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Environmental Impact Statement – Appendix F5: Matters of National Environment Significance – Biodiversity

Warragamba Dam Raising

Reference No. 30012078
Prepared for WaterNSW
10 September 2021

SMEC INTERNAL REF. 30012078

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Executive Summary

Overview

Warragamba Dam Raising is a project to provide flood mitigation to reduce the significant existing risk to life and property in the Hawkesbury-Nepean Valley downstream of the dam. This would be achieved through raising the level of the central spillway crest by around 12 metres and the auxiliary spillway crest by around 14 metres above the existing full supply level for temporary storage of inflows. The spillway crest levels and outlets control the extent and duration of the temporary upstream inundation. There would be no change to the existing maximum volume of water stored for water supply. The area of temporary storage is referred to as the flood mitigation zone (FMZ).

The Project would include the following main activities and elements:

- demolition or removal of parts of the existing Warragamba Dam, including the existing drum and radial gates,
- thickening and raising of the dam abutments
- thickening and raising of the central spillway
- new gates or slots to control discharge of water from the FMZ
- modifications to the auxiliary spillway
- operation of the dam for flood mitigation
- environmental flow infrastructure.

The Project site is located approximately 65 kilometres west of the Sydney Central Business District in the Wollondilly Local Government Area. To the west of the Project site are the Blue Mountains, various national parks and state conservation areas and the Greater Blue Mountains World Heritage Area, which make up part of the catchment of Lake Burragorang which is the water storage formed by Warragamba Dam. To the east of the Project site are the Warragamba and Silverdale townships and surrounding rural residential areas.

Statutory and planning framework

The Project is being assessed by the NSW Government on behalf of the Australian Government in accordance with the bilateral agreement in relation to environmental assessment. As such the EIS must include an assessment of matters protected under Part 3 of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) in relation to the controlling provisions; World Heritage, National Heritage, and threatened species and communities. On 17 July 2017, the Minister made a decision that the project is a controlled action and noted that it would be assessed under the bilateral agreement.

This report addresses the third controlling provision, that is, threatened species and communities identified in the Commonwealth's requirements, which form Attachment A to the Secretary's Environmental Assessment Requirements. The attachment also notes the obligation on proponents to consider other relevant matters that may not necessarily be explicitly identified. In this regard, consideration has also been given to potential impacts on specific migratory species that could be potentially impacted by the Project.

Assessment of potential impacts has been undertaken with regard to the *Matters of National Environmental Significance Significant Impact Guidelines 1.1* (DoE 2013). These guidelines which provide guidance for proponents to assess whether a proposal should be referred with regard to whether approval would be required under the EPBC Act. The guidelines identify specific criteria with regard to assessing significance of impact.

The *Environment Protection and Biodiversity Conservation Act 1999 Environmental Offsets Policy* (EPBC Act Offsets Policy) provides guidance on the role of offsets in environmental impact assessments and how the Department of Agriculture, Water and the Environment considers the suitability of a proposed offset package. The EPBC Act Offsets Policy states that an offsets package should be a suite of actions that a proponent undertakes in order to compensate for the residual significant impact of a project.

The offsets package can comprise a combination of direct offsets and other compensatory measures. Biodiversity offsets are a last resort in instances where an action will give rise to residual impacts, even after the application of management measures.

Methodology

Assessment of potential impacts on biodiversity in the upstream and construction study areas has been carried out in accordance with the NSW Framework for Biodiversity Assessment (FBA). Assessment of potential impacts on biodiversity in the downstream study area was carried out in accordance with the relevant provisions of the NSW

Threatened Species Conservation Act 1995 through the effect of the Biodiversity Conservation (Savings and Transitional) Regulation 2017, addressing the matters listed in Attachment B to the Secretary's Environmental Assessment Requirements.

Potential impacts on threatened species

Based on consideration of relevant criteria in the EPBC Act significant impact guidelines, the Project would likely have a significant impact on 47 threatened flora species and 11 threatened fauna species listed under the EPBC Act.

Potential impacts on threatened ecological communities

The only affected TEC in the upstream study area is the critically endangered *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland*, which would be affected by temporary inundation during operation of the FMZ. The assessment of significance against the significant impact guidelines criteria concluded that the Project would likely have a significant impact on this community.

The only affected TEC in the construction study area is the critically endangered *Shale Sandstone Transition Forest of the Sydney Basin Bioregion*. Construction activities would require clearing of 1.64 hectares of this TEC. Operation of the FMZ would not affect this TEC. The assessment of significance against the significant impact guidelines criteria concluded that the Project would not likely have a significant impact on this community.

Based on consideration of the criteria in the significant assessment guidelines, the Project could potentially have a significant impact on the following TECs in the downstream study area:

- Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest
- River-flat eucalypt forest on coastal floodplains of southern New South Wales and eastern Victoria
- Shale Sandstone Transition Forest of the Sydney Basin Bioregion
- Western Sydney Dry Rainforest and Moist Woodland on Shale.

All the above TECs are currently affected by the operation of the existing dam during both normal operation and during flood events, with impacts associated with the latter being influenced by the magnitude of individual flood events. Flooding from other catchments such as the Nepean, Grose, Colo and South Creek also contribute to and influence downstream flooding, and this would not change with the Project.

The Project would not likely have a significant impact on the Turpentine-Ironbark Forest of the Sydney Basin Bioregion TEC.

Potential impacts on migratory species

While the Project may impact on areas of vegetation utilised by some migratory species, overall it would not likely have a significant impact on migratory species listed under the EPBC Act.

Mitigation and management of potential impacts

Impacts, including on biodiversity-related Protected Matters, would be offset principally through the Biodiversity Offset Strategy (BOS) that has been developed for the Project. The BOS provides an offset strategy for construction-related impacts comprising:

- an assessment of BSA site options
- purchase of credits from the market
- contribution to the Biodiversity Conservation Fund.

Offsetting of impacts in the upstream study area would occur through a program of measures within the Warragamba Offset Program which sits within the BOS. The program will include measures formally endorsed as part of the *NSW Biodiversity Offsets Policy for Major Projects* (NSW Government 2014), as well as additional measures where implementation of formally accepted measures may be difficult.

Development of the operational protocol for the FMZ would seek to minimise potential impacts on downstream vegetation from temporary inundation subject to meeting operational priorities for protection of life and property.

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Abbreviations and acronyms

Abbreviation	Description
AEP	Annual exceedance probability
AoS	Assessment of Significance (with regard to the Significant impact guidelines – see below)
BAR	Biodiversity Assessment Report
BBAM	BioBanking Assessment Methodology
BC Act	*Biodiversity Conservation Act 2016* (NSW)
BOS	Biodiversity Offset Strategy
BSA	Biodiversity Stewardship Agreement
BVT	Biometric vegetation type
CEEC	Critically endangered ecological community
DoEE	Australian Government Department of the Environment and Energy; now the Australian Government Department of Agriculture, Water and the Environment, DAWE (from 1 February 2020)
DPIE	NSW Department of Planning, Industry and Environment (formerly the Department of Planning and Environment)
DSEWPaC	Former Australian Government Department of Sustainability, Environment, Water, Population and Communities
EEC	Endangered ecological community
EIS	Environmental Impact Statement
EP&A Act	*Environmental Planning and Assessment Act 1979* (NSW)
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
EPBC Act Offsets Policy	Environment Protection and Biodiversity Conservation Act 1999 Environmental Offsets Policy
EPBC Regulations	Environment Protection and Biodiversity Conservation Regulations 2000
FBA	Framework for Biodiversity Assessment
FESM	Fire Extent and Severity Mapping (prepared by DPIE Remote Sensing & Regulatory Mapping team in collaboration with the NSW Rural Fire Service following the 2019-2020 bushfire event)
FM Act	*Fisheries Management Act 1994* (NSW)
GBMWHA	Greater Blue Mountains World Heritage Area
GDE	Groundwater dependent ecosystem
GL	gigalitres
IBRA	Interim Biogeographic Regionalisation for Australia
INSW	Infrastructure NSW
LGA	Local Government Area
MNES	Matter(s) of national environmental significance
NPW Act	*National Parks and Wildlife Act 1974l* (NSW)
NPWS	National Parks and Wildlife Service
NSW	New South Wales
OEH	Former NSW Office of Environment and Heritage, now part of DPIE
PCT	Plant Community Type
PMF	Probable Maximum Flood

Abbreviation	Description
PMST	Protected Matters Search Tool
SEARs	Secretary's Environmental Assessment Requirements
SEPP	State Environmental Planning Policy
Significant impact guidelines	Matters of National Environmental Significance Significant impact guidelines 1.1
SSI	State significant infrastructure
TEC	Threatened ecological community
TSC Act	*Threatened Species Conservation Act 1995* (NSW, repealed)
VIS	Vegetation Information System
Wilderness Act	*Wilderness Act 1987* (NSW)
WTSBREP	Wildlife and Threatened Species Bushfire Recovery Expert Panel

1 Introduction

WaterNSW is a New South Wales (NSW) state-owned corporation, and is the owner and operator of Warragamba Dam. WaterNSW was requested by the NSW Government to seek project planning approval for the Warragamba Dam Raising Project (the Project). The approval is being sought under Division 5.2 (section 5.12) (State significant infrastructure) of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act).

The Project is a controlled action (ref 2017/7940) because it has the potential to impact on matters of national environmental significance (MNES), and as such requires assessment under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). In accordance with the bilateral agreement reached between the NSW and Commonwealth governments, an Environmental Impact Statement (EIS) under the EP&A Act for State significant infrastructure (SSI) can also be used for an EIS under the EPBC Act for a controlled action, where directed by the Commonwealth Minister for the Environment. The direction was given for the Project to be assessed under the bilateral agreement on 17 July 2017. The Project will be assessed by relevant NSW departments in the first instance followed by a determination by the Commonwealth Minister for the Environment.

Items for the SEARs Key Issue 10 - Heritage and Attachment A of the SEARs are directly relevant to biodiversity for this report and are documented in Table 1-1 and Table 1-2.

Table 1-1. Secretary's Environmental Assessment Requirements: Biodiversity-related MNES

Desired performance outcomes	Secretary's Environmental Assessment Requirements[1]	Where addressed
1. Environmental impact assessment process The process for assessment of the proposal is transparent, balanced, well focussed and legal.	1.2 The project requires approval under the EPBC Act and is being assessed under the Bilateral Agreement.	Section 1 Section 3.1
6. Biodiversity The project design considers all feasible measures to avoid and minimise impacts on terrestrial and aquatic biodiversity. Offsets and/or supplementary measures are assured which are equivalent to any remaining impacts of project construction and operation.	6.4 The Proponent must identify whether the project as a whole, or any component of the project, would be classified as a Key Threatening Process in accordance with the listings in the *Threatened Species Conservation Act 1995* (TSC Act), *Fisheries Management Act 1994* (FM Act) and *Environment Protection and Biodiversity Conservation Act 2000* (EPBC Act).	Appendix A (where relevant)

Table 1-2. SEARs Attachment A requirements for biodiversity-related MNES

Requirement	Where addressed
1. To meet requirements, the project must be assessed in the manner specified in Schedule 1 to that agreement including that the assessment documentation contains: (i) An assessment of all impacts that the action is likely to have on each matter protected by a provision of Part 3 of the EPBC Act. (ii) Enough information about the proposal and its relevant impacts to allow the Commonwealth Minister to make an informed decision on whether or not to approve. Information addressing the matters outlined in Schedule 4 of the *Environment Protection and Biodiversity Conservation Regulations* (2000).	This report

Requirement	Where addressed
2. In the circumstance that a proposal has been determined to be a 'controlled action' requiring full assessment, the decision will identify which MNES protected under the EPBC Act have triggered for assessment. These are called the controlling provisions. Proponents are only required to provide an assessment of protected matters under the controlling provisions that have been triggered. Following is the list of controlling provisions: • listed threatened species and communities (sections 18 and 18A).	This report
3. The proponent must consider each of the protected matters under the triggered controlling provisions that may be significantly impacted by the development. The Department of the Environment has provided a list of threatened species and communities that are considered to be at risk of impact from the proposal at Attachment 1. Note that this may not be a complete list and it is the responsibility of the proponent to undertake an analysis of the significance of the relevant impacts and ensure all protected matters that are likely to be significantly impacted are assessed for the Commonwealth Minister's consideration.	This report
4. Assessment documentation prepared for the purposes of approval under the EPBC Act must, in addition to providing sufficient information for a decision, address the matters outlined in Schedule 4 of the *Environment Protection and Biodiversity Conservation Regulations 2000* (Cwlth.). The following includes requirements that have been identified as additional to the requirements prescribed in Schedule 2 of the NSW *Environmental Planning and Assessment Regulations 2000*. Proponents are advised to check that requirements in Schedule 4 of the EPBC Regulations have been appropriately addressed.	This report
9. The EIS must include an assessment of the relevant impacts of the action on the matters protected by the controlling provisions, including: i. 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 ii. a statement whether any relevant impacts are likely to be unknown, unpredictable or irreversible iii. analysis of the significance of the relevant impacts iv. any technical data and other information used or needed to make a detailed assessment of the relevant impacts.	This report Appendix F1 Appendix F2 Appendix F3 Appendix F4
Avoidance, mitigation and offsetting 10. 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 manage the relevant impacts of the action including: i. a description, and an assessment of the expected or predicted effectiveness of the mitigation measures, ii. any statutory policy basis for the mitigation measures; iii. the cost of the mitigation measures; iv. an outline of an environmental management plan that sets out the framework for continuing management, mitigation and monitoring programs for the relevant impacts of the action, including any provisions for independent environmental auditing; v. the name of the agency responsible for endorsing or approving each mitigation measure or monitoring program.	Section 13.1

Requirement	Where addressed
11. Where a significant residual adverse impact to a relevant protected matter 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.	Section 13.2
12. For each of the relevant matters likely to be significantly impacted by the development the EIS must provide reference to, and consideration of, relevant Commonwealth guidelines and policy statements including any: i. conservation advice or recovery plan for the species or community, ii. relevant threat abatement plan for a process that threatens the species or community iii. wildlife conservation plan for the species iv. management plan for Ramsar wetland v. management plan for a World Heritage property or National Heritage place vi. Marine Bioregional Plan vii. any strategic assessment.	Appendix A
Key Issues: Biodiversity (threatened species and communities) 14. The EIS must identify each EPBC Act listed threatened species and community likely to be significantly impacted by the development. Provide evidence why other threatened species and communities likely to be located in the project area or in the vicinity will not be significantly impacted in accordance with the Matters of National Environmental Significance - Significant impact guidelines 1.1 (2013) EPBC Act.	Section 8
15. For each of the EPBC Act listed threatened species and communities likely to be significantly impacted by the development the EIS must provide a separate:	
a. description of the habitat (including identification and mapping of suitable breeding habitat, suitable foraging habitat, important populations and habitat critical for survival), with consideration of, and reference to, any relevant Commonwealth guidelines and policy statements including listing advice, conservation advice and recovery plans	Section 7
b. 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	Section 6.4
c. description of the relevant impacts of the action having regard to the full national extent of the species or community's range	Section 10
d. description of the specific proposed avoidance and mitigation measures to deal with relevant impacts of the action	Section 12
e. identification of significant residual adverse impacts likely to occur after the proposed activities to avoid and mitigate all impacts are taken into account	Section 12
f. a description of any offsets proposed to address residual adverse significant impacts and how these offsets will be established	Section 12
g. details of how the current published NSW Framework for Biodiversity Assessment (FBA) has been applied in accordance with the objects of the EPBC Act to offset significant residual adverse impacts	Section 6.1
h. details of the offset package to compensate for significant residual impacts including details of the credit profiles required to offset the development in accordance with the FBA and/or mapping and descriptions of the extent and condition of the relevant habitat and/or threatened communities occurring on proposed offset sites.	Section 12

Requirement	Where addressed
16. Any significant residual impacts not addressed by the FBA may need to be addressed in accordance with the Environment Protection and Biodiversity Conservation Act 1999 Environmental Offset Policy.	Section 13.3

This report provides an assessment of the potential impacts of the Project on MNES related to listed threatened species and communities, and migratory species. The extent of the upstream, downstream and construction site assessment was determined through consultation with the then Office of Environment and Heritage (OEH) and the then Department of the Environment and Energy[1] (DoEE). It was agreed that Protected Matters relating to this MNES assessment for the Project would be assessed up to the Probable Maximum Flood[2] (PMF) level.

1.1 Project background

The Hawkesbury-Nepean Valley (the valley) in western Sydney has the highest flood risk in New South Wales, if not Australia. The potential for significant flooding of the Hawkesbury-Nepean Valley was known by the local Aboriginal community before the first European settlement of the area in the 1790s. In the early years of European settlement, the risk of flooding was recognised and a series of proclamations were issued that warned of the risk of flooding. This high flood risk arises from the river being confined by narrow sandstone gorges, creating rapid deep backwater flooding over extensive floodplains. The floodplains are home to a large existing population who would be impacted in a major flood.

During the 1980s and 1990s updated flood investigation techniques and new geological evidence predicted that floods significantly larger than any historically recorded could occur in the Hawkesbury-Nepean Valley. The dam was raised by five metres in the late 1980s to meet modern dam safety requirements. Further investigations into flooding and flood mitigation were undertaken and culminated in 1995 in a proposal to raise Warragamba Dam by 23 metres primarily for dam safety but also to provide for flood mitigation. The 1995 proposal did not proceed. In the late 1990s, major upgrades of Warragamba Dam were undertaken to prevent dam failure during extreme flooding events, to protect Sydney's water supply, and to prevent catastrophic downstream floods from dam failure. This resulted in the construction of the auxiliary spillway. However, these works only dealt with dam safety issues and did not address the major flood risks to the people and businesses in the Hawkesbury-Nepean Valley and the NSW economy.

In 2011, an approximately 1 in 100 chance in a year flood impacted Brisbane, resulting in significant damage, economic costs, and social disruption. The substantial impacts of the 2011 Brisbane flood led the NSW Government to recommence investigations into flood mitigation options for the Hawkesbury-Nepean Valley.

In 2013, the NSW Government in response to the State Infrastructure Strategy and community concerns, initiated the Hawkesbury-Nepean Valley Flood Management Review to consider flood planning, flood mitigation and flood response in the Hawkesbury-Nepean Valley. The review found that current flood management and planning arrangements could be improved, and no single mitigation option could address all the flood risks present in the Hawkesbury-Nepean Valley (Department of Primary Industries (DPI) 2014a). The review concluded that raising Warragamba Dam to capture inflows is the most effective infrastructure measure that could have a major influence on flood levels during those events, when most of the damages occur. Other complementary and non-infrastructure options were also identified to mitigate flood risks (DPI 2014a).

Under the direction of Infrastructure NSW (INSW), the Hawkesbury-Nepean Valley Flood Management Taskforce was established to investigate feasible flood options to reduce overall risk to the Hawkesbury-Nepean Valley. In June 2016, the former Premier and Minister for Western Sydney, Mike Baird MP, announced the NSW Government plan to raise Warragamba Dam to significantly reduce the risk of flooding in the Hawkesbury-Nepean Valley. The cost-benefit analysis demonstrated that the Warragamba Dam Raising would provide a 75 percent reduction in flood damages on average, and reduce current levels of flood damages from $5 billion to $2 billion (2016 dollars).

[1] On 1 February 2020, the Department of Agriculture, Water and the Environment was established, combining the former Department of Agriculture and Department of the Environment and Energy (Environment portfolio).

[2] The PMF is a hypothetical flood estimate relevant to a specific catchment whose magnitude is such that there is negligible chance of it being exceeded. It represents a notional upper limit of flood magnitude and no attempt is made to assign a probability of exceedance to such an event (Ball *et al*. 2019). The PMF is unlikely to occur in nature given the size of the Warragamba Dam catchment.

Raising Warragamba Dam would significantly reduce flood risk; however, it would not eliminate the risk completely. Regardless of the increase in the dam's height, flooding can be generated from catchments other than Warragamba Dam. The raising of Warragamba Dam would therefore be complemented with other non-infrastructure and policy actions. In May 2017, INSW released *Resilient Valley, Resilient Communities*, which outlines the Hawkesbury-Nepean Valley Flood Risk Management Strategy (the Flood Strategy) (INSW 2017). The Flood Strategy covers the geographic region between Bents Bridge and the Brooklyn Bridge, encompassing areas within the Local Government Areas (LGAs) of Liverpool City, Penrith City, Hawkesbury City, The Hills Shire Blacktown City, Central Coast, and Hornsby Shire.

The objective of the Flood Strategy is to reduce flood risk to life, property and social amenity from floods in the Hawkesbury-Nepean Valley. The strategy includes nine key outcomes; a combination of infrastructure and non-infrastructure initiatives to mitigate the flood risk to the Hawkesbury-Nepean Valley floodplain downstream of Warragamba Dam. Actions include:

- coordinated flood risk management across the Hawkesbury-Nepean Valley now and in the future
- strategic and integrated consideration of flood risk in land use and emergency planning
- engaging and providing flood risk information for an aware, prepared and responsive community.

The Flood Strategy provides the context and policy impetus to mitigate flood risk in the Hawkesbury-Nepean Valley.

A description of alternatives considered as feasible flood options to reduce risk to the Hawkesbury-Nepean Valley, as well as alternatives considered for the Warragamba Dam Raising Project, is provided in Chapter 4 (Project development and alternatives) of the EIS.

1.2 The Project

Warragamba Dam Raising is a project to provide flood mitigation to reduce the significant existing risk to life and property in the Hawkesbury-Nepean Valley downstream of the dam. This would be achieved through raising the level of the central spillway crest by around 12 metres and the auxiliary spillway crest by around 14 metres above the existing full supply level for temporary storage of inflows. The spillway crest levels and outlets control the extent and duration of the temporary upstream inundation. There would be no change to the existing maximum volume of water stored for water supply.

