturbed native vegetation	4
	Mixed native vegetation and pasture/exotics	3
	Mainly pasture, crops or pine plantation	2
	Urban	1
2. Width of riparian strip of woody vegetation	More than 30m	4
	Between 5-30m	3
	Less than 5 m	2
	No woody vegetation	1
3. Completeness of riparian strip of woody vegetation	Riparian strip without breaks in vegetation	4
	Breaks at intervals of more than 50m	3
	Breaks at intervals of 10-50m	2
	Breaks at intervals of less than 10m	1
4. Vegetation of riparian zone within 10m of channel	Native tree and shrub species	4
	Mixed native and exotic trees and shrubs	3
	Exotic trees and shrubs	2
	Exotic grasses/weeds only	1
5. Stream bank structure	Banks fully stabilised by trees, shrubs	4
	Banks firm but held mainly by grass and herbs	3
	Banks loose, partly held by sparse grass	2
	Banks unstable, mainly loose sand or soil	1
6. Bank undercutting	None, or restricted by tree roots	4
	Only on curves and at constrictions	3
	Frequent along all parts of stream	2
	Severe, bank collapses common	1
7. Channel form	Deep: width/depth ratio less than 7:1	4
	Medium: width/depth ration 8:1 to 15:1	3
	Shallow: width/depth ration greater than 15:1	2
	Artificial: concrete or excavated channel	1
8. Riffle/pool sequence	Frequent alternation of riffles and pools	4
	Long pools with infrequent short riffles	3
	Natural channel without riffle/pool sequence	2
	Artificial channel, no riffle/pool sequence	1
9. Retention devices in stream	Many large boulders and/or debris dams	4
	Rocks/logs present; limited damming effect	3
	Rocks/logs present but unstable, no damming	2
	Stream with few or no rocks/logs	1
10. Channel sediment accumulations	Little or no accumulation of loose sediments	4
	Some gravel bars but little sand or silt	3

	Bars of sand and silt common	2
	Braiding by loose sediment	1
11. Stream bottom	Mainly clean stones with obvious interstices	4
	Mainly stones with some cover of algae/silt	3
	Bottom heavily silted but stable	2
	Bottom mainly loose and mobile sediments	1
12. Stream detritus	Mainly unsilted wood, bark, leaves	4
	Some wood, leaves etc. with much fine detritus	3
	Mainly fine detritus mixed with sediment	2
	Little or no organic detritus	1
13. Aquatic vegetation	Little or no macrophyte or algal growth	4
	Substantial algal growth; few macrophytes	3
	Substantial macrophyte growth; little algae	2
	Substantial macrophyte and algal growth	1

Appendix C. Sampling dates, weather Conditions and site locations

(a) Sampling dates

Season	Date
Autumn 2012	09/05/12, 10/05/12, 11/05/12, 14/05/12, 15/05/12, 16/05/12
Autumn 2012	07/06/12, 08/06/12, 12/06/12, 13/06/12, 27/06/12, 28/06/12
Spring 2012	15/10/12, 16/10/12, 17/10/12, 18/10/12, 24/10/12
Spring 2012	26/11/12, 27/11/12, 28/11/12, 29/11/12
Autumn 2013	21/03/13, 22/03/13, 25/03/13, 26/03/13, 27/03/13, 02/04/013, 03/04/13
Autumn 2013	29/04/13, 30/04/13, 01/05/13, 02/05/13
Spring 2013	11/09/13, 12/09/13, 13/09/13, 16/09/13, 17/09/13, 18/09/13, 19/09/13
Spring 2013	14/10/13; 15/10/13; 16/10/13; 17/10/13

b) Weather conditions

Date	Temperature (°C)	Rain (mm) [a]	Wind Dir/Spd [b]
09/05/12	15.0-24.3	0	NE 13
10/05/12	18.7-26.8	0	SE 15
11/05/12	16.5-23.5	0	NE 22
14/05/12	8.5-16.6	0	SSW 30
15/05/12	10.2-18.1	0	S 26
16/05/12	12.1-18.0	0	SSE 20
07/06/12	9.4-15.7	6.2	SSE 26
08/06/12	7.1-15.2	0	SSE 17
12/06/12	12.2-17.4	18.2	SSW 19
13/06/12	11.5-16.6	10.2	S 24
27/06/12	9.6-14.5	10.0	S 13
28/06/12	7.9-16.9	0.8	NE 15
15/10/12	13.2-23.7	0	NW 13
16/10/12	16.6-30.9	0	ESE 6
17/10/12	16.8-19.3	0	SE 24
18/10/12	15.7-19.9	0	NNE 17
26/11/12	18.9-22.8	0	SSW 15
27/11/12	18.6-21.2	0	SSW 19
28/11/12	18.3-21.1	10.8	SSW 17
29/11/12	18.4-24.1	0	ENE 6
21/03/13	19.4-24.8	0	NE 46
22/03/13	21.1-31.1	0	NNW 24
25/03/13	19.0-24.9	0	S 30
26/03/13	20.4-26.2	0	NNE 20
27/03/13	21.4-25.9	0	NNE 24
02/04/13	15.3-23.2	0.4	SSE 15
03/04/13	15.1-19.1	18.8	SSW 31
29/04/13	16.1-22.5	0	WNW 22
30/04/13	17.3-21.1	0	S 20
01/05/13	17.4-21.8	0	S 20
02/05/13	12.3-18.2	0	SSW30
11/09/13	13.4-23.1	0	W 24
12/09/13	11.4-20.7	0	ENE 13
13/09/13	9.3-16.2	0	ESE 6
16/09/13	14.4-17.4	0	NE 37
17/09/13	15.1-22.2	57.8	NNW 22
18/09/13	15.7-23.7	0	WNW 24
19/09/13	13.8-22.7	0.8	W 15
14/10/13	12.5-17.5	1.4	SE 19
15/10/13	10.0-19.9	0	NE 15
16/10/13	12.2-25.6	0	NE 41
17/10/13	19.2-33.0	0	NW 50

a = Precipitation in the 24 hrs to 9am; b = Direction and Speed in kilometres/hour at 3 pm. Source: Bureau of Meteorology, Bellambi AWS (station 068228).

(c) Geographic coordinates

Watercourse	Site	Easting	Northing	Location
Potential Subsidence Impact Sites				
Dog Trap Creek	DTC9	278879	6205973	Upstream
Dog Trap Creek	DTC10	279194	6206395	Downstream
Tea Tree Hollow	TTH11	277437	6206801	Upstream
Tea Tree Hollow	TTH12	277815	6207605	Downstream
Tea Tree Hollow	TTH12a	277845	6208001	Downstream
Hornes Creek	HC13	275705	6203691	Upstream
Hornes Creek	HC14	275575	6204588	Downstream
Bargo River	BR15	274424	6206513	Upstream
Bargo River	BR16	274739	6207065	Downstream
Subsidence Control Sites				
Cow Creek	CWC1	281150	6201769	Upstream
Cow Creek	CWC2	281800	6202674	Downstream
Carters Creek	CC3	281793	6203862	Upstream
Carters Creek	CC4	282280	6205005	Downstream
Dry Creek	DC5	282336	6208295	Upstream
Dry Creek	DC6	281729	6207068	Downstream
Eliza Creek	EC7	280740	6205795	Upstream
Eliza Creek	EC8	281517	6208087	Downstream
Bargo River	CBR1	274097	6206068	Upstream
Bargo River	CBR2	274152	6205906	Downstream
Moore Creek	CMC3	270959	6200225	Upstream
Moore Creek	CMC4	271328	6204392	Downstream
Cedar Creek	CCC5	275305	6214919	Upstream
Cedar Creek	CCC6	275344	6214869	Downstream
Stonequarry Creek	CSQC7	276399	6216376	Upstream
Stonequarry Creek	CSQC8	277499	6217234	Downstream
Surface Facilities Monitoring Sites				
Bargo River: Downstream Picton Weir	SBR1	274424	6206513	Upstream
Bargo River: Downstream Picton Weir	SBR2	274739	6207065	Downstream
Bargo River: Remembrance Driveway	SBR3	276964	6208797	Upstream
Bargo River: Remembrance Driveway	SBR4	277034	6208893	Downstream
Bargo River: Tea Tree Hollow Confluence	SBR5	278231	6208039	Upstream
Bargo River: Tea Tree Hollow Confluence	SBR6	278555	6208082	Downstream
Bargo River: Rockford Bridge	SBR7	279490	6207467	Upstream
Bargo River: Rockford Bridge	SBR8	279630	6207585	Downstream

C = Control monitoring sites; S = Surface facilities monitoring sites

Appendix D. Water quality: subsidence monitoring sites

Mean (±S.E.) water quality results for subsidence monitoring sites measured during the Tahmoor South baseline aquatic monitoring surveys conducted in (a) autumn: May 2012 (b) autumn: June 2012 (c) spring: October 2012 (d) spring: November 2012 (e) autumn: March 2013 (f) autumn: April 2013 (g) spring: September 2013 (h) spring: October 2013 (n=3).

a) Autumn: May 2012

Location	Site	Temp. °C		Cond. µS/cm		Turb. NTU		Sal.ppt		pH		ORP mV		DO% sat'n		DO mg/L		Alk. ppm
ANZECC default trigger values				**3-350**		**2-25**				**6.5-7.5**				**90-110**				
Potential Impact Sites		**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	
DTC9	U	11.32	0.05	317.00	1.53	5.57	0.07	0.21	0.00	7.49	0.06	275.33	1.86	92.90	0.62	10.17	0.03	14
DTC10	D	10.79	0.05	292.00	2.31	4.40	0.00	0.20	0.01	7.27	0.09	250.00	3.46	**62.47**	1.59	6.93	0.15	18
TTH11	U	10.19	0.02	274.33	0.33	6.33	0.13	0.19	0.00	6.81	0.02	240.67	7.31	**81.87**	0.65	9.17	0.07	30
TTH12	D	10.85	0.01	**1535.33**	3.84	2.30	0.00	0.94	0.00	**8.91**	0.01	274.33	2.96	98.83	0.26	10.87	0.03	14
HC13	U	9.83	0.03	345.67	1.33	2.53	0.03	0.22	0.00	7.34	0.04	258.33	0.67	**84.07**	1.52	9.50	0.15	16
HC14	D	9.77	0.04	**393.33**	4.10	4.80	0.00	0.24	0.00	7.45	0.06	267.67	0.67	**82.83**	1.89	9.37	0.17	16
BR15	U	11.12	0.01	209.00	0.00	3.20	0.20	0.15	0.01	6.81	0.03	269.33	3.84	**80.13**	1.95	8.73	0.15	10
BR16	D	10.95	0.01	212.67	1.33	2.80	0.00	0.14	0.00	6.89	0.03	263.33	1.86	**89.13**	0.91	9.83	0.09	10
Control Sites																		
CWC1	U	11.75	0.06	193.00	13.43	7.60	0.12	0.12	0.01	**6.39**	0.03	264.00	10.82	**45.27**	2.01	4.83	0.19	40
CWC2	D	13.31	0.07	135.33	1.33	5.07	0.26	0.11	0.00	6.86	0.14	254.33	9.70	**81.20**	2.43	8.47	0.23	100
CC3	U	11.81	0.03	327.00	0.00	5.53	0.15	0.21	0.00	7.35	0.02	227.67	1.45	**80.57**	1.24	8.67	0.12	14
CC4	D	13.19	0.04	**462.00**	1.00	3.97	0.07	0.27	0.01	**7.54**	0.10	279.33	2.91	95.23	4.88	9.90	0.45	13
DC5	U	13.13	0.00	**382.00**	0.00	6.07	0.07	0.23	0.01	6.99	0.06	283.33	3.48	**76.97**	1.58	8.03	0.13	18

Location	Site	Temp. °C		Cond. µS/cm		Turb. NTU		Sal.ppt		pH		ORP mV		DO% sat'n		DO mg/L		Alk. ppm
DC6	D	13.28	0.12	**502.33**	3.84	7.93	0.07	0.28	0.01	6.98	0.08	277.33	1.20	95.00	2.50	9.23	0.30	16
EC7	U	12.66	0.03	231.33	1.33	19.23	0.03	0.15	0.00	6.85	0.02	278.00	1.15	**56.83**	1.70	6.00	0.15	15
EC8	D	15.25	0.02	**1139.33**	1.45	8.37	0.07	0.67	0.00	6.99	0.01	203.67	2.85	101.67	0.80	10.13	0.09	15
CBR1	U	11.42	0.05	203.00	0.00	3.30	0.10	0.14	0.00	7.08	0.09	253.33	0.88	**82.00**	1.51	8.90	0.10	10
CBR2	D	10.30	0.00	264.33	0.33	0.13	0.07	0.17	0.01	6.71	0.07	259.33	0.88	**89.40**	0.87	10.00	0.12	10
CMC3	U	8.68	0.02	181.00	0.00	0.23	0.03	0.12	0.00	**5.76**	0.03	306.33	5.55	**60.37**	0.93	7.03	0.09	4
CMC4	D	9.28	0.01	210.67	1.67	0.37	0.07	0.14	0.00	**5.92**	0.01	306.67	0.88	**77.30**	1.36	8.83	0.13	4
CCC5	U	10.60	0.01	**433.00**	1.53	4.47	0.07	0.26	0.00	**6.42**	0.00	311.00	4.73	**73.30**	0.15	8.23	0.09	4
CCC6	D	11.24	0.04	**394.33**	2.60	4.93	0.07	0.26	0.00	6.67	0.07	237.67	2.91	**78.90**	1.04	8.63	0.09	4
CSQC7	U	10.83	0.04	**680.33**	4.06	6.67	0.03	0.41	0.00	7.30	0.02	242.00	0.00	92.27	0.37	10.30	0.06	17
CSQC8	D	10.35	0.01	**673.33**	2.33	3.20	0.00	0.42	0.00	7.14	0.00	259.00	0.58	**89.33**	0.43	10.00	0.06	16

Temp = Temperature; Cond. = Conductivity; Turb. = Turbidity; Sal. = salinity; ORP = Oxidation-Reduction Potential; DO% = percentage Dissolved Oxygen; Alk = Alkalinity. N/A = readings were below the detection levels of field titration kits. NB: Default trigger values (ANZECC, 2000) are only available for DO%, pH, Turbidity and Salinity (Conductivity µS/cm). Values in bold are outside the default trigger values recommended by ANZECC (2000) for upland rivers in South-east Australia.

(b) Autumn: June 2012

Location	Site	Temp. °C		Cond. µS/cm		Turb. NTU		Sal.ppt		pH		ORP mV		DO% sat'n		DO mg/L		Alk. ppm
ANZECC default trigger values				**3-350**		**2-25**				**6.5-7.5**				**90-110**				
Potential Impact Sites		**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	
DTC9	U	11.05	0.02	286.67	3.33	**59.80**	0.80	0.19	0.00	7.15	0.06	257.00	2.08	97.50	0.78	10.73	0.09	15
DTC10	D	11.07	0.00	286.00	0.00	**43.93**	0.34	0.19	0.00	7.49	0.01	265.33	0.88	94.47	1.09	10.57	0.03	17
TTH11	U	10.85	0.00	281.67	2.67	17.27	0.18	0.19	0.00	7.22	0.01	223.33	4.41	90.03	0.30	9.97	0.03	20
TTH12	D	11.10	0.01	**1026.67**	1.33	**47.00**	0.40	0.62	0.00	**8.80**	0.00	231.67	0.67	93.93	0.30	10.33	0.03	12

Location	Site	Temp. °C		Cond. µS/cm		Turb. NTU		Sal.ppt		pH		ORP mV		DO% sat'n		DO mg/L		Alk. ppm
HC13	U	11.59	0.03	348.67	1.33	**39.27**	0.13	0.24	0.01	7.48	0.02	247.33	8.51	96.87	0.41	10.53	0.03	17
HC14	D	11.46	0.01	349.33	1.67	**63.83**	0.70	0.23	0.00	**7.61**	0.01	274.33	0.33	95.30	0.52	10.40	0.06	17
BR15	U	10.51	0.01	225.00	0.00	3.30	0.10	0.16	0.00	7.02	0.02	297.00	0.58	88.40	0.38	9.83	0.03	15
BR16	D	10.60	0.00	225.33	3.18	3.33	0.07	0.16	0.00	7.07	0.01	297.33	1.45	91.83	0.30	10.23	0.03	15
Control Sites																		
CWC1	U	9.29	0.03	217.67	2.03	4.33	0.07	0.15	0.01	6.91	0.09	228.33	2.85	**54.47**	1.52	6.23	0.15	100
CWC2	D	9.69	0.02	14.37	0.13	5.23	0.13	0.12	0.00	7.16	0.05	236.67	2.60	**77.57**	0.55	8.80	0.06	130
CC3	U	10.95	0.01	280.67	1.33	4.13	0.03	0.19	0.00	**8.05**	0.09	234.67	2.33	95.23	0.79	10.53	0.09	14
CC4	D	11.37	0.01	**381.00**	0.00	7.43	0.09	0.24	0.01	**7.75**	0.04	241.67	0.88	95.53	1.02	10.43	0.09	15
DC5	U	9.80	0.03	**441.00**	4.16	5.37	0.18	0.27	0.00	7.23	0.09	259.00	2.31	**73.20**	1.05	8.23	0.09	70
DC6	D	9.44	0.01	**449.67**	1.67	11.37	0.07	0.27	0.00	7.28	0.03	272.67	1.45	**79.27**	0.03	9.10	0.00	24
EC7	U	10.16	0.00	**238.33**	1.67	**25.27**	0.07	0.17	0.00	7.20	0.03	270.67	0.88	**82.47**	1.28	9.27	0.12	25
EC8	D	11.45	0.02	**609.00**	2.31	13.90	0.10	0.38	0.00	7.36	0.03	243.33	6.44	95.93	0.46	10.47	0.07	20
CBR1	U	10.39	0.00	221.00	0.00	3.77	0.07	0.15	0.01	7.37	0.07	280.67	0.67	89.10	0.52	10.00	0.06	8
CBR2	D	10.77	0.01	253.00	0.00	5.20	0.10	0.16	0.00	7.10	0.05	290.33	0.33	89.77	0.33	9.97	0.03	8
CMC3	U	11.63	0.03	164.00	0.00	5.93	0.07	0.11	0.00	**5.84**	0.06	321.00	5.29	80.60	1.70	8.67	0.12	4
CMC4	D	11.22	0.03	171.33	1.33	3.33	0.07	0.13	0.01	**6.37**	0.19	268.67	12.81	95.17	0.58	10.47	0.09	4
CCC5	U	11.36	0.00	330.00	0.00	20.67	0.07	0.21	0.00	**6.38**	0.02	303.67	0.67	76.57	0.33	8.40	0.06	4
CCC6	D	11.36	0.01	337.67	1.33	20.40	0.00	0.21	0.00	**6.48**	0.02	304.33	0.33	77.27	0.98	8.43	0.09	4
CSQC7	U	11.25	0.01	**522.67**	0.33	7.73	0.24	0.31	0.00	**7.56**	0.01	276.33	2.40	90.47	0.27	9.93	0.03	20
CSQC8	D	11.27	0.01	**549.33**	1.33	10.60	0.10	0.33	0.00	**7.52**	0.02	280.00	3.21	88.83	0.13	9.73	0.03	15

Temp = Temperature; Cond. = Conductivity; Turb. = Turbidity; Sal. = salinity; ORP = Oxidation-Reduction Potential; DO% = percentage Dissolved Oxygen; Alk = Alkalinity. N/A = readings were below the detection levels of field titration kits. NB: Default trigger values (ANZECC, 2000) are only available for DO%, pH, Turbidity and Salinity (Conductivity µS/cm). Values in bold are outside the default trigger values recommended by ANZECC (2000) for upland rivers in South-east Australia.

c) Spring: October 2012

Location	Site	Temp. °C		Cond. µS/cm		Turb. NTU		Sal.ppt		pH		ORP mV		DO% sat'n		DO mg/L		Alk. ppm
ANZECC default trigger values				**3-350**		**2-25**				**6.5-7.5**				**90-110**				
Potential Impact Sites		**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	
DTC9	U	Dry																
DTC10	D	Dry																
TTH11	U	16.49	0.04	**421.67**	0.33	13.57	0.41	0.29	0.00	**6.40**	0.06	346.00	2.31	**33.73**	2.09	3.30	0.25	50.00
TTH12	D	16.71	0.21	**590.33**	8.76	**222.33**	13.62	0.40	0.01	**8.60**	0.02	312.33	4.84	**53.30**	2.74	5.00	0.21	11.00
HC13	U	17.00	0.05	144.33	19.41	11.43	0.13	0.10	0.01	7.47	0.10	353.00	1.00	94.53	0.79	9.10	0.21	60.00
HC14	D	20.52	0.30	216.67	0.33	18.67	0.17	0.14	0.01	7.42	0.12	335.00	1.00	**113.33**	0.33	10.20	0.06	22.00
BR15	U	17.61	0.03	204.33	1.20	15.63	2.46	0.15	0.00	**6.35**	0.00	365.00	1.53	**62.17**	0.38	5.93	0.03	8.00
BR16	D	16.32	0.00	172.67	24.33	9.20	0.49	0.11	0.02	**6.13**	0.11	372.33	2.03	**81.07**	1.03	7.97	0.12	8.00
Control Sites																		
CWC1	U	14.39	0.01	130.67	0.67	17.33	0.07	0.09	0.00	6.61	0.03	318.00	2.52	**23.23**	2.39	2.43	0.28	100.00
CWC2	D	16.03	0.12	120.33	0.67	22.50	0.90	0.08	0.00	6.69	0.13	328.67	1.20	**44.43**	0.87	4.40	0.06	100.00
CC3	U	12.87	0.04	345.33	0.88	20.90	0.00	0.23	0.01	7.18	0.02	334.00	1.15	93.13	0.26	9.83	0.03	18.00
CC4	D	14.73	0.01	**475.67**	1.20	**74.73**	0.73	0.33	0.00	6.88	0.01	327.00	0.58	**50.87**	1.11	5.17	0.12	23.00
DC5	U	16.23	0.09	229.33	3.67	**74.23**	1.18	0.15	0.00	**6.15**	0.02	307.67	3.18	**50.47**	1.59	5.03	0.18	100.00
DC6	D	13.60	0.00	**572.33**	1.33	12.27	0.43	0.39	0.00	**6.43**	0.02	335.33	4.06	**32.03**	0.58	3.30	0.06	100.00

Location	Site	Temp. °C		Cond. µS/cm		Turb. NTU		Sal.ppt		pH		ORP mV		DO% sat'n		DO mg/L		Alk. ppm
EC7	U	14.72	0.06	238.33	1.33	**69.63**	4.86	0.16	0.00	6.90	0.02	369.67	0.88	**29.43**	0.66	3.07	0.09	17.00
EC8	D	19.14	0.54	**1175.67**	1.45	9.00	0.06	0.79	0.00	6.75	0.01	338.33	3.71	**89.43**	0.34	8.23	0.09	100.00
CBR1	U	19.45	0.06	187.00	1.53	10.97	0.62	0.12	0.00	6.38	0.02	357.67	0.33	**78.00**	1.08	7.20	0.10	10.00
CBR2	D	18.49	0.01	187.33	3.93	7.00	0.20	0.12	0.00	**6.47**	0.01	371.00	1.53	**62.83**	0.61	5.90	0.06	10.00
CMC3	U	15.26	0.00	165.33	2.33	1.93	0.03	0.11	0.00	**4.44**	0.00	442.00	3.79	**68.10**	0.15	6.83	0.03	4.00
CMC4	D	-	-	-	-	-	-	-	-	**-**	-	-	-	**-**	-	-	-	-
CCC5	U	18.91	0.01	186.67	2.03	3.33	0.20	0.12	0.00	6.59	0.05	347.67	1.45	**61.60**	0.53	5.70	0.06	4.00
CCC6	D	18.91	0.01	186.67	2.03	3.33	0.20	0.12	0.00	6.59	0.05	347.67	1.45	**61.60**	0.53	5.70	0.06	4.00
CSQC7	U	15.25	0.02	**724.33**	17.07	15.97	0.97	0.49	0.01	**5.70**	0.01	351.67	5.81	**64.57**	3.32	6.80	0.26	13.00
CSQC8	D	15.06	0.03	**603.33**	12.72	13.17	0.07	0.41	0.01	**6.43**	0.02	331.33	4.06	**42.80**	0.97	4.27	0.07	13.00

Temp = Temperature; Cond. = Conductivity; Turb. = Turbidity; Sal. = salinity; ORP = Oxidation-Reduction Potential; DO% = percentage Dissolved Oxygen; Alk = Alkalinity. N/A = readings were below the detection levels of field titration kits. NB: Default trigger values (ANZECC, 2000) are only available for DO%, pH, Turbidity and Salinity (Conductivity µS/cm). Sample sites on Dog Trap Creek were dry at the time of sampling.

d) Spring November 2012

Location	Site	Temp. °C		Cond. µS/cm		Turb. NTU		Sal.ppt		pH		ORP mV		DO% sat'n		DO mg/L		Alk. ppm
ANZECC default trigger values				**3-350**		**2-25**				**6.5-7.5**				**90-110**				
Potential Impact Sites		**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	
DTC9	U	Dry																
DTC10	D	Dry																
TTH11	U	20.21	0.03	**369.67**	0.33	**197.67**	1.45	0.24	0.00	7.03	0.04	275.00	0.58	**19.43**	0.39	1.73	0.03	14.00
TTH12	D	21.27	0.04	**1333.33**	75.86	**43.17**	0.94	0.92	0.06	**8.76**	0.00	292.00	0.00	**67.20**	0.15	5.90	0.00	11.00

Location	Site	Temp. °C		Cond. µS/cm		Turb. NTU		Sal.ppt		pH		ORP mV		DO% sat'n		DO mg/L		Alk. ppm
HC13	U	20.45	0.02	82.00	0.00	**48.80**	1.50	0.05	0.00	7.04	0.04	262.67	0.88	**57.67**	1.17	5.17	0.07	30.00
HC14	D	20.02	0.01	246.00	0.00	11.03	0.18	0.16	0.00	6.80	0.04	287.67	1.20	**67.90**	0.25	6.13	0.03	25.00
BR15	U	21.03	0.00	172.00	0.00	7.83	1.01	0.11	0.00	6.67	0.06	302.00	2.00	**52.97**	1.52	4.70	0.10	10
BR16	D	20.62	0.01	168.00	1.00	5.90	0.12	0.11	0.00	6.61	0.01	296.67	3.53	**70.83**	0.20	6.37	0.03	10
Control Sites																		
CWC1	U	22.29	0.03	108.00	2.00	**54.37**	1.54	0.07	0.00	**6.19**	0.01	260.33	0.33	**15.97**	0.33	1.37	0.03	26.00
CWC2	D	23.94	0.15	86.33	0.88	21.17	0.54	0.07	0.00	**6.18**	0.00	275.00	1.53	**40.40**	1.11	3.40	0.10	100.00
CC3	U	25.53	0.54	302.33	1.20	16.67	0.20	0.19	0.00	6.71	0.04	287.00	2.31	90.57	1.07	7.43	0.13	16.00
CC4	D	25.76	0.28	**420.33**	0.33	**62.07**	0.07	0.29	0.00	7.06	0.01	278.67	0.33	**33.27**	1.53	2.73	0.09	17.00
DC5	U	20.92	0.06	240.33	9.28	**69.50**	0.50	0.17	0.01	7.03	0.02	292.33	1.33	**20.03**	0.98	1.80	0.06	16.00
DC6	D	23.64	0.03	339.00	4.36	**49.74**	0.37	0.23	0.01	6.92	0.01	287.33	0.67	**39.41**	0.67	3.29	0.07	16.67
EC7	U	23.95	0.64	194.00	2.31	**136.33**	3.71	0.13	0.01	6.95	0.02	271.67	0.33	**25.97**	3.33	2.10	0.26	13.00
EC8	D	23.40	0.20	**951.00**	28.88	7.67	0.07	0.63	0.03	6.88	0.03	294.00	4.93	**83.20**	0.26	7.03	0.03	60.00

Temp = Temperature; Cond. = Conductivity; Turb. = Turbidity; Sal. = salinity; ORP = Oxidation-Reduction Potential; DO% = percentage Dissolved Oxygen; Alk = Alkalinity. N/A = readings were below the detection levels of field titration kits. NB: Default trigger values (ANZECC, 2000) are only available for DO%, pH, Turbidity and Salinity (Conductivity µS/cm). Sample sites on Dog Trap Creek were dry at the time of sampling.

e) Autumn: March 2013

Location	Site	Temp. °C		Cond. µS/cm		Turb. NTU		Sal.ppt		pH		ORP mV		DO% sat'n		DO mg/L		Alk. ppm
ANZECC default trigger values				**3-350**		**2-25**				**6.5-7.5**				**90-110**				
Potential Impact Sites		**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	

Location	Site	Temp. °C		Cond. µS/cm		Turb. NTU		Sal.ppt		pH		ORP mV		DO% sat'n		DO mg/L		Alk. ppm
DTC9	U	21.18	0.04	55.67	0.33	12.07	0.79	0.13	0.00	6.58	0.04	278.67	2.03	90.47	0.37	8.03	0.03	18.00
DTC10	D	20.00	0.05	38.67	0.88	18.33	0.34	0.12	0.00	**6.14**	0.01	267.33	2.03	**45.83**	0.41	4.17	0.03	15.00
TTH11	U	19.37	0.00	81.00	0.00	**44.40**	0.32	0.18	0.00	6.68	0.01	287.00	1.15	**51.20**	0.06	4.70	0.00	18.00
TTH12	D	20.92	0.00	**419.00**	0.00	**52.90**	0.20	0.61	0.00	**8.59**	0.02	291.33	1.20	91.13	0.03	8.10	0.00	10.00
HC13	U	17.71	0.02	50.67	0.33	6.10	0.10	0.15	0.00	**6.13**	0.03	267.67	11.29	**65.67**	0.38	6.27	0.03	25.00
HC14	D	21.76	0.02	39.67	0.33	9.50	0.10	0.11	0.00	7.74	0.08	273.67	0.88	**118.33**	4.10	10.47	0.32	23.00
BR15	U	21.50	0.00	0.00	0.00	10.50	1.01	0.06	0.00	6.66	0.05	288.33	0.88	**55.50**	16.80	6.40	0.00	N/A
BR16	D	21.19	0.02	0.00	0.00	17.93	1.39	0.06	0.00	6.76	0.07	281.67	2.60	**82.33**	0.24	7.30	0.00	N/A
Control Sites																		
CWC1	U	18.63	0.12	0.00	0.00	12.20	0.17	0.07	0.00	**5.81**	0.01	247.33	3.28	**23.03**	0.22	2.10	0.06	50.00
CWC2	D	19.30	0.05	0.00	0.00	9.43	0.24	0.07	0.00	**6.05**	0.14	244.67	0.33	**27.47**	0.62	2.57	0.07	40.00
CC3	U	21.85	0.39	71.67	0.33	21.60	0.80	0.16	0.01	6.79	0.02	261.33	1.45	**79.13**	1.02	6.97	0.09	14.00
CC4	D	20.40	0.26	118.67	2.33	16.20	0.10	0.22	0.01	**6.40**	0.01	263.67	1.45	**62.37**	1.45	5.73	0.15	13.50
DC5	U	19.82	0.00	68.67	0.67	5.67	0.27	0.16	0.00	**6.43**	0.03	252.67	1.76	**32.23**	0.30	2.93	0.03	20.00
DC6	D	19.72	0.00	138.67	0.88	18.60	0.44	0.25	0.00	**6.35**	0.00	267.00	1.15	**27.57**	0.09	2.50	0.00	18.00
EC7	U	22.60	0.00	11.67	0.33	**55.53**	2.15	0.08	0.00	**5.93**	0.01	267.00	1.73	**56.67**	0.82	4.93	0.09	18.00
EC8	D	23.41	0.03	**403.67**	1.76	**36.37**	0.23	0.58	0.00	7.29	0.13	285.00	2.52	98.87	0.61	8.40	0.06	18.00
CBR1	U	22.29	0.01	0.00	0.00	14.83	0.41	0.06	0.00	**6.40**	0.01	287.33	1.45	**72.20**	0.38	6.27	0.03	N/A
CBR2	D	22.28	0.01	0.00	0.00	14.90	0.42	0.06	0.00	**6.39**	0.01	287.33	0.88	**72.13**	0.39	6.23	0.03	N/A
CMC3	U	19.38	0.12	0.00	0.00	4.33	0.33	0.07	0.00	**5.63**	0.01	294.67	4.33	**79.80**	0.31	7.40	0.00	6.00
CMC4	D	19.37	0.09	0.00	0.00	4.43	0.23	0.07	0.00	**5.62**	0.00	295.00	4.04	**79.93**	0.29	7.40	0.00	6.00
CCC5	U	20.90	0.00	67.00	0.00	11.50	0.36	0.15	0.00	6.34	0.03	289.33	0.88	**66.67**	0.03	5.97	0.03	12.00
CCC6	D	20.91	0.00	67.33	0.33	11.43	0.30	0.15	0.00	6.35	0.03	289.00	1.15	**66.63**	0.03	6.00	0.06	12.00

Location	Site	Temp. °C		Cond. µS/cm		Turb. NTU		Sal.ppt		pH		ORP mV		DO% sat'n		DO mg/L		Alk. ppm
CSQC7	U	18.93	0.00	248.00	0.00	15.70	2.20	0.39	0.00	6.76	0.05	297.00	1.15	**79.73**	0.26	7.37	0.03	16.00
CSQC8	D	19.02	0.00	198.00	1.00	34.73	0.23	0.31	0.00	6.60	0.04	294.33	0.67	**61.77**	0.29	5.73	0.03	16.00

Temp = Temperature; Cond. = Conductivity; Turb. = Turbidity; Sal. = salinity; ORP = Oxidation-Reduction Potential; DO% = percentage Dissolved Oxygen; Alk = Alkalinity. N/A = readings were below the detection levels of field titration kits. NB: Default trigger values (ANZECC, 2000) are only available for DO%, pH, Turbidity and Salinity (Conductivity µS/cm).

f) Autumn: April 2013

Location	Site	Temp. °C		Cond. µS/cm		Turb. NTU		Sal.ppt		pH		ORP mV		DO% sat'n		DO mg/L		Alk. ppm
ANZECC default trigger values				**3-350**		**2-25**				**6.5-7.5**				**90-110**				
Potential Impact Sites		**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	
DTC9	U	20.55	0.18	254.67	0.67	8.00	0.68	0.12	0.00	6.79	0.04	303.67	0.33	96.63	1.18	8.63	0.09	18.00
DTC10	D	17.72	0.01	248.33	0.33	8.10	0.00	0.13	0.00	**6.07**	0.00	291.67	0.33	**38.10**	0.90	3.60	0.06	17.00
TTH11	U	18.15	0.17	319.67	2.03	14.33	0.13	0.16	0.01	**6.42**	0.07	293.67	0.67	**76.10**	1.59	7.13	0.12	30.00
TTH12	D	17.02	0.07	**973.67**	4.98	11.17	0.38	0.51	0.00	**8.02**	0.00	294.00	0.58	**80.70**	2.01	7.67	0.12	N/A
HC13	U	17.99	0.03	**361.33**	1.33	9.70	1.10	0.17	0.00	**6.21**	0.06	290.33	5.78	**83.33**	0.19	7.90	0.00	26.00
HC14	D	14.52	0.01	307.67	0.33	1.37	0.03	0.16	0.00	7.37	0.01	312.67	0.33	**73.23**	0.09	7.50	0.00	24.00
BR15	U	16.74	0.02	167.67	0.33	2.63	0.07	0.08	0.00	**6.44**	0.06	300.33	2.03	**61.27**	0.38	5.93	0.03	10.00
BR16	D	16.44	0.01	169.00	0.00	2.50	0.20	0.08	0.00	6.63	0.04	306.33	0.33	**78.97**	0.43	7.73	0.03	10.00
Control Sites																		
CWC1	U	16.76	0.01	116.00	0.00	10.00	0.50	0.06	0.00	**6.01**	0.01	292.67	0.88	**22.53**	2.77	2.23	0.27	30.00
CWC2	D	17.38	0.10	118.67	0.33	5.17	0.26	0.06	0.00	**6.18**	0.02	297.33	0.88	**51.30**	5.84	5.07	0.58	30.00
CC3	U	16.69	0.03	23.33	0.33	14.03	0.38	0.10	0.01	**6.34**	0.06	271.67	2.60	**78.77**	1.34	7.63	0.09	15.00
CC4	D	17.03	0.02	76.67	0.33	11.60	0.70	0.17	0.00	**6.53**	0.03	281.33	0.33	**62.03**	2.34	5.97	0.20	14.00

Location	Site	Temp. °C		Cond. µS/cm		Turb. NTU		Sal.ppt		pH		ORP mV		DO% sat'n		DO mg/L		Alk. ppm
DC5	U	17.74	0.00	28.00	0.58	12.53	0.44	0.11	0.00	**6.09**	0.02	271.33	0.33	**36.10**	2.60	3.33	0.19	25.00
DC6	D	17.55	0.05	58.67	0.33	15.13	0.09	0.15	0.00	**6.17**	0.01	278.67	0.33	**36.80**	1.60	3.43	0.03	19.00
EC7	U	16.08	0.01	153.00	0.00	13.53	0.15	0.07	0.01	**6.39**	0.00	305.00	0.58	**36.10**	0.31	3.53	0.03	25.00
EC8	D	15.94	0.01	**1000.00**	0.00	6.47	0.20	0.53	0.00	6.99	0.01	312.00	0.00	90.10	0.15	8.87	0.03	18.00

Temp = Temperature; Cond. = Conductivity; Turb. = Turbidity; Sal. = salinity; ORP = Oxidation-Reduction Potential; DO% = percentage Dissolved Oxygen; Alk = Alkalinity. N/A = readings were below the detection levels of field titration kits. NB: Default trigger values (ANZECC, 2000) are only available for DO%, pH, Turbidity and Salinity (Conductivity µS/cm).

g) Spring: September 2013

Location	Site	Temp. °C		Cond. µS/cm		Turb. NTU		Sal.ppt		pH		ORP mV		DO% sat'n		DO mg/L		Alk. ppm
ANZECC default trigger values				**3-350**		**2-25**				**6.5-7.5**				**90-110**				
Potential Impact Sites		**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	
DTC9	U	14.17	0.02	196.33	0.33	12.60	1.45	0.09	0.00	7.36	0.08	613.33	5.24	**76.47**	0.49	7.82	0.06	26.00
DTC10	D	13.74	0.15	204.67	0.33	14.10	0.67	0.09	0.00	7.17	0.02	645.00	0.00	**72.03**	0.09	7.45	0.01	20.00
TTH11	U	15.11	0.01	165.33	0.33	16.43	0.20	0.09	0.00	7.10	0.15	512.00	2.52	**83.17**	1.31	8.33	0.11	20.00
TTH12	D	17.85	0.01	**2106.33**	0.33	19.07	1.30	1.13	0.00	**8.65**	0.00	500.33	5.49	**78.40**	0.38	7.39	0.04	1400.00
HC13	U	13.99	0.01	283.33	0.33	14.77	0.09	0.13	0.00	7.03	0.06	387.67	1.20	**73.40**	0.17	7.58	0.02	24.00
HC14	D	12.83	0.01	265.67	0.33	16.67	1.07	0.13	0.00	7.24	0.07	577.33	0.67	**68.63**	0.30	7.25	0.03	22.00
BR15	U	12.84	0.01	156.00	0.00	3.17	0.87	0.06	0.00	**6.37**	0.06	529.67	2.33	**62.13**	0.61	6.56	0.04	10.00
BR16	D	12.62	0.01	164.00	0.00	0.20	0.00	0.06	0.00	6.85	0.20	334.33	6.36	**73.33**	0.62	7.79	0.06	8.00
Control Sites																		

Location	Sit e	Temp. °C		Cond. µS/cm		Turb. NTU		Sal.ppt		pH		ORP mV		DO% sat'n		DO mg/L		Alk. ppm
CWC1	U	11.12	0.03	129.00	0.00	11.50	0.20	0.07	0.00	**6.07**	0.09	445.33	11.35	**10.50**	0.68	1.15	0.06	16.00
CWC2	D	12.23	0.01	104.00	0.00	1.50	0.10	0.03	0.00	**6.22**	0.08	524.67	3.76	**45.53**	0.75	4.86	0.07	8.00
CC3	U	13.69	0.06	306.33	0.33	5.47	0.97	0.16	0.00	6.85	0.01	362.33	3.38	**84.17**	1.13	8.72	0.10	34.00
CC4	D	13.85	0.05	**817.00**	1.53	N/A		0.40	0.00	7.22	0.01	646.00	1.53	**89.77**	0.54	9.43	0.09	56.00
DC5	U	13.53	0.04	327.67	0.88	N/A		0.16	0.00	**6.45**	0.04	446.33	4.63	**60.43**	0.84	6.27	0.09	14.00
DC6	D	13.72	0.01	**685.33**	0.33	19.63	0.32	0.33	0.00	7.33	0.10	540.00	1.15	**81.87**	0.73	8.45	0.07	14.00
EC7	U	15.05	0.01	159.00	0.00	**38.67**	0.12	0.09	0.00	6.83	0.13	541.33	6.67	**74.20**	1.23	7.46	0.12	16.00
EC8	D	14.22	0.01	**850.00**	11.00	**98.03**	0.99	0.43	0.01	7.16	0.04	319.00	1.53	**77.23**	0.09	7.90	0.01	18.00
CBR1	U	11.43	0.02	156.00	0.00	N/A		0.06	0.00	6.72	0.09	292.00	7.00	**66.30**	0.85	7.22	0.08	16.00
CBR2	D	12.56	0.01	157.67	0.33	3.93	1.43	0.06	0.00	6.56	0.11	444.33	3.84	**68.43**	0.60	7.29	0.06	8.00
CMC3	U	11.33	0.06	168.67	2.33	N/A	0.00	0.06	0.00	**5.22**	0.17	338.00	18.50	**68.63**	0.81	7.54	0.06	2.00
CMC4	D	12.32	0.03	159.00	0.00	N/A	0.00	0.06	0.00	**4.92**	0.01	395.67	7.88	**70.03**	0.71	7.49	0.06	4.00
CCC5	U	19.13	0.01	302.67	1.33	12.17	0.23	0.16	0.00	6.63	0.04	279.33	0.88	91.77	0.23	8.50	0.00	8.00
CCC6	D	19.02	0.00	300.00	0.00	6.37	0.23	0.16	0.00	6.94	0.01	280.00	1.15	**89.23**	0.09	8.30	0.00	8.00
CSQC7	U	19.07	0.23	**969.33**	6.01	22.50	0.86	0.53	0.01	**5.85**	0.03	268.33	7.31	99.83	1.99	9.27	0.15	6.00
CSQC8	D	20.37	0.09	**836.00**	32.51	**27.87**	0.33	0.44	0.01	6.40	0.03	273.67	1.45	**80.43**	0.32	7.23	0.03	44.00

Temp = Temperature; Cond. = Conductivity; Turb. = Turbidity; Sal. = salinity; ORP = Oxidation-Reduction Potential; DO% = percentage Dissolved Oxygen; Alk = Alkalinity. N/A = Water quality probe was faulty. NB: Default trigger values (ANZECC, 2000) are only available for DO%, pH, Turbidity and Salinity (Conductivity µS/cm).

(h) Spring: October 2013

Location	Site	Temp. °C		Cond. µS/cm		Turb. NTU		Sal.ppt		pH		ORP mV		DO% sat'n		DO mg/L		Alk. ppm
ANZECC default trigger values				**3-350**		**2-25**				**6.5-7.5**				**90-110**				
Potential Impact Sites		**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	
DTC10	D	15.79	0.34	263.33	1.45	**25.50**	1.40	0.13	0.00	6.93	0.04	256.00	2.89	**87.87**	0.93	8.77	0.15	28.00
TTH11	U	12.58	0.07	**514.67**	2.40	**38.97**	0.15	0.27	0.00	6.66	0.07	234.33	3.84	**47.73**	1.05	5.10	0.12	35.00
TTH12	D	12.84	0.03	**2471.00**	1.73	9.03	1.20	1.36	0.00	**9.06**	0.04	261.33	0.88	92.73	0.34	9.73	0.03	1400.00
HC13	U	12.80	0.15	**711.67**	1.20	**77.13**	0.87	0.36	0.01	**6.14**	0.03	288.33	7.26	**35.60**	0.74	3.83	0.09	10.00
HC14	D	12.56	0.06	**391.00**	0.58	2.77	0.67	0.19	0.00	**8.73**	0.03	218.67	4.06	**81.23**	0.67	8.63	0.07	24.00
BR15	U	14.37	0.08	200.33	1.86	**36.50**	3.16	0.10	0.01	**6.44**	0.01	255.33	2.03	**77.60**	1.47	7.97	0.15	10.00
BR16	D	14.42	0.06	203.33	0.33	21.97	0.60	0.09	0.00	7.09	0.05	264.67	0.33	92.70	1.06	9.53	0.09	12.00
Control Sites																		
CWC1	U	11.29	0.04	124.00	0.00	24.90	0.83	0.06	0.01	7.47	0.12	215.67	6.89	**10.80**	0.26	1.20	0.06	16.00
CWC2	D	12.31	0.03	127.67	1.67	16.73	1.03	0.07	0.00	6.87	0.03	264.00	0.58	**43.17**	0.58	4.67	0.07	10.00
CC3	U	14.82	0.00	**384.33**	2.60	17.03	0.95	0.19	0.01	7.20	0.10	245.33	2.91	**60.23**	0.30	6.10	0.00	36.00
CC4	D	14.94	0.03	**562.33**	0.33	**29.17**	2.08	0.28	0.00	7.74	0.02	251.00	2.65	**56.77**	0.30	5.73	0.03	80.00
DC5	U	15.85	0.00	**360.67**	1.33	**28.67**	0.81	0.18	0.00	7.19	0.08	264.33	1.45	**68.20**	0.44	6.77	0.07	16.00
DC6	D	15.62	0.22	**602.67**	1.86	**30.70**	0.40	0.31	0.01	6.45	0.03	249.67	2.60	**38.40**	0.82	3.87	0.12	22.00
EC7	U	17.29	0.36	192.67	2.60	**74.47**	0.23	0.10	0.00	6.85	0.04	233.00	2.31	**76.23**	2.03	7.33	0.20	22.00
EC8	D	19.49	1.07	**1411.33**	7.31	**27.00**	2.58	0.74	0.01	6.81	0.05	258.00	2.31	96.40	1.25	8.97	0.42	14.00
DTC9	U	18.34	0.04	269.33	1.20	**28.03**	0.47	0.13	0.01	6.79	0.01	256.33	2.03	95.73	0.67	9.03	0.09	25.00

Temp = Temperature; Cond. = Conductivity; Turb. = Turbidity; Sal. = salinity; ORP = Oxidation-Reduction Potential; DO% = percentage Dissolved Oxygen; Alk = Alkalinity. N/A = readings were below the detection levels of field titration kits. NB: Default trigger values (ANZECC, 2000) are only available for DO%, pH, Turbidity and Salinity (Conductivity µS/cm)

Appendix E. Water quality: mine water discharge monitoring sites

Mean (±S.E.) water quality results for mine water discharge monitoring sites on Bargo River measured during the Tahmoor South baseline aquatic monitoring surveys conducted in spring: October 2012 and autumn: March 2013 (n=3).

Site	Temp. °C		Cond. µS/cm		Turb. NTU		Sal.ppt		pH		ORP mV		DO% sat'n		DO mg/L		Alk. ppm
ANZECC default trigger values			**3-350**		**2-25**				**6.5-7.5**				**90-110**				
Spring 2012	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	
SBR1	17.61	0.03	204.33	1.20	15.63	2.46	0.15	0.00	**6.35**	0.00	365.00	1.53	**62.17**	0.38	5.93	0.03	8.00
SBR2	16.32	0.00	172.67	24.33	9.20	0.49	0.11	0.02	**6.13**	0.11	372.33	2.03	**81.07**	1.03	7.97	0.12	8.00
SBR3	20.51	0.01	136.0	0.0	4.73	0.07	0.09	0.00	6.74	0.00	328.33	0.88	**84.53**	0.26	7.63	0.03	4.00
SBR4	20.51	0.01	136.0	0.0	4.73	0.07	0.09	0.00	6.74	0.00	328.33	0.88	**84.53**	0.26	7.63	0.03	4.00
SBR5	19.22	0.02	**774.0**	5.6	4.10	0.00	0.52	0.00	**9.04**	0.01	325.67	1.76	**75.30**	0.40	6.93	0.03	12.00
SBR6	20.48	0.01	**879.0**	9.7	7.60	0.12	0.60	0.01	**8.75**	0.01	306.67	0.33	91.83	0.45	8.23	0.03	12.00
SBR7	22.49	0.12	**1091.0**	2.9	12.20	0.56	0.74	0.00	**8.68**	0.00	293.33	0.33	**86.97**	0.43	7.47	0.03	12.00
SBR8	22.55	0.02	**1052.7**	15.7	8.43	0.24	0.70	0.01	**8.66**	0.01	293.00	0.00	98.27	0.61	8.50	0.06	12.00
Autumn 2013																	
SBR1	21.50	0.00	0.00	0.00	10.50	1.01	0.06	0.00	6.66	0.05	288.33	0.88	**55.50**	16.80	6.40	0.00	N/A
SBR2	21.19	0.02	0.00	0.00	17.93	1.39	0.06	0.00	6.76	0.07	281.67	2.60	**82.33**	0.24	7.30	0.00	N/A
SBR3	21.75	0.20	11.7	0.3	24.93	0.43	0.08	0.00	**6.01**	0.02	278.33	0.88	104.87	0.82	9.27	0.09	6.00
SBR4	20.78	0.15	7.0	0.0	7.60	0.00	0.08	0.00	7.14	0.01	283.67	0.33	**89.60**	0.06	8.00	0.00	10.00
SBR5	20.69	0.00	457.3	0.9	3.40	0.00	0.66	0.01	9.36	0.00	288.33	0.33	80.43	0.23	7.17		
SBR6	20.74	0.00	458.0	0.0	2.70	0.10	0.67	0.00	9.24	0.00	284.00	0.00	83.80	0.06	7.50		
SBR7	21.62	0.00	414.3	0.7	0.30	0.00	0.60	0.00	9.03	0.00	282.00	0.00	71.37	0.07	6.30		

Site	Temp. °C		Cond. µS/cm		Turb. NTU		Sal.ppt		pH		ORP mV		DO% sat'n		DO mg/L		Alk. ppm
SBR8	21.65	0.02	414.3	0.3	0.95	0.03	0.62	0.02	9.04	0.01	282.00	0.00	71.33	0.17	6.47		

Temp = Temperature; Cond. = Conductivity; Turb. = Turbidity; Sal. = salinity; ORP = Oxidation-Reduction Potential; DO% = percentage Dissolved Oxygen; Alk = Alkalinity. N/A = readings were below the detection levels of field titration kits. NB: Default trigger values (ANZECC, 2000) are only available for DO%, pH, Turbidity and Salinity (Conductivity µS/cm)

Values in bold are outside the default trigger values recommended by ANZECC (2000) for upland rivers in South-east Australia.

Appendix F. Aquatic fauna trapping: subsidence monitoring sites

Aquatic fauna caught in bait traps and dip nets at subsidence monitoring sites during the Tahmoor South baseline aquatic surveys conducted in (a) Autumn: May 2012 (b) autumn: June 2012 (c) spring: October 2012 (d) spring: November 2012 (e) autumn: March 2013 (f) autumn: April 2013 (g) spring: September 2013 (h) spring: October 2013 (n=3).

a) Autumn: May 2012

May 2012		**Sites**																
	Method	**CWC1**	**CWC2**	**CC3**	**CC4**	**DC5**	**DC6**	**EC7**	**EC8**	**DTC9**	**DTC10**	**TTH11**	**TTH12**	**HC13**	**HC14**	**BR15**	**BR16**	**Total**
Yabby *Cherax destructor*	BT	4	1	1	0	8	1	0	0	0	2	0	0	0	0	0	0	17
	DN	0	0	1	0	7	4	2	0	10	7	1	0	0	0	0	0	32
Common Freshwater Shrimp *Paratya australiensis*	BT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	DN	0	0	3	30	0	0	0	0	0	3	0	0	0	17	0	8	70
Mosquito Fish *Gambusia holbrooki*	BT	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	2
	DN	0	0	4	4	7	0	7	0	3	0	1	1	6	1	0	1	35

BT = Bait traps; DN = Dip nets. Control Locations: Bait trap and dip net surveys recorded no aquatic fauna at control locations.

(b) Autumn: June 2012

October 2012		**Sites**																
	Method	**CWC1**	**CWC2**	**CC3**	**CC4**	**DC5**	**DC6**	**EC7**	**EC8**	**DTC9**	**DTC10**	**TTH11**	**TTH12**	**HC13**	**HC14**	**BR15**	**BR16**	**Total**
Yabby *Cherax destructor*	BT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	DN	6	0	0	0	1	3	1	0	0	1	0	0	0	0	0	0	12
Common Freshwater Shrimp *Paratya australiensis*	BT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	DN	20	15	30	15	1	0	0	0	2	15	1	0	0	1	10	0	110
Mosquito Fish *Gambusia holbrooki*	BT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	DN	0	0	9	4	4	5	4	6	0	1	1	2	4	1	1	0	42
Firetail Gudgeon *Hypseleotris galii*	BT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	DN	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2

BT = Bait traps , DN = Dip nets. Control Locations: Bait trap and dip net surveys recorded no aquatic fauna at control locations.

c) Spring: October 2012

October 2012		Sites																
	Method	**CWC1**	**CWC2**	**CC3**	**CC4**	**DC5**	**DC6**	**EC7**	**EC8**	**DTC9**	**DTC10**	**TTH11**	**TTH12**	**HC13**	**HC14**	**BR15**	**BR16**	**Total**
Yabby	BT	0	0	1	0	12	0	0	0	dry	dry	1	0	0	0	0	0	14
Cherax destructor	DN	1	1	2	0	2	0	5	0	dry	dry	2	8	1	0	0	0	22
Common Freshwater Shrimp	BT	0	0	0	0	0	0	0	0	dry	dry	0	0	0	0	0	0	0
Paratya australiensis	DN	1	10	16	15	10	0	1	0	dry	dry	0	0	0	0	0	0	53
Mosquito Fish	BT	0	0	0	0	3	0	0	0	dry	dry	0	0	0	0	0	0	3
Gambusia holbrooki	DN	0	0	13	0	0	0	4	0	dry	dry	6	1	0	0	0	0	24
Australian Smelt	BT	0	0	0	0	0	0	0	0	dry	dry	0	0	0	0	0	0	0
Retropinna semoni	DN	0	0	0	0	0	0	0	0	dry	dry	0	0	0	0	2	0	2

BT = Bait traps; DN = Dip nets. NB. Dog Trap Creek sites (DTC9 & DTC10) were not sampled due to insufficient water depth. Control Locations: Bait trap and dip net surveys recorded no aquatic fauna at control locations.

d) Spring: November 2012

November 2012		Sites																
	Method	**CWC1**	**CWC2**	**CC3**	**CC4**	**DC5**	**DC6**	**EC7**	**EC8**	**DTC9**	**DTC10**	**TTH11**	**TTH12**	**HC13**	**HC14**	**BR15**	**BR16**	**Total**
Yabby																		
Cherax destructor	DN	4	14	10	2	0	4	1	0			0	0	0	0	0	0	35
Common Freshwater Shrimp																		
Paratya australiensis	DN	8	0	0	20	0	0	0	0			0	0	0	0	0	0	28
Mosquito Fish																		
Gambusia holbrooki	DN	0	0	0	0	3	0	1	0	dry	dry	0	0	0	2	0	0	6

DN = Dip nets. NB. Dog Trap Creek sites (DTC9 & DTC10) were not sampled due to insufficient water depth. Control Locations: Bait trap and dip net surveys recorded no aquatic fauna at control locations.

e) Autumn: March 2013

March 2013		Sites																
	Method	CWC1	CWC2	CC3	CC4	DC5	DC6	EC7	EC8	DTC9	DTC10	TTH11	TTH12	HC13	HC14	BR15	BR16	Total
Yabby	BT	3	25	13	0	22	10	18	1	3	20	10	6	0	1	0	0	131
Cherax Destructor	DN	3	1	1	0	6	2	9	0	9	8	1	3	0	0	0	0	43
Common Freshwater Shrimp	BT	3	13	5	4	0	0	0	2	0	0	0	0	0	2	1	4	27
Paratya australiensis	DN	3	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	6
Mosquito Fish	BT	0	0	314	1	0	0	0	0	0	0	0	0	54	0	24	8	315
Gambusia holbrooki	DN	0	0	7	10	0	0	1	0	0	1	1	12	0	0	0	0	32
Common Jollytail	BT	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Galaxias maculatus	DN	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Mountain Galaxias	BT	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Galaxias olidus	DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Australian Smelt	BT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	9
Retropinna semoni	DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

BT = Bait traps; DN = Dip nets. Control Locations: The following were caught using bait traps: CMC3 – Yabby (2) and Common Jollytail (5); CMC4 - Spiny crayfish *Euastacus spinifer* (3) and Common Jollytail (9); CCC5 – Mosquito Fish (1); CCC6 – Mosquito Fish (2); CSQC8 – Empire Gudgeon *Hypseleotris compressa* (1).

f) Autumn: April 2013

April 2013		Sites																
	Method	CWC1	CWC2	CC3	CC4	DC5	DC6	EC7	EC8	DTC9	DTC10	TTH11	TTH12	HC13	HC14	BR15	BR16	Total
Yabby																		
Cherax destructor	DN	3	5	4	0	0	9	4	1	4	3	4	5	0	0	0	0	42
Common Freshwater Shrimp																		
Paratya australiensis	DN	3	15	20	2	0	0	0	2	10	8	0	0	0	6	5	9	80
Mosquito Fish																		
Gambusia holbrooki	DN	0	0	30	12	0	0	7	3	1	0	3	4	50	7	2	0	119

DN = Dip nets. Control Locations: No fish were observed.

g) Spring: September 2013

September 2013		Sites																
	Method	CWC1	CWC2	CC3	CC4	DC5	DC6	EC7	EC8	DTC9	DTC10	TTH11	TTH12	HC13	HC14	BR15	BR16	Total
Yabby *Cherax destructor*	BT	0	0	6	0	0	0	0	0	3	4	2	0	0	0	0	1	16
	DN	0	0	0	0	0	2	4	0	6	1	0	0	0	0	0	0	13
Common Freshwater Shrimp *Paratya australiensis*	BT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	DN	0	0	0	10	0	0	0	0	5	0	1	0	0	0	0	0	16
Mosquito Fish *Gambusia holbrooki*	BT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	DN	0	0	0	0	1	0	0	0	0	0	0	0	5	0	0	0	6
Common Jollytail *Galaxias maculatus*	BT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	DN	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1

BT = Bait traps; DN = Dip nets. Control Locations: The following were caught using bait traps: CMC3 – Spiny Crayfish (4); CMC4 - Spiny Crayfish (3).

h) Spring: October 2013

October 2013		Sites																
	Method	CWC1	CWC2	CC3	CC4	DC5	DC6	EC7	EC8	DTC9	DTC10	TTH11	TTH12	HC13	HC14	BR15	BR16	Total
Yabby *Cherax destructor*	BT	12	8	10	0	6	6	5	0	20	13	0	0	0	0	0	0	80
	DN	5	5	5	0	10	7	19	1	0	8	5	0	0	0	0	0	65
Common Freshwater Shrimp *Paratya australiensis*	BT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	DN	2	10	8	2	0	0	0	0	0	0	3	0	0	0	2	5	32
Mosquito Fish *Gambusia holbrooki*	BT	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
	DN	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Common Jollytail *Galaxias maculatus*	BT	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
	DN	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2
Firetail Gudgeon *Hypseleotris galii*	BT	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2
	DN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

BT = Bait traps; DN = Dip nets. Control Locations: No fish were observed.

Appendix G. Aquatic fauna trapping: mine water discharge monitoring sites

Aquatic fauna caught in bait traps and dip nets at mine water discharge monitoring sites during the Tahmoor South baseline aquatic surveys conducted in (a) spring: October 2012 and (b) autumn: March 2013 (n=3).

a) Spring: October 2012

October 2012		**Sites**								
	Method	**SBR1**	**SBR2**	**SBR3**	**SBR4**	**SBR5**	**SBR6**	**SBR7**	**SBR8**	**Total**
Yabby *Cherax destructor*	BT	0	0	0	0	1	0	0	1	2
	DN	0	0	0	0	0	0	0	0	0
Common Freshwater Shrimp *Paratya australiensis*	BT	0	0	0	0	0	0	0	0	0
	DN	0	0	0	10	0	0	0	0	10
Mosquito Fish *Gambusia holbrooki*	BT	0	0	0	0	0	0	1	0	1
	DN	0	0	0	0	2	0	0	0	2
Australian Smelt *Retropinna semoni*	BT	0	0	0	2	6	0	22	1	31
	DN	2	0	0	0	0	0	0	0	2

BT = Bait traps; DN = Dip nets.

b) Autumn: March 2013

March 2013		**Sites**								
	Method	**SBR1**	**SBR2**	**SBR3**	**SBR4**	**SBR5**	**SBR6**	**SBR7**	**SBR8**	**Total**
Common Freshwater Shrimp *Paratya australiensis*	BT	1	4	0	0	0	0	0	0	5
	DN	0	0	20	0	0	0	0	0	20
Mosquito Fish *Gambusia holbrooki*	BT	24	7	19	2	0	3	1	4	60
	DN	0	1	1	1	10	10	1	3	27
Australian Smelt *Retropinna semoni*	BT	1	2	0	8	23	19	3	11	67
	DN	0	0	0	0	0	0	0	0	0

BT = Bait traps; DN = Dip nets.

Appendix H. Macrophyte sampling

All macrophytes recorded at sample locations during the Tahmoor South baseline aquatic monitoring surveys...

Scientific Name	Common Name
Baumea juncea	
Carex appressa	
Cotula australis	
Cyperus eragrostis	Umbrella Sedge
Cyperus gracilis	
Cyperus polystachyos	
Elodea canadensis	Canadian Pondweed
Eleocharis sphacelata	Tall Spikerush
Gahia clarkei	Saw Sedge
Geranium homeanum	
Geranium solanderi	
Isolepis prolifera	
Juncus aciculatus	
Juncus acuminatus	
Juncus planifolius	
Juncus usitatus	
Persicaria dicipens	Slender knotweed
Potamogeton tricarinatus	Floating pond weed
Ranunculus muricatus	
Rorippa laciniata	
Rumex brownie	
Schoenus melanostachys	
Spirodela spp	
Typha orientalis	Cumbungi

Appendix I. BC Act Assessment of Significance

Sydney Hawk Dragonfly ***Austrocordulia leonardi***	
Assessment of Significance criteria (Seven Part Test) **Note: Assessment conducted under transitional aarngements.**	**Discussion of criteria**
a) In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction	The following is known about the life cycle of Sydney Hawk dragonfly:: The Sydney Hawk dragonfly has a very restricted distribution The known distribution of the species includes three locations in a small area south of Sydney, from Audley to Picton. . However have recently have been located north of the Hunter increasing its known distribution (Theischinger et al.2013). The species was discovered in 1968 from Woronora River and Kangaroo Creek, south of Sydney and later recorded from the Nepean River at the Maldon Bridge near Wilton. The Sydney Hawk dragonfly spends most of its life underwater (1-2 years) as an aquatic larva, before metamorphosing and emerging from the water as an adult. Adults are thought to only live for a few weeks. All dragonflies are predatory. The larvae stalk or ambush their aquatic prey while the adults capture their prey on their wings. The Sydney Hawk dragonfly has specific habitat requirements, and has only ever been collected from deep and shady riverine pools with cooler water and is thought to occur in larger streams in the Sydney basin (Theischinger et al. 2013). Larvae are found under rocks where they co-exist with *Austrocordulia refracta* (DPI, 2011a). Due to their 1-2 year larval development, Sydney-Hawk dragonfly are thought to require good stream connectivity. Sampling for the threatened dragonfly by target sampling and the baseline monitoring program failed to detect the presence of Sydney Hawk dragonfly however potential habitat is likely in the larger streams such as Bargo River and Nepean River. Subsidence is not predicted to impact these streams therefore no impact to dragonfly lifecycle or population is expected. Mine water discharge is not expected to change the current condition of these streams and may actually improve as a result of the installation of a heavy metal treatment plant. Therefore mine water discharge is not expected to impact the dragonfly's lifecycle or population.
b) In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction	N/A
c) In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:	N/A

i. Is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or ii. Is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction	
d) In relation to the habitat of a threatened species, population or ecological community: i. The extent to which habitat is likely to be removed or modified as a result of the action proposed, and ii. Whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and iii. The importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality.	<u>Extent of habitat</u> As this species is so rare and there are few recorded occurrences, little is known of its exact habitat requirements and preferences. Targeted surveys were conducted using the limited information available regarding habitat preferences (i.e. deep pools with a cobble substrate). Due to their long life cycle, good stream connectivity is also thought to be important. The most appropriate habitat with in the study area includes the larger streams such as the Bargo River and Nepean River. These streams are unlikely to be modified by the proposed action. <u>Fragmentation</u> The habitat is unlikely to become fragmented as Bargo River and Nepean River will not experience subsidence impacts. Also no known populations occur in the Project Area. Importance of habitat to be impacted It is unclear as to how important the habitat is to the sustainability of the species. However given no Sydney Hawk dragonfly has been observed in the Bargo River and they have only been recorded in the Nepean River at Maldon Bridge that the potential habitat in the Project Area is of low-moderate importance.
e) Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly)	No areas of critical habitat for the Sydney Hawk dragonfly have been recommended or declared in NSW.
f) Whether the action proposed is consistent with the objectives or actions of a recovery plan or TAP	There are no recovery plans or threat abatement plans relevant to this species. Conservation and recovery actions listed in DPI (2007) include: Allocate and manage environmental water through water sharing planning processes, to lessen the impacts of altered flows. • Prevent sedimentation and poor water quality by using conservation farming and grazing practices, conserve and restore riparian (river bank) vegetation and use effective erosion and sediment control measures. • Rehabilitate degraded habitats. Protect riparian vegetation and encourage the use of effective sediment control measures in catchments where the dragonfly may occur. • Protect the few remaining sites with the potential to support the species, and address key threats such as habitat degradation and water quality decline. • Conduct further research into the species' biology, ecology and distribution.

	The most relevant action is water quality decline, as mine water discharge may change water quality in areas of potential habitat. However the proposed action will not negatively alter water quality. With the installation of a heavy metal treatment plant the water quality from mine water discharge is expected to improve. The proposed action is therefore unlikely to degrade any potential habitat in the Bargo River and Nepean River.
g) Whether the action proposed constitutes or is part of a KTP or is likely to result in the operation of, or increase the impact of, a KTP	While longwall mining resulting in the alteration of habitat is listed as a Key Threatening Process (KTP) under the BC Act 2016, the proposed action is not classed as a KTP under the FM Act 1994, under which Sydney Hawk dragonfly are listed. Human induced climate change is listed as a KTP under the FM Act. There is physical evidence that human-caused climate change is affecting biodiversity globally, in terrestrial, freshwater and marine systems. The International Panel on Climate Change (IPCC 2013) stated that “observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature changes”. Climate change is also predicted to have an impact on freshwater communities through the changes in the seasonality of rainfall (increases and decreases) and the frequency and severity of storm events. Annually, the numbers of extreme warm events is likely to increase. The regional scenario for NSW freshwater aquatic systems is for drying of aquatic areas, increased drought occurrence, higher water temperatures with diminished water flows, which will produce low oxygen levels and increased conductivity (salinity). Freshwater communities of fish and invertebrates in rivers, swamps and floodplains are likely to experience additional impacts as most species have specialised habitat and dietary requirements. Compared to the open estuaries and ocean waters, freshwater rivers are geographically constrained and limit the migratory options for aquatic plants, invertebrates and fish. Freshwater flows are a stimulus for breeding in many Australian freshwater fish species and thus the changes in volume and timing of spring floods are predicted to significantly impact fish recruitment. With low or reduced flow, freshwater river systems will shift towards lotic rather than lentic environments with a corresponding shift in the biological communities. In shallow freshwater rivers and lakes there is a balance between the phytoplankton communities (heterotrophy) and the bacterial biofilm (mostly autotrophs) on the substrate as the primary producers. Under some climate change scenarios a metabolic shift from heterotrophic communities to autotrophic communities is predicted. Coal extraction of up to 4.4 million tonnes of ROM coal per annum is proposed as part of the development. The Proposed developments main sources of Green House Gas (GHG) emissions include fugitive methane from mine ventilation, pre and post-drainage and flaring. Other emissions include diesel, unleaded petrol consumption, post-mining activities, electricity use and use of SF_6 (sulphur hexafluoride gas) (Pacific Environment, 2018). The GHG Assessment prepared for Tahmoor Coal found that the proposed developments contribution to the projected climate change and the associated impacts would be in proportion with its contribution to global GHG emissions. Average annual scope 1 emissions from the proposed development (0.5 million tonnes (Mt CO_2-e) would represent approximately 0.1% of Australia’s commitment under the Kyoto Protocol (591.5 Mt CO_2-e) and a very small portion of global greenhouse emissions, given that Australia contributed approximately 1.5% of global GHG emissions in 2005 (Pacific Environment 2018). This value does not include the energy use to produce both thermal and coking coal and the combustion of product coal, which is by far the greatest contributing factor to GHG emissions. While the majority of the product coal will be combusted in other countries, the burning of coal is the largest contributor to CO_2 emissions and will contribute to climate change regardless of where it is burned. Tahmoor Coal will employ a number of mitigation measures at the Project site to minimise the generation of GHG emissions. Such measures will include fugitive methane abatement such as the use of flares and recycling through a co-generation plant and Continuous Emissions Monitoring of fugitive emissions (Pacific Environment 2018). The extraction and later burning of coal is likely to contribute to human-induced climate change in the long term and as such the proposal is considered likely to increase a KTP listed under the FM Act.

Conclusion: The proposed action will not have a significant impact on the Sydney Hawk Dragonfly.

Appendix J. AUSRIVAS macroinvertebrate results

a) Autumn May 2012

SITE	CWC1	CWC2	CC3	CC4	DC5	DC6	EC7	EC8	DTC9	DTC10	TTH11	TTH12	HC13	HC14	BR15	BR16
Acarina	0	1	1	2	1	3	2	5	1	2	5	13	3	3	6	3
Aeshnidae	0	1	1	1	2	1	1	4	0	1	1	0	3	0	0	0
Atriplectididae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Atyidae	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Baetidae	0	0	0	0	4	1	2	0	11	19	9	108	0	0	0	0
Caenidae	0	0	2	0	0	1	0	2	3	0	0	4	0	0	0	0
Calamoceratidae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Ceinidae	0	3	1	9	1	0	0	6	0	0	2	0	0	7	6	4
Ceratopogonidae	0	0	0	1	0	0	0	0	0	0	1	0	1	0	1	0
Chaoboridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chironominae	2	1	15	2	12	7	26	3	7	10	14	1	36	16	2	2
Cladocera	0	0	6	0	0	0	1	0	0	1	0	0	1	0	0	0
Coenagrionidae	0	0	5	22	0	2	2	1	0	3	0	3	11	10	0	1
Collembola	0	0	0	0	0	0	0	1	1	3	3	0	0	1	0	0
Corbiculidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Cordulephyidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Culicidae	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0
Diphlebidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dixidae	1	7	0	11	0	4	1	0	2	1	4	3	0	5	0	0
Dytiscidae	6	3	3	3	5	2	4	2	10	3	7	5	0	0	0	0
Ecnomidae	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Gelastocoridae	0	0	3	0	0	0	0	0	0	0	0	0	0	1	0	0
Gomphidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Gyrinidae	2	0	0	0	0	0	0	2	5	0	1	0	0	0	2	1
Harpacticoida	0	1	0	0	4	3	11	1	6	5	1	0	2	0	0	0

Hemicorduliidae	0	0	6	2	2	1	0	1	0	0	0	0	25	4	0	0
Hydraenidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Hydrobiosidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Hydrophilidae	0	0	0	1	0	0	1	0	0	0	0	0	0	4	0	1
Isostictidae	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0
Leptoceridae	27	26	14	10	1	17	1	21	1	4	23	13	0	6	37	12
Leptophlebiidae	21	33	25	22	23	33	50	65	57	41	19	24	6	3	84	44
Lymnaeidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Megapodagrionidae	9	4	5	0	0	2	0	19	0	0	1	0	9	0	1	2
Odontoceridae	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1
Oligochaeta	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0
Orthocladiinae	0	0	0	0	0	0	0	1	4	0	0	3	4	2	0	1
Ostracoda	0	0	0	0	2	5	2	0	0	2	3	0	0	0	0	0
Parastacidae	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Philorheithridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Physidae	0	0	0	4	0	0	0	0	0	0	1	5	0	1	0	0
Pleidae	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Polycentropodidae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Scirtidae	6	15	2	2	3	1	1	0	0	1	0	0	0	4	3	4
Simuliidae	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	4
Sisyridae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Stratiomyidae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Styloniscidae	0	0	2	0	0	0	0	0	0	0	1	1	0	0	0	0
Synlestidae	0	0	0	0	0	0	0	8	0	0	8	5	0	0	0	0
Synthemistidae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Talitridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanypodinae	0	3	0	0	2	1	4	1	1	0	11	5	7	2	2	0

Telephlebiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Tipulidae	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
Turbellaria	0	0	0	1	0	0	0	1	0	0	0	0	3	0	1	0
Veliidae	0	0	0	0	1	0	1	0	2	0	0	0	0	1	0	0

b) Autumn June 2012

SITE	CWC1	CWC2	CC3	CC4	DC5	DC6	EC7	EC8	DTC9	DTC10	TTH11	TTH12	HC13	HC14	BR15	BR16
Acarina	1	5	0	1	1	3	0	2	0	0	0	9	6	4	3	12
Aeshnidae	0	0	2	2	1	0	0	11	0	0	0	0	2	1	0	0
Ancylidae	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Atyidae	0	1	0	4	0	0	0	0	1	0	1	0	0	0	0	0
Baetidae	0	2	1	7	16	2	11	0	60	46	3	8	0	0	5	2
Caenidae	0	0	1	0	1	0	0	1	2	0	0	3	0	0	0	0
Ceinidae	0	6	0	18	0	0	0	10	0	0	9	0	0	2	3	3
Ceratopogonidae	2	2	0	0	0	0	1	3	0	2	0	1	0	1	0	1
Chironominae	6	2	39	10	4	4	58	5	23	11	27	3	57	34	3	3
Cladocera	0	0	1	1	0	0	2	0	0	23	2	0	0	2	12	1
Coenagrionidae	0	0	12	12	1	0	4	1	0	0	0	2	13	3	0	0
Collembola	0	0	1	0	0	0	0	1	5	5	1	0	2	1	0	0
Corbiculidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Cordulephyidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Corixidae	0	2	13	1	0	0	0	0	24	0	5	10	0	5	1	0
Culicidae	0	0	1	0	0	0	1	0	0	3	0	0	0	1	0	0
Cyclopoida	2	4	10	5	16	0	8	1	14	6	5	1	9	7	0	0
Dixidae	3	2	0	31	4	0	4	0	3	0	7	4	5	5	0	0
Dytiscidae	5	6	1	13	8	1	8	3	6	0	9	3	0	8	0	0
Ecnomidae	2	0	0	0	0	0	0	4	0	0	0	0	0	1	0	0
Empididae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1

Gelastocoridae	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0
Gyrinidae	3	0	1	0	0	0	0	0	4	11	2	8	0	0	0	1
Hemicorduliidae	0	0	2	2	0	0	0	0	0	0	0	0	12	2	0	0
Hydraenidae	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0
Hydridae	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrobiosidae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Hydrophilidae	0	0	0	0	0	0	1	0	0	0	0	2	0	4	0	0
Hydroptilidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Isostictidae	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
Leptoceridae	33	29	0	25	6	30	11	19	8	9	18	18	8	40	22	34
Leptophlebiidae	40	87	28	54	9	63	45	92	21	51	13	21	7	23	75	32
Libellulidae	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Megapodagrionidae	3	5	0	1	0	6	0	24	0	0	0	2	2	1	0	0
Mesoveliidae	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Naucoridae	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Nematoda	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Notonectidae	10	9	6	3	7	7	9	4	19	12	6	13	1	3	7	5
Odontoceridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Oligochaeta	0	0	0	1	1	1	1	0	0	0	0	1	0	1	0	0
Orthocladiinae	0	0	2	0	0	1	0	0	3	1	0	0	14	8	0	0
Ostracoda	0	1	2	10	4	4	2	2	6	0	8	0	0	1	0	2
Philorheithridae	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	1
Physidae	0	0	0	0	0	0	0	1	0	0	4	5	1	1	0	0
Psephenidae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Psychodidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Scirtidae	2	4	1	0	2	2	3	3	1	2	0	1	0	4	0	0
Simuliidae	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0

Sisyridae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Styloniscidae	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Synlestidae	0	0	1	0	0	0	0	11	0	0	16	2	0	0	0	0
Talitridae	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
Tanypodinae	1	4	4	9	0	2	0	14	2	4	10	4	6	9	5	2
Telephlebiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Tipulidae	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0
Turbellaria	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0
Veliidae	0	0	0	1	0	1	1	0	1	0	1	0	0	0	0	0

c) Spring October 2012

SITE	CWC1	CWC2	CC3	CC4	DC5	DC6	EC7	EC8	TTH11	TTH12	HC13	HC14	BR15 (SBR1)	BR16 (SBR2)	SBR 3	SBR4	SBR5	SBR6	SBR7	SBR8
Dugesiidae	0	0	0	1	0	0	0	0	0	0	2	0	0	1	1	1	1	1	0	0
Glossiphoniidae	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Sialidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2		
Pyralidae	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
Ancylidae	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Physidae	0	0	0	5	0	0	0	0	5	1	0	1	0	0	0	0	0	0	0	0
Corbiculidae	0	0	0	5	0	0	0	1	0	0	0	5	4	0	0	2	1	6	0	0
Nematoda	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Oligochaeta	0	0	0	1	0	0	1	0	2	0	4	1	0	0	0	1	0	0	1	0
Gripopterygidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Acarina	3	4	0	0	0	0	3	0	1	3	0	1	3	0	3	1	4	5	5	8
Talitridae	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1
Ostrocoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	3	0	0	0	0
Ceinidae	0	1	0	27	0	0	1	0	12	0	0	0	1	0	27	0	1	0	5	15
Oniscidae	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	2	0	1	2

Atyidae	4	5	5	1	0	0	1	0	0	0	0	0	3	2	0	0	1	0	2	0
Dytiscidae	2	3	1	3	1	0	5	0	6	4	4	3	2	0	1	0	4	0	1	2
Gyrinidae	0	2	0	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	1
Elmidae	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	18	6
Hydrophilidae	1	0	2	1	2	1	4	0	0	1	1	0	0	0	0	0	0	0	0	0
Hydraenidae	0	0	1	2	0	1	5	0	1	1	1	1	1	0	0	0	0	0	0	0
Scirtidae	4	3	0	3	0	4	1	0	0	6	1	1	5	4	0	0	0	0	0	1
Psephenidae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrochidae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	4	0	0	1	3	1
Tipulidae	0	1	1	1	0	0	0	0	3	0	0	0	0	1	0	0	0	0	0	6
Chaoboridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0
Dixidae	0	0	11	29	4	2	2	0	12	2	0	0	1	24	6	4	24	5	10	1
Culicidae	1	0	1	1	0	3	53	0	2	0	0	0	1	0	0	0	0	0	0	0
Ceratopogonidae	0	0	2	0	0	1	0	1	1	2	0	7	1	1	0	1	13	1	5	11
Tanypodinae	0	1	0	1	0	0	0	3	5	0	3	16	2	2	9	1	10	6	7	10
Podonominae	0	0	0	0	0	0	1	1	0	0	1	3	0	0	3	0	0	0	0	0
Orthocladiinae	0	0	0	0	0	0	0	0	0	0	2	2	0	0	16	64	1	8	4	1
Chironominae	0	2	4	6	2	2	5	0	3	2	23	3	0	5	0	1	28	4	8	2
Baetidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
Leptophlebiidae	26	26	16	36	7	2	45	35	2	2	0	2	71	22	0	0	0	1	0	0
Caenidae	1	0	0	0	0	0	0	0	0	4	0	0	0	1	0	0	0	0	1	0
Veliidae	1	1	2	0	1	5	8	1	1	0	0	0	0	1	3	1	12	4	7	1
Gelastocoridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	8	0
Gerridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	7
Corixidae	0	1	8	1	0	4	0	0	9	14	0	0	0	0	2	1	0	0	0	0
Notonectidae	7	4	1	3	2	1	2	5	4	2	0	0	5	0	0	0	0	0	0	0
Hydrometridae	3	1	0	0	1	0	0	1	1	0	0	0	0	0	11	2	2	2	8	0
Pleidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
Sisyridae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0

Coenagrionidae	1	0	2	15	0	0	2	0	3	0	32	6	0	0	0	0	0	0	0	0
Isostictidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0
Lestidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Megapodagrionidae	3	0	0	0	3	2	0	1	4	0	14	1	1	6	0	4	0	1	0	0
Synlestidae	0	1	1	0	0	0	0	3	2	2	0	0	3	0	0	0	0	0	1	0
Aeshnidae	0	0	0	1	0	0	0	1	0	0	5	0	0	0	2	0	0	0	0	0
Gomphidae	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
Corduliidae	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
Telephlebiidae	1	0	2	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0
Synthemistidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hemicorduliidae	0	0	0	1	0	0	0	0	0	1	39	3	0	0	0	0	0	0	0	0
Hydrobiosidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polycentropodidae	0	0	0	0	0	0	0	0	0	0	0	0	1	1	4	0	0	0	4	3
Ecnomidae	0	0	1	0	0	0	0	0	0	4	0	1	0	0	1	1	5	0	3	5
Odontoceridae	0	0	0	1	0	0	0	1	0	0	0	0	6	0	0	1	0	0	0	0
Atriplectididae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	4	0	0	0	0
Calamoceratidae	0	0	0	0	0	0	0	2	0	0	0	0	4	2	0	4	0	4	2	0
Leptoceridae	23	25	13	25	6	28	4	11	35	11	2	12	3	54	14	26	2	2	17	6

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SITE	CWC1	CWC2	CC3	CC4	DC5	DC6	EC7	EC8	TTH11	TTH12	HC13	HC14	BR15	BR16
Dugesiidae	0	0	0	6	0	0	1	0	0	0	1	0	0	0
Glossiphoniidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sialidae	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Lymnaeidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Pyralidae	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Ancylidae	1	0	0	0	0	0	0	0	2	0	0	0	0	0
Planorbidae	0	0	0	4	0	0	0	0	0	0	0	0	0	0

Physidae	0	0	0	0	0	0	0	0	0	1	1	2	0	0
Corbiculidae	0	0	0	18	0	0	0	0	0	0	0	3	5	0
Nematoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oligochaeta	0	2	0	4	0	1	9	0	0	0	0	2	1	1
Gripopterygidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acarina	1	3	1	1	0	0	1	0	1	1	0	0	0	1
Talitridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceinidae	0	3	0	7	0	1	0	0	1	0	0	0	0	0
Oniscidae	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Atyidae	8	12	3	8	0	0	0	0	0	0	0	0	5	3
Dytiscidae	6	7	0	0	10	9	11	0	16	2	0	7	0	1
Gyrinidae	0	2	0	0	0	0	0	0	1	0	0	1	3	0
Elmidae	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Hydrophilidae	1	0	0	2	0	0	2	0	0	0	0	2	0	0
Hydraenidae	0	0	0	0	1	0	3	0	6	4	0	0	0	0
Scirtidae	2	1	0	0	0	1	0	0	1	0	0	0	1	4
Hydrochidae	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Tipulidae	0	0	0	0	1	1	0	1	0	0	0	1	1	0
Dixidae	0	0	0	0	2	0	0	0	0	2	0	0	0	14
Culicidae	0	0	0	0	0	19	3	1	0	6	0	2	3	0
Ceratopogonidae	0	0	0	0	0	0	0	1	0	0	0	2	2	0
Tanypodinae	0	5	0	1	6	10	0	1	16	0	0	1	0	0
Podonominae	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Orthocladiinae	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chironominae	12	1	8	1	6	1	21	30	12	0	0	32	1	0
Baetidae	0	0	0	0	0	0	0	0	4	0	0	0	0	0
Leptophlebiidae	44	73	17	27	21	32	56	34	53	4	2	4	26	17
Caenidae	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Veliidae	1	0	1	4	0	17	5	0	2	1	0	0	1	0

Gelastocoridae	0	0	0	1	0	0	0	0	0	2	0	2	0	0
Gerridae	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Corixidae	0	1	16	1	1	1	5	0	17	5	4	5	0	0
Notonectidae	7	13	0	2	1	4	8	1	9	1	0	3	3	3
Hydrometridae	0	0	0	0	0	3	0	0	2	1	0	1	0	0
Pleidae	0	0	0	0	0	0	0	1	0	0	2	0	1	0
Sisyridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coenagrionidae	0	0	0	0	0	0	0	0	0	0	6	6	0	0
Diphlebidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lestidae	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Megapodagrionidae	0	6	0	1	0	0	0	7	0	0	3	5	1	1
Synlestidae	0	3	0	1	0	0	0	3	4	0	0	3	8	13
Aeshnidae	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Gomphidae	0	0	0	0	0	0	1	2	0	0	0	0	0	2
Corduliidae	0	0	0	6	0	0	0	0	1	0	0	0	0	0
Telephlebiidae	0	0	0	1	0	0	0	3	0	0	0	0	0	1
Synthemistidae	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Hemicorduliidae	0	0	0	0	0	0	0	0	0	0	33	7	0	0
Polycentropodidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ecnomidae	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Philorheithridae	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Odontoceridae	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Atriplectididae	0	0	0	0	0	0	0	0	0	0	0	0	3	1
Calamoceratidae	0	0	0	1	0	0	0	0	0	0	0	0	5	1
Leptoceridae	25	28	1	22	1	7	3	16	11	1	0	21	35	37

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SITE	CWC1	CWC2	CC3	CC4	DC5	DC6	EC7	EC8	DTC9	DTC10	TTH11	TTH12	HC13	HC14	BR15 (SBR1)	BR16 (SBR2)	SBR3	SBR4	SBR5	SBR6	SBR7	SBR8
Turbellaria	0	0	0	0	0	0	0	0	0	0	0	0	1	7	0	3		3				
Sialidae	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0		1				
Physidae	0	0	0	2	0	0	0	0	0	0	1	1	0	8	0	0						
Corbiculidae	0	0	0	1	0	0	0	1	0	0	0	0	0	4	7	0		1	1	1		
Oligochaeta	0	0	0	6	0	0	0	0	0	0	0	0	0	0	1	3		2				
Gripopterygidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3						
Acarina	1	2	1	0	0	1	2	4	1	2	2	0	0	0	4	3	3	6	1	11	16	2
Cladocera	0	0	0	0	2	2	1	0	0	0	0	0	0	0	0	0						
Ostracoda	0	2	0	1	3	1	1	0	0	0	0	0	0	0	0	0						
Ceinidae	0	1	0	0	0	0	0	9	0	0	1	0	0	0	8	3	1	1				
Atyidae	3	13	5	4	0	0	0	2	0	0	0	0	0	1	1	4	23	1	3			10
Parastacidae	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0				1		
Dytiscidae	6	5	0	2	7	4	14	0	11	30	14	8	1	5	3	2	3		4	1	2	
Gyrinidae	0	1	0	0	0	0	0	0	2	2	1	1	0	0	1	1		1				
Elmidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	1				
Hydrophilidae	0	0	0	0	0	0	1	0	0	0	0	5	0	0	0	2		2		1		
Hydraenidae	1	0	0	2	0	0	0	0	0	0	1	0	6	3	0	3						
Scirtidae	2	0	0	0	0	0	0	1	0	1	0	0	0	0	0	2						
Tipulidae	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0		1				
Dixidae	0	0	1	3	0	0	0	0	0	1	0	0	0	0	0	2						
Culicidae	0	0	0	0	1	1	3	0	0	0	0	0	0	0	1	0						
Ceratopogonidae	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	1		2				
Tanypodinae	1	1	1	2	0	0	0	1	2	0	0	0	6	5	4	1	1	5	2		1	
Orthocladiinae	0	0	0	2	0	0	0	0	2	0	0	0	10	23	0	0		1		1	2	4
Chironominae	0	0	4	4	2	7	4	11	5	2	6	2	73	21	1	1		8	34	11	7	11

Baetidae	0	1	3	2	12	0	2	0	4	2	1	4	7	1	0	0	1		8	2		4
Leptophlebiidae	40	46	20	38	19	74	46	27	52	89	2	5	17	5	61	51	4	27	3	8	1	5
Caenidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1		2	3	1		6
Veliidae	0	0	0	2	3	0	1	2	0	1	3	0	0	2	0	0		2				
Gelastocoridae	0	1	1	0	0	0	0	0	0	1	1	0	0	4	0	0		1				
Belostomatidae	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0						
Gerridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			1			
Corixidae	0	1	8	5	2	0	3	0	0	1	24	0	0	1	0	3	3	3	21	25	9	5
Notonectidae	7	5	3	0	0	0	11	4	7	0	0	3	3	0	0	0						
Hydrometridae	0	1	0	1	2	0	0	0	0	0	0	0	0	0	0	0						
Coenagrionidae	0	0	6	2	1	0	4	3	1	1	1	2	39	21	3	3	41	5	2	6	2	2
Isostictidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					3	
Megapodagrionidae	2	1	0	0	0	2	0	8	0	0	0	0	9	8	2	2	2					
Synlestidae	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0						
Aeshnidae	0	0	0	0	0	0	0	2	0	0	0	2	2	3	0	0					1	
Gomphidae	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0				1		
Telephlebiidae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0		1	1			1
Synthemistidae	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0		1				
Hemicorduliidae	0	0	1	0	1	1	1	0	0	0	0	0	18	17	0	1	1					1
Cordulephyidae	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0						
Protonourida e	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					8	1
Libellulidae	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0		1				

Polycentropodidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
Ecnomidae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0		1	8	2		2
Philorheithridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0						
Odontoceridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1						
Atriplectididae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1						
Calamoceratidae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	3			1			
Leptoceridae	5	2	0	8	1	4	2	8	1	0	0	0	0	26	29	43	13		2	20	10	20

f) Autumn April 2013

SITE	CWC 1	CWC2	CC3	CC4	DC5	DC6	EC7	EC8	DTC9	DTC10	TTH11	TTH12	HC13	HC14	BR15	BR16
Turbellaria	0	0	0	7	0	0	0	0	0	0	0	0	3	0	0	0
Sialidae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Lymnaeidae	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Physidae	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	0
Corbiculidae	0	0	0	12	0	0	0	0	0	0	0	0	1	3	0	0
Oligochaeta	0	0	0	1	0	0	0	0	1	0	0	0	2	1	0	0
Pyrilidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Acarina	1	12	0	0	1	0	1	0	2	1	3	0	0	1	3	0
Ceinidae	0	0	0	17	0	0	0	2	0	0	2	0	0	2	1	3
Atyidae	3	5	3	1	0	0	0	2	0	0	0	0	0	1	2	6
Parastacidae	1	0	1	0	3	1	2	0	4	2	1	3	0	0	0	0
Dytiscidae	0	3	1	5	2	3	8	0	11	15	2	11	1	3	1	5
Gyrinidae	2	0	1	0	0	1	0	1	1	3	0	4	0	1	3	2
Elmidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrophilidae	0	1	0	1	0	0	2	0	0	0	1	0	0	3	0	0

Hydraenidae	2	0	0	3	1	0	3	2	2	0	3	2	1	2	0	0
Scirtidae	3	0	0	6	0	0	2	0	1	0	0	0	0	1	0	0
Psephenidae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Chrysomeliidae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Hydrochidae	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Tipulidae	0	0	0	0	0	0	0	3	1	1	0	0	0	0	0	1
Dixidae	0	0	0	2	0	0	0	0	2	3	0	0	0	1	0	1
Culicidae	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0
Ceratopogonidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Tanypodinae	3	0	2	1	0	1	0	1	0	3	2	1	3	10	0	3
Orthocladiinae	0	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0
Chironominae	3	2	1	4	3	0	0	2	4	2	4	0	29	34	2	1
Baetidae	0	0	1	0	0	1	0	1	2	2	0	13	0	1	0	4
Leptophlebiidae	51	16	14	58	17	49	6	27	24	38	11	6	13	1	67	16
Caenidae	0	0	0	1	0	0	0	0	0	3	0	0	0	0	1	0
Veliidae	0	0	0	1	2	0	2	0	2	1	1	0	1	2	0	0
Gelastocoridae	1	1	3	1	0	0	0	0	1	0	0	0	1	3	0	1
Belostomatidae	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Gerridae	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Corixidae	0	1	0	1	0	3	1	3	3	2	11	20	1	1	0	9
Notonectidae	7	9	12	8	4	0	0	0	3	0	0	0	0	0	0	0
Hydrometridae	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
Pleidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Coenagrionidae	0	0	4	25	0	0	0	0	0	2	0	4	24	11	0	1
Isostictidae	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	0
Megapodagrionidae	0	0	1	10	1	0	0	10	0	0	0	1	8	3	0	1
Synlestidae	0	0	0	0	0	0	0	2	0	0	0	1	0	1	0	0
Aeshnidae	0	1	1	3	1	0	0	1	0	0	0	5	0	3	0	0

Gomphidae	0	0	0	1	0	0	0	5	0	1	0	0	0	1	0	1
Telephlebiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Synthemistidae	0	0	0	0	1	0	1	0	1	1	0	0	0	0	0	0
Hemicorduliidae	0	0	0	0	0	0	0	1	1	0	0	0	18	10	0	0
Cordulephyidae	0	0	0	0	0	0	0	0	0	0	0	0	4	4	2	1
Austrocorduliidae	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Protonouridae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Libellulidae	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0
Polycentropodidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Hydroptilidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Ecnomidae	1	0	1	0	0	0	0	0	3	0	0	0	0	0	0	0
Odontoceridae	0	0	0	4	0	0	0	3	0	0	0	0	0	0	0	0
Atriplectididae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Calamoceratidae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Leptoceridae	3	18	2	32	16	2	21	10	8	10	24	7	7	22	12	30

g) Spring September 2013

SITE	CWC1	CWC2	CC3	CC4	DC5	DC6	EC7	EC8	DTC9	DTC10	TTH11	TTH12	HC13	HC14	BR15	BR16
Turbellaria	0	0	0	5	0	0	0	0	0	0	2	0	0	0	0	0
Sialidae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Lymnaeidae	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Ancylidae	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Physidae	0	0	0	2	0	0	0	0	0	0	1	0	3	0	0	0
Corbiculidae	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
Oligochaeta	0	0	0	0	0	0	0	1	0	2	0	0	1	4	2	4
Acarina	1	9	0	0	0	1	3	3	0	2	0	5	0	0	3	3
Ceinidae	0	0	0	2	1	0	1	2	0	0	2	0	0	3	1	3

Atyidae	0	1	3	4	0	0	0	0	4	0	1	0	0	0	5	0
Parastacidae	1	1	5	0	2	1	5	0	7	0	0	0	0	0	0	0
Dytiscidae	4	3	1	0	6	10	4	3	13	8	7	10	4	3	0	1
Gyrinidae	0	1	0	1	0	0	0	1	1	0	0	1	0	0	1	0
Elmidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3
Hydrophilidae	0	0	0	1	1	2	1	1	0	1	1	0	0	3	4	2
Hydraenidae	1	0	0	1	0	4	1	4	2	2	8	0	1	0	0	0
Scirtidae	5	0	3	4	15	11	2	3	10	2	2	0	4	3	1	1
Psephenidae	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrochidae	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0
Tipulidae	0	0	0	0	0	0	1	0	0	8	6	0	0	0	0	0
Dixidae	0	1	0	11	15	0	10	0	16	4	7	1	3	11	0	0
Simuliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Stratiomiyidae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Culicidae	0	0	0	3	1	0	5	0	1	3	1	0	0	0	3	0
Ceratopogonidae	0	2	0	0	0	0	1	1	5	1	2	0	1	4	3	7
Tanypodinae	3	0	0	0	0	0	0	9	1	2	0	11	5	15	6	5
Orthocladiinae	1	2	0	0	0	0	0	4	1	0	0	0	6	12	0	1
Chironominae	12	4	2	2	1	27	4	8	2	3	4	6	46	65	5	8
Baetidae	0	0	0	2	2	1	2	0	13	5	7	1	1	4	5	18
Leptophlebiidae	44	28	27	23	14	6	18	21	31	47	12	36	22	3	52	44
Caenidae	0	0	1	0	0	0	0	0	1	3	1	15	0	1	0	1
Veliidae	2	0	0	3	2	4	2	1	0	3	0	0	1	2	1	1
Gelastocoridae	1	1	1	2	0	0	0	2	0	2	0	0	2	2	0	0
Gerridae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Corixidae	0	0	7	11	1	4	1	0	3	1	2	1	0	0	0	1
Notonectidae	8	3	1	3	4	4	9	3	4	1	2	2	9	0	0	0
Hydrometridae	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
Coenagrionidae	0	0	1	10	0	0	0	1	1	1	0	3	18	7	3	1

Isostictidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Megapodagrionidae	0	1	1	3	0	0	0	17	0	0	0	0	11	4	0	0
Synlestidae	0	0	0	0	0	0	0	2	0	0	0	3	0	0	0	1
Aeshnidae	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
Gomphidae	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0
Telephlebiidae	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1
Synthemistidae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Hemicorduliidae	0	0	0	0	1	0	0	0	7	0	0	2	7	3	1	2
Cordulephyidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Libellulidae	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Polycentropodidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Ecnomidae	0	1	1	0	0	0	0	0	3	0	0	1	0	0	0	1
Philorheithridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Odontoceridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Atriplectididae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Calamoceratidae	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0
Leptoceridae	26	23	1	18	9	7	21	19	21	15	16	2	7	32	22	30

h) Spring October 2013

SITE	CWC 1	CWC2	CC3	CC4	DC5	DC6	EC7	EC8	DTC9	DTC10	TTH11	TTH12	HC13	HC14	BR15	BR16
Turbellaria	0	0	0	1	0	1	0	0	0	0	0	0	2	0	0	0
Sialidae	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0

Corydalidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Physidae	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
Corbiculidae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Oligochaeta	0	1	3	2	0	0	0	0	0	0	0	0	1	0	0	0
Acarina	0	1	0	3	1	0	2	0	0	0	1	2	0	0	0	2
Ceinidae	0	0	0	13	0	0	0	0	0	0	7	0	0	1	0	0
Atyidae	0	6	5	6	0	0	0	0	1	1	2	0	0	3	3	2
Parastacidae	2	1	2	0	2	3	3	1	0	4	1	0	0	0	0	0
Dytiscidae	11	5	2	7	19	10	10	1	15	19	8	11	12	4	1	2
Gyrinidae	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
Elmidae	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1
Hydrophilidae	0	0	0	1	1	0	1	0	0	0	3	1	0	0	0	1
Hydraenidae	1	0	0	3	1	1	0	0	0	0	1	1	0	3	0	0
Scirtidae	2	4	0	3	4	3	2	0	3	1	0	0	5	6	3	2
Psephenidae	0	0	3	1	0	0	0	0	0	1	0	0	0	0	0	0
Hydrochidae	0	0	0	0	1	0	0	2	0	0	1	0	0	0	0	0
Tipulidae	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0
Dixidae	1	0	1	11	9	2	3	0	2	0	3	0	1	4	0	1
Simuliidae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Stratiomiyidae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Culicidae	1	3	4	4	6	5	6	0	3	1	1	2	0	4	0	0
Ceratopogonidae	0	0	4	0	0	1	0	0	0	0	0	0	1	2	0	0
Tanypodinae	1	3	2	0	0	2	3	0	0	1	4	14	1	6	2	4
Orthocladiinae	0	0	0	1	1	0	0	0	0	0	0	0	0	2	0	0
Chironominae	11	1	20	4	6	3	4	3	3	9	18	9	91	19	2	1
Baetidae	0	0	4	2	4	0	5	0	1	3	6	0	0	0	0	2
Leptophlebiidae	45	26	73	0	24	48	31	53	22	29	47	9	10	5	16	34
Caenidae	0	0	3	39	0	0	0	1	1	0	0	3	0	0	0	0
Veliidae	1	0	0	0	5	2	3	0	0	0	0	0	0	1	0	0

Gelastocoridae	0	0	0	1	0	0	0	0	1	0	0	0	2	1	0	0
Corixidae	0	0	2	6	2	3	0	0	2	8	13	4	0	0	0	1
Notonectidae	6	2	1	2	1	0	7	2	5	10	2	9	0	2	9	0
Hydrometridae	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0
Coenagrionidae	0	0	0	3	0	0	0	0	0	0	0	5	23	5	0	0
Isostictidae	0	0	0	0	0	0	0	0	0	0	0	0	1	4	0	0
Megapodagrionida e	0	0	4	3	1	0	1	12	1	0	1	0	8	7	0	0
Synlestidae	0	0	0	0	0	0	0	1	0	0	0	15	0	1	0	0
Aeshnidae	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0
Gomphidae	0	0	0	0	0	0	0	3	0	0	0	0	0	3	0	0
Telephlebiidae	0	0	0	0	0	0	0	0	1	0	0	3	1	0	0	1
Synthemistidae	0	0	0	0	2	0	8	1	0	0	0	0	0	0	0	0
Hemicorduliidae	0	0	1	4	2	0	0	0	1	0	1	0	10	6	1	0
Cordulephyidae	0	0	0	0	0	0	0	0	1	0	2	2	0	3	0	0
Libellulidae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Polycentropodidae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Hydroptilidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Ecnomidae	0	0	0	0	0	0	0	2	2	1	0	5	0	0	0	0
Odontoceridae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Calamoceratidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Leptoceridae	6	21	1	23	10	2	6	12	5	2	10	1	5	13	2	3

Appendix K. Quantitative macroinvertebrate benthic data

Quantitative macroinvertebrate benthic data - mean density (3 replicates at each site) of each taxa at each site for (a) spring 2012 (b) autumn 2013 (c) spring 2013. Subsampled data (35%) was multiplied by 100/35 to estimate macroinvertebrate family densities.

a) Spring 2012

	CWC1	CWC2	CC3	CC4	DC5	DC6	EC7	EC8	TTH11	TTH12	HC13	HC14	BR15 SBR1	BR16 SBR2	CBR1	CBR2	CMC3	CMC4	CCC5	CCC6	CSQC7	CSQC8	SBR3	SBR4	SBR5	SBR6	SBR7	SBR8
Gordiidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00
Nemertea	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nematoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.90	0.00	0.00	0.00	0.00
Tricladida	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	1.90	0.95	0.00	0.00	0.00	0.00	0.00	0.00	3.62	0.00	0.00	0.95	0.00	0.00	0.95	0.00
Oligochaeta	0.00	5.19	3.81	8.57	1.62	4.67	98.89	5.71	4.92	38.10	10.48	0.95	4.76	10.48	1.29	25.71	1.62	1.90	1.90	2.86	7.00	0.00	0.00	78.10	0.00	10.48	4.76	4.76
Ceinidae	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.90	0.00	0.00	0.00	0.00
Atyidae	0.00	0.00	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.24	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sphaeriidae	0.00	0.00	0.00	9.52	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	3.81	0.95	4.14	0.95	0.33	0.00	0.00	0.00	2.57	0.00	0.00	20.95	1.90	0.95	0.00	0.00
Ancylidae	0.00	2.57	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Physidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Baetidae	0.00	0.00	0.00	1.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00
Caenidae	0.00	0.00	0.95	1.29	0.00	0.00	0.00	0.00	1.90	19.05	0.00	0.00	3.81	0.95	0.00	0.95	0.33	0.95	0.00	0.00	0.00	0.95	0.95	6.67	51.43	41.90	40.00	9.52
Leptophlebiidae	54.29	137.81	2.86	27.19	17.62	22.67	53.65	41.90	20.79	14.29	0.00	0.00	55.24	48.57	36.76	34.05	59.19	33.33	19.05	3.81	12.95	10.48	4.76	27.62	1.90	0.95	0.00	0.95
Chorismagrionidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.90	0.00	0.00	0.00	0.00	0.00	0.00
Coenagrionidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.90	0.00	0.00	0.00	0.00	0.00	0.00	8.57	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Magapodagrionidae	0.00	0.33	0.00	0.00	0.00	0.00	0.00	1.90	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.95	0.00	0.00	1.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Synlestidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Austrocorduliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cordulephyidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00
Gomphidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.90	1.90	0.95	0.00
Libulllidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hemicorduliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.86	0.00	3.81	0.00	0.33	0.00	0.00	0.00	1.90	4.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Synthemistidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Telephlebiidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00
Gripopterygidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sialidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corixidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.95	1.90	0.00	0.00
Notonectidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	CWC1	CWC2	CC3	CC4	DC5	DC6	EC7	EC8	TTH11	TTH12	HC13	HC14	BR15 SBR1	BR16 SBR2	CBR1	CBR2	CMC3	CMC4	CCC5	CCC6	CSQC7	CSQC8	SBR3	SBR4	SBR5	SBR6	SBR7	SBR8
Dytiscidae	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	1.11	0.00	0.00	0.95	0.00	0.00	0.00	0.00	2.86	0.95	0.00	0.00	2.24	11.43	0.00	0.00	0.00	0.00	0.95	0.00
Dytiscidae (adult)	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.86	0.00	0.00	0.00	0.00	0.00	0.00
Elmidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.90	3.81	0.67	6.05	0.33	0.00	0.00	0.00	0.00	0.00	0.95	3.81	0.00	0.95	0.00	0.00
Elmidae (adult)	0.00	0.00	0.00	0.00	0.00	0.00	1.11	0.00	0.00	0.00	0.00	0.00	2.86	0.95	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gyrinidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.95	0.00	0.00	0.00	0.00	0.00	0.00	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydraenidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrophilidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrophilidae(adult)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Psephenidae	0.00	1.90	1.90	5.71	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00
Scirtidae	0.00	0.00	0.00	0.00	0.00	0.00	1.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aphroteniinae	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ceratopogonidae	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	3.81	2.86	0.00	0.00	9.52	8.57	1.90	7.05	0.67	2.86	13.33	2.86	0.67	4.76	0.95	4.76	0.00	2.86	2.86	1.90
Chironominae	24.76	16.29	104.76	78.38	82.81	49.33	259.21	20.00	237.94	116.19	221.90	50.10	23.81	91.43	4.86	8.67	64.76	77.14	198.10	212.38	330.71	393.33	76.19	131.43	92.38	30.48	40.00	110.48
Tanypodininae	8.57	26.52	7.62	23.43	1.29	1.67	10.95	24.76	60.32	34.29	11.43	0.95	26.67	29.52	18.14	13.14	13.38	18.10	17.14	46.67	77.24	23.81	23.81	12.38	122.86	39.05	51.43	52.38
Orthocladininae	0.95	0.00	3.81	1.29	0.00	0.00	0.00	0.95	0.00	0.95	3.81	2.62	1.90	3.81	0.95	0.00	9.52	3.81	1.90	0.00	1.90	1.90	0.95	3.81	3.81	9.52	9.52	9.52
Podinae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Culicidae	0.00	0.00	0.00	0.00	0.00	0.33	8.10	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	5.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dixidae	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Empididae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00
Psychodidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Simuliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stratiomyidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dolichopodidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tabanidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tipulidae	0.95	0.00	0.00	1.90	0.00	0.00	0.00	0.00	1.90	0.00	0.95	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplectididae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calamoceratidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.86	1.90	0.00	0.00	0.33	0.00	0.00	1.90	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00
Conoesucidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ecnomidae	8.57	0.00	2.86	0.00	0.00	0.00	0.00	0.95	0.00	3.81	0.00	1.00	8.57	3.81	2.24	0.33	1.29	1.90	1.90	0.00	2.29	0.00	5.71	0.95	4.76	0.00	0.00	16.19
Hydrobiosidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydroptilidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Leptoceridae	0.00	0.00	0.00	2.29	0.00	0.33	0.00	0.00	0.95	0.00	0.00	0.00	2.86	0.00	5.71	6.67	0.33	0.00	3.81	0.00	2.24	0.00	0.00	1.90	1.90	0.95	0.00	0.00
Odontoceridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	CWC1	CWC2	CC3	CC4	DC5	DC6	EC7	EC8	TTH11	TTH12	HC13	HC14	BR15 SBR1	BR16 SBR2	CBR1	CBR2	CMC3	CMC4	CCC5	CCC6	CSQC7	CSQC8	SBR3	SBR4	SBR5	SBR6	SBR7	SBR8
Polycentropodidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	1.90	0.00	0.00	0.00	0.95	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyralidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Glossiphoniidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Acarina	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00
Parastacidae	0.00	0.00	0.00	0.00	0.00	0.33	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00

b) Autumn 2013

	CWC1	CWC2	CC3	CC4	DC5	DC6	EC7	EC8	TTH11	TTH12	HC13	HC14	BR15 SBR1	BR16 SBR2	CBR1	CBR2	CMC3	CMC4	CCC5	CCC6	CSQC7	CSQC8	SBR3	SBR4	SBR5	SBR6	SBR7	SBR8
Gordiidae	0.00	0.00	0.00	0.33	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nemertea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nematoda	2.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00
Tricladida	0.95	17.14	0.00	3.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	4.76	1.43	0.00	0.67	0.67	0.00	0.00	0.00	1.90	0.00	0.00	0.95	0.00	0.00	0.00
Oligochaeta	0.00	0.00	18.48	55.33	0.67	1.33	1.62	6.00	3.00	3.90	1.00	4.76	0.00	0.00	1.93	8.10	6.81	20.71	0.95	3.81	2.86	3.81	17.86	1.29	3.95	5.71	0.67	0.67
Ceinidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atyidae	0.00	0.00	0.00	2.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.24	4.14	0.00	0.00	0.00	0.00	1.62	2.29	0.00	0.00	0.00	0.00
Sphaeriidae	0.00	0.00	0.00	1.29	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	1.29	3.81	2.86	0.95	0.00	12.43	0.00	0.00	0.00	0.00	0.33	0.00	3.19	8.57	2.24	2.86
Ancylidae	0.00	2.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Physidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.95	0.00	0.00	0.00	0.00	0.00	0.00
Baetidae	0.00	0.00	4.81	3.57	3.33	0.00	0.33	0.67	5.33	2.57	4.00	9.90	2.86	0.95	1.50	1.67	1.33	2.67	0.95	0.00	19.05	7.62	0.00	2.29	1.29	0.00	1.67	0.00
Caenidae	0.00	0.00	0.95	0.00	0.33	0.00	0.00	2.00	1.29	0.00	0.33	0.00	0.00	0.00	0.00	2.33	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	2.29	5.19
Leptophlebiidae	80.95	321.14	10.29	28.90	5.24	24.00	10.19	23.67	39.62	6.14	7.00	1.33	0.95	0.00	34.71	60.76	29.86	23.14	11.43	33.33	5.71	18.10	4.76	2.67	4.76	11.43	1.00	0.67
Chorismagrionidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coenagrionidae	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.90	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.95	0.00	0.00	0.00
Magapodagrionidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Synlestidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Austrocorduliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cordulephyidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gomphidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00	0.67	0.00	0.33	0.00	0.00	0.00	1.29	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.33	0.00	2.24	2.00
Libulllidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hemicorduliidae	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Synthemistidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.90	0.95	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00

	CWC1	CWC2	CC3	CC4	DC5	DC6	EC7	EC8	TTH11	TTH12	HC13	HC14	BR15 SBR1	BR16 SBR2	CBR1	CBR2	CMC3	CMC4	CCC5	CCC6	CSQC7	CSQC8	SBR3	SBR4	SBR5	SBR6	SBR7	SBR8
Telephlebiidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gripopterygidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sialidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corixidae	0.00	0.00	0.00	2.29	1.29	1.33	0.00	0.00	0.00	0.00	5.33	5.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.95	0.95	2.95	0.00	9.48	4.33
Notonectidae	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.67	0.00	0.00	0.00	0.50	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
Dytiscidae	0.00	0.00	0.95	0.67	0.67	0.00	0.00	0.00	1.33	2.29	0.33	0.95	0.00	0.95	1.00	0.00	0.00	0.00	0.00	0.95	3.81	8.57	0.00	1.62	0.00	0.00	1.90	0.00
Dytiscidae (adult)	0.00	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.90	0.00	0.00	0.95	0.00	0.00	0.33	0.00
Elmidae	0.95	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.50	10.62	2.00	21.76	0.00	0.00	0.00	0.00	0.00	0.00	2.24	3.81	0.00	0.33
Elmidae (adult)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gyrinidae	0.00	0.95	0.00	0.00	0.00	0.33	0.00	0.67	0.00	0.00	0.33	0.00	0.00	0.00	1.50	0.95	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00
Hydraenidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrophilidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.81	0.00	1.00	0.00	1.29	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.95	0.00	0.00
Hydrophilidae(adult)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.67	0.00	0.95	0.00
Psephenidae	0.00	0.00	1.90	1.33	0.00	0.00	0.00	2.00	0.00	0.00	0.33	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00
Scirtidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aphroteniinae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ceratopogonidae	0.95	0.00	0.00	0.00	0.00	0.95	0.00	0.67	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	6.67	13.33	0.95	0.00	0.95	0.00	0.95	0.00
Chironominae	20.33	4.48	70.48	9.86	8.81	47.48	14.14	12.67	167.90	30.29	33.33	30.19	100.52	280.00	6.86	5.62	6.67	36.52	12.38	18.10	417.14	470.48	43.76	90.19	72.33	147.62	98.52	33.10
Tanypodininae	1.90	3.19	19.86	9.95	3.00	1.00	0.00	32.00	4.24	4.86	5.00	6.95	7.33	8.57	6.29	6.52	21.33	6.48	46.67	33.33	43.81	83.81	8.48	4.57	13.71	11.43	12.14	4.52
Orthocladininae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	3.67	0.00	0.00	1.95	0.95	64.76	2.00	19.95	0.95	0.00	0.95	0.95	1.90	1.90	0.00	1.62	0.00	1.90	1.29	1.95
Podinae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Culicidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dixidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Empididae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Psychodidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Simuliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stratiomyidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dolichopodidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tabanidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tipulidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atriplectididae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00

	CWC1	CWC2	CC3	CC4	DC5	DC6	EC7	EC8	TTH1 1	TTH1 2	HC13	HC14	BR15 SBR1	BR16 SBR2	CBR1	CBR 2	CMC 3	CMC 4	CCC5	CCC6	CSQC7	CSQC8	SBR3	SBR4	SBR5	SBR6	SBR7	SBR8
Calamoceratidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.86	3.19	0.95	0.00	0.00	0.00	0.95	0.00	0.00	0.33	0.95	0.00	1.00	1.29
Conoesucidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ecnomidae	0.00	0.00	1.90	0.00	0.00	0.00	0.00	2.33	1.29	0.00	0.00	3.62	0.00	0.00	3.93	1.33	3.86	1.33	2.86	1.90	0.00	1.90	0.00	0.00	6.57	7.62	5.48	6.95
Hydrobiosidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydroptilidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Leptoceridae	0.00	0.00	1.62	3.19	0.33	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	2.86	4.19	1.00	1.33	0.95	0.95	1.90	0.95	3.81	0.33	8.57	0.00	0.95	1.29
Odontoceridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Polycentropodidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00
Pyralidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Glossiphoniidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Acarina	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Parastacidae	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.67	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.95	0.00	0.00	0.00	0.00	0.00	0.00

c) Spring 2013

	CWC1	CWC2	CC3	CC4	DC5	DC6	EC7	EC8	TTH11	TTH12	HC13	HC14	BR15 SBR1	BR16 SBR2	CBR1	CBR2	CMC3	CMC4	CCC5	CCC6	CSQC7	CSQC8	SBR3	SBR4	SBR5	SBR6	SBR7	SBR8
Gordiidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nemertea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00
Nematoda	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	1.90	0.00	0.00	0.00	0.00	0.00	1.00
Tricladida	0.00	0.00	0.00	1.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.00	0.00	0.00	0.33	0.00	0.00	0.00	1.67
Oligochaeta	7.67	16.19	29.00	5.67	2.00	0.00	2.67	1.00	0.33	0.33	6.67	0.00	5.00	0.33	3.81	3.62	7.00	252.38	38.00	51.48	41.67	71.43	1.29	0.67	7.67	16.19	29.00	5.67
Ceinidae	0.00	0.00	0.00	7.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.14	0.00	0.00	5.71	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.33
Atyidae	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	1.00	0.95	0.00	0.00	0.00	0.00	0.95	0.33	0.00	0.00	0.00	0.67
Sphaeriidae	0.00	0.00	0.00	9.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	1.90	0.00	0.00	13.33	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	9.00
Ancylidae	0.00	2.86	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	2.86	0.00	0.00
Physidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Baetidae	0.00	0.00	0.33	0.33	0.67	0.33	0.00	0.00	1.33	0.33	0.33	0.95	0.00	0.00	1.29	0.33	3.00	8.57	0.00	0.00	0.33	0.00	0.95	0.00	0.00	0.00	0.33	0.33
Caenidae	0.00	0.00	0.33	0.00	0.67	0.33	0.00	0.33	9.81	0.67	0.00	0.95	0.33	0.00	0.00	1.62	0.67	1.90	0.00	0.00	0.00	0.00	1.33	0.00	0.00	0.00	0.33	0.00
Leptophlebiidae	10.33	221.90	10.00	37.00	2.67	5.00	2.62	23.00	9.52	15.00	1.67	6.67	0.00	0.00	134.86	54.86	35.33	60.00	90.67	122.67	0.67	0.95	13.19	6.67	10.33	221.90	10.00	37.00
Chorismagrionidae	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.33	0.00	0.00	0.00	0.33
Coenagrionidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Magapodagrionidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.95	0.00	0.00	0.00	0.00	0.00
Synlestidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.67	0.33	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Austrocorduliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Cordulephyidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gomphidae	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.67	0.33	0.00	0.00	2.86	0.00	0.00	0.00	2.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33
Libulllidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hemicorduliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	3.90	0.33	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Synthemistidae	0.00	0.00	0.00	0.00	0.00	0.00	3.19	0.33	1.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Telephlebiidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gripopterygidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.33	6.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sialidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corixidae	0.00	0.00	0.00	0.33	0.67	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.33	0.00	0.00	0.00	0.00	0.33
Notonectidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dytiscidae	0.00	0.00	1.33	0.00	0.33	0.00	0.00	0.00	4.95	0.00	0.00	1.90	0.00	0.00	0.67	0.00	0.00	0.95	0.00	3.81	0.67	2.86	0.33	0.33	0.00	0.00	1.33	0.00
Dytiscidae (adult)	0.33	1.90	0.00	0.00	0.33	0.33	0.00	0.00	5.48	0.00	0.67	0.00	0.33	1.90	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.95	0.00	0.00	0.33	1.90	0.00	0.00
Elmidae	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.67	0.00	11.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Elmidae (adult)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gyrinidae	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.29	0.00	0.00	0.95	0.00	1.29	0.00	0.00	0.33	0.00	0.33	0.00	0.00	0.00
Hydraenidae	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00
Hydrophilidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrophilidae(adult)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.33	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Psephenidae	0.00	0.00	4.33	1.33	0.33	0.00	0.00	0.33	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.67	0.00	0.00	4.33	1.33
Scirtidae	0.67	0.95	0.67	0.00	0.00	1.33	0.00	0.00	0.00	1.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.67	0.95	0.67	0.00
Aphroteniinae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ceratopogonidae	4.67	0.00	2.33	2.00	0.67	32.67	7.10	2.67	5.81	6.67	1.67	2.24	4.00	0.00	0.00	3.24	1.00	9.52	0.33	1.00	9.33	8.57	2.24	1.00	4.67	0.00	2.33	2.00
Chironominae	25.00	6.67	46.00	21.67	42.33	21.33	21.62	10.33	102.48	19.67	39.33	298.48	69.33	101.29	11.24	9.33	7.33	135.24	78.67	75.86	64.67	46.67	44.90	34.33	25.00	6.67	46.00	21.67
Tanypodininae	8.33	5.71	10.00	37.67	0.33	14.33	1.67	32.33	7.24	1.00	4.33	82.29	15.00	12.67	15.71	26.29	22.33	99.05	29.67	33.95	9.67	8.57	26.19	2.33	8.33	5.71	10.00	37.67
Orthocladiinae	0.00	0.00	3.00	0.67	0.00	0.00	4.52	21.67	2.67	0.00	3.00	1.62	7.67	72.67	1.62	1.29	0.33	3.81	30.00	28.24	0.00	0.00	3.29	4.00	0.00	0.00	3.00	0.67
Podinae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Culicidae	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.67	0.00	0.00	0.00
Dixidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Empididae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Psychodidae	0.00	0.00	0.00	0.00	0.00	5.67	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Simuliidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stratiomyidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00
Dolichopodidae	0.00	0.00	0.00	0.00	0.00	0.67	2.57	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tabanidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tipulidae	0.00	0.00	0.67	0.00	0.00	4.00	2.00	0.00	1.95	1.00	4.33	0.95	0.33	0.00	0.00	0.67	0.00	0.00	0.33	0.00	0.00	1.90	0.67	0.67	0.00	0.00	0.67	0.00

Atriplectididae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Calamoceratidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.67	0.00	0.00	0.00	0.67	0.95	0.00	0.00	0.00	0.00	0.00	0.00
Conoesucidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ecnomidae	0.33	0.00	1.67	0.33	0.00	0.00	0.00	6.67	7.24	0.00	0.00	12.52	0.33	1.62	2.24	0.33	2.33	13.33	0.67	0.95	0.00	0.00	2.00	0.00	0.33	0.00	1.67	0.33
Hydrobiosidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydroptilidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Leptoceridae	1.67	0.95	0.33	2.33	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.33	0.00	6.71	13.10	0.00	0.00	1.00	4.76	1.67	0.00	11.43	0.00	1.67	0.95	0.33	2.33
Odontoceridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Polycentropodidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pyralidae	0.00	0.00	0.00	0.00	0.00	0.00	1.90	0.00	0.95	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Glossiphoniidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Acarina	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Parastacidae	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	1.90	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix L. SIMPER procedure results

a) Subsidence results

SIMPER
Similarity Percentages - species contributions

One-Way Analysis

Data worksheet
Name: Data2
Data type: Abundance
Sample selection: All
Variable selection: All

Parameters
Resemblance: S17 Bray Curtis similarity
Cut off for low contributions: 90.00%