The NSW Government announcement in 2016 proposed that the dam wall be raised by 14 metres. Subsequently, the Secretary's Environmental Assessment Requirements (SEARs) required the project to be designed, constructed and operated to be resilient to the future impacts of climate change and incorporate specific adaptation actions in the design.

Peer reviewed climate change research found that by 2090 it is likely an additional three metres of spillway height would be required to provide similar flood mitigation outcomes as the current flood mitigation Project. Raising the dam side walls and roadway by an additional three metres may not be feasible in the future, both in terms of engineering constraints and cost. The current design includes raising the dam side walls and roadway by 17 metres now to enable adaptation to projected climate change. Any consideration of raising spillway heights is unlikely before the mid to late 21st century and would be subject to a separate planning approval process.

The 17-metre raising height of the dam abutments (side walls) and roadway has been considered and accounted for in the EIS and design. The potential maximum height and duration of upstream inundation remains consistent with what was originally proposed in 2016.

The Project also includes providing infrastructure to facilitate variable environmental flows to be released from Warragamba Dam.

The Project would include the following main activities and elements:

- demolition or removal of parts of the existing Warragamba Dam, including the existing drum and radial gates,
- thickening and raising of the dam abutments
- thickening and raising of the central spillway
- new gates or slots to control discharge of water from the FMZ
- modifications to the auxiliary spillway
- operation of the dam for flood mitigation
- environmental flow infrastructure.

The Project would take the opportunity, during the construction period for the dam raising, to install the physical infrastructure to allow for management of environmental flows as outlined in the NSW Government 2017 Metropolitan Water Plan. However, the actual environmental flow releases themselves do not form part of the Project and are subject to administration under the *Water Management Act 2000*. Further details are provided in Chapter 5 (Project Description) of the EIS.

Figure 1-1 shows the local and regional context of the Project. The Project site is located approximately 65 kilometres west of the Sydney Central Business District in the Wollondilly Local Government Area (LGA). To the west of the Project site are the Blue Mountains, various national parks and state conservation areas and the Greater Blue Mountains World Heritage Area (GBMWHA), which make up part of the catchment of Lake Burragorang - which is the water storage formed by Warragamba Dam. To the east of the Project site are the Warragamba and Silverdale townships and surrounding rural residential areas.

The Project study area is defined as the area within the changed PMF extent (upstream and downstream). The Project study area is subdivided into:

- upstream study area, covering the area upstream of the dam wall
- construction study area, covering the development footprint and immediate surrounds
- downstream study area, covering the area downstream of the dam.

1.3 Main activities and elements

Figure 1-2 shows the existing dam with relevant key features. Figure 1-3 shows the modified dam after the Project works have been completed.

1.4 Operation of the dam for flood mitigation

Operational objectives in order of priority are to:

- maintain the structural integrity of the dam
- minimise risk to life
- maintain Sydney's water supply
- minimise downstream impact of flooding to properties:
- minimise environmental impact
- minimise social impact.

There would be two different modes of operation for the raised Warragamba Dam: normal and flood operations. In both modes Warragamba Dam would continue to store and supply up to 80 percent of Sydney's drinking water. The storage capacity, which is the dam's full supply level, would not change. The current and future operation of the dam is shown in Figure 1-4 and Figure 1-5 respectively.

Some areas of the GBMWHA would already experience temporary inundation during flood events due to existing dam, and the Project would result in an increase in the extent and duration of temporary inundation.

1.4.1 Normal operations

Normal operations would occur when the dam storage level is at or lower than the full supply level (FSL).

Normal operations mode for the modified dam would be essentially the same as current operations, apart from environmental flow releases. Inflows would be captured up to FSL, after which environmental flows releases would cease and flood operation procedures would be implemented.

1.4.2 Flood operations

During large rainfall events when the storage level rises above FSL, flood operations mode would commence. In this mode, inflows to Lake Burragorang would be captured and temporarily stored (increasing water levels in Lake Burragorang and upstream tributaries). The raised dam would provide capacity (i.e. the flood mitigation zone (FMZ)) to capture temporarily around 1,000 gigalitres of water during a flood event.

Water would be discharged in a controlled manner via the gated conduits or slots until the dam level returns to FSL. FMZ operating protocols would guide this process and be developed for approval by the relevant regulatory authorities.

The raised dam would not be able to fully capture inflows from all floods. For floods that exceed the capacity of the FMZ, water would spill firstly over the central spillway and then, depending on the size of the flood, the auxiliary spillway.

Figure 1-1. Warragamba Dam Raising Project study area

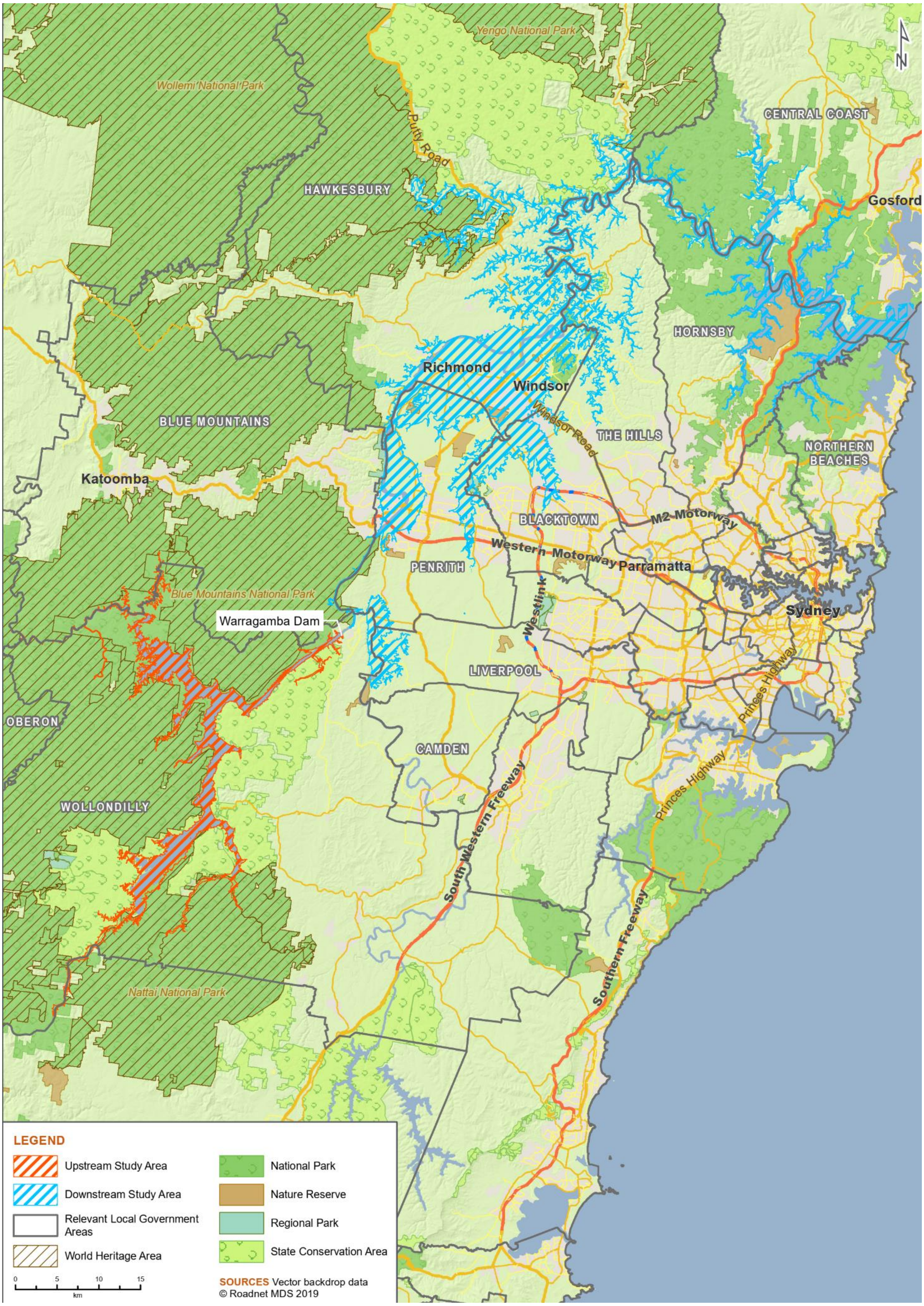


Figure 1-2. Existing dam and features

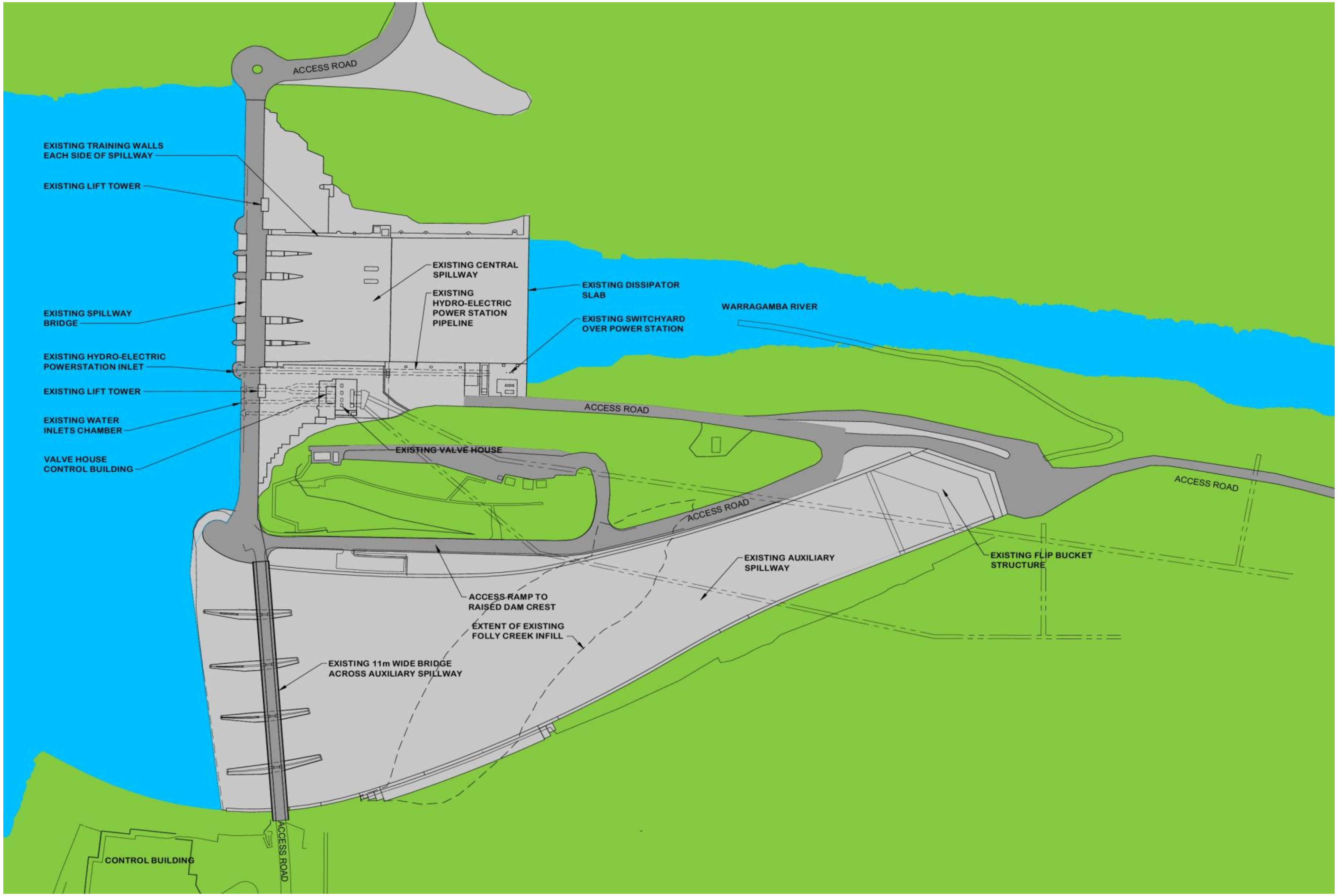


Figure 1-3. Modified dam from the Project works

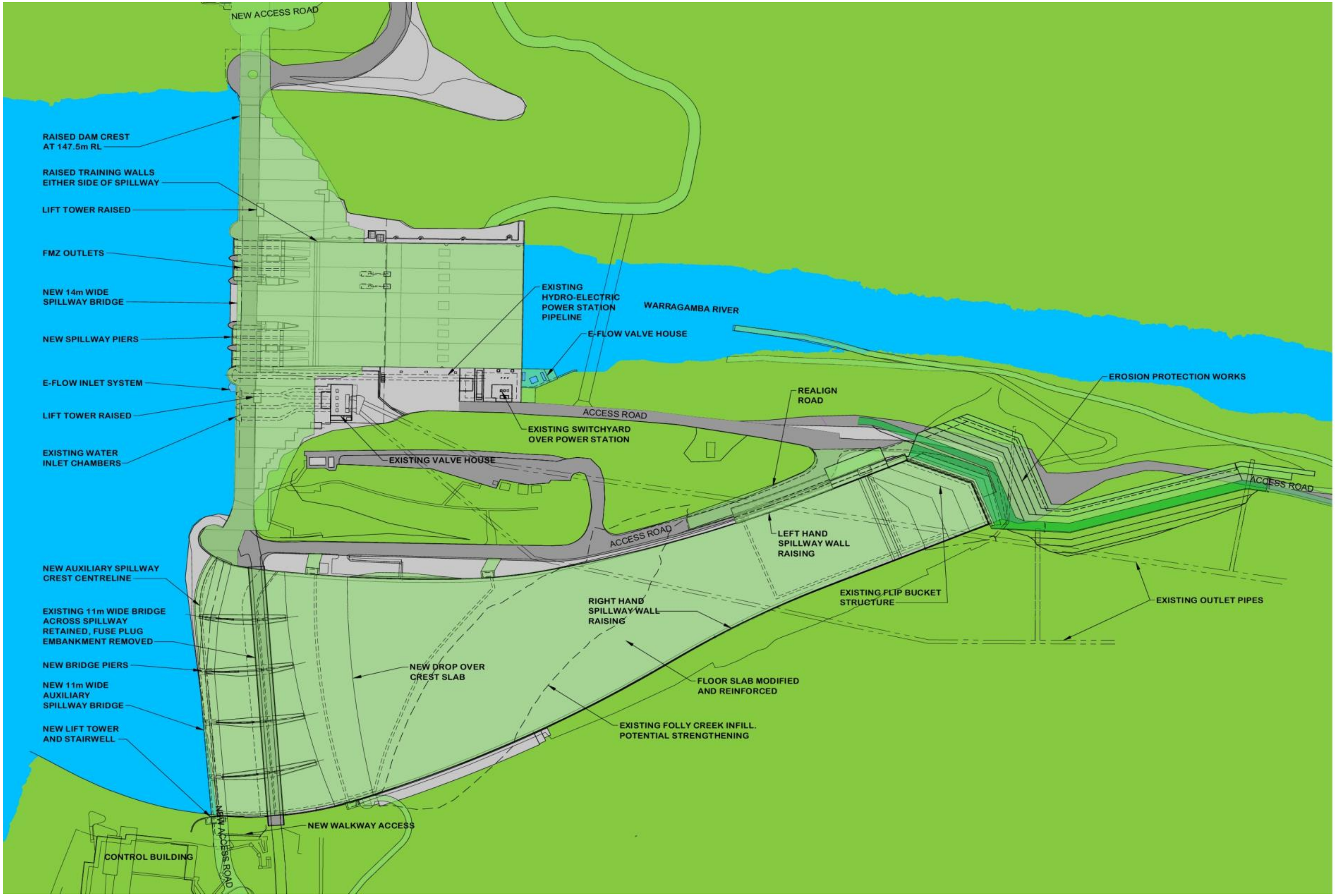


Figure 1-4. Existing operation of the dam

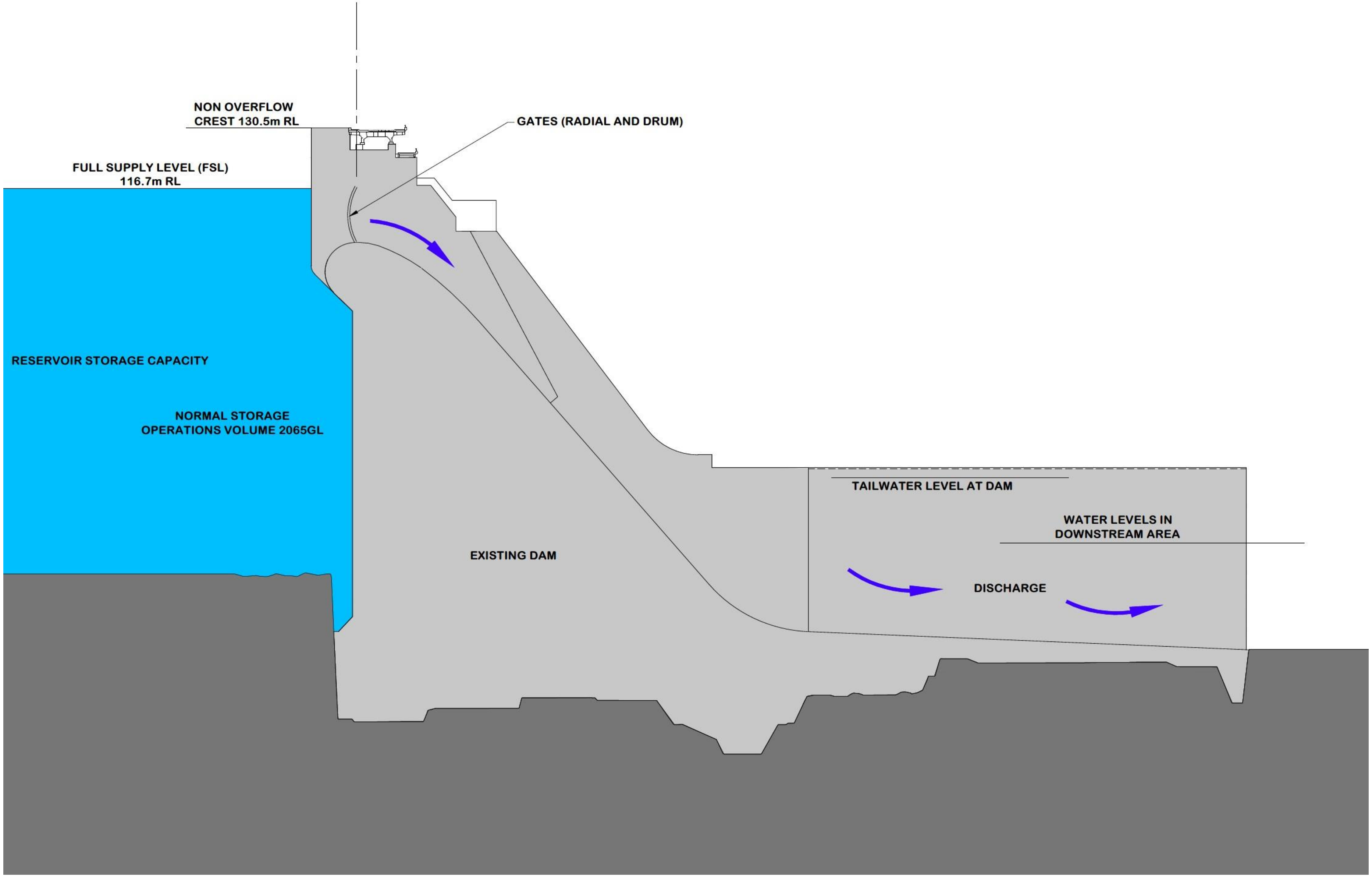
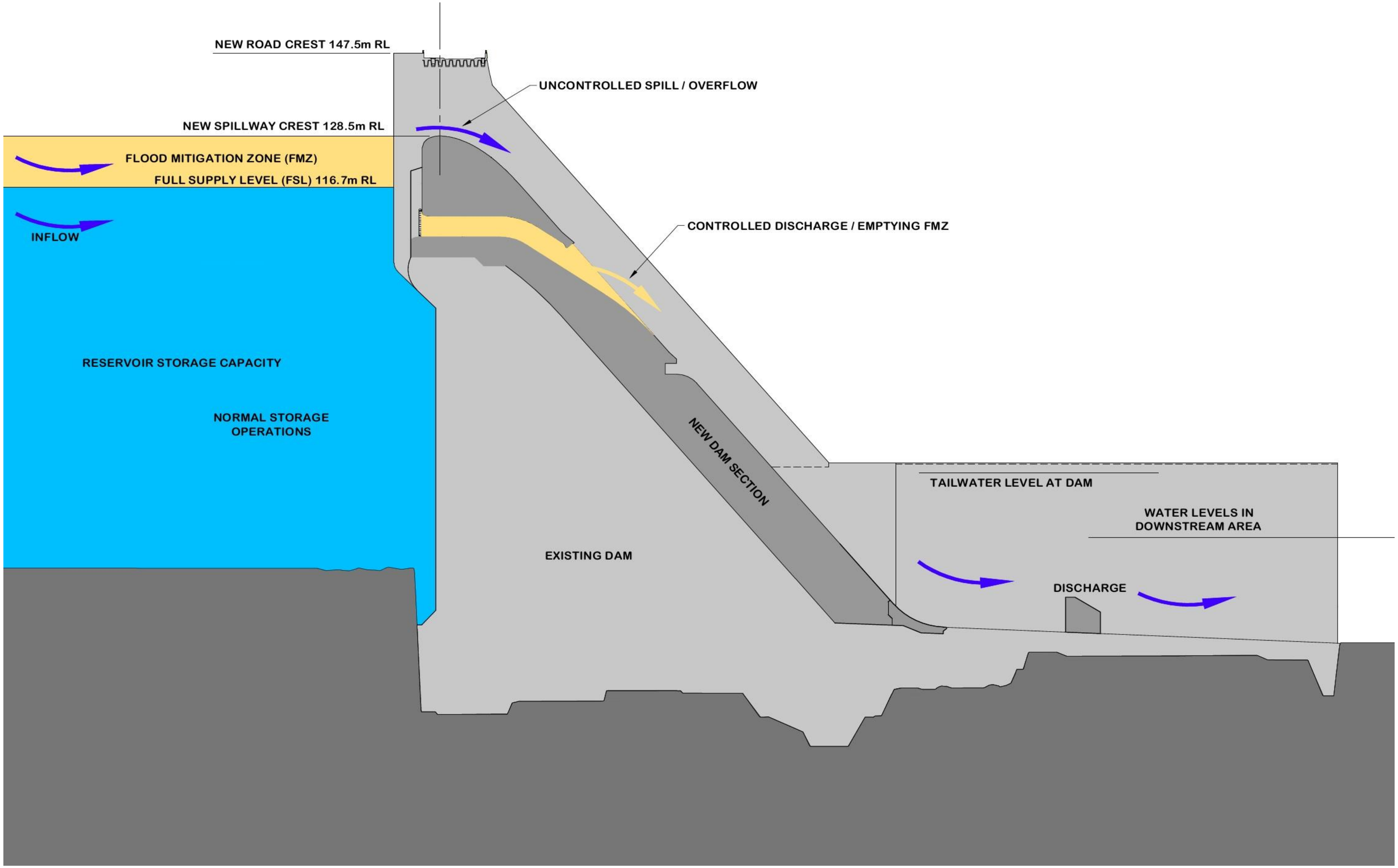


Figure 1-5. Future operations of the dam

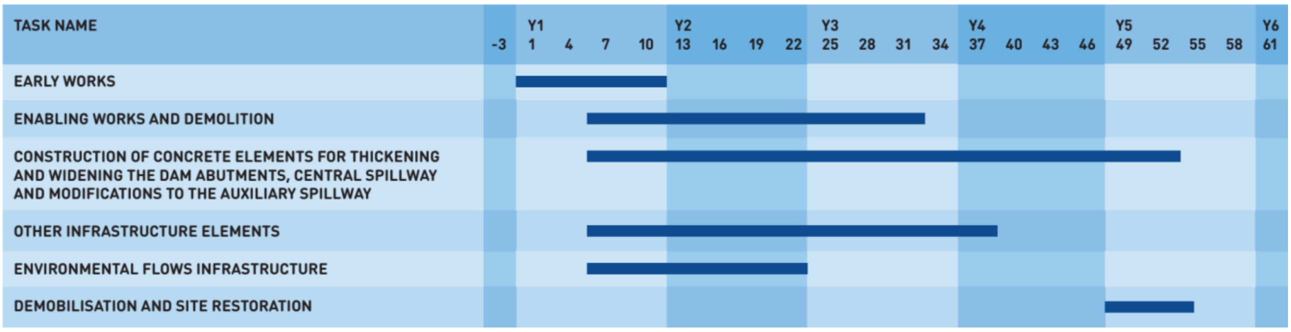


1.5 Project construction

If the Project is approved, further detailed construction planning would take place prior to commencement to inform a Construction Environmental Management Plan (CEMP). This plan would consider methods and the scheduling of activities to minimise impacts on the community and the environment such as noise, access and amenity, and would detail mitigation and management measures. The Project would not directly impact upon protected matters relating to World Heritage areas and therefore no detailed information on the construction methodology has been provided.

A preliminary construction program is presented in Figure 1-6 with the Project anticipated to be completed between four to five years after commencement.

Figure 1-6. Preliminary construction program



1.6 2019-2020 bushfires

New South Wales, including the catchment of Lake Burragorang, experienced severe bushfires starting in June 2019 and continuing through to early 2020. The bushfires have been described as unprecedented in their extent and intensity affecting at least 5.4 million hectares (seven percent of NSW) including 27 percent of the national park estate, more than 81 percent of the GBMWHA and 54 percent of the NSW components of the Gondwana Rainforests of Australia World Heritage property (DPIE 2020).

The fires affecting the study area began in late October 2019 within remote bushland near Lake Burragorang, near Yerranderie, as well as within the Kanangra-Boyd National Park. Due to the extreme isolation of the area and rugged inaccessible terrain, the fire spread and merged to eventually become the Green Wattle Creek Fire on 27 November 2019. This fire rapidly affected the study area where it burnt out of control for over nine weeks. A total of 278,700 hectares in the Wollondilly area were affected by this fire until it was officially declared ‘contained’ on 30 January 2020. The fire was declared ‘extinguished’ by the NSW Rural Fire Service on 10 February 2020 following a significant rainfall event over the preceding week.

The ‘NPWS Fire History – Wildfires and Prescribed Burns’ is a mapping layer released by DPIE on the history of fire in national parks based on data captured by the RFS and Forestry Corporation NSW (DPIE 2020). According to this mapping, the majority of the upstream study area has been affected by wildfire historically and at least 30 percent of the extent has been subjected to a prescribed burn. Wildfires have affected the catchment variably since 1964-65 however none have been as extensive in size as the 2019-2020 fire. Historically, the catchment has experienced at least four earlier major wildfire events: 1964-65 1994-95 1997-98 and 2001-02 (DPIE 2020).

The effects of the 2019-2020 bushfires on the environment, including the ecological consequences, are not yet fully understood. Though bushfires are not uncommon in Australia, they are usually of a lower scale and intensity that only affect small parts of the overall distribution of ecosystems and habitats (DPIE 2020). Post-fire studies have found that a number of species (both threatened and not currently threatened) have had their entire global populations burnt in the 2019-2020 fires (DPIE 2020). This includes some species and ecological communities that are known to be sensitive to severe fire (DPIE 2020). The long-term fire regime including fire frequency, intensity and seasonality influence the ecosystem in various ways, including having both positive and negative effects. If fires are too frequent, plants may be killed before they have matured or before they have set sufficient seed to ensure population recovery. Alternatively, infrequent fires can impact negatively on plants that rely on fire to regenerate. If fire is too infrequent, these species can grow old and die, and their seeds rot in the soil before germinating. In this way, plant community species richness and composition can be shaped by the fire regime. Some plant species have no or limited natural fire tolerance and may be extirpated or significantly reduced in density over their affected ranges. Other ecological inputs following fire, particularly widespread and intense fires, can have additional effects on post-fire ecology. These inputs may include soon recurrent fire, drought, intense rainfall, flood, erosion, and predation.

This notwithstanding, a number of threatened ecological communities, threatened species, and non-threatened species are considered to have been disproportionately impacted by the 2019-2020 bushfires. DAWE has released a list of threatened and migratory species that have more than 10 percent of their known or predicted distribution in areas affected by bushfires in southern and eastern Australia between 1 August 2019 and 13 January 2020. There are 48 species recorded or predicted to have a moderate or greater likelihood of occurrence in the upstream study area, which include:

- *Bossiaea oligosperma* (10 to <30 percent)
- *Eucalyptus benthamii* (30 to <50 percent)
- *Eucalyptus glaucina* (10 to <30 percent)
- *Hakea dohertyi* (≥ 80 percent)
- *Pomaderris brunnea* (50 to <80 percent)
- Regent Honeyeater (10 to <30 percent)
- Koala (10 to <30 percent)
- Brushtail Rock Wallaby (30 to <50 percent)
- Greater Glider (10 to <30 percent)
- Broad-headed Snake (50 to <80 percent).

1.6.1 Provisional list of plants requiring urgent management intervention recorded or likely to occur within the study area

An interim national provisional prioritisation of Australian plants affected by the 2019-2020 bushfire season (Gallagher *et al.* 2020) was undertaken for the Wildlife and Threatened Species Bushfire Recovery Expert Panel (WTSBREP) to establish a provisional list of plants requiring urgent management intervention (DAWE 2020). This assessed 19,004 mainly vascular plants of Australia's approximately 25,000 species against a set of eleven criteria which combine the proportion of the geographic range that burned, species fire response traits, and the interactive effects of other stressors such as drought, herbivory, disease, weed invasion, and erosion. The analysis includes plants in bioregions that have been impacted by fires from south-west Western Australia, southern South Australia, Victoria, southern and eastern New South Wales, south-eastern Queensland and Tasmania; the Warragamba Dam Raising Project study area fits within these bioregions. The preliminary analysis area of the interim provisional prioritisation may be revised in future versions.

Gallagher *et al.* (2020) noted that the pattern and intensity of fire will vary within the fire affected areas and that fires will not have impacted all areas within the mapped extent equally across the affected bioregions. Although spatial analyses incorporate information about fire severity and impacts, field assessments may reveal areas assessed as burnt to be unburnt, and vice versa. The WTSBREP's understanding of the fire impacts on plant species will improve after information from on-ground surveys is gathered.

A total of 709 plant species were prioritised as being at high risk from the impacts of the 2019-20 bushfires. Of these, 471 plant species have been identified by experts as the highest priorities for urgent management intervention in the weeks and months following the 2019-2020 bushfires to support recovery. These species were all already listed as Critically Endangered or Endangered under the EPBC Act or equivalent state legislation, or had more than 80 percent of their range burnt, or were identified as at high risk under two or more prioritisation criteria requiring unique management actions. These 471 high priority plant species are from 127 genera and occur in a variety of vegetation types. One hundred and three of these priority plant species are either known to occur or predicted likely to occur within the study area (refer Table 1-3).

The provisional high priority list includes the highest priority plant species, but many more have been identified at risk. More than 200 additional plants are at high risk under any one of the criteria with further fire impacts assessment required.

Prioritisation criteria ranked as high are the risk assessment criteria under which each species has been listed as a high priority for immediate action. The prioritisation process identifies eleven criteria (A-K) that are based on mechanisms which are known to cause the greatest potential risk of population decline or local extinction associated with bushfires:

- Criterion A. Interactive effects of fire and drought

- Criterion B. Short fire intervals (impacts of high fire frequency)
- Criterion C. Post-fire herbivore impacts
- Criterion D. Fire-disease interactions
- Criterion E. High fire severity
- Criterion F. Weed invasion
- Criterion G. Elevated winter temperatures or changed temperature regimes
- Criterion H. Fire sensitivity
- Criterion I. Post-fire erosion
- Criterion J. Cumulative exposure to high risks
- Criterion K. Other plausible threats or expert-driven nominations.

More detailed criterion descriptions are provided following Table 1-3.

While limited threatened flora surveys have been carried out within the study area, with limitations to survey area, range of species, and effort of time, a likelihood of occurrence assessment has been carried out for the provisional high priority list of plants within the study area (refer Table 1-3). This includes both threatened species (listed under the EPBC Act or BC Act), and species not listed as threatened under either Act. The likelihood was assessed using a preliminary high-level assessment of mapped records on BioNet, Australian Virtual Herbarium and Atlas of Living Australia, and also considered suitable available habitat. It should be noted that a number of rare or threatened plant species have been incidentally noted within the study area that occur as significant range extensions or records of species not seen across their regional or global extent for many years, sometimes decades.

Notwithstanding past targeted threatened species survey efforts carried out both historically and for the Project, there are still significant constraints in assessing how species on the priority flora list have been affected by the bushfires and how they might be impacted in the future with the Project. This data gap also currently limits practical application of management interventions.

Table 1-3. Species on provisional high priority list likely to occur in the study area

Species	EPBC Act status	Likelihood of occurrence			Risk assessment criteria likely relevant for species with project impacts in study area (* = likely relevant for species)										
		Upstream	Downstream	Construction	A	B	C	D	E	F	G	H	I	J	K
Acacia chalkeri	-	Moderate	Low	Low	*	*	*	*	*	*			*	*	*
Acacia clunies-rossiae	-	Recorded	Low	Moderate	*	*	*	*	*	*			*	*	*
Acacia dorothea	-	Moderate	Low	Low	*	*	*	*	*	*			*	*	*
Acacia echinula	-	High	High	High	*	*	*	*	*	*			*	*	*
Acacia flocktoniae	Vulnerable	Moderate	Low	Low	*	*	*	*	*	*			*	*	*
Acacia hamiltoniana	-	High	Low	Low	*	*	*	*	*	*			*	*	*
Acacia jonesii	-	High	Low	Low	*	*	*	*	*	*			*	*	*
Acacia ptychoclada	-	High	Low	Low	*	*	*	*	*	*			*	*	*
Acacia subtilinervis		Moderate	Moderate	Low	*	*	*	*	*	*			*	*	*
Acacia trinervata	-	High	High	High	*	*	*	*	*	*			*	*	*
Actinotus forsythii	-	High	Low	Low	*	*	*	*	*	*	*		*	*	*
Almaleea incurvata	-	Moderate	Low	Low	*	*	*	*	*	*			*	*	*
Asterolasia buxifolia	-	Low	Moderate	Low	*	*	*	*	*	*	*		*	*	*
Atkinsonia ligustrina	-	Moderate	Moderate	Low	*	*	*	*	*	*			*	*	*
Baeckea brevifolia	-	High	Low	Low	*	*	*	*	*	*			*	*	*
Baloskion longipes	Vulnerable	Moderate	Low	Low	*	*	*	*	*	*			*	*	*
Banksia paludosa subsp. *astrolux*	-	Moderate	Low	Low	*	*	*	*	*	*	*		*	*	*
Banksia penicillata	-	Moderate	Low	Low	*	*	*	*	*	*	*		*	*	*
Boronia barkeriana subsp. *barkeriana*	-	Moderate	Low	Low	*	*	*	*	*	*	*		*	*	*
Boronia floribunda	-	High	Moderate	High	*	*	*	*	*	*	*		*	*	*
Callistemon megalongensis	Critically Endangered	Moderate	Low	Low	*	*	*	*	*	*			*	*	*
Callistemon subulatus	-	High	Low	Low	*	*	*	*	*	*			*	*	*

Species	EPBC Act status	Likelihood of occurrence			Risk assessment criteria likely relevant for species with project impacts in study area (* = likely relevant for species)										
		Upstream	Downstream	Construction	A	B	C	D	E	F	G	H	I	J	K
Callitris muelleri	-	Moderate	Low	Low	*	*	*	*	*	*			*	*	*
Cyphanthera scabrella	-	Recorded	High	High	*	*	*	*	*	*	*	*	*	*	*
Darwinia fascicularis subsp. *oligantha*	-	Moderate	Low	Low	*	*	*	*	*	*	*		*	*	*
Darwinia taxifolia subsp. *taxifolia*	-	Moderate	Low	Low	*	*	*	*	*	*	*		*	*	*
Deyeuxia microseta	-	High	Low	Low	*	*	*	*	*	*			*	*	*
Dillwynia acicularis	-	Low	High	Low	*	*	*	*	*	*			*	*	*
Dillwynia brunioides	-	High	Low	Low	*	*	*	*	*	*			*	*	*
Dillwynia stipulifera	-	Moderate	Low	Low	*	*	*	*	*	*			*	*	*
Epacris calvertiana	-	Moderate	High	Low	*	*	*	*	*	*	*	*	*	*	*
Epacris hamiltonii	Endangered	Moderate	Low	Low	*	*	*	*	*	*	*	*	*	*	*
Epacris lithophila	-	Moderate	Low	Low	*	*	*	*	*	*	*	*	*	*	*
Epacris rigida	-	High	Low	Low	*	*	*	*	*	*	*	*	*	*	*
Epacris purpurascens var. onosmiflora	-	Moderate	Low	Low	*	*	*	*	*	*	*		*	*	*
Eucalyptus moorei	-	Moderate	Low	Low	*	*	*	*	*	*			*	*	*
Eucalyptus cunninghamii	-	Moderate	Low	Low	*	*	*	*	*	*			*	*	*
Eucryphia moorei	-	Moderate	Low	Low	*	*	*	*	*	*		*	*	*	*
Gahnia filifolia	-	High	Low	Low	*	*	*	*	*	*			*	*	*
Goodenia heterophylla subsp. *montana*	-	High	Low	Low	*	*	*	*	*	*			*	*	*
Goodenia rostrivalvis	-	Moderate	Low	Low	*	*	*	*	*	*			*	*	*
Grevillea arenaria subsp. *arenaria*	-	Recorded	High	High	*	*	*	*	*	*	*		*	*	*
Grevillea baueri subsp. *baueri*	-	Moderate	Low	Low	*	*	*	*	*	*	*		*	*	*
Grevillea johnsonii	-	Recorded	Low	Low	*	*	*	*	*	*	*		*	*	*
Grevillea phylicoides	-	High	High	High	*	*	*	*	*	*	*		*	*	*

Species	EPBC Act status	Likelihood of occurrence			Risk assessment criteria likely relevant for species with project impacts in study area (* = likely relevant for species)										
		Upstream	Downstream	Construction	A	B	C	D	E	F	G	H	I	J	K
Grevillea sericea subsp. *riparia*	-	Moderate	Low	Low	*	*	*	*	*	*	*		*	*	*
Grevillea acanthifolia	-	Moderate	Low	Low	*	*	*	*	*	*	*		*	*	*
Grevillea aspleniifolia	-	Recorded	Low	Low	*	*	*	*	*	*	*		*	*	*
Grevillea kedumbensis	-	High	High	Moderate	*	*	*	*	*	*	*		*	*	*
Hakea constablei	-	High	Low	Low	*	*	*	*	*	*	*		*	*	*
Hakea dohertyi	Endangered	Recorded	Low	Low	*	*	*	*	*	*	*		*	*	*
Hakea pachyphylla	-	Moderate	Low	Low	*	*	*	*	*	*	*		*	*	*
Haloragodendron gibsonii	-	Moderate	Low	Low	*	*	*	*	*	*			*	*	*
Hibbertia circinata	-	Low	Moderate	Low	*	*	*	*	*	*			*	*	*
Hibbertia cistiflora subsp. *quadristaminea*	-	High	Low	Moderate	*	*	*	*	*	*			*	*	*
Hibbertia coloensis	-	Low	Moderate	Low	*	*	*	*	*	*			*	*	*
Hibbertia saligna	-	Moderate	High	Low	*	*	*	*	*	*			*	*	*
Hibbertia acaulothrix	-	High	Low	Low	*	*	*	*	*	*			*	*	*
Hymenophyllum pumilum	-	Moderate	Moderate	Low	*	*	*	*	*	*	*	*	*	*	*
Isopogon fletcheri	Vulnerable	Moderate	Low	Low	*	*	*	*	*	*	*	*	*	*	*
Isopogon prostratus	-	Moderate	Low	Low	*	*	*	*	*	*	*		*	*	*
Lasiopetalum joyceae	Vulnerable	Low	Moderate	Low	*	*	*	*	*	*			*	*	*
Leptospermum blakelyi	-	Moderate	Low	Low	*	*	*	*	*	*			*	*	*
Leptospermum macrocarpum	-	Moderate	Moderate	Low	*	*	*	*	*	*			*	*	*
Leptospermum petraeum	-	Moderate	Low	Low	*	*	*	*	*	*			*	*	*
Leptospermum rotundifolium	-	Moderate	Low	Low	*	*	*	*	*	*			*	*	*
Leptospermum spectabile	-	Low	High	Low	*	*	*	*	*	*			*	*	*
Leucopogon setiger	-	High	High	High	*	*	*	*	*	*	*		*	*	*

Species	EPBC Act status	Likelihood of occurrence			Risk assessment criteria likely relevant for species with project impacts in study area (* = likely relevant for species)										
		Upstream	Downstream	Construction	A	B	C	D	E	F	G	H	I	J	K
Microlaena stipoides var. breviseta	-	Moderate	Low	Low	*	*	*		*	*			*	*	*
Myoporum bateae	-	Moderate	Low	Moderate	*	*	*	*	*	*			*	*	*
Ochrosperma oligomerum	-	Moderate	Moderate	Moderate	*	*	*	*	*	*			*	*	*
Olearia burgessii	-	High	Low	Moderate	*	*	*	*	*	*		*	*	*	*
Olearia cordata	Vulnerable	Moderate	Moderate	Moderate	*	*	*	*	*	*		*	*	*	*
Olearia quercifolia	-	High	Low	Moderate	*	*	*	*	*	*		*	*	*	*
Pentachondra dehiscens	-	Moderate	Low	Low	*	*	*	*	*	*	*	*	*	*	*
Persoonia acerosa	Vulnerable	Moderate	Low	Moderate	*	*	*	*	*	*	*		*	*	*
Persoonia mollis subsp. *mollis*	-	High	Low	Moderate	*	*	*	*	*	*	*		*	*	*
Persoonia oblongata	-	Low	High	Low	*	*	*	*	*	*	*		*	*	*
Persoonia chamaepitys	-	Moderate	High	Low	*	*	*	*	*	*	*		*	*	*
Persoonia myrtilloides	-	Moderate	Low	Low	*	*	*	*	*	*	*		*	*	*
Philotheca hispidula	-	High	High	Moderate	*	*	*	*	*	*	*		*	*	*
Phyllota squarrosa	-	Moderate	Low	Low	*	*	*	*	*	*			*	*	*
Pimelea latifolia subsp. *elliptifolia*	-	Low	Moderate	Low	*	*	*	*	*	*			*	*	*
Pomaderris brunnea	Vulnerable	Recorded	Low	Moderate	*	*	*	*	*	*			*	*	*
Pomaderris cotoneaster	Endangered	Moderate	Low	Low	*	*	*	*	*	*			*	*	*
Prostanthera caerulea	-	high	Moderate	Low	*	*	*	*	*	*			*	*	*
Prostanthera saxicola var. montana	-	Moderate	Low	Low	*	*	*	*	*	*			*	*	*
Prostanthera violacea	-	High	Moderate	Low	*	*	*	*	*	*			*	*	*
Pultenaea canescens	-	moderate	Moderate	Low	*	*	*	*	*	*			*	*	*
Pultenaea echinula	-	moderate	Low	Low	*	*	*	*	*	*			*	*	*
Pultenaea glabra	Vulnerable	High	Low	Moderate	*	*	*	*	*	*			*	*	*

Species	EPBC Act status	Likelihood of occurrence			Risk assessment criteria likely relevant for species with project impacts in study area (* = likely relevant for species)										
		Upstream	Downstream	Construction	A	B	C	D	E	F	G	H	I	J	K
Pultenaea villifera	-	High	Low	Low	*	*	*	*	*	*			*	*	*
Pultenaea viscosa (as *P. mollis*)	-	moderate	Moderate	Low	*	*	*	*	*	*			*	*	*
Solanum armourense	-	Recorded	Low	Low	*	*	*	*	*	*			*	*	*
Spyridium burragorang	-	Recorded	Low	Low	*	*	*	*	*	*			*	*	*
Styphelia laeta subsp. *latifolia*	-	low	High	Low	*	*	*	*	*	*	*		*	*	*
Symphionema montanum	-	Moderate	Low	Low	*	*	*	*	*	*	*		*	*	*
Tetratheca rupicola	-	High	High	High	*	*	*	*	*	*			*	*	*
Trachymene scapigera	Endangered	Moderate	Low	Low	*	*	*	*	*	*			*	*	*
Velleia perfoliata	Vulnerable	Moderate	Low	Moderate	*	*	*	*	*	*			*	*	*
Veronica lithophila	-	Recorded	Low	Moderate	*	*	*	*	*	*		*	*	*	*
Veronica derwentiana subsp. *subglauca*	-	Moderate	Low	Low	*	*	*	*	*	*			*	*	*
Zieria covenyi	Endangered	High	Low	Low	*	*	*	*	*	*			*	*	*

CRITERION A. Interactive effects of fire and drought

Pre-fire drought can: i) reduce internally stored resources of resprouter plants that are critical in sustaining post-fire regeneration; and ii) reduce pre-fire reproductive output, impacting on the size of the seed bank available for post-fire recruitment.