Factor Groups

Sample	Stream
CWC1 SPR12	CWC
CWC2 SPR12	CWC
CWC1 AUT13	CWC
CWC2 AUT13	CWC
CWC1 SPR13	CWC
CWC2 SPR13	CWC
CC3 SPR12	CC
CC4 SPR12	CC
CC3 AUT13	CC
CC4 AUT13	CC
CC3 SPR13	CC
CC4 SPR13	CC
DC5 SPR12	DC
DC6 SPR12	DC
DC5 AUT13	DC
DC6 AUT13	DC
DC5 SPR13	DC
DC6 SPR13	DC
EC7 SPR12	EC
EC8 SPR12	EC
EC7 AUT13	EC
EC8 AUT13	EC
EC7 SPR13	EC
EC8 SPR13	EC
TTH11 SPR12	TTH
TTH12 SPR12	TTH
TTH11 AUT13	TTH
TTH12 AUT13	TTH
TTH11 SPR13	TTH
TTH12a SPR13	TTH
HC13 SPR12	HC
HC14 SPR12	HC
HC13 AUT13	HC
HC14 AUT13	HC
HC13 SPR13	HC
HC14 SPR13	HC
BR15 SPR12	BR
BR16 SPR12	BR
BR15 AUT13	BR
BR 16 AUT13	BR
BR15 SPR13	BR

BR 16	SPR13	BR
CBR1	SPR12	CBR
CBR2	SPR12	CBR
CBR1	AUT13	CBR
CBR2	AUT13	CBR
CBR1	SPR13	CBR
CBR2	SPR13	CBR
CMC3	SPR12	CMC
CMC4	SPR12	CMC
CMC3	AUT13	CMC
CMC4	AUT13	CMC
CMC3	SPR13	CMC
CMC4	SPR13	CMC
CCC5	SPR12	CCC
CCC6	SPR12	CCC
CCC5	AUT13	CCC
CCC6	AUT13	CCC
CCC5	SPR13	CCC
CCC6	SPR13	CCC
CSQC7	SPR12	CSQC
CSQC8	SPR12	CSQC
CSQC7	AUT13	CSQC
CSQC8	AUT13	CSQC
CSQC7	SPR13	CSQC
CSQC8	SPR13	CSQC
DTC9	AUT13	DTC
DTC10	AUT13	DTC
DTC9	SPR13	DTC
DTC10	SPR13	DTC

Group CWC
Average similarity: 54.59

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Leptophlebiidae	3.17	20.63	3.63	37.79	37.79
Chironominae	1.94	13.62	5.62	24.95	62.73
Tanypodininae	1.62	10.85	8.04	19.87	82.61
Dytiscidae (adult)	0.64	2.50	0.76	4.57	87.18
Oligochaeta	0.86	2.30	0.48	4.21	91.39

Group CC
Average similarity: 64.02

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Chironominae	2.60	12.10	3.70	18.89	18.89
Tanypodininae	2.00	9.51	10.64	14.86	33.75
Leptophlebiidae	1.99	8.96	6.89	13.99	47.74
Oligochaeta	1.96	8.68	5.41	13.56	61.30
Psephenidae	1.25	5.98	7.12	9.35	70.65
Leptoceridae	0.95	3.37	1.29	5.27	75.92
Baetidae	0.91	2.97	1.23	4.64	80.56
Orthocladininae	0.78	2.14	0.76	3.34	83.91
Ecnomidae	0.73	2.13	0.74	3.32	87.23
Caenidae	0.63	1.98	0.77	3.09	90.31

Group DC
Average similarity: 57.51

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Chironominae	2.45	19.91	3.96	34.63	34.63
Leptophlebiidae	1.79	14.26	3.18	24.80	59.43
Tanypodininae	1.20	8.87	4.12	15.43	74.85
Oligochaeta	0.96	6.64	1.33	11.55	86.40
Corixidae	0.51	1.69	0.48	2.93	89.33

Ceratopogonidae	0.71	1.43	0.48	2.49	91.82

Group EC
Average similarity: 46.42

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Chironominae	2.32	11.91	4.09	25.66	25.66
Leptophlebiidae	2.12	10.97	3.94	23.64	49.30
Oligochaeta	1.61	7.39	4.25	15.92	65.22
Tanypodininae	1.66	5.89	1.27	12.69	77.91
Orthocladininae	0.92	2.12	0.76	4.57	82.48
Parastacidae	0.50	1.57	0.48	3.37	85.85
Ceratopogonidae	0.64	1.05	0.47	2.26	88.12
Ecnomidae	0.64	1.03	0.48	2.23	90.34

Group TTH
Average similarity: 54.94

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Chironominae	3.10	15.29	6.53	27.82	27.82
Tanypodininae	2.13	9.98	4.37	18.16	45.98
Leptophlebiidae	1.59	7.76	4.57	14.13	60.11
Oligochaeta	1.34	5.26	1.31	9.57	69.68
Ceratopogonidae	0.84	2.65	0.78	4.83	74.51
Orthocladininae	0.77	2.42	0.78	4.40	78.90
Baetidae	0.82	2.23	0.73	4.06	82.96
Dytiscidae	0.66	2.10	0.78	3.82	86.78
Caenidae	0.84	2.07	0.77	3.76	90.55

Group HC
Average similarity: 52.77

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Chironominae	3.31	22.18	11.10	42.03	42.03
Tanypodininae	1.67	10.93	5.06	20.71	62.75
Orthocladininae	1.85	10.10	3.28	19.13	81.88
Oligochaeta	0.84	2.98	0.75	5.65	87.53
Sphaeriidae	0.58	1.39	0.48	2.63	90.17

Group BR
Average similarity: 61.34

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Leptophlebiidae	2.79	10.00	15.53	16.31	16.31
Tanypodininae	2.01	6.90	8.03	11.24	27.55
Chironominae	2.01	6.46	10.97	10.53	38.08
Oligochaeta	1.49	5.16	12.45	8.41	46.49
Orthocladininae	1.34	4.39	9.98	7.16	53.65
Ecnomidae	1.26	4.09	4.06	6.67	60.32
Elmidae	1.25	4.07	6.07	6.64	66.96
Leptoceridae	1.26	3.54	1.34	5.77	72.73
Calamoceratidae	1.02	2.87	1.33	4.68	77.41
Sphaeriidae	0.97	2.72	1.33	4.43	81.84
Gyrinidae	0.86	2.56	1.35	4.17	86.02
Caenidae	0.79	1.54	0.78	2.51	88.53
Baetidae	0.68	1.52	0.76	2.48	91.00

Group CBR
Average similarity: 61.42

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Leptophlebiidae	2.44	11.09	7.21	18.06	18.06
Tanypodininae	2.17	8.97	5.77	14.61	32.67

Chironominae	2.05	7.77	8.52	12.65	45.32
Oligochaeta	2.11	7.24	4.41	11.79	57.11
Ecnomidae	1.27	4.93	4.50	8.03	65.14
Elmidae	1.28	3.69	1.28	6.00	71.14
Ceratopogonidae	1.09	3.47	1.32	5.64	76.79
Atyidae	0.98	3.33	1.30	5.41	82.20
Sphaeriidae	1.03	2.31	0.76	3.77	85.97
Leptoceridae	0.87	2.28	0.76	3.71	89.68
Baetidae	0.90	2.09	0.78	3.40	93.08

Group CMC
Average similarity: 64.18

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Chironominae	2.61	12.16	6.57	18.94	18.94
Leptophlebiidae	2.64	12.03	9.84	18.75	37.69
Tanypodininae	2.29	11.31	6.22	17.62	55.30
Orthocladininae	1.63	6.49	4.54	10.12	65.42
Oligochaeta	1.64	6.31	4.72	9.83	75.25
Ecnomidae	1.10	5.41	4.49	8.43	83.68
Leptoceridae	0.87	3.08	1.30	4.80	88.49
Dytiscidae	0.78	2.12	0.78	3.30	91.78

Group CCC
Average similarity: 59.84

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Chironominae	3.70	16.44	6.46	27.47	27.47
Tanypodininae	2.29	10.15	7.59	16.95	44.43
Ceratopogonidae	1.70	8.17	5.43	13.66	58.09
Oligochaeta	1.77	7.14	2.90	11.93	70.02
Leptophlebiidae	1.50	6.10	4.03	10.19	80.21
Dytiscidae	0.89	2.18	0.78	3.64	83.85
Leptoceridae	0.78	2.15	0.77	3.59	87.44
Calamoceratidae	0.68	2.02	0.78	3.38	90.81

Group CSQC
Average similarity: 56.91

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Chironominae	3.23	14.57	6.00	25.60	25.60
Tanypodininae	1.97	8.47	5.60	14.88	40.48
Leptophlebiidae	1.66	8.12	6.97	14.26	54.74
Orthocladininae	1.04	3.98	1.33	6.99	61.73
Oligochaeta	1.12	3.80	1.28	6.67	68.40
Ceratopogonidae	0.93	3.51	1.30	6.17	74.57
Atyidae	0.85	3.28	1.29	5.77	80.34
Dytiscidae	0.95	2.97	1.28	5.22	85.56
Leptoceridae	0.87	2.09	0.74	3.67	89.23
Psephenidae	0.48	0.99	0.48	1.73	90.96

Group DTC
Average similarity: 57.23

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Chironominae	2.81	13.90	5.67	24.29	24.29
Leptophlebiidae	1.95	10.06	5.84	17.57	41.86
Tanypodininae	1.39	7.27	3.79	12.70	54.56
Baetidae	1.16	5.67	3.00	9.91	64.47
Oligochaeta	1.06	5.19	2.31	9.08	73.55
Dytiscidae	0.95	3.28	0.89	5.73	79.28
Ceratopogonidae	0.98	2.61	0.84	4.57	83.85
Caenidae	0.93	2.48	0.90	4.34	88.19

Parastacidae	0.71	2.09	0.90	3.66	91.85

Groups CWC & CC
Average dissimilarity = 53.52

Species	Group CWC Av.Abund	Group CC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Leptophlebiidae	3.17	1.99	4.12	1.54	7.69	7.69
Oligochaeta	0.86	1.96	3.84	1.36	7.17	14.86
Psephenidae	0.20	1.25	3.35	2.30	6.26	21.12
Baetidae	0.00	0.91	2.81	1.71	5.25	26.37
Chironominae	1.94	2.60	2.45	1.51	4.57	30.94
Ecnomidae	0.41	0.73	2.36	1.32	4.40	35.35
Leptoceridae	0.35	0.95	2.32	1.43	4.34	39.69
Orthocladiinae	0.16	0.78	2.32	1.23	4.33	44.02
Sphaeriidae	0.00	0.76	2.21	0.95	4.13	48.15
Tricladida	0.50	0.42	2.11	0.91	3.95	52.10
Caenidae	0.00	0.63	2.08	1.35	3.89	55.98
Ancylidae	0.64	0.00	2.02	0.98	3.77	59.76
Dytiscidae (adult)	0.64	0.00	2.01	1.29	3.75	63.51
Dytiscidae	0.00	0.62	1.95	1.35	3.64	67.15
Ceratopogonidae	0.41	0.57	1.92	1.07	3.58	70.74
Atyidae	0.00	0.55	1.75	0.94	3.28	74.01
Tanypodininae	1.62	2.00	1.50	1.48	2.80	76.82
Ceinidae	0.00	0.44	1.26	0.67	2.35	79.16
Tipulidae	0.16	0.35	1.25	0.80	2.34	81.50
Scirtidae	0.32	0.15	1.13	0.79	2.11	83.61
Nematoda	0.22	0.17	1.01	0.61	1.90	85.51
Corixidae	0.00	0.33	0.98	0.66	1.82	87.33
Gyrinidae	0.29	0.00	0.91	0.68	1.70	89.03
Elmidae	0.16	0.13	0.79	0.61	1.48	90.51

Groups CWC & DC
Average dissimilarity = 49.76

Species	Group CWC Av.Abund	Group DC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Leptophlebiidae	3.17	1.79	5.98	1.89	12.02	12.02
Oligochaeta	0.86	0.96	3.64	1.76	7.32	19.35
Ceratopogonidae	0.41	0.71	3.07	1.05	6.16	25.51
Ancylidae	0.64	0.28	2.69	1.19	5.41	30.92
Chironominae	1.94	2.45	2.66	1.47	5.34	36.26
Dytiscidae (adult)	0.64	0.25	2.37	1.18	4.77	41.02
Tanypodininae	1.62	1.20	2.29	1.52	4.60	45.62
Tricladida	0.50	0.00	2.17	0.64	4.37	49.99
Corixidae	0.00	0.51	2.10	0.97	4.23	54.22
Baetidae	0.00	0.50	2.00	0.89	4.02	58.24
Leptoceridae	0.35	0.25	1.83	0.98	3.67	61.91
Ecnomidae	0.41	0.00	1.73	0.62	3.47	65.38
Caenidae	0.00	0.40	1.58	0.98	3.17	68.55
Scirtidae	0.32	0.18	1.55	0.80	3.11	71.66
Gyrinidae	0.29	0.13	1.39	0.79	2.80	74.46
Tipulidae	0.16	0.24	1.35	0.63	2.71	77.17
Parastacidae	0.00	0.29	1.27	0.69	2.55	79.72
Dytiscidae	0.00	0.28	1.14	0.69	2.28	82.00
Psephenidae	0.20	0.13	1.14	0.61	2.28	84.28
Elmidae	0.16	0.13	1.05	0.61	2.10	86.38
Culicidae	0.15	0.13	0.98	0.62	1.98	88.36
Nematoda	0.22	0.00	0.96	0.44	1.93	90.29

Groups CC & DC
Average dissimilarity = 48.92

Group CC Group DC

Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Psephenidae	1.25	0.13	3.78	3.01	7.72	7.72
Oligochaeta	1.96	0.96	3.26	1.65	6.66	14.38
Tanypodininae	2.00	1.20	2.76	2.18	5.64	20.02
Orthocladininae	0.78	0.00	2.62	1.25	5.36	25.38
Ecnomidae	0.73	0.00	2.55	1.25	5.20	30.58
Leptoceridae	0.95	0.25	2.52	1.67	5.16	35.74
Ceratopogonidae	0.57	0.71	2.49	1.11	5.08	40.82
Sphaeriidae	0.76	0.00	2.33	0.95	4.77	45.59
Baetidae	0.91	0.50	2.29	1.25	4.68	50.28
Atyidae	0.55	0.00	1.86	0.94	3.81	54.08
Chironominae	2.60	2.45	1.81	1.29	3.70	57.79
Corixidae	0.33	0.51	1.81	1.07	3.69	61.48
Dytiscidae	0.62	0.28	1.80	1.19	3.68	65.16
Caenidae	0.63	0.40	1.75	1.15	3.57	68.72
Leptophlebiidae	1.99	1.79	1.59	1.52	3.26	71.98
Tipulidae	0.35	0.24	1.47	0.82	3.01	74.99
Ceinidae	0.44	0.00	1.32	0.67	2.70	77.70
Tricladida	0.42	0.00	1.31	0.68	2.68	80.37
Parastacidae	0.00	0.29	1.01	0.68	2.06	82.43
Ancylidae	0.00	0.28	0.94	0.69	1.92	84.35
Scirtidae	0.15	0.18	0.87	0.62	1.79	86.14
Dytiscidae (adult)	0.00	0.25	0.76	0.69	1.56	87.70
Psychodidae	0.00	0.26	0.75	0.44	1.54	89.25
Elmidae	0.13	0.13	0.68	0.61	1.38	90.63

Groups CWC & EC
Average dissimilarity = 54.43

	Group CWC	Group EC				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Leptophlebiidae	3.17	2.12	4.27	1.37	7.84	7.84
Oligochaeta	0.86	1.61	3.90	1.37	7.16	15.00
Tanypodininae	1.62	1.66	2.93	1.08	5.39	20.39
Orthocladininae	0.16	0.92	2.75	1.20	5.05	25.44
Ecnomidae	0.41	0.64	2.33	1.03	4.28	29.72
Ceratopogonidae	0.41	0.64	2.30	1.02	4.22	33.94
Ancylidae	0.64	0.00	2.24	0.94	4.12	38.06
Dytiscidae (adult)	0.64	0.00	2.23	1.22	4.09	42.15
Chironominae	1.94	2.32	2.00	0.83	3.68	45.83
Parastacidae	0.00	0.50	1.99	0.95	3.66	49.49
Tricladida	0.50	0.16	1.97	0.71	3.63	53.12
Psephenidae	0.20	0.49	1.66	0.97	3.05	56.17
Gomphidae	0.00	0.53	1.60	0.96	2.93	59.10
Magapodagrionidae	0.13	0.49	1.54	1.00	2.82	61.93
Leptoceridae	0.35	0.29	1.53	0.88	2.81	64.74
Scirtidae	0.32	0.30	1.43	0.88	2.64	67.38
Culicidae	0.15	0.28	1.30	0.60	2.39	69.77
Gyrinidae	0.29	0.15	1.18	0.77	2.17	71.93
Synthemistidae	0.00	0.35	1.14	0.64	2.09	74.03
Baetidae	0.00	0.28	1.09	0.68	2.00	76.03
Tipulidae	0.16	0.20	1.08	0.61	1.99	78.02
Sphaeriidae	0.00	0.32	0.96	0.69	1.77	79.79
Caenidae	0.00	0.32	0.94	0.67	1.73	81.52
Polycentropodidae	0.00	0.29	0.89	0.68	1.63	83.16
Notonectidae	0.16	0.13	0.85	0.58	1.56	84.71
Nematoda	0.22	0.00	0.80	0.43	1.46	86.18
Dolichopodidae	0.00	0.21	0.74	0.44	1.35	87.53
Pyralidae	0.00	0.20	0.68	0.44	1.25	88.78
Elmidae	0.16	0.00	0.61	0.43	1.11	89.89
Aphroteniinae	0.16	0.00	0.59	0.43	1.08	90.97

Groups CC & EC
Average dissimilarity = 48.77

Species	Group CC Av.Abund	Group EC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Psephenidae	1.25	0.49	2.37	1.31	4.87	4.87
Chironominae	2.60	2.32	2.37	1.51	4.86	9.73
Tanypodininae	2.00	1.66	2.31	0.88	4.74	14.47
Oligochaeta	1.96	1.61	2.22	1.39	4.55	19.02
Orthocladininae	0.78	0.92	2.19	1.19	4.49	23.51
Leptoceridae	0.95	0.29	2.18	1.46	4.48	27.99
Sphaeriidae	0.76	0.32	2.07	1.07	4.25	32.24
Baetidae	0.91	0.28	2.06	1.44	4.23	36.47
Ecnomidae	0.73	0.64	1.99	1.15	4.08	40.55
Ceratopogonidae	0.57	0.64	1.90	1.10	3.90	44.45
Dytiscidae	0.62	0.00	1.78	1.29	3.64	48.09
Caenidae	0.63	0.32	1.72	1.19	3.54	51.62
Parastacidae	0.00	0.50	1.60	0.95	3.27	54.90
Atyidae	0.55	0.00	1.60	0.92	3.27	58.17
Leptophlebiidae	1.99	2.12	1.49	1.29	3.05	61.22
Gomphidae	0.13	0.53	1.38	1.02	2.84	64.06
Tricladida	0.42	0.16	1.30	0.79	2.67	66.73
Magapodagrionidae	0.00	0.49	1.25	0.94	2.55	69.28
Tipulidae	0.35	0.20	1.21	0.78	2.47	71.76
Ceinidae	0.44	0.00	1.15	0.66	2.36	74.12
Scirtidae	0.15	0.30	0.98	0.78	2.01	76.13
Synthemistidae	0.00	0.35	0.95	0.64	1.95	78.08
Corixidae	0.33	0.00	0.89	0.65	1.83	79.91
Culicidae	0.00	0.28	0.80	0.44	1.63	81.54
Polycentropodidae	0.00	0.29	0.75	0.68	1.54	83.08
Dolichopodidae	0.00	0.21	0.61	0.44	1.25	84.32
Hydraenidae	0.13	0.13	0.57	0.60	1.16	85.48
Pyralidae	0.00	0.20	0.56	0.44	1.16	86.64
Nemertea	0.16	0.00	0.54	0.43	1.11	87.75
Elmidae (adult)	0.00	0.17	0.48	0.44	0.99	88.74
Coenagrionidae	0.16	0.00	0.46	0.43	0.94	89.68
Austrocorduliidae	0.00	0.16	0.44	0.44	0.90	90.59

Groups DC & EC
Average dissimilarity = 51.95

Species	Group DC Av.Abund	Group EC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Tanypodininae	1.20	1.66	3.48	1.61	6.69	6.69
Orthocladininae	0.00	0.92	3.01	1.20	5.80	12.49
Ceratopogonidae	0.71	0.64	2.94	1.08	5.66	18.15
Chironominae	2.45	2.32	2.76	1.37	5.31	23.46
Oligochaeta	0.96	1.61	2.57	0.92	4.94	28.40
Leptophlebiidae	1.79	2.12	2.04	1.53	3.92	32.32
Ecnomidae	0.00	0.64	2.00	0.96	3.85	36.17
Parastacidae	0.29	0.50	1.98	0.98	3.82	39.99
Baetidae	0.50	0.28	1.91	1.02	3.68	43.67
Corixidae	0.51	0.00	1.88	0.92	3.63	47.29
Gomphidae	0.00	0.53	1.69	0.96	3.25	50.54
Caenidae	0.40	0.32	1.65	1.04	3.18	53.72
Psephenidae	0.13	0.49	1.61	1.00	3.10	56.83
Magapodagrionidae	0.00	0.49	1.56	0.94	3.00	59.82
Leptoceridae	0.25	0.29	1.40	0.88	2.69	62.52
Culicidae	0.13	0.28	1.36	0.60	2.63	65.14
Scirtidae	0.18	0.30	1.29	0.77	2.49	67.63
Tipulidae	0.24	0.20	1.28	0.61	2.47	70.11
Synthemistidae	0.00	0.35	1.21	0.63	2.33	72.44
Dolichopodidae	0.15	0.21	1.11	0.60	2.13	74.58
Ancylidae	0.28	0.00	1.06	0.67	2.04	76.61
Sphaeriidae	0.00	0.32	1.02	0.69	1.96	78.58
Dytiscidae	0.28	0.00	1.02	0.66	1.96	80.54
Polycentropodidae	0.00	0.29	0.94	0.68	1.81	82.35
Dytiscidae (adult)	0.25	0.00	0.84	0.68	1.62	83.97

Psychodidae	0.26	0.00	0.83	0.43	1.60	85.57
Gyrinidae	0.13	0.15	0.81	0.61	1.56	87.13
Pyralidae	0.00	0.20	0.73	0.44	1.40	88.53
Elmidae (adult)	0.00	0.17	0.62	0.44	1.20	89.73
Tricladida	0.00	0.16	0.56	0.44	1.07	90.81

Groups CWC & TTH
Average dissimilarity = 55.07

	Group CWC	Group TTH				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Leptophlebiidae	3.17	1.59	5.42	1.88	9.85	9.85
Chironominae	1.94	3.10	3.79	1.48	6.89	16.73
Oligochaeta	0.86	1.34	3.35	1.32	6.09	22.82
Baetidae	0.00	0.82	2.80	1.17	5.08	27.90
Caenidae	0.00	0.84	2.75	1.15	4.99	32.89
Ecnomidae	0.41	0.78	2.68	1.12	4.86	37.76
Ceratopogonidae	0.41	0.84	2.48	1.27	4.51	42.27
Orthocladininae	0.16	0.77	2.36	1.29	4.28	46.54
Tanypodininae	1.62	2.13	2.30	1.31	4.18	50.73
Dytiscidae	0.00	0.66	2.22	1.37	4.02	54.75
Corixidae	0.00	0.63	2.20	0.90	4.00	58.75
Ancylidae	0.64	0.00	2.14	0.98	3.89	62.64
Tipulidae	0.16	0.60	1.98	1.01	3.59	66.23
Dytiscidae (adult)	0.64	0.28	1.89	1.24	3.43	69.66
Tricladida	0.50	0.00	1.72	0.64	3.13	72.79
Leptoceridae	0.35	0.16	1.35	0.80	2.45	75.24
Notonectidae	0.16	0.28	1.19	0.80	2.16	77.41
Scirtidae	0.32	0.13	1.17	0.81	2.12	79.53
Culicidae	0.15	0.29	1.17	0.80	2.12	81.65
Gyrinidae	0.29	0.13	1.12	0.80	2.03	83.67
Nematoda	0.22	0.16	1.11	0.62	2.01	85.69
Gomphidae	0.00	0.34	1.11	0.68	2.01	87.70
Psephenidae	0.20	0.13	0.95	0.63	1.72	89.41
Elmidae	0.16	0.00	0.58	0.44	1.05	90.46

Groups CC & TTH
Average dissimilarity = 43.65

	Group CC	Group TTH				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Psephenidae	1.25	0.13	3.10	3.29	7.10	7.10
Leptoceridae	0.95	0.16	2.30	1.72	5.28	12.38
Chironominae	2.60	3.10	2.28	1.53	5.21	17.60
Oligochaeta	1.96	1.34	2.26	1.27	5.17	22.76
Ecnomidae	0.73	0.78	2.14	1.34	4.91	27.68
Sphaeriidae	0.76	0.00	1.97	0.95	4.51	32.18
Baetidae	0.91	0.82	1.90	1.25	4.34	36.53
Corixidae	0.33	0.63	1.86	1.03	4.27	40.80
Ceratopogonidae	0.57	0.84	1.86	1.11	4.27	45.07
Caenidae	0.63	0.84	1.85	1.21	4.23	49.30
Orthocladininae	0.78	0.77	1.70	1.10	3.90	53.20
Tipulidae	0.35	0.60	1.68	1.06	3.86	57.06
Tanypodininae	2.00	2.13	1.68	1.70	3.85	60.91
Leptophlebiidae	1.99	1.59	1.58	1.55	3.61	64.52
Atyidae	0.55	0.00	1.54	0.95	3.54	68.06
Dytiscidae	0.62	0.66	1.37	1.12	3.15	71.21
Ceinidae	0.44	0.00	1.12	0.67	2.57	73.77
Tricladida	0.42	0.00	1.10	0.68	2.53	76.30
Gomphidae	0.13	0.34	1.03	0.78	2.36	78.67
Culicidae	0.00	0.29	0.81	0.69	1.86	80.53
Notonectidae	0.00	0.28	0.78	0.69	1.79	82.32
Dytiscidae (adult)	0.00	0.28	0.78	0.69	1.78	84.10
Nemertea	0.16	0.13	0.74	0.61	1.69	85.79
Nematoda	0.17	0.16	0.73	0.61	1.67	87.46

Chorismagrionidae	0.13	0.15	0.65	0.61	1.48	88.94
Scirtidae	0.15	0.13	0.64	0.62	1.48	90.42

Groups DC & TTH
Average dissimilarity = 46.96

Species	Group DC Av.Abund	Group TTH Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Tanypodininae	1.20	2.13	3.50	1.58	7.44	7.44
Ceratopogonidae	0.71	0.84	2.98	1.35	6.36	13.80
Chironominae	2.45	3.10	2.94	1.36	6.26	20.06
Orthocladininae	0.00	0.77	2.69	1.35	5.72	25.78
Ecnomidae	0.00	0.78	2.69	0.97	5.72	31.50
Baetidae	0.50	0.82	2.62	1.16	5.59	37.09
Oligochaeta	0.96	1.34	2.56	1.33	5.45	42.54
Caenidae	0.40	0.84	2.52	1.12	5.37	47.92
Corixidae	0.51	0.63	2.44	1.19	5.19	53.11
Tipulidae	0.24	0.60	2.21	1.00	4.71	57.82
Dytiscidae	0.28	0.66	2.05	1.24	4.37	62.19
Leptophlebiidae	1.79	1.59	1.71	1.34	3.65	65.84
Dytiscidae (adult)	0.25	0.28	1.26	0.89	2.69	68.52
Parastacidae	0.29	0.13	1.22	0.80	2.60	71.13
Leptoceridae	0.25	0.16	1.22	0.82	2.60	73.73
Culicidae	0.13	0.29	1.20	0.80	2.55	76.28
Gomphidae	0.00	0.34	1.18	0.68	2.50	78.78
Notonectidae	0.00	0.28	1.00	0.69	2.14	80.92
Ancylidae	0.28	0.00	1.00	0.70	2.13	83.06
Scirtidae	0.18	0.13	0.87	0.63	1.85	84.91
Dolichopodidae	0.15	0.15	0.84	0.61	1.79	86.69
Psychodidae	0.26	0.00	0.80	0.44	1.70	88.39
Gyrinidae	0.13	0.13	0.77	0.61	1.64	90.03

Groups EC & TTH
Average dissimilarity = 50.95

Species	Group EC Av.Abund	Group TTH Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chironominae	2.32	3.10	3.27	1.43	6.42	6.42
Tanypodininae	1.66	2.13	3.09	1.02	6.06	12.48
Ecnomidae	0.64	0.78	2.39	1.11	4.68	17.16
Oligochaeta	1.61	1.34	2.36	1.12	4.63	21.79
Caenidae	0.32	0.84	2.32	1.08	4.56	26.35
Orthocladininae	0.92	0.77	2.28	1.22	4.47	30.82
Baetidae	0.28	0.82	2.25	1.21	4.41	35.23
Ceratopogonidae	0.64	0.84	2.23	1.15	4.38	39.61
Leptophlebiidae	2.12	1.59	2.02	1.54	3.96	43.57
Dytiscidae	0.00	0.66	2.01	1.30	3.94	47.51
Corixidae	0.00	0.63	1.99	0.87	3.91	51.42
Tipulidae	0.20	0.60	1.83	0.97	3.59	55.02
Parastacidae	0.50	0.13	1.65	1.01	3.23	58.24
Gomphidae	0.53	0.34	1.64	1.08	3.21	61.46
Culicidae	0.28	0.29	1.44	0.80	2.82	64.28
Psephenidae	0.49	0.13	1.35	1.01	2.66	66.94
Magapodagrionidae	0.49	0.00	1.31	0.94	2.57	69.50
Leptoceridae	0.29	0.16	1.06	0.77	2.08	71.58
Synthemistidae	0.35	0.00	1.00	0.64	1.97	73.55
Polycentropodidae	0.29	0.16	1.00	0.78	1.96	75.51
Scirtidae	0.30	0.13	0.99	0.78	1.93	77.44
Notonectidae	0.13	0.28	0.96	0.76	1.89	79.33
Dolichopodidae	0.21	0.15	0.94	0.61	1.84	81.18
Sphaeriidae	0.32	0.00	0.85	0.69	1.68	82.85
Dytiscidae (adult)	0.00	0.28	0.85	0.68	1.67	84.52
Pyralidae	0.20	0.13	0.85	0.61	1.66	86.18
Sialidae	0.15	0.16	0.72	0.61	1.41	87.59
Gyrinidae	0.15	0.13	0.68	0.61	1.33	88.92

Elmidae (adult)	0.17	0.00	0.51	0.44	1.00	89.93
Chorismagrionidae	0.00	0.15	0.49	0.43	0.96	90.89

Groups CWC & HC
Average dissimilarity = 62.95

Species	Group CWC Av.Abund	Group HC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Leptophlebiidae	3.17	0.16	11.54	3.23	18.33	18.33
Orthocladiinae	0.16	1.85	6.33	2.06	10.06	28.38
Chironominae	1.94	3.31	5.13	2.42	8.15	36.53
Oligochaeta	0.86	0.84	3.39	1.34	5.39	41.92
Tricladida	0.50	0.41	2.54	0.90	4.04	45.96
Ancylidae	0.64	0.00	2.45	0.98	3.89	49.85
Ecnomidae	0.41	0.48	2.36	1.09	3.75	53.60
Dytiscidae (adult)	0.64	0.49	2.13	1.18	3.38	56.98
Sphaeriidae	0.00	0.58	2.09	0.97	3.32	60.30
Ceratopogonidae	0.41	0.24	1.93	0.80	3.06	63.36
Tanypodinae	1.62	1.67	1.55	1.37	2.46	65.82
Leptoceridae	0.35	0.13	1.47	0.81	2.33	68.15
Hemicorduliidae	0.00	0.38	1.46	0.69	2.33	70.48
Baetidae	0.00	0.38	1.40	0.68	2.23	72.71
Tipulidae	0.16	0.29	1.36	0.79	2.16	74.87
Dytiscidae	0.00	0.33	1.29	0.69	2.05	76.92
Nematoda	0.22	0.17	1.29	0.62	2.04	78.97
Coenagrionidae	0.00	0.32	1.20	0.67	1.91	80.88
Scirtidae	0.32	0.00	1.17	0.69	1.85	82.73
Gyrinidae	0.29	0.00	1.10	0.68	1.75	84.48
Podinae	0.00	0.24	1.04	0.44	1.66	86.14
Hydrophilidae	0.00	0.23	0.81	0.44	1.29	87.43
Psephenidae	0.20	0.00	0.74	0.44	1.18	88.60
Cordulephyidae	0.00	0.18	0.68	0.44	1.09	89.69
Notonectidae	0.16	0.00	0.66	0.44	1.05	90.74

Groups CC & HC
Average dissimilarity = 52.62

Species	Group CC Av.Abund	Group HC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Leptophlebiidae	1.99	0.16	5.57	3.72	10.58	10.58
Psephenidae	1.25	0.00	3.87	6.00	7.36	17.94
Oligochaeta	1.96	0.84	3.59	1.57	6.82	24.76
Orthocladiinae	0.78	1.85	3.43	1.25	6.51	31.27
Leptoceridae	0.95	0.13	2.62	1.79	4.97	36.24
Chironominae	2.60	3.31	2.36	1.35	4.48	40.72
Sphaeriidae	0.76	0.58	2.35	1.20	4.46	45.18
Baetidae	0.91	0.38	2.34	1.39	4.44	49.62
Caenidae	0.63	0.13	1.90	1.28	3.62	53.24
Ecnomidae	0.73	0.48	1.89	1.19	3.59	56.84
Ceratopogonidae	0.57	0.24	1.82	1.02	3.46	60.30
Tricladida	0.42	0.41	1.75	0.92	3.32	63.62
Atyidae	0.55	0.00	1.73	0.94	3.28	66.90
Dytiscidae	0.62	0.33	1.69	1.16	3.21	70.11
Dytiscidae (adult)	0.00	0.49	1.50	0.94	2.85	72.97
Ceinidae	0.44	0.13	1.41	0.82	2.68	75.65
Tipulidae	0.35	0.29	1.36	0.93	2.59	78.24
Hemicorduliidae	0.13	0.38	1.33	0.82	2.53	80.77
Tanypodinae	2.00	1.67	1.28	1.09	2.43	83.20
Coenagrionidae	0.16	0.32	1.19	0.79	2.26	85.47
Corixidae	0.33	0.00	0.96	0.66	1.83	87.29
Nemertea	0.16	0.16	0.91	0.61	1.72	89.02
Podinae	0.00	0.24	0.83	0.44	1.57	90.59

Groups DC & HC

Average dissimilarity = 59.67

Species	Group DC Av.Abund	Group HC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Orthocladininae	0.00	1.85	7.49	2.51	12.56	12.56
Leptophlebiidae	1.79	0.16	6.79	2.59	11.38	23.94
Chironominae	2.45	3.31	3.48	1.45	5.84	29.78
Ceratopogonidae	0.71	0.24	2.91	0.96	4.87	34.65
Oligochaeta	0.96	0.84	2.73	1.47	4.57	39.22
Tanypodininae	1.20	1.67	2.41	1.81	4.04	43.26
Baetidae	0.50	0.38	2.31	1.03	3.87	47.14
Sphaeriidae	0.00	0.58	2.24	0.96	3.75	50.89
Corixidae	0.51	0.00	2.06	0.96	3.46	54.35
Ecnomidae	0.00	0.48	2.06	0.94	3.45	57.80
Dytiscidae (adult)	0.25	0.49	2.00	1.03	3.34	61.14
Dytiscidae	0.28	0.33	1.75	0.91	2.93	64.07
Tipulidae	0.24	0.29	1.66	0.82	2.79	66.86
Tricladida	0.00	0.41	1.59	0.68	2.67	69.53
Caenidae	0.40	0.13	1.58	0.99	2.65	72.17
Hemicorduliidae	0.00	0.38	1.57	0.68	2.64	74.81
Coenagrionidae	0.00	0.32	1.29	0.66	2.17	76.98
Parastacidae	0.29	0.00	1.25	0.69	2.09	79.06
Leptoceridae	0.25	0.13	1.24	0.78	2.07	81.14
Ancylidae	0.28	0.00	1.16	0.69	1.95	83.08
Podinae	0.00	0.24	1.14	0.44	1.90	84.99
Psychodidae	0.26	0.00	0.90	0.44	1.51	86.50
Hydrophilidae	0.00	0.23	0.87	0.44	1.45	87.95
Cordulephyidae	0.00	0.18	0.74	0.44	1.23	89.19
Nematoda	0.00	0.17	0.69	0.44	1.15	90.34

Groups EC & HC
Average dissimilarity = 60.85

Species	Group EC Av.Abund	Group HC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Leptophlebiidae	2.12	0.16	6.60	3.02	10.85	10.85
Chironominae	2.32	3.31	4.18	2.00	6.87	17.72
Orthocladininae	0.92	1.85	4.15	1.18	6.82	24.54
Oligochaeta	1.61	0.84	3.25	1.21	5.34	29.88
Tanypodininae	1.66	1.67	2.83	1.03	4.65	34.54
Ecnomidae	0.64	0.48	2.15	1.15	3.53	38.07
Ceratopogonidae	0.64	0.24	2.15	0.95	3.53	41.60
Parastacidae	0.50	0.00	1.96	0.94	3.22	44.82
Sphaeriidae	0.32	0.58	1.92	1.01	3.16	47.98
Dytiscidae (adult)	0.00	0.49	1.66	0.91	2.73	50.71
Baetidae	0.28	0.38	1.66	0.96	2.72	53.44
Gomphidae	0.53	0.00	1.57	0.96	2.59	56.02
Tricladida	0.16	0.41	1.53	0.77	2.51	58.54
Magapodagrionidae	0.49	0.00	1.45	0.94	2.39	60.92
Psephenidae	0.49	0.00	1.45	0.95	2.38	63.30
Tipulidae	0.20	0.29	1.33	0.79	2.19	65.49
Hemicorduliidae	0.00	0.38	1.32	0.66	2.16	67.66
Dytiscidae	0.00	0.33	1.16	0.67	1.91	69.57
Synthemistidae	0.35	0.00	1.12	0.64	1.84	71.41
Caenidae	0.32	0.13	1.11	0.79	1.82	73.23
Leptoceridae	0.29	0.13	1.09	0.78	1.79	75.02
Coenagrionidae	0.00	0.32	1.09	0.65	1.78	76.80
Culicidae	0.28	0.00	0.95	0.44	1.55	78.36
Scirtidae	0.30	0.00	0.94	0.67	1.54	79.90
Podinae	0.00	0.24	0.93	0.43	1.53	81.43
Polycentropodidae	0.29	0.00	0.88	0.68	1.44	82.87
Hydroptilidae	0.13	0.16	0.77	0.60	1.26	84.13
Hydrophilidae	0.00	0.23	0.73	0.43	1.21	85.34
Dolichopodidae	0.21	0.00	0.72	0.44	1.19	86.53
Pyralidae	0.20	0.00	0.67	0.44	1.10	87.63

Cordulephyidae	0.00	0.18	0.62	0.43	1.01	88.64
Elmidae (adult)	0.17	0.00	0.58	0.44	0.95	89.59
Nematoda	0.00	0.17	0.57	0.43	0.94	90.53

Groups TTH & HC
Average dissimilarity = 53.08

Species	Group TTH Av.Abund	Group HC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Leptophlebiidae	1.59	0.16	4.68	2.56	8.81	8.81
Orthocladininae	0.77	1.85	3.65	1.23	6.88	15.70
Oligochaeta	1.34	0.84	2.92	1.36	5.51	21.21
Ceratopogonidae	0.84	0.24	2.58	1.27	4.87	26.07
Caenidae	0.84	0.13	2.58	1.13	4.86	30.94
Chironominae	3.10	3.31	2.54	1.54	4.78	35.72
Baetidae	0.82	0.38	2.54	1.17	4.78	40.50
Ecnomidae	0.78	0.48	2.52	1.32	4.75	45.24
Tanypodininae	2.13	1.67	2.28	1.40	4.30	49.55
Corixidae	0.63	0.00	2.17	0.90	4.08	53.63
Tipulidae	0.60	0.29	1.96	1.09	3.69	57.32
Dytiscidae	0.66	0.33	1.88	1.20	3.55	60.86
Sphaeriidae	0.00	0.58	1.81	0.97	3.42	64.28
Dytiscidae (adult)	0.28	0.49	1.63	1.07	3.07	67.34
Tricladida	0.00	0.41	1.29	0.68	2.43	69.78
Hemicorduliidae	0.00	0.38	1.26	0.69	2.37	72.15
Gomphidae	0.34	0.00	1.09	0.68	2.05	74.20
Coenagrionidae	0.00	0.32	1.04	0.67	1.96	76.16
Culicidae	0.29	0.00	0.96	0.69	1.82	77.98
Notonectidae	0.28	0.00	0.93	0.69	1.75	79.73
Nematoda	0.16	0.17	0.90	0.61	1.70	81.43
Podinae	0.00	0.24	0.88	0.44	1.66	83.09
Leptoceridae	0.16	0.13	0.82	0.62	1.54	84.63
Nemertea	0.13	0.16	0.82	0.62	1.54	86.17
Hydrophilidae	0.00	0.23	0.71	0.44	1.33	87.51
Cordulephyidae	0.00	0.18	0.59	0.44	1.11	88.62
Acarina	0.00	0.16	0.55	0.44	1.03	89.64
Chorismagrionidae	0.15	0.00	0.53	0.44	1.00	90.65

Groups CWC & BR
Average dissimilarity = 56.94

Species	Group CWC Av.Abund	Group BR Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Orthocladininae	0.16	1.34	3.03	2.26	5.32	5.32
Elmidae	0.16	1.25	2.80	2.34	4.92	10.25
Leptoceridae	0.35	1.26	2.67	1.59	4.69	14.94
Calamoceratidae	0.00	1.02	2.60	2.08	4.56	19.50
Ecnomidae	0.41	1.26	2.58	2.10	4.52	24.03
Sphaeriidae	0.00	0.97	2.52	2.04	4.43	28.46
Oligochaeta	0.86	1.49	2.34	1.42	4.11	32.57
Leptophlebiidae	3.17	2.79	2.02	1.48	3.54	36.11
Ceratopogonidae	0.41	0.80	2.01	1.13	3.54	39.65
Caenidae	0.00	0.79	1.94	1.37	3.40	43.05
Baetidae	0.00	0.68	1.83	1.33	3.22	46.27
Tricladida	0.50	0.54	1.80	1.07	3.17	49.44
Gyrinidae	0.29	0.86	1.72	1.41	3.03	52.47
Ancylidae	0.64	0.00	1.65	0.98	2.91	55.38
Dytiscidae (adult)	0.64	0.00	1.65	1.29	2.89	58.27
Hemicorduliidae	0.00	0.59	1.50	0.92	2.63	60.89
Elmidae (adult)	0.00	0.55	1.32	0.98	2.32	63.21
Tanypodininae	1.62	2.01	1.27	1.49	2.23	65.44
Chironominae	1.94	2.01	1.23	1.31	2.17	67.61
Ceinidae	0.00	0.40	1.03	0.66	1.80	69.41
Gomphidae	0.00	0.39	1.01	0.69	1.77	71.18
Scirtidae	0.32	0.14	0.94	0.80	1.65	72.83

Dytiscidae	0.00	0.32	0.90	0.69	1.58	74.41
Telephlebiidae	0.00	0.33	0.87	0.70	1.53	75.95
Polycentropodidae	0.00	0.36	0.86	0.70	1.52	77.46
Hydrophilidae	0.00	0.33	0.85	0.70	1.49	78.95
Synlestidae	0.00	0.32	0.84	0.69	1.47	80.42
Nematoda	0.22	0.13	0.79	0.61	1.39	81.81
Hydrophilidae(adult)	0.00	0.31	0.78	0.68	1.37	83.18
Psephenidae	0.20	0.14	0.78	0.63	1.36	84.55
Aphroteniinae	0.16	0.20	0.77	0.62	1.36	85.90
Odontoceridae	0.00	0.32	0.77	0.68	1.35	87.25
Hydrobiosidae	0.00	0.29	0.72	0.69	1.27	88.53
Notonectidae	0.16	0.14	0.71	0.62	1.24	89.77
Tipulidae	0.16	0.15	0.69	0.62	1.20	90.97

Groups CC & BR
Average dissimilarity = 46.18

Species	Group CC Av.Abund	Group BR Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Elmidae	0.13	1.25	2.51	2.63	5.45	5.45
Psephenidae	1.25	0.14	2.43	3.13	5.26	10.71
Calamoceratidae	0.00	1.02	2.25	2.07	4.86	15.57
Gyrinidae	0.00	0.86	1.92	2.09	4.15	19.72
Leptophlebiidae	1.99	2.79	1.84	1.43	3.97	23.70
Chironominae	2.60	2.01	1.82	1.45	3.95	27.65
Sphaeriidae	0.76	0.97	1.79	1.52	3.88	31.53
Ceratopogonidae	0.57	0.80	1.74	1.23	3.78	35.31
Orthocladininae	0.78	1.34	1.48	1.11	3.20	38.51
Leptoceridae	0.95	1.26	1.43	1.13	3.10	41.60
Ecnomidae	0.73	1.26	1.37	1.24	2.96	44.56
Tricladida	0.42	0.54	1.34	1.07	2.90	47.47
Hemicorduliidae	0.13	0.59	1.30	1.00	2.82	50.28
Ceinidae	0.44	0.40	1.30	0.91	2.82	53.10
Caenidae	0.63	0.79	1.29	1.23	2.80	55.90
Baetidae	0.91	0.68	1.27	1.25	2.76	58.66
Atyidae	0.55	0.16	1.24	1.00	2.69	61.35
Oligochaeta	1.96	1.49	1.22	1.23	2.65	64.00
Dytiscidae	0.62	0.32	1.19	1.18	2.59	66.59
Elmidae (adult)	0.00	0.55	1.15	0.97	2.49	69.08
Gomphidae	0.13	0.39	0.96	0.80	2.08	71.15
Tipulidae	0.35	0.15	0.87	0.80	1.88	73.03
Tanypodininae	2.00	2.01	0.79	1.51	1.71	74.74
Polycentropodidae	0.00	0.36	0.75	0.69	1.63	76.37
Telephlebiidae	0.00	0.33	0.75	0.69	1.63	78.00
Hydrophilidae	0.00	0.33	0.73	0.70	1.59	79.58
Synlestidae	0.00	0.32	0.72	0.69	1.56	81.14
Corixidae	0.33	0.00	0.70	0.66	1.52	82.67
Hydrophilidae(adult)	0.00	0.31	0.68	0.68	1.46	84.13
Odontoceridae	0.00	0.32	0.67	0.68	1.45	85.58
Coenagrionidae	0.16	0.20	0.64	0.62	1.39	86.97
Hydrobiosidae	0.00	0.29	0.63	0.69	1.36	88.34
Nemertea	0.16	0.16	0.63	0.61	1.36	89.69
Chorismagrionidae	0.13	0.20	0.59	0.61	1.28	90.97

Groups DC & BR
Average dissimilarity = 60.92

Species	Group DC Av.Abund	Group BR Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Orthocladininae	0.00	1.34	3.63	3.58	5.96	5.96
Ecnomidae	0.00	1.26	3.40	4.23	5.58	11.53
Elmidae	0.13	1.25	3.06	2.59	5.03	16.56
Leptoceridae	0.25	1.26	2.96	1.91	4.85	21.42
Calamoceratidae	0.00	1.02	2.72	2.06	4.47	25.89
Leptophlebiidae	1.79	2.79	2.66	2.06	4.37	30.25

Sphaeriidae	0.00	0.97	2.64	2.01	4.34	34.59
Ceratopogonidae	0.71	0.80	2.43	1.25	3.99	38.58
Tanypodininae	1.20	2.01	2.25	2.13	3.70	42.28
Gyrinidae	0.13	0.86	2.10	1.79	3.45	45.73
Chironominae	2.45	2.01	1.93	1.54	3.17	48.90
Caenidae	0.40	0.79	1.75	1.38	2.87	51.76
Baetidae	0.50	0.68	1.64	1.24	2.70	54.46
Hemicorduliidae	0.00	0.59	1.57	0.92	2.57	57.03
Tricladida	0.00	0.54	1.44	0.97	2.37	59.40
Oligochaeta	0.96	1.49	1.42	1.24	2.33	61.73
Elmidae (adult)	0.00	0.55	1.38	0.98	2.26	63.99
Corixidae	0.51	0.00	1.36	0.97	2.24	66.23
Dytiscidae	0.28	0.32	1.15	0.90	1.88	68.11
Ceinidae	0.00	0.40	1.08	0.66	1.77	69.87
Gomphidae	0.00	0.39	1.06	0.69	1.73	71.61
Telephlebiidae	0.00	0.33	0.92	0.69	1.50	73.11
Polycentropodidae	0.00	0.36	0.90	0.70	1.48	74.59
Hydrophilidae	0.00	0.33	0.89	0.70	1.46	76.05
Synlestidae	0.00	0.32	0.88	0.69	1.44	77.49
Tipulidae	0.24	0.15	0.86	0.63	1.40	78.89
Hydrophilidae(adult)	0.00	0.31	0.82	0.68	1.34	80.24
Parastacidae	0.29	0.00	0.81	0.69	1.33	81.57
Odontoceridae	0.00	0.32	0.80	0.68	1.32	82.88
Hydrobiosidae	0.00	0.29	0.76	0.69	1.24	84.13
Ancylidae	0.28	0.00	0.76	0.69	1.24	85.37
Scirtidae	0.18	0.14	0.74	0.63	1.21	86.59
Psephenidae	0.13	0.14	0.63	0.61	1.04	87.63
Dytiscidae (adult)	0.25	0.00	0.63	0.69	1.04	88.66
Psychodidae	0.26	0.00	0.63	0.44	1.03	89.69
Chorismagrionidae	0.00	0.20	0.50	0.44	0.82	90.51

Groups EC & BR
Average dissimilarity = 53.43

Species	Group EC Av.Abund	Group BR Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Elmidae	0.00	1.25	2.98	3.53	5.58	5.58
Leptoceridae	0.29	1.26	2.57	1.65	4.81	10.39
Calamoceratidae	0.15	1.02	2.19	1.69	4.10	14.49
Ecnomidae	0.64	1.26	1.98	1.34	3.71	18.21
Orthocladininae	0.92	1.34	1.92	1.24	3.59	21.80
Ceratopogonidae	0.64	0.80	1.90	1.12	3.56	25.36
Tanypodininae	1.66	2.01	1.87	0.90	3.51	28.87
Sphaeriidae	0.32	0.97	1.86	1.37	3.49	32.36
Gyrinidae	0.15	0.86	1.84	1.59	3.44	35.79
Leptophlebiidae	2.12	2.79	1.72	1.19	3.22	39.01
Caenidae	0.32	0.79	1.63	1.24	3.05	42.06
Chironominae	2.32	2.01	1.63	0.95	3.05	45.11
Baetidae	0.28	0.68	1.43	1.29	2.67	47.77
Hemicorduliidae	0.00	0.59	1.38	0.91	2.58	50.36
Gomphidae	0.53	0.39	1.35	1.04	2.52	52.88
Parastacidae	0.50	0.00	1.30	0.96	2.43	55.31
Tricladida	0.16	0.54	1.28	0.98	2.39	57.70
Elmidae (adult)	0.17	0.55	1.25	0.99	2.34	60.04
Oligochaeta	1.61	1.49	1.24	0.92	2.32	62.37
Magapodagrionidae	0.49	0.16	1.11	0.99	2.08	64.44
Psephenidae	0.49	0.14	1.10	1.01	2.07	66.51
Polycentropodidae	0.29	0.36	1.04	0.91	1.94	68.45
Ceinidae	0.00	0.40	0.95	0.65	1.77	70.22
Telephlebiidae	0.13	0.33	0.89	0.79	1.66	71.88
Synlestidae	0.13	0.32	0.85	0.78	1.60	73.48
Dytiscidae	0.00	0.32	0.83	0.68	1.55	75.02
Scirtidae	0.30	0.14	0.82	0.78	1.54	76.57
Synthemistidae	0.35	0.00	0.80	0.64	1.49	78.06
Hydrophilidae	0.00	0.33	0.78	0.69	1.46	79.52

Hydrophilidae(adult)	0.00	0.31	0.72	0.67	1.35	80.87
Odontoceridae	0.00	0.32	0.71	0.68	1.33	82.20
Tipulidae	0.20	0.15	0.71	0.62	1.33	83.53
Hydrobiosidae	0.00	0.29	0.67	0.68	1.25	84.79
Culicidae	0.28	0.00	0.66	0.44	1.24	86.03
Sialidae	0.15	0.16	0.57	0.61	1.06	87.09
Notonectidae	0.13	0.14	0.54	0.60	1.02	88.11
Dolichopodidae	0.21	0.00	0.50	0.44	0.95	89.05
Pyralidae	0.20	0.00	0.47	0.44	0.88	89.93
Chorismagrionidae	0.00	0.20	0.44	0.44	0.83	90.76

Groups TTH & BR
Average dissimilarity = 53.94

Species	Group TTH Av.Abund	Group BR Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Elmidae	0.00	1.25	2.91	4.07	5.40	5.40
Chironominae	3.10	2.01	2.81	1.59	5.21	10.61
Leptophlebiidae	1.59	2.79	2.80	2.26	5.18	15.80
Leptoceridae	0.16	1.26	2.69	1.84	4.98	20.78
Calamoceratidae	0.00	1.02	2.34	2.08	4.35	25.12
Sphaeriidae	0.00	0.97	2.27	2.04	4.21	29.33
Ecnomidae	0.78	1.26	1.89	1.48	3.51	32.84
Ceratopogonidae	0.84	0.80	1.87	1.27	3.46	36.30
Gyrinidae	0.13	0.86	1.80	1.82	3.33	39.63
Caenidae	0.84	0.79	1.70	1.22	3.14	42.78
Baetidae	0.82	0.68	1.57	1.34	2.91	45.69
Corixidae	0.63	0.00	1.51	0.90	2.80	48.49
Orthocladininae	0.77	1.34	1.48	1.00	2.74	51.23
Tanypodininae	2.13	2.01	1.41	1.58	2.62	53.85
Tipulidae	0.60	0.15	1.38	1.02	2.56	56.41
Hemicorduliidae	0.00	0.59	1.35	0.92	2.50	58.91
Oligochaeta	1.34	1.49	1.33	1.15	2.46	61.37
Dytiscidae	0.66	0.32	1.32	1.23	2.44	63.81
Tricladida	0.00	0.54	1.24	0.97	2.30	66.12
Gomphidae	0.34	0.39	1.20	0.94	2.23	68.34
Elmidae (adult)	0.00	0.55	1.20	0.98	2.22	70.56
Ceinidae	0.00	0.40	0.93	0.66	1.72	72.28
Polycentropodidae	0.16	0.36	0.92	0.80	1.70	73.98
Hydrophilidae(adult)	0.13	0.31	0.80	0.79	1.49	75.47
Telephlebiidae	0.00	0.33	0.78	0.70	1.45	76.92
Notonectidae	0.28	0.14	0.78	0.79	1.45	78.37
Hydrophilidae	0.00	0.33	0.76	0.70	1.42	79.79
Synlestidae	0.00	0.32	0.75	0.69	1.39	81.18
Odontoceridae	0.00	0.32	0.70	0.68	1.29	82.48
Chorismagrionidae	0.15	0.20	0.68	0.63	1.27	83.75
Culicidae	0.29	0.00	0.68	0.69	1.26	85.01
Hydrobiosidae	0.00	0.29	0.66	0.69	1.22	86.22
Dytiscidae (adult)	0.28	0.00	0.65	0.69	1.20	87.43
Sialidae	0.16	0.16	0.59	0.61	1.09	88.52
Nematoda	0.16	0.13	0.57	0.62	1.06	89.58
Nemertea	0.13	0.16	0.56	0.62	1.04	90.63

Groups HC & BR
Average dissimilarity = 59.90

Species	Group HC Av.Abund	Group BR Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Leptophlebiidae	0.16	2.79	6.68	4.67	11.16	11.16
Chironominae	3.31	2.01	3.42	1.94	5.72	16.87
Elmidae	0.00	1.25	3.19	4.03	5.33	22.20
Leptoceridae	0.13	1.26	3.03	1.92	5.06	27.26
Calamoceratidae	0.00	1.02	2.57	2.07	4.28	31.54
Gyrinidae	0.00	0.86	2.19	2.08	3.66	35.20
Ecnomidae	0.48	1.26	2.04	1.58	3.41	38.61

Oligochaeta	0.84	1.49	1.96	1.43	3.27	41.88
Ceratopogonidae	0.24	0.80	1.95	1.02	3.26	45.14
Orthocladininae	1.85	1.34	1.85	1.14	3.09	48.23
Caenidae	0.13	0.79	1.83	1.38	3.05	51.29
Sphaeriidae	0.58	0.97	1.72	1.21	2.87	54.15
Baetidae	0.38	0.68	1.64	1.24	2.73	56.88
Hemicorduliidae	0.38	0.59	1.61	1.07	2.68	59.57
Tricladida	0.41	0.54	1.53	1.08	2.55	62.12
Elmidae (adult)	0.00	0.55	1.30	0.98	2.18	64.30
Dytiscidae (adult)	0.49	0.00	1.23	0.95	2.06	66.35
Tanypodininae	1.67	2.01	1.16	1.31	1.94	68.29
Dytiscidae	0.33	0.32	1.14	0.89	1.91	70.20
Ceinidae	0.13	0.40	1.14	0.79	1.90	72.10
Hydrophilidae	0.23	0.33	1.13	0.83	1.89	73.99
Coenagrionidae	0.32	0.20	1.01	0.79	1.69	75.68
Gomphidae	0.00	0.39	1.00	0.69	1.66	77.34
Tipulidae	0.29	0.15	0.88	0.79	1.47	78.81
Telephlebiidae	0.00	0.33	0.86	0.70	1.44	80.25
Polycentropodidae	0.00	0.36	0.85	0.70	1.43	81.67
Synlestidae	0.00	0.32	0.83	0.69	1.38	83.05
Hydrophilidae(adult)	0.00	0.31	0.77	0.68	1.29	84.34
Odontoceridae	0.00	0.32	0.76	0.68	1.27	85.61
Cordulephyidae	0.18	0.18	0.75	0.61	1.26	86.87
Hydrobiosidae	0.00	0.29	0.72	0.69	1.20	88.06
Nemertea	0.16	0.16	0.69	0.61	1.14	89.21
Podinae	0.24	0.00	0.66	0.44	1.11	90.32

Groups CWC & CBR
Average dissimilarity = 54.67

Species	Group CWC Av.Abund	Group CBR Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Oligochaeta	0.86	2.11	3.99	1.43	7.29	7.29
Elmidae	0.16	1.28	3.34	1.71	6.12	13.41
Ecnomidae	0.41	1.27	2.96	2.27	5.41	18.81
Sphaeriidae	0.00	1.03	2.94	1.32	5.38	24.20
Atyidae	0.00	0.98	2.88	1.99	5.27	29.47
Leptophlebiidae	3.17	2.44	2.84	1.67	5.19	34.66
Ceratopogonidae	0.41	1.09	2.59	1.51	4.74	39.40
Baetidae	0.00	0.90	2.51	1.37	4.59	43.99
Leptoceridae	0.35	0.87	2.35	1.20	4.30	48.28
Ancylidae	0.64	0.00	1.90	0.97	3.48	51.76
Dytiscidae (adult)	0.64	0.00	1.89	1.28	3.46	55.22
Orthocladininae	0.16	0.69	1.86	1.29	3.40	58.62
Tanypodininae	1.62	2.17	1.81	1.53	3.32	61.94
Tricladida	0.50	0.30	1.81	0.87	3.30	65.24
Chironominae	1.94	2.05	1.65	1.49	3.01	68.25
Caenidae	0.00	0.51	1.45	0.98	2.65	70.91
Ceinidae	0.00	0.52	1.35	0.69	2.47	73.38
Gripopterygidae	0.00	0.41	1.30	0.63	2.38	75.76
Gyrinidae	0.29	0.16	1.01	0.79	1.85	77.62
Calamoceratidae	0.00	0.32	0.97	0.70	1.78	79.39
Scirtidae	0.32	0.00	0.91	0.69	1.67	81.06
Sialidae	0.00	0.28	0.88	0.69	1.61	82.67
Hemicorduliidae	0.00	0.25	0.80	0.70	1.46	84.13
Tipulidae	0.16	0.13	0.76	0.62	1.39	85.51
Notonectidae	0.16	0.13	0.75	0.62	1.38	86.89
Nematoda	0.22	0.00	0.67	0.44	1.22	88.12
Psephenidae	0.20	0.00	0.58	0.44	1.05	89.17
Gomphidae	0.00	0.16	0.55	0.44	1.00	90.17