Post-fire drought can negatively impact post-fire recruitment success by reducing seed germination (due to insufficient soil moisture), seedling survival (through desiccation) and survival of resprouts (through xylem embolism in susceptible new shoots). Risks to mortality may be large if drought occurs in the first autumn-winter after fire or the following spring-summer.

Combined environmental effects of inundation with drought and/or fire would compound impacts to plant species and associated feedback loops to ecological and environmental processes. Post inundation response (for example, reshooting, germination, early senility/morbidity, disease) would likely be significantly affected by post-fire drought and pre-fire drought, and, as per criterion K, post-inundation drought or post-inundation fire. Additionally, the combined or interactive effects of drought and fire pre-inundation may result in impacts to listed priority flora species.

CRITERION B. Short fire intervals (impacts of high fire frequency)

Exposure to short temporal intervals between successive fires can disrupt the replenishment of seed banks which are essential to post-fire recruitment and population persistence. Species most susceptible include obligate seeders (species that lack regenerative organs and rely entirely on seed germination for post-fire recovery) and resprouters (species with the capacity to generate new shoots from dormant buds post-fire) that suffer high mortality rates. The time required to replenish seed banks post-fire varies. For most species, up to 15 years between successive fires is needed to ensure that a seed bank is sufficiently replenished to maintain future post-fire populations, although some trees (for example) may require longer fire-free periods. Short intervals between fires may also kill juveniles of resprouting plants before they become large enough to survive subsequent fires. The species that are most susceptible to these risks are resprouters that are slow to develop regenerative structures (that is, lignotubers, thick bark, rhizomes etc.) or slow to replace mortality due to low fecundity. At least 15 years between successive fires is needed to ensure the juveniles of most plant species can develop their fire-regenerative organs, although some species such as mallee eucalypts may require at least 25 years. Finally, some long-lived trees may suffer basal scarring where fires (or other factors related to fires such as falling trees or limbs) damage and/or kill bark tissue. This enables subsequent fires to smoulder into heartwood and weaken the structural integrity of the tree, causing mortality, collapse and structural change to the ecosystem. Trees with thin bark are most prone to this impact and replacement depends on fecundity and growth rates. Many rainforest trees and some eucalypts are susceptible and are likely to require at least 50 years between successive fires to enable partial recovery and replacement.

Impacts associated with the Project may increase fire frequency due to changes in vegetation structure, fuel load and floristics. Impacts would also likely affect lifecycle changes related particularly to recruitment of obligate seeding species, with any associated changes to fire frequency feeding into reductions in the ability to carry out lifecycle processes.

CRITERION C. Post-fire herbivore impacts

Plants are often at their most palatable and least resilient to herbivore activity (for example, leaf and shoot removal, trampling and substrate degradation) in the post-fire environment where herbivores have enhanced foraging efficiency and converge on regenerating burnt areas to exploit fresh growth. Concentrations of herbivores may therefore increase mortality of both seedlings and resprouters of palatable plants. In some cases, elevated mortality may lead to local extinction. Effects may be exacerbated when burnt patches are small or have high perimeter to area ratios which promote herbivore incursions in high densities.

Herbivory dynamics are known to be particularly strong across many herbivore-plant interaction post disturbance events such as drought and fire. This relates to increased or decreased availability of plant-based food sources and can affect plant-based food resources such as leaves, sap, floral resources, seeds, fruit and wood and relate to all herbivore groups. While most plant species in the study area likely show adaptions to natural disturbance regimes such as fire, the combined impacts of increased hydrological change would likely accentuate feedback loops of herbivory impacts.

CRITERION D. Fire-disease interactions

Plant species from particular genera and families are susceptible to diseases such as *Phytophthora* spp., *Armillaria* spp., Myrtle Rust, Canker fungi and other pathogens. Tissue death caused by these diseases reduces the capacity of plants to acquire resources through their roots and/or leaves. Plants are more sensitive to resource deprivation in the post-fire period and reduced post-fire survival rates have been observed in areas infected by disease, such that fire accelerates disease-related population decline. Resprouting individuals in certain families appear most susceptible to this threat. Disease effects may be exacerbated by drought.

As most of the study area is occupied by communities and component species not adapted to inundation and waterlogging, the effects and plant response of flood stress either before or after fire may increase susceptibility to plants affected by fire-disease interactions. The inclusion of flood-disease interactions to fire-disease interactions could compound the same or similar disease, symptoms or risks, and may also increase plant stress through different diseases, symptoms and risks.

CRITERION E. High fire severity

In some plant species, survival of established individuals and/or seed banks may be sensitive to fire severity due to limitations in the insulating capacity of protective tissues (thickness of bark or walls of serotinous fruits). Species that rely on persistence of long-lived standing plants (due to low fecundity) or post-fire regeneration from small serotinous fruits are most susceptible to this mechanism of decline. For long-lived trees, these effects may be cumulative through successive fires (high fire frequency – see CRITERION B, above) that undermine their structural integrity. In such cases, fire severity impacts may be influenced by prolonged basal and internal smouldering rather than canopy consumption (as commonly reflected in fire severity maps).

Effects may be exacerbated by drought reducing water content within insulating tissues prior to fires. Inundation and waterlogging prior to fires may also decrease functionality of insulative tissue of soil-stored seed tissue, underground plant parts and epicormic buds.

Inundation or waterlogging after a high severity fire would likely exacerbate the impacts of severe fire. These cumulative and interactive effects would likely include additional reduction in successful lifecycle process effected by fire or inundation (germination, flowering, reshooting, fruiting), as well as increased morbidity of species affected by fire through flood stress. These refuges may include gullies, rocky areas, cliffs, perennially moist communities or communities with sparse fuel like open woodland, derived native grassland or sparse heath/scrub.

CRITERION F. Weed invasion

Some sites are predisposed to invasion by transformer exotic plants. Fire may provide opportunities for growth of existing exotics or entry of these species into the vegetation (especially where weed sources are within or proximal to burnt areas) and subsequent elimination of native species through competition. Native species that occur mainly in areas where bushland has been fragmented, disturbed by logging or clearing, or affected by runoff from nutrient sources (for example, urban infrastructure, improved pasture, wastewater, or stormwater disposal etc.) are most susceptible to this mechanism, and these factors should be considered in assessing the likelihood of weed impacts below.

There are many strong correlations to increased inputs of water effects in natural terrestrial systems and it is very likely that the effects of increased depth and inundation from the Project would favour the establishment, spread and colonisation of weeds. The combined ecological inputs of fire and changes to hydrology would very likely increase the diversity, extent and biomass of non-local flora species in the study area.

CRITERION G. Elevated winter temperatures or changed temperature regimes

Seed germination of some plants in alpine and subalpine (or frost-hollow) habitats is reliant on cold stratification during winter. Alpine plant phenology is also affected by temperature. If the 2020 winter is warm, seedling regeneration may be reduced with flow-on effects on seed bank replenishment. Species with short-lived standing plants and/or short-lived seed banks are likely to be most susceptible. Enhanced insolation of fire-blackened soils may exacerbate climatic warming effects. For other species diurnal temperature cycles cue germination and changes to these cycles may delay or reduce germination.

Changes to edaphic conditions post-flood may significantly affect temperature regimes, including increased albedo effects of anaerobic bacterial breakdown of dead organic matter producing widespread blackening of soil and organic matter resulting from the formation of iron sulphides and pyrite. The increase in soil moisture can increase potential thermal mass and heat conductivity, particularly with associated post flood and/or fire light access due to reduction of vegetation cover and darkening of soil through fire/flood blackened soils.

While the study area is not alpine or sub-alpine, frost drainage is noticeable, and some species are likely to require cold stratification of soil stored seed to effect germination, particularly Ericaceae. Water-borne root diseases such as *Phytophthora* are exacerbated by increases in soil and water temperatures.

CRITERION H. Fire sensitivity

Some plant species have no means of in situ persistence through fire events because their standing plants lack protected regenerative organs and there is no seed bank. A single fire may eliminate such species or damage a significant proportion of individuals in the population, which must then rely entirely on dispersal from unburnt populations for re-establishment in the area.

Fire may have different severity in differing landscape positions, vegetation types and relative to recent fire history. Inundation events are strongly tied to different landscape positions and impacts from the Project would affect much vegetation not adapted to inundation and is relatively stochastic relative to fire or flood history. Any inundation impacts from the Project would spatially affect fire-refuge locations within the flood area.

CRITERION I. Post-fire erosion

Intense rainfall events after fires may lead to extensive localised erosion that either covers recovering plants in soil and ash or depletes soil seed banks. In steep terrain, post-fire erosion may dislodge rocks and trees or cause larger scale landslides with associated plant mortality. Effects are likely to be localised and evident in the first few months after a fire. Steep habitats, riparian habitats, peaty habitats and unconsolidated floodplains or sandplains would seem to be potentially vulnerable to erosion.

Fire and flood have been shown to interact to compound erosive processes which can be significantly impactful for post-disturbance ecology, noting that most species and communities in the study area are not adapted to inundation.

CRITERION J. Cumulative exposure to high risks

Loss of all mature plants in a species exposes it to risks associated with recruiting new plants to replace those lost. Where fire causes such losses in obligate seeding species, risks include stochastic events, failure or limited successful recruitment of new plants (for example, through grazing, weed, pathogen and drought impacts). This criterion addresses where the current 2019-2020 fires have exposed obligate seeding species to having significant proportions of their entire known populations as immature plants, as cumulatively the current fires have added to previous fires in other locations that have eliminated all mature plants. Species with canopy seed banks are most at risk as these can be completely exhausted after a single fire event. Species with soil seed banks may have more resilience but there may still be little to no seed bank remaining after a fire in some cases.

In a study area where most communities and plant species are not adapted to inundation, changes to natural hydrology would add a significant cumulative impact to impacts from the 2019-2020 bushfire impacts and other associated impacts.

CRITERION K. Other plausible threats or expert-driven nomination

Other plausible threats not addressed by criteria A-J above may arise and this criterion is designed to capture their effects on species impacted by the 2019-2020 fires. Species identified as having had approximately 50 percent or more of their range burned and other known threats by state agencies have been included under this criterion.

Flood stress was not specifically considered in Gallagher *et al.* (2020), however, the impact of the Warragamba Dam raising Project would, in that report's author's scientific opinion, jeopardise the recovery of species affected by the 2019-2020 fire season - both those identified at high risk and those which may be placed at a higher risk through the mitigation Project - if populations are lost to inundation (R. Gallagher, pers. comm., 9 September 2020). As a result, the direct impacts of plant death and decline from flood stress associated with temporary inundation have been considered to be a component of Criterion K.

Table 1-4 shows those EPBC listed species on the provisional flora list that were either incidentally recorded or considered likely to occur in the study area.

Table 1-4. EPBC listed priority species likely impacts

Species	EPBC Status	Likelihood of occurrence upstream	Generalised extent of incidentally observed records relative to flood models with project	Estimated extent within upstream study area (ha)	Estimated area burnt[1] (ha)
Acacia flocktoniae	Vulnerable	Moderate	Not incidentally observed during current study	554.3	192.8
Baloskion longipes	Vulnerable	Moderate	Not incidentally observed during current study	84.2	21.4
Callistemon megalongensis	Critically Endangered	Moderate	Not incidentally observed during current study	11.0	7.8
Hakea dohertyi	Endangered	Recorded by current study	Known from one location within the upstream study area: Tonalli Cove.	383.8	116.0
Isopogon fletcheri	Vulnerable	Moderate	Not incidentally observed during current study	212.9	64.2
Olearia cordata	Vulnerable	Moderate	Not incidentally observed during current study	8.5	1.5
Persoonia acerosa	Vulnerable	Moderate	Not incidentally observed during current study	32.3	4.6
Pomaderris brunnea	Vulnerable	Recorded by current study	For the extent of the species records upstream from Warragamba Dam (which are largely SMEC records), the majority occur within Fire Extent and Severity Mapping (FESM) burnt areas, although many records along the Coxs River extent are mapped as unburnt.	1,375.7	618.2
Pultenaea glabra	Vulnerable	High	Not incidentally observed during current study	32.3	4.6
Trachymene scapigera	Endangered	Moderate	Not incidentally observed during current study	491.6	246.0
Velleia perfoliata	Vulnerable	Moderate	Not incidentally observed during current study	457.2	141.1
Zieria covenyi	Endangered	High	Not incidentally observed during current study	16.3	3.4

1 Burn severity of 'Moderate' or greater as per FESM

1.6.2 Urgent management intervention

Various urgent management intervention actions to support recovery have been deemed as likely to be immediately necessary for quantifying the response of species to the fires, although these criteria will vary depending upon the species (DAWE 2020). These criteria are not definitive or exhaustive:

- field inspections – damage and threats
- germplasm collection
- field inspections – resprouting assessment
- field inspections – seedling emergence assessment
- disease – field assessments and emergency germplasm collection of cuttings where resprouting is affected
- exclude forestry/silvicultural impacts
- alleviate herbivory
- field inspections – recovery assessment
- irrigation
- carefully planned translocation
- weed control
- exclude prescribed fire
- rapid response to wildfire
- minimise development impacts
- alleviate pollinator competition from feral bees and European wasp
- prevent illegal collecting or over-collecting of germplasm or plants
- minimise habitat disturbance from human activities.

Each species has life-history traits which make it prone to population declines or local extinctions where targeted as part of the prioritisation. Three components were involved in identifying species potentially at risk of being impacted as a result of these fires:

- Identifying potential mechanisms of decline.
- Identifying where in the landscape these mechanisms are most likely to have an impact.
- Identifying the species most exposed to risks associated with these mechanisms.

In February 2020, the NSW Department of Planning, Industry and Environment (DPIE) released a set of guidelines relating to carrying out biodiversity assessments under the Framework for Biodiversity Assessment at severely burnt sites. Further detail with regard to the Project is provided in Appendix F1 of the EIS (Biodiversity assessment report - upstream).

2 Existing regional environment

2.1 Warragamba Dam and catchment

Warragamba Dam is on a narrow gorge on the Warragamba River. The damming of Warragamba River, completed in 1960, flooded the Burragorang Valley, creating Lake Burragorang. The lake's capacity is four times that of Sydney Harbour and provides about 80 percent of Sydney's water supply (WaterNSW 2018a). At present the dam is 142 metres high and 351 metres in length, which makes it one of the largest domestic water supply dams in the world (WaterNSW 2018a). The Warragamba Dam catchment represents 80 percent of the total Hawkesbury-Nepean catchment at Penrith and 70 percent of the total catchment at Windsor (INSW 2017).

2.2 Hawkesbury-Nepean catchment

The Hawkesbury-Nepean catchment covers an area of about 21,400 square kilometres[3]. For the purposes of this assessment the catchment was divided into two sub-catchments – upstream (of Warragamba Dam) and downstream, each of which comprise several smaller catchments.

The upstream catchment (including the construction area) encompasses the five main tributaries which drain into Lake Burragorang, the reservoir created by Warragamba Dam. The five main tributaries include the Coxs, Kowmung, Wollondilly, Nattai, and Kedumba Rivers. The upstream catchment area comprises about 9,050 square kilometres (WaterNSW 2018b).

The downstream catchment encompasses seven rivers and four major creeks. The seven rivers include the Hawkesbury, Lower Hawkesbury, Upper Nepean, Nepean, Grose, Colo, and Macdonald Rivers. The four major creeks include the Erskine, Webbs, South, and Cattai Creeks. The downstream catchment area comprises about 12,350 square kilometres.

2.3 Landform and topography

The upstream catchment has unique topographic features, including extensive dissected sandstone plateaux; the most extensive sandstone canyon system in eastern Australia; karst landscapes with several cave systems of importance; prominent basalt-capped peaks and other significant features associated with periods of volcanic activity; quaternary alluvial deposits which support significant heath and woodland vegetation; perched perennial freshwater lakes, and; steep, narrow valleys surrounding watercourses (GHD 2016). The upstream catchment generally consists of deep sandstone gorges, which reach an escarpment via a single tributary, the Warragamba River.

The topography downstream from Warragamba Dam consists of floodplains, undulating valleys, narrow constrained gorges at confluences of major rivers, as well as along the Hawkesbury and Lower Hawkesbury Rivers downstream from Sackville. Below the escarpment (and dam wall) the Warragamba River meets the Nepean River, which crosses the mid-catchment floodplain. Erskine Creek and the Grose River enter the Nepean River to the south of Richmond, just before the point at which the Nepean River meets the Hawkesbury River. From Richmond, the Hawkesbury River flows across the floodplain through Windsor, where South Creek enters, until it reaches the first narrow sandstone gorge of the downstream catchment at Sackville. From Sackville, the Hawkesbury River winds through the narrow gorges of the downstream catchment, along the way joined by Webb Creek and the Colo and MacDonald Rivers, before it opens out at Broken Bay. This contrasts with other coastal floodplains and river valleys, which tend to progressively widen as the river approaches the estuary.

2.4 Land use

Land use in the upstream catchment comprises protected areas, including the GBMWHA, several national parks (Blue Mountains, Kanangra-Boyd, Nattai), state conservation areas (Jenolan Karst, Yerranderie, Nattai and Burragorang), and 'Special' and 'Controlled' Areas declared under the *Water NSW Act 2014*. For Warragamba Dam, minor land uses adjacent to protected areas include urban development, tourism facilities, grazing, forestry, agriculture, manufacturing and mining.

[3] NSW Department of Planning, Industry and Environment

Land use in the downstream catchment area is dominated by urban development, commercial and manufacturing services, with protected areas in the far east of the catchment.

3 Statutory and planning framework

3.1 Environment Protection and Biodiversity Conservation Act 1999

The Project is a controlled action (ref 2017/7940) because it has the potential to impact on matters of national environmental significance (MNES), and as such requires assessment under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act). In accordance with the bilateral agreement reached between the NSW and Australian Governments, an environmental impact statement (EIS) prepared under the EP&A Act for State Significant Infrastructure (SSI) can also be used for an EIS under the EPBC Act for a controlled action, where directed by the Commonwealth Minister for the Environment. The direction was given for the Project to be assessed under the bilateral agreement on 17 July 2017. The Project will be assessed by relevant NSW departments in the first instance followed by a decision by the Commonwealth Minister for the Environment.

The referral to the Australian Government was accompanied by a preliminary consideration of relevant MNES, principally those relating to biodiversity and heritage. This included the areas of the GBMWHA that would be impacted by temporary increased inundation during significant flood events due to the operation of the Project. The referral identified that the following MNES could be potentially impacted:

- World Heritage properties (EPBC Act, sections 12 and 15A)
- national Heritage Places (EPBC Act, sections 15B and 15C)
- listed threatened species and communities (EPBC Act, section 18 and 18A).

Consideration of the first two controlling provisions is addressed in Appendix J of the EIS (World Heritage assessment report) and Chapter 20 (Protected and sensitive lands). This report addresses the third controlling provision listed above, listed threatened species and communities.

Revised SEARs were issued by DPIE on 13 March 2018 which contained the EPBC Act assessment requirements as Attachment A to the SEARs. This provided additional information on the assessment requirements under the EPBC Act.

3.2 Environment Protection and Biodiversity Conservation Regulations 2000

The Environment Protection and Biodiversity Conservation Regulations 2000 (EPBC Regulations) support the implementation of the EPBC Act. Part 5 provides for assessment of controlled actions with clause 5.04 specifying that an EIS must address the matters mentioned in Schedule 4 to the EPBC Regulations.

Schedule 4 covers the following matters:

- general information
- a description of the Project, identify specific matters
- relevant impacts
- proposed safeguards and mitigation measures
- other approvals and conditions
- the environmental record of the person proposing to take the action
- information sources.

This report addresses the third and fourth bullet points as they relate to relevant biodiversity matters.

3.3 Matters of National Environmental Significance Significant impact guidelines 1.1

The *Matters of National Environmental Significance Significant Impact Guidelines 1.1* (DoE 2013) (significant impact guidelines) provide guidance for proponents to assess if a proposal should be referred to DAWE with regard to whether approval would be required under the EPBC Act. The significant impact guidelines identify specific criteria with regard to assessing significance of impact. Those of relevance with regard to the biodiversity-related controlling provisions identified in Attachment A to the SEARs are as follows.

For critically endangered and endangered species, an action is likely to have a significant impact if there is a real chance or possibility that it will:

- lead to a long-term decrease in the size of a population
- reduce the area of occupancy of the species

- fragment an existing population into two or more populations
- adversely affect habitat critical to the survival of a species
- disrupt the breeding cycle of a population
- modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline
- result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat
- introduce disease that may cause the species to decline, or
- interfere with the recovery of the species.

For vulnerable species, an action is likely to have a significant impact 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
- reduce the area of occupancy of an important population
- fragment an existing important population into two or more populations
- adversely affect habitat critical to the survival of a species
- disrupt the breeding cycle of an important population
- modify, destroy, remove or isolate or decrease the availability or 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
- introduce disease that may cause the species to decline, or
- interfere substantially with the recovery of the species.

For critically endangered and endangered ecological communities, an action is likely to have a significant impact if there is a real chance or possibility that it will:

- reduce the extent of an ecological community
- fragment or increase fragmentation of an ecological community, for example by clearing vegetation for roads or transmission lines
- adversely affect habitat critical to the survival of an ecological community
- modify or destroy abiotic (non-living) factors (such as water, nutrients, or soil) necessary for an ecological community's survival, including reduction of groundwater levels, or substantial alteration of surface water drainage patterns
- 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
- 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
- interfere with the recovery of an ecological community.

For migratory species, an action is likely to have a significant impact 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
- 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
- seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.

3.4 Environment Protection and Biodiversity Conservation Act 1999 Environmental Offsets Policy

The *Environment Protection and Biodiversity Conservation Act 1999 Environmental Offsets Policy* (DSEWPaC 2012) (Environmental Offsets Policy) outlines the Australian Government's approach to biodiversity offsets under the EPBC Act. The policy defined offsets as measures that compensate for the residual adverse impacts resulting from an action on the environment. The policy ensures that the process around determining the suitability of an offset is transparent. The suitability of a proposed offset is considered as part of the decision as to whether or not to approve a proposed action under the EPBC Act.

The Environmental Offsets Policy relates to all matters protected under the EPBC Act. For the Project, these matters are:

- World Heritage properties
- National heritage places
- listed threatened species and ecological communities.

Section 2.1 of the Environmental Offsets Policy notes

> *The use of offsets to compensate for adverse impacts to heritage values is appropriate in some circumstances. In cases where offsetting of adverse impacts on heritage values is considered possible and appropriate, the principles of this policy apply with regard to determining what constitutes a suitable offset. Offsets for impacts on heritage values should improve the integrity and resilience of the heritage values of the property involved. This may include offsets in areas adjacent to the property.*

There are two types of offsets under the policy:

- Direct Offset: Direct offsets are actions that provide a measurable conservation gain for an impacted protected matter. A minimum of 90 percent of the offset requirements for any given impact must be met through direct offsets. Direct offsets benefit from conservation gains delivered to the protected matter. Conservation gains can be achieved by:
  - Improving existing habitat for a protected matter
  - Creating new habitat for a protected matter
  - Reducing threats to a protected matter
  - Increasing values of a heritage place
  - Averting the loss of a protected matter or its habitat under threat.
- Compensatory measures: Compensatory measures are actions that do not directly offset the impacts on the protected matter but are expected to lead to benefits for the impacted protected matter. Compensatory measures may include research or educational programs.

Suitable offsets under the policy meet must eight requirements as discussed as follows.

Suitable offsets must deliver an overall conservation outcome that improves or maintains the viability of the protected matter

Offsets must deliver a conservation outcome that improves or maintains the viability of the protected matter though directly contributing to its ongoing viability as compared to what would have likely happened under the status quo. This is achieved though offsets which specifically relate to the attribute of the protected matter impacted by the proposal. Offsets must:

- not be traded across different protected matters
- adequately compensate for the specific residual impact
- meet, as a minimum, the quality of the habitat on the impact site.

Suitable offsets must be built around direct offsets but may include other compensatory measures

Offsets should take the form of direct offsets over compensatory measures. Direct offsets should make up a minimum of 90 percent of the offset requirement, with compensatory measures making up to a minimum of 10 percent of the offset requirement. Where possible, an offset should reflect key priority actions for the protected matter, with higher priority action preferred over low priority actions.

Suitable offsets must be in proportion to the level of statutory protection that applies to the protected matter

Offsets for protected matters with a higher conservation status must be higher than offsets for protected matters with a lower conservation status. This is to account for the higher risk involved with protecting matters of greater conservation significance.

Suitable offsets must be of a size and scale proportionate to the residual impacts on the protected matter

Offsets must adequately compensate for the impacts on the protected matter by being of proportionate size and scale of the residual impacts. The size and scale of the offset is determined by a number of different considerations, including but not limited to:

- level of statutory protection
- lag time between impact and the conservation gain of the offset
- risk of conservation gain not being achieved.

Suitable offsets must effectively account for and manage the risks of the offset not succeeding

Offsets should sufficiently consider the risk of the offsets not succeeding. This could be achieved by taking into account the nature of the impact, as well as the type, size, location, and timing of the offset.

Suitable offsets must be additional to what is already required, determined by law or planning regulations, or agreed to under other schemes or programs

Offsets must deliver a conservation gain which is new or additional to what is already required by a duty of care, or as a result of any other environmental planning laws at any level of government or paid for under other conservation schemes or programs. Where there is overlap between state and federal offset requirements, a state offset may count towards an offset under EPBC requirements to the extent to which it compensates for the residual impact on the protected matter.

Suitable offsets must be efficient, effective, timely, transparent, scientifically robust and reasonable

Offsets which are most efficient and effective are those which maintain or improve the viability of the protected matter though the sound allocation of resources and aligned offset requirements. Offsets must also be implemented either before or at the same point in time as the impact arising from the action. Lastly, offsets must be based on scientifically rigorous, robust, and transparent information which documents how the offset benefits the protected matter.

Suitable offsets must have transparent governance arrangements including being able to be readily measured, monitored, audited and enforced

The delivery of offsets must include appropriate and transparent governance arrangements. They must also be delivered with an appropriate monitoring, compliance, and audit program. Annual reports must track the success of the offset so that the condition of approval as varied if the offsets are not delivering their desired outcome.

4 Potential changes in hydrology and flooding

In any consideration of potential impacts associated with the Project, it is important to remember that there is already a potential flooding impact associated with the existing dam, and therefore the focus of the assessment is on the potential incremental impact associated with the Project.

This section provides a detailed discussion of the potential changes in hydrology and flooding associated with the Project for both the upstream and downstream environments. Further details are also provided in Appendix H1 (Flooding and Hydrology Assessment report) and Chapter 15 (Flooding and Hydrology) of the EIS.

4.1 Methodology for flooding assessment

The flood modelling carried out for the Project is discussed in detail in Appendix H1 (Flooding and Hydrology assessment report). This describes the assessment methodology, data requirements and selection of computer simulation models. Modelling involved the use of a hydrological model to develop the inflow hydrographs to a hydraulic model to simulate the passage of various size floods through the river channels and floodplain to produce water levels and velocities.

A summary is provided as follows.

4.1.1 Hydrological model

The hydrological model simulates the rate at which rainfall runs off the catchment which is dependent on:

- catchment slope, area, vegetation, urbanisation, and other characteristics
- variations in the distribution, intensity, and amount of rainfall
- moisture conditions (dryness/wetness) of the catchment.

The interactive runoff and streamflow routing program RORB[4] was used for hydrological modelling with the catchment divided into 121 sub-areas. The model was calibrated to available streamflow and rainfall data, mainly at stations upstream of the dam, and the calibration parameters used to estimate suitable parameters in ungauged catchments in the downstream valley.

A special sub-routine was added to the RORB program to model flows through Lake Burragorang, which incorporates the gate operations at the dam. The subroutine was modified as part of the Regional Flood Study to also include simulation of the fuse plug operation on the auxiliary spillway (WMAwater 2019).

The model was calibrated to available streamflow and rainfall data, mainly at stations upstream of the dam, and the calibration parameters used to estimate suitable parameters in catchments in the downstream valley.

Outputs from the hydrological model are a series of flow hydrographs at selected locations, which are used by the hydraulic model to simulate the passage of various size floods through the river channels and floodplain to produce water levels and velocities. A modelling report was prepared that provided details of the data used, model development, and calibration and verification of the model (WMAwater 2019).

4.1.2 Hydraulic model

Hydraulic modelling of flood flows was carried out using the following models:

- *Upstream*: An existing MIKE11[5] one-dimensional hydraulic model, which was originally developed in the 1990s to assess flow behaviour prior to the dam construction. The MIKE11 model was used to assist in the calibration of the RORB model between the dam and the inflow gauges.
- *Downstream*: A quasi two-dimensional RUBICON model (hydrodynamic model software used to quantify the hydraulic aspects of flood behaviour) was used, which covered a river length of 360 kilometres and was

[4] RORB is a general runoff and streamflow routing program used to calculate flood hydrographs from rainfall and other channel inputs. The 'ROR' of 'RORB' stands for 'runoff routing'. The 'B' no longer has significance but at one time indicated that the program was developed and maintained on a Burroughs B6700 computer (RORB FAQ webpage). Further information on RORB is available at https://www.monash.edu/engineering/departments/civil/research/themes/water/rorb

[5] MIKE 11 is a computer program that simulates flow and water level, water quality and sediment transport in rivers, floodplains, irrigation canals, reservoirs and other inland water bodies. Further information on the MIKE software suite is available from DHI Group.

calibrated and verified against 10 historical flood events. The model has been extensively reviewed and endorsed by numerous Australian and international experts (WMAwater 2019).

4.1.3 Modelling data and calibration

Data used in the modelling and location of data monitoring stations are discussed in Appendix H1 (Section 2.3) and comprised the following:

- *Model cross sections*: model cross sections are generally located approximately one to two kilometres apart and the modelled branches extend up to where gauged inflows are recorded.
- *Rainfall data*: a comprehensive rainfall monitoring network has been installed in the catchment and in 1998 there were 93 pluviographs (real-time rainfall monitoring) and 376 daily rainfall gauges. For each calibration event a spatial pattern was created across the catchment. Temporal rainfall patterns were taken from available pluviographs for each event.
- *Stream flows*: there are over 100 stream gauging stations in the catchment. Ten representative gauging stations were chosen for use as calibration locations or for model verification.
- *Terrain*: a merged digital elevation model (DEM) was created across the catchment and was used to give an overview of the catchment and for calculation of the average slope of sub-catchments.
- *Dam operations and inflows*: WaterNSW supplied a daily time-series of Lake Burragorang lake levels from 1960 to 2017, and hourly time-series of releases for the period covering the calibration events.

Model calibration involved:

- increasing the number of model sub-areas
- calibrating the model at additional locations within the catchment
- inclusion of baseflows
- calibrating the model for significant flood events recorded in June 1964, June 1975, March 1978, August 1986, May 1988, August 1990, and August 1998. A plot of observed floods compared to Monte Carlo modelled events generally shows good correlation, and the model was deemed suitable for modelling potential Project impacts.

4.1.4 Approach to flood modelling

Every flood is different due to the variability in various factors including:

- *rainfall intensity and frequency*: the number of times, during a specified period of years, that rainfall of a certain magnitude or greater occurs
- *spatial pattern of rainfall*: where in the catchment rain falls
- *temporal pattern of rainfall*: when, during the event, rain falls
- *initial loss*: rain 'lost' at the beginning of an event through infiltration into the soil
- *pre-burst rainfall*: rain that occurs before the most intense storm burst
- *dam drawdown*: the level of Warragamba Dam before the start of an event
- *relative timings of dam inflows*: when water flows from rivers and streams to the dam
- *tides*: tidal influences in the Hawkesbury River.

> **Monte Carlo simulation** performs risk analysis by building models of possible results by substituting a range of values—a probability distribution—for any factor that has inherent uncertainty. It then calculates results over and over, each time using a different set of random values from the probability functions.

To account for this variability, a Monte Carlo approach to modelling was undertaken. This involved varying the above factors, modelling the different scenarios and then statistically analysing the hydrographs.

The flood modelling framework and use of the Monte Carlo analysis considers antecedent conditions as a variable in the assessment of flooding conditions for existing and Project scenarios. Accordingly, the variability in both wet and dry conditions at the onset of flood producing rainfall is incorporated in the probabilistic estimation of the timing and response of surface water flows to rainfall, and subsequent estimation of peak flood levels and inundation extents.

About 20,000 model runs were undertaken to capture the variability in flood events. Using the Monte Carlo modelling approach, flood events along the whole flood frequency curve were generated. A description of the Monte Carlo approach to modelling is provided in Appendix H1 (Section 2.4).

The Monte Carlo approach recognises that any design flood characteristic (e.g. peak flow) could result from a variety of combinations of flood-producing factors, rather than from a single combination. The approach mimics ‘Mother Nature’ in that the influence of all probability distributed inputs are explicitly considered, thereby providing a more realistic representation of the flood generation processes. The model outputs for a particular flood event with a specific chance of occurrence in any given year are therefore represented by an ‘envelope’ of events, which cover a wide range of flood durations and affected areas.

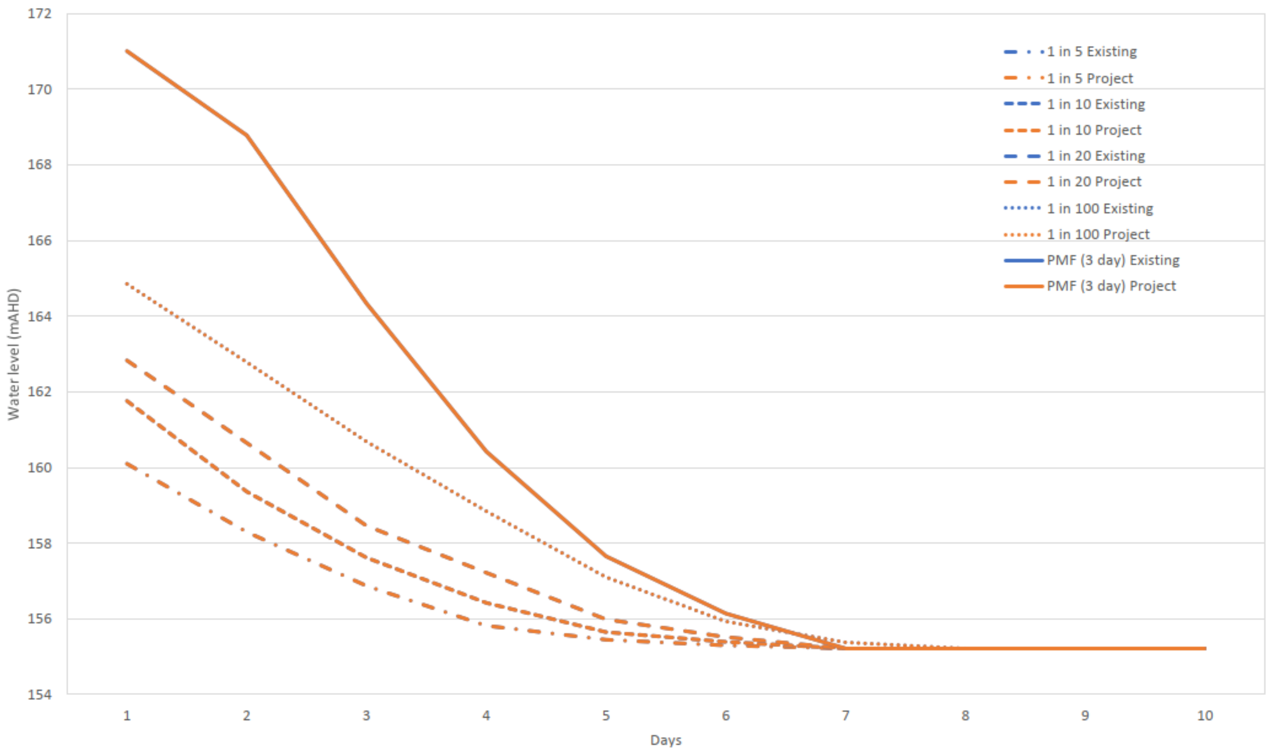
The hydraulic model is based on a series of discrete channel/floodplain cross sections that assume a uniform water level across the section perpendicular to the direction of flow. The model outputs include water level, flow rate and cross-section average flow velocity for each cross section for each model time-step. From these outputs, time-series of water levels, flow rates and flow velocities can be generated for each event, and peak values for each parameter identified, for each event simulated.

A slightly different approach was adopted for the upstream area. The MIKE11 model was not used to discretely simulate each of the Monte Carlo design flood scenarios. Rather, it was used to extract rating curves (flow-height relationships) under different dam raising scenarios. These rating curves were then used to derive hydrographs from flow inputs (from the RORB model) at all cross-sections for the 20,000 Monte Carlo runs of the existing dam and the Project. These hydrographs were then used to obtain estimates of inundation times upstream of the dam and to give an indication of the change in inundation time between the existing dam and the Project.

4.1.5 Truncation of flood extents

Figure 4-1 shows the depth-duration curves for SEARs events at the upstream-most cross section in the MIKE11 model on the Wollondilly River. This shows that there is no material difference between the existing and Project curves at this location for all flood events shown.

Figure 4-1. Depth-duration curves for SEARs events at WOLLONDILLY_US_0



Moving progressively downstream, the depth-duration curves start to diverge as shown in Figure 4-2 and Figure 4-3, reflecting the increasing influence of the Project. At cross section WOLLONDILLY_0 (about 10 kilometres downstream), the depth-duration curve for the PMF has started to diverge and the curve for the 1 in 100 chance in a year event is also diverging slightly. At cross section WOLLONDILLY_3380, which is about a further 3.4 kilometres downstream, the divergence of the curves for the 1 in 10 chance in a year event and greater is clearly apparent. While not shown, a similar pattern occurs for the depth-duration curves for the Nattai River, Kowmung River and Coxs River.

The depth-duration curves were used to identify the cross sections beyond which the Project would not have any impact for the individual SEARs events. These locations were then used to truncate the flood events for the individual SEARs events to assess the potential impacts of the Project.