Groups CC & CBR
Average dissimilarity = 41.58

Group CC Group CBR

Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Psephenidae	1.25	0.00	3.13	5.55	7.53	7.53
Elmidae	0.13	1.28	2.91	1.74	6.99	14.52
Chironominae	2.60	2.05	2.25	1.54	5.42	19.94
Sphaeriidae	0.76	1.03	2.25	1.24	5.41	25.35
Ceratopogonidae	0.57	1.09	1.93	1.27	4.64	29.99
Oligochaeta	1.96	2.11	1.86	1.26	4.47	34.46
Baetidae	0.91	0.90	1.68	1.25	4.03	38.50
Atyidae	0.55	0.98	1.64	1.19	3.96	42.46
Leptoceridae	0.95	0.87	1.62	1.24	3.89	46.34
Ceinidae	0.44	0.52	1.59	0.92	3.83	50.17
Orthocladininae	0.78	0.69	1.54	1.22	3.71	53.89
Ecnomidae	0.73	1.27	1.52	1.24	3.66	57.54
Dytiscidae	0.62	0.16	1.48	1.24	3.56	61.10
Caenidae	0.63	0.51	1.34	1.14	3.22	64.32
Tricladida	0.42	0.30	1.28	0.96	3.09	67.41
Leptophlebiidae	1.99	2.44	1.26	1.15	3.03	70.44
Gripopterygidae	0.00	0.41	1.09	0.63	2.63	73.06
Tanypodininae	2.00	2.17	1.03	1.28	2.48	75.54
Tipulidae	0.35	0.13	0.96	0.81	2.31	77.85
Calamoceratidae	0.00	0.32	0.82	0.69	1.97	79.82
Corixidae	0.33	0.00	0.79	0.66	1.90	81.71
Hemicorduliidae	0.13	0.25	0.77	0.78	1.85	83.56
Sialidae	0.00	0.28	0.74	0.69	1.78	85.34
Coenagrionidae	0.16	0.15	0.66	0.61	1.58	86.92
Gomphidae	0.13	0.16	0.64	0.60	1.53	88.45
Nemertea	0.16	0.00	0.46	0.44	1.12	89.57
Hydrophilidae	0.00	0.18	0.44	0.44	1.05	90.62

Groups DC & CBR
Average dissimilarity = 55.87

	Group DC	Group CBR				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Ecnomidae	0.00	1.27	3.88	4.84	6.95	6.95
Elmidae	0.13	1.28	3.62	1.73	6.47	13.42
Oligochaeta	0.96	2.11	3.35	1.42	6.00	19.42
Sphaeriidae	0.00	1.03	3.10	1.31	5.56	24.98
Atyidae	0.00	0.98	3.04	1.95	5.45	30.43
Tanypodininae	1.20	2.17	3.02	2.04	5.40	35.83
Ceratopogonidae	0.71	1.09	2.84	1.49	5.08	40.91
Leptoceridae	0.25	0.87	2.55	1.32	4.57	45.47
Chironominae	2.45	2.05	2.47	1.58	4.41	49.89
Baetidae	0.50	0.90	2.29	1.29	4.11	53.99
Orthocladininae	0.00	0.69	2.09	1.36	3.74	57.73
Leptophlebiidae	1.79	2.44	1.95	1.69	3.49	61.22
Corixidae	0.51	0.00	1.58	0.96	2.83	64.04
Caenidae	0.40	0.51	1.57	1.15	2.80	66.84
Ceinidae	0.00	0.52	1.42	0.69	2.54	69.38
Gripopterygidae	0.00	0.41	1.38	0.63	2.47	71.85
Dytiscidae	0.28	0.16	1.03	0.80	1.85	73.70
Calamoceratidae	0.00	0.32	1.03	0.69	1.84	75.54
Tipulidae	0.24	0.13	0.95	0.63	1.70	77.24
Parastacidae	0.29	0.00	0.94	0.68	1.69	78.93
Sialidae	0.00	0.28	0.93	0.69	1.67	80.60
Tricladida	0.00	0.30	0.93	0.69	1.66	82.27
Ancylidae	0.28	0.00	0.88	0.69	1.58	83.84
Hemicorduliidae	0.00	0.25	0.84	0.69	1.51	85.35
Dytiscidae (adult)	0.25	0.00	0.72	0.69	1.29	86.65
Psychodidae	0.26	0.00	0.71	0.44	1.28	87.92
Gyrinidae	0.13	0.16	0.69	0.63	1.24	89.17
Gomphidae	0.00	0.16	0.58	0.44	1.04	90.21

Groups EC & CBR
Average dissimilarity = 51.88

Species	Group EC Av.Abund	Group CBR Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Elmidae	0.00	1.28	3.35	1.76	6.45	6.45
Atyidae	0.00	0.98	2.63	1.87	5.08	11.53
Oligochaeta	1.61	2.11	2.46	1.26	4.74	16.27
Sphaeriidae	0.32	1.03	2.46	1.26	4.73	21.00
Tanypodininae	1.66	2.17	2.42	0.92	4.67	25.67
Ecnomidae	0.64	1.27	2.27	1.36	4.38	30.05
Ceratopogonidae	0.64	1.09	2.22	1.28	4.28	34.33
Leptoceridae	0.29	0.87	2.19	1.18	4.21	38.54
Chironominae	2.32	2.05	2.10	1.09	4.04	42.58
Baetidae	0.28	0.90	2.08	1.48	4.00	46.58
Orthocladininae	0.92	0.69	1.99	1.26	3.83	50.42
Parastacidae	0.50	0.00	1.50	0.95	2.89	53.30
Caenidae	0.32	0.51	1.42	1.06	2.73	56.03
Gomphidae	0.53	0.16	1.36	0.98	2.62	58.65
Leptophlebiidae	2.12	2.44	1.30	1.16	2.51	61.17
Ceinidae	0.00	0.52	1.25	0.68	2.40	63.57
Gripopterygidae	0.00	0.41	1.19	0.62	2.28	65.85
Magapodagrionidae	0.49	0.00	1.18	0.94	2.28	68.14
Psephenidae	0.49	0.00	1.18	0.95	2.27	70.41
Calamoceratidae	0.15	0.32	1.00	0.77	1.92	72.33
Tricladida	0.16	0.30	0.97	0.79	1.87	74.21
Polycentropodidae	0.29	0.17	0.93	0.77	1.79	75.99
Sialidae	0.15	0.28	0.93	0.77	1.78	77.78
Synthemistidae	0.35	0.00	0.90	0.64	1.74	79.51
Tipulidae	0.20	0.13	0.78	0.62	1.50	81.02
Scirtidae	0.30	0.00	0.76	0.67	1.46	82.48
Culicidae	0.28	0.00	0.75	0.44	1.45	83.93
Elmidae (adult)	0.17	0.16	0.75	0.61	1.45	85.38
Hemicorduliidae	0.00	0.25	0.72	0.68	1.40	86.77
Gyrinidae	0.15	0.16	0.61	0.61	1.18	87.95
Dolichopodidae	0.21	0.00	0.57	0.44	1.11	89.06
Synlestidae	0.13	0.13	0.56	0.60	1.08	90.14

Groups TTH & CBR
Average dissimilarity = 50.72

Species	Group TTH Av.Abund	Group CBR Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chironominae	3.10	2.05	3.28	1.54	6.46	6.46
Elmidae	0.00	1.28	3.25	1.85	6.42	12.88
Sphaeriidae	0.00	1.03	2.62	1.32	5.17	18.05
Atyidae	0.00	0.98	2.56	1.99	5.05	23.10
Oligochaeta	1.34	2.11	2.56	1.27	5.05	28.14
Leptoceridae	0.16	0.87	2.22	1.24	4.38	32.53
Leptophlebiidae	1.59	2.44	2.22	1.96	4.38	36.91
Ecnomidae	0.78	1.27	2.18	1.60	4.30	41.21
Baetidae	0.82	0.90	1.98	1.26	3.90	45.11
Caenidae	0.84	0.51	1.89	1.15	3.72	48.83
Ceratopogonidae	0.84	1.09	1.76	1.20	3.48	52.31
Tanypodininae	2.13	2.17	1.74	1.84	3.44	55.75
Corixidae	0.63	0.00	1.72	0.90	3.39	59.14
Dytiscidae	0.66	0.16	1.65	1.25	3.25	62.40
Tipulidae	0.60	0.13	1.56	1.04	3.08	65.47
Orthocladininae	0.77	0.69	1.56	1.23	3.07	68.54
Ceinidae	0.00	0.52	1.22	0.69	2.40	70.94
Gripopterygidae	0.00	0.41	1.15	0.63	2.27	73.21
Gomphidae	0.34	0.16	1.08	0.81	2.13	75.34
Sialidae	0.16	0.28	0.94	0.81	1.85	77.19
Calamoceratidae	0.00	0.32	0.86	0.70	1.70	78.88
Notonectidae	0.28	0.13	0.85	0.79	1.67	80.56
Tricladida	0.00	0.30	0.78	0.70	1.55	82.11
Culicidae	0.29	0.00	0.77	0.69	1.52	83.63

Dytiscidae (adult)	0.28	0.00	0.74	0.69	1.45	85.08
Polycentropodidae	0.16	0.17	0.70	0.61	1.39	86.47
Hemicorduliidae	0.00	0.25	0.70	0.69	1.39	87.85
Gyrinidae	0.13	0.16	0.60	0.63	1.19	89.04
Hydrophilidae(adult)	0.13	0.16	0.59	0.63	1.16	90.19

Groups HC & CBR
Average dissimilarity = 59.43

Species	Group HC Av.Abund	Group CBR Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Leptophlebiidae	0.16	2.44	6.62	4.95	11.14	11.14
Chironominae	3.31	2.05	4.05	1.86	6.82	17.96
Oligochaeta	0.84	2.11	3.69	1.50	6.22	24.18
Elmidae	0.00	1.28	3.60	1.85	6.06	30.24
Orthocladininae	1.85	0.69	3.47	1.33	5.83	36.07
Ceratopogonidae	0.24	1.09	2.89	1.71	4.86	40.93
Atyidae	0.00	0.98	2.84	1.97	4.78	45.71
Leptoceridae	0.13	0.87	2.53	1.27	4.26	49.97
Sphaeriidae	0.58	1.03	2.48	1.30	4.18	54.15
Ecnomidae	0.48	1.27	2.30	1.58	3.87	58.02
Baetidae	0.38	0.90	2.21	1.24	3.72	61.74
Tanypodininae	1.67	2.17	1.57	1.15	2.65	64.39
Ceinidae	0.13	0.52	1.51	0.84	2.54	66.92
Tricladida	0.41	0.30	1.46	0.94	2.46	69.38
Caenidae	0.13	0.51	1.44	1.04	2.42	71.81
Dytiscidae (adult)	0.49	0.00	1.41	0.94	2.38	74.19
Hemicorduliidae	0.38	0.25	1.38	0.97	2.32	76.51
Gripopterygidae	0.00	0.41	1.28	0.63	2.16	78.67
Dytiscidae	0.33	0.16	1.10	0.77	1.86	80.52
Coenagrionidae	0.32	0.15	1.10	0.79	1.86	82.38
Hydrophilidae	0.23	0.18	0.98	0.62	1.65	84.03
Tipulidae	0.29	0.13	0.97	0.79	1.64	85.67
Calamoceratidae	0.00	0.32	0.96	0.70	1.61	87.28
Sialidae	0.00	0.28	0.87	0.69	1.46	88.74
Podinae	0.24	0.00	0.77	0.44	1.30	90.04

Groups BR & CBR
Average dissimilarity = 40.27

Species	Group BR Av.Abund	Group CBR Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Atyidae	0.16	0.98	1.83	1.65	4.55	4.55
Ceratopogonidae	0.80	1.09	1.81	1.40	4.50	9.05
Calamoceratidae	1.02	0.32	1.70	1.54	4.23	13.28
Gyrinidae	0.86	0.16	1.64	1.57	4.07	17.35
Sphaeriidae	0.97	1.03	1.60	1.44	3.96	21.31
Oligochaeta	1.49	2.11	1.58	1.09	3.91	25.22
Leptoceridae	1.26	0.87	1.57	1.23	3.90	29.12
Orthocladininae	1.34	0.69	1.53	1.22	3.81	32.93
Baetidae	0.68	0.90	1.40	1.31	3.49	36.42
Caenidae	0.79	0.51	1.34	1.20	3.33	39.75
Ceinidae	0.40	0.52	1.34	0.93	3.33	43.08
Elmidae	1.25	1.28	1.32	1.33	3.29	46.37
Chironominae	2.01	2.05	1.27	1.10	3.15	49.52
Hemicorduliidae	0.59	0.25	1.25	1.10	3.11	52.63
Tricladida	0.54	0.30	1.15	1.07	2.85	55.48
Elmidae (adult)	0.55	0.16	1.12	1.00	2.78	58.26
Gomphidae	0.39	0.16	0.96	0.81	2.39	60.66
Gripopterygidae	0.00	0.41	0.92	0.63	2.29	62.94
Tanypodininae	2.01	2.17	0.92	1.27	2.28	65.23
Polycentropodidae	0.36	0.17	0.86	0.80	2.13	67.35
Hydrophilidae	0.33	0.18	0.84	0.79	2.09	69.45
Leptophlebiidae	2.79	2.44	0.83	1.15	2.07	71.51
Dytiscidae	0.32	0.16	0.83	0.78	2.05	73.56

Synlestidae	0.32	0.13	0.78	0.81	1.94	75.50
Hydrophilidae(adult)	0.31	0.16	0.77	0.79	1.91	77.40
Sialidae	0.16	0.28	0.75	0.81	1.87	79.27
Ecnomidae	1.26	1.27	0.74	1.36	1.84	81.11
Telephlebiidae	0.33	0.00	0.72	0.69	1.78	82.89
Odontoceridae	0.32	0.00	0.64	0.68	1.60	84.49
Hydrobiosidae	0.29	0.00	0.60	0.69	1.50	85.99
Coenagrionidae	0.20	0.15	0.60	0.63	1.49	87.48
Tipulidae	0.15	0.13	0.51	0.62	1.26	88.74
Notonectidae	0.14	0.13	0.50	0.61	1.25	89.99
Chorismagrionidae	0.20	0.00	0.40	0.44	0.99	90.97

Groups CWC & CMC
Average dissimilarity = 50.06

	Group CWC	Group CMC				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Orthocladininae	0.16	1.63	4.44	2.54	8.88	8.88
Oligochaeta	0.86	1.64	3.55	1.75	7.09	15.96
Leptophlebiidae	3.17	2.64	2.91	1.35	5.81	21.78
Ecnomidae	0.41	1.10	2.87	2.31	5.73	27.50
Dytiscidae	0.00	0.78	2.38	1.38	4.76	32.26
Chironominae	1.94	2.61	2.29	1.79	4.58	36.84
Tanypodininae	1.62	2.29	2.25	1.72	4.49	41.33
Leptoceridae	0.35	0.87	2.15	1.41	4.30	45.63
Ancylidae	0.64	0.00	2.03	0.97	4.05	49.67
Ceratopogonidae	0.41	0.66	2.02	1.22	4.03	53.70
Dytiscidae (adult)	0.64	0.15	1.92	1.24	3.84	57.55
Tricladida	0.50	0.25	1.85	0.82	3.70	61.24
Synthemistidae	0.00	0.51	1.71	0.94	3.41	64.65
Gyrinidae	0.29	0.34	1.36	0.92	2.71	67.36
Tipulidae	0.16	0.32	1.29	0.77	2.58	69.94
Magapodagrionidae	0.13	0.33	1.22	0.81	2.45	72.39
Gripopterygidae	0.00	0.39	1.07	0.65	2.15	74.53
Polycentropodidae	0.00	0.33	1.06	0.69	2.12	76.65
Scirtidae	0.32	0.00	0.97	0.69	1.94	78.58
Nematoda	0.22	0.13	0.95	0.59	1.90	80.49
Caenidae	0.00	0.29	0.94	0.68	1.89	82.37
Elmidae (adult)	0.00	0.33	0.93	0.69	1.87	84.24
Hydroptilidae	0.00	0.29	0.88	0.67	1.76	86.00
Elmidae	0.16	0.13	0.79	0.61	1.58	87.59
Baetidae	0.00	0.16	0.62	0.44	1.23	88.82
Psephenidae	0.20	0.00	0.61	0.44	1.22	90.04

Groups CC & CMC
Average dissimilarity = 41.70

	Group CC	Group CMC				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Psephenidae	1.25	0.00	3.30	5.52	7.92	7.92
Orthocladininae	0.78	1.63	2.39	1.40	5.74	13.66
Baetidae	0.91	0.16	2.13	1.57	5.11	18.77
Oligochaeta	1.96	1.64	1.99	1.53	4.78	23.55
Leptophlebiidae	1.99	2.64	1.93	1.40	4.64	28.19
Sphaeriidae	0.76	0.13	1.90	1.03	4.56	32.74
Ceratopogonidae	0.57	0.66	1.59	1.17	3.81	36.55
Dytiscidae	0.62	0.78	1.52	1.21	3.65	40.20
Caenidae	0.63	0.29	1.47	1.18	3.53	43.73
Atyidae	0.55	0.00	1.47	0.94	3.53	47.26
Chironominae	2.60	2.61	1.42	1.15	3.41	50.67
Synthemistidae	0.00	0.51	1.42	0.94	3.40	54.07
Leptoceridae	0.95	0.87	1.36	1.16	3.25	57.32
Ecnomidae	0.73	1.10	1.28	1.06	3.07	60.38
Tricladida	0.42	0.25	1.28	0.94	3.06	63.45
Tipulidae	0.35	0.32	1.25	0.89	3.01	66.46

Ceinidae	0.44	0.13	1.19	0.79	2.85	69.30
Tanypodininae	2.00	2.29	1.08	1.39	2.59	71.90
Gripopterygidae	0.00	0.39	0.92	0.64	2.21	74.11
Magapodagrionidae	0.00	0.33	0.92	0.69	2.21	76.31
Polycentropodidae	0.00	0.33	0.89	0.69	2.12	78.44
Gyrinidae	0.00	0.34	0.86	0.69	2.06	80.50
Corixidae	0.33	0.00	0.83	0.66	1.99	82.49
Elmidae (adult)	0.00	0.33	0.80	0.69	1.91	84.40
Hydroptilidae	0.00	0.29	0.74	0.67	1.79	86.19
Nematoda	0.17	0.13	0.61	0.62	1.46	87.65
Gomphidae	0.13	0.15	0.59	0.61	1.41	89.06
Hemicorduliidae	0.13	0.13	0.56	0.60	1.34	90.39

Groups DC & CMC
Average dissimilarity = 51.83

Species	Group DC Av.Abund	Group CMC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Orthocladininae	0.00	1.63	5.27	3.93	10.16	10.16
Ecnomidae	0.00	1.10	3.75	3.91	7.24	17.40
Tanypodininae	1.20	2.29	3.72	2.20	7.18	24.58
Leptophlebiidae	1.79	2.64	2.81	1.98	5.42	30.00
Ceratopogonidae	0.71	0.66	2.48	1.16	4.78	34.79
Oligochaeta	0.96	1.64	2.34	1.15	4.51	39.29
Leptoceridae	0.25	0.87	2.27	1.54	4.38	43.67
Dytiscidae	0.28	0.78	2.24	1.33	4.33	48.00
Synthemistidae	0.00	0.51	1.82	0.93	3.51	51.51
Chironominae	2.45	2.61	1.79	1.35	3.44	54.95
Baetidae	0.50	0.16	1.72	0.96	3.32	58.28
Corixidae	0.51	0.00	1.69	0.96	3.26	61.53
Tipulidae	0.24	0.32	1.52	0.78	2.94	64.47
Caenidae	0.40	0.29	1.44	1.02	2.78	67.25
Gyrinidae	0.13	0.34	1.24	0.82	2.39	69.64
Magapodagrionidae	0.00	0.33	1.18	0.69	2.28	71.91
Gripopterygidae	0.00	0.39	1.13	0.65	2.18	74.09
Polycentropodidae	0.00	0.33	1.12	0.69	2.17	76.26
Parastacidae	0.29	0.00	1.01	0.68	1.95	78.21
Dytiscidae (adult)	0.25	0.15	0.99	0.80	1.91	80.12
Elmidae (adult)	0.00	0.33	0.98	0.69	1.90	82.02
Ancylidae	0.28	0.00	0.94	0.69	1.82	83.84
Hydroptilidae	0.00	0.29	0.93	0.67	1.80	85.64
Psychodidae	0.26	0.00	0.76	0.44	1.46	87.10
Tricladida	0.00	0.25	0.73	0.69	1.42	88.52
Elmidae	0.13	0.13	0.67	0.61	1.30	89.82
Acarina	0.00	0.16	0.58	0.44	1.12	90.94

Groups EC & CMC
Average dissimilarity = 46.53

Species	Group EC Av.Abund	Group CMC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Orthocladininae	0.92	1.63	2.83	1.28	6.08	6.08
Tanypodininae	1.66	2.29	2.56	0.78	5.50	11.57
Chironominae	2.32	2.61	2.24	1.47	4.82	16.40
Dytiscidae	0.00	0.78	2.17	1.33	4.67	21.07
Ecnomidae	0.64	1.10	2.13	1.25	4.58	25.65
Oligochaeta	1.61	1.64	2.05	1.07	4.40	30.05
Leptophlebiidae	2.12	2.64	1.98	1.36	4.25	34.30
Leptoceridae	0.29	0.87	1.96	1.34	4.22	38.52
Ceratopogonidae	0.64	0.66	1.92	1.18	4.13	42.65
Synthemistidae	0.35	0.51	1.66	1.03	3.58	46.23
Parastacidae	0.50	0.00	1.60	0.95	3.44	49.67
Magapodagrionidae	0.49	0.33	1.44	1.00	3.09	52.76
Gomphidae	0.53	0.15	1.40	0.99	3.01	55.77
Psephenidae	0.49	0.00	1.24	0.95	2.67	58.44

Tipulidae	0.20	0.32	1.23	0.75	2.65	61.09
Polycentropodidae	0.29	0.33	1.21	0.87	2.59	63.69
Caenidae	0.32	0.29	1.20	0.90	2.59	66.28
Baetidae	0.28	0.16	1.08	0.81	2.33	68.60
Gyrinidae	0.15	0.34	1.07	0.78	2.29	70.89
Elmidae (adult)	0.17	0.33	1.06	0.77	2.28	73.17
Gripopterygidae	0.00	0.39	0.99	0.64	2.12	75.29
Sphaeriidae	0.32	0.13	0.95	0.80	2.05	77.34
Hydroptilidae	0.13	0.29	0.92	0.76	1.97	79.32
Tricladida	0.16	0.25	0.88	0.80	1.89	81.21
Scirtidae	0.30	0.00	0.80	0.67	1.72	82.93
Culicidae	0.28	0.00	0.80	0.44	1.72	84.64
Synlestidae	0.13	0.16	0.62	0.61	1.34	85.98
Calamoceratidae	0.15	0.13	0.62	0.62	1.33	87.31
Dolichopodidae	0.21	0.00	0.61	0.44	1.31	88.62
Pyralidae	0.20	0.00	0.56	0.44	1.21	89.83
Acarina	0.00	0.16	0.50	0.43	1.06	90.90

Groups TTH & CMC
Average dissimilarity = 45.09

Species	Group TTH Av.Abund	Group CMC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Leptophlebiidae	1.59	2.64	2.88	1.97	6.38	6.38
Orthocladininae	0.77	1.63	2.51	1.37	5.57	11.95
Chironominae	3.10	2.61	2.34	1.43	5.19	17.14
Oligochaeta	1.34	1.64	2.19	1.37	4.86	22.01
Baetidae	0.82	0.16	2.19	1.19	4.85	26.86
Ecnomidae	0.78	1.10	2.16	1.79	4.80	31.66
Leptoceridae	0.16	0.87	2.09	1.61	4.64	36.31
Caenidae	0.84	0.29	2.07	1.13	4.59	40.90
Corixidae	0.63	0.00	1.82	0.90	4.04	44.94
Ceratopogonidae	0.84	0.66	1.80	1.20	3.99	48.94
Tanypodininae	2.13	2.29	1.74	1.83	3.85	52.79
Tipulidae	0.60	0.32	1.70	1.06	3.76	56.55
Dytiscidae	0.66	0.78	1.60	1.21	3.56	60.11
Synthemistidae	0.00	0.51	1.49	0.94	3.31	63.42
Gomphidae	0.34	0.15	1.09	0.80	2.41	65.83
Polycentropodidae	0.16	0.33	1.07	0.78	2.37	68.20
Gyrinidae	0.13	0.34	1.04	0.82	2.30	70.50
Magapodagrionidae	0.00	0.33	0.97	0.70	2.15	72.66
Gripopterygidae	0.00	0.39	0.96	0.65	2.14	74.79
Dytiscidae (adult)	0.28	0.15	0.93	0.79	2.05	76.85
Elmidae (adult)	0.00	0.33	0.83	0.69	1.85	78.70
Culicidae	0.29	0.00	0.82	0.69	1.81	80.51
Notonectidae	0.28	0.00	0.78	0.69	1.74	82.25
Hydroptilidae	0.00	0.29	0.78	0.67	1.73	83.98
Nematoda	0.16	0.13	0.67	0.61	1.48	85.46
Tricladida	0.00	0.25	0.63	0.70	1.39	86.84
Acarina	0.00	0.16	0.48	0.44	1.06	87.91
Chorismagrionidae	0.15	0.00	0.45	0.44	0.99	88.89
Sialidae	0.16	0.00	0.42	0.44	0.93	89.82
Dolichopodidae	0.15	0.00	0.41	0.44	0.91	90.74

Groups HC & CMC
Average dissimilarity = 51.08

Species	Group HC Av.Abund	Group CMC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Leptophlebiidae	0.16	2.64	7.54	5.17	14.77	14.77
Oligochaeta	0.84	1.64	2.97	1.51	5.81	20.58
Chironominae	3.31	2.61	2.46	1.20	4.82	25.40
Orthocladininae	1.85	1.63	2.41	1.29	4.71	30.11
Leptoceridae	0.13	0.87	2.39	1.71	4.69	34.80
Ceratopogonidae	0.24	0.66	2.04	1.26	4.00	38.80

Dytiscidae	0.33	0.78	2.03	1.22	3.97	42.76
Ecnomidae	0.48	1.10	2.02	1.31	3.95	46.72
Tanypodininae	1.67	2.29	2.00	1.34	3.92	50.63
Sphaeriidae	0.58	0.13	1.73	1.03	3.39	54.03
Synthemistidae	0.00	0.51	1.68	0.94	3.29	57.32
Dytiscidae (adult)	0.49	0.15	1.53	0.98	3.00	60.32
Tricladida	0.41	0.25	1.47	0.91	2.87	63.19
Tipulidae	0.29	0.32	1.39	0.88	2.71	65.90
Baetidae	0.38	0.16	1.37	0.79	2.68	68.58
Hemicorduliidae	0.38	0.13	1.31	0.79	2.57	71.15
Magapodagrionidae	0.00	0.33	1.09	0.70	2.14	73.29
Hydroptilidae	0.16	0.29	1.08	0.78	2.11	75.39
Gripopterygidae	0.00	0.39	1.06	0.65	2.08	77.47
Caenidae	0.13	0.29	1.05	0.78	2.06	79.53
Polycentropodidae	0.00	0.33	1.04	0.69	2.04	81.57
Gyrinidae	0.00	0.34	1.00	0.69	1.97	83.53
Coenagrionidae	0.32	0.00	0.99	0.66	1.93	85.46
Elmidae (adult)	0.00	0.33	0.92	0.69	1.80	87.27
Acarina	0.16	0.16	0.87	0.61	1.71	88.98
Podinae	0.24	0.00	0.83	0.44	1.63	90.60

Groups BR & CMC
Average dissimilarity = 43.80

Species	Group BR Av.Abund	Group CMC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Elmidae	1.25	0.13	2.52	2.59	5.76	5.76
Calamoceratidae	1.02	0.13	2.07	1.87	4.73	10.49
Sphaeriidae	0.97	0.13	2.00	1.81	4.56	15.04
Ceratopogonidae	0.80	0.66	1.76	1.42	4.02	19.06
Chironominae	2.01	2.61	1.75	1.60	4.00	23.06
Leptoceridae	1.26	0.87	1.58	1.44	3.61	26.67
Caenidae	0.79	0.29	1.50	1.32	3.43	30.10
Dytiscidae	0.32	0.78	1.46	1.28	3.33	33.44
Gyrinidae	0.86	0.34	1.45	1.26	3.32	36.76
Baetidae	0.68	0.16	1.45	1.27	3.30	40.06
Hemicorduliidae	0.59	0.13	1.30	0.98	2.97	43.03
Oligochaeta	1.49	1.64	1.26	1.43	2.87	45.90
Orthocladininae	1.34	1.63	1.25	1.40	2.86	48.76
Tricladida	0.54	0.25	1.20	1.10	2.74	51.50
Elmidae (adult)	0.55	0.33	1.18	1.03	2.70	54.20
Synthemistidae	0.00	0.51	1.18	0.95	2.70	56.91
Leptophlebiidae	2.79	2.64	1.10	1.23	2.52	59.43
Polycentropodidae	0.36	0.33	1.03	0.91	2.36	61.78
Gomphidae	0.39	0.15	0.98	0.81	2.24	64.03
Ceinidae	0.40	0.13	0.98	0.77	2.24	66.26
Tanypodininae	2.01	2.29	0.90	1.23	2.05	68.31
Tipulidae	0.15	0.32	0.88	0.77	2.00	70.31
Magapodagrionidae	0.16	0.33	0.87	0.78	1.99	72.30
Synlestidae	0.32	0.16	0.83	0.79	1.90	74.20
Gripopterygidae	0.00	0.39	0.79	0.64	1.81	76.01
Telephlebiidae	0.33	0.00	0.75	0.69	1.72	77.73
Hydrophilidae	0.33	0.00	0.73	0.69	1.68	79.40
Hydrophilidae(adult)	0.31	0.00	0.68	0.68	1.55	80.95
Odontoceridae	0.32	0.00	0.67	0.68	1.53	82.48
Ecnomidae	1.26	1.10	0.65	1.63	1.49	83.97
Hydroptilidae	0.00	0.29	0.63	0.67	1.44	85.41
Hydrobiosidae	0.29	0.00	0.63	0.69	1.44	86.85
Acarina	0.13	0.16	0.56	0.62	1.29	88.14
Nematoda	0.13	0.13	0.46	0.61	1.04	89.18
Chorismagrionidae	0.20	0.00	0.42	0.44	0.95	90.13

Groups CBR & CMC
Average dissimilarity = 43.05

Species	Group CBR Av.Abund	Group CMC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Elmidae	1.28	0.13	2.91	1.72	6.77	6.77
Atyidae	0.98	0.00	2.44	1.96	5.68	12.45
Sphaeriidae	1.03	0.13	2.41	1.34	5.60	18.05
Orthocladininae	0.69	1.63	2.40	1.43	5.57	23.62
Oligochaeta	2.11	1.64	2.29	1.38	5.32	28.94
Chironominae	2.05	2.61	2.19	1.82	5.08	34.02
Baetidae	0.90	0.16	2.01	1.36	4.67	38.69
Dytiscidae	0.16	0.78	1.80	1.27	4.18	42.88
Ceratopogonidae	1.09	0.66	1.75	1.25	4.07	46.94
Leptoceridae	0.87	0.87	1.59	1.26	3.68	50.63
Gripopterygidae	0.41	0.39	1.47	0.86	3.41	54.03
Synthemistidae	0.00	0.51	1.34	0.94	3.12	57.15
Ceinidae	0.52	0.13	1.28	0.81	2.98	60.13
Caenidae	0.51	0.29	1.27	1.07	2.95	63.08
Leptophlebiidae	2.44	2.64	1.11	1.43	2.57	65.65
Tanypodininae	2.17	2.29	1.09	1.54	2.54	68.19
Polycentropodidae	0.17	0.33	0.98	0.78	2.28	70.47
Tipulidae	0.13	0.32	0.96	0.76	2.23	72.70
Tricladida	0.30	0.25	0.94	0.91	2.19	74.89
Gyrinidae	0.16	0.34	0.94	0.78	2.18	77.07
Elmidae (adult)	0.16	0.33	0.92	0.78	2.13	79.20
Calamoceratidae	0.32	0.13	0.92	0.80	2.13	81.32
Magapodagrionidae	0.00	0.33	0.87	0.69	2.03	83.35
Hemicorduliidae	0.25	0.13	0.76	0.78	1.76	85.11
Sialidae	0.28	0.00	0.74	0.69	1.72	86.83
Ecnomidae	1.27	1.10	0.73	1.35	1.69	88.51
Hydroptilidae	0.00	0.29	0.71	0.67	1.64	90.16

Groups CWC & CCC
Average dissimilarity = 56.42

Species	Group CWC Av.Abund	Group CCC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Leptophlebiidae	3.17	1.50	5.45	1.81	9.66	9.66
Chironominae	1.94	3.70	5.29	2.45	9.37	19.03
Ceratopogonidae	0.41	1.70	4.08	2.04	7.24	26.27
Oligochaeta	0.86	1.77	3.89	1.35	6.90	33.16
Baetidae	0.00	0.92	2.66	1.26	4.71	37.87
Dytiscidae	0.00	0.89	2.64	1.35	4.68	42.55
Tanypodininae	1.62	2.29	2.21	1.54	3.92	46.47
Calamoceratidae	0.00	0.68	2.15	1.35	3.82	50.28
Leptoceridae	0.35	0.78	2.12	1.16	3.75	54.04
Ancylidae	0.64	0.16	2.02	1.05	3.57	57.61
Dytiscidae (adult)	0.64	0.36	1.87	1.21	3.31	60.92
Ecnomidae	0.41	0.39	1.83	0.92	3.25	64.17
Tricladida	0.50	0.20	1.81	0.75	3.22	67.39
Orthocladininae	0.16	0.59	1.74	1.02	3.09	70.48
Hemicorduliidae	0.00	0.44	1.46	0.69	2.60	73.07
Coenagrionidae	0.00	0.45	1.36	0.64	2.41	75.49
Nematoda	0.22	0.20	1.13	0.62	2.00	77.49
Tipulidae	0.16	0.20	0.99	0.62	1.75	79.24
Nemertea	0.00	0.33	0.97	0.69	1.72	80.96
Scirtidae	0.32	0.00	0.96	0.69	1.71	82.67
Gyrinidae	0.29	0.00	0.91	0.68	1.60	84.27
Corixidae	0.00	0.29	0.88	0.70	1.57	85.84
Physidae	0.00	0.33	0.88	0.70	1.56	87.40
Parastacidae	0.00	0.33	0.88	0.70	1.56	88.95
Culicidae	0.15	0.16	0.84	0.61	1.48	90.44

Groups CC & CCC
Average dissimilarity = 44.76

Group CC Group CCC

Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Psephenidae	1.25	0.00	3.28	5.53	7.34	7.34
Ceratopogonidae	0.57	1.70	3.06	1.66	6.83	14.16
Chironominae	2.60	3.70	2.97	1.71	6.63	20.79
Baetidae	0.91	0.92	1.97	1.41	4.40	25.19
Sphaeriidae	0.76	0.16	1.90	1.03	4.24	29.43
Oligochaeta	1.96	1.77	1.88	1.46	4.20	33.63
Calamoceratidae	0.00	0.68	1.80	1.35	4.02	37.66
Dytiscidae	0.62	0.89	1.78	1.40	3.98	41.63
Leptophlebiidae	1.99	1.50	1.75	1.49	3.91	45.54
Ecnomidae	0.73	0.39	1.74	1.13	3.89	49.43
Orthocladininae	0.78	0.59	1.74	1.12	3.89	53.32
Caenidae	0.63	0.16	1.61	1.22	3.60	56.93
Leptoceridae	0.95	0.78	1.50	1.06	3.36	60.29
Atyidae	0.55	0.00	1.46	0.94	3.26	63.55
Hemicorduliidae	0.13	0.44	1.33	0.82	2.96	66.51
Coenagrionidae	0.16	0.45	1.30	0.75	2.91	69.43
Tanypodininae	2.00	2.29	1.29	1.38	2.89	72.31
Tricladida	0.42	0.20	1.22	0.79	2.73	75.05
Corixidae	0.33	0.29	1.13	0.92	2.52	77.57
Tipulidae	0.35	0.20	1.11	0.79	2.49	80.06
Ceinidae	0.44	0.00	1.07	0.67	2.38	82.44
Nemertea	0.16	0.33	1.00	0.77	2.25	84.68
Dytiscidae (adult)	0.00	0.36	0.89	0.69	1.99	86.68
Nematoda	0.17	0.20	0.79	0.61	1.78	88.45
Physidae	0.00	0.33	0.76	0.69	1.69	90.14

Groups DC & CCC
Average dissimilarity = 49.48

	Group DC	Group CCC				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Ceratopogonidae	0.71	1.70	4.15	1.97	8.38	8.38
Chironominae	2.45	3.70	3.99	1.71	8.07	16.45
Tanypodininae	1.20	2.29	3.58	2.13	7.23	23.68
Oligochaeta	0.96	1.77	2.89	1.05	5.84	29.53
Baetidae	0.50	0.92	2.56	1.31	5.18	34.71
Dytiscidae	0.28	0.89	2.52	1.36	5.10	39.81
Leptoceridae	0.25	0.78	2.31	1.36	4.66	44.47
Calamoceratidae	0.00	0.68	2.29	1.34	4.62	49.09
Leptophlebiidae	1.79	1.50	1.87	1.21	3.77	52.86
Orthocladininae	0.00	0.59	1.80	0.97	3.63	56.49
Corixidae	0.51	0.29	1.70	1.07	3.43	59.92
Hemicorduliidae	0.00	0.44	1.56	0.69	3.15	63.07
Coenagrionidae	0.00	0.45	1.44	0.63	2.91	65.98
Dytiscidae (adult)	0.25	0.36	1.40	0.95	2.82	68.81
Caenidae	0.40	0.16	1.37	1.02	2.78	71.58
Parastacidae	0.29	0.33	1.37	0.91	2.77	74.35
Ecnomidae	0.00	0.39	1.26	0.69	2.55	76.90
Ancylidae	0.28	0.16	1.19	0.80	2.41	79.30
Tipulidae	0.24	0.20	1.18	0.62	2.37	81.68
Nemertea	0.00	0.33	1.03	0.69	2.08	83.76
Physidae	0.00	0.33	0.92	0.69	1.86	85.62
Culicidae	0.13	0.16	0.86	0.62	1.74	87.36
Psychodidae	0.26	0.00	0.75	0.44	1.52	88.87
Nematoda	0.00	0.20	0.69	0.44	1.39	90.26

Groups EC & CCC
Average dissimilarity = 52.53

	Group EC	Group CCC				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chironominae	2.32	3.70	4.28	1.94	8.14	8.14
Ceratopogonidae	0.64	1.70	3.24	1.37	6.18	14.32
Tanypodininae	1.66	2.29	2.79	0.95	5.31	19.63

Dytiscidae	0.00	0.89	2.41	1.30	4.59	24.22
Orthocladininae	0.92	0.59	2.21	1.20	4.21	28.44
Baetidae	0.28	0.92	2.20	1.30	4.19	32.62
Leptophlebiidae	2.12	1.50	2.18	1.46	4.16	36.78
Oligochaeta	1.61	1.77	2.18	1.01	4.15	40.93
Leptoceridae	0.29	0.78	1.97	1.18	3.75	44.68
Calamoceratidae	0.15	0.68	1.83	1.20	3.49	48.17
Ecnomidae	0.64	0.39	1.78	1.04	3.38	51.55
Parastacidae	0.50	0.33	1.51	0.93	2.87	54.42
Gomphidae	0.53	0.16	1.39	0.99	2.65	57.08
Hemicorduliidae	0.00	0.44	1.33	0.68	2.53	59.61
Magapodagrionidae	0.49	0.13	1.30	1.00	2.47	62.07
Coenagrionidae	0.00	0.45	1.24	0.62	2.37	64.44
Psephenidae	0.49	0.00	1.24	0.95	2.35	66.79
Culicidae	0.28	0.16	1.12	0.61	2.14	68.93
Sphaeriidae	0.32	0.16	1.02	0.77	1.94	70.87
Caenidae	0.32	0.16	1.00	0.79	1.90	72.77
Dytiscidae (adult)	0.00	0.36	0.96	0.68	1.83	74.60
Tipulidae	0.20	0.20	0.96	0.60	1.82	76.42
Synthemistidae	0.35	0.00	0.95	0.64	1.80	78.23
Nemertea	0.00	0.33	0.89	0.68	1.69	79.92
Physidae	0.00	0.33	0.81	0.69	1.54	81.46
Corixidae	0.00	0.29	0.81	0.68	1.54	82.99
Tricladida	0.16	0.20	0.80	0.62	1.52	84.51
Scirtidae	0.30	0.00	0.79	0.67	1.51	86.03
Polycentropodidae	0.29	0.00	0.75	0.68	1.42	87.45
Hydroptilidae	0.13	0.16	0.69	0.59	1.32	88.77
Dolichopodidae	0.21	0.00	0.60	0.44	1.15	89.92
Nematoda	0.00	0.20	0.59	0.43	1.12	91.03

Groups TTH & CCC
Average dissimilarity = 44.22

Species	Group TTH Av.Abund	Group CCC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chironominae	3.10	3.70	2.72	1.53	6.15	6.15
Ceratopogonidae	0.84	1.70	2.44	1.27	5.51	11.66
Oligochaeta	1.34	1.77	2.36	1.18	5.33	16.99
Baetidae	0.82	0.92	2.24	1.33	5.06	22.05
Caenidae	0.84	0.16	2.18	1.12	4.94	27.00
Ecnomidae	0.78	0.39	2.12	1.10	4.79	31.78
Leptoceridae	0.16	0.78	2.00	1.25	4.51	36.30
Calamoceratidae	0.00	0.68	1.90	1.35	4.29	40.58
Dytiscidae	0.66	0.89	1.87	1.41	4.23	44.82
Tanypodininae	2.13	2.29	1.85	1.52	4.19	49.00
Corixidae	0.63	0.29	1.82	1.06	4.11	53.12
Orthocladininae	0.77	0.59	1.72	1.06	3.89	57.01
Tipulidae	0.60	0.20	1.67	0.99	3.78	60.79
Leptophlebiidae	1.59	1.50	1.42	1.35	3.21	64.00
Hemicorduliidae	0.00	0.44	1.28	0.69	2.91	66.90
Dytiscidae (adult)	0.28	0.36	1.22	0.96	2.77	69.67
Coenagrionidae	0.00	0.45	1.21	0.64	2.73	72.40
Gomphidae	0.34	0.16	1.08	0.80	2.45	74.85
Culicidae	0.29	0.16	1.00	0.79	2.27	77.12
Nemertea	0.13	0.33	0.99	0.81	2.24	79.36
Parastacidae	0.13	0.33	0.94	0.83	2.14	81.50
Nematoda	0.16	0.20	0.86	0.62	1.94	83.43
Physidae	0.00	0.33	0.79	0.70	1.78	85.22
Notonectidae	0.28	0.00	0.78	0.69	1.76	86.98
Ancylidae	0.00	0.16	0.49	0.44	1.10	88.08
Tricladida	0.00	0.20	0.48	0.44	1.08	89.16
Sphaeriidae	0.00	0.16	0.48	0.44	1.08	90.24

Groups HC & CCC
Average dissimilarity = 52.30

Species	Group HC Av.Abund	Group CCC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Ceratopogonidae	0.24	1.70	4.58	2.45	8.76	8.76
Leptophlebiidae	0.16	1.50	4.06	2.30	7.77	16.53
Orthocladininae	1.85	0.59	4.06	1.35	7.76	24.29
Oligochaeta	0.84	1.77	3.44	1.29	6.57	30.86
Baetidae	0.38	0.92	2.48	1.31	4.75	35.61
Chironominae	3.31	3.70	2.48	1.56	4.74	40.35
Dytiscidae	0.33	0.89	2.33	1.34	4.45	44.80
Leptoceridae	0.13	0.78	2.27	1.30	4.35	49.15
Calamoceratidae	0.00	0.68	2.12	1.35	4.05	53.20
Tanypodininae	1.67	2.29	1.99	1.26	3.81	57.02
Hemicorduliidae	0.38	0.44	1.82	0.92	3.47	60.49
Coenagrionidae	0.32	0.45	1.74	0.89	3.32	63.81
Sphaeriidae	0.58	0.16	1.73	1.00	3.31	67.12
Ecnomidae	0.48	0.39	1.72	1.06	3.28	70.40
Dytiscidae (adult)	0.49	0.36	1.63	1.04	3.12	73.52
Tricladida	0.41	0.20	1.43	0.80	2.73	76.25
Tipulidae	0.29	0.20	1.21	0.80	2.32	78.57
Nemertea	0.16	0.33	1.15	0.78	2.20	80.76
Nematoda	0.17	0.20	0.97	0.62	1.86	82.62
Corixidae	0.00	0.29	0.87	0.70	1.67	84.29
Physidae	0.00	0.33	0.87	0.70	1.66	85.94
Parastacidae	0.00	0.33	0.87	0.70	1.66	87.60
Hydroptilidae	0.16	0.16	0.84	0.61	1.60	89.21
Podinae	0.24	0.00	0.82	0.44	1.57	90.78

Groups BR & CCC
Average dissimilarity = 51.89

Species	Group BR Av.Abund	Group CCC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chironominae	2.01	3.70	3.78	2.12	7.28	7.28
Leptophlebiidae	2.79	1.50	2.90	2.03	5.60	12.88
Elmidae	1.25	0.00	2.78	3.91	5.36	18.23
Ceratopogonidae	0.80	1.70	2.23	1.21	4.30	22.53
Ecnomidae	1.26	0.39	2.06	1.67	3.97	26.50
Sphaeriidae	0.97	0.16	1.91	1.65	3.69	30.19
Gyrinidae	0.86	0.00	1.91	2.07	3.68	33.87
Orthocladininae	1.34	0.59	1.80	1.15	3.47	37.35
Dytiscidae	0.32	0.89	1.67	1.36	3.23	40.57
Leptoceridae	1.26	0.78	1.67	1.21	3.22	43.79
Baetidae	0.68	0.92	1.64	1.45	3.16	46.95
Caenidae	0.79	0.16	1.58	1.29	3.05	50.00
Hemicorduliidae	0.59	0.44	1.47	1.06	2.84	52.84
Oligochaeta	1.49	1.77	1.31	1.02	2.53	55.37
Calamoceratidae	1.02	0.68	1.28	1.16	2.46	57.83
Tricladida	0.54	0.20	1.22	0.99	2.35	60.19
Tanypodininae	2.01	2.29	1.16	1.52	2.24	62.43
Elmidae (adult)	0.55	0.00	1.14	0.97	2.21	64.64
Coenagrionidae	0.20	0.45	1.13	0.76	2.18	66.82
Gomphidae	0.39	0.16	0.98	0.79	1.88	68.70
Ceinidae	0.40	0.00	0.88	0.66	1.70	70.40
Nemertea	0.16	0.33	0.82	0.78	1.59	71.99
Dytiscidae (adult)	0.00	0.36	0.76	0.69	1.46	73.45
Polycentropodidae	0.36	0.00	0.75	0.69	1.45	74.90
Telephlebiidae	0.33	0.00	0.75	0.69	1.44	76.34
Hydrophilidae	0.33	0.00	0.73	0.69	1.41	77.75
Synlestidae	0.32	0.00	0.72	0.69	1.38	79.13
Hydrophilidae(adult)	0.31	0.00	0.67	0.68	1.30	80.43
Odontoceridae	0.32	0.00	0.67	0.68	1.29	81.72
Tipulidae	0.15	0.20	0.67	0.62	1.29	83.00
Physidae	0.00	0.33	0.65	0.70	1.25	84.26
Parastacidae	0.00	0.33	0.65	0.70	1.25	85.51

Nematoda	0.13	0.20	0.63	0.61	1.22	86.73
Corixidae	0.00	0.29	0.63	0.69	1.21	87.94
Hydrobiosidae	0.29	0.00	0.63	0.69	1.21	89.15
Magapodagrionidae	0.16	0.13	0.54	0.63	1.05	90.20

Groups CBR & CCC
Average dissimilarity = 48.97

Species	Group CBR Av.Abund	Group CCC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chironominae	2.05	3.70	4.29	1.96	8.76	8.76
Elmidae	1.28	0.00	3.09	1.83	6.32	15.07
Atyidae	0.98	0.00	2.43	1.96	4.96	20.03
Leptophlebiidae	2.44	1.50	2.38	1.73	4.86	24.89
Sphaeriidae	1.03	0.16	2.36	1.32	4.82	29.71
Ecnomidae	1.27	0.39	2.30	1.67	4.69	34.40
Oligochaeta	2.11	1.77	2.25	1.41	4.59	38.99
Baetidae	0.90	0.92	2.03	1.41	4.15	43.14
Dytiscidae	0.16	0.89	2.03	1.29	4.14	47.28
Leptoceridae	0.87	0.78	1.71	1.17	3.49	50.77
Ceratopogonidae	1.09	1.70	1.67	1.22	3.42	54.19
Orthocladininae	0.69	0.59	1.55	1.27	3.17	57.36
Calamoceratidae	0.32	0.68	1.44	1.16	2.93	60.29
Hemicorduliidae	0.25	0.44	1.36	0.97	2.77	63.06
Tanypodininae	2.17	2.29	1.35	1.57	2.76	65.82
Caenidae	0.51	0.16	1.25	1.00	2.55	68.37
Coenagrionidae	0.15	0.45	1.23	0.75	2.51	70.88
Ceinidae	0.52	0.00	1.16	0.69	2.37	73.25
Gripopterygidae	0.41	0.00	1.09	0.63	2.22	75.47
Tricladida	0.30	0.20	0.96	0.82	1.96	77.43
Dytiscidae (adult)	0.00	0.36	0.85	0.69	1.74	79.17
Nemertea	0.00	0.33	0.78	0.69	1.60	80.77
Sialidae	0.28	0.00	0.74	0.69	1.50	82.27
Tipulidae	0.13	0.20	0.73	0.62	1.48	83.75
Physidae	0.00	0.33	0.72	0.69	1.47	85.23
Parastacidae	0.00	0.33	0.72	0.69	1.47	86.70
Corixidae	0.00	0.29	0.71	0.69	1.44	88.15
Gomphidae	0.16	0.16	0.68	0.60	1.39	89.53
Nematoda	0.00	0.20	0.51	0.44	1.04	90.57

Groups CMC & CCC
Average dissimilarity = 44.91

Species	Group CMC Av.Abund	Group CCC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chironominae	2.61	3.70	3.04	1.52	6.77	6.77
Leptophlebiidae	2.64	1.50	3.02	1.85	6.74	13.50
Orthocladininae	1.63	0.59	2.89	1.53	6.44	19.94
Ceratopogonidae	0.66	1.70	2.80	1.66	6.24	26.18
Baetidae	0.16	0.92	2.15	1.27	4.80	30.98
Ecnomidae	1.10	0.39	2.08	1.46	4.63	35.61
Oligochaeta	1.64	1.77	1.95	1.06	4.35	39.96
Dytiscidae	0.78	0.89	1.80	1.23	4.02	43.98
Calamoceratidae	0.13	0.68	1.69	1.30	3.77	47.75
Leptoceridae	0.87	0.78	1.50	1.18	3.34	51.09
Synthemistidae	0.51	0.00	1.41	0.94	3.14	54.23
Hemicorduliidae	0.13	0.44	1.32	0.79	2.93	57.16
Tanypodininae	2.29	2.29	1.21	1.55	2.70	59.85
Coenagrionidae	0.00	0.45	1.15	0.64	2.56	62.42
Tipulidae	0.32	0.20	1.13	0.76	2.51	64.93
Dytiscidae (adult)	0.15	0.36	1.03	0.80	2.29	67.21
Magapodagrionidae	0.33	0.13	1.03	0.82	2.29	69.50
Caenidae	0.29	0.16	0.94	0.78	2.09	71.59
Hydroptilidae	0.29	0.16	0.94	0.77	2.08	73.68
Gripopterygidae	0.39	0.00	0.92	0.64	2.04	75.72

Polycentropodidae	0.33	0.00	0.88	0.69	1.96	77.68
Tricladida	0.25	0.20	0.88	0.81	1.95	79.63
Gyrinidae	0.34	0.00	0.86	0.69	1.91	81.54
Nemertea	0.00	0.33	0.82	0.69	1.84	83.38
Elmidae (adult)	0.33	0.00	0.79	0.69	1.77	85.14
Physidae	0.00	0.33	0.76	0.69	1.68	86.83
Parastacidae	0.00	0.33	0.76	0.69	1.68	88.51
Corixidae	0.00	0.29	0.75	0.69	1.66	90.17

Groups CWC & CSQC
Average dissimilarity = 54.62

	Group CWC	Group CSQC				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Leptophlebiidae	3.17	1.66	4.99	1.74	9.13	9.13
Chironominae	1.94	3.23	3.96	1.53	7.26	16.39
Oligochaeta	0.86	1.12	3.02	1.36	5.54	21.92
Dytiscidae	0.00	0.95	2.94	1.64	5.38	27.30
Orthocladininae	0.16	1.04	2.90	1.73	5.31	32.62
Atyidae	0.00	0.85	2.74	1.92	5.02	37.64
Leptoceridae	0.35	0.87	2.48	1.25	4.53	42.17
Ceratopogonidae	0.41	0.93	2.43	1.45	4.45	46.62
Ancylidae	0.64	0.16	2.06	1.01	3.78	50.40
Tricladida	0.50	0.36	2.05	0.89	3.75	54.15
Dytiscidae (adult)	0.64	0.38	1.98	1.24	3.62	57.77
Ecnomidae	0.41	0.40	1.82	0.89	3.34	61.11
Tanypodininae	1.62	1.97	1.79	1.37	3.28	64.39
Psephenidae	0.20	0.48	1.71	1.01	3.13	67.52
Corixidae	0.00	0.46	1.53	0.94	2.80	70.32
Chorismagrionidae	0.00	0.47	1.50	0.95	2.74	73.06
Gyrinidae	0.29	0.43	1.41	1.04	2.58	75.64
Culicidae	0.15	0.38	1.24	0.79	2.26	77.90
Tipulidae	0.16	0.30	1.17	0.79	2.14	80.05
Scirtidae	0.32	0.13	1.15	0.81	2.10	82.15
Baetidae	0.00	0.37	1.13	0.68	2.08	84.22
Magapodagrionidae	0.13	0.34	1.10	0.83	2.01	86.23
Sphaeriidae	0.00	0.34	1.04	0.69	1.90	88.14
Caenidae	0.00	0.34	1.02	0.70	1.87	90.01

Groups CC & CSQC
Average dissimilarity = 41.14

	Group CC	Group CSQC				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Oligochaeta	1.96	1.12	2.53	1.40	6.15	6.15
Chironominae	2.60	3.23	2.30	1.32	5.60	11.75
Psephenidae	1.25	0.48	2.02	1.47	4.91	16.66
Baetidae	0.91	0.37	2.02	1.37	4.91	21.57
Sphaeriidae	0.76	0.34	1.98	1.14	4.82	26.39
Ecnomidae	0.73	0.40	1.83	1.12	4.44	30.83
Leptoceridae	0.95	0.87	1.81	1.25	4.39	35.22
Ceratopogonidae	0.57	0.93	1.76	1.19	4.28	39.50
Dytiscidae	0.62	0.95	1.66	1.18	4.03	43.53
Orthocladininae	0.78	1.04	1.61	1.04	3.91	47.45
Atyidae	0.55	0.85	1.60	1.22	3.89	51.34
Caenidae	0.63	0.34	1.54	1.15	3.74	55.08
Tricladida	0.42	0.36	1.43	0.94	3.48	58.55
Tanypodininae	2.00	1.97	1.40	1.52	3.39	61.95
Corixidae	0.33	0.46	1.39	1.06	3.37	65.32
Leptophlebiidae	1.99	1.66	1.27	1.51	3.09	68.41
Chorismagrionidae	0.13	0.47	1.26	0.99	3.05	71.46
Tipulidae	0.35	0.30	1.18	0.91	2.87	74.33
Ceinidae	0.44	0.00	1.08	0.67	2.64	76.97
Gyrinidae	0.00	0.43	1.05	0.97	2.56	79.53
Dytiscidae (adult)	0.00	0.38	1.03	0.69	2.52	82.04

Culicidae	0.00	0.38	0.87	0.65	2.11	84.16
Magapodagrionidae	0.00	0.34	0.79	0.69	1.92	86.08
Coenagrionidae	0.16	0.15	0.66	0.61	1.60	87.68
Scirtidae	0.15	0.13	0.65	0.62	1.58	89.25
Nemertea	0.16	0.00	0.50	0.44	1.22	90.47

Groups DC & CSQC
Average dissimilarity = 49.05

Species	Group DC Av.Abund	Group CSQC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Orthocladininae	0.00	1.04	3.42	2.00	6.97	6.97
Atyidae	0.00	0.85	2.92	1.87	5.95	12.91
Chironominae	2.45	3.23	2.91	1.17	5.93	18.85
Ceratopogonidae	0.71	0.93	2.76	1.37	5.62	24.47
Tanypodininae	1.20	1.97	2.73	1.68	5.56	30.03
Dytiscidae	0.28	0.95	2.61	1.35	5.33	35.36
Leptoceridae	0.25	0.87	2.60	1.28	5.29	40.65
Oligochaeta	0.96	1.12	2.12	1.15	4.32	44.97
Baetidae	0.50	0.37	1.90	1.02	3.87	48.84
Corixidae	0.51	0.46	1.78	1.06	3.62	52.46
Psephenidae	0.13	0.48	1.71	0.98	3.49	55.95
Chorismagrionidae	0.00	0.47	1.59	0.95	3.24	59.18
Caenidae	0.40	0.34	1.58	1.09	3.22	62.40
Dytiscidae (adult)	0.25	0.38	1.57	0.92	3.20	65.60
Tipulidae	0.24	0.30	1.42	0.82	2.90	68.50
Leptophlebiidae	1.79	1.66	1.35	1.41	2.76	71.26
Gyrinidae	0.13	0.43	1.35	1.00	2.76	74.02
Culicidae	0.13	0.38	1.27	0.78	2.58	76.60
Ancylidae	0.28	0.16	1.17	0.80	2.38	78.98
Parastacidae	0.29	0.13	1.14	0.77	2.33	81.31
Ecnomidae	0.00	0.40	1.14	0.69	2.32	83.63
Tricladida	0.00	0.36	1.11	0.69	2.27	85.90
Sphaeriidae	0.00	0.34	1.10	0.69	2.25	88.15
Magapodagrionidae	0.00	0.34	0.97	0.69	1.97	90.12

Groups EC & CSQC
Average dissimilarity = 52.32

Species	Group EC Av.Abund	Group CSQC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chironominae	2.32	3.23	3.43	1.51	6.56	6.56
Dytiscidae	0.00	0.95	2.68	1.56	5.12	11.68
Tanypodininae	1.66	1.97	2.65	1.03	5.06	16.74
Atyidae	0.00	0.85	2.49	1.78	4.76	21.50
Oligochaeta	1.61	1.12	2.34	1.08	4.48	25.98
Leptoceridae	0.29	0.87	2.25	1.19	4.31	30.29
Orthocladininae	0.92	1.04	2.22	1.21	4.24	34.53
Ceratopogonidae	0.64	0.93	2.14	1.27	4.10	38.63
Ecnomidae	0.64	0.40	1.79	1.04	3.41	42.04
Leptophlebiidae	2.12	1.66	1.71	1.56	3.27	45.31
Parastacidae	0.50	0.13	1.60	0.96	3.06	48.37
Psephenidae	0.49	0.48	1.56	1.05	2.98	51.35
Culicidae	0.28	0.38	1.43	0.75	2.74	54.08
Magapodagrionidae	0.49	0.34	1.42	1.02	2.72	56.80
Corixidae	0.00	0.46	1.39	0.91	2.65	59.45
Gomphidae	0.53	0.00	1.37	0.95	2.62	62.08
Baetidae	0.28	0.37	1.37	0.95	2.61	64.69
Chorismagrionidae	0.00	0.47	1.36	0.93	2.60	67.29
Sphaeriidae	0.32	0.34	1.29	0.93	2.46	69.75
Caenidae	0.32	0.34	1.28	0.91	2.44	72.19
Gyrinidae	0.15	0.43	1.20	1.00	2.30	74.49
Tipulidae	0.20	0.30	1.16	0.79	2.22	76.70
Tricladida	0.16	0.36	1.16	0.80	2.22	78.92
Dytiscidae (adult)	0.00	0.38	1.13	0.67	2.15	81.07

Synthemistidae	0.35	0.13	1.11	0.75	2.13	83.20
Scirtidae	0.30	0.13	0.97	0.78	1.86	85.06
Polycentropodidae	0.29	0.00	0.76	0.68	1.46	86.51
Empididae	0.13	0.16	0.69	0.60	1.32	87.83
Calamoceratidae	0.15	0.13	0.65	0.61	1.24	89.07
Dolichopodidae	0.21	0.00	0.62	0.44	1.18	90.25

Groups TTH & CSQC
Average dissimilarity = 44.79

	Group TTH	Group CSQC				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chironominae	3.10	3.23	2.44	1.28	5.46	5.46
Atyidae	0.00	0.85	2.41	1.93	5.38	10.83
Leptoceridae	0.16	0.87	2.27	1.26	5.08	15.91
Oligochaeta	1.34	1.12	2.27	1.32	5.06	20.97
Baetidae	0.82	0.37	2.17	1.16	4.84	25.81
Ecnomidae	0.78	0.40	2.16	1.05	4.82	30.62
Caenidae	0.84	0.34	2.13	1.11	4.76	35.38
Tanypodininae	2.13	1.97	1.97	1.36	4.41	39.79
Corixidae	0.63	0.46	1.89	1.21	4.22	44.01
Dytiscidae	0.66	0.95	1.74	1.21	3.89	47.90
Ceratopogonidae	0.84	0.93	1.69	1.15	3.76	51.66
Tipulidae	0.60	0.30	1.68	1.08	3.76	55.42
Orthocladininae	0.77	1.04	1.62	0.98	3.62	59.04
Psephenidae	0.13	0.48	1.41	1.00	3.14	62.18
Chorismagrionidae	0.15	0.47	1.35	1.00	3.01	65.19
Dytiscidae (adult)	0.28	0.38	1.35	0.95	3.01	68.20
Culicidae	0.29	0.38	1.30	0.94	2.89	71.10
Gyrinidae	0.13	0.43	1.14	1.00	2.54	73.64
Leptophlebiidae	1.59	1.66	1.08	1.49	2.41	76.05
Gomphidae	0.34	0.00	0.94	0.67	2.10	78.14
Tricladida	0.00	0.36	0.93	0.68	2.08	80.23
Sphaeriidae	0.00	0.34	0.92	0.69	2.05	82.28
Magapodagrionidae	0.00	0.34	0.83	0.70	1.84	84.12
Notonectidae	0.28	0.00	0.80	0.68	1.78	85.89
Scirtidae	0.13	0.13	0.62	0.61	1.38	87.27
Parastacidae	0.13	0.13	0.57	0.60	1.27	88.54
Empididae	0.00	0.16	0.46	0.44	1.04	89.58
Nematoda	0.16	0.00	0.46	0.44	1.02	90.59