Figure 4-2. Depth-duration curves for SEARs events at WOLLONDILLY_0

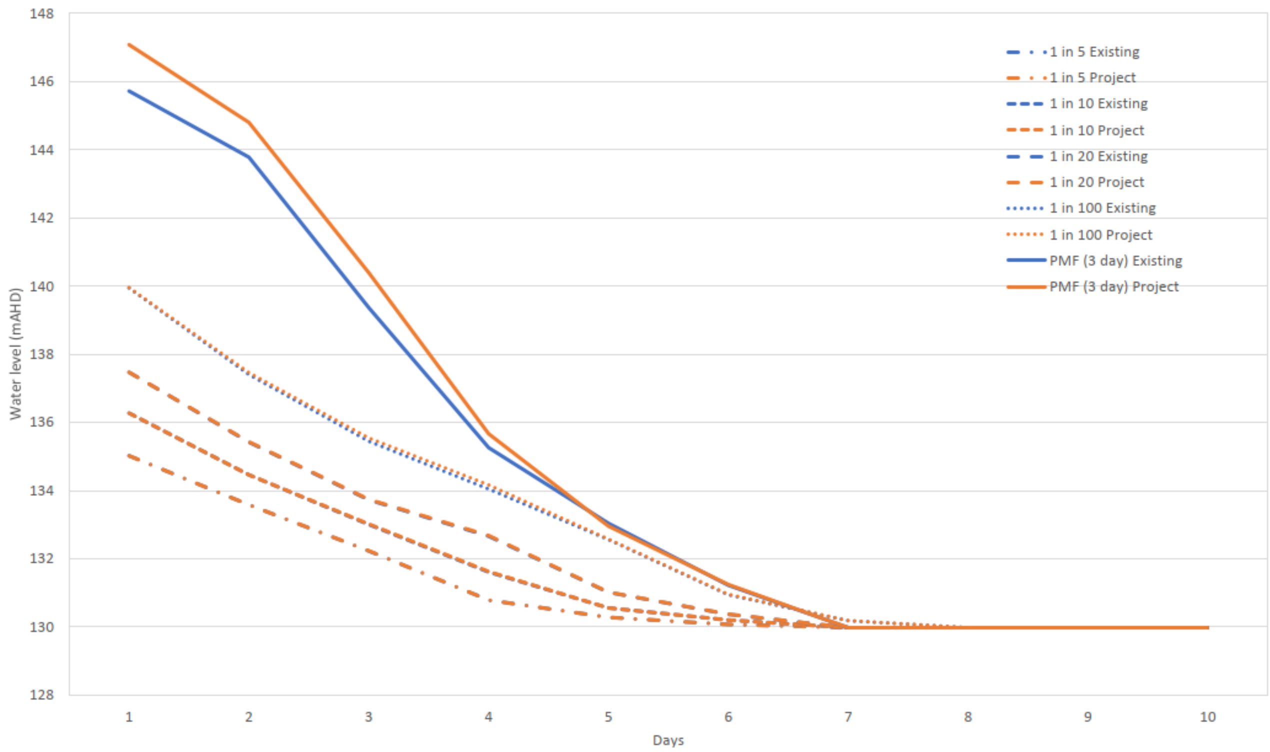
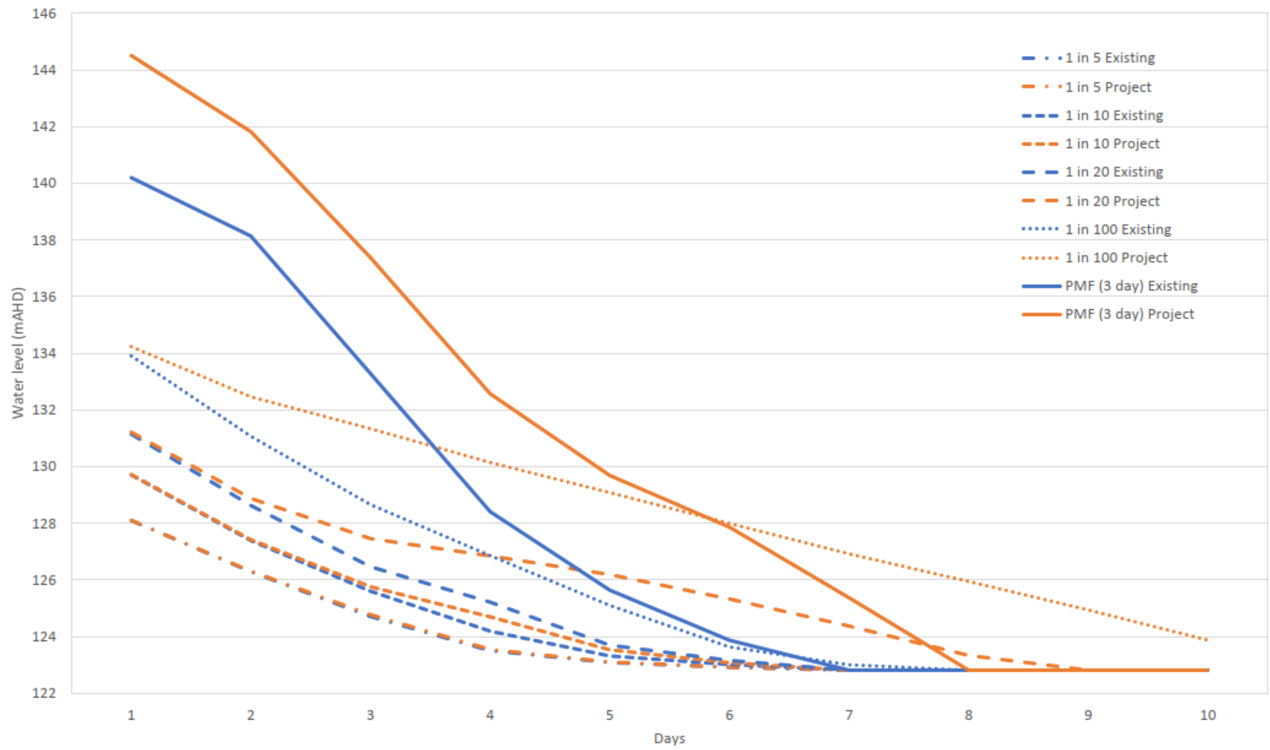


Figure 4-3. Depth-duration curves for SEARs events at WOLLONDILLY_3380



4.2 Upstream

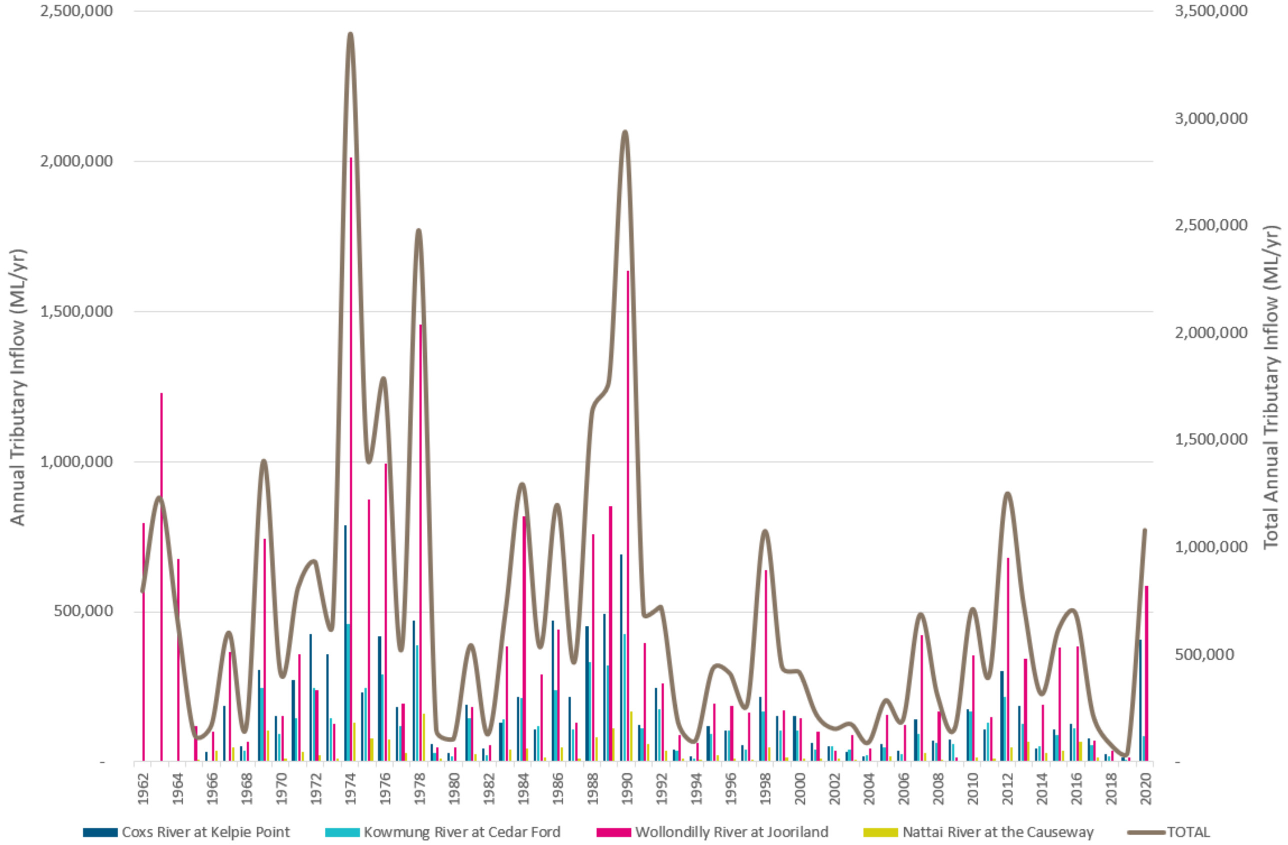
4.2.1 Existing hydrology and flooding

The upstream environment includes the reservoir formed by Warragamba Dam (Lake Burragorang) and its tributaries. The catchment covers an area of about 9,050 square kilometres and includes State Conservation Areas, National Parks and areas of the Greater Blue Mountains World Heritage Area (GBMWHA). The catchment extends to the south near Lake Bathurst, where rainfall is comparatively low, and drains to Mulwaree Ponds near Goulburn and then to the Wollondilly River, which flows north-east to Lake Burragorang. A major tributary of the Wollondilly River is the Wingecarribee River, which rises in an area of high rainfall near Bowral to the east.

Lake Burragorang is 52 kilometres long, has 354 kilometres of foreshore and covers a waterway area of approximately 75 square kilometres. Warragamba Dam is situated in a steep, narrow gorge. Before the dam was built the gorge carried the Warragamba River from the junction of the Wollondilly and Coxs Rivers down to the Nepean River below Wallacia. The total length of the Warragamba River was 22 kilometres, though since the creation of Lake Burragorang it is currently 3.5 kilometres long.

Major tributaries have differing flow characteristics due to variable rainfall across the upstream catchment. WaterNSW records streamflow into Lake Burragorang for the Wollondilly River, Nattai River, Coxs River (upstream of Kowmung River confluence) and Kowmung River. Annual tributary inflows and combined total inflow to Lake Burragorang between 1962-2016 are shown in Figure 4-4. Total inflows to the reservoir have varied considerably since construction of Warragamba Dam, ranging from over 3,390,000 megalitres in 1974 to a low of 87,000 megalitres in 2004.

Figure 4-4. Annual tributary inflows into Lake Burragorang

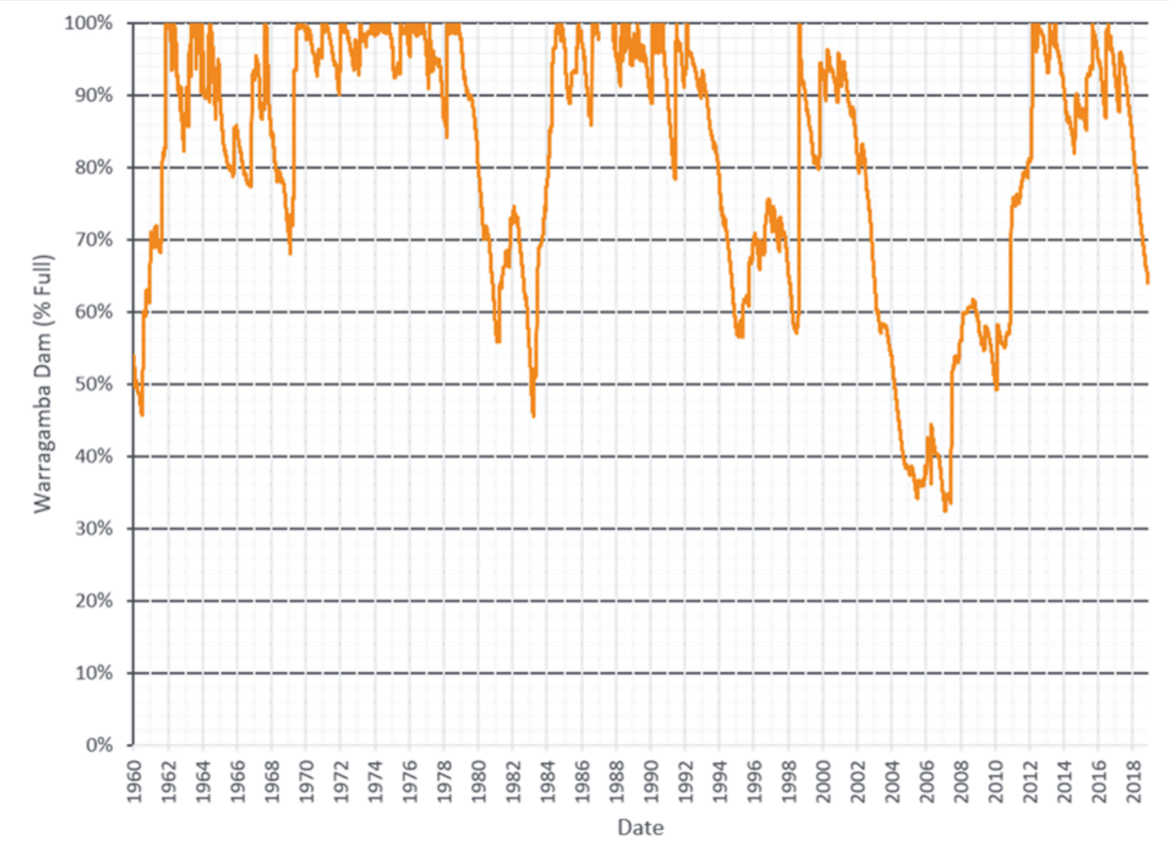


Note: During the period 2003 to 2007 the Wollondilly River inflows include transfers from the Shoalhaven.
Source: Appendix H1, Figure 3-7

Historic dam levels (as percentages) are shown on Figure 4-5. Since 1960 the dam storage level has been above 80 percent full for most of the time, however the level has dropped to less than 60 percent full on several occasions, and in the early 2000s the dam storage level dropped below 40 percent. The dam storage level was at about 60 percent capacity in late 2018 and was at 100 percent capacity in mid-August 2020. The dam has also exceeded 100 percent capacity and spilled on numerous occasions during the 1960s and 1970s. Recent dam spills occurred in 2012, 2013 and 2015 February 2020 and March 2021.

Lake Burragorang has altered hydrological and sediment transport regimes between the upstream catchment and downstream rivers and floodplain. The lake functions as a sediment 'sink' and reduces sediment loads downstream of the dam.

Figure 4-5. Historic dam levels



Source: Appendix H1, Figure 3-11

Flooding in the upstream catchment is characterised by backwater inundation, with inflows building on the upstream side of the dam wall. The water level increases until the outflow exceeds the inflow, at which time the water level recedes to the FSL (116.7 mAHD). The extent and duration of inundation is dependent upon the magnitude of the flood-producing rainfall event, the water level in the dam storage at the time of the inflow event and the rate of release of water from the dam. Monte Carlo flood modelling results at the dam wall are shown in Table 4-1 (with the dam at FSL). Existing peak flood levels may be higher in the upper tributary reaches.

Table 4-1. Existing upstream peak flood events at dam wall

Flood event (1 in x chance in a year)	Water level (mAHD)	Approximate days above FSL
5	117.4	2.8
10	118.0	3.4
20	118.6	4.0
100	121.5	4.0
200	122.9	4.1
500	124.6	4.5
PMF (3 day)	131.2	4.2

The extent of inundation is controlled by the peak flood level at the dam wall and the topography across the upstream catchment. Steep terrain extends upstream from the dam wall for at least 20 kilometres, so that the extent of land inundated changes at a relatively small rate with increasing magnitude floods. However, the rate of change and inundated area increases as terrain flattens about where the Wollondilly River and Coxs River enter Lake Burragorang. Flood hydrographs and corresponding water level time-series in Lake Burragorang are provided in Appendix H1 (Section 3.2.1.3).

Water levels in Lake Burragorang remain elevated for a period of about three to five days depending on the size of the event (see Table 4-1). Although lake levels remain elevated for a period of days, the period of inundation for specific locations would vary depending on where they are in the catchment, with duration decreasing with elevation.

Flood storage areas are characterised by deep, low velocity inflows, although relatively higher velocities would be expected where major tributaries discharge into the lake.

4.2.2 Potential flooding with the Project

4.2.2.1 Changes to flood levels and duration of temporary inundation

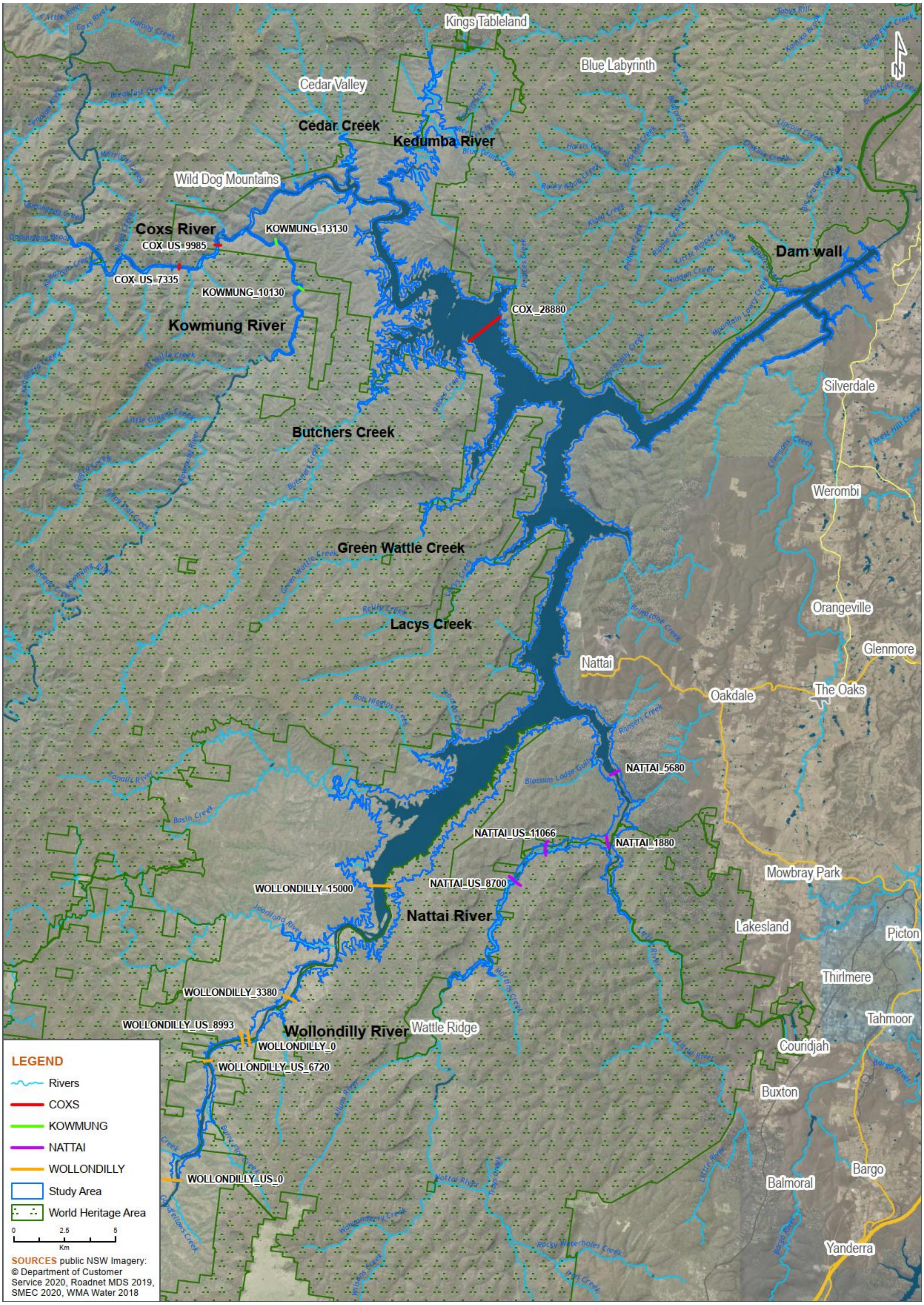
Modelling included development of depth-duration curves at numerous cross sections within the lake and along major tributaries. These curves show the amount of time that water levels are at or above a specific elevation, and are of use in comparing different flood events at a specific location or, in this case, comparing flood events of a specific chance of occurrence for the existing situation and the Project.

Depth-duration curves were examined for a selection of locations (shown in Figure 4-6) comprising:

- the dam wall as these nominally show the greatest influence of the Project
- approximately where contributions from the local catchments begin to decline and the contribution to flooding by the Project for the PMF event begins to dominate representing the upstream limit of the Project
- locations approximating to the extent of the 1 in 100 chance in a year flood event downstream of the upstream-most locations; these were used to examine the increasing influence of the Project (or otherwise) moving downstream
- intermediate locations within Lake Burragorang, one on the Wollondilly River and one on the Coxs River; these were used to assess the influence of the Project nominally midway in the two main arms of Lake Burragorang
- four cross sections on the Nattai River to examine changes in the pattern of the depth-duration curves moving downstream.

The results of the analyses are discussed as follows for the individual tributaries.

Figure 4-6. Upstream locations for depth-duration and flood frequency analyses



Dam wall

Predicted changes at the dam wall with the Project are shown in Figure 4-7 and summarised in Table 4-2. It should be noted that the figures for the incremental depths and duration are based on representative hydrographs from the Monte Carlo analysis and could vary reflecting the inherent variability in the results of the Monte Carlo analysis.