Groups HC & CSQC
Average dissimilarity = 53.53

	Group HC	Group CSQC				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Leptophlebiidae	0.16	1.66	4.67	3.48	8.73	8.73
Orthocladininae	1.85	1.04	2.88	1.02	5.38	14.12
Ceratopogonidae	0.24	0.93	2.72	1.70	5.09	19.20
Atyidae	0.00	0.85	2.70	1.90	5.04	24.25
Leptoceridae	0.13	0.87	2.54	1.24	4.75	29.00
Chironominae	3.31	3.23	2.54	1.48	4.74	33.74
Oligochaeta	0.84	1.12	2.50	1.28	4.67	38.41
Dytiscidae	0.33	0.95	2.42	1.38	4.52	42.93
Sphaeriidae	0.58	0.34	1.85	1.12	3.46	46.39
Tanypodininae	1.67	1.97	1.78	1.47	3.32	49.71
Ecnomidae	0.48	0.40	1.77	1.07	3.30	53.02
Dytiscidae (adult)	0.49	0.38	1.75	1.05	3.27	56.29
Tricladida	0.41	0.36	1.67	0.95	3.12	59.41
Baetidae	0.38	0.37	1.61	0.89	3.01	62.42
Psephenidae	0.00	0.48	1.60	0.95	2.98	65.40
Corixidae	0.00	0.46	1.51	0.93	2.82	68.21
Chorismagrionidae	0.00	0.47	1.47	0.95	2.75	70.97
Tipulidae	0.29	0.30	1.28	0.90	2.39	73.36
Gyrinidae	0.00	0.43	1.22	0.97	2.28	75.64

Hemicorduliidae	0.38	0.00	1.21	0.68	2.27	77.90
Coenagrionidae	0.32	0.15	1.16	0.77	2.16	80.06
Caenidae	0.13	0.34	1.15	0.82	2.15	82.22
Culicidae	0.00	0.38	1.00	0.65	1.86	84.08
Magapodagrionidae	0.00	0.34	0.91	0.70	1.69	85.78
Podinae	0.24	0.00	0.85	0.44	1.58	87.36
Hydrophilidae	0.23	0.00	0.68	0.44	1.27	88.63
Cordulephyidae	0.18	0.00	0.57	0.44	1.06	89.69
Nematoda	0.17	0.00	0.53	0.44	0.99	90.68

Groups BR & CSQC
Average dissimilarity = 52.24

	Group BR	Group CSQC				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chironominae	2.01	3.23	2.93	1.57	5.61	5.61
Elmidae	1.25	0.00	2.83	3.83	5.41	11.02
Leptophlebiidae	2.79	1.66	2.58	2.45	4.93	15.95
Ecnomidae	1.26	0.40	2.16	1.61	4.14	20.10
Calamoceratidae	1.02	0.13	2.08	1.88	3.99	24.09
Ceratopogonidae	0.80	0.93	1.83	1.60	3.51	27.60
Leptoceridae	1.26	0.87	1.78	1.23	3.42	31.01
Sphaeriidae	0.97	0.34	1.78	1.54	3.41	34.42
Dytiscidae	0.32	0.95	1.71	1.42	3.27	37.70
Atyidae	0.16	0.85	1.69	1.60	3.23	40.93
Caenidae	0.79	0.34	1.51	1.21	2.89	43.82
Baetidae	0.68	0.37	1.42	1.20	2.72	46.54
Oligochaeta	1.49	1.12	1.41	1.35	2.69	49.23
Gyrinidae	0.86	0.43	1.37	1.26	2.62	51.85
Tricladida	0.54	0.36	1.31	1.13	2.51	54.36
Hemicorduliidae	0.59	0.00	1.31	0.92	2.51	56.87
Tanypodininae	2.01	1.97	1.19	1.44	2.28	59.15
Elmidae (adult)	0.55	0.00	1.16	0.97	2.23	61.37
Chorismagrionidae	0.20	0.47	1.14	1.01	2.18	63.56
Psephenidae	0.14	0.48	1.12	1.01	2.15	65.71
Corixidae	0.00	0.46	1.06	0.94	2.03	67.74
Orthocladininae	1.34	1.04	1.03	0.79	1.98	69.72
Ceinidae	0.40	0.00	0.90	0.66	1.72	71.44
Gomphidae	0.39	0.00	0.88	0.69	1.69	73.12
Dytiscidae (adult)	0.00	0.38	0.87	0.69	1.66	74.79
Magapodagrionidae	0.16	0.34	0.81	0.79	1.56	76.35
Tipulidae	0.15	0.30	0.79	0.78	1.51	77.85
Polycentropodidae	0.36	0.00	0.76	0.69	1.46	79.31
Telephlebiidae	0.33	0.00	0.76	0.69	1.46	80.77
Culicidae	0.00	0.38	0.75	0.65	1.43	82.20
Hydrophilidae	0.33	0.00	0.74	0.69	1.42	83.62
Synlestidae	0.32	0.00	0.73	0.69	1.40	85.02
Hydrophilidae(adult)	0.31	0.00	0.68	0.68	1.31	86.33
Odontoceridae	0.32	0.00	0.68	0.68	1.30	87.63
Hydrobiosidae	0.29	0.00	0.64	0.69	1.22	88.85
Coenagrionidae	0.20	0.15	0.60	0.62	1.15	89.99
Scirtidae	0.14	0.13	0.55	0.61	1.04	91.03

Groups CBR & CSQC
Average dissimilarity = 48.94

	Group CBR	Group CSQC				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chironominae	2.05	3.23	3.40	1.55	6.96	6.96
Elmidae	1.28	0.00	3.15	1.81	6.44	13.39
Oligochaeta	2.11	1.12	2.70	1.27	5.51	18.90
Ecnomidae	1.27	0.40	2.42	1.61	4.95	23.86
Sphaeriidae	1.03	0.34	2.32	1.36	4.73	28.59
Dytiscidae	0.16	0.95	2.19	1.45	4.47	33.06
Leptophlebiidae	2.44	1.66	2.00	2.42	4.09	37.15

Leptoceridae	0.87	0.87	1.94	1.27	3.95	41.11
Baetidae	0.90	0.37	1.93	1.24	3.95	45.06
Orthocladininae	0.69	1.04	1.61	1.25	3.28	48.34
Tanypodininae	2.17	1.97	1.53	1.46	3.12	51.46
Ceratopogonidae	1.09	0.93	1.41	1.14	2.89	54.35
Caenidae	0.51	0.34	1.32	1.03	2.70	57.05
Psephenidae	0.00	0.48	1.28	0.94	2.61	59.65
Corixidae	0.00	0.46	1.20	0.94	2.46	62.11
Chorismagrionidae	0.00	0.47	1.19	0.95	2.43	64.54
Ceinidae	0.52	0.00	1.18	0.69	2.41	66.95
Atyidae	0.98	0.85	1.17	1.00	2.40	69.35
Tricladida	0.30	0.36	1.16	0.96	2.37	71.72
Gripopterygidae	0.41	0.00	1.11	0.63	2.27	73.99
Gyrinidae	0.16	0.43	1.07	1.02	2.20	76.18
Dytiscidae (adult)	0.00	0.38	0.98	0.68	2.01	78.19
Calamoceratidae	0.32	0.13	0.93	0.81	1.91	80.10
Tipulidae	0.13	0.30	0.87	0.80	1.79	81.88
Culicidae	0.00	0.38	0.83	0.65	1.70	83.58
Magapodagrionidae	0.00	0.34	0.75	0.69	1.54	85.12
Sialidae	0.28	0.00	0.75	0.69	1.53	86.65
Hemicorduliidae	0.25	0.00	0.68	0.69	1.39	88.04
Coenagrionidae	0.15	0.15	0.60	0.60	1.23	89.27
Gomphidae	0.16	0.00	0.46	0.44	0.94	90.21

Groups CMC & CSQC
Average dissimilarity = 44.46

Species	Group CMC Av.Abund	Group CSQC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Leptophlebiidae	2.64	1.66	2.57	1.91	5.79	5.79
Chironominae	2.61	3.23	2.36	1.25	5.30	11.09
Atyidae	0.00	0.85	2.29	1.90	5.16	16.25
Ecnomidae	1.10	0.40	2.24	1.47	5.05	21.30
Oligochaeta	1.64	1.12	2.15	1.28	4.84	26.14
Orthocladininae	1.63	1.04	1.96	1.18	4.41	30.55
Leptoceridae	0.87	0.87	1.82	1.41	4.09	34.64
Dytiscidae	0.78	0.95	1.77	1.24	3.99	38.63
Tanypodininae	2.29	1.97	1.65	1.45	3.72	42.35
Ceratopogonidae	0.66	0.93	1.55	1.11	3.49	45.85
Synthemistidae	0.51	0.13	1.43	1.00	3.21	49.06
Psephenidae	0.00	0.48	1.35	0.94	3.04	52.10
Corixidae	0.00	0.46	1.27	0.93	2.86	54.96
Gyrinidae	0.34	0.43	1.27	1.07	2.85	57.81
Chorismagrionidae	0.00	0.47	1.26	0.95	2.83	60.64
Tipulidae	0.32	0.30	1.21	0.89	2.72	63.36
Magapodagrionidae	0.33	0.34	1.19	0.88	2.69	66.05
Caenidae	0.29	0.34	1.17	0.91	2.63	68.67
Dytiscidae (adult)	0.15	0.38	1.16	0.79	2.61	71.28
Baetidae	0.16	0.37	1.15	0.79	2.58	73.86
Tricladida	0.25	0.36	1.11	0.91	2.49	76.34
Sphaeriidae	0.13	0.34	0.98	0.80	2.21	78.55
Gripopterygidae	0.39	0.00	0.93	0.64	2.10	80.65
Polycentropodidae	0.33	0.00	0.90	0.69	2.02	82.68
Culicidae	0.00	0.38	0.87	0.65	1.96	84.64
Elmidae (adult)	0.33	0.00	0.81	0.69	1.82	86.45
Hydroptilidae	0.29	0.00	0.76	0.67	1.70	88.15
Calamoceratidae	0.13	0.13	0.57	0.61	1.27	89.43
Acarina	0.16	0.00	0.46	0.44	1.04	90.47

Groups CCC & CSQC
Average dissimilarity = 44.55

Species	Group CCC Av.Abund	Group CSQC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chironominae	3.70	3.23	2.63	1.45	5.89	5.89

Oligochaeta	1.77	1.12	2.48	1.18	5.56	11.45
Atyidae	0.00	0.85	2.28	1.90	5.11	16.56
Baetidae	0.92	0.37	2.15	1.27	4.83	21.39
Ceratopogonidae	1.70	0.93	2.09	1.49	4.70	26.09
Dytiscidae	0.89	0.95	1.92	1.31	4.30	30.39
Leptoceridae	0.78	0.87	1.90	1.23	4.27	34.66
Orthocladininae	0.59	1.04	1.81	1.07	4.07	38.73
Tanypodininae	2.29	1.97	1.78	1.47	3.99	42.72
Calamoceratidae	0.68	0.13	1.71	1.31	3.84	46.56
Ecnomidae	0.39	0.40	1.36	0.88	3.05	49.61
Dytiscidae (adult)	0.36	0.38	1.35	0.91	3.03	52.64
Psephenidae	0.00	0.48	1.34	0.94	3.01	55.65
Coenagrionidae	0.45	0.15	1.29	0.73	2.89	58.54
Corixidae	0.29	0.46	1.27	1.02	2.86	61.40
Leptophlebiidae	1.50	1.66	1.26	1.57	2.84	64.24
Chorismagrionidae	0.00	0.47	1.25	0.95	2.80	67.04
Hemicorduliidae	0.44	0.00	1.24	0.68	2.78	69.82
Tricladida	0.20	0.36	1.11	0.81	2.49	72.31
Culicidae	0.16	0.38	1.09	0.79	2.45	74.77
Tipulidae	0.20	0.30	1.07	0.80	2.39	77.16
Sphaeriidae	0.16	0.34	1.06	0.82	2.38	79.54
Gyrinidae	0.00	0.43	1.05	0.96	2.35	81.90
Caenidae	0.16	0.34	1.01	0.79	2.26	84.15
Magapodagrionidae	0.13	0.34	0.95	0.83	2.14	86.29
Parastacidae	0.33	0.13	0.88	0.81	1.98	88.27
Nemertea	0.33	0.00	0.84	0.69	1.87	90.14

Groups CWC & DTC
Average dissimilarity = 54.72

Species	Group CWC Av.Abund	Group DTC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Leptophlebiidae	3.17	1.95	4.46	1.55	8.15	8.15
Baetidae	0.00	1.16	3.98	3.05	7.27	15.41
Dytiscidae	0.00	0.95	3.18	1.62	5.81	21.23
Oligochaeta	0.86	1.06	2.97	1.80	5.42	26.65
Chironominae	1.94	2.81	2.85	1.35	5.22	31.87
Caenidae	0.00	0.93	2.84	1.60	5.19	37.06
Ceratopogonidae	0.41	0.98	2.76	1.34	5.05	42.11
Ecnomidae	0.41	0.68	2.35	1.07	4.29	46.40
Parastacidae	0.00	0.71	2.19	1.67	4.00	50.39
Ancylidae	0.64	0.00	2.18	0.95	3.99	54.38
Dytiscidae (adult)	0.64	0.57	2.09	1.35	3.82	58.20
Orthocladininae	0.16	0.67	2.08	1.03	3.80	62.00
Tricladida	0.50	0.00	1.76	0.63	3.21	65.22
Tipulidae	0.16	0.55	1.70	1.00	3.10	68.32
Gomphidae	0.00	0.42	1.45	0.89	2.65	70.96
Scirtidae	0.32	0.27	1.44	0.84	2.63	73.59
Synthemistidae	0.00	0.44	1.31	0.98	2.39	75.98
Tanypodininae	1.62	1.39	1.27	1.19	2.33	78.31
Leptoceridae	0.35	0.00	1.17	0.68	2.13	80.44
Psephenidae	0.20	0.25	1.10	0.68	2.01	82.45
Gyrinidae	0.29	0.00	0.98	0.67	1.79	84.24
Notonectidae	0.16	0.19	0.91	0.66	1.67	85.91
Sphaeriidae	0.00	0.25	0.86	0.56	1.57	87.48
Hydraenidae	0.00	0.25	0.86	0.56	1.57	89.04
Nematoda	0.22	0.00	0.77	0.43	1.41	90.46

Groups CC & DTC
Average dissimilarity = 44.45

Species	Group CC Av.Abund	Group DTC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Psephenidae	1.25	0.25	2.95	1.92	6.63	6.63
Leptoceridae	0.95	0.00	2.59	1.93	5.82	12.45

Oligochaeta	1.96	1.06	2.44	1.65	5.48	17.93
Ceratopogonidae	0.57	0.98	2.18	1.34	4.91	22.84
Sphaeriidae	0.76	0.25	2.03	1.05	4.58	27.42
Ecnomidae	0.73	0.68	2.00	1.23	4.50	31.92
Orthocladininae	0.78	0.67	1.95	1.08	4.39	36.31
Chironominae	2.60	2.81	1.89	1.53	4.26	40.57
Parastacidae	0.00	0.71	1.84	1.65	4.14	44.71
Dytiscidae	0.62	0.95	1.77	1.28	3.97	48.68
Caenidae	0.63	0.93	1.73	1.23	3.89	52.57
Tanypodininae	2.00	1.39	1.70	1.65	3.83	56.40
Atyidae	0.55	0.00	1.56	0.92	3.52	59.91
Tipulidae	0.35	0.55	1.50	1.04	3.38	63.29
Dytiscidae (adult)	0.00	0.57	1.50	0.95	3.38	66.67
Baetidae	0.91	1.16	1.39	1.03	3.12	69.79
Leptophlebiidae	1.99	1.95	1.27	1.35	2.86	72.65
Gomphidae	0.13	0.42	1.19	0.93	2.67	75.33
Ceinidae	0.44	0.00	1.13	0.66	2.54	77.87
Tricladida	0.42	0.00	1.12	0.67	2.51	80.38
Synthemistidae	0.00	0.44	1.10	0.97	2.48	82.87
Scirtidae	0.15	0.27	0.97	0.70	2.18	85.05
Hydraenidae	0.13	0.25	0.88	0.70	1.99	87.03
Corixidae	0.33	0.00	0.88	0.65	1.97	89.00
Hemicorduliidae	0.13	0.19	0.66	0.67	1.49	90.49

Groups DC & DTC
Average dissimilarity = 45.04

Species	Group DC Av.Abund	Group DTC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Ceratopogonidae	0.71	0.98	3.22	1.37	7.15	7.15
Dytiscidae	0.28	0.95	2.91	1.45	6.45	13.60
Baetidae	0.50	1.16	2.83	1.33	6.27	19.88
Caenidae	0.40	0.93	2.48	1.37	5.50	25.38
Chironominae	2.45	2.81	2.42	1.55	5.37	30.75
Orthocladininae	0.00	0.67	2.13	0.94	4.73	35.47
Ecnomidae	0.00	0.68	2.09	0.97	4.64	40.12
Parastacidae	0.29	0.71	2.01	1.32	4.47	44.59
Tipulidae	0.24	0.55	1.96	1.02	4.35	48.94
Dytiscidae (adult)	0.25	0.57	1.92	1.06	4.26	53.20
Corixidae	0.51	0.00	1.83	0.94	4.06	57.26
Leptophlebiidae	1.79	1.95	1.62	1.48	3.60	60.86
Oligochaeta	0.96	1.06	1.56	1.30	3.46	64.32
Gomphidae	0.00	0.42	1.55	0.88	3.45	67.76
Tanypodininae	1.20	1.39	1.45	1.81	3.22	70.99
Psychodidae	0.26	0.23	1.40	0.72	3.10	74.09
Synthemistidae	0.00	0.44	1.38	0.97	3.07	77.16
Scirtidae	0.18	0.27	1.26	0.68	2.80	79.96
Ancylidae	0.28	0.00	1.02	0.68	2.28	82.23
Leptoceridae	0.25	0.00	0.96	0.68	2.13	84.36
Psephenidae	0.13	0.25	0.95	0.72	2.11	86.47
Sphaeriidae	0.00	0.25	0.91	0.56	2.03	88.50
Hydraenidae	0.00	0.25	0.91	0.56	2.03	90.52

Groups EC & DTC
Average dissimilarity = 48.86

Species	Group EC Av.Abund	Group DTC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Dytiscidae	0.00	0.95	2.88	1.51	5.90	5.90
Baetidae	0.28	1.16	2.68	1.82	5.49	11.39
Chironominae	2.32	2.81	2.66	1.32	5.44	16.84
Tanypodininae	1.66	1.39	2.66	1.40	5.44	22.28
Orthocladininae	0.92	0.67	2.46	1.17	5.04	27.32
Ceratopogonidae	0.64	0.98	2.44	1.18	4.99	32.30
Caenidae	0.32	0.93	2.33	1.35	4.77	37.07

Ecnomidae	0.64	0.68	2.12	1.12	4.35	41.41
Oligochaeta	1.61	1.06	1.96	0.95	4.00	45.42
Dytiscidae (adult)	0.00	0.57	1.64	0.93	3.35	48.77
Parastacidae	0.50	0.71	1.62	1.11	3.32	52.09
Gomphidae	0.53	0.42	1.61	1.06	3.30	55.39
Tipulidae	0.20	0.55	1.60	0.96	3.28	58.67
Leptophlebiidae	2.12	1.95	1.59	1.42	3.25	61.92
Synthemistidae	0.35	0.44	1.51	1.02	3.09	65.01
Psephenidae	0.49	0.25	1.42	1.00	2.91	67.91
Magapodagrionidae	0.49	0.00	1.32	0.92	2.71	70.62
Scirtidae	0.30	0.27	1.26	0.81	2.57	73.19
Sphaeriidae	0.32	0.25	1.20	0.81	2.46	75.66
Pyralidae	0.20	0.25	1.00	0.67	2.05	77.70
Hydraenidae	0.13	0.25	0.94	0.68	1.92	79.63
Culicidae	0.28	0.00	0.85	0.43	1.74	81.37
Leptoceridae	0.29	0.00	0.84	0.66	1.72	83.09
Polycentropodidae	0.29	0.00	0.80	0.67	1.63	84.72
Psychodidae	0.00	0.23	0.70	0.55	1.44	86.15
Notonectidae	0.13	0.19	0.66	0.68	1.34	87.50
Dolichopodidae	0.21	0.00	0.65	0.43	1.33	88.83
Glossiphoniidae	0.00	0.19	0.59	0.55	1.21	90.03

Groups TTH & DTC
Average dissimilarity = 42.12

Species	Group TTH Av.Abund	Group DTC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chironominae	3.10	2.81	2.38	1.26	5.65	5.65
Ecnomidae	0.78	0.68	2.38	1.15	5.64	11.29
Tanypodininae	2.13	1.39	2.25	1.17	5.35	16.64
Caenidae	0.84	0.93	2.24	1.24	5.33	21.97
Ceratopogonidae	0.84	0.98	2.19	1.26	5.20	27.17
Orthocladininae	0.77	0.67	2.02	1.13	4.79	31.96
Oligochaeta	1.34	1.06	1.98	1.41	4.69	36.65
Baetidae	0.82	1.16	1.96	1.36	4.66	41.31
Corixidae	0.63	0.00	1.95	0.88	4.63	45.94
Dytiscidae	0.66	0.95	1.82	1.26	4.33	50.26
Tipulidae	0.60	0.55	1.82	1.06	4.32	54.58
Parastacidae	0.13	0.71	1.78	1.49	4.22	58.80
Dytiscidae (adult)	0.28	0.57	1.63	1.12	3.86	62.66
Leptophlebiidae	1.59	1.95	1.53	1.28	3.62	66.28
Gomphidae	0.34	0.42	1.46	1.06	3.47	69.75
Synthemistidae	0.00	0.44	1.16	0.98	2.75	72.51
Scirtidae	0.13	0.27	0.99	0.71	2.34	74.85
Notonectidae	0.28	0.19	0.98	0.81	2.33	77.18
Culicidae	0.29	0.00	0.87	0.68	2.07	79.25
Psephenidae	0.13	0.25	0.83	0.72	1.97	81.22
Pyralidae	0.13	0.25	0.80	0.72	1.91	83.13
Sphaeriidae	0.00	0.25	0.75	0.56	1.78	84.90
Hydraenidae	0.00	0.25	0.75	0.56	1.78	86.68
Psychodidae	0.00	0.23	0.68	0.56	1.61	88.29
Glossiphoniidae	0.00	0.19	0.57	0.56	1.35	89.64
Leptoceridae	0.16	0.00	0.50	0.43	1.20	90.83

Groups HC & DTC
Average dissimilarity = 54.25

Species	Group HC Av.Abund	Group DTC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Leptophlebiidae	0.16	1.95	5.96	3.13	10.99	10.99
Orthocladininae	1.85	0.67	4.35	1.25	8.01	19.00
Baetidae	0.38	1.16	2.95	1.56	5.43	24.43
Ceratopogonidae	0.24	0.98	2.87	1.36	5.30	29.73
Chironominae	3.31	2.81	2.68	1.40	4.94	34.67
Caenidae	0.13	0.93	2.64	1.53	4.86	39.53

Dytiscidae	0.33	0.95	2.57	1.37	4.73	44.27
Ecnomidae	0.48	0.68	2.17	1.21	4.00	48.27
Oligochaeta	0.84	1.06	2.17	1.40	4.00	52.26
Parastacidae	0.00	0.71	2.16	1.66	3.97	56.24
Dytiscidae (adult)	0.49	0.57	2.00	1.25	3.68	59.92
Sphaeriidae	0.58	0.25	1.88	1.00	3.46	63.38
Tipulidae	0.29	0.55	1.71	1.07	3.16	66.54
Hemicorduliidae	0.38	0.19	1.45	0.81	2.67	69.20
Gomphidae	0.00	0.42	1.42	0.89	2.62	71.83
Tanypodininae	1.67	1.39	1.42	1.56	2.61	74.44
Tricladida	0.41	0.00	1.31	0.67	2.42	76.86
Synthemistidae	0.00	0.44	1.29	0.98	2.37	79.23
Coenagrionidae	0.32	0.00	1.06	0.65	1.95	81.18
Scirtidae	0.00	0.27	0.91	0.56	1.67	82.85
Podinae	0.24	0.00	0.90	0.43	1.66	84.52
Hydraenidae	0.00	0.25	0.84	0.56	1.55	86.07
Psychodidae	0.00	0.23	0.76	0.56	1.40	87.47
Hydrophilidae	0.23	0.00	0.72	0.43	1.32	88.80
Psephenidae	0.00	0.25	0.65	0.56	1.19	89.99
Glossiphoniidae	0.00	0.19	0.64	0.56	1.18	91.17

Groups BR & DTC
Average dissimilarity = 54.10

Species	Group BR Av.Abund	Group DTC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Leptoceridae	1.26	0.00	2.98	1.96	5.51	5.51
Elmidae	1.25	0.00	2.94	3.67	5.43	10.93
Calamoceratidae	1.02	0.00	2.36	2.00	4.37	15.30
Chironominae	2.01	2.81	2.21	1.53	4.09	19.38
Gyrinidae	0.86	0.00	2.02	2.01	3.73	23.11
Orthocladininae	1.34	0.67	1.99	1.22	3.69	26.80
Leptophlebiidae	2.79	1.95	1.99	1.64	3.68	30.48
Ceratopogonidae	0.80	0.98	1.96	1.24	3.63	34.11
Ecnomidae	1.26	0.68	1.96	1.40	3.63	37.74
Sphaeriidae	0.97	0.25	1.90	1.47	3.51	41.25
Dytiscidae	0.32	0.95	1.79	1.46	3.31	44.56
Caenidae	0.79	0.93	1.59	1.23	2.93	47.49
Parastacidae	0.00	0.71	1.55	1.65	2.87	50.36
Tanypodininae	2.01	1.39	1.44	1.62	2.67	53.03
Hemicorduliidae	0.59	0.19	1.37	0.98	2.53	55.56
Baetidae	0.68	1.16	1.29	1.23	2.39	57.95
Dytiscidae (adult)	0.00	0.57	1.26	0.94	2.33	60.28
Tricladida	0.54	0.00	1.25	0.95	2.32	62.60
Gomphidae	0.39	0.42	1.25	1.10	2.31	64.91
Elmidae (adult)	0.55	0.00	1.20	0.96	2.23	67.13
Tipulidae	0.15	0.55	1.20	1.02	2.21	69.34
Oligochaeta	1.49	1.06	1.01	1.49	1.87	71.22
Synthemistidae	0.00	0.44	0.94	0.97	1.73	72.95
Ceinidae	0.40	0.00	0.93	0.65	1.72	74.67
Scirtidae	0.14	0.27	0.82	0.72	1.51	76.18
Telephlebiidae	0.33	0.00	0.79	0.68	1.46	77.65
Polycentropodidae	0.36	0.00	0.79	0.69	1.46	79.11
Hydrophilidae	0.33	0.00	0.77	0.69	1.42	80.53
Synlestidae	0.32	0.00	0.76	0.68	1.40	81.93
Hydrophilidae(adult)	0.31	0.00	0.71	0.67	1.31	83.25
Psephenidae	0.14	0.25	0.71	0.70	1.30	84.55
Odontoceridae	0.32	0.00	0.70	0.67	1.30	85.85
Glossiphoniidae	0.16	0.19	0.67	0.71	1.24	87.10
Hydrobiosidae	0.29	0.00	0.66	0.68	1.22	88.32
Notonectidae	0.14	0.19	0.60	0.67	1.12	89.43
Hydraenidae	0.00	0.25	0.59	0.56	1.09	90.53

Groups CBR & DTC
Average dissimilarity = 51.12

Species	Group CBR Av.Abund	Group DTC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Elmidae	1.28	0.00	3.29	1.78	6.43	6.43
Chironominae	2.05	2.81	2.67	1.58	5.22	11.65
Oligochaeta	2.11	1.06	2.65	1.41	5.19	16.84
Atyidae	0.98	0.00	2.59	1.90	5.06	21.91
Sphaeriidae	1.03	0.25	2.44	1.29	4.78	26.69
Leptoceridae	0.87	0.00	2.42	1.24	4.73	31.42
Dytiscidae	0.16	0.95	2.32	1.44	4.53	35.95
Ecnomidae	1.27	0.68	2.25	1.46	4.40	40.35
Tanypodininae	2.17	1.39	2.02	1.68	3.96	44.31
Ceratopogonidae	1.09	0.98	1.91	1.24	3.74	48.05
Caenidae	0.51	0.93	1.82	1.26	3.56	51.61
Orthocladininae	0.69	0.67	1.80	1.31	3.52	55.13
Parastacidae	0.00	0.71	1.75	1.64	3.42	58.55
Baetidae	0.90	1.16	1.64	1.14	3.21	61.76
Leptophlebiidae	2.44	1.95	1.45	1.61	2.83	64.59
Dytiscidae (adult)	0.00	0.57	1.42	0.95	2.79	67.37
Tipulidae	0.13	0.55	1.34	1.06	2.63	70.00
Ceinidae	0.52	0.00	1.23	0.68	2.40	72.40
Gomphidae	0.16	0.42	1.19	0.96	2.33	74.73
Gripopterygidae	0.41	0.00	1.16	0.62	2.27	77.01
Synthemistidae	0.00	0.44	1.05	0.97	2.06	79.06
Calamoceratidae	0.32	0.00	0.87	0.68	1.70	80.76
Hemicorduliidae	0.25	0.19	0.84	0.80	1.64	82.40
Tricladida	0.30	0.00	0.79	0.68	1.55	83.95
Sialidae	0.28	0.00	0.79	0.68	1.54	85.49
Scirtidae	0.00	0.27	0.72	0.56	1.41	86.90
Hydraenidae	0.00	0.25	0.67	0.56	1.31	88.21
Notonectidae	0.13	0.19	0.61	0.68	1.20	89.41
Psychodidae	0.00	0.23	0.61	0.56	1.19	90.59

Groups CMC & DTC

Average dissimilarity = 46.32

Species	Group CMC Av.Abund	Group DTC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Orthocladininae	1.63	0.67	3.08	1.44	6.64	6.64
Baetidae	0.16	1.16	2.81	2.20	6.06	12.70
Tanypodininae	2.29	1.39	2.58	2.22	5.58	18.28
Leptoceridae	0.87	0.00	2.39	1.91	5.16	23.44
Ecnomidae	1.10	0.68	2.12	1.37	4.57	28.01
Leptophlebiidae	2.64	1.95	2.09	1.58	4.52	32.52
Caenidae	0.29	0.93	2.08	1.40	4.49	37.01
Ceratopogonidae	0.66	0.98	2.04	1.31	4.41	41.42
Chironominae	2.61	2.81	1.90	1.49	4.10	45.52
Parastacidae	0.00	0.71	1.84	1.64	3.98	49.50
Oligochaeta	1.64	1.06	1.84	1.27	3.97	53.47
Dytiscidae	0.78	0.95	1.75	1.12	3.79	57.26
Dytiscidae (adult)	0.15	0.57	1.54	1.02	3.33	60.59
Tipulidae	0.32	0.55	1.53	1.02	3.30	63.89
Synthemistidae	0.51	0.44	1.50	1.05	3.23	67.12
Gomphidae	0.15	0.42	1.22	0.93	2.63	69.75
Magapodagrionidae	0.33	0.00	0.98	0.68	2.12	71.87
Gripopterygidae	0.39	0.00	0.97	0.64	2.10	73.97
Polycentropodidae	0.33	0.00	0.94	0.68	2.04	76.01
Gyrinidae	0.34	0.00	0.91	0.68	1.97	77.98
Sphaeriidae	0.13	0.25	0.88	0.70	1.90	79.88
Elmidae (adult)	0.33	0.00	0.84	0.68	1.82	81.70
Hydroptilidae	0.29	0.00	0.79	0.66	1.71	83.41
Scirtidae	0.00	0.27	0.76	0.56	1.65	85.06
Hydraenidae	0.00	0.25	0.71	0.56	1.54	86.60
Psychodidae	0.00	0.23	0.64	0.56	1.39	87.98
Tricladida	0.25	0.00	0.63	0.68	1.36	89.34

Hemicorduliidae	0.13	0.19	0.62	0.69	1.34	90.69

Groups CCC & DTC
Average dissimilarity = 45.96

Species	Group CCC Av.Abund	Group DTC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chironominae	3.70	2.81	3.05	1.53	6.65	6.65
Tanypodininae	2.29	1.39	2.43	1.71	5.29	11.94
Ceratopogonidae	1.70	0.98	2.34	1.05	5.10	17.04
Caenidae	0.16	0.93	2.23	1.43	4.85	21.89
Oligochaeta	1.77	1.06	2.17	1.03	4.73	26.61
Leptoceridae	0.78	0.00	2.17	1.27	4.71	31.33
Baetidae	0.92	1.16	2.07	1.51	4.51	35.84
Calamoceratidae	0.68	0.00	1.92	1.31	4.18	40.02
Dytiscidae	0.89	0.95	1.91	1.21	4.15	44.17
Orthocladininae	0.59	0.67	1.83	1.06	3.98	48.15
Ecnomidae	0.39	0.68	1.82	1.08	3.97	52.11
Leptophlebiidae	1.50	1.95	1.75	1.33	3.82	55.93
Dytiscidae (adult)	0.36	0.57	1.66	1.15	3.61	59.55
Parastacidae	0.33	0.71	1.62	1.32	3.53	63.08
Tipulidae	0.20	0.55	1.47	0.98	3.20	66.28
Hemicorduliidae	0.44	0.19	1.43	0.81	3.12	69.40
Gomphidae	0.16	0.42	1.24	0.95	2.70	72.10
Coenagrionidae	0.45	0.00	1.22	0.63	2.66	74.76
Synthemistidae	0.00	0.44	1.10	0.97	2.39	77.15
Sphaeriidae	0.16	0.25	0.95	0.68	2.06	79.21
Nemertea	0.33	0.00	0.87	0.68	1.90	81.11
Physidae	0.33	0.00	0.80	0.68	1.73	82.84
Corixidae	0.29	0.00	0.79	0.68	1.72	84.56
Scirtidae	0.00	0.27	0.76	0.56	1.65	86.21
Hydraenidae	0.00	0.25	0.71	0.56	1.54	87.75
Psychodidae	0.00	0.23	0.64	0.56	1.39	89.14
Nematoda	0.20	0.00	0.57	0.43	1.25	90.39

Groups CSQC & DTC
Average dissimilarity = 47.24

Species	Group CSQC Av.Abund	Group DTC Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Chironominae	3.23	2.81	2.53	1.34	5.36	5.36
Baetidae	0.37	1.16	2.52	1.53	5.33	10.69
Atyidae	0.85	0.00	2.44	1.83	5.17	15.86
Leptoceridae	0.87	0.00	2.41	1.20	5.10	20.96
Caenidae	0.34	0.93	2.11	1.31	4.47	25.42
Orthocladininae	1.04	0.67	2.05	1.08	4.34	29.77
Ceratopogonidae	0.93	0.98	1.95	1.31	4.12	33.89
Ecnomidae	0.40	0.68	1.84	1.07	3.90	37.79
Dytiscidae	0.95	0.95	1.84	1.20	3.89	41.68
Tanypodininae	1.97	1.39	1.79	1.35	3.79	45.47
Dytiscidae (adult	0.38	0.57	1.75	1.14	3.71	49.18
Parastacidae	0.13	0.71	1.74	1.45	3.69	52.86
Oligochaeta	1.12	1.06	1.72	1.33	3.63	56.50
Tipulidae	0.30	0.55	1.48	1.06	3.13	59.63
Psephenidae	0.48	0.25	1.47	0.97	3.11	62.74
Corixidae	0.46	0.00	1.36	0.91	2.88	65.62
Chorismagrionidae	0.47	0.00	1.34	0.93	2.83	68.44
Sphaeriidae	0.34	0.25	1.24	0.88	2.62	71.06
Gomphidae	0.00	0.42	1.21	0.90	2.56	73.62
Synthemistidae	0.13	0.44	1.16	1.00	2.45	76.07
Leptophlebiidae	1.66	1.95	1.15	1.13	2.44	78.51
Gyrinidae	0.43	0.00	1.11	0.95	2.36	80.87
Scirtidae	0.13	0.27	0.97	0.71	2.06	82.93
Tricladida	0.36	0.00	0.94	0.67	2.00	84.93
Culicidae	0.38	0.00	0.92	0.64	1.94	86.87

Magapodagrionidae	0.34	0.00	0.83	0.68	1.76	88.63
Hydraenidae	0.00	0.25	0.72	0.56	1.53	90.16

b) Discharge monitoring result

SIMPER

Similarity Percentages - species contributions

One-Way Analysis

Data worksheet

Name: Data2

Data type: Abundance

Sample selection: All

Variable selection: All

Parameters

Resemblance: S17 Bray Curtis similarity

Cut off for low contributions: 50.00%

Factor Groups

Sample	impact/control
TTH11 SPR12	control
SBR1 SPR12	control
SBR2 SPR12	control
SBR3 SPR12	control
SBR4 SPR12	control
TTH11 AUT13	control
SBR1 AUT13	control
SBR2 AUT13	control
SBR3 AUT13	control
SBR4 AUT13	control
TTH11 SPR13	control
SBR1 SPR13	control
SBR 2 SPR13	control
TTH12 SPR12	impact
SBR5 SPR12	impact
SBR6 SPR12	impact
SBR7 SPR12	impact
SBR8 SPR12	impact
TTH12 AUT13	impact
SBR5 AUT13	impact
BR6 AUT13	impact
SBR7 AUT13	impact
SBR8 AUT13	impact
TTH12a SPR13	impact

Group control

Average similarity: 53.59

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Chironominae	2.59	10.01	2.73	18.68	18.68
Leptophlebiidae	2.21	8.21	4.67	15.33	34.00
Tanypodininae	1.97	8.03	5.00	14.99	48.99
Oligochaeta	1.46	5.06	2.14	9.44	58.43

Group impact

Average similarity: 63.14

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Chironominae	3.11	15.66	5.01	24.80	24.80
Tanypodininae	2.34	11.46	4.36	18.14	42.94
Caenidae	1.69	7.09	1.68	11.22	54.17

Groups control & impact
Average dissimilarity = 47.34

	Group control	Group impact				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Leptophlebiidae	2.21	0.98	3.17	1.61	6.70	6.70
Caenidae	0.71	1.69	2.98	1.45	6.30	13.00
Oligochaeta	1.46	0.96	2.30	1.26	4.85	17.85
Chironominae	2.59	3.11	2.28	1.44	4.81	22.66
Elmidae	0.96	0.16	2.18	1.54	4.59	27.25
Corixidae	0.35	0.89	2.07	1.27	4.38	31.63
Sphaeriidae	0.85	0.43	1.94	1.14	4.10	35.73
Leptoceridae	0.88	0.58	1.90	1.26	4.00	39.73
Ecnomidae	1.03	1.28	1.88	1.08	3.97	43.71
Ceratopogonidae	0.83	0.66	1.84	1.20	3.88	47.59
Gomphidae	0.24	0.71	1.69	1.22	3.57	51.16

Niche Environment and Heritage

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TAHMOOR SOUTH PROJECT

Stygofauna Assessment

Prepared for Tahmoor Coal Pty Ltd

Document control

Business Unit	Niche Environment and Heritage – Illawarra		
Project No.	1490		
Document Description	Stygofauna baseline assessment focusing on the impact assessment of the proposed Tahmoor South Project		
	Name	Signed	Date
Supervising Director	Matthew Richardson		7 May 2014
Document Manager	Matthew Russell – Aquatic Ecologist, Niche Environment and Heritage		
Contributing Authors	Matthew Russell – Aquatic Ecologist, Niche Environment and Heritage Peter Serov – Director, Stygoecologia		
Document Prepared For	Tahmoor Coal Pty Ltd		
Local Government Area	Wollondilly and Wingecarribee, NSW		
Document Status			

Revision #	Date	Internal Review	External Review
Revision 0	10 February 2014	Matthew Richardson	Ben Streckeisen Project Manager – Tahmoor South Project

Front Cover Photograph: Upstream tributary of the Bargo River. (© Stygoecologia)

EXECUTIVE SUMMARY

Tahmoor Coal Pty Ltd (Tahmoor Coal) owns and operates the Tahmoor Mine, an underground coal mine approximately 80 km south-west of Sydney in the Southern Coalfields of NSW. Tahmoor Coal is a wholly owned entity within Glencore's coal business (Glencore Xstrata plc.).

Tahmoor Coal is seeking approval for the Tahmoor South Project (the proposed development or Project), being the extension of underground coal mining at Tahmoor Mine, to the south and east of the existing Tahmoor Mine surface facilities area.

The proposed development will use longwall mining to extract coal from the Bulli seam within the bounds of CCL 716 and CCL 747. Coal extraction of up to 4.4 million tonnes of ROM coal per annum is proposed as part of the development. Once the coal has been extracted and brought to the surface, it will be processed at Tahmoor Mine's existing Coal Handling & Preparation Plant (CHPP), and then transported via the existing rail loop, the Main Southern Railway and the Moss Vale to Unanderra Railway to Port Kembla for export to the international market.

The components of the proposed development comprise:

- Mine development including underground pit bottom redevelopment, vent shaft construction, pre-gas drainage and service connection;
- Longwall mining in the Central and Eastern Domains;
- Upgrades to the existing surface facilities area including:
    - upgrades to the CHPP;
    - expansion of the existing REA;
    - additional mobile plant for coal handling;
    - additions to the existing bathhouses, stores and associated access ways; and
    - upgrades to offsite service infrastructure, including electrical supply;
- Rail transport of product coal to Port Kembla;
- On-going exploration;
- Mine closure and rehabilitation; and
- Environmental management.

Niche Environment and Heritage (Niche) was commissioned by Tahmoor Coal to undertake stygofauna assessment for the proposed development. Specifically this report assesses whether subterranean groundwater dependent ecosystems occur within the area of the Project and if they exist, whether the Project is likely to have a significant impact on them. This assessment included a baseline aquifer ecosystem evaluation for stygofauna across the area of impact and to provide a risk assessment of the proposed development to this ecosystem. There has been no previous sampling for stygofauna conducted in the area of the development although stygofauna have previously been recorded from the region.

Results of the stygofauna pilot study

The results showed stygofauna (groundwater) and hyporheic fauna (streams) exist in small isolated populations within the study area. The hyporheic assemblages were found in all main river sites that were supported by a perennial baseflow. These assemblages were dominated by surface macroinvertebrate taxa, but also included ostracods and worms associated with the phreatic environment that indicated a linkage/connectivity between the aquifers and the streams. The low diversity and abundance is likely to be influenced by the small, transient, disconnected nature of the riverine hyporheic zone habitats.

Of the groundwater sites sampled, only 3 bores registered fauna and of these only 1 bore registered the presence of stygofauna. While stygofauna are present within the Wianamatta Shale aquifers they were not collected from the deeper aquifers or within the shallow Hawkesbury Sandstone unit underlying the Shales. The fine grained nature of the geology and sediments and lack of fracture zones; hilly/sloping topography reduces the occurrence of upland swamp complexes and thus may be a factor limiting stygofaunal habitat and diversity and abundance with in the study area. The depauperate, sporadic nature of this community across the study was assessed as having a low ecological value for the sites surveyed, except for Cows' Creek that recorded a moderate value.

Assessment of impacts to groundwater dependent ecosystems

Subsidence was identified as the main issue with this project although only presenting as a moderate ecological risk. The potential impacts include:

- water table levels;
- aquifer flow paths;
- aquifer discharge volume to off-site GDEs;
- the frequency/timing of water table level fluctuations;
- river base flow;
- spring water pressure;
- natural groundwater chemistry; and
- groundwater salinity levels.

The river sites that yielded positive results for fauna were identified as having moderate risk from subsidence related impacts although all bores surveyed including the one bore that recorded stygofauna are assessed as having a low risk of mine related impacts. The risk matrix assessment ranged from Class G risk to the stygofauna and an E, H assessment for the hyporheic sites. The short term management actions include the establishment of baseline risk monitoring of physicochemical parameters such as water level and water chemistry incorporated with periodic biological survey monitoring for the identified hot spot sites. This is to be carried out within a long term adaptive management and monitoring program.

GLOSSARY OF TERMS

TERM	DEFINITION
Aquaclude	Geologic formation which contains water but can not transmit it rapidly enough to furnish a significant supply.
Aquifer	Geologic formation, group of formations, or part of a formation capable of transmitting and yielding quantities of water.
Aquitard	A saturated but poorly permeable bed, formation, or group of formations that does not yield water freely to a well or a spring. An aquitard may transmit appreciable water to or from adjacent aquifers.
Baseflow	The component of stream flow that is sourced from groundwater discharging into the stream.
Bed	Stratum of coal or other sedimentary deposit.
Bore	A cylindrical drill hole sunk into the ground from which water is pumped for use or monitoring.
Borehole	A hole produced in the ground by drilling for the investigation and assessment of soil and rock profiles.
Bulli seam	Shallowest coal horizon in the Illawarra Coal Measures in the Southern Coalfield. The Bulli coal seam is a primary source of coking coal, located in the Illawarra and Southern Coalfields of New South Wales.
Catchment	The area from which a surface watercourse or a groundwater system derives its water.
Clearing	The removal of vegetation or other obstacles at or above ground level.
Coal handling and preparation plant (CHPP)	Treatment by screening to give coal of various sizes to meet a purchasers requirements and treatment by one or more processes to reduce the amount of waste (ash) present in the coal.
Coking coal	Coal suitable for the manufacture of coke.
Confined aquifer	An aquifer that lies below a low permeability material. The piezometric surface in confined aquifers is above the base of the confining material; e.g. artesian aquifers
Consolidated rock	Consolidated rock is rock that contains very few holes or cracks for water to get through. Unconsolidated rock is rock such as gravel. Consolidated rock can serve as a confining bed.
Critical habitat	A critical habitat as defined under the *Threatened Species Conservation Act 1995* includes, the whole or any part or parts of the area or areas of land comprising the habitat of an endangered species, population or ecological community or critically endangered species or ecological community that is critical to the survival of the species, population or ecological community.
Cumulative impacts	Combination of individual effects of the same kind due to multiple actions from various sources over time.
Development	The operations involved in preparing a mine for extraction, including cutting roadways and headings. Also includes tunnelling, sinking, crosscutting, drifting, and raising.
Discharge	A release of water from a particular source.
Drainage	Natural or artificial means for the interception and removal of surface or subsurface water.
Drawdown	The distance between the static water level and the surface of the cone of depression.
Ecology	The study of the relationship between living things and the environment.

TERM	DEFINITION
Ecologically sustainable development (ESD)	As defined by the *Protection of the Environment Administration Act 1991*, requires the effective integration of economic and environmental considerations in decision making processes including: ❑ The precautionary principle. ❑ Inter-generational equity. ❑ Conservation of biological diversity and ecological integrity. Improved valuation, pricing and incentive mechanisms (includes polluter pays, full life cycle costs, cost effective pursuit of environmental goals).
Ecosystem	As defined in the *Environment Protection and Biodiversity Conservation Act 1999*, an ecosystem is a 'dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.'
Endangered ecological community (EEC)	An ecological community identified by the *Threatened Species Conservation Act 1995* that is facing a very high risk of extinction in New South Wales in the near future, as determined in accordance with criteria prescribed by the regulations, and is not eligible to be listed as a critically endangered ecological community.
Edge effects	A change in species composition, physical conditions or other ecological factors at the boundary between two ecosystems or the ecological changes that occur at the boundaries of ecosystems (including changes in species composition, gradients of moisture, sunlight, soil and air temperature, wind speed and other factors).
Emission	The discharge of a substance into the environment.
Endemic	Pertaining to organisms in a specific geographical region or ecological habitat; organisms native to a region and not introduced, Gordh and Headrick, 2001 .
Environmental Management Plan (EMP)	A plan used to manage environmental impacts during each phase of project development. It is a synthesis of proposed mitigation, management and monitoring actions, set to a timeline with defined responsibilities and follow up actions.
Environmental management system (EMS)	A quality system that enables an organisation to identify, monitor and control its environmental aspects. An EMS is part of an overall management system, which includes organisational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy.
Environment	As defined within the *Environmental Protection & Assessment Act, 1979*, all aspects of the surroundings of humans, whether affecting any human as an individual or in his or her social groupings.
Ephemeral	Existing for a short duration of time.
EPL	Environment Protection Licence. EPLs are issued by EPA under the *Protection of the Environment Operations Act 1997*. EPLs with respect to scheduled development work or scheduled activities or non-scheduled activities may regulate all forms of pollution (including water pollution) resulting from that work or those activities. EPLs authorising or controlling an activity carried on at any premises may also regulate pollution resulting from any other activity carried on at the premises to which the licence applies. .
Exploration	The work done to prove or establish the extent of the coal resource.
Fault	Break in the continuity of a coal seam or rock strata.
Gaining stream	A stream where baseflow, or groundwater discharge, serves to maintain and even increase stream flow as one goes downstream (see losing stream).
Greenhouse gases	Gases with the potential to cause climate change (e.g. methane, carbon dioxide and others listed in the *National Greenhouse and Energy Reporting Act 2007*). Expressed in terms of carbon dioxide equivalent.
Groundwater	Water located within an aquifer that is, held in the rocks and soil beneath the earth's surface.
Groundwater dependent ecosystem or GDE	Is a broad, overarching term encompassing all ecosystems that use groundwater either permanently or occasionally to survive. In this context the term covers a vast majority of terrestrial and aquatic ecosystems. Serov et al, 2012 .

TERM	DEFINITION
Habitat	The place where a species, population or ecological community lives (whether permanently, periodically or occasionally).
Hydrogeology	The study of subsurface water in its geological context.
Hydrology	The study of rainfall and surface water runoff processes.
Hyporheic zone	The ecotonal zone below and within the porous sand and gravel substrate of a river bed. This ecotonal zone often connects the surface running water system to that of the deep subterranean.
Hyporheos	The characteristic fauna that inhabit the hyporheic zone of rivers
Impact	Influence or effect exerted by a project or other activity on the natural, built and community environment.
Key threatening process	As defined under the *Threatened Species Conservation Act 1994*, a key threatening process is any listed process under the Act that adversely affects threatened species, populations or ecological communities, or that could cause species, populations or ecological communities that are not threatened to become threatened.
Landscape character	The aggregate of built, natural and cultural aspects that make up an area and provide a sense of place. Includes all aspects of a tract of land – built, planted and natural topographical and ecological features.
Losing stream	A stream where water is lost to the surrounding and underlying groundwater system (see gaining stream).
Longwall	A system of coal mining, where the coal seam is extracted from on a broad front or long face.
Panel	The mining unit that has previously been extracted or is currently being extracted.
Obligate GDE	A GDE that is entirely dependent on groundwater. Typically most karst, wetland and hypogean/aquifer GDEs, all baseflow and some terrestrial GDEs will be obligate (see facultative GDEs).
Perched Water	Unconfined groundwater held above the water table by a layer of impermeable rock or sediment.
Perched water table	This occurs when the water percolation is interrupted by another confining layer above the main regional water table.
Permeability	The property or capacity of a porous rock, sediment, or soil for transmitting a fluid; it is a measure of the relative ease of fluid flow under unequal pressure.
Pholeteros	Aquatic fauna inhabiting the burrows of freshwater crayfish.
Phreatic water	Water below the level at which all voids in the rock are completely filled with water
Phreatic zone	Zone where voids in the rock are completely filled with water. Also refers to deep groundwater.
Phreatobite	Are stygobites that are restricted to the deep groundwater substrata of alluvial aquifers (phreatic waters), Gilbert et al, 1994. All species within this classification have specialised morphological and physiological adaptations.
Piezometer	A narrow tube, pipe or borehole for measuring the moisture in a soil or water level in an aquifer.
Pollutant	Any matter that is not naturally present in the environment.
Preparation plant	A place where coal is sized, treated by one or more processes, including washing, to reduce the amount of waste (ash) present and prepared for market.
Project Area	It comprises an area external to the Existing Tahmoor Approved Mining Area (with the exception of the inclusion of the Surface Facilities Area, vent shafts, and surface water monitoring locations).
Proposed development	Extension of underground coal mining and associated activities at Tahmoor Mine within the Project Area. Referred to as The Tahmoor South Project, as described in Section 4 of this EIS.

TERM	DEFINITION
Riparian	Relating to the banks of a natural waterway.
Run-off	The portion of water that drains away as surface flow.
Seam	Layer or bed of coal.
Shuttle car	An electrically-propelled vehicle on rubber tires or caterpillar treads used to transfer materials, such as coal.
Stygofauna	This an all encompassing term for all animals that occur in subsurface waters, Ward et al., 2000.
Stygophiles	Having greater affinities with the groundwater environment than stygoxenes, because they appear to actively exploit resources in the groundwater system and /or actively seek protection from unfavourable situations in the surface environment resulting from biotic or stochastic processes. Stygophiles can be divided into: 1. Occasional or temporary hyporheos 2. Permanent hyporheos. The occasional or temporary hyporheos include individuals of the same species that could either spend their lives in the surface environment or spend a part of their lives in the surface environment and a part in groundwater (Ceratopogonidae fly larvae). The permanent hyporheos is present during all life stages in either groundwater or in benthic habitats (Gibert et al., 1994.) and possess specialist adaptations for living in this environment.
Stygoxenes	Organisms that have no affinities with the groundwater systems, but occur accidentally in caves and alluvial sediments. Some planktonic groups (Calanoida Copepoda) and a variety of benthic crustacean and insect species (Simuliidae fly larvae, Caenidae Mayflies) may passively infiltrate alluvial sediments, (Gibert et al, 1994).
Subsidence	The vertical lowering, sinking or collapse of the ground surface.
Surface Facilities Area	Comprises surface land containing mining and non-mining infrastructure.
Surface water	Water flowing or held in streams, rivers and other wetlands in the landscape.
Tributary	A river or stream flowing into a larger river or lake.
Unconfined aquifer	A water table aquifer or an aquifer that does not have an impermeable bed between the water table and the lands surface e.g. Alluvial and Coastal Sand Bed aquifers.
Vulnerable	As defined under the *Threatened Species Conservation Act 1995*, a species that is facing a high risk of extinction in New South Wales in the medium-term future.
Water table	The surface of saturation in an unconfined aquifer at which the pressure of the water is equal to that of the atmosphere.
Waterway	Any flowing stream of water, whether natural or artificially regulated (not necessarily permanent).

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ACRONYMS

ACRONYM	TERM/DEFINITION
AHD	Australian Height Datum
CCL	Consolidated Coal Lease
CHPP	Coal Handling & Preparation Plant
DGRs	Director-General's requirements
DP&I	Department of Planning and Infrastructure
EEC	Endangered Ecological Community
EIS	Environmental Impact Statement
EPA	NSW Environment Protection Authority
EP&A Act	*Environmental Planning and Assessment Act 1979* (NSW)
EPBC Act	*Environment Protection and Biodiversity Act 1999* (Cth)
EPL	Environment Protection Licence
GDE	Groundwater Dependent Ecosystem
Ha	Hectare/s
GHG	Greenhouse gas
LGA	Local Government Area
mg/L	Milligrams per litre
micron	One millionth of a metre (abbreviation μ)
mL	Millilitre
ML	Mining Lease
NES	Matters of National environmental significance (from the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*).
pH	A measure of acidity or alkalinity of a solution. The potential of hydrogen.
PRP	Pollution Reduction Program
REA	Rejects emplacement area. Can also be called refuse emplacement area.
RMZ	Risk Management Zone
SEPP	State Environmental Planning Policy
DE	Department of Environment
SSTF	Shale Sandstone Transition Forest
TSC Act	*Threatened Species Conservation Act 1995* (NSW)

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1 INTRODUCTION

1.1 Tahmoor South Project

This section provides an introduction to the Tahmoor Mine, the proposed development (the Tahmoor South Project), and the purpose and content of this report.

1.1.1. Overview

Tahmoor Coal Pty Ltd (Tahmoor Coal) owns and operates the Tahmoor Mine, an underground coal mine approximately 80 km south-west of Sydney in the Southern Coalfields of NSW (Figure 1). Tahmoor Coal is a wholly owned entity within Glencore's coal business (Glencore Xstrata plc.). Tahmoor Coal produces up to two million tonnes per annum of product coal from its existing operations at the Tahmoor Mine, and undertakes underground mining under existing development consents, licences and the conditions of relevant mining leases.

Tahmoor Coal is seeking approval for the Tahmoor South Project (the proposed development or Project), being the extension of underground coal mining at Tahmoor Mine, to the south and east of the existing Tahmoor Mine surface facilities area. The proposed development will continue to be accessed via the existing surface facilities at Tahmoor Mine, located between the towns of Tahmoor and Bargo.

The proposed development seeks to extend the life of underground mining at Tahmoor Mine until approximately 2040. The proposal will enable mining to be undertaken within the southern portion of Tahmoor Coal's existing lease areas and for operations and employment of the current workforce to continue for approximately a further 18 years.

The proposed development will extend mining at Tahmoor Mine within the Project Area, using longwall methods, with the continued use of ancillary infrastructure at the existing Tahmoor Mine surface facilities area. The Project Area is shown on Figure 2 and comprises an area adjacent to, and to the south of, the Existing Tahmoor Approved Mining Area. It also overlaps a small area of the Existing Tahmoor Approved Mining Area comprising the surface facilities area, historical workings and other existing mine infrastructure.

Groundwater constitutes an estimated 97% of all non-frozen freshwater on earth and supports a vast range of ecosystems that cover a large percentage of the landscape from the coast to the mountain tops. These include: unique subterranean communities (stygofauna) in caves and aquifer ecosystems; most rivers; wetlands; native vegetation; and even marine and estuarine environments. Groundwater dependent ecosystems (GDEs) are reliant on the high water quality and consistency of groundwater levels and pressure to survive. In turn, these ecosystems provide a range of environmental services that benefit the environment and ultimately, the community. These ecosystems also contain many highly sensitive, specialised and highly localised, endemic flora and fauna that cannot be found elsewhere and have little tolerance to change. They also include species that may represent remnants of ancient environments.

The uniqueness of Australia's biodiversity is encapsulated and magnified tenfold by its groundwater dependent biodiversity. Groundwater in an aquifer is a body of underground water but it is not isolated or stationary. Neither is it devoid of life or an inexhaustible supply of clean water. It flows in much the same way as a river from its surface recharge zone to its surface discharge areas and will transport impacts such as pollutants or reductions of quantity throughout the subsurface environments to the surface land and waters. Therefore, there is always a flow-on effect from one point of impact on the groundwater quantity or quality to the rest of the landscape.

The parameters that make groundwater environments a separate entity to many surface water environments and which has contributed to the development of many specialised, highly endemic ecosystems, communities and species, is the relatively consistent nature of its flow, pressure, level, and water chemistry.

1.1.2. Proposed development

The proposed development will use longwall mining to extract coal from the Bulli seam within the bounds of CCL 716 and CCL 747. Coal extraction of up to 4.4 million tonnes of ROM coal per annum is proposed as part of the development. Once the coal has been extracted and brought to the surface, it will be processed at Tahmoor Mine's existing Coal Handling & Preparation Plant (CHPP), and then transported via the existing rail loop, the Main Southern Railway and the Moss Vale to Unanderra Railway to Port Kembla for export to the international market.

The components of the proposed development comprise:

- Mine development including underground pit bottom redevelopment, vent shaft construction, pre-gas drainage and service connection;
- Longwall mining in the Central and Eastern Domains;
- Upgrades to the existing surface facilities area including:
  - upgrades to the CHPP;
  - expansion of the existing REA;
  - additional mobile plant for coal handling;
  - additions to the existing bathhouses, stores and associated access ways; and
  - upgrades to offsite service infrastructure, including electrical supply;
- Rail transport of product coal to Port Kembla;
- On-going exploration;
- Mine closure and rehabilitation; and
- Environmental management.

1.1.3. Project timeframes

The Tahmoor South Project seeks to extend the life of underground mining at Tahmoor Mine beyond the forecast completion of mining at Tahmoor North in approximately 2022, which is dependent upon geological and mining conditions.

A number of pre-mining activities are required to be completed prior to commencement of longwall mining for the Tahmoor South Project. These pre-mining activities include:

- gas drainage;
- redevelopment of the pit bottom;
- longwall development including establishment of gate roads;

- installation of underground electrical, water and gas management networks; and
- the purchase and installation of equipment.

The Tahmoor South Project's pre-mining activities are anticipated to take approximately five years to complete before longwall mining can commence in the Central domain and needs to begin in 2016.

Longwall mining is proposed to commence in the Central Domain once mining is completed at Tahmoor North, anticipated in approximately 2022, dependent upon geological and mining conditions. Longwall mining from the Central Domain is expected to be completed by approximately 2034, depending upon geological and mining conditions.

Longwall mining is proposed to commence in the Eastern Domain once mining is completed in the Central Domain, in approximately 2034, depending upon geological and mining conditions, with mining competed by approximately 2040, with surface works, rehabilitation and mine closure occurring after this time.

1.1.4. Proposed operations

Tahmoor Coal is seeking approval for the continuation of mining at Tahmoor Mine, extending underground operations and associated infrastructure south, within the Bargo area, and to the east within the Pheasants Nest area. The proposed development seeks to extend the life of underground mining at Tahmoor Mine until approximately 2040, depending upon geological and mining parameters.

The proposed development will use longwall mining methods to extract coal from the Bulli seam within CCL 716 and CCL 747. Coal extraction of up to 4.4 million tonnes of ROM coal per annum is proposed as part of the development. The ROM coal brought to the surface will be processed at Tahmoor Mine's existing CHPP, and transported via the existing rail loop, the Main Southern Railway and the Moss Vale to Unanderra Railway to Port Kembla for export to international markets.

The proposed development will utilise the existing surface infrastructure at the Tahmoor Mine surface facilities area, with some upgrades proposed to facilitate the extension.

The proposed development includes on-going exploration activities within CCL 716 and CCL 747 to continue to confirm coal quality and geological structure, and also incorporates the planning for rehabilitation and mine closure.

1.1.5. Underground mining operations

The Tahmoor South Project area is operationally divided into three different mining domains based on geological complexity and mining potential. The mining domains are the Central Domain, Eastern Domain and Southern Domain.

The proposed development seeks to undertake longwall mining of the Bulli seam within the Central and Eastern Domains, at a depth of between approximately 375 metres and 430 metres below ground level.

During the mine planning process, a constraints analysis, risk assessment and detailed fieldwork were undertaken to identify sensitive natural surface features (such as waterways, cliffs, and Aboriginal heritage sites) and to develop risk management zones (RMZs). Following the completion of the risk assessment process, the proposed longwall layout was modified to minimise significant subsidence impacts to natural features.

The longwall layout will continue to be refined during the detailed design phase of the proposed development, the area studied within this document is shown in Figure 1 and Figure 2.

1.2 Stygofauna Ecology

Stygofauna are animals that live in underground water. They generally comprised of invertebrates including; crustaceans and other invertebrate groups such as worms, snails, mites and even blind insects. Stygofauna are animals that spend their entire lives in groundwater and due to their specific habitat requirements, the species are generally highly endemic. As such, these organisms have highly specialised adaptations to survive in relatively resource-poor aquifers, where there limited light, space, and food supply (Humphreys 2008).

Stygofauna are blind, colourless, have slow metabolism, reduced body size, specialised anatomies and low reproduction rates (Coineau 2000). As there is no photosynthesis below ground, these groundwater environments rely on inputs of organic matter from the surface to provide the basis of the food web on which stygofauna depend (Schneider et al. 2011). Despite their small size, the cumulative effect of stygofauna activity plays an important part in maintaining groundwater quality. This process is evident in alluvial aquifers where water flowing though sediment particles is cleaned during transit by stygofauna, in much the same way as water moving through slow sand filters or trickle filters in water and sewage treatment (Hancock et al. 2005). Stygofauna therefore play a functional role in aquifers and are also considered a direct and sensitive indicator of the quality of an underground water source.

1.2.1 Stygofauna ecological requirements

Stygofauna are intricately linked both ecologically and physiologically to the aquifer environment and are adapted to the relative stability of their surroundings. Compared to surface environments, groundwater fluctuates less both in level and physico-chemical variables such as electrical conductivity, temperature, and pH (Hancock et al. 2005). Groundwater is also generally lower in dissolved oxygen and has less readily available organic matter than surface water environments (Humphreys 2002). As there is no direct photosynthesis in aquifers, stygofauna rely on connections to the land surface to provide them with food. These connections may be hydrological, with infiltrating water bringing dissolved or particulate organic matter to form the basis of subterranean food webs, or it may be more direct, with tree roots that extend below the water table providing leachates or organic carbon or fine rootlets for food (Hancock et al. 2005). Generally, stygofauna biodiversity is highest near the water table and declines with depth (Datry et al. 2005).

Stygofauna biodiversity is also higher in areas of recharge where the water table is close (< 20 m) to the land surface (Humphreys 2001, Hancock and Boulton 2008). This is because the water table is likely to have the highest concentration of oxygen and organic matter. Stygofauna can occur at considerable depth below the water table, but are fewer in number, have lower diversity, and may change in community composition (Datry et al. 2005). In some karstic aquifers, where there is relatively high vertical exchange, or flow does not come into contact with large microbial surface areas (such as occurs in sedimentary aquifers), stygofaunal communities can occur at depths exceeding 100 m (Humphreys 2001).

In Australia, stygofauna are known from alluvial, limestone, fractured rock, and calcrete aquifers (Hancock et al. 2005; Humphreys 2008). As yet, no species are known from coal aquifers. Most coal aquifers occur as confined aquifers and as such have very low dissolved oxygen, high salinity and have a general lack of connectivity with surface environments. Stygofauna require space to live, which is dependent on the porosity of the sediments, degree of fracturing, or extent of cavity development. These requirements must be sufficient to enable fauna to move through the substrate.

1.2.2 Processes that threaten stygofauna

There are three critical factors that are essential requirements for stygofauna communities in aquifers.

1) Stable water quality/physicochemical parameters

Many groundwater species have evolved under strict physiochemical constraints and require a level of stability of these parameters for their continued existence. Stygofauna are able to tolerate natural fluctuations in water parameters such as level, electrical conductivity, and temperature, and this has been demonstrated experimentally (Tomlinson et al. 2007) for stygofaunal amphipods, copepods, and syncarids. However, changes outside the natural range of water quality, water chemistry and levels such as rapid drawdown or changes to water chemistry such as a pollution plume is likely to have significant impacts on the community composition, biodiversity and overall sustainability of the community.

2) Surface connectivity

Groundwater communities require links to the surface environment to provide organic matter and oxygen. If that linkage is broken or disrupted, the stygofauna community in the area affected could decline over time.

3) Subterranean connectivity

The third critical factor is their high degree of endemicity (Humphreys 2008). This comes about because, unlike many surface-dwelling aquatic invertebrates, stygofauna do not have aerially dispersing life stages. To migrate between areas, stygofauna must be able to swim or crawl through the aquifer matrix, however, as aquifers are not homogenous in porosity and change over geological time, natural hydrological barriers within the matrix restrict their movement. Overtime, these natural barriers encourage genetic isolation and ultimately, speciation. Barriers, however, can also be created rapidly by changes in water levels or water chemistry/quality such as an area of lower porosity and sections of poor water quality. If any area is impacted by a disturbance that results in a loss of biodiversity, these new barriers to dispersal may prevent decolonisation of the habitat.

Many species of stygofauna are restricted to small geographical areas. This is particularly the case in non-alluvial aquifers such as some of the limestone karsts of NSW (Eberhard & Spate 1995; Thurgate et al. 2001), and calcrete aquifers in Western Australia, where one or more species are known only from a single aquifer, or part of an aquifer (Humphreys 2002). This means that any process that threatens the aquifer, potentially threatens an entire species and community. There is also a high degree of endemism in alluvial aquifers, even between adjacent systems (Hancock and Boulton 2008). However, providing there is sufficient hydrological connectivity within the aquifer, and physico-chemical conditions are suitable, the distribution of species will not be restricted to small parts of an aquifer.

Stygofauna are potentially threatened by activities that change the quality or quantity of groundwater, disrupt connectivity between the surface and aquifer, or remove living space. These impacts to groundwater and aquifer conditions have become a particular issue for mining proponents over the last decade or so, principally because of the perceived biodiversity value of stygofauna and the fact that little is known of their environmental water requirements.

1.2.3 Effects of mining on stygofauna

Mining operations may incorporate a range of activities in their operations that may result in impacts on water resources, including some or all of the following (Serov et al. 2012):

- Below water table mining;
- Water supply development (e.g. groundwater, dewatering, surface water);
- Desalination for potable supply (with subsequent brine disposal);
- Dust suppression;
- Tailings disposal;
- Overburden storages;
- Backfilling and rehabilitation works;
- Water diversions and surface sealing;
- Hazardous and dangerous goods storage;
- Water storages including waste water ponds; and
- Disturbance/removal of terrestrial vegetation.

In recognition of the above mining activities, direct effects on groundwater dependent ecosystems may be as follows:

- Quantity (groundwater levels, pressures and fluxes);
- Quality (changes outside of natural ranges, concentrations of salts, heavy metals and other toxic water quality constituents);
- Groundwater interactions (interactions between groundwater systems and between groundwater and surface systems); and
- Physical disruption of aquifers (excavation of mining pits and underground workings, compaction of aquifer matrix through dewatering, increase in porosity by blasting, or overburden compaction).

The existence and extent of these water affecting activities, and their potential impact on local to regional scale groundwater resources will depend largely on the scale of the mining operation, mining method, and process water requirements, as well as the climatic and geological setting.

1.2.4 Other studies

The National Water Commission (NWC) has reported (RPS 2011) that extensive gaps exist in our knowledge of the distribution, composition and biodiversity value of Australian stygofauna. Despite this incomplete inventory it is apparent that stygofauna are present across a variety of Australian subsurface environments and are generally characterised by high diversity and local-scale endemicity. They are also often of high scientific interest; for example, the occurrence of the only known southern hemisphere representatives of several phylogenetic relict lineages.

In Australia, at least 750 stygofauna species have been described (Humphreys 2008), but this is a conservative estimate of total continental biodiversity as more than 66 % of known species come from just two regions of Western Australia (Humphreys 2008) and large parts of Australia remain un-surveyed. In NSW there are approximately 400 species of stygofauna known, but this estimate is likely to increase as more surveys are conducted and taxonomic knowledge improves.

Knowledge of groundwater dependent ecosystems in eastern Australia is limited and patchy (e.g. Eberhard and Spate 1995; Thurgate et al. 2001; Hancock 2002; 2004, Hancock & Boulton 2008; Hose et al. 2005; SMEC 2006; Watts et al. 2007). At least two surveys (SMEC 2006; Hose 2008) have confirmed the presence of stygofaunal taxa (Anaspidacean Syncarida, Cyclopoid Copepoda, Harpacticoid Copepoda, Candonid Ostracoda, Acarina, Nematoda, Oligochaeta, Coleoptera (beetle) larva and Collembola) in the Upper Nepean region in recent years. With the exception of these two reports we are unaware of other studies of groundwater dependent ecosystems in fractured rock aquifers in eastern Australia, and even internationally, studies of groundwater ecosystems in fractured rock are scarce.

The SMEC (2006) Baseline Groundwater Dependent Ecosystem Evaluation Study provides a comprehensive assessment of the vegetation and terrestrial invertebrate assemblages of the upland swamps and the riverine macroinvertebrates in their study area, but knowledge of the fauna inhabiting the perched and regional groundwater within the swamps, sandstone aquifers and hyporheic zones is limited. As part of that study, SMEC (2006) sampled the sandstone aquifer and perched groundwater for stygofauna and obligate groundwater invertebrates. A new species of syncarid was identified from the perched water table in Butlers Swamp (bore 2M1p) and Cyclopoid copepods were collected from the shallow fractured sandstone aquifer (bore 2M2s, 24 m depth), also nearby to Butlers Swamp. Fauna were not recorded in samples from deeper bores 1A or 3B that fully penetrate the sandstone aquifer at other locations.

The samples collected during the SMEC (2006) study were from alluvial/sedimentary aquifers rather than coal seam aquifers. The likely reason for this is that the water in the alluvial aquifers has lower electrical conductivity (EC) than coal seam aquifers.

One coal mining area that has a longer history of stygofauna sampling is the Hunter Valley in NSW, where surveys of alluvial aquifers were conducted between 2000 and 2008. Surveys of the groundwater/surface water interface along the Hunter River between Singleton and Glenbawn Dam from 2000 and 2003 found a diverse community of stygofauna (Hancock 2004). A follow-up project from 2004 to 2008 surveyed groundwater monitoring bores in agricultural areas and several mine sites of the upper Hunter Valley (Hancock and Boulton 2008). This latter work found at least 40 taxa new to science (this number is likely to increase since not all specimens have yet been identified to species level) and confirmed that stygofauna can exist in areas dominated by coal mining. It is worth mentioning that although the Hunter Valley has one of the richest known communities of stygofauna in Australia, no animals were collected from coal seams. All of the bores that contained stygofauna were in alluvial aquifers of the Hunter River and its tributaries. This may reflect a sampling bias, since most of the bores surveyed entered alluvium rather than coal seams, and the presence of stygofauna in coal seams should not be ruled out. It is, however, likely that the majority of taxa in the Hunter Valley do live in alluvial aquifer as well as the upland swamps as highlighted in the Kangaloon studies which is also likely to be the case for stygofauna in the Southern Coal fields.

1.3 Terminology used in this report

Stygofauna can be classified by the degree to which they are dependent on groundwater. Those that are completely dependent on groundwater are termed stygobites and consist predominantly of crustaceans. Those that rely on groundwater to a lesser extent and can live in mixed surface and groundwater are termed stygoxenes or stygophiles depending on their adaptation to the subterranean environment (Marmonier et al. 1993). The distinction is often ambiguous because it is difficult to know the degree of surface/groundwater mixing in an aquifer, and the classifications are regularly disputed (Sket 2010). However, classifications based on affiliation to groundwater can be useful when assessing the conservation status of species and their vulnerability to potential impacts and in this report we adopt the following definitions:

Stygoxenes are organisms that have no affinities with groundwater systems but regularly occur by accident in caves and alluvial sediments. Some planktonic groups (e.g. Calanoida Copepoda) and a variety of benthic crustacean and insect species (e.g. Simullid larvae, Caenidae Mayflies) may passively infiltrate alluvial sediments (Gibert et al.1994).

Stygophiles have greater affinities with the groundwater environment than stygoxenes because they appear to actively exploit resources in the groundwater system and/or actively seek protection from unfavourable surface water conditions. Stygophiles can be divided into occasional/temporary hyporheos and permanent hyporheos.

1.3.1 Occasional/temporary hyporheos and permanent hyporheos

The occasional or temporary hyporheos include individuals that could either spend their lives in the surface environment or spend a part of their lives in the sub-surface environment (e.g. Ceratopogonidae larvae). The permanent hyporheos is present during all life stages in either groundwater or benthic habitats (Gibert et al.1994) and possess specialist adaptations for living in this environment (Gibert et al.1994).

Stygobites are obligate subterranean species, restricted to subterranean environments and typically possessing specialised character traits related to a subterranean existence (troglomorphisms), such as reduced or absent eyes and pigmentation, and enhanced non-optic sensory structures.

Phreatobites are stygobites that are restricted to the deep groundwater substrata of alluvial aquifers (phreatic waters). All species within this classification have specialised morphological and physiological adaptations (Gibert et al 1994).

Stygofauna is an all-encompassing term for animals that occur in subsurface waters (Ward et al. 2000).

1.4 Purpose of this report

The Tahmoor South Project Environmental Impact Statement has been prepared in accordance with Division 4.1, *Part 4 of the Environmental Planning and Assessment Act 1979* (EP&A Act) which ensures that the potential environmental effects of a proposal are properly assessed and considered in the decision-making process.

This stygofauna and groundwater dependant ecosystems assessment has been prepared as a requirement within the Director–General's Requirements (DGRs) for the Tahmoor South Project (SSD 5583) issued on 6 November 2012 to address Clause 75F of the EP&A Act 1979.

Table 1: Director General Requirements applicable to the aquatic impact assessment

Study Requirements		Section Addressed
Director Generals Requirements		
Impacts to Biodiversity-	Detailed assessment of potential impacts of the development on any groundwater dependent ecosystems including macroinvertebrates, macrophytes or **stygofauna**	**Section 5** Impact assessment
Key Agency Requirements		
The NSW Office of Water		
Ensure the sustainable and integrated management of water sources as define in *Water Management Act 2000.*	Assessment of GDEs for condition and water quality requirements for both terrestrial and aquatic systems (macroinvertebrate, macrophytes and **stygofauna**) and is to include diversity and abundance assessments	**Section 4.0** Results

1.5 Impact Assessment Objectives

The aim of the stygofauna baseline surveys and impact assessment is to determine the presence of stygofauna within the area of current and proposed future developments and to assess the potential impacts of the proposed development on groundwater and groundwater fed (baseflow) stream ecology including aquatic threatened species, populations, communities or their habitats that are dependent on groundwater. The assessment addresses the impacts of subsidence from underground coal mining.

The specific objectives were to:

- Describe the natural/pre-mine development characteristics of stream and groundwater ecology through quantitative and qualitative monitoring of stygofauna and baseflow, hyporheic fauna;
- Identify or determine the likelihood of occurrence of threatened species, populations, habitat and/or communities with in the study area;
- Determine if subsidence could affect groundwater and baseflow stream ecology;

- Assess whether these impacts will cause significant adverse effects to groundwater and baseflow stream ecology; and
- Determine whether these impacts will significantly impair any identified threatened species, populations, habitat or communities.

1.6 Report Structure

This report is structured as follows:

Section 1.0 Introduction – outlines the Project and presents the purpose of the report.

Section 2.0 Methodology – describes the methodology employed for the aquatic ecology impact assessment.

Section 3.0 Existing Environment – describing the physical characteristics of each site surveyed.

Section 4.0 Results – Report the findings of the surveys.

Section 5.0 Impact Assessment – Assesses and describes the potential risks and impacts to aquatic ecology resulting from the proposed project.

Section 6.0 Safeguards and management - provides a summary of environmental mitigation, management and monitoring responsibilities in relation to aquatic ecology management for the Project.

Section 7.0 Conclusion.

Section 8.0 References.

2 METHODOLOGY

The groundwater dependent aquatic ecology impact assessment methods were structured to specifically reflect current relevant legislation, specific guidelines; and to address requirements from director general, and advice from local, state, and federal agency stakeholders. These methods include monitoring design and impact assessment criteria.

2.1 Legislation, policy, criteria and/or guidelines

Groundwater ecosystem dependence is an increasingly important component of surface and groundwater initiatives in NSW and has been incorporated within Groundwater Management Plans under the Water Reform Agenda.

The impact assessment for the Tahmoor South Project is assessed as State Significant Development under Division 4.1 of the EP&A Act and addresses director general requirements and guidelines (Table 1) as required under Schedule 2 EP& A Regulation 2000.

The NSW State Government also has an obligation under the WMA 2000 and the Groundwater Dependent Ecosystem Policy to “manage GDEs in such a way that it:

- Applies the principles of ecologically sustainable development;
- Protects, enhances and restores water sources, their associated ecosystem, ecological processes and biological diversity and their water quality;
- Integrates the management of water sources with the management of other aspects of the environment, including the land, its soils, its native vegetation and its native fauna.”

The *Water Management Act 2000* also provides water management principles that are relevant to the management of GDEs. These include:

- water sources, floodplains and dependent ecosystems (including groundwater and wetlands) should be protected and restored and, where possible, land should not be degraded;
- habitats, animals and plants that benefit from water or are potentially affected by managed activities should be protected and (in the case of habitats) restored; the quality of all water sources should be protected and, wherever possible, enhanced;
- the cumulative impacts of water management licences and approvals and other activities on water sources and their dependent ecosystems, should be considered and minimised;
- the principles of adaptive management should be applied, which should be responsive to monitoring and improvements in understanding of ecological water requirement.

The following policies are relevant to the protection and management of GDEs in NSW:

- NSW State Groundwater Policy Framework document, Department of Land and Water Conservation, 1997. http://www.water.nsw.gov.au/Water-Management/Law-and-Policy/Keypolicies/

- NSW State Groundwater Dependent Ecosystems Policy, Department of Land and Water Conservation, 2002. http://www.water.nsw.gov.au/Water-Management/Law-and-Policy/Keypolicies/
- NSW Groundwater Quality Protection Policy, Department of Land and Water Conservation, 1998. http://www.water.nsw.gov.au/Water-Management/Law-and-Policy/Keypolicies/
- NSW Wetlands Management Policy, Department of Environment, Climate Change and Water, 2010a.
- State Environmental Planning Policy No. 14 – Coastal Wetlands, SEPP 14.
- Risk assessment guidelines for groundwater dependent ecosystems – the conceptual framework NSW Office of Water, September 2012
- NSW State Rivers and Estuaries Policy – NSW Water Resources Council NSW Government, 1993. http://www.water.nsw.gov.au/Water-Management/Law-and-Policy/Keypolicies/
- Water Compliance Policy (NSW Office of Water, 2010a). http://www.water.nsw.gov.au/Water-Management/Law-and-Policy/Key-policies
- NSW Water Extraction Monitoring Policy. http://www.water.nsw.gov.au/Waterlicensing/Metering/default.aspx

The following legislation is also considered in this project for the protection and management of GDEs in NSW:

- *Threatened Species Conservation Act 1995*. This Act and its listings are used in the determination of the ecological value of a GDE, i.e. if a GDE contains a threatened species as listed under this Act, the GDE is taken to have higher ecological value.
- *Native Vegetation Act 2003*. This Act is relevant to the protection of vegetation which may be or form part of a GDE community.
- *Fisheries Management Act 1994*. This Act is relevant to the determination of the ecological value of a GDE (i.e. if the GDE contains a threatened species as listed under this Act, the GDE is taken to have higher ecological value).
- Draft New South Wales Biodiversity Strategy, Department of Environment, Climate Change and Water NSW and Industry and Investment NSW, 2010. The Strategy is directly relevant as its objectives include the: smarter biodiversity investment and improved partnerships whole of landscape planning effectively managing threats sustainable production environments.
- NSW Natural Resources Monitoring, Evaluation and Reporting Strategy 2010-2015.

2.2 Study area

The Study Area for the purposes of this report includes all watercourses and aquifers that occur within the Subsidence Study Area, as defined within the MSEC Subsidence Report (MSEC 2014).

2.2.1 Literature and database review

Literature and data sources reviewed included:

- AECOM (2012) Tahmoor South Project Preliminary Environmental Assessment, prepared for Tahmoor Coal August 2012;
- Niche (2012) Tahmoor South Pilot Study, Prepared for Tahmoor Coal;
- Niche (2013) Tahmoor South Aquatic Ecology Monitoring Project Year 2012-2013;
- DOP (2008) Impacts of Underground Coal Mining on Natural Features in the Southern Coalfields -Strategic Review. State of NSW through the Department of Planning, 2008 (commonly referred to as the Southern Coalfields Inquiry);
- PAC (2009) The Metropolitan Coal Project Review Report. State of NSW through the NSW Planning Assessment Commission, 2009;
- PAC (2009) Review of the Bulli Seam Operations Project. State of New South Wales through the NSW Planning Assessment Commission, 2010;
- NPWS (2003) Native Vegetation of the Woronora, O'Hares and Metropolitan Catchments;
- DECC (2008) Threatened Species Profiles Database, NSW Department of Environment and Climate Change (now OEH);
- OEH Atlas of NSW Wildlife (accessed April 2013); and
- The EPBC Act Protected Matters Search Tool (accessed April 2013).
- DPI threatened and protected species records viewer (accessed June 2013).

2.2.2 Review of previous studies

- Bioanalysis Part 3A Bulli seam Aquatic Ecology Impact Assessment;
- Russell, G. N., Green, R.T., Spencer, J. and Hayes, J., 2010, Thirlmere Lakes Groundwater Assessment. Report NOW 10_389 by NSW Office of Water, Sydney. ISBN 978 0 7313 3467 4. 73p;
- Pells, P. and Pells, S., 2011, Report on the Water Levels of Thirlmere Lakes. Pells Consulting Report P053.R1, October 2011. 103p. + Appendices A-E;
- Heritage Computing - Thirlmere Groundwater Appraisal Ver.E 16 March 2012 HC2012/3;
- Hose, G, 2008. Stygofauna baseline assessment for Kangaloon borefield investigations Southern Highlands NSW. Access Macquarie Limited;
- SMEC 2006. Baseline Groundwater Dependent Ecosystem Evaluation Study –Upper Nepean Groundwater Pilot Studies – Final Report. Report to Sydney Catchment Authority. SMEC Australia Pty Ltd, Sydney.

2.3 Stygofauna program

2.3.1 Project objectives

The primary objectives of the study are to:

1) Determine whether any substantial stygofauna (and targeted hyporheic) communities exist within the aquifers associated with the area of proposed development as well as in both the upstream and downstream of the likely area of influence of any groundwater impact;
2) Determination of species ranges if stygofauna exist, identifying conservation values such as short range endemics;

3) Determine the factors influencing stygofauna distribution such as water quality (DO, pH, conductivity, temperature), aquifer structure, and connectivity to rivers;
4) Recommend any future work programs to potentially investigate and/or monitor this ecosystem over time.

In preparing for each round of stygofauna sampling it is necessary to keep in mind the needs of a future monitoring program that will be required to determine if there has been any significant changes to either the water resource or the dependent ecosystems. This is best done by using a BACI (Before/After Control/Impact) experimental design i.e. before and after sampling at experimental and control (reference) sites.

The development of any sampling protocol involves:

- Selecting sampling location points (bores, wells, piezometers, appropriate hyporheic habitat etc.);
- Deciding on an appropriate sampling method (pumps, bailers, plankton nets, Bou Rouche pump etc.);
- Determining sample handling procedures (such as filtration, transfer, preservation, etc.); and minimum disturbance to biological specimens.

2.3.2 Sampling methodology

In order to sample a habitat effectively it is often necessary to use a combination of techniques to comprehensively collect all possible biota as the stygofaunal community occupies a range of habitat niches. For routine surveying or monitoring of bores and wells a submersible pump or hand pump, bailer (1) and or plankton nets (Mathieu et al. 1991) are the preferred devices. Whereas for hyporheic zones and spring sites hand pumps/syringe devices, hand nets and artificial substrates are preferred. The sampling techniques used for the Tahmoor stygofauna and hyporheic fauna surveys are described below.

<u>The Phreatic/hypogean zone</u>

The phreatic zone is the subsurface area within an aquifer where voids in the rock are completely filled with water. This is occupied by phreatobites. Pheatobites have adapted to tolerate suboxic conditions (dissolved oxygen concentration (DO) less than 3.0 milligrams per litre) or limited food supply (Malard and Hervant 1999; Hervant and Renault 200;, Datry et al. 2005) and even hypoxia (DO less than 0.01milligrams per litre) (Thomlinson & Boulton, 2008). Dissolved oxygen (DO) concentrations below 1.0 to 0.5 mg/l are the critical threshold for most groundwater fauna (metazoans) (Hahn 2006). The stygofauna community was sampled using two standardised methods and one non-standard method.

The first technique is the Phreatobiology Net. This is the standard technique that has been used successfully overseas and in Australia (Bou, 1974). The method used conforms to WA guideline [2003 & 2007] requirements. This method involves using a weighted long haul or plankton net with a 150 μm mesh. Sampling consisted of dropping the net down to the bottom of the bore and taking at least three consecutive hauls from the entire water column at each bore. Upon removal from the bore the net is washed of sediment and animals and the contents of the sampling jar (the weighted container at the bottom of the net) are decanted through a 150 μm mesh sieve. The contents of the sieve are then transferred to a labelled sample jar and preserved with 100% ethanol.

The second method is the use of a groundwater bailer. A bailer is typically used by hydrogeologists to taken water samples from bores for water quality/water chemistry analysis. The bailer used for this study is 1 meter long by 40mm clear plastic tube with a running ball valve at the bottom. The advantage of using a bailer is twofold. The main reason for using a bailer is that it is able to sample the bottom sediment of a bore that cannot be sampled by a haul net and therefore enables the collection of cryptic invertebrates that do not inhabit the water column or sides of the bore. The second advantage is that in shallow bores down to 5 meters in sediments with low transitivity porosity) a bailer is able to empty the entire contents of a bore and thereby confidently collect all animals within the bore. The contents of the bailer are emptied into a cleaned bucket from which the water is then decanted through a 150 μm mesh sieve. The contents of the sieve are transferred to a labelled sample jar and preserved with 100% ethanol. Following sampling and preservation of the sample and prior to the next sampling all equipment including the bailer, net and sieves must be rinsed clean with clean water via a spray bottle to remove any sediment and animals that may have remained attached to the sampling devices. This is to reduce the possibility of cross contamination of organisms (stygofauna or bacteria) or pollutants from one aquifer or bore to another.

The third (non-standard) method was used only one bores that had a pump (works) attached that created access restrictions with the other two methods. This involved pumping water through the pump to the surface for approximately ten minutes, which removed an estimated two bore volumes. This was drained through a 150µl sieve. The resulting sediment was washed into a container and preserved in 100% ethanol. The pump and pipe work was not removed from the bore and therefore the entire water column was not sampled using either the bailer or phreatobiology net as in the other two sites.

Hyporheic zone.

The Hyporheic Zone is the ecotone zone below and within the porous sand and gravel substrate of a riverbed. The fauna that inhabits this ecotone is thus termed the hyporheos. The hyporheos represents and diverse range of organisms from surface macroinvertebrates to groundwater Crustacea to Oligochaeta depending on the depth and origin of the water parameters i.e. whether the water is groundwater or surface water dominated.

The hyporheic zone is a highly variable and fluid ecotone that is controlled by the river flow rates, groundwater baseflow, whether the river is a gaining or loosing system, sediment type, sediment porosity and water chemistry/quality, habitat connectivity with other habitats and the longevity of the habitat. Two to four collections were conducted at each riffle zone depending on habitat availability across the bottom of the riffle zone. This area has been shown to contain the highest concentration of groundwater fauna (Boulton et al. 2003, 2004) as it represents the upwelling zone of a river bed as opposed to the top of a riffle which is the downwelling zone.

Each hyporheic sample is taken using the Bou-Rouch Pump method (Bou and Rouch, 1967), which is similar to the method used by Boulton et al. (2003, 2004). The principle of the method is to drive a pipe or spear point into the substrate and to extract water and animals via an attached pump. This method creates a pressure and flow alteration within the substrate which disturbs the sediment and maintains an interstitial flow around the pipe that is sufficient to dislodge subsurface invertebrates (PASCALIS 2003; Bou and Rouch 1967). A hollow steel pipe with a 16 mm internal diameter was hammered between 0.5-1.0 m into the riffle substratum. After attaching a hand pump up to 30 litres of water is pumped from the riffle into a bucket and the sample was then filtered through a 150µm mesh. All animals and material collected was then preserved in 100% ethanol. Up to 4 samples were taken from each riffle site.

2.4 Laboratory methods

2.4.1 Stygofauna and aquatic macroinvertebrates

All samples are preserved in the field with 100% ethanol and returned to the laboratory where each sample is sorted under a stereomicroscope and stored in 100% alcohol. All specimens are identified to the lowest possible taxonomic level, generally to genus, where possible. Specimens are identified under a compound microscope using a combination of current taxonomic works and keys such as Williams (1981) and the taxonomic identification series (Serov 2002) produced by the Murray Darling Freshwater Research Centre as well as the authors taxonomic expertise and experience.

2.5 Impact assessment

2.5.1 Impact assessment methodology

Mining developments, in which stygofauna are considered to be a relevant environmental factor need to be assessed with respect to the extent of the proposed groundwater drawdown zone and the likely impacts on groundwater quality and quantity. Both of these activities, over time, may impact stygofauna habitat. While stygofauna are able to tolerate natural fluctuations in water parameters such as water level, electrical conductivity, and temperature, it has been demonstrated both in Australia and overseas that stygofaunal species are detrimentally impacted by changes outside the natural range of water level, quality, and water chemistry. Changes such as rapid drawdown and pollution plumes can have impacts on the community composition, biodiversity and overall sustainability of the community.

Groundwater communities also require links to the surface environment to provide organic matter and oxygen. If that linkage is broken or disrupted, the stygofauna community in the area affected could decline over time. A high degree of endemism can occur in aquifers, even within the same system or between adjacent systems. However, providing there is sufficient hydrological connectivity within and along the flow path of the aquifer, and the physico-chemical conditions are suitable and remain stable, the distribution of species will not be restricted to small parts of an aquifer.

The ecological valuation and risk assessment process used to assess the risk and potential impacts of the proposed development for the identified GDEs is the “Risk Assessment Guidelines for Groundwater Dependent Ecosystems (Serov *et al*, 2012)”. This methodology was developed by the NSW Office of Water to:

1. Assist agency staff support the requirements of the *Water Management Act 2000*
2. Provide methods to identify and value groundwater dependent ecosystems (GDEs) to assist reporting against the state-wide Target for Groundwater that:

'By 2015 there is an improvement in the ability of groundwater systems to support groundwater dependent ecosystems and designated beneficial uses', NSW Natural Resources Monitoring, Evaluation and Reporting Strategy 2010–2015.

3. Provide a risk assessment framework for GDEs for the National Water Commission Project Coastal Groundwater Quality and Groundwater Dependent Ecosystems (GDE)
4. The conceptual framework allows potential and actual impacts of proposed activities on GDEs to be assessed in accordance with the WM Act (Chapter 1.3 of the Act) and other relevant legislation. (Serov *et al* 2012).

In summary, GDEs are first identified and classified and the level of dependency on groundwater for individual GDEs inferred. Once the current ecological value of individual aquifers has been determined, the ecological value of the GDEs associated with that aquifer must then be assessed. The individual value of each GDE within the aquifer can also be assessed as a stand-alone unit. Following an assessment of the aquifer and associated GDEs current value, the potential future impact of a proposed activity on the aquifer and associated GDEs must then be determined. The magnitude of risk from that activity to the ecological value of the GDE(s) and aquifer is then determined. Finally, the Risk Matrix is applied to determine the most appropriate management response for a given environmental value.

2.5.2 State of NSW

The assessment of the Project has been carried out for approval under the provision for State Significant Development within Part 4, Division 1 of the EP&A Act. Threatened biodiversity as listed on the NSW TSC Act and FM Act have been considered in this assessment.

2.6 Assumptions and limitations

This report is a preliminary baseline assessment, which focuses on the Study Area.

Mine subsidence predictions undertaken by MSEC have been used to define the likely subsidence impacts of the Project.

Groundwater bore and hyporheic sites sampled are assumed to be representative of the groundwater and stream ecosystems present across the area of consideration, temporally and spatially. While every effort was given to maximise the representativeness of the system it does not cover the full extent of the bores and streams in the Study Area. Temporal variations between autumn and spring also cannot be assessed at this stage as there has been no seasonal replication.

3 EXISTING ENVIRONMENTS

3.1 Study area context

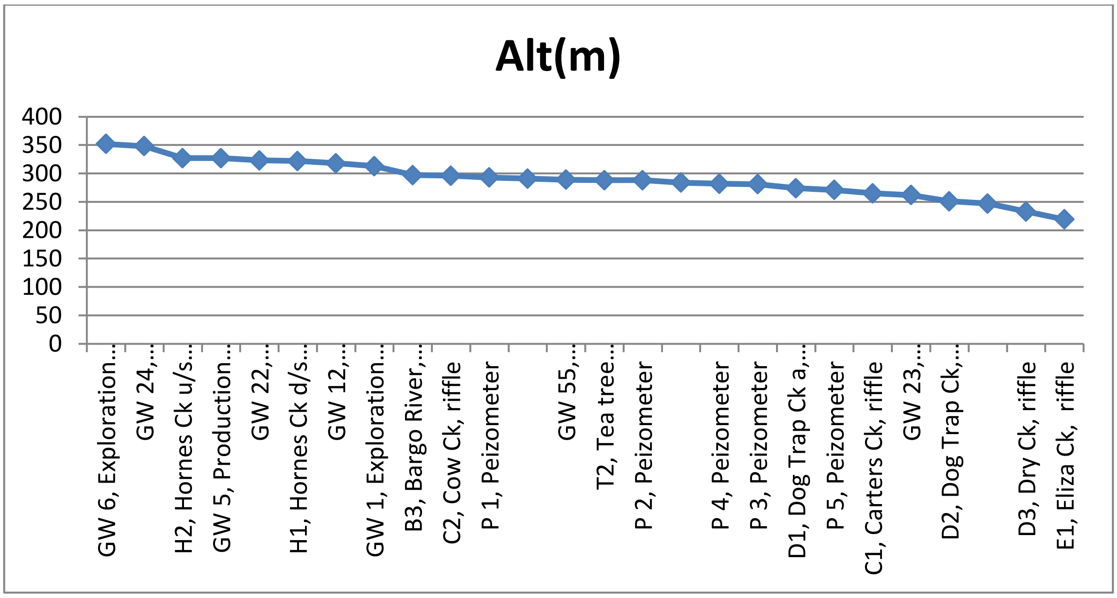
3.1.1 Key characteristics of the site

Consolidated Coal Lease No. 747 and 716 (CCL 747 and CCL 716) lie within the Southern Coalfields. The following landscape information is summarised from NSW DoP (2008) and is a generalised description of the land encompassed by the Southern Coalfields.

3.1.2 Geology

The proposed Tahmoor South mine extension area lies in a gently deformed sequence of interbedded Triassic sandstone, shale, and Permian claystone beds that form the upper sequence of the southern Sydney Basin. All formations have a consistent west to east dip. This is also reflected in the topography with the western margin of the area containing the highest sites (GW6 and Hornes Creek followed by a gradual dipping towards the north east with Dry Creek and Eliza Creek being the lowest sites) (Graph 1).

Graph 1 Altitude distribution of the survey sites



The main surface geological unit in the area is the Hawkesbury Sandstone of Triassic age (<225 million years ago) although this is overlaid with exposures of a capping of younger shale-dominated Wianamatta Group. (Merrick 2012).

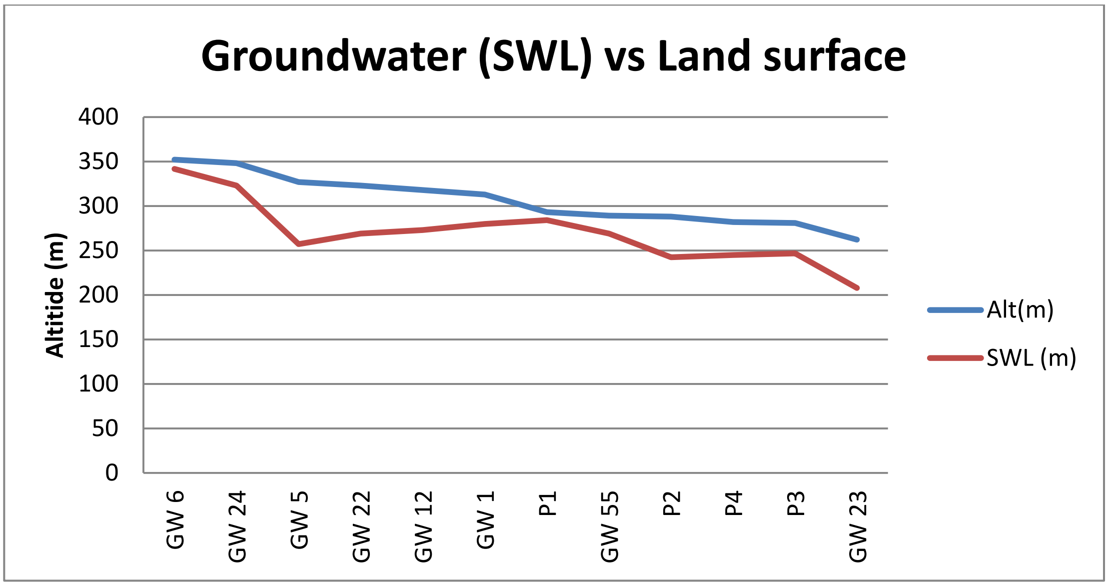
The majority of mining in the Southern Coalfield extracts coal from the Bulli or Wongawilli Seams within the Illawarra Coal Measures. At the Tahmoor Mine, only the Bulli Seam is mined. The Narrabeen Group immediately overlies the uppermost Bulli Coal unit at a depth 300-350m (Merrick 2012). The Hawkesbury Sandstone, overlays the strata of the Narrabeen Group, where the Bald Hill Claystone act as an aquitard (Pell 2011; Merrick 2012).

3.1.3 Groundwater

The main aquifers in the area occur within the Hawkesbury Sandstone, whereas the Wianamatta Shales contain a number of smaller and often transitory, perched aquifers in the upper catchment. Groundwater is recharged by rainfall along the ridgelines and discharges as springs in the mid to lower slope areas, providing base flow to most of the small streams. The Wianamatta Shale serves as the upper confining layers for some parts of the sandstone aquifer.

The Hawkesbury Sandstone is the widespread regional aquifer. It however, has a dual aquifer system including both primary and secondary permeability (Hose 2008), with the main aquifers occurring between 30 to 120 m depth (See drillers logs in Bore survey sites below) although standing water level (SWL) vary from 9 to 70 m.

Graph 2 Standing water levels (SWL) against land surface.



The most productive (fractured) horizons within the sandstone vary from area to area and can occur at any depth but at most locations are above 80 m. Groundwater movement is variable, with both primary granular/porous flow and secondary fracture flow along joints/shear zones. There are a number of faults occurring across the region, however, only the Nepean fault is hydrologically charged (Merrick 2012).

3.1.4 Topography

The essential landscape feature which has determined the valley forms and cliff lines of the Southern Coalfields is the Hawkesbury Sandstone, which is highly resistant to weathering. This has meant that weathering and erosion caused by moving water has been concentrated along the networks of faults and joints which occur naturally in this rock as the result of stresses imposed during geologic time, leading to the development of a system of deeply incised river gorges which drain the plateaus. The river valleys, particularly the downstream sections as they approach the Hawkesbury River Valley, are often narrow with steep sides and stream beds largely composed of the sandstone bed rock, with rock bars and boulder-strewn channels. These steep-sided valleys, particularly the downstream sections, may take the form of a gorge, with large sandstone cliffs on one or both sides of the river. An example is the Bargo River Gorge, located between Pheasants Nest and Tahmoor (NSW DoP, 2008), which is within the boundary of the CCL 747.

Further upstream in most catchments, the rivers are less incised and their valleys are broader and more open in form although the sandstone bedrock still remains the key geomorphological determinant. Stream beds are still generally composed of exposed sandstone bedrock, with rock bars and channels strewn with smaller boulders and cobbles. The sandstone bedrock becomes a drainage surface, being fed by from point source discharges from groundwater seeps emanating from fractures within the sandstone. The groundwater provides variable quantities of base flow for most of the streams with many streams exhibiting the generally perennial characteristics of the larger streams and rivers (NSW DoP, 2008).

3.1.5 Watercourses

The geomorphology described above usually creates pools and riffle sections in 1st and 2nd order creeks, which provide important macro-invertebrate habitat and fish refuge. The higher order streams are typically broader and provide habitat for larger fish species (NSW DoP, 2008). Within the Study Area there are eight named creeks ranging in order from 1st order to 4th order creeks (using Strahlers', 1952 stream order system). A characteristic of most streams is that the majority of the creeks within the Study Area have a riparian zone dominated by Mat Rush (*Lomandra longifolia)* while the substrate is dominated almost exclusively by bedrock and/or boulder on bedrock, with small infrequent patches of sand, gravel and fine organic material. The sand beds usually consist of fine grained sands (0.50-1.0mm) with high levels of fine allochthonous (leaf and twig particles) matter. Due to the fine nature of the material the subsurface environment is usually anoxic.

Habitat attributes within these creeks included pools with bank overhand and trailing bank vegetation, rock bars, small waterfalls and sections of dry bed dominated by *L. longifolia* and boulders. Many of the creeks had an obvious orange discolouration of the water indicating the presence of iron rich groundwater. The iron occurs naturally in a dissolved state within the groundwater environment, however, on contact with the atmosphere or oxygenated water it precipitates out as an orange/yellow flock. There is also the presence of some filamentous algae. Macrophytes were not common due to the lack of suitable holdfast substrate and the high energy nature of these streams. Many of the creeks contained Freshwater Crayfish (*Cherax sp.* and *Euastacus sp.)*, Freshwater Shrimp (*Paratya australiensis)* and the exotic Mosquito Fish (*Gambusia holbrooki)*.

Bargo River is the main natural feature within the Study Area and it is located on the western side of the Study Area. Bargo River is a tributary of the Nepean River and falls within the Bargo River Sub-catchment, which is the smallest sub-catchment (130.70 km^2) of the Hawkesbury Nepean catchment. It contains two reaches separated by the Bargo reservoir. Reach one, Bargo R1, is considered to be in near intact condition, while Bargo R2 has experienced some impacts from mining activity and access to the riparian zone. Picton Weir upstream also has an impact on this reach (HNCMA 2006).

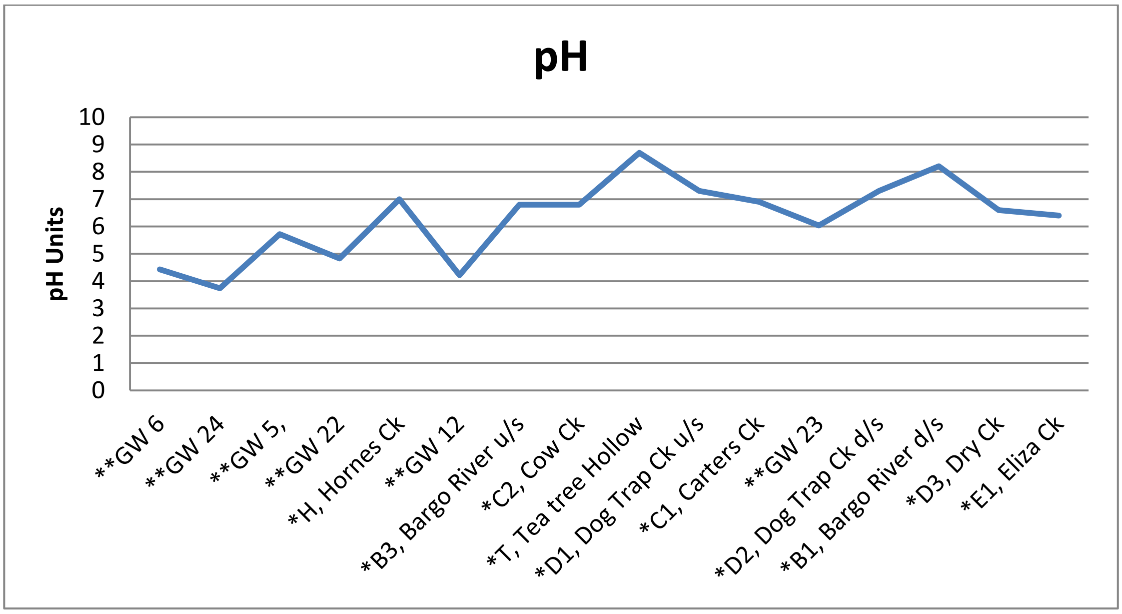
Following its confluence with Bargo River, the Nepean River continues to flow north, through the Nepean River Sub-catchment, eventually flowing into the Hawkesbury River which enters the Pacific Ocean. Both the Bargo River and Upper Nepean River sub-catchments form part of the Western Sydney Region of the Hawkesbury-Nepean Catchment Management Authority (CMA).

3.1.6 Water Quality

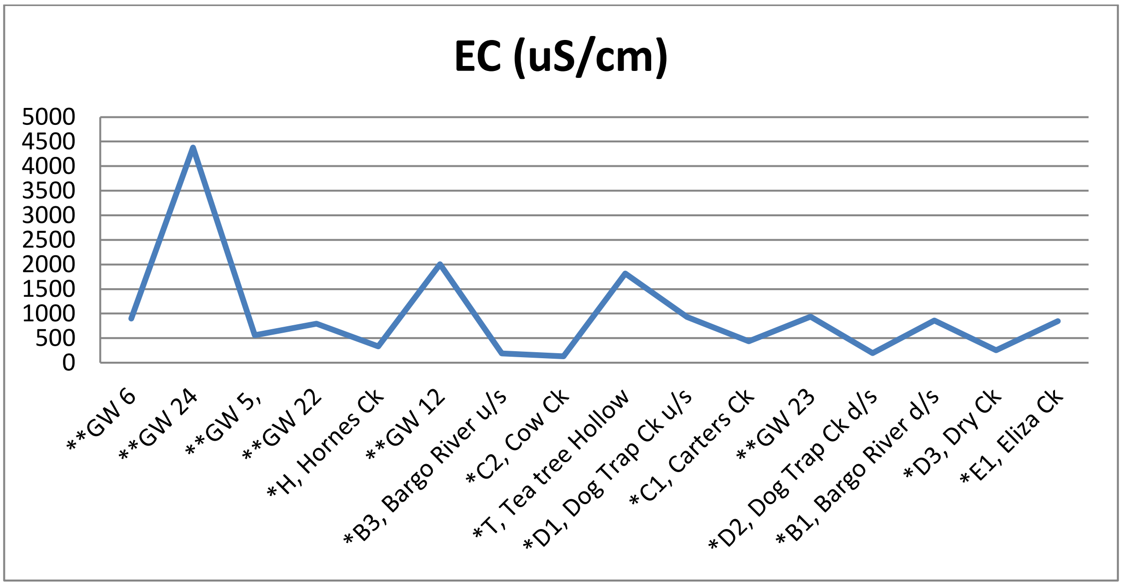
Water quality varied considerable across the Study Area. The surface stream water quality is characterised by having relatively neutral pH ranging from an average 6.6 in Dry Creek to moderate alkaline at 8.7 in the bottom section of Tea Tree Hollow. There is a general trend towards an increase in pH with a reduction in altitude across the area from west to east (Graph 3). Salinity was also variable but generally low to moderate ranging from an average low of 130uS/cm in Cow Creek to an average high of 1,815 uS/cm at the bottom section of Tea Tree Hollow. The general trend across all sites is towards a marked reduction in values with a reduction in altitude across the area from west to east (Graph 4). Salinity is (and lower pH vales) generally elevated in those streams that have a significant groundwater contribution (from either regional or perched aquifers) such as Eliza Creek, Lower Dog Trap Ck, Carters Ck and Hornes Ck.

Groundwater quality differs from the surface streams by having moderate to strongly acidic pH ranging from 6.03 at GW 23 to 3.74 at GW 24. In comparison the generally neutral river water, particularly in those streams that have a significant groundwater contribution indicates there is significant buffering occurring through high alkalinity values. Alkalinity is the water's capacity to resist changes in pH that would make the water more acidic. This capacity is commonly known as “buffering capacity” and partly explains the consistent pH values recorded. Alkalinity of natural water is determined by the soil and bedrock through which it passes. In streams, the fluctuations are related to the relative proportions of groundwater and rainfall mixing where the alkalinity levels show an inverse relationship to river flow or rainfall events. Therefore, the fluctuations in alkalinity increase during periods of low flows and decrease during periods of higher rainfall. The alkalinity levels have been sufficient to buffer the rivers from any significant changes across the sites.

Graph 3 pH variation across the sites against altitude i.e. west to east downslope.

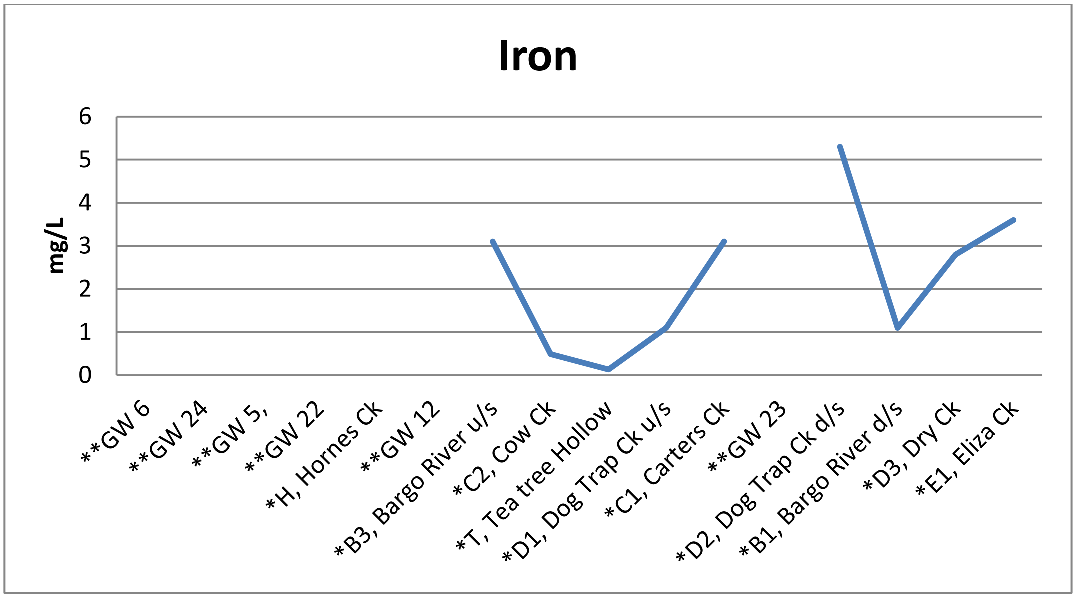


Graph 4 EC variation across the sites against altitude i.e. west to east downslope



Stygofauna appear to prefer water with EC less than 5 000 µS/cm, although records of some syncarid species and genera of Koonungidae in Victoria and Tasmania are adapted to exist in naturally high EC 33 000 µS/cm waters. Stygofauna have been collected in bores with EC up to 18 000 µS/cm, so it is possible to collect animals in salinities in excess of 10,000 EC. However, it must be remembered that the vast majority of fauna have been collected in salinities generally less than 1000 µS/cm. Other variables thought to be suitable for stygofauna are a shallow water table (<50 m), moderate concentrations of dissolved oxygen (1-3 mg/L), and pH between about 6.2 and 7.2 (Hancock 2008) although this range is considered quite narrow (Serov, P, Pers comm.).

Graph 5 Iron variation across the sites against altitude i.e. west to east downslope.



3.1.7 Vegetation

The riparian vegetation around Bargo River is dominated by Hinterland Sandstone Gully Forest. This vegetation community also occurs around Hornes Creek, Dog Trap Creek and Cow Creek. Cumberland Shale Sandstone Transition Forest is mapped along parts of Eliza Creek, Dry Creek and Cow Creek, while areas of Sydney Hinterland Transition Woodland occur predominantly along Eliza Creek and Dog Trap Creek (Tozer 2010). Further description is given in each of the stream site descriptions.

3.1.8 Hyporheic survey sites

The hyporheic baseline survey program included two rounds of survey with the first commencing on the 3rd of June 2013 and the second on the 16th of July. The surveys included 13 hyporheic sites covering 8 streams with multiple sites on 4 streams (See Table 10, Figure 2). The sites were selected to cover as broad a coverage of the Study Area as possible, with sites located both within and outside (controls) the potential area of impact, as well the broadest range of habitat types. The survey sites are listed below in Table 2. For a full list of sites see Table 10.

Table 2 Hyporheic Survey Sites.

Locality Name	Habitat	Substrate
B1, Bargo River, Rockford Bridge,	Sandbar	Fine sand/organics
B2, Bargo River middle	Riffle	Fine sand/detritus
B3, Bargo River, upper riffle	Riffle	Fine sand/detritus
C1, Carters Ck, riffle	Riffle	Fine sand/detritus/iron
C2, Cow Ck, riffle	Riffle	Fine sand/detritus
D1, Dog Trap Ck a, riffle	Riffle	Fine sand/organics
D2, Dog Trap Ck, Rockford Bridge, riffle	Riffle	Fine sand/organics
D3, Dry Ck, riffle	Riffle	Fine sand/detritus
E1, Eliza Ck, riffle	Riffle	Fine sand/detritus/iron
H1, Hornes Ck d/s road crossing, sandbar	Sandbar	Fine sand/detritus/iron
H2, Hornes Ck u/s road crossing, sandbar	Sandbar	Fine sand/detritus
T1, Tea tree Hollow near road crossing	Gravel bank	Gravel/sand
T2, Tea tree Hollow u/ road crossing	Pholeteros/riffle	Grey sand, minor clay

3.1.8.1 Subsidence control sites

__Bargo River (B1, B2, B3 Plate 1a and b)__

The three Bargo River hyporheic sites are located upstream of the Rockford Road Bridge. The first site (B1) is the downstream site located approximately 50m upstream from the Rockford Road Bridge. The site consists of a small sand bar on the downstream side of the main pool. The pool is bordered upstream and downstream by bedrock bars with very few disconnected patches of sand and macrophytes. The pool contains a number of patches of emergent macrophytes (Phragmites sp.) contributed to 10% of the surface water area at this site. The substrate at the site of the hyporheic sample consisted of very fine sand, silt and fine organic material.

Bargo River Site 2 (B2) is located approximately 2 km upstream along the fire trail and consists of a substantial riffle section approximately 20 long and rising approximately 0.5-0.7m between the downstream and upstream pool. The riffle consisted of course sand, gravel and cobble. The hyporheic zone of the riffle contained a number of lenses of course, loose, unconsolidated sediments indicating a high subsurface flow and porosity and containing a high proportion of fine organic material. Water turbidity was low with no algal development. The riparian zone consisted of dense predominantly un-impacted native rainforest species with an over-hanging canopy.

Bargo River Site 3 (B3) is a riffle located approximately 4-5 km upstream along the fire trail approximately 50m downstream of where the road crosses a small tributary. The riffle consists of course sand, gravel and cobble and is approximately 15 long and rising approximately 0.5m between the downstream and upstream pool. The hyporheic zone of the riffle contained a number of lenses of course, loose, unconsolidated sediments indicating a high subsurface flow and porosity and containing a high proportion of fine organic material. Water turbidity was low with no algal development. The riparian zone consisted of dense predominantly un-impacted native rainforest species with an over-hanging canopy.

Hornes Creek (H1, H2, Plate 5b, c)

Hornes Creek is located near the south western portion of the Study Area and has a catchment area of approximately 2,000 ha. The catchment consists of native bushland (owned by Tahmoor Coal) and a portion of the township of Bargo. Hornes Creek flows into Bargo River approximately 100 m upstream of the Picton Weir.

The hyporheic survey of this stream included two sites, one upstream and one downstream of the Ashby Close road crossing. Hornes Creek is a 3rd order stream with the bed dominated by bedrock with a lot of bank overhang, trailing bank vegetation, snags and small waterfalls and occasional large pools. There were very few sandbars habitats within this stream. The hyporheic habitats consisted of very small thin, disconnected sandbars composed of fine sands, silts and fine organic material. The stream bed had a distinct orange discolouration. Only minor disturbance to the riparian zone was observed.

The riparian vegetation has been mapped as Sydney Hinterland Transition Woodland (Tozer et al. 2010). The dominant canopy species consisted of large smooth barked eucalypt species with a middle stratum dominated by Black Wattle *Callicoma serratifolia*, *Melaleuca* sp., *Leptospermum* sp., *Acacia longifolia*, *Hakea* sp., *Pomaderris* sp. and *Banksia* sp. The lower stratum was dominated by *Lomandra longifolia, Banksia spinosa* and native sedges *Schoenus melanostachys* with some ferns.

The downstream survey site is located approximately 100m downstream in a large pool. The sandbar is located adjacent to the waterfall feeding the pool and consisted of a mound of fine sand, organic material and macrophytes with a subsurface layer of fine, anoxic organic mud.

The upstream survey site is a small sandbar connected to the bank and is located approximately 100m upstream between a series of shallow bedrock riffles. The sandbar was approximately 0.6m in thickness on bedrock and consisted of very fine sands and organic material.

3.1.8.2 Impact sites

Carters Creek (C1, Plate 1c, d)

Carters Creek is located in the south-eastern corner of the Study Area and has a catchment area of approximately 1,000 ha. The catchment of this creek consists mostly of rural residential properties and some farming, with some riparian bushland still intact. Carters Creek feeds into the Nepean River approximately 2.5 km downstream of the Cordeaux River confluence. The dominant canopy species at both survey sites included Grey Gum *Eucalyptus punctata* and Sydney peppermint *Eucalyptus piperita*, while middle stratum was dominated by *Melaleuca* sp. and *Acacia longifolia*. The lower stratum was dominated by *Lomandra longifolia*, with some ferns (*Pteridium esculentum* and *Adiantum aethiopicum*). The width of the creek varies from 0.5m to 8 m, with the modal width being ~ 3 m. Habitat features such as pools, small waterfalls, undercut banks, trailing vegetation, snags and shallow riffle sections are characteristic of this creek. The bed substrate primarily consists of bedrock.

The survey site is located downstream of the Mockingbird Road bridge overpass, outside of the Study Area. This site encompasses a northern arm of Carters Creek, which is also within the Study Area. Some sections of the creek appear to have little to no water, with the drainage line defined only by a high density of Lomandra longifolia. Disturbance to water quality at this site was evident by major orange colouration of the water and a significant layer of orange flocculent covering the substrate. There was some rubbish instream. Smaller amounts of Crofton weed was observed along with some exotic grasses.

The hyporheic zone was sampled from a small sand, gravel riffle approximately 3m in length with a fall of approximately 0.4m into the next pool. The bottom of the riffle had some minor erosion that formed a small waterfall. The base of the stream consists of a dense yellow clay. The subsurface substrate was consisted of loose course unconsolidated sediments that indicated a high porosity and subsurface voids. The sample consisted of anoxic sand and fine particulate allochthonous material and large quantities of precipitated iron. This stream at this site appears to be highly impacted by a combination of factors.

Cow Creek (C2, Plate 2a, b)

Cow Creek is located in the south-eastern corner of the Study Area and has a catchment area of approximately 500 ha. The majority of its catchment falls within the Sydney Water Catchment Area (SCA). Cow Creek feeds into the Nepean River approximately 5.5 km upstream of its confluence with the Cordeaux River. The riparian vegetation has been mapped at as Hinterland Sandstone Gully Forest (Tozer 2006). The dominant trees include Stringybark species and Sydney Peppermint *Eucalyptus piperita*. The middle stratum consists of *Melaleuca* sp., *Leptospermum* sp., *Banksia* sp. and *Persoonia* sp. while the lower stratum is dominated by ferns *Pteridium esculentum* and *Blechnum* sp. The width of the creek varies from 0.5m to 8 m, with the modal width being ~ 3 m. Habitat features such as pools, small waterfalls, undercut banks, trailing vegetation, snags and shallow riffle sections are characteristic of this creek. The bed substrate primarily consists of boulders and a thin sediment layer over bedrock.