Figure 4-7. Depth-duration curves for the dam wall

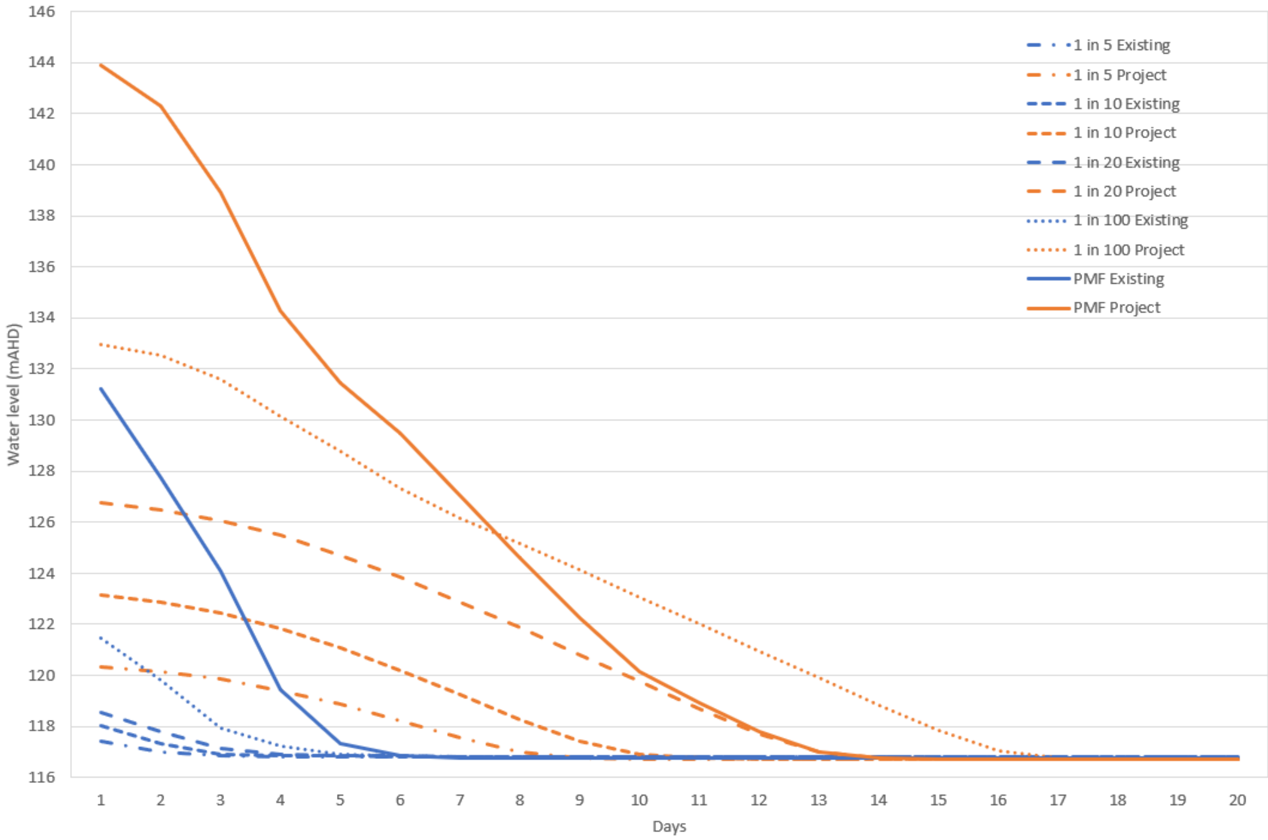


Table 4-2. Changes to temporary inundation levels and durations at dam wall

Event (1 in x chance in a year)	Existing			Project			
	Level (RL m)	Depth (m)	Inundation[1] (days)	Level (RL m)	Depth (m)	Increase in inundation (days)	Total inundation (days)
5	117.4	0.7	2.8	120.3	2.9	4.6	7.4
10	118.0	1.3	3.4	123.1	5.1	6	9.4
20	118.6	1.9	4.0	126.8	8.2	8.6	12.6
100	121.5	4.8	4.0	132.0	10.5	10.8	14.8
PMF	131.2	14.5	4.2	143.9	12.7	7	11.2

1: Duration of temporary inundation has been calculated as when the rising limb of the hydrograph exceeds FSL (116.7 metres) and the falling limb of the hydrograph reaches FSL.

The above analysis indicates that changes to the duration of upstream inundation at the dam wall would be up to about five days for the relatively more frequent 1 in 5 chance in a year flood, and up to about 11 days for a rarer 1 in 100 chance in a year flood event.

Wollondilly River

The Wollondilly River is one of the two main arms of Lake Burragorang (the other being the Coxs River). Depth-duration curves were examined for five cross-sections on the Wollondilly River as follows:

- WOLLONDILLY_US_0 is the upstream-most cross-section used in the MIKE11 model on the Wollondilly River and is located beyond the influence of the Project
- WOLLONDILLY_US_6720 represents the approximate location of the Project PMF event, and the limit of Project influence on the Wollondilly River
- WOLLONDILLY_8933 represents the approximate location of the Project for the 1 in 100 chance in a year event
- WOLLONDILLY_3380 and WOLLONDILLY_15000 are two further downstream cross-sections, the latter located within Lake Burragorang.

The results of the analysis are summarised in Table 4-3 and the associated depth-duration curves shown in Figure 4-8 to Figure 4-12. The table also includes the results for the dam wall to facilitate a comparison with the situation at the downstream-most location in the upstream study area.

Table 4-3. Upstream changes in temporary inundation depth and duration with the Project: Wollondilly River

Location (refer Figure 4-6)	Flood event (1 in x chance in a year)							
	1 in 5		1 in 10		1 in 20		1 in 100	
	E[1]	P[2]	E	P	E	P	E	P
WOLLONDILLY_US_0								
Depth (m)	4.3	<0.5	6.5	<0.5	8.5	<0.5	9.2	<0.5
Duration (days)	5.9	<0.5	5.4	<0.5	6.2	<0.5	5.2	<0.5
WOLLONDILLY_US_6720								
Depth (m)	4.4	<0.5	6.2	<0.5	9.0	<0.5	10.0	<0.5
Duration (days)	5.9	<0.5	5.4	<0.5	6.2	<0.5	5.2	<0.5
WOLLONDILLY_US_8993								
Depth (m)	4.0	<0.5	5.6	<0.5	7.9	<0.5	8.7	<0.5
Duration (days)	5.9	<0.5	5.4	<0.5	6.2	<0.5	5.2	<0.5
WOLLONDILLY_3380								
Depth (m)	4.7	<0.5	6.8	<0.5	9.6	<0.5	10.6	<0.5
Duration (days)	5.9	<0.5	5.4	<0.5	6.2	3.2	5.2	3.6
WOLLONDILLY_15000								
Depth (m)	0.7	2.5	1.3	5.0	2.3	9.0	5.2	10.7
Duration (days)	6.8	2.4	6.4	3.8	7.2	8.0	6.8	8.3
Dam wall								
Depth (m)	0.7	2.9	1.3	5.1	1.9	8.2	4.8	10.5
Duration (days)	2.8	4.6	3.4	6	4.0	8.6	4.0	10.8

Notes: 1 – E = existing; 2 – P = additional depth/duration with Project

The above summary shows:

- Increases in the depth and duration of temporary inundation are generally less than half a metre and half a day respectively for the three upstream most cross-sections for all SEARs events, the exception being the PMF event for cross-section WOLLONDILLY_US_8993 where the increase in depth is about 1.1 metres.

- At cross-section WOLLONDILLY_3380, increases in depth are less than half a metre for all events up to the 1 in 100 chance in a year event; for the PMF event, the increase in depth is about 4.3 metres.
- At cross-section WOLLONDILLY_3380, increases in temporary inundation are less than half a day up to the 1 in 10 chance in a year event, then increasing up to 3.6 days for the 1 in 100 chance in a year event.
- At WOLLONDILLY_15000, there is a clear increase in depths and durations for temporary inundation for all SEARs events, these broadly mirroring the those at the dam wall for respective flood events.
- An increasing influence of the Project moving downstream with the increase in temporary depth and duration of temporary inundation within Lake Burragorang generally reflecting that at the dam wall.

Figure 4-8. Depth-duration curves for WOLLONDILLY_US_0

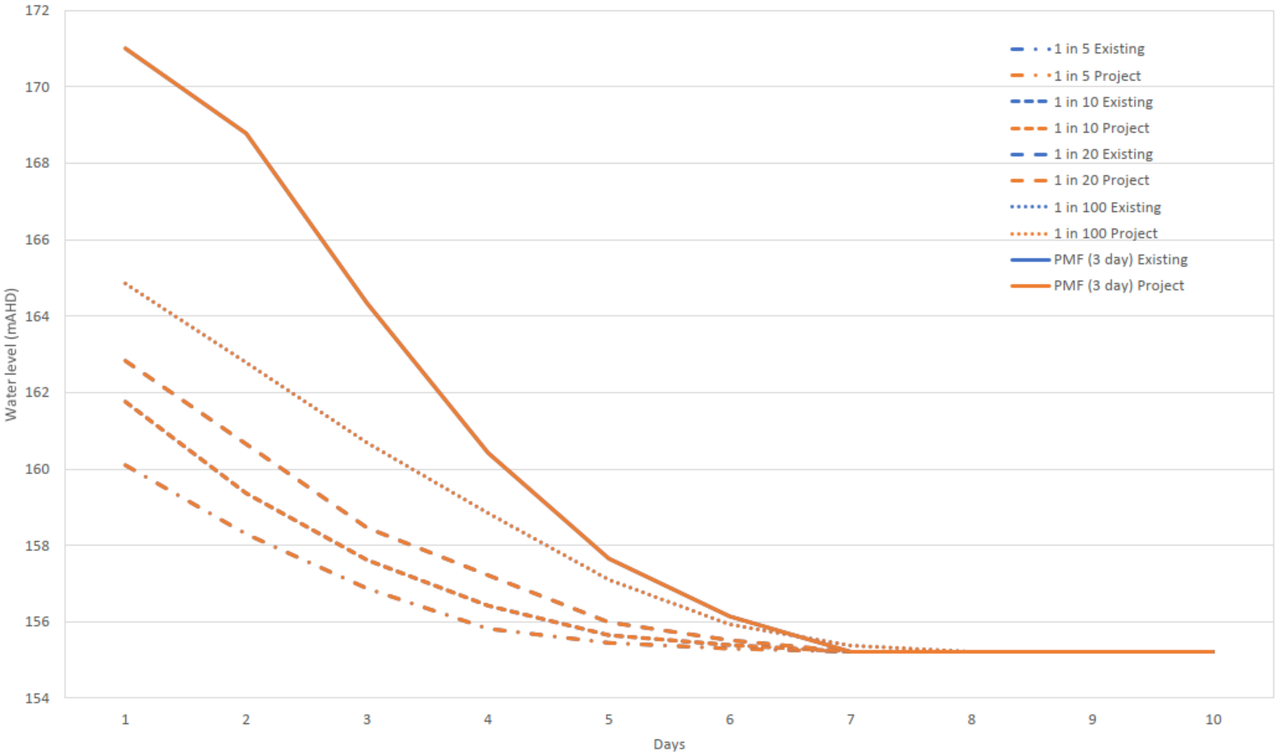


Figure 4-9. Depth-duration curves for WOLLONDILLY_US_6720

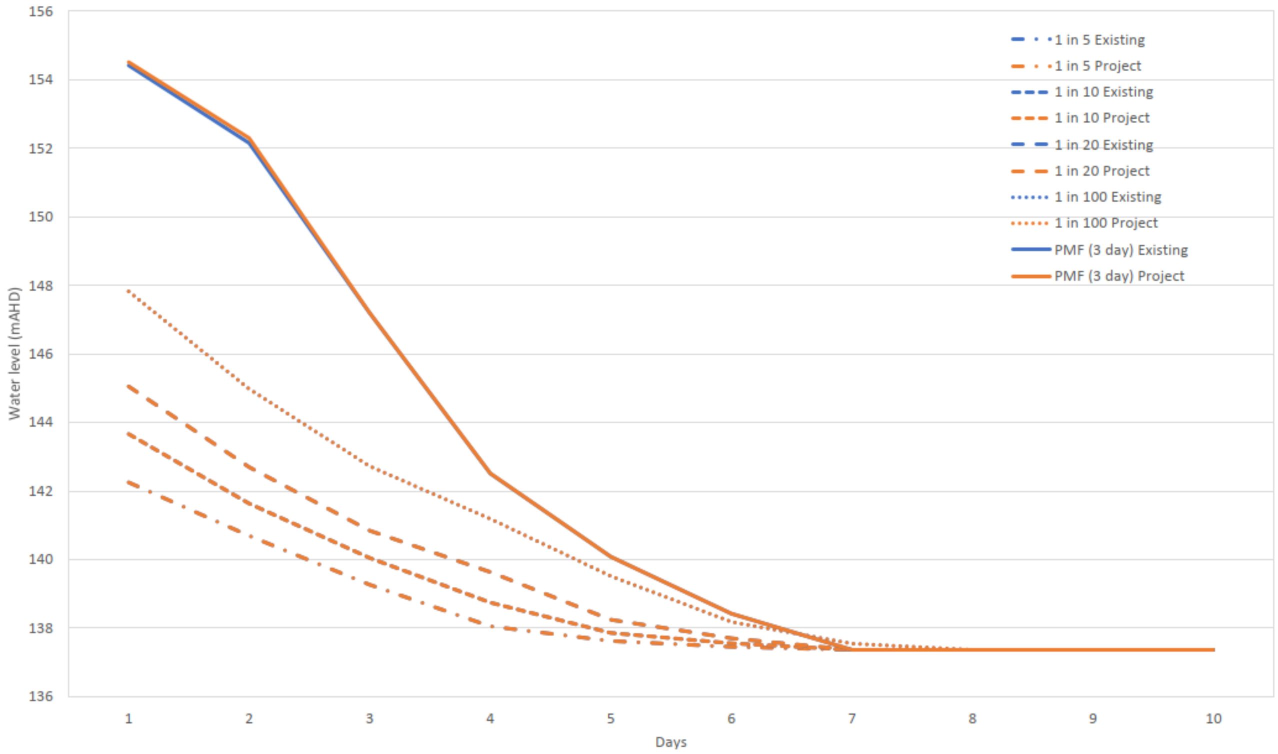


Figure 4-10. Depth-duration curves for WOLLONDILLY_US_8933

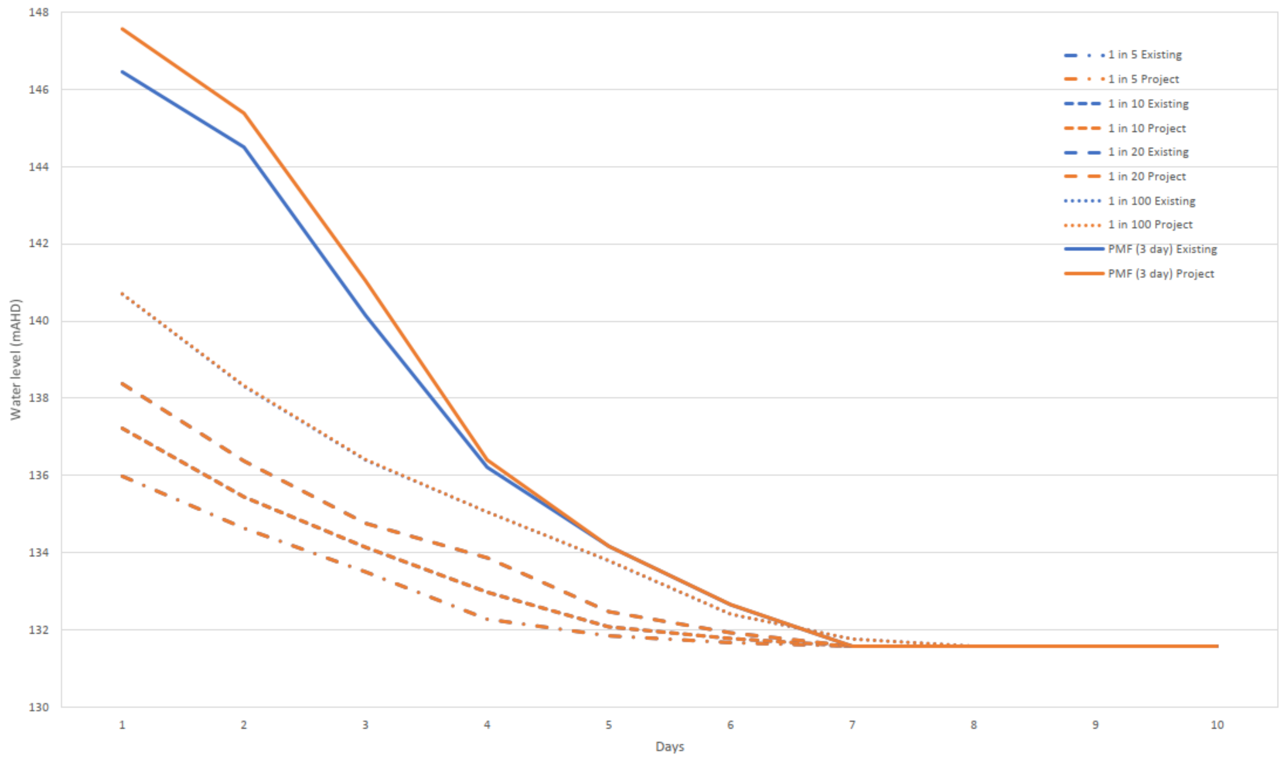


Figure 4-11. Depth-duration curves for WOLLONDILLY_3380

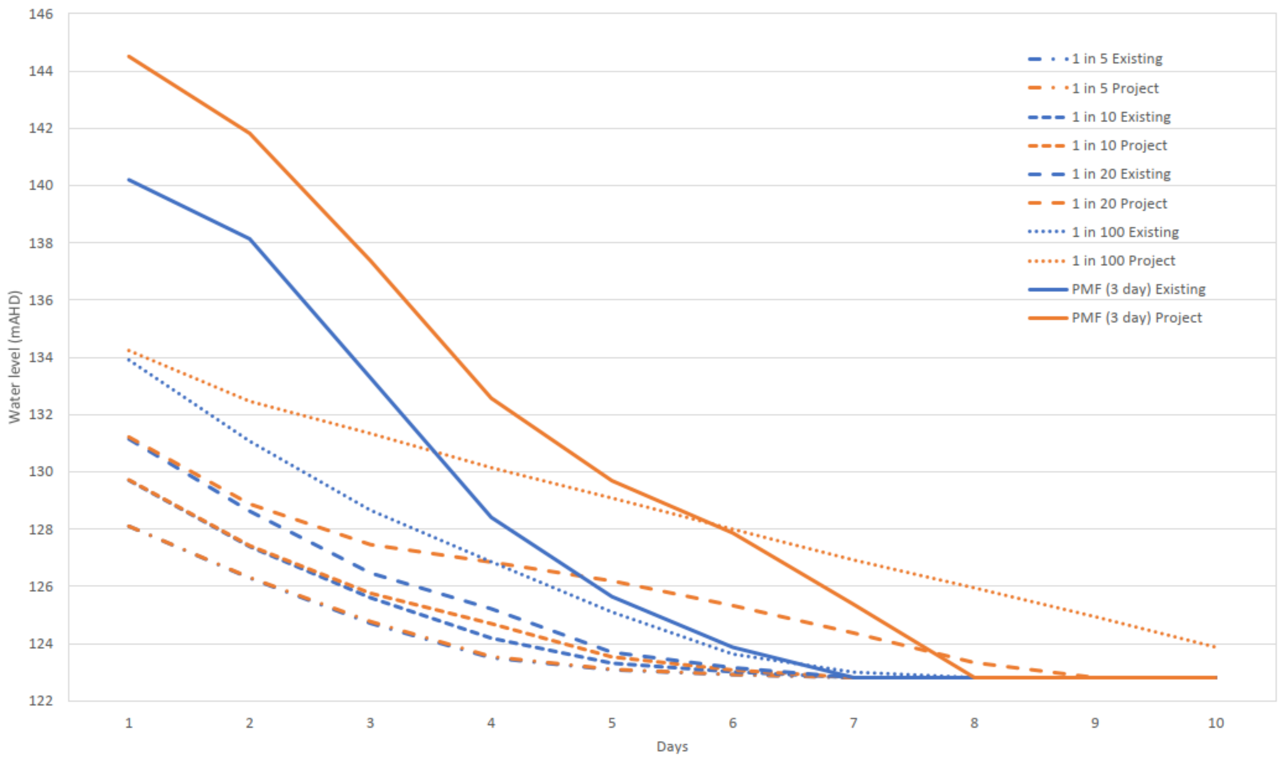
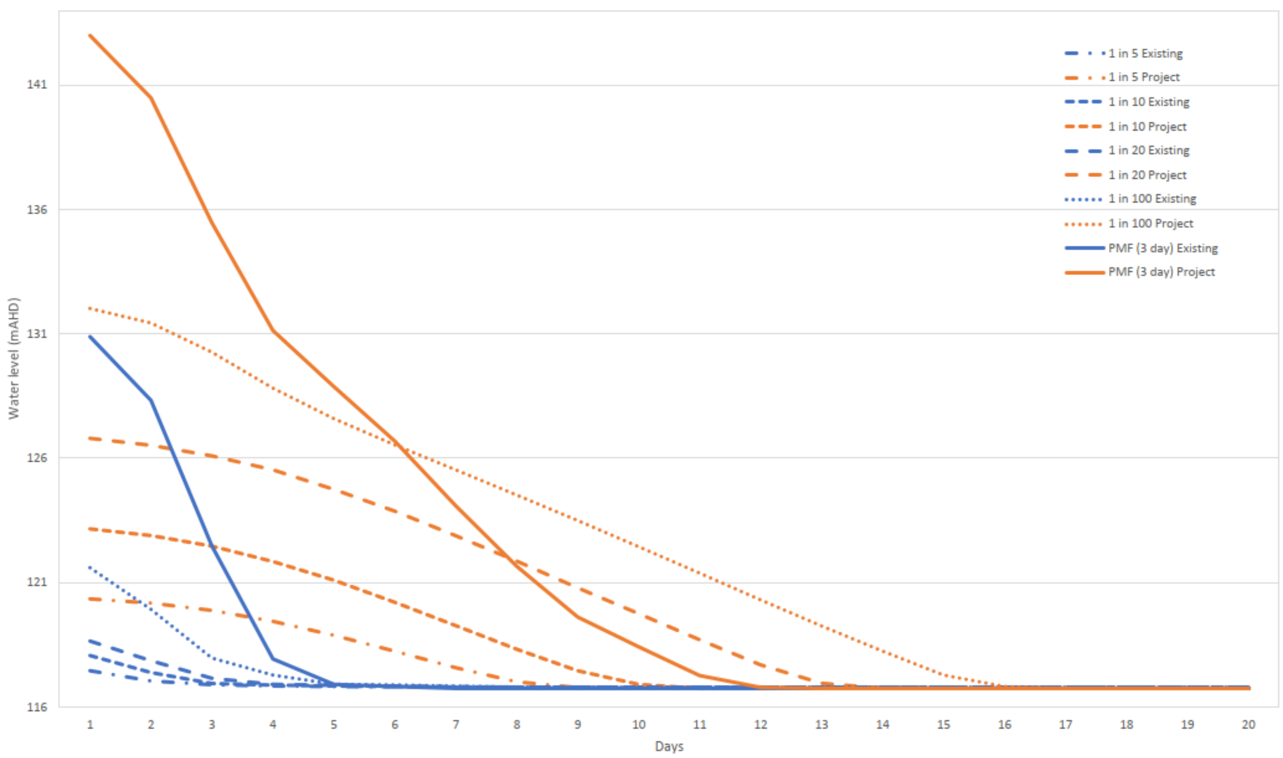


Figure 4-12. Depth-duration curves for WOLLONDILLY_15000



Coxs River

Depth-duration curves were examined for three cross-sections on the Coxs River as follows:

- COX_US_7335 represents the approximate location of the Project PMF event, and the limit of Project influence on the Coxs River.