The survey site is located outside of the Study Area and downstream where other first order tributaries (that are sourced within the Study Area) have entered the creek. At this point, the catchment area is approximately 325 ha, the majority of which is within the RMZ. During the survey period, there was no evidence of disturbance to the water quality, instream habitat or riparian zone. The site is located approximately 20m upstream of the junction with a small tributary. The substrate consists of fine to course sands with fine particulate allochthonous material. Water quality appeared high with very low turbidity and no iron staining. It was difficult to find an appropriate sampling point due to the compacted sediments, large boulders and shallow sediment depths on bedrock.

Dog Trap Creek (D1, D2, Plate 2c, d)

Dog Trap Creek is located in the central section of the Study Area and has a relatively large catchment area of approximately 1,440 ha that is almost entirely within the Study Area. The catchment consists of rural residential areas with farming. Dog Trap Creek flows into Bargo River approximately 1 km upstream of Mermaids Pool and is characterised by areas of very steep sided valleys. The creek is dominated by bedrock and ranges in width from 1-7 metres with a modal width of approximately 4 metres. Habitat features include pools, small waterfalls, undercut banks, trailing vegetation, snags and shallow riffle sections over bedrock and sandstone boulders.

The riparian vegetation has been mapped as Sydney Hinterland Transition Woodland (p146; NPWS 2002) with a canopy consisting mostly of Grey Gum *Eucalyptus punctata* and Sydney peppermint *Eucalyptus piperita*, the middle stratum dominated by *Melaleuca* sp., *Leptospermum* sp., *Acacia* sp., and Black Wattle *Callicoma serratifolia*. The lower stratum was dominated by *Lomandra longifolia*. At both survey sites, the banks are characterised by native forest however there are rural properties upstream.

The upstream survey site is located in a valley to the east of Charlie's Point Road off a fire trail. A visual assessment of the water quality indicated some minor disturbance with turbid waters. The riparian zone showed evidence of high flow damage, with large deposits of debris along the bank. The survey site consisted of large sandstone boulders with interlayered fine sand and silts.

The downstream survey site is located approximately 30m downstream of the Rockford Road Bridge and has similar attributes to the upstream location, however the sides of the creek are steeper with some escarpments sections. A visual assessment of water quality indicated minor disturbance to water quality, with moderate turbidity. Instream disturbance included high flow debris and rubbish although there was little evidence of weed invasion. The survey site consisted of a boulder/cobble riffle zone approximately 3m long with a 0.4m drop to the pool below. The subsurface substrate consisted of course sands and gravel with some clay. The riffle had a high subsurface porosity/through flow as evidence by the easy of substrate type and easy of pumping. There was no evidence of iron staining in the surface water or subsurface samples.

Dry Creek (D3, Plate 3a, b)

Dry Creek is located in the eastern portion of the Study Area and has a catchment area of approximately 386 hectares, the majority of which is within the Study Area. For a length of nearly 2 km, the creek bed runs over a proposed longwall. The catchment of this creek consists mostly of rural residential with some farming practices. Dry Creek feeds into the Nepean River approximately 1.7 km upstream of its confluence with the Bargo River. The riparian vegetation has been previously mapped as Cumberland Shale Sandstone Transition Forest (Tozer et al. 2010). The canopy at both survey sites is dominated by Grey Gum *Eucalyptus punctata*, Sydney peppermint *Eucalyptus piperita* and Stringybark species. The middle stratum is dominated by *Melaleuca* sp., *Leptospermum* sp. and *Allocasuarina littoralis*. The lower stratum is dominated by *Lomandra longifolia*, with only a small percentage cover of ferns, vines and native sedges (Schoenus melanostachys). The width of the creek varies from 0.5m to 8 m, with the modal width being ~ 1 m. Habitat features such as pools, small waterfalls, undercut banks, trailing vegetation, snags and shallow riffle sections are characteristic of this creek. The bed substrate primarily consists of bedrock with large boulders with interlayers of fine sands forming pools and small waterfall. There is little hyporheic habitat available. The majority of the creek is dominated by little to no water flow, with the creek bed often being defined only by a high density of *L. longifolia*.

The upstream survey site (DC5, Figure 2) is located on a section of creek that is a 2nd order stream, upstream of the Pheasants Nest Road Bridge. At this point, the catchment area is approximately 184 hectares. During 2012 aquatic ecology baseline monitoring, a visual assessment of disturbance related to human activities indicated there was evidence of disturbance to water quality, with orange colouration resulting in very turbid looking water. The instream habitat was also disturbed, with some rubbish evident.

Eliza Creek (E1, Plate 3c, d, Plate 4a)

Eliza Creek is located in the eastern portion of the Study Area and runs through rural properties. It has a catchment area of approximately 504 hectares, all of which lies within the Study Area. The proposed longwalls track along and roughly parallel to Eliza Creek for much of its length. Eliza Creek feeds into the Nepean River approximately 1.4 km upstream of its confluence with Bargo River. The width of the creek ranges from 1 – 5 metres, with a modal width of approximately 2 m.

The catchment consists of farmland with grazing cattle and sheep. The riparian vegetation has been mapped as Sydney Hinterland Transition Woodland (p146; NPWS 2003). The upper canopy at this site is dominated by Grey Gum Eucalyptus punctata, Sydney peppermint *Eucalyptus piperita* and Blue Gum *Eucalyptus saligna*, and the middle stratum contained *Allocasuarina littoralis*, Acacia sp., *Melaleuca nodosa, Persoonia linearis* and *Leptospermum* sp. The lower stratum was the dominant layer and was dominated almost entirely by *Lomandra longifolia*, with occasion occurrences of sedges *Schoenus melanostachys* and ferns (*Pteridium esculentum* and *Adiantum aethiopicum*). There was significant disturbance at the site due to the breaking of an upstream earth impoundment during resent heavy rainfalls. The earth weir had formed a significant wetland of Cumbungi macrophytes. The destruction of the weir had caused a large amount flood debris and fine sand to be deposited in the pools downstream. Turbidity was moderate. It was evident that groundwater was a significant contributor to stream flow due to the large amount of iron staining of the water and the substrate as well as numerous seepage zones present within and adjacent to the stream (see Plate 4a).

The survey site is located in a riffle and consisted of large boulders and cobbles interlayered with fine to course sands. Porosity was high and the subsurface substrate consisted of fine sand with fine particulate allochthonous material and iron precipitate.

Tea Tree Hollow (T1, T2, Plate 6a, b, c, d)

Teatree Hollow is located in the upper middle section of the Study Area and has a catchment area of approximately 719 ha that is almost entirely within the Study Area.

Teatree Hollow flows into Bargo River approximately 4 km upstream of Mermaids Pool and the catchment is defined by Tahmoor Mine. The Tahmoor Mine discharges water into several of the lower channels that form parts of Teatree Hollow, without which, the creek would likely be a dry gully (Cardno Ecology Lab, 2009). The riparian vegetation community at both sites along Teatree Hollow has been mapped as Sydney Hinterland Transition Woodland (Tozer 2010). The dominant canopy species recorded were Sydney Peppermint *Eucalyptus piperita* and Scribbly Gum *Eucalyptus sclerophylla* while the middle stratum was dominated by Black Wattle *Callicoma serratifolia*, *Melaleuca* sp., *Leptospermum* sp., *Acacia longifolia*, *Hakea* sp., *Pomaderris* sp., and *Lambertia formosa*. While *Lomandra longifolia* dominated the lower stratum, with some ferns including Tree ferns (*cf. Cyathea australis*), exotic grasses and exotic herbs also present. The gully flora are characteristic of flora species that require the presence of permanent shallow water tables indicating that there is consistent diffuse subsurface groundwater baseflow.

The upstream and downstream survey sites are located upstream of a cleared track that crosses the creek. The site is upstream of the Tahmoor Mine licensed discharge point (LDP1) and access along this track is through the mine site. The visual assessment of water quality at the time of the survey indicated some influence from runoff presumably for the access road as the water was slightly turbid.

The bed of the creek in the lower sections and at survey site (T1) is highly influenced by the mine operations, with anthropogenic sediment deposits present, along with habitat attributes such as pools with undercut banks and trailing vegetation, riffle sections, snags and small drop offs. The bed of the stream in the upper survey site (T2) was in a relatively natural state with small riffles and pool. The substrate consists of highly porous fine grey sands and clay lenses. At the time of the survey the stream was flowing due to recent rainfall however, this section would normally be ephemeral and dry of the surface. A find at this site was the presence of a substantial crayfish community as indicated by the large numbers of crayfish burrows. This is significant not only because of the presence of the crayfish (species yet to be collected and identified) but also because their presence is a direct indicator of subsurface groundwater baseflow. Most species of Australian freshwater crayfish form burrows into the stream bed and banks as a survival strategy against predation and desiccation. The burrow construction is generally genus specific but always ends in a wet chamber typically located below the groundwater water table. In this regard, most crayfish species can be regarded obligate groundwater dependent species i.e. being entirely dependent on the presence of groundwater either through the providing permanent baseflow in surface streams or providing permanent accessible shallow water tables. As a result of this requirement there are many highly endemic species and populations of crayfish along the Great Dividing Range and as well as making them a useful and sensitive indicator of changes in both groundwater level and quality.

The water environment in the burrows of crayfish also form a distinct ecosystem type termed the 'Pholeteros' which often contains a unique mix of hyporheic/phreatic and surface aquatic invertebrate species that represents a transition zone between the surface and groundwater environments.

Despite the artificial nature of the low sections of the creek the upper sections of this creek should be included in a future GDE monitoring program as: it is a named 3rd order stream that flows directly over the proposed longwalls.

3.1.9 Bore survey sites

A total of 13 bores were sampled for stygofauna inside and outside the Study Area which included 6 water bores, 2 production bores with pumps attached, and 5 piezometers or monitoring bores. The water bores and productions bores are typically constructed with a short steel casing extending from ground level to approximately 3-6m below the surface followed by an open well into the bedrock. Piezometers on the other hand are constructed with a plastic casing extending the length of the bore with a terminal cap to prevent sediment entering from the bottom. The section of the casing that corresponds with the water bearing zone, that is required to be monitored, is equipped with slots to allow the water to enter. The survey sites are listed below in Table 3. For a full list of sites see Table 10.

Table 3 Bore survey sites.

Locality Name	Bore (GW)	Alt(m)	SWL (m)	Total Depth (m)	Water column (m)	Substrate
GW 1, Water bore	7445	313	33.4	134.1	100.7	sand
GW 5, Production bore	54146	327	70	104	34	Roots/sand
GW 6, Water bore	56632	352	10.5	32.5	22	rust
GW 12, Water bore	101936	318	44.97	126	89.94	rust
GW 22, Production bore	109257	323	54	120	66	Rust, plant material
GW 23, Water bore	G23	262	54	?	?	Rust
GW 24, Water bore	G24	348	24.93	?	?	rust
GW 55, Water bore	59618	289	19.88	117	97.12	rust
P 1, Piezometer	106281	293	9.3	48.5	39.2	Sand/grass
P 2, Piezometer	no GW no.	288	45.43	450	404.57	rust
P 3, Piezometer	no GW no.	281	34.39	?	?	rust
P 4, Piezometer	67570	282	37.11	40	3	Plant material sand/rust
P 5, Piezometer	63525	271	?	?	?	Plant material sand/rust

3.1.9.1 Subsidence control sites

GW 6 (GW 56632) Water bore (Plate 4d)

GW 6 is a disused stock and domestic bore that has its pump currently removed. It is located along Silica Rd in the far south east of the Study Area. Water turbidity was very low and the sediment in the sample consisted of fine sand grain and rust from the casing.

Table 4 GW 56632 Drillers Log.

Geological Description - 56632	Depth (m)
Topsoil Dark	0.00 - 0.60
Shale Clay	0.60 - 4.10
Clay White	4.10 - 5.20
Sandstone Yellow	5.20 - 25.40
Clay Grey Shale	25.40 - 29.50
Sandstone Grey Coarse Open Water Supply	29.50 - 31.60
Sandstone Yellow	31.60 - 36.00

GW23 (G23) Water bore

No drillers log available was available for this bore. This bore is located adjacent to a house along Nightingale Road, Pheasants Nest. The bore is an old disused house bore without any works. The casing is highly eroded resulting in the sediment being composed entirely of rust fragments.

Piezometer 1 (GW 106281)

This bore is located on the corner of corner of Denmead Street and Thirlmere Way, Tahmoor, adjacent to a small gully and forest reserve. It is situated outside the area of impact in the far north west of the study area. While the water turbidity was very low, the bore contains a large amount of tree roots, grass clippings and fine sand grains.

Table 5 GW 106281 Drillers Log.

Geological Description - 106281	Depth (m)
Soil	0.00 - 0.20
Clays	0.20 - 2.40
Sandstones	2.40 - 48.00

Piezometer 2 (No GW No.)

No drillers log or groundwater bore number available was available for this bore, however the landowner indicated it was approximately 300-400 m in total depth although this could not be confirmed. The bore is disused and located along Glenanne Place, Thirlmere at the back of the property outside the area of impact in the far north west of the study area. While the water turbidity was very low, the bore sediment was composed entirely of rust fragments form the old casing.

Piezometer 3 (No GW No.)

No drillers log or groundwater bore number available was available for this bore. This bore is located along Hilton Park Road, Thirlmere outside the area of impact in the far north west of the Study Area. While the water turbidity was very low, the bore sediment was composed entirely of rust fragments from the old casing.

Piezometer 4 (GW 67570)

No drillers log available for this bore. It is located in a cow paddock at the northern end of Innes Street. Water turbidity is very low.

Piezometer 5 (GW 63525)

No drillers log available for this bore. It is located along Nixon Rd, Thirlmere.

3.1.9.2 Impact sites

GW 1 (GW 7445) Water bore (Plate 4b, c).

This bore is located along the Great Southern Rd in the south east of the study area. It is an old, disused bore with low turbidity and fine black sediment in the sump.

Table 6 GW 7445 Drillers Log.

Geological Description - 7445	Depth (m)
Shale Bands Nominal	0.00 - 62.48
Rock Nominal	62.48 - 89.92
Shale Bands Nominal	62.48 - 89.92
Rock Solid Nominal	89.92 - 117.35
Rock Nominal Interlayered	117.35 - 134.11
Shale Nominal Interlayered	117.35 - 134.11
Shale Nominal	134.11 - 134.13

GW 5 (GW 54146) Production bore

This bore is located adjacent to a house along Arina Road, Bargo. The bore has a pump installed and is used only occasionally domestically. Water turbidity was very low with only fine sand grain sediment collected.

Table 7 GW 54146 Drillers Log.

Geological Description - 54146	Depth (m)
Soil	0.00 - 0.40
Shale Clay	0.40 - 2.40
Sandstone Yellow	2.40 - 72.10
Sandstone Grey	72.10 - 86.00
Sandstone Grey Open Water Supply	86.00 - 87.20
Sandstone Grey	87.20 - 94.60
Shale	94.60 - 94.90
Sandstone Grey	94.90 - 104.00

GW 12 (GW 101936) Water bore (Plate 5a)

The bore is located along Arina Road, Bargo, on a pastoral property used for growing vegetables. The pump has been removed and the bore appears disused. Water turbidity was moderate and the sediment consisted entirely of rust fragments form the casing.

Table 8 GW 101936 Drillers Log.

Geological Description - 101936	Depth (m)
Soil	0.00 - 0.30
Clays	0.30 - 1.70
Sandstone	1.70 - 54.00
Shale	54.00- 58.00
Sandstone	58.00- 64.00
Shales	64.00- 66.00
Sandstone	66.00 - 72.00
Shale	72.00 - 74.00
Sandstone	74.00 - 102.00
Shale	102.00 - 103.00
Sandstone	103.00 - 126.00

GW 22 (GW 109257) Production bore

No Driller log details were available for this bore.

GW 24 (GW 24) Water bore

No drillers log available.

GW 55 (GW 59618) Water bore

Table 9 GW 59618 Drillers Log.

Geological Description - 59618	Depth (m)
Topsoil Dark	0.00 - 0.40
Shale Clay	0.40 - 2.60
Sandstone Yellow	2.60 - 9.30
Sandstone Grey Water Supply	9.30 - 58.50
Sandstone Grey Some Shale	58.50 - 66.30
Sandstone Grey	66.30 - 69.30
Sandstone Grey Open Water Supply	69.30 - 69.70
Sandstone Grey	69.70 - 111.80
Sandstone Grey Open Water Supply	111.80 - 112.30
Sandstone Grey	112.30 - 117.00

4 RESULTS

The stygofauna and hyporheic baseline survey program included two rounds of survey in order to firstly cover enough sites to identify the presence of stygofauna within the Study Area and secondly to repeat a number sites to confirm and expand the finding of the first round. The first round of surveys commenced on the 3rd of June 2013 and the second on the 16th of July. The surveys included 26 sites separated into 13 hyporheic sites covering 8 streams (with multiple sites on 4 streams) and 13 bores (See Table 10, Figure 2). The sites were selected to cover as broad a coverage of the Project Area as possible, with sites located both within and outside (controls) the potential area of impact, as well the broadest range of habitat types. The bore types range from shallow observation piezometers accessing groundwater situated in the Hawkesbury Sandstone aquifers to deeper bores that extended to the levels of the coal seams.

Table 10 Type and location of sampling sites

Locality Name	Bore (GW)	Habitat	EASTING	NORTHING	Alt(m)
B1, Bargo River, Rockford Bridge,	Sandbar	Hyporheic	27959	6207348	247
B2, Bargo River middle	Riffle	Hyporheic	275778	6207459	291
B3, Bargo River, upper riffle	Riffle	Hyporheic	274759	6207115	297
C1, Carters Ck, riffle	Riffle	Hyporheic	282280	6205005	265
C2, Cow Ck, riffle	Riffle	Hyporheic	282102	6202935	296
D1, Dog Trap Ck a, riffle	Riffle	Hyporheic	279194	6206395	274
D2, Dog Trap Ck, Rockford Bridge, riffle	Riffle	Hyporheic	279750	6207338	251
D3, Dry Ck, riffle	Riffle	Hyporheic	281770	6207136	233
E1, Eliza Ck, riffle	Riffle	Hyporheic	281517	6208087	219
H1, Hornes Ck d/s road crossing, sandbar	Sandbar	Hyporheic	275689	6203808	322
H2, Hornes Ck u/s road crossing, sandbar	Sandbar	Hyporheic	275663	6203573	327
T1, Tea tree Hollow nr road crossing,	gravel bank	Hyporheic	277437	6206801	284
T2, Tea tree Hollow u/s road crossing	Pholeteros/riffle	Hyporheic	277425	6206546	288
GW 1, Exploration bore	7445	Phreatic	277437	6204264	313
GW 5, Production bore	54146	Phreatic	279886	6204676	327
GW 6, Exploration bore	56632	Phreatic	277206	6201582	352
GW 12, Exploration bore	101936	Phreatic	280605	6202853	318
GW 22, Production bore	109257	Phreatic	276603	6205052	323
GW 23, Exploration bore	G23	Phreatic	282653	6205669	262
GW 24, Exploration bore	G24	Phreatic	278900	6201875	348
GW 55, Exploration bore	59618	Phreatic	281592	6204270	289
P 1, Piezometer	106281	Phreatic	276607.38	6210936.6	293
P 2, Piezometer	no GW no.	Phreatic	277070.2	6211630.2	288
P 3, Piezometer	no GW no.	Phreatic	277854.2	6211740	281
P 4, Piezometer	67570	Phreatic	277070.2	6213716.2	282
P 5, Piezometer	63525	Phreatic	276568.1	6214326.3	271

The surveys recorded fauna from 13 of the 34 samples collected and from 12 of the 26 sites. In total there were 139 invertebrates collected that included 4 phylum, 7 classes, 16 families and 19 genera identified. The fauna composition included: Oligochaeta (freshwater worms); a number of insect orders including aquatic beetles, fly larvae, mayflies, dragonflies; soil invertebrates including Collembola, aquatic microcrustaceans such as Copepods and Ostracods (Seed Shrimps); terrestrial Isopoda (Slaters); Gordian worms; and flatworms. These included species that are classed by ecotones as stygobite, stygoxenes, and edaphobites.

Table 11 Number of stygobite, stygoxene, and edaphobite individuals and taxa

Locality Name	No. of individuals	No. of stygobites/no. of taxa.	No. of stygoxenes/no. of taxa	No. of edaphobites
B1, Bargo River, Rockford Bridge,	0	0	0	0
B2, Bargo River middle	14	8/ 1	4/ 5	0
B3, Bargo River, upper riffle	16	7/1	9/3	0
C1, Carters Ck, riffle	0	0	0	0
C2, Cow Ck, riffle	10	5/1	1/2	4/2
D1, Dog Trap Ck a, riffle	2	1/1	0	1/1
D2, Dog Trap Ck, Rockford Brg, riffle	35	0	0	0
D3, Dry Ck, riffle	0	0	0	0
E1, Eliza Ck, riffle	22	3/2	18/8	1/1
H1, Hornes Ck d/s road crossing, sandbar	1	0	1/1	0
H2, Hornes Ck u/s road crossing, sandbar	0	0	0	0
T1, Tea tree Hollow nr road crossing,	4	0	3/1	1/1
T2, Tea tree Hollow u/s road crossing	1	0	1/1	0
GW 1, Water bore	25	23/1	1/1	2/2
GW 5, Production bore	0	0	0	0
GW 6, Water bore	0	0	0	0
GW 12, Water bore	0	0	0	0
GW 22, Production bore	0	0	0	0
GW 23, Water bore	0	0	0	0
GW 24, Water bore	0	0	0	0
GW 55, Water bore	0	0	0	0
P 1, Piezometer	0	0	0	0
P 2, Piezometer	0	0	0	0
P 3, Piezometer	0	0	0	0
P 4, Piezometer	7	0	0	7/2

Locality Name	No. of individuals	No. of stygobites/no. of taxa.	No. of stygoxenes/no. of taxa	No. of edaphobites
P 5, Piezometer	3	0	3/3	0

Of the sites that registered fauna only 3 bores (GW 1, P4, P5) registered fauna and of these only 1 bore (GW 1) (SWL 33.4m and depth 134.1m) registered the presence of stygofauna. The small number of taxa and numbers of specimens collected at each site indicates a depauperate fauna within the aquifer at the bore sites and a minimal level of connectivity within the aquifer, possibly due to the substrate consisting of massive sandstone with limited secondary porosity through fine fractures as well as inappropriate water chemistry.

Despite only a minimal level of connectivity indicated by stygofauna, connectivity is supported by hydrochemical and isotopic data (Geoterra 2013) which indicated that groundwater and surface water bodies are hydraulically connected, with shallow groundwater from the Hawkesbury Sandstone providing baseflow discharge to the more incised streambeds and gorges in the local catchments.

The relative consistency of the faunal composition across the bores and the hyporheic zones sampled suggests that the subterranean community diversity is naturally low compared with other regions. The fauna composition indicates a shallow/hyporheic groundwater system where the river system is experiencing a gaining flow situation where by the groundwater is partly feeding into the river.

The porosity of the aquifer substrate appears to be one of the significant factors in determining the fauna composition. The low porosity of the fractures zones and seeming lack of unconsolidated sediments within the sandstone is indicated by the small size of the phreatic fauna collected.

Although the fauna is depauperate it formed relatively consistent compositions between habitats and formed 3 distinct ecotonal units. These being the Stygobites groundwater fauna, the Hyporheic Fauna - Riverine Macroinvertebrate fauna, and the incidental Edaphobite Soil Fauna. These ecotones are described below in more detail.

Ecotone 1 - Stygobites - Sites: GW 1; Dog Trap 2; Dog Trap 1; Tea Tree d/s; and Cow Creek (Table 11).

Five sites recorded the presence of stygofauna, which included 4 stream sites and 1 bore site. This first ecotone is characterised by the community of obligate groundwater fauna represented by Ostracods, Copepoda, and the Oligochaeta (Family Enchytraeidae). This faunal assemblage can be found in both the temporary and permanent hyporheic as well as the shallow hypogean (true groundwater) ecosystem.

Ostracoda

Ostracods occur in almost every conceivable habitat in marine, estuarine, and fresh waters. In freshwaters, their habitats include streams, rivers, lakes, springs, caves, groundwater, temporary ponds, moist organic mats (e.g. among mosses), and even the axial cups of plants like bromeliads (Delorme 2001). Most ostracods are benthic dwellers, living on sediment surfaces, on plants, or interstitially within sediments, where most feed on detritus, although some are herbivores and a few are carnivorous (Delorme 2001). Some are good swimmers, using long, swimming setae on their two antennae for propulsion. Many, however, are truly benthic, having replaced long swimming setae on their antennae with stouter setae or claw-like spines more suited to crawling over the bottom or between sediment particles.

Ostracods are present in all groundwater habitats from fractured rock aquifers, to karst and alluvial aquifer systems, as well as in hyporheic and parafluvial habitats within rivers. Research indicates that species have quite distinct distributions and, apparently, habitat preferences, with highest biodiversity adjacent to rivers and lower diversity in alluvial aquifers more distant from surface rivers (Ward et al. 1994). Other studies indicate that proximity to running water rich in organic matter is important (Rouch & Danielopol 1997). Their distributions are more complicated than simple proximity to rivers or concentration of organic content. There appear to be few meaningful correlations between ostracod abundances and individual physical factors (organic content, alkalinity, calcium, oxygen concentration. Instead, differences in habitat stability in terms of complexes of physico-chemical factors (e.g., water temperature and organic content) and the upwelling or downwelling nature of interstitial flows seem important, with some taxa more common in variable habitats and others more abundant where conditions are more constant, Ward & Palmer 1994).

Worldwide, more than 300 species of ostracods live exclusively in the hypogean habitats (Danielopol & Hartman 1986). Truly hypogean or stygobitic ostracods are recognised by their morphological and/or ecological characteristics. For example, some subsurface ostracods have extremely elongated or triangular and trapezoidal carapaces, sometimes with large dorsal protuberances. Most hypogean ostracods belong to the Podocopida with many of the common groundwater taxa being largely cosmopolitan in occurrence (Danielopol et al. 1994b). Thus, the Candonidae is regarded as the most diversified family worldwide (Danielopol & Hartman 1986). The second most important hypogean ostracod family is the Cyprididae, with others, such as the Limnocytheridae, Entocytheridae, and Cyclocypridae, also represented.

The first 4 sites are characterised by the presence of the Candonopsis (Candonidae) Ostracoda (Seed Shrimp). This genus has been collected from four sites including one bore site, GW1. The other sites are upper and lower Dog Trap Creek and Tea Tree Hollow. This represents connectivity between these sites as these fauna can only disperse via hydrological connectivity. Further examination of these taxa is necessary to determine if these represent one species or three separate, short range endemic species. This family has previously been recorded in the Upper Nepean, Kangaloon area and represents a fauna characteristic of shallow groundwater environments. Other taxa that also support this delineation include the white (colourless) Dugesiidae Flatworm, the Cyclopoid Copepoda, Mesocyclops. The community also included a number of other faunal elements including the hyporheic/phreatic worms belonging to the Phreodrilidae and the hyporheic fauna such as, aquatic Coleoptera, and Diptera larva and the edaphobitic soil fauna consisting of the Collembola species.

Cow Creek is included within this category even though the other fauna have not been collected. This is due to the presence of the Family Enchytraeidae. This family is becoming a more prominent stygofauna species as more surveys are done and has been collected in groundwaters in NSW and Queensland. Their presence within the hyporheic zone is therefore a direct indicator of groundwater discharge and connectivity.

Oligochaeta

In Australasia, the Oligochaeta are represented in freshwaters by the families Aeolosomatidae, Haplotaxidae, Lumbriculidae, Phreodrilidae, Naididae, and Tubificidae (Brinkhurst 1971). Of these families, the Naididae appear to be poorly represented in Australia, with particularly low diversity in Tasmania (Pinder 2001) although increasingly prominent in groundwaters.

The family Phreodrilidae is particularly diverse in Australia with more than 50 species (Pinder & Brinkhurst 1997). The Phreodrilidae are mostly sediment-dwelling freshwater oligochaetes that occur in Australia, South America, Africa, New Zealand, and Sri Lanka, as well as many southern oceanic islands (Pinder & Brinkhurst 1997). This global distribution indicates a Gondwanan origin, with evidence of a more recent dispersal (Pinder 2001). In a review of the stygobitic oligochaete fauna of the world, Juget & Dumnicka (1986) noted 66 species in seven families (Aeolosomatidae, Potamodrilidae, Haplotaxidae, Lumbriculidae, Dorydrilidae, Tubificidae, and Enchytraeidae). More recently, Giani et al. (2001) reported 57 species that can be classified as stygobites in southern Europe alone, suggesting the global diversity far exceeds initial estimates (e.g., Juget & Dumnicka 1936). Indeed, Giani et al. (2001) estimated that, when records from other areas of the world (e.g., North America, Africa, Europe) are added, a total of 96 stygobitic freshwater oligochaetes are known in the world (they excluded Australasia from their estimate for some reason). It should be noted that it is often difficult to make a clear separation between stygobitic and stygophilic oligochaetes. For example, the features that distinguish stygobitic crustaceans from epigean forms, such as absence of eyes, lack of pigmentation, and elongation of body, do not distinguish between stygobitic and epigean oligochaetes. Giani et al. (2001) noted that very few species of Naididae are stygobites.

Groundwater habitats have played an important role in the evolution of freshwater oligochaetes. Indeed, Lafont (1989) suggested that groundwater might have been the primary source of colonisation of all freshwater oligochaete ancestors. Whether this is true or not, groundwater habitats are a rich source of oligochaete diversity, and many of the more "interesting" species in Australasia seem to be predominantly groundwater-dwelling forms (Brinkhurst 1971).

The presence of worms, belonging to the Family Enchytraeidae and Phreodrilidae, and a general paucity of large crustaceans indicates that the water quality is characterised by elevated organic carbon, and possibly high levels of dissolved iron, lower (acidic) pH levels ranging from approximately 6-4 pH units and relatively low DO. The relatively small size (1-5mm) of the Oligochaete (worm) species present indicates a low to moderate connectivity within the river/aquifer environment. The shallow water table levels within the riverine hyporheic zone and the presence of the family of Enchytraeidae suggests a direct association/connectivity with a slow base flow river system with a shallow alluvial water table. There is very little known about the diversity and distribution of freshwater Enchytraeidae, therefore the identification can only be given to the family level. Subterranean Oligochaetes are an increasingly important component of Australia’s groundwater fauna that contain a large number of short range endemic species with large faunas along the continental marginal areas, particular in the southwest and eastern seaboards.

In terms of their ranking within current surface water environmental sensitivity indices such as the SIGNAL Index ranking, they can only be assessed at the Order level of Oligochaeta which has a ranking of 2. This equates to a family which is quite tolerant of environmental disturbance. This, however, is misleading as the family is usually associated with high water quality environments.

Although primarily phreatobites i.e. belonging to the shallow groundwater ecotone, this family can also be found within the riverine, hyporheic zones in areas of groundwater discharge where the discharge can be either point source springs or diffuse discharge through a moderate to course grained substrate such as sand or gravels (Gilbert 1994).

Platyhelminthes

Worldwide there is a substantial stygobitic flatworm fauna (Gourbault 1986). As in many other groups, there has been little work to describe Australian species and further work is required. Stygobitic species are recognised by a reduction in pigmentation and a loss or reduction of eyes.

Copepoda

The Copepoda are a subclass of Crustacea comprising over 10,000 known species (Williamson and Read 2001). Copepoda are predominantly marine, although 3 of the 10 orders are widespread and abundant in freshwater habitats. These are the Calanoida, Cyclopoida and Harpacticoida. The first order occurs in the water column as plankton only, whereas the latter two are common in benthic habitats of surface waters and are important components of many groundwater communities.

Lescher-Moutoué (1986) noted that of the roughly 670 species of cyclopoids described from continental freshwaters, about 23% are considered hypogean. However, it is often difficult to characterise species as either hypogean or epigean, without detailed study of life history and distribution, although the absence of ocular pigments (eyes) is a reliable indicator of hypogean habits (Lescher-Moutoué 1986).

The Copepoda Cyclopidae is normally associated with fine to course sandy substrates of still water environments of rivers, wetlands, the hyporheic zone and shallow groundwaters. Although they are a ubiquitous component of these habitats, their small size means that they are often overlooked and undercounted. In terms of management, therefore, they are potentially very useful bioindicators, particular of base flow fed streams or alluvial aquifers or flow through wetlands, as they are sensitive to changes in the environment (Tomlinson & Boulton, 2008).

***Ecotone 2- Hyporheic Fauna*- Riverine Macroinvertebrate fauna. Sites: Bargo River mid and upstream; Eliza Ck, Tea Tree Hollow upstream, Hornes Ck downstream; and Bore P5 (Table 11).**

The hyporheic zone of a river is characterized by being nonphotic, exhibiting chemical/redox gradients, and having a heterotrophic food web based on the consumption of organic carbon sourced from surface waters (Feris et al. 2003). The fauna and sites within this ecotone are characterised by a variably mixed community of subterranean stygophiles (permanent hyporheic fauna), and surface water (stygoxenes or temporary hyporheic fauna) macroinvertebrate. The sites can be further divided in those that have a pronounced presence of stygophiles and long-term habitats and those that are composed solely of rapid colonizing taxa characteristic of transient habitats.

The sites containing permanent hyporheos or the community that occurs within the shallow to deep sand and gravel beds associated with areas of groundwater discharge (Gilbert,

1994) include Bargo River mid and upstream and Eliza Ck. These sites represent the transition zone between the permanent shallow hyporheic ecotone and the groundwater hypogean environment. (Gilbert 1994). The sites containing the 'temporary hyporheos' Tea Tree Hollow upstream, Hornes Ck downstream; and Bore P5. These sites represent localities that do not develop sufficient habitat to sustain invertebrates with longer life spans either through the development of appropriate habitat or the permanence of flow.

These habitat types contain a relatively consistent assemblage of surface water macroinvertebrate species that are associated with slow moving or still face water bodies with soft silty sediments and high organic (allochthonous) content on the substrate. The presence of temporary hyporheos within the well P5 indicates that the sites are located directly adjacent to a stream with an intact riparian zone that supplies large amounts of leaf material and/or a highly connected base flow river system with permanent pools or water bodies or wetland. If the stream is an intermittent or ephemeral system then the shallow groundwater within the well will represent a refuge environment for these surface water species.

The only species associated with possible groundwater environments is the Oligochaete Family Phreodrilidae. The family consists of five genera in Australia with a particularly rich diversity of species. Endemicity is confined to the species level and they have a predominantly southern hemisphere and southern Australian distribution with the highest diversity being found in Tasmania and eastern Victoria (Pinder & Brinkhurst 1994). They have a preference for cool, freshwater environments and are soft sediment dwellers, although some species have an association (ectocommensal or symbiotic relationship) with freshwater crayfish (Pinder & Brinkhurst 1994). This is most likely due to the burrowing habits of most Australian freshwater crayfish. This group of Oligochaetes is increasingly becoming a vital component of groundwater ecosystems in southern Australia and now Queensland as our knowledge of their environmental requirements and diversity improves and is also increasingly being recognised with ecosystems with high water quality. They exhibit high diversity and possible high endemicity.

Coleoptera

Of the more than 300,000 different species of beetles described worldwide, only about 9,500 are aquatic in their adult and/or larval stages. Of these, only around 15 species are known as true stygobites (Spangler 1986). Stygobitic beetles belong to five families (Dytiscidae, Noteridae, Hydrophilidae, Scirtidae and Elmidae) and may be distinguished from the surface-inhabiting forms by several features. Firstly stygobites have vestigial eyes or, more commonly, a complete absence of eyes. They usually exhibit greatly reduced or complete lack of pigmentation. Exoskeletons are usually thin and soft, and metathoracic wings are often absent or vestigial. Larvae of stygobitic beetles generally lack ocelli (Spangler 1986).

Elmidae are commonly encountered in hyporheic samples, with several undescribed species of true stygobites recently being discovered in eastern and north west NSW. There are several known genera of true groundwater Elmidae around the world (Spangler 1981,1986).

Diptera

The presence of a single specimen of an aquatic Tipulidae larva is regarded as an incidental (stygoxene) species that indicates the bore or well may have been open allowing access. The Tipulidae are a very diverse but poorly studied group of Diptera that have an aquatic larval stage and a wing arboreal adult stage. They have poor dispersal capabilities and are normally associated with the riparian zone and corridor. In terms of water quality, the Tipulidae are ranked as a 5 within the SIGNAL - HU97B (Chessman et al. 1997), which is indicative of a relatively disturbance tolerant family. They are, however, normally associate with river pool and wetland environments with good water quality, soft sediments and large quantities of allochthonous material (leaf packs).

Ecotone 3 – Edaphobites – Soil Fauna. Sites: P4, GW 1; Dog Trap 2; Dog Trap 1; Tea Tree d/s; Eliza Ck; and Cow Creek (Table 11).

A number of sites recorded the presence of terrestrial invertebrates. These sites offer not only a reliable source of flow for the streams but also a reliable source of moisture for the riparian zones associated with them. These humic rich, moist environments harbor a rich community of soil and leaf litter invertebrates that are closely associated with the edge of the water and are often collected in surface water macroinvertebrate and hyporheic samples environments. As they have physiological requirements for high humidity they occupy the transition zone between the terrestrial and aquatic environments and other refugial environments such as inside bores. Their presence in these habitats including bores is therefore regarded as incidental.

The dominant group collected belonged to the primitive soil insects, the Collembola. The Collembola specimens collected from area belongs to the families Isotomidae and Onychiuridae. These are large family of Collembola, with all subfamilies occurring in Australia. They are common in leaf litter. They are typically detrital or fungal feeders associated with the ground litter layer and tree bark. Their presence in the samples is most likely coincidental either by falling in or occupying the vegetation adjacent to the bore or living within the bore above the water table, as they have a preference for humid environments. As they are terrestrial soil and leaf litter fauna and not associated with groundwater environments no further description will be given.

4.1 Discussion

All aerobic organisms require a specific range of conditions in order to survive and function including a physical living space, an energy source or food, and oxygen. If these specific parameters for life are changed then a change to the community structure of an ecosystem is to be anticipated. Surface aquatic invertebrate communities for example have long been recognised as being ideally suited for the assessment of environmental health and condition in riverine ecosystems for the following reasons:

1) they are diverse;
2) they occupy every available niche within a water body;
3) they are one of the major contributors to the processing of energy through an ecosystem;
4) they respond directly to physico-chemical changes within the aquatic environment,
5) the composition of these communities reliably reflects both natural and threatening processes operating within a catchment;
6) the specific range of habitat requirements of each species dictate the distribution of each component of both the species and community levels, which;
7) enables their diversity to be used as an indicator of a water body's connectivity and condition within a catchment.

Stygofauna communities possess all of the above features. It has been acknowledged that they are intrinsically adapted to their specialised environment both in terms of their specialised morphology, physiologies, habitat requirements and long life cycles. Therefore the link between flow conditions, geochemical conditions and the abundance, diversity and composition of the stygofauna community should be anticipated and utilised.

Groundwater abstractions can lead to decreasing groundwater levels in aquifers. This abstraction can have impacts on flow in streams that are hydraulically connected to the aquifers being pumped. These impacts range from a reduction in base flow to a change from a gaining to a losing stream or to a complete cessation of flow. The consequences in terms of stream flow are obvious, particular in regards to the ecology of the instream surface water ecosystems. In recent years it has been realised that these changes may also cause changes in groundwater chemistry. For example dissolved and particulate organic matter in the stream water may percolate into the streambed and the aquifer and may lead to a consumption of oxygen and reducing conditions.

Physico-chemical variables are also unlikely to be the sole determinants of species distributions and community assemblages. Dispersal constraints (Belyea and Lancaster 1999), such as hydrological disconnection (Sheldon and Thoms 2006), could isolate parent populations from which populations observed at any particular sampling time are derived. Lag effects are likely, so that the species presence and abundance data collected at any sampling time could result from previous rather than current physico chemical conditions. There might also be multiple points of population or community stability due to varying influences of different combinations of driving variables as environmental conditions change.

Hydraulic conductivity also determines the availability of electron donors for biogeochemical processes. Interstitial storage of dissolved organic matter and the availability of dissolved oxygen are influenced by particle size and pore size (Maridet et al. 1996). Larger particle size and high porosity allow higher flows and higher availability of oxygen but reduce entrapment and retention of nutrients.

In fractured rock and karstic aquifers, uneven porosity due to the distribution of fissures, fractures and solutional conduits creates preferential flow paths, which create spatial heterogeneity in biogeochemical cycling. Spatial and temporal variability in groundwater flow paths is also influenced by surface microtopography and by stream channel morphology. The functional diversity of subsurface ecological processes is thus determined by shifting gradients in oxygen, nutrients and physico-chemical conditions, which create pockets of oxia and anoxia, nitrification and denitrification.

As in other ecosystems, heterogeneity in subsurface environments is a critical determinant of ecosystem function. Disturbance to the groundwater regime, including disruption of patterns of hydrological connectivity and sediment wetting/drying cycles might potentially alter spatial and temporal patterns of groundwater flow, flux and quality, with implications for rates of organic matter mineralisation and nutrient cycling.

Prolonged desiccation of sediments caused by water table drawdown can alter the balance between aerobic and anaerobic processes and change the composition of microbial populations, reducing the incidence or rate of anaerobic metabolism. Disturbance to the groundwater regime can alter the rate and nature of subsurface ecological processes, resulting in reduced availability of carbon, nitrogen and phosphorus, with flow-on effects for biodiversity and ecosystem services, not only within the aquifer, but also in connected ecosystems including rivers, riparian zones and estuaries.

Changes in biological diversity

The quantity and quality of the various kinds of pressures on groundwater systems are able to induce drastic changes in the diversity of organisms living underground. Two types of such changes can impact an aquifers water quality parameters and its associated ecosystem, namely (1) decline in groundwater-dwelling organism populations leading to species extinctions and (2) penetration of alien species belonging to surface-water communities. Both processes determine changes in the functioning of groundwater systems, generally reducing the efficiency of some ecosystem processes.

The presence, composition and complexity of fauna of hyporheic habitats are determined by a number of factors. These factors can include: flow duration or permanence of the water source, the size, substrate type and depth and longevity of the hyporheic environment; the connectivity of the hyporheic habitats both along the river corridor and with the riparian zone; and the connection with the groundwater i.e. whether the river is a gaining or losing system. This is particular relevant to ephemeral or intermittent streams where the drying of streams and the interruption of water infiltration into adjacent-shallow subsurface areas reduce the suitability of the habitat for a range of aquatic organisms. As the flow reliability reduces so does the number and type of organisms present, resulting in the community only being represented by a few epigean species that can survive the dry period until the next rewetting.

Mining developments, in which stygofauna are considered to be a relevant environmental factor, need to be closely assessed with respect to the extent of the proposed groundwater drawdown zone and the likely impacts on groundwater quality. Both of these activities, over time, may cause prospective stygofauna habitat to be degraded or lost with the potential for significant impact on groundwater communities. Stygofauna are able to tolerate natural fluctuations in water parameters such as water level, electrical conductivity, and temperature, and this has been demonstrated experimentally (Tomlinson unpublished) for stygofaunal amphipods, copepods, and syncarids. However, changes outside the natural range of water quality, water chemistry and levels such as rapid drawdown or changes to water chemistry such as a pollution plumes are likely to have impacts on the community composition, biodiversity and overall sustainability of the community.

Groundwater communities also require links to the surface environment to provide organic matter and oxygen. If that linkage is broken or disrupted, the stygofauna community in the area affected could decline over time. A high degree of endemism can occur in aquifers, even within the same system or between adjacent systems (Hancock and Boulton 2008). However, providing there is sufficient hydrological connectivity within and along the flow path of the aquifer, and the physico-chemical conditions are suitable and remain stable, the distribution of species will not be restricted to small parts of an aquifer.

5 IMPACT ASSESSMENT

5.1 Preliminary GDE risk assessment

5.1.1 Aquifer risk assessment

The aquifer risk assessment considered the risk that groundwater extraction and the impacts of longwall mining places on the groundwater source and its dependent groundwater dependent ecosystems (GDEs). In this process the ecological value of a GDE is assessed in association with the risk that a groundwater source and associated GDEs would be under from these impacts, which is turn dictates the level of management action required. That is, if the aquifer has a high conservation value or a number of high priority GDEs and therefore is of high ecological value, its value has a high risk of being altered by extraction. Conversely if a groundwater source/GDE has low ecological value then there is a low risk of altering its value by extraction. This assessment was completed for each groundwater source and identifies risks to three main aquifer assets according to several attributes as follows:

- Ecological Assets;
  - Risk of a change in groundwater levels/pressures on GDEs,
  - Risk of a change in the timing of groundwater level fluctuations on GDEs,
  - Risk of changing base flow conditions on GDEs.
  - Risk of changing aquifer flow paths.

- Water Quality Assets;
  - Risk of changing the chemical conditions of the water source,
  - Risk on the water source by a change in the freshwater/salt water interface, and
  - Likelihood of a change in beneficial use of the water source.

- Aquifer Integrity Assets;
  - Risk of substrate compaction.

The ecological valuation and risk assessment process is outlined in the flow diagram below. The numbers below each action refer to the section within the Risk Assessment Guidelines for Groundwater Dependent Ecosystems (Serov et al. 2012).

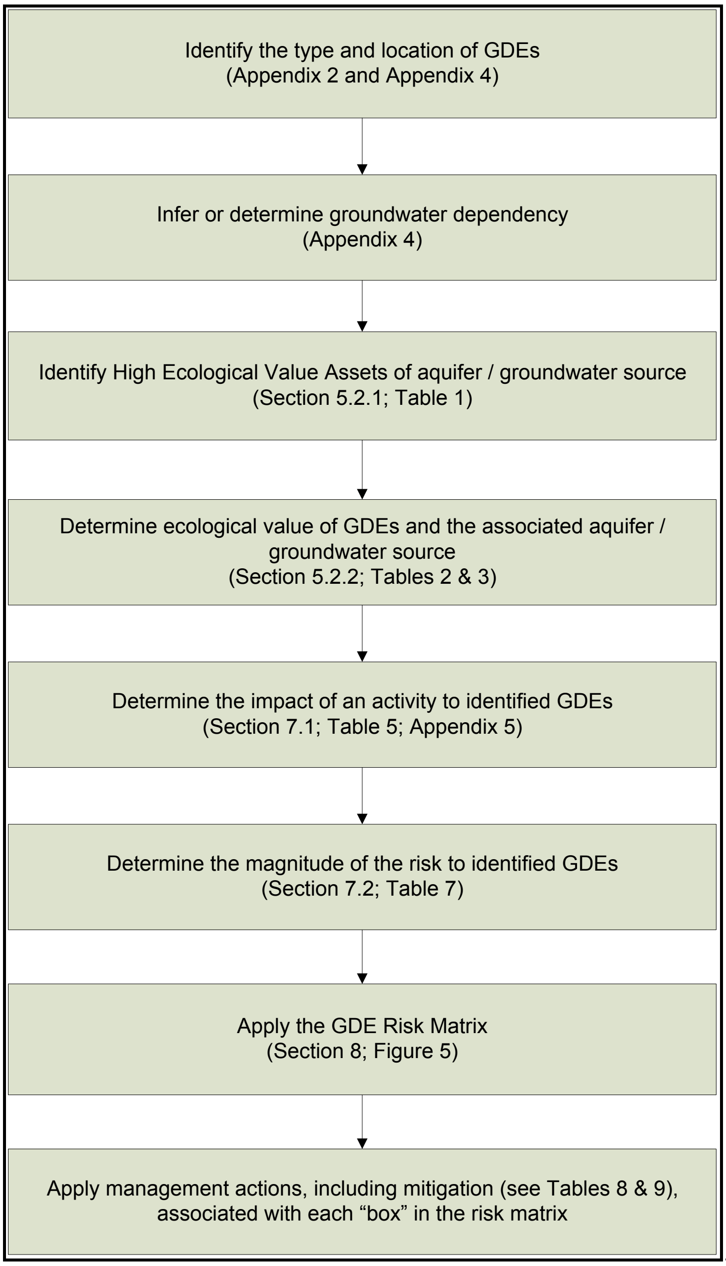


Diagram 1 Ecological valuation and risk assessment process. Serov et al. 2012

5.1.2 GDE risk assessment results

The assessment of the value and risk to stygofauna community at each of the sites surveyed as well as an overall assessment of the shallow aquifers that supply the water to the identified GDEs of the groundwater dependent ecosystems is presented in Table 12. Tahmoor South ecological value and risk Assessment Table. below. The blue colour represents the bore site that registered positive to stygofauna, the yellow represents the river hyporheic sites that registered positive for fauna, and white represent negative results.

Table 12. Tahmoor South ecological value and risk Assessment Table.

Locality Name	Habitat	Survey Result	Ecological Value	Ecological Risk	Matrix Ranking
Overall Aquifer Values			**High**	**Moderate**	**B**
GW 1, Exploration bore	Bore	Stygofauna	Low	Low	G
B2, Bargo River middle	Hyporheic	Hyporheic	Low	Moderate	H
B3, Bargo River, upper riffle	Hyporheic	Hyporheic	Low	Moderate	H
C2, Cow Ck, riffle	Hyporheic	Hyporheic	Moderate	Moderate	E
D1, Dog Trap Ck a, riffle	Hyporheic	Hyporheic	Low	Moderate	H
D2, Dog Trap Ck, Rockford Bridge, riffle	Hyporheic	Hyporheic	Low	Moderate	H
E1, Eliza Ck, riffle	Hyporheic	Hyporheic	Low	Moderate	H
T1, Tea tree Hollow near Rd Crossing,	Hyporheic	Hyporheic	Low	Low	G
H1, Hornes Ck d/s road crossing, sandbar	Hyporheic	Negative	Low	Low	G
T2, Tea tree Hollow u/s road crossing	Hyporheic	Negative	Low	Low	G
B1, Bargo River, Rockford Bridge	Hyporheic	Negative	Low	Low	G
C1, Carters Ck, riffle	Hyporheic	Negative	Low	Low	G
D3, Dry Ck, riffle	Hyporheic	Negative	Low	Low	G
H2, Hornes Ck u/s road crossing, sandbar	Hyporheic	Negative	Low	Low	G
GW 5, Production bore	Bore	Negative	Low	Low	G
GW 6, Exploration bore	Bore	Negative	Low	Low	G
GW 12, Exploration bore	Bore	Negative	Low	Low	G
GW 22, Production bore	Bore	Negative	Low	Low	G
GW 23, Exploration bore	Bore	Negative	Low	Low	G
GW 24, Exploration bore	Bore	Negative	Low	Low	G
GW 55, Exploration bore	Bore	Negative	Low	Low	G
P 1, Piezometer	Bore	Negative	Low	Low	G
P 2, Piezometer	Bore	Negative	Low	Low	G
P 3, Piezometer	Bore	Negative	Low	Low	G
P 4, Piezometer	Bore	Negative	Low	Low	G
P 5, Piezometer	Bore	Negative	Low	Low	G

The ecological and risk assessment was based on current data and is a snapshot of the current condition of the aquatic and subterranean environments as of mid-2013.

Most of the sites registered low ecological value for stygofauna due to either no fauna collected at all or the faunal community was in very small numbers and very low biodiversity. This general result was the same across both the area of potential impact within the mining lease and at the control sites outside of the lease area. Only one location recorded higher than a low value. This was Cow Creek on the south east area that drains into the Nepean River. This location recorded a higher value due to the higher numbers of hyporheic species and the location within the protected drinking water catchment of the Upper Nepean catchment..

The risk assessment recorded a low value for all sites which recorded no fauna. A low value was recorded for the only ore site (GW1) due to the depauperate fauna, a lack of water level and quality data as well as the low potential for impact from the mining operations, while still recognising that this maybe a potentially endemic species. All of the riverine hyporheic sites recorded a moderate level of risk, de mainly from the potential impact of streambed cracking and the potential impact from the modelled levels of drawdown. As these are all shallow, most intermittent streams, mostly on bedrock with little refugial habitat, a small decrease in water levels would have a significant impact on habitat availability.

An overall value and risk assessment was also conducted focusing on the shallow aquifers as a whole to place the sites into a landscape perspective and to demonstrate the condition and ecosystem function performed by the aquifers. The results of this assessment demonstrated that the aquifers are in good condition in regards to water levels, water quality, as well as supporting a range of groundwater dependent ecosystems type and subtypes. As with the individual sites that supported subterranean fauna the aquifers within the overlying shale units and the shallow sandstone unit are at moderate risk of impact from the mining activity as listed below:

- Five GDE types were identified in the study area including:
  - Subsurface Phreatic aquifer ecosystems
  - Baseflow Stream (Surface Ecosystems)
  - Baseflow Stream (Hyporheic Ecosystems)
  - Phreatophytes - Groundwater Dependent Terrestrial Vegetation
  - GDE wetlands (note these are not threatened wetlands listed under Endangered Ecological Communities under Threatened Species Act but is still defined under the risk assessment as wetlands).

In summary, in terms of the stygofauna community across the area of interest the following points are noted

- Limited and localised subterranean ecosystems both in the aquifer and the rivers systems were identified to exist, although none are currently listed as endemic, relictual, rare, or endangered biota (fauna or flora) populations or communities as listed under the TSC Act, FM Act or the Commonwealth EPBC Act or identified by an acknowledged expert Taxonomist/Regional Ecologist as being important.
- The ecological values of the sites that contain stygofauna were generally low although there was connectivity between the shallow aquifers within the overlying Shales with the underlying sandstones and the associated rivers as indicated by the occurrence of both the Candonidae Ostracoda) linking GW!, Dog Trap Creek, the Bargo River and Tea Tree Hollow, and the Phreodrilidae, (Oligochaeta) linking Dog Trap Creek with the Bargo River and Eliza Creek.
- The risk of the proposed development to these subterranean ecosystems was rate as moderate to low. This is attributed to the shallow aquifers that support these ecosystems being separated from the deeper coal being aquifers by an Aquaclude and as most of the hyporheic sites are situated on the periphery of the operations area and therefore at a lesser risk from subduction. The only exception GW1.
- There was insufficient data to determine whether past land use practices have impacted aquifers and associated GDEs or to the nature of these impacts. These values were categorised as unknown in the identification of the ecological values

of the Aquifer/Groundwater Source section of the assessment. As there was no long term physicochemical such as time series water level and quality fluctuations the confidence of the overall risk assessment is moderate. It is likely that the GDEs are in a moderate to low condition given the limited development in the area. However, on-going in situ monitoring could give greater confidence to this assessment.

- Only one bore recorded one species of stygofauna.
- Three hyporheic sites within the proposed mining operation recorded hyporheic fauna that included stygofauna
- Four hyporheic sites outside the proposed mining operation also recorded similar hyporheic fauna that included stygofauna
- There was connectivity between the bore site (GW1), Dog Trap Creek and Eliza Creek via the Bargo River.
- Cow Creek also recorded hyporheic fauna however, this is suggested not to be directly connected to the other sites as it belongs to a different watershed by draining directly into the Nepean and not he Bargo River.
- The fauna in Cow Creek and Eliza Creek indicate that these two are perennial whereas the other streams are intermittent.

5.1.3 Cumulative impacts

Cumulative effects may result from a number of activities interacting with the environment. The nature and scale of these effects can vary depending on factors such as the type of activity performed, the proximity of activities to each other and the characteristics of the surrounding natural, social and economic environments. They may also be caused by the synergistic and antagonistic effects of different individual activities, as well as the temporal or spatial characteristics of the activities. Importantly, cumulative effects are not necessarily just additive. The implication of multiple mining actives in one region is that impacts may overlap and result in larger impacts than would be expected for a single mining operation (cumulative effects).

6 SAFEGUARDS AND MANAGEMENT

6.1 Management

This survey identified the presence of subterranean fauna within a shallow perched shale aquifer and hyporheic fauna within the subsurface hyporheic zone of a number of the baseflow fed streams. There were a total of three GDE types and seven GDE subtypes identified for the Study Area including the downstream ecosystems. While the numbers of animals and diversity were low they do indicate good water quality, a strong connectivity between the river and groundwater system (Serov et al. 2012.). The restricted distribution of the stygobitic fauna recorded would strongly suggest that there is narrow connectivity within the aquifers with subterranean fauna being present only in isolated locations, which should be considered as short range endemics (SREs). From a management perspective stygobites (phreatobites) usually face a higher risk of extinction as they live only in small geographical areas with narrow physiological tolerance ranges.

The Risk Matrix identified proposed activity to be a Class G risk indicating the ecological values of the aquifers in the Study Area to be low with a moderate potential impact. The prescribed management actions are as follows

Short and medium term management priorities:

- Protection of hotspots by continued baseline risk monitoring of aquifer structure, water levels, water chemistry and periodic biodiversity surveys.
- Mitigation actions to avoid or reduce changes in aquifer structural integrity, water levels and water chemistry.
- Periodic assessment of mitigation measures; Ongoing monitoring of water levels, water chemistry and biodiversity and periodic assessment of mitigation.

6.2 Suggested management actions

The surveyed sites that were identified to have biodiversity value should be regarded as one component of a series of benchmarked sites across the aquifer that can be used to characterise the distribution, environmental ranges and requirements of the subterranean and hyporheic ecosystems.

Possible further work that could be considered for future baseline stygofauna monitoring includes:

- Identify stygofauna to species (particularly those listed as phreatobites) to determine levels of endemicity of the stygofauna community;
- Conduct periodic biodiversity surveys every two years of the site with known biodiversity
- Conduct further surveys in other bores associated with the Wianamatta Shale perched aquifers and the hydrologically charged Nepean fault to determine the reference composition of the subterranean biodiversity in this geological setting;
- Species identification and distribution of the freshwater crayfish fauna as an indicator of groundwater connectivity and to identify potential short range endemic species.

7 CONCLUSION

The baseline sampling and assessment of the groundwater and river hyporheic ecosystems that exist in the Study Area has confirmed that small isolated populations of stygofauna and baseflow hyporheic fauna exist. In particular the surveys have demonstrated that:

- Stygofauna were present within one groundwater bore sampled, within the surface perched Wianamatta Shale aquifer;
- The ecological value of the stygofauna community across the area is low with hotspots of biodiversity with potentially a high degree of endemism.
- Stygofauna were present within 3 surface stream sampling sites within the Study area and 4 outside the area of the proposed mining operation;
- Stygofauna were not collected from the deep aquifer of the coal bearing zone;
- Hyporheic fauna were present in most stream sites sampled on the periphery of the study area;
- The groundwater fauna of the hypogean (groundwater) and hyporheic zones (rivers) are quite depauperate as result of the
    - Water chemistry, i.e. very low levels of groundwater dissolved oxygen, high levels of dissolved iron, lower (acidic) pH levels ranging from approximately 6-4 pH units;
    - Fine grained nature of the geology and sediments and lack of fracture zones
    - The small, transient, disconnected nature of the riverine hyporheic zone habitats.
- Although the geology and water chemistry is similar to other areas in the region that do contain stygofauna, as well as being connected with the Nepean River system, the geomorphology is sufficiently different to significantly reduce the number, longevity and types of appropriate habitats.
- The stream and groundwater fauna composition is dictated by the availability of suitable habitat along with stream and groundwater water chemistry.
- Stygofauna assemblage data suggest that there is a possible linkage between the perched, shallow aquifers and the hyporheic zones in the along the northern margin of the Study Area. The most likely scenario is a connection through groundwater flow in the fractures of the sandstone bedrock.
- Hyporheic assemblages were found at all river sites that were supported by a perennial baseflow. These assemblages were dominated by surface macroinvertebrate taxa, but also included ostracods and worms associated with the phreatic environment. The risk matrix assessed the GDEs as of moderate ecological value with moderate risk of impact.

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Plates


1a)

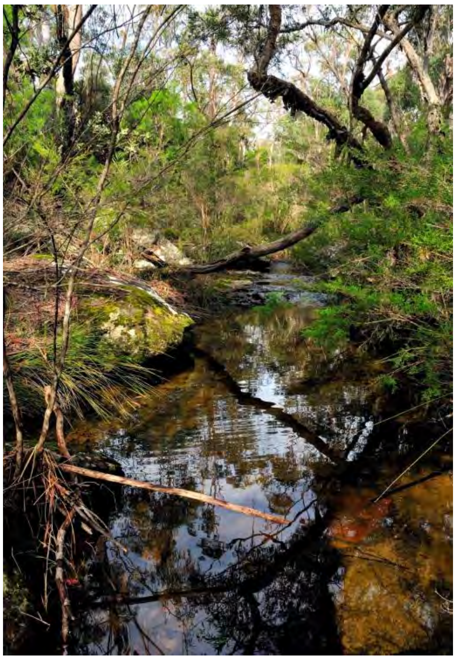

1b)


1c)


1d)

Plate 1 Hyporheic sites used in baseline survey. a) Bargo River, pool at downstream site; b) Bargo River, upstream site; (c) Carters Creek, pool downstream of bridge; and d) Carters Creek, riffle section sampled.

2a)



2b)

2c)

2d)

Plate 2 Hyporheic sites used in baseline survey. a) Cow Creek, survey section; b) Cow Creek, upstream section; c) Dog Trap Creek site downstream of Rockford Rd Bridge; d) Dog Trap Creek, upstream site.

3a) 3b) 3c) 3d)

Plate 3 Hyporheic sites used in baseline survey. a) Dry Creek, adjacent to survey section; b) Dry Creek, survey section with Bou Rouche pump In situ; c) Eliza Creek upstream of sample site showing bedrock substrate; d) Eliza Creek, , above survey site.

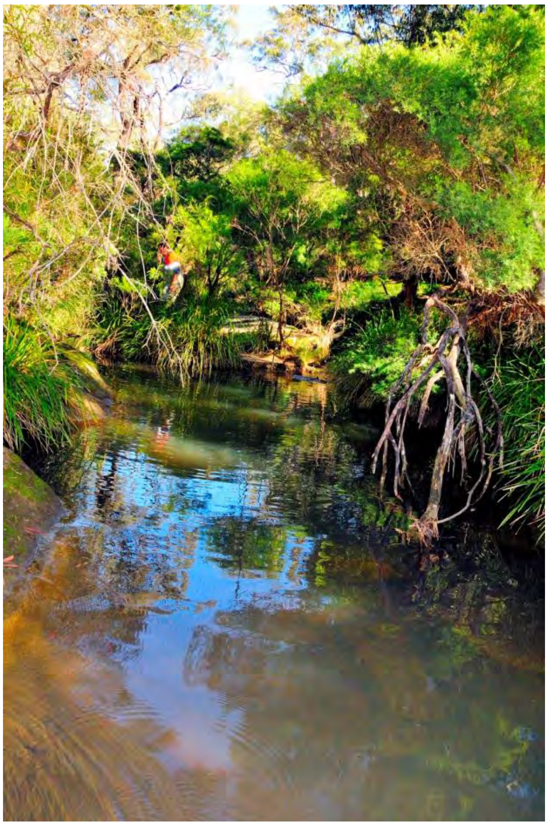
4a) 4b)

4c) 4d)

Plate 4 Hyporheic and Bore sites used in baseline survey. a) Eliza Creek seepage showing iron flocculent; b) Bore GW 1 (7445); c) Bore GW1 (7445) view of bore opening; d) Bore GW6 (56632).

5a)

5b)



5c)

Plate 5 Hyporheic and Bore sites used in baseline survey. a) Bore GW 12 (101936); b) Hornes Creek downstream survey site below waterfall; c) Hornes Creek, upstream site.

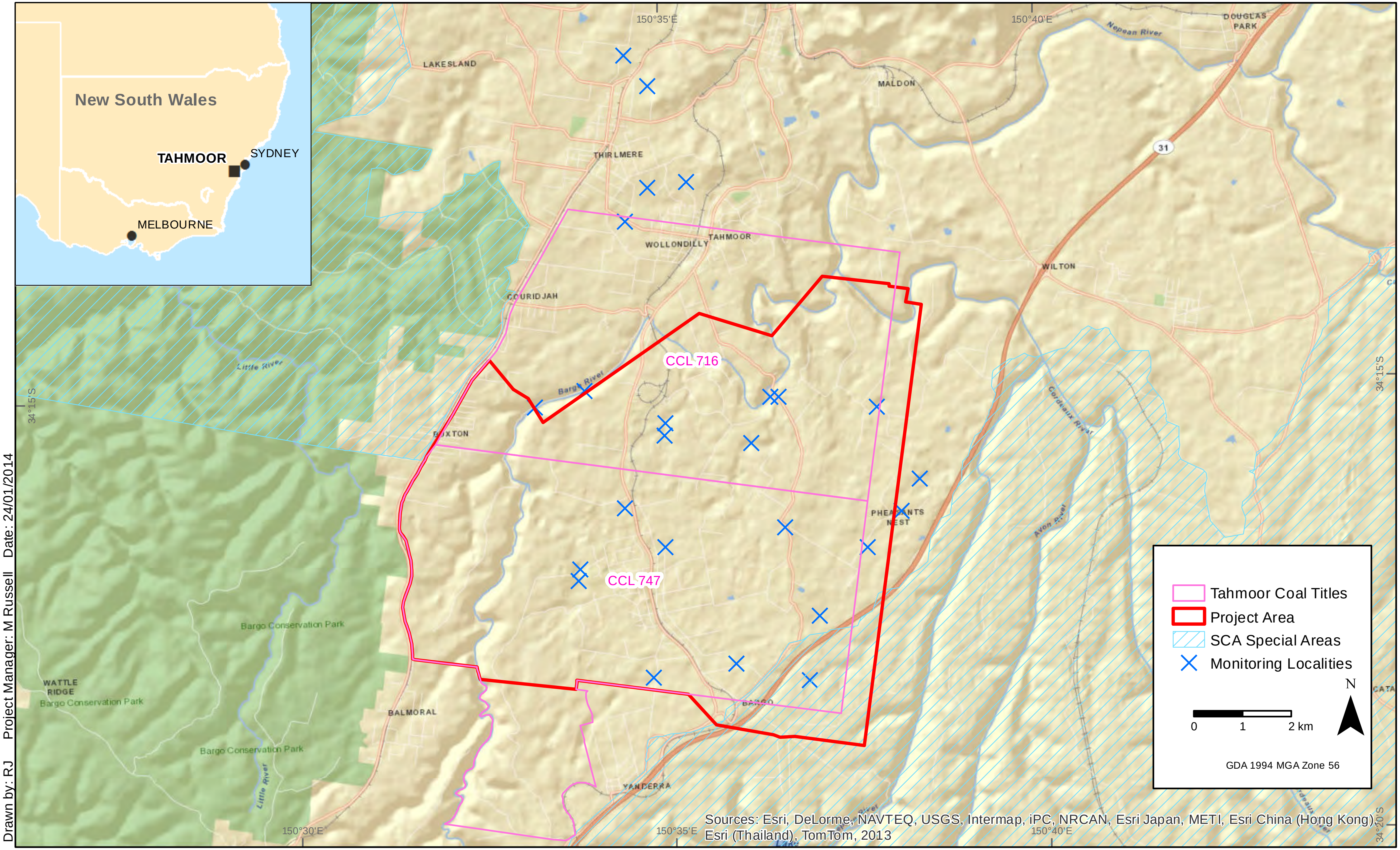
6a)

6b)

6c)

6d)

Plate 6 Hyporheic sites at Tea Tree Hollow used in baseline survey. a) Tea Tree Hollow upstream site viewed upstream; b) Tea Tree Hollow upstream site viewed downstream; c) Crayfish burrows at upstream site; d) Tea Tree Hollow upstream site showing streambed condition



Drawn by: RJ Project Manager: M Russell Date: 24/01/2014

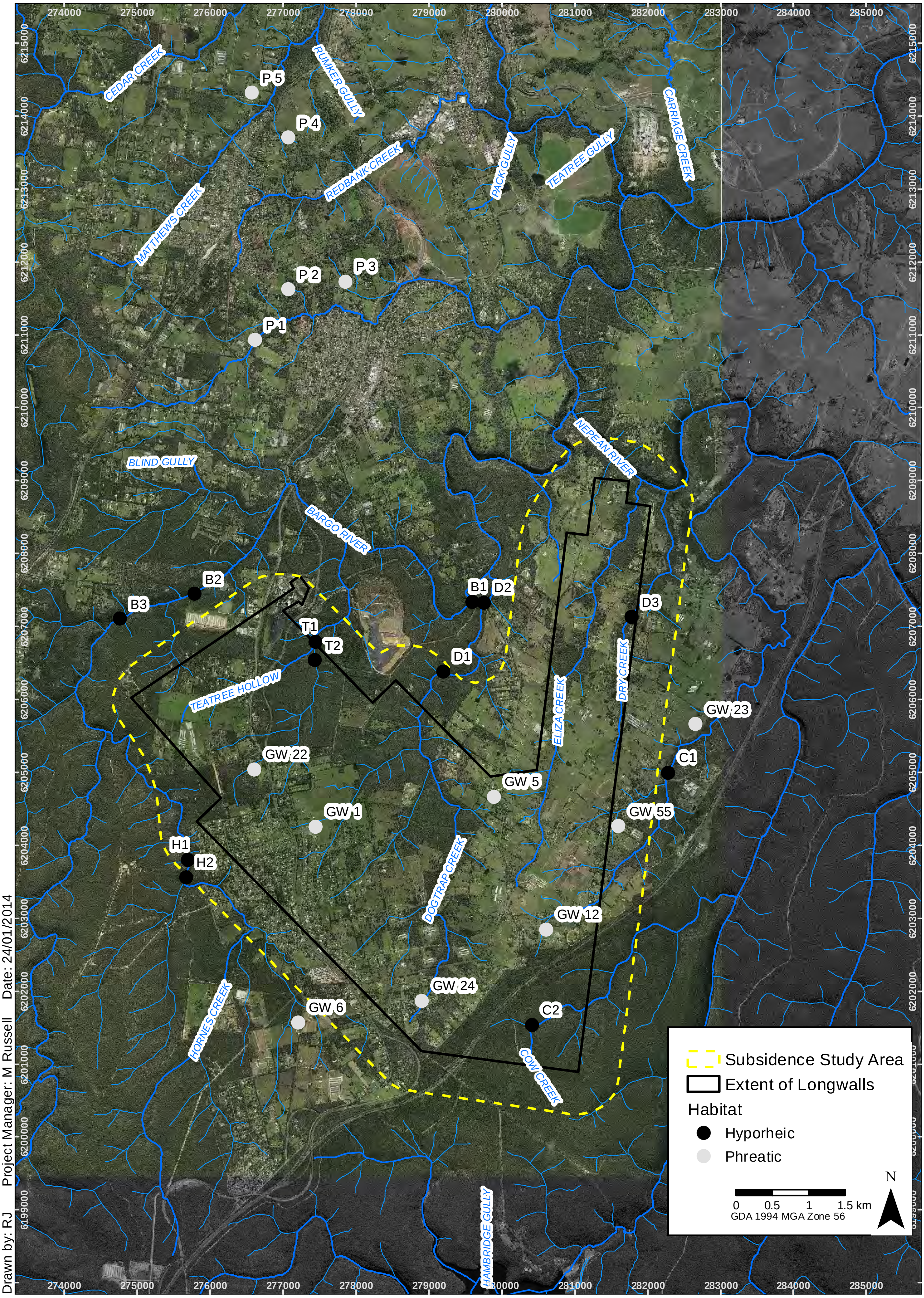
Regional Project Location

Stygofauna Monitoring at Tahmoor Colliery

FIGURE 1

niche Environment and Heritage

Path: P:\spatial\projects\a1400\a1490_TahmoorStygofauna\Maps\1490_Figure_1_StudyArea.mxd



Site Map

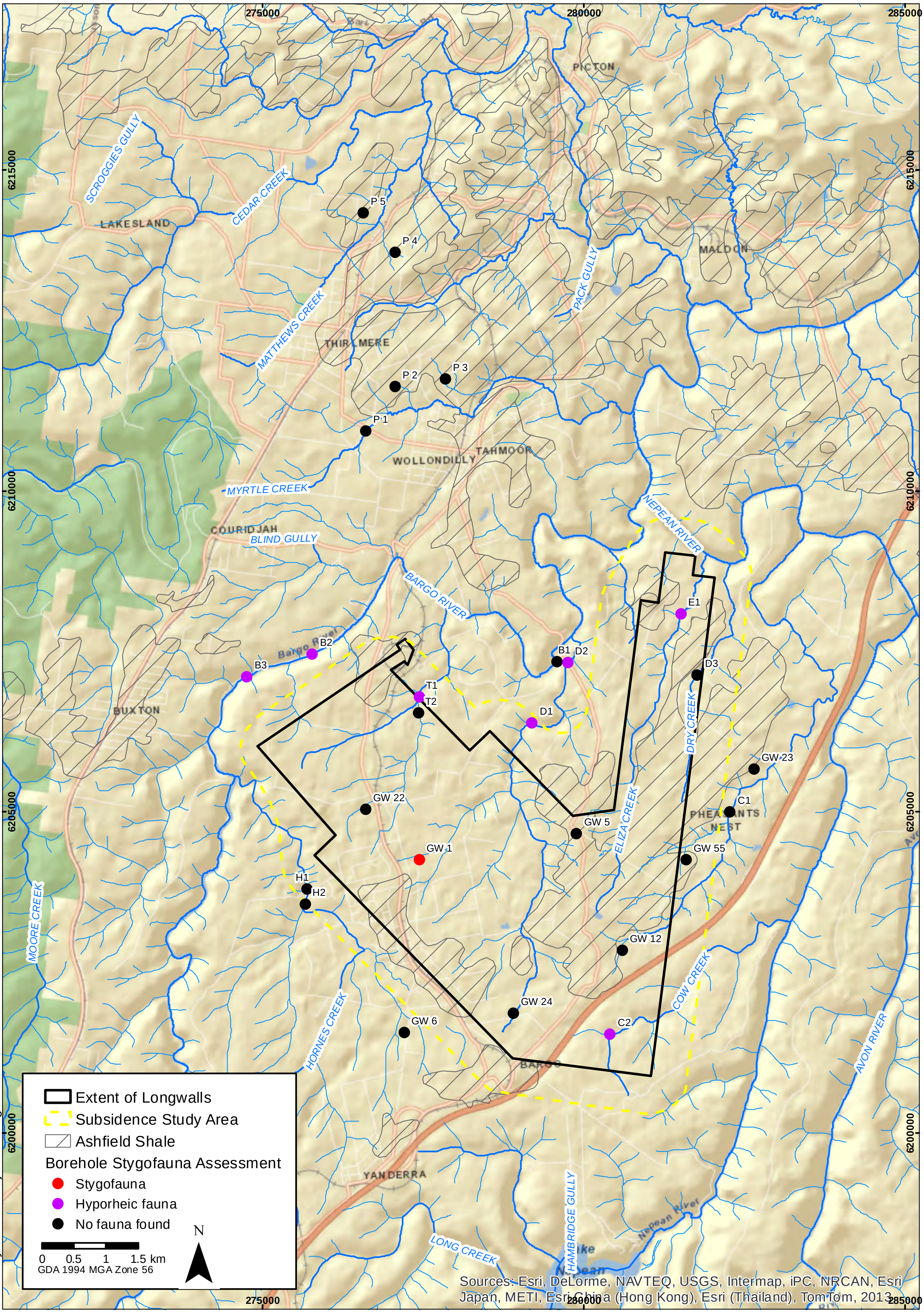
Stygofauna Monitoring at Tahmoor Colliery

FIGURE 2

niche Environment and Heritage

Path: P:\spatial\projects\a1400\a1490_TahmoorStygofauna\Maps\1490_Figure_2_SiteMap.mxd

Imagery: (c) Glencore 2013-06-18, LPI 2003



Drawn by: RJ Project Manager: M Russell Date: 10/02/2014

Stygofauna results

Stygofauna Monitoring at Tahmoor Colliery

FIGURE 3

niche Environment and Heritage

Path: P:\spatial\projects\a1400\a1490_TahmoorStygofauna\Maps\1490_Figure_3_Stygo.mxd

Imagery: (c) Glencore 2013-06-18, LPI 2003

Appendix 1: Species list per site for stygofauna and hyporheic aquatic baseline surveys of the Tahmoor South Project Area

Phylum	Class	Order	Family	Subfamily	Genus	Bargo d/s, 03/06/2013	Bargo mid, 18/07/2013	Bargo u/s, 05/06/2013	Carters, 03/06/2013	Cow, 18/07/2013	Dog Trap 1, 03/06/2013	Dog Trap 2, 17/07/2013	Dry, 03/06/2013	Eliza, 18/07/2013	Hornes d/s, 03/06/2013	Hornes u/s, 18/07/2013	Tea tree ds, 03/06/2013	Tea tree u/s, 17/07/2013	GW 1, 04/06/2013	GW 1, 17/07/2013	GW 5, 17/07/2013	GW 6, 04/06/2013	GW 6, 16/07/2013	GW 12, 04/06/2013	GW 12, 16/07/2013	GW 22, 04/06/2013	GW 22, 17/07/2013	GW 23, 04/06/2013	GW 24, 05/06/2013	GW 24, 16/07/2013	GW 55, 04/06/2013	GW 55, 16/07/2013	P 1, 16/07/2013	P 2, 05/06/2013	P 3, 05/06/2013	P 3, 17/07/2013	P 4, 05/06/2013	P 4, 17/07/2013	P 5, 17/07/2013
Annelida	Oligochaeta	Tubificida	Enchytraeidae		*Unidentified*					5																													
Annelida	Oligochaeta	Tubificida	Phreodrilidae		*Phreodriloides*		8	7				8		2																									
Arthropoda	Insecta	Coleoptera	Elmidae		*Kingolus flavopliatus c.f.*		1																																
Arthropoda	Insecta	Coleoptera	Scirtidae		*Scirtes*							2																											
Arthropoda	Insecta	Collembola	Isotomidae		*Isotomodes c.f*					1		1		1			1			1																		1	
Arthropoda	Insecta	Collembola	Onychiuridae		*Tullbergia*					3	1								1																			6	
Arthropoda	Insecta	Diptera	Ceratopogonidae		*Bezzia*									1																									
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladinae	*Paralimnophyes*		1	3						4				1																					1
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	*Tanytarsus*		1	3				1		5																									
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	*Nilotanypus c.f*					1		15																											
Arthropoda	Insecta	Diptera	Tipulidae		*Prionocera c.f.*		1							3	1																								1
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae		*Ulmerophlebia*									1																									
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae		*Atalophlebia*									2																									
Arthropoda	Insecta	Odonata	Megapodagrionidae		*Austroargiolestes*									1																									
Arthropoda	Malacostraca	Isopoda	Styloniscidae		*Styloniscus*							3																											
Arthropoda	Maxillopoda	Cyclopoida	Cyclopidae		*Mesocyclops*							1																											
Arthropoda	Ostracoda	Myodocopida	Candonidae	Candoninae	*Candonopsis cf.*						1	1					3		18	3																			
Nematomorpha	Not assigned	Gordioidea	Gordiidae		*Gordius*		2	3						1					1																				1
Platyhelminthes	Turbellaria	Tricladida	Dugesiidae		*Unidentified*							3		1																									
					Total No. species	0	6	4	0	4	2	9	0	11	1	0	2	1	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3
					Total No. of animals	0	14	16	0	10	2	15	0	22	1	0	2	1	20	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	2

Appendix 2: Species list for stygofauna and hyporheic aquatic baseline surveys of the Tahmoor South Project Area

Phylum	Class	Order	Family	Subfamily	Genus
Annelida	Oligochaeta	Tubificida	Enchytraeidae		Unidentified
Annelida	Oligochaeta	Tubificida	Phreodrilidae		Phreodriloides
Arthropoda	Insecta	Coleoptera	Elmidae		Kingolus flavopliatus c.f.
Arthropoda	Insecta	Coleoptera	Scirtidae		Scirtes
Arthropoda	Insecta	Collembola	Isotomidae		Isotomodes c.f
Arthropoda	Insecta	Collembola	Onychiuridae		Tullbergia
Arthropoda	Insecta	Diptera	Ceratopogonidae		Bezzia
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladinae	Paralimnophyes
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Tanytarsus
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	Nilotanypus c.f
Arthropoda	Insecta	Diptera	Tipulidae		Prionocera c.f.
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae		Ulmerophlebia
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae		Atalophlebia
Arthropoda	Insecta	Odonata	Megapodagrionidae		Austroargiolestes
Arthropoda	Malacostraca	Isopoda	Styloniscidae		Styloniscus
Arthropoda	Maxillopoda	Cyclopoida	Cyclopidae		Mesocyclops
Arthropoda	Ostracoda	Myodocopida	Candonidae	Candoninae	Candonopsis cf.
Nematomorpha	Not assigned	Gordioidea	Gordiidae		Gordius
Platyhelminthes	Turbellaria	Tricladida	Dugesiidae		Unidentified

Appendix 3: Water Quality Summary for Stygofauna and Hyporheic Surveys 2013

Locality Name	Bore (GW)	pH	EC (uS/cm)	Iron
*B1, Bargo River, Rockford Bridge,	Sandbar	8.2	857	1.1
*B3, Bargo River, upper riffle	Riffle	6.8	188	124
*C1, Carters Ck, riffle	Riffle	6.9	440	3.1
*C2, Cow Ck, riffle	Riffle	6.8	130	0.49
*D1, Dog Trap Ck a, riffle	Riffle	7.3	934	1.1
*D2, Dog Trap Ck, Rockford Brg, riffle	Riffle	7.3	198	5.3
*D3, Dry Ck, riffle	Riffle	6.6	255	2.8
*E1, Eliza Ck, riffle	Riffle	6.4	846	3.6
*H, Hornes Ck	Sandbar	7	333	5
*T, Tea tree Hollow	gravel bank	8.7	1815	0.13
**GW 1, Exploration bore	7445			
**GW 5, Production bore	54146	5.72	561	low-mod
**GW 6, Exploration bore	56632	4.43	898	clear
**GW 12, Exploration bore	101936	4.22	2005	high
**GW 22, Production bore	109257	4.83	797	low
**GW 23, Exploration bore	G23	6.03	940	strong
**GW 24, Exploration bore	G24	3.74	4380	clear
**GW 55, Exploration bore	59618			low - mod
**P 1, Piezometer	106281			
**P 2, Piezometer	no GW no.			
**P 3, Piezometer	no GW no.			
**P 4, Piezometer	67570			
**P 5, Piezometer	63525			

Data Source *Tahmoor Coal and **Niche survey

Appendix 4: Risk Register Process

GDE types identified in study area.

Aquifer Type	GDE type
Consolidated Porous Sandstone/shale Aquifer	
	Subsurface Phreatic aquifer ecosystems
	Groundwater Dependent Wetlands
	Springs and seeps
	Rockpools and Waterholes
	Baseflow Stream (Surface Ecosystems)
	Surface Water Riverine Ecosystems
	Baseflow Stream (Hyporheic Ecosystems)
	Subsurface Hyporheic Ecosystems
	Phreatophytes - Groundwater Dependent Terrestrial Vegetation

Identification of High Ecological Value Assets/High Priority GDEs within the Aquifer/Groundwater Source.

	Yes	No	List/Comments
Does the aquifer or portion of it occur within a state reserve or support any GDEs within a sub-catchment identified as High Conservation Value (e.g. Stressed Rivers; high value vegetation, SEPP wetlands, DIWA wetland etc)?		X	Although the area of investigation does not fall within a reserve the aquifer that feeds the streams ultimately enters the Sydney Water Catchment Area
Does the aquifer support obligate/entirely dependent GDEs including: karsts, springs, mound springs, subterranean aquifer ecosystems and some wetlands such as hanging swamps.	X		Obligate stygofauna, were recorded
Does the aquifer support GDEs that have any endemic, relictual, rare, or endangered biota (fauna or flora) populations or communities as listed under the NSW Threatened Species Act (1995), NSW Fisheries Management Act (1994) or the Commonwealth Environment Protection and Biodiversity Conservation Act (1999) or identified by an acknowledged expert Taxonomist/Regional Ecologist as being important?		X	No however the survey identified potentially new stygofauna species that have not been examined or listed. .

Aquifer/GDE Impact Checklist for a proposed activity.

Groundwater Management Area/Zone: Tahmoor South, Sothern Coal fields Sydney Sandstone and Wianamatta Shale			
Activity to be Assessed: Long wall mining			
Water Quantity Impacts	**Likely**	**Unlikely**	**Insufficient data**
Will there be an alteration to the water table levels (rising or dropping water tables)?	X		
Will there be any alteration to the aquifer flow paths?		X	
Will there be any alteration of aquifer discharge volume to off site GDEs?		X	
Will there be an alteration of the frequency/timing of water table level fluctuations?	X		
Will there be any alteration of river base flow in the karst/cave?			NA
Will there be an alteration of surface river base flow?	X		
Will there a reduction in artesian/spring water pressure?	X		
Water Quality Impacts		X	
Will there be an alteration to the natural groundwater chemistry and/or chemical gradients?	X		
Will acid sulphate soils be exposed, resulting in the acidification of groundwater source and acid runoff?			NA
Will there be an alteration in nutrient loads?		X	
Will there be an alteration in sediment loads?		X	
Will there be an alteration in groundwater salinity levels?		X	
Will there be an alteration in groundwater temperatures?		X	
Will there be any bioaccumulation of heavy metals?			X

Risk Matrix.

Category 1 High Ecological Value (HEV) Sensitive Environmental Area (SEA)	A	B	C
Category 2 Moderate Ecological Value (MEV) Sensitive Environmental Area (SEA)	D	E	F
Category 3 Low Ecological Value (LEV)	G	H	I
	Category 1. Low Risk	Category 2. Moderate Risk	Category 3. High Risk

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Risk Matrix Management Actions

Risk Matrix Box	Descriptor	Management action short term	Management action mid term	Management action long term **
A	High value/Low risk	Protection measures for aquifer and GDEs.	Continue protection measures for aquifers and GDEs.	Adaptive management. Continue monitoring.
		Baseline Risk monitoring.	Periodic monitoring and assessment.	
B	High value/Moderate Risk	Protection measures for aquifer and GDEs.	Protection measures for aquifer and GDEs.	Adaptive management. Continue monitoring.
		Baseline Risk monitoring. Mitigation action.	Monitoring and periodic assessment of mitigation.	
C	High Value/High Risk	Protection measures for aquifer and GDEs.	Protection measures for aquifer and GDEs.	Adaptive management. Continue monitoring.
		Baseline Risk monitoring. Mitigation.	Monitoring and annual *assessment of mitigation.	
D	Moderate Value/Low Risk	Protection of hotspots.	Protection of hotspots.	Adaptive management. Continue monitoring.
		Baseline Risk monitoring.	Baseline Risk monitoring.	
E	Moderate Value/Moderate Risk	Protection of hotspots.	Protection of hotspots.	Adaptive management. Continue monitoring.
		Baseline Risk monitoring.	Monitoring and periodic assessment of mitigation.	
		Mitigation action.		
F	Moderate Value/High Risk	Protection of hotspots.	Protection of hotspots.	Adaptive management. Continue monitoring.
		Baseline Risk monitoring. Mitigation Action.	Monitoring and annual *assessment of mitigation.	
G	Low value/Low risk	Protect hotspots (if any).	Protect hotspots (if any).	Adaptive management. Continue monitoring.
		Baseline Risk monitoring.	Baseline Risk monitoring.	
H	Low Value/Moderate Risk	Protect hotspots (if any).	Protect hotspots (if any).	Adaptive management. Continue monitoring.
		Baseline Risk monitoring. Mitigation action.	Monitoring and periodic assessment of mitigation.	
I	Low Value/High Risk	Protect hotspots (if any).	Protect hotspots (if any).	Adaptive management. Continue monitoring.
		Baseline Risk monitoring. Mitigation Action.	Monitoring and annual *assessment of mitigation.	

Appendix 5: Ecological Valuation Tables

Ecological value assessments of the Aquifer/Groundwater Source in 2013.

GDE ENVIRONMENT					
	High	**Moderate**	**Low**	**Unknown**	**Comments**
% of aquifer area covered by native GDE vegetation.			20% Low		
% of GDE area reserved in National Estates, listed wetlands, SEPP 26 etc.			< 10%		
Presence of exotic flora or fauna			> 80% exotic flora in rural and urbanized areas		
Removal or alteration of a GDE type or subtype		Minor change or alteration in physical structure, species composition, or size resulting in a temporary change in GDE type or subtype.			Low urbanized and rural catchment area. Physical structure of surface aquifer and landscape remains intact, however as this is the first investigation to examine species composition it is unknown if there has been any previous impacts to biodiversity

AQUIFER					
Water quantity parameters	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
Alteration of the frequency and/or magnitude and/or	No detectable change from				The only fluctuations are seasonal fluctuations based on bore census data as stated by Glencore.

timing of water table level fluctuations.	natural seasonal variation.				
Alteration of groundwater pressure	No detectable change from natural seasonal variation.				Low based upon groundwater bore census data
Alteration to direction of hydraulic gradients	No detectable change from natural seasonal variation.				Low based upon groundwater bore census data
Alteration of base flow conditions	No detectable change from natural seasonal variation.				Although we have no previous data we do have surface water communities that contained long lived species therefore indicate the level of base flow has remained sufficient for their survival over time. The presence of short- ranged dispersers and long lived fauna indicate base flow conditions have remained with in natural variation.
Degree of Acid runoff or acidification of groundwater source.	No detectable change from natural seasonal variation.				Low based upon groundwater bore census data
Degree of nutrient load.	No detectable change from natural seasonal variation.				Within back ground levels (Geoterra 2013)
Degree of groundwater salinity.	No detectable change from natural seasonal variation.				Within back ground levels (Geoterra 2013)

Degree of bioaccumulation i.e. heavy metal contamination	No detectable change from natural seasonal variation.				Within back ground levels (Geoterra 2013)
Aquifer structure	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
Degree of alteration of aquifer structure (e.g. quarrying of limestone around karsts, tramping of cave habitats, sand and gravel extraction, compaction of aquifer, etc.).	No detectable change in aquifer structure				At this point in time there appears to be no large alterations to aquifer structures
BIODIVERSITY					
Rarity within catchment/groundwater source	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
Presence of Threatened, Rare, Vulnerable or Endangered species, population or ecological community.			Low		
Presence of indicator, keystone, flagship, endemic or significant species, populations or communities. ***	yes				A small, localised community of stygofauna has been identified with in the Study Area

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Diversity within catchment/groundwater source	High	Moderate	Low	Unknown	Comments
Diversity of GDE type. Refer to GDE Classification table	Presence of greater than 4 GDE types				
Diversity of GDE subtypes. Refer to GDE Classification table.	Presence of 5 or more subtypes.				
SPECIAL FEATURES WITHIN CATCHMENT/GROUNDWATER SOURCE					
	High	**Moderate**	**Low**	**Unknown**	**Comments**
Maintains ecosystems by providing water		Provides water to identified GDEs			See GDE types
Presence of rare physical/physico-chemical features or environments (e.g. karsts, mound springs, natural saline wetlands, peat swamps etc.)			Occurs within the State		Stygofauna were found associated with the Wianamatta Shales. This aquifer habitat is localized with in a small section of the Study Area. Although this habitat occurs regionally they occur in isolated pockets
Delivers ecosystem services through biogeochemical processes: carbon processing, nitrification/denitrification, biodegradation through			Consolidated Aquifer connected to terrestrial and aquatic		

aquifer connectivity			ecosystems		
TOTAL NUMBER OF ATTRIBUTES	**13**	**2**	**6**		
OVERALL VALUE	**High**				
COMMENTS	**Due to the limited time frame of the physicochemical data the confidence level of this assessment is moderate and therefore requires the establishment ongoing monitoring to increase the confidence of this assessment. Particularly for water chemistry and water level monitoring.**				

Ecological value assessments of the stygofauna community within the groundwater source in 2013.

Site GW1

Locality	GW1				
GDE ENVIRONMENT	High	Moderate	Low	Unknown	Comments
GDE or part thereof occurs or is reserved in National Estates, listed wetlands, SEPP 26 etc.			No		
Presence of exotic fauna within GDE	None known to exist				
Removal or alteration of GDE type or subtype	No detectable change in physical structure, species composition or size in GDE type or subtype.				
BIODIVERSITY					
Rarity within catchment/groundwater source	High	Moderate	Low	Unknown	Comments
Presence of Threatened, Rare, Vulnerable or Endangered species, population or ecological community within GDE.			No		
Presence of indicator, keystone, flagship, endemic or significant species, populations or communities within GDE ***	Yes				
Diversity within catchment/groundwater source	High	Moderate	Low	Unknown	Comments
Diversity of groundwater dependent native flora and fauna species within a GDE.			Presence of one species or less than 50% of species relative to reference sites		
SPECIAL FEATURES WITHIN CATCHMENT/GROUNDWATER SOURCE	High	Moderate	Low	Unknown	Comments
Provides drought refuge for terrestrial or aquatic species			Access to multiple water sources.		
Presence of rare physical/physico-chemical features or environments (e.g. karsts, mound			Occurs only within the State		

springs, natural saline wetlands, peat swamps etc.)					
Delivers ecosystem services through biogeochemical processes: carbon processing, nitrification/denitrification, biodegradation through aquifer connectivity	Unconfined aquifer with connection to terrestrial and aquatic ecosystems.				
Delivers ecosystem services through biogeochemical processes: carbon processing, nitrification/denitrification, biodegradation relating to aquifer structure and porosity			Consolidated aquifer connected to terrestrial and aquatic ecosystems		
TOTAL NUMBER OF ATTRIBUTES	**4**	0	6		
OVERALL VALUE	Low				
COMMENTS	The low ecological value for this bore is attributed to the low biodiversity of the stygofauna community at this location, while acknowledging the presence of potentially endemic fauna.				

Site B2

Locality	**B2**				
GDE ENVIRONMENT	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
GDE or part thereof occurs or is reserved in National Estates, listed wetlands, SEPP 26 etc.			No		
Presence of exotic flora or fauna within GDE	None collected in survey				
Removal or alteration of GDE type or subtype	No detectable change in physical structure, species composition or size in GDE type or subtype.				
BIODIVERSITY					

Rarity within catchment/groundwater source	High	Moderate	Low	Unknown	Comments
Presence of Threatened, Rare, Vulnerable or Endangered species, population or ecological community within GDE.			No		
Presence of indicator, keystone, flagship, endemic or significant species, populations or communities within GDE ***	Yes				
Diversity within catchment/groundwater source	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
Diversity of groundwater dependent native flora and fauna species within a GDE.			Presence of one species or less than 50% of species relative to reference sites		
SPECIAL FEATURES WITHIN CATCHMENT/GROUNDWATER SOURCE	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
Provides drought refuge for terrestrial or aquatic species			Access to multiple water sources.		
Presence of rare physical/physico-chemical features or environments (e.g. karsts, mound springs, natural saline wetlands, peat swamps etc.)			Occurs only within the State		
Delivers ecosystem services through biogeochemical processes: carbon processing, nitrification/denitrification, biodegradation through aquifer connectivity	Unconfined aquifer with connection to terrestrial and aquatic ecosystems.				
Delivers ecosystem services through biogeochemical processes: carbon processing, nitrification/denitrification, biodegradation relating to aquifer structure and porosity			Consolidated aquifer connected to terrestrial and aquatic ecosystems		
TOTAL NUMBER OF ATTRIBUTES	**4**	0	6		
OVERALL VALUE	Low				
COMMENTS	The high values recorded here indicative of the intact nature of the riverine habitat and the ecosystem services the groundwater contributes via baseflow to the other GDE				

	types, in particular the hyporheic habitat surveyed. The comparable numbers of low values represents the low numbers of permanent hyporheic (stygofauna) recorded. The ecological value of this site terms of the stygofauna community this site is low.

Site B3

Locality	**B3**				
GDE ENVIRONMENT	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
GDE or part thereof occurs or is reserved in National Estates, listed wetlands, SEPP 26 etc.			No		
Presence of exotic flora or fauna within GDE	None collected in survey				
Removal or alteration of GDE type or subtype	No detectable change in physical structure, species composition or size in GDE type or subtype.				
BIODIVERSITY					
Rarity within catchment/groundwater source	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
Presence of Threatened, Rare, Vulnerable or Endangered species, population or ecological community within GDE.			No		
Presence of indicator, keystone, flagship, endemic or significant species, populations or communities within GDE ***	Yes				
Diversity within catchment/groundwater source	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
Diversity of groundwater dependent native flora and fauna species within a GDE.			Presence of one species or less than 50% of species relative to reference sites		
SPECIAL FEATURES WITHIN CATCHMENT/GROUNDWATER SOURCE	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
Provides drought refuge for terrestrial or			Access to multiple water sources.		

aquatic species					
Presence of rare physical/physico-chemical features or environments (e.g. karsts, mound springs, natural saline wetlands, peat swamps etc.)			Occurs only within the State		
Delivers ecosystem services through biogeochemical processes: carbon processing, nitrification/denitrification, biodegradation through aquifer connectivity	Unconfined aquifer with connection to terrestrial and aquatic ecosystems.				
Delivers ecosystem services through biogeochemical processes: carbon processing, nitrification/denitrification, biodegradation relating to aquifer structure and porosity			Consolidated aquifer connected to terrestrial and aquatic ecosystems		
TOTAL NUMBER OF ATTRIBUTES	**4**	0	6		
OVERALL VALUE	Low				
COMMENTS	The high values recorded here are indicative of the intact nature of the riverine habitat and the ecosystem services the groundwater contributes via base flow to the other GDE types, in particular the hyporheic habitat surveyed. The comparable numbers of low values represents the low numbers of permanent hyporheic (stygofauna) recorded. The ecological value of this site terms of the stygofauna community this site is low.				

Site C2

Locality	**C2**				
GDE ENVIRONMENT	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
GDE or part thereof occurs or is reserved in National Estates, listed wetlands, SEPP 26 etc.	Yes				
Presence of exotic flora or fauna within GDE	None collected in survey				
Removal or alteration of GDE type or subtype	No detectable change in physical structure, species composition or size in GDE type or subtype.				
BIODIVERSITY					

Rarity within catchment/groundwater source	High	Moderate	Low	Unknown	Comments
Presence of Threatened, Rare, Vulnerable or Endangered species, population or ecological community within GDE.			No		
Presence of indicator, keystone, flagship, endemic or significant species, populations or communities within GDE ***	Yes				
Diversity within catchment/groundwater source	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
Diversity of groundwater dependent native fauna species within a GDE.			Presence of one species or less than 50% of species relative to reference sites		
SPECIAL FEATURES WITHIN CATCHMENT/GROUNDWATER SOURCE	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
Provides drought refuge for terrestrial or aquatic species			Access to multiple water sources.		
Presence of rare physical/physico-chemical features or environments (e.g. karsts, mound springs, natural saline wetlands, peat swamps etc.)			Occurs only within the State		
Delivers ecosystem services through biogeochemical processes: carbon processing, nitrification/denitrification, biodegradation through aquifer connectivity	Unconfined aquifer with connection to terrestrial and aquatic ecosystems.				
Delivers ecosystem services through biogeochemical processes: carbon processing, nitrification/denitrification, biodegradation relating to aquifer structure and porosity			Consolidated aquifer connected to terrestrial and aquatic ecosystems		
TOTAL NUMBER OF ATTRIBUTES	**5**	0	5		
OVERALL VALUE	Moderate				
COMMENTS	The high values recorded here indicative of the intact nature of the riverine habitat and the ecosystem services the groundwater contributes via baseflow to the other GDE				

	types, in particular the hyporheic habitat surveyed. The comparable numbers of low values represents the low numbers of permanent hyporheic (stygofauna) recorded. The high and low values are equal the ecological value of this site terms of the stygofauna community this site is moderate.

Site D1

Locality	D1				
GDE ENVIRONMENT	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
GDE or part thereof occurs or is reserved in National Estates, listed wetlands, SEPP 26 etc.			No		
Presence of exotic flora or fauna within GDE	None collected in survey				
Removal or alteration of GDE type or subtype	No detectable change in physical structure, species composition or size in GDE type or subtype.				
BIODIVERSITY					
Rarity within catchment/groundwater source	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
Presence of Threatened, Rare, Vulnerable or Endangered species, population or ecological community within GDE.			No		
Presence of indicator, keystone, flagship, endemic or significant species, populations or communities within GDE ***	Yes				
Diversity within catchment/groundwater source	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
Diversity of groundwater dependent native flora and fauna species within a GDE.			Presence of one species or less than 50% of species relative to reference sites		
SPECIAL FEATURES WITHIN CATCHMENT/GROUNDWATER SOURCE	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
Provides drought refuge for terrestrial or aquatic species			Access to multiple water sources.		

Presence of rare physical/physico-chemical features or environments (e.g. karsts, mound springs, natural saline wetlands, peat swamps etc.)			Occurs only within the State		
Delivers ecosystem services through biogeochemical processes: carbon processing, nitrification/denitrification, biodegradation through aquifer connectivity	Unconfined aquifer with connection to terrestrial and aquatic ecosystems.				
Delivers ecosystem services through biogeochemical processes: carbon processing, nitrification/denitrification, biodegradation relating to aquifer structure and porosity			Consolidated aquifer connected to terrestrial and aquatic ecosystems		
TOTAL NUMBER OF ATTRIBUTES	4	0	6		
OVERALL VALUE	Low				
COMMENTS	The high values recorded here indicative of the intact nature of the riverine habitat and the ecosystem services the groundwater contributes via baseflow to the other GDE types, in particular the hyporheic habitat surveyed. The comparable numbers of low values represents the low numbers of permanent hyporheic (stygofauna) recorded. The ecological value of this site terms of the stygofauna community this site is low.				

Site D2

Locality	D2				
GDE ENVIRONMENT	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
GDE or part thereof occurs or is reserved in National Estates, listed wetlands, SEPP 26 etc.			No		
Presence of exotic flora or fauna within GDE	None collected in survey				
Removal or alteration of GDE type or subtype	No detectable change in physical structure, species composition or size in GDE type or subtype.				
BIODIVERSITY					
Rarity within catchment/groundwater source	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
Presence of Threatened, Rare, Vulnerable or Endangered species, population or ecological community within GDE.			No		
Presence of indicator, keystone, flagship, endemic or significant species, populations or communities within GDE ***	Yes				
Diversity within catchment/groundwater source	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
Diversity of groundwater dependent native flora and fauna species within a GDE.		Presence of 2-4 species or 80-50% of species relative to reference sites			
SPECIAL FEATURES WITHIN CATCHMENT/GROUNDWATER SOURCE	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
Provides drought refuge for terrestrial or aquatic species			Access to multiple water sources.		
Presence of rare physical/physico-chemical features or environments (e.g. karsts, mound springs, natural saline wetlands, peat swamps			Occurs only within the State		

etc.)					
Delivers ecosystem services through biogeochemical processes: carbon processing, nitrification/denitrification, biodegradation through aquifer connectivity	Unconfined aquifer with connection to terrestrial and aquatic ecosystems.				
Delivers ecosystem services through biogeochemical processes: carbon processing, nitrification/denitrification, biodegradation relating to aquifer structure and porosity			Consolidated aquifer connected to terrestrial and aquatic ecosystems		
TOTAL NUMBER OF ATTRIBUTES	**4**	1	5		
OVERALL VALUE	Low				
COMMENTS	The high values recorded here indicative of the intact nature of the riverine habitat and the ecosystem services the groundwater contributes via baseflow to the other GDE types, in particular the hyporheic habitat surveyed. The moderate value was recorded for the higher numbers of permanent hyporheic (stygofauna) collected. The ecological value of this site terms of the stygofauna community this site is low.				

Site E1

Locality	**E1**				
GDE ENVIRONMENT	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
GDE or part thereof occurs or is reserved in National Estates, listed wetlands, SEPP 26 etc.			No		
Presence of exotic flora or fauna within GDE	None collected in survey				
Removal or alteration of GDE type or subtype	No detectable change in physical structure, species composition or size in GDE type or subtype.				
BIODIVERSITY					
Rarity within catchment/groundwater source	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
Presence of Threatened, Rare, Vulnerable or Endangered species, population or ecological			Yes		

community within GDE.					
Presence of indicator, keystone, flagship, endemic or significant species, populations or communities within GDE ***	Yes				
Diversity within catchment/groundwater source	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
Diversity of groundwater dependent native flora and fauna species within a GDE.		Presence of 2-4 species or 80-50% of species relative to reference sites			
SPECIAL FEATURES WITHIN CATCHMENT/GROUNDWATER SOURCE	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
Provides drought refuge for terrestrial or aquatic species			Access to multiple water sources.		
Presence of rare physical/physico-chemical features or environments (e.g. karsts, mound springs, natural saline wetlands, peat swamps etc.)			Occurs only within the State		
Delivers ecosystem services through biogeochemical processes: carbon processing, nitrification/denitrification, biodegradation through aquifer connectivity	Unconfined aquifer with connection to terrestrial and aquatic ecosystems.				
Delivers ecosystem services through biogeochemical processes: carbon processing, nitrification/denitrification, biodegradation relating to aquifer structure and porosity			Consolidated aquifer connected to terrestrial and aquatic ecosystems		
TOTAL NUMBER OF ATTRIBUTES	**4**	1	5		
OVERALL VALUE	Low				
COMMENTS	The high values recorded here are indicative of the intact nature of the riverine habitat and the ecosystem services the groundwater contributes via baseflow to the other GDE types, in particular the higher numbers of hyporheic fauna surveyed. The moderate value was recorded for the higher numbers of permanent hyporheic (stygofauna) collected. The ecological value of this site terms of the stygofauna community this site is low.				

Site T1

Locality	T1				
GDE ENVIRONMENT	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
GDE or part thereof occurs or is reserved in National Estates, listed wetlands, SEPP 26 etc.			No		
Presence of exotic flora or fauna within GDE	None collected in survey				
Removal or alteration of GDE type or subtype	No detectable change in physical structure, species composition or size in GDE type or subtype.				
BIODIVERSITY					
Rarity within catchment/groundwater source	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
Presence of Threatened, Rare, Vulnerable or Endangered species, population or ecological community within GDE.			No		
Presence of indicator, keystone, flagship, endemic or significant species, populations or communities within GDE ***	Yes				
Diversity within catchment/groundwater source	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
Diversity of groundwater dependent native flora and fauna species within a GDE.			Presence of one species or less than 50% of species relative to reference sites		
SPECIAL FEATURES WITHIN CATCHMENT/GROUNDWATER SOURCE	**High**	**Moderate**	**Low**	**Unknown**	**Comments**
Provides drought refuge for terrestrial or aquatic species			Access to multiple water sources.		
Presence of rare physical/physico-chemical features or environments (e.g. karsts, mound springs, natural saline wetlands, peat swamps			Occurs only within the State		

etc.)					
Delivers ecosystem services through biogeochemical processes: carbon processing, nitrification/denitrification, biodegradation through aquifer connectivity	Unconfined aquifer with connection to terrestrial and aquatic ecosystems.				
Delivers ecosystem services through biogeochemical processes: carbon processing, nitrification/denitrification, biodegradation relating to aquifer structure and porosity			Consolidated aquifer connected to terrestrial and aquatic ecosystems		
TOTAL NUMBER OF ATTRIBUTES	**4**	0	6		
OVERALL VALUE	Low				
COMMENTS	The low ecological value for this bore is attributed to the low biodiversity of the stygofauna community at this location, while acknowledging the presence of potentially endemic fauna. The high values recorded here indicative of the intact nature of the riverine habitat and the ecosystem services the groundwater contributes via baseflow to the other GDE types, in particular the hyporheic habitat surveyed and the presence of a burying crayfish community. The ecological value in terms of stygofauna is low.				

Appendix 6: Ecological Risk Tables

Aquifer Risk Assessment 2013.

Groundwater Source Name:	Perched Wianamatta Shale and Sydney Sandstone aquifers			
RISK FACTORS				
Water Quantity Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What will be the risk of a change in groundwater levels/pressure on GDEs?		Reduction in groundwater level(s) or piezometric pressure is unlikely to go beyond seasonal variation.		Although assessed as moderate, there is a potential for permanent alteration to water levels.
What will be the risk of a change in the timing or magnitude of groundwater level fluctuations on GDEs?		Fluctuation in groundwater level(s) or piezometric pressure beyond seasonal variation, resulting in temporary loss or alteration of defined habitat type.		
What will be the risk of changing base flow conditions on GDEs?		Potential for localised, temporary loss of surface flow from stream bed cracking but not total loss of stream flow from system		There may be permanent change or loss in some section s of streams through cracking
Water Quality Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What is the risk of changing the chemical conditions of the groundwater source?		Temporary change (e.g. in pH, DO, nutrients, temperature and/or turbidity)		
What is the risk on the groundwater source by a change in the freshwater/salt water interface?			Very limited – deeper saline groundwater separated from fresh	

			water aquifers by aquitard	
What is the likelihood of a change in beneficial use (BU) of the groundwater source?			Limited from previous mining history at Tahmoor Mine over past 30 years	
Aquifer Integrity Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What is the risk of damage to the geologic structure?		Temporary adjustment to the aquifer matrix. Minor cracking/fracturing of the bedrock/stream bed leading to partial dewatering of the GDE		
Biological Integrity Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What is the risk of alterations to the number of native species within the groundwater dependent communities (fauna and flora)?				Unknown
What is the risk of alterations to the species composition of the groundwater dependent communities (fauna and flora)?		Possible		
What is the risk of increasing the presence of exotic flora or fauna?		Species in small numbers.		
What is the risk of removing or altering a GDE subtype habitat (e.g. quarrying of limestone around karsts, tramping of cave habitats, sand and gravel extraction)?				Insufficient data
Risk Valuation				
Risk : There is a moderate risk of impact from the proposed activity.				

Ecological risk assessments of the stygofauna community within the groundwater source in 2013.

Site GW1

Locality	**GW1**			
Water Quantity Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What will be the risk of a change in groundwater levels/pressure on GDEs?		Reduction in groundwater level(s) or piezometric pressure beyond seasonal variation, resulting in temporary loss or alteration of defined habitat type.		
What will be the risk of a change in the timing or magnitude of groundwater level fluctuations on GDEs?			No change in timing of water level fluctuations.	
Water Quality Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What is the risk of changing the chemical conditions of the groundwater source?			Negligible change (<5%)	
What is the risk on the groundwater source by a change in the freshwater/salt water interface?			Very limited – deeper saline groundwater separated from fresh water aquifers by aquitard	
What is the likelihood of a change in beneficial use (BU) of the groundwater source?			Limited from previous mining history at Tahmoor Mine over past 30 years	
Aquifer Integrity Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What is the risk of damage to the geologic structure?		Temporary adjustment to the aquifer matrix. Minor cracking/fracturing of the bedrock/stream bed leading to partial dewatering of the GDE		
Biological Integrity Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What is the risk of alterations to the number of				X

native species within the groundwater dependent communities (fauna and flora)?				
What is the risk of alterations to the species composition of the groundwater dependent communities (fauna and flora)?		10-5% change in species composition.		
What is the risk of increasing the presence of exotic flora or fauna?			None exist.	
What is the risk of removing or altering a GDE subtype habitat (e.g. quarrying of limestone around karsts, tramping of cave habitats, sand and gravel extraction)?				X
Risk Valuation	0	3	5	
Risk	**Low**			

Site B2

Locality	**B2**			
Water Quantity Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What will be the risk of a change in groundwater levels/pressure on GDEs?		Reduction in groundwater level(s) or piezometric pressure beyond seasonal variation, resulting in temporary loss or alteration of defined habitat type.		
What will be the risk of a change in the timing or magnitude of groundwater level fluctuations on GDEs?		Fluctuation in groundwater level(s) or piezometric pressure beyond seasonal variation, resulting in temporary loss or alteration of defined habitat type.		
What will be the risk of changing base flow conditions on GDEs?			No change in direction of flow.	

Water Quality Asset	High	Moderate	Low	Insufficient data or unknown
What is the risk of changing the chemical conditions of the groundwater source?			Negligible change (<5%)	
What is the risk on the groundwater source by a change in the freshwater/salt water interface?			No change or not applicable	
What is the likelihood of a change in beneficial use (BU) of the groundwater source?			Negligible change for identified triggers (<5%)	
Aquifer Integrity Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What is the risk of damage to the geologic structure?		Temporary adjustment to the aquifer matrix. Minor cracking/fracturing of the bedrock/stream bed leading to partial dewatering of the GDE		
Biological Integrity Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What is the risk of alterations to the number of native species within the groundwater dependent communities (fauna and flora)?		10-5% reduction in No. of species.		
What is the risk of alterations to the species composition of the groundwater dependent communities (fauna and flora)?	>10% change in species composition.			
What is the risk of increasing the presence of exotic flora or fauna?		Species in small numbers.		
What is the risk of removing or altering a GDE subtype habitat (e.g. quarrying of limestone around karsts, tramping of cave habitats, sand and gravel extraction)?		10-20% removal or alteration of habitat.		
Risk Valuation	1	7	4	
Risk	**Moderate**			

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Site B3

Locality	B3			
Water Quantity Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What will be the risk of a change in groundwater levels/pressure on GDEs?		Reduction in groundwater level(s) or piezometric pressure beyond seasonal variation, resulting in temporary loss or alteration of defined habitat type.		
What will be the risk of a change in the timing or magnitude of groundwater level fluctuations on GDEs?		Fluctuation in groundwater level(s) or piezometric pressure beyond seasonal variation, resulting in temporary loss or alteration of defined habitat type.		
What will be the risk of changing base flow conditions on GDEs?			No change in direction of flow.	
Water Quality Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What is the risk of changing the chemical conditions of the groundwater source?			Negligible change (<5%)	
What is the risk on the groundwater source by a change in the freshwater/salt water interface?			No change or not applicable	
What is the likelihood of a change in beneficial use (BU) of the groundwater source?			Negligible change for identified triggers (<5%)	
Aquifer Integrity Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What is the risk of damage to the geologic structure?		Temporary adjustment to the aquifer matrix. Minor cracking/fracturing of the bedrock/stream bed leading to partial dewatering of the GDE		
Biological Integrity Asset	**High**	**Moderate**	**Low**	**Insufficient data**

				or unknown
What is the risk of alterations to the number of native species within the groundwater dependent communities (fauna and flora)?		10-5% reduction in No. of species.		
What is the risk of alterations to the species composition of the groundwater dependent communities (fauna and flora)?	>10% change in species composition.			
What is the risk of increasing the presence of exotic flora or fauna?		Species in small numbers.		
What is the risk of removing or altering a GDE subtype habitat (e.g. quarrying of limestone around karsts, tramping of cave habitats, sand and gravel extraction)?		10-20% removal or alteration of habitat.		
Risk Valuation	1	7	4	
Risk	**Moderate**			

Site C2

Locality	C2			
Water Quantity Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What will be the risk of a change in groundwater levels/pressure on GDEs?		Reduction in groundwater level(s) or piezometric pressure beyond seasonal variation, resulting in temporary loss or alteration of defined habitat type.		
What will be the risk of a change in the timing or magnitude of groundwater level fluctuations on GDEs?		Fluctuation in groundwater level(s) or piezometric pressure beyond seasonal variation, resulting in temporary loss or alteration of defined habitat type.		
What will be the risk of changing base flow conditions on GDEs?		Temporary reversal of base flow conditions exceeding seasonal variation.		
Water Quality Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What is the risk of changing the chemical conditions of the groundwater source?			Negligible change (<5%)	
What is the risk on the groundwater source by a change in the freshwater/salt water interface?			No change or not applicable	
What is the likelihood of a change in beneficial use (BU) of the groundwater source?			Negligible change for identified triggers (<5%)	
Aquifer Integrity Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What is the risk of damage to the geologic structure?		Temporary adjustment to the aquifer matrix. Minor cracking/fracturing of the bedrock/stream bed leading to partial dewatering of the GDE		
Biological Integrity Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**

What is the risk of alterations to the number of native species within the groundwater dependent communities (fauna and flora)?	>10% change in species composition.	10-5% reduction in No. of species.		
What is the risk of alterations to the species composition of the groundwater dependent communities (fauna and flora)?	>10% change in species composition.			
What is the risk of increasing the presence of exotic flora or fauna?			None exist.	
What is the risk of removing or altering a GDE subtype habitat (e.g. quarrying of limestone around karsts, tramping of cave habitats, sand and gravel extraction)?		10-20% removal or alteration of habitat.		
Risk Valuation	2	6	4	
Risk	**Moderate**			

Site D1

Locality	**d1**			
Water Quantity Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What will be the risk of a change in groundwater levels/pressure on GDEs?		Reduction in groundwater level(s) or piezometric pressure beyond seasonal variation, resulting in temporary loss or alteration of defined habitat type.		
What will be the risk of a change in the timing or magnitude of groundwater level fluctuations on GDEs?		Fluctuation in groundwater level(s) or piezometric pressure beyond seasonal variation, resulting in temporary loss or alteration of defined habitat type.		
What will be the risk of changing base flow conditions on GDEs?		Temporary reversal of base flow conditions exceeding seasonal variation.		
Water Quality Asset	**High**	**Moderate**	**Low**	**Insufficient data**

				or unknown
What is the risk of changing the chemical conditions of the groundwater source?			Negligible change (<5%)	
What is the risk on the groundwater source by a change in the freshwater/salt water interface?			No change or not applicable	
What is the likelihood of a change in beneficial use (BU) of the groundwater source?			Negligible change for identified triggers (<5%)	
Aquifer Integrity Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What is the risk of damage to the geologic structure?		Temporary adjustment to the aquifer matrix. Minor cracking/fracturing of the bedrock/stream bed leading to partial dewatering of the GDE		
Biological Integrity Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What is the risk of alterations to the number of native species within the groundwater dependent communities (fauna and flora)?	>10% change in species composition.	10-5% reduction in No. of species.		
What is the risk of alterations to the species composition of the groundwater dependent communities (fauna and flora)?	>10% change in species composition.			
What is the risk of increasing the presence of exotic flora or fauna?			None exist.	
What is the risk of removing or altering a GDE subtype habitat (e.g. quarrying of limestone around karsts, tramping of cave habitats, sand and gravel extraction)?		10-20% removal or alteration of habitat.		
Risk Valuation	2	6	4	
Risk	**Moderate**			

Site D2

Locality	D2			
Water Quantity Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What will be the risk of a change in groundwater levels/pressure on GDEs?		Reduction in groundwater level(s) or piezometric pressure beyond seasonal variation, resulting in temporary loss or alteration of defined habitat type.		
What will be the risk of a change in the timing or magnitude of groundwater level fluctuations on GDEs?		Fluctuation in groundwater level(s) or piezometric pressure beyond seasonal variation, resulting in temporary loss or alteration of defined habitat type.		
What will be the risk of changing base flow conditions on GDEs?		Temporary reversal of base flow conditions exceeding seasonal variation.		
Water Quality Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What is the risk of changing the chemical conditions of the groundwater source?			Negligible change (<5%)	
What is the risk on the groundwater source by a change in the freshwater/salt water interface?			No change or not applicable	
What is the likelihood of a change in beneficial use (BU) of the groundwater source?			Negligible change for identified triggers (<5%)	
Aquifer Integrity Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What is the risk of damage to the geologic structure?		Temporary adjustment to the aquifer matrix. Minor cracking/fracturing of the bedrock/stream bed leading to partial dewatering of the GDE		
Biological Integrity Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What is the risk of alterations to the number of native species within the groundwater	>10% change in species composition.	10-5% reduction in No. of species.		

dependent communities (fauna and flora)?				
What is the risk of alterations to the species composition of the groundwater dependent communities (fauna and flora)?	>10% change in species composition.			
What is the risk of increasing the presence of exotic flora or fauna?			None exist.	
What is the risk of removing or altering a GDE subtype habitat (e.g. quarrying of limestone around karsts, tramping of cave habitats, sand and gravel extraction)?		10-20% removal or alteration of habitat.		
Risk Valuation	2	6	4	
Risk	**Moderate**			

Site E1

Locality	**D2**			
Water Quantity Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What will be the risk of a change in groundwater levels/pressure on GDEs?		Reduction in groundwater level(s) or piezometric pressure beyond seasonal variation, resulting in temporary loss or alteration of defined habitat type.		
What will be the risk of a change in the timing or magnitude of groundwater level fluctuations on GDEs?		Fluctuation in groundwater level(s) or piezometric pressure beyond seasonal variation, resulting in temporary loss or alteration of defined habitat type.		
What will be the risk of changing base flow conditions on GDEs?		Temporary reversal of base flow conditions exceeding seasonal variation.		
Water Quality Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What is the risk of changing the chemical			Negligible change (<5%)	

conditions of the groundwater source?				
What is the risk on the groundwater source by a change in the freshwater/salt water interface?			No change or not applicable	
What is the likelihood of a change in beneficial use (BU) of the groundwater source?			Negligible change for identified triggers (<5%)	
Aquifer Integrity Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What is the risk of damage to the geologic structure?		Temporary adjustment to the aquifer matrix. Minor cracking/fracturing of the bedrock/stream bed leading to partial dewatering of the GDE		
Biological Integrity Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What is the risk of alterations to the number of native species within the groundwater dependent communities (fauna and flora)?	>10% change in species composition.			
What is the risk of alterations to the species composition of the groundwater dependent communities (fauna and flora)?	>10% change in species composition.			
What is the risk of increasing the presence of exotic flora or fauna?		Small numbers		
What is the risk of removing or altering a GDE subtype habitat (e.g. quarrying of limestone around karsts, tramping of cave habitats, sand and gravel extraction)?		10-20% removal or alteration of habitat.		
Risk Valuation	2	6	3	
Risk	**Moderate**			

Site T1

Locality	**T1**			
Water Quantity Asset	**High**	**Moderate**	**Low**	**Insufficient data**

				or unknown
What will be the risk of a change in groundwater levels/pressure on GDEs?		Reduction in groundwater level(s) or piezometric pressure beyond seasonal variation, resulting in temporary loss or alteration of defined habitat type.		
What will be the risk of a change in the timing or magnitude of groundwater level fluctuations on GDEs?		Fluctuation in groundwater level(s) or piezometric pressure beyond seasonal variation, resulting in temporary loss or alteration of defined habitat type.		
What will be the risk of changing base flow conditions on GDEs?			No change in direction of flow.	
Water Quality Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What is the risk of changing the chemical conditions of the groundwater source?			Negligible change (<5%)	
What is the risk on the groundwater source by a change in the freshwater/salt water interface?			No change or not applicable	
What is the likelihood of a change in beneficial use (BU) of the groundwater source?			Negligible change for identified triggers (<5%)	
Aquifer Integrity Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What is the risk of damage to the geologic structure?			No change	
Biological Integrity Asset	**High**	**Moderate**	**Low**	**Insufficient data or unknown**
What is the risk of alterations to the number of native species within the groundwater dependent communities (fauna and flora)?		10-5% reduction in No. of species.		
What is the risk of alterations to the species composition of the groundwater dependent communities (fauna and flora)?		10-5% change in species composition.		

What is the risk of increasing the presence of exotic flora or fauna?			None exist.	
What is the risk of removing or altering a GDE subtype habitat (e.g. quarrying of limestone around karsts, tramping of cave habitats, sand and gravel extraction)?		10-20% removal or alteration of habitat.		
Risk Valuation	0	5	6	
Risk	**Low**			

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