- COX_US_9985 represents the approximate location of the Project for the 1 in 100 chance in a year event and is about 2.5 kilometres downstream of COX_US_7335.
- COXS_28800 is further downstream located within Lake Burragorang.

The results of the analysis are summarised in Table 4-4; the associated depth-duration curves shown in Figure 4-13, Figure 4-14, and Figure 4-15. The table also includes the results for the dam wall to facilitate a comparison with the situation at the downstream-most location in the upstream study area.

The analysis indicates:

- increases in the depth and duration of temporary inundation are half a metre (for the PMF event) or less and half a day respectively for cross-section COX_US_7335 for all events
- increases in the depth of temporary inundation for cross-section COX_US_9985 are half a metre or less up to the 1 in 100 chance in year event, and about 3.5 metres for the PMF event
- increases in the duration of temporary inundation for cross-section COX_US_9985 are less than half a day up to the 1 in 20 chance in a year event; this increases slightly to 0.7 days for the 1 in 100 chance in a year event and the PMF event
- at COXS_28800, there is a clear increase in depths and durations for temporary inundation for all SEARs events, these broadly mirroring the those at the dam wall for respective flood events
- an increasing influence of the Project moving downstream with the increase in temporary depth and duration of temporary inundation within Lake Burragorang generally reflecting that at the dam wall.

Table 4-4. Upstream changes in temporary inundation depth and duration with the Project: Coxs River

Location (refer Figure 4-6)	Flood event (1 in x chance in a year)							
	1 in 5		1 in 10		1 in 20		1 in 100	
	E[1]	P[2]	E	P	E	P	E	P
COX_US_7335								
Depth (m)	2.4	<0.5	4.6	<0.5	5.3	<0.5	6.7	<0.5
Duration (days)	5.8	<0.5	5.4	<0.5	6.2	<0.5	5.3	<0.5
COX_US_9985								
Depth (m)	2.1	<0.5	4.5	<0.5	5.3	<0.5	6.9	0.5
Duration (days)	5.8	<0.5	5.4	<0.5	6.2	<0.5	5.1	0.7
COXS_28800								
Depth (m)	0.7	2.5	1.3	5.1	2.2	9.1	5.1	10.8
Duration (days)	6.8	2.4	6.4	3.8	7.2	8.0	6.4	8.3
Dam wall								
Depth (m)	0.7	2.9	1.3	5.1	1.9	8.2	4.8	10.5
Duration (days)	2.8	4.6	3.4	6	4.0	8.6	4.0	10.8

Notes: 1 – E = existing; 2 – P = additional depth/duration with Project

Figure 4-13. Depth-duration curves for COXS_US_7335

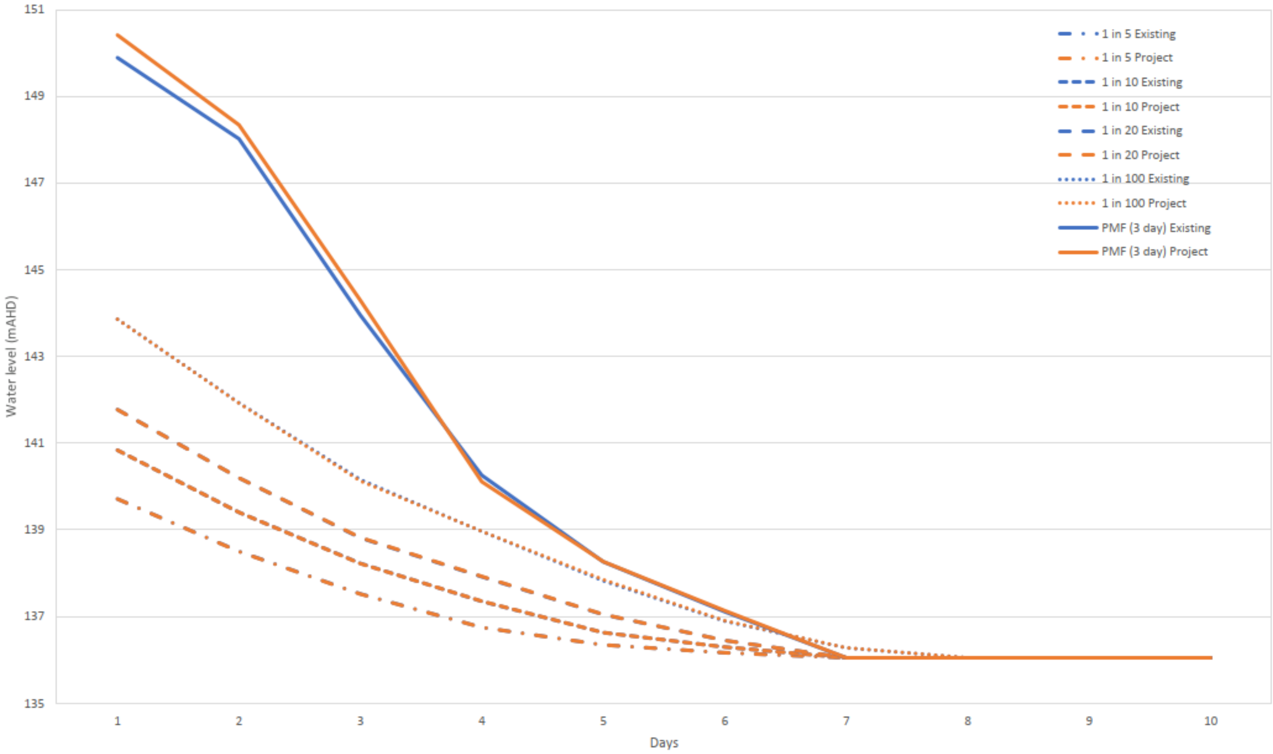


Figure 4-14. Depth-duration curves for COXS_US_9985

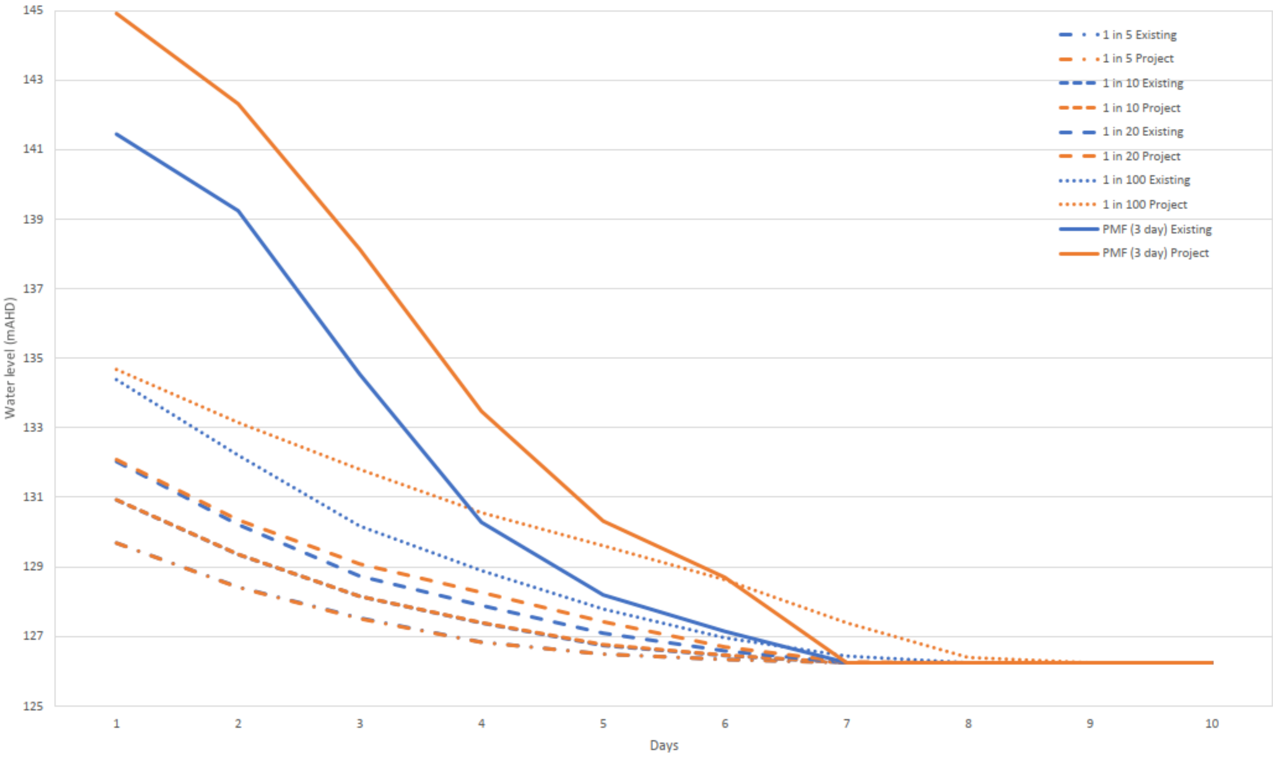
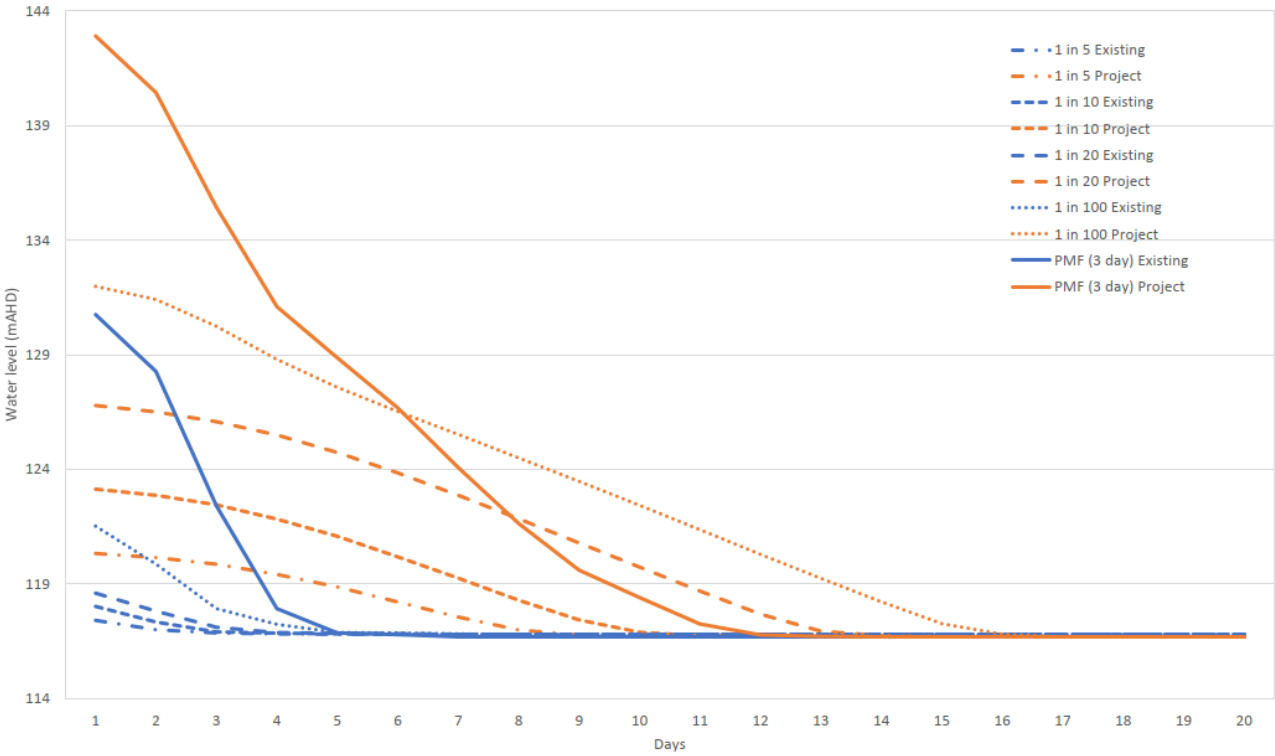


Figure 4-15. Depth-duration curves for COXS_28880



Nattai River

Depth-duration curves were examined for four cross-sections on the Nattai River as follows:

- NATTAI_US_8700 represents the approximate location of the Project PMF event, and the limit of Project influence on the Nattai River.
- NATTAI_US_11066 is about 2.4 kilometres downstream of NATTAI_US_8700 and represents the approximate location of the Project for the 1 in 100 chance in a year event.
- NATTAI_1880 is about 2.6 kilometres downstream of cross-section NATTAI_US_11066.
- NATTAI_5680 is a further 3.8 kilometres downstream and is where the Nattai River broadens out into Lake Burragorang.

The results of the analysis are summarised in Table 4-5 and the associated depth-duration curves shown in Figure 4-16 to Figure 4-19. The table also includes the results for the dam wall to facilitate a comparison with the situation at the downstream-most location in the upstream study area.

The analysis indicates:

- Increases in the depth and duration of temporary inundation for cross-sections NATTAI_US_8700 and NATTAI_US_11066 are less than half a metre and half a day respectively for all events with the exception of the PMF event for NATTAI_US_11066 which would increase by about 7.8 metres.
- Increases in the depth and duration of temporary inundation are more noticeable at cross-section NATTAI_1880, particularly for the 1 in 20 chance in a year and larger events.
- At NATTAI_5680, there is also a clear increase in depths and durations for temporary inundation for all SEARs events, these broadly mirroring the those at the dam wall for the respective 1 in 20 chance in a year and larger flood events.

Table 4-5. Upstream changes in temporary inundation depth and duration with the Project: Nattai River

Location (refer Figure 4-6)	Flood event (1 in x chance in a year)							
	1 in 5		1 in 10		1 in 20		1 in 100	
	E[1]	P[2]	E	P	E	P	E	P
NATTAI_US_8700								
Depth (m)	3.4	<0.5	3.7	<0.5	4.3	<0.5	4.3	<0.5
Duration (days)	5.9	<0.5	5.4	<0.5	6.2	<0.5	6.2	<0.5
NATTAI_US_11066								
Depth (m)	3.8	<0.5	4.1	<0.5	4.8	<0.5	5.9	<0.5
Duration (days)	5.9	<0.5	5.4	<0.5	6.2	<0.5	5.2	<0.5
NATTAI_1880								
Depth (m)	2.8	0.5	3.1	3.2	4.0	7.4	5.9	10.0
Duration (days)	6.8	2.4	6.4	3.8	6.7	8.0	6.4	8.3
NATTAI_5680								
Depth (m)	0.8	2.4	1.3	5.0	2.4	9.0	5.2	10.6
Duration (days)	6.8	2.4	6.4	3.8	7.2	8.0	6.4	8.3
Dam wall								
Depth (m)	0.7	2.9	1.3	5.1	1.9	8.2	4.8	10.5
Duration (days)	2.8	4.6	3.4	6	4.0	8.6	4.0	10.8

Notes: 1 – E = existing; 2 – P = additional depth/duration with Project

Figure 4-16. Depth-duration curves for NATTAI_US_8700

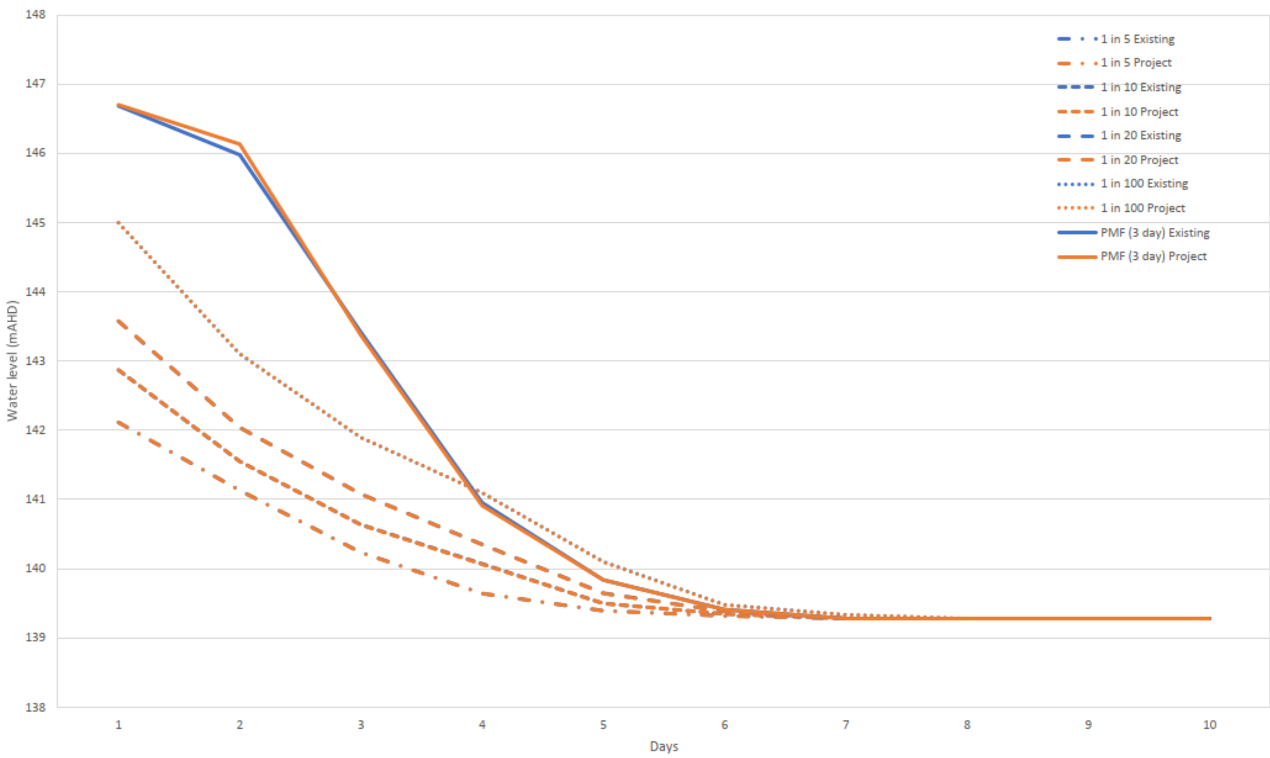


Figure 4-17. Depth-duration curves for NATTAI_US_11066

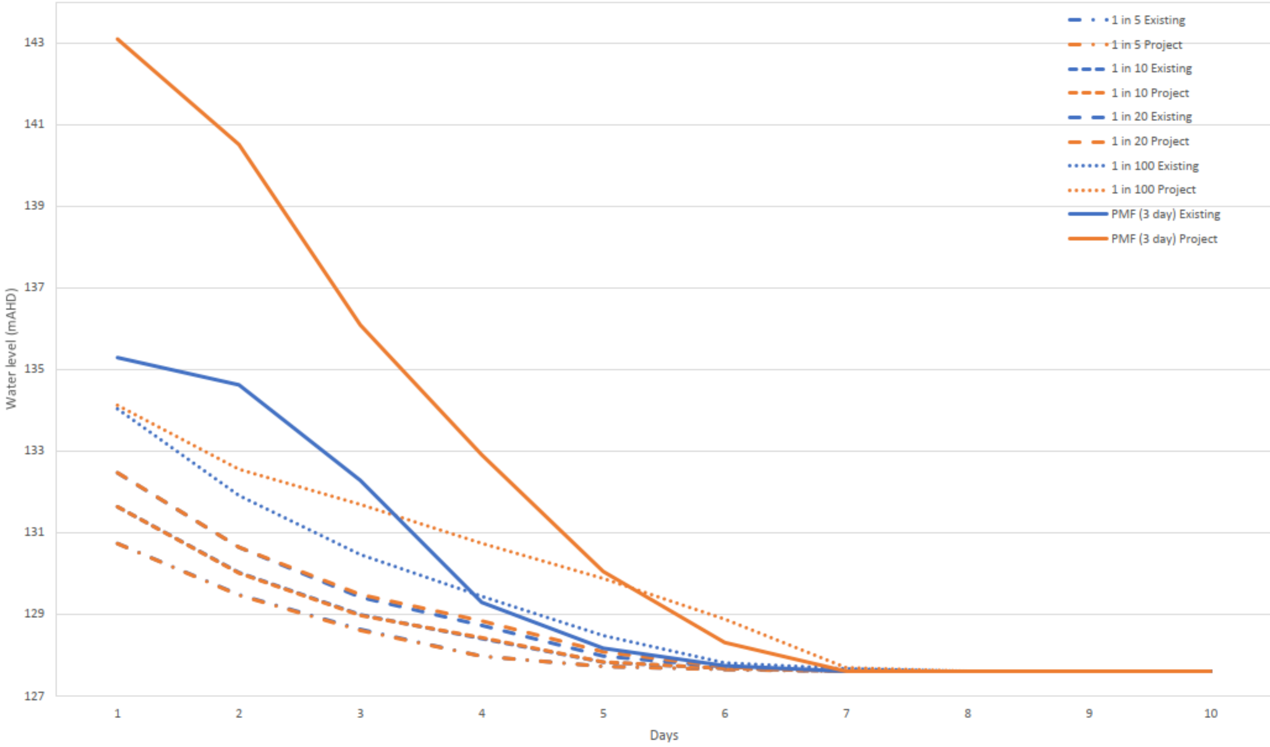


Figure 4-18. Depth-duration curves for NATTAI_1880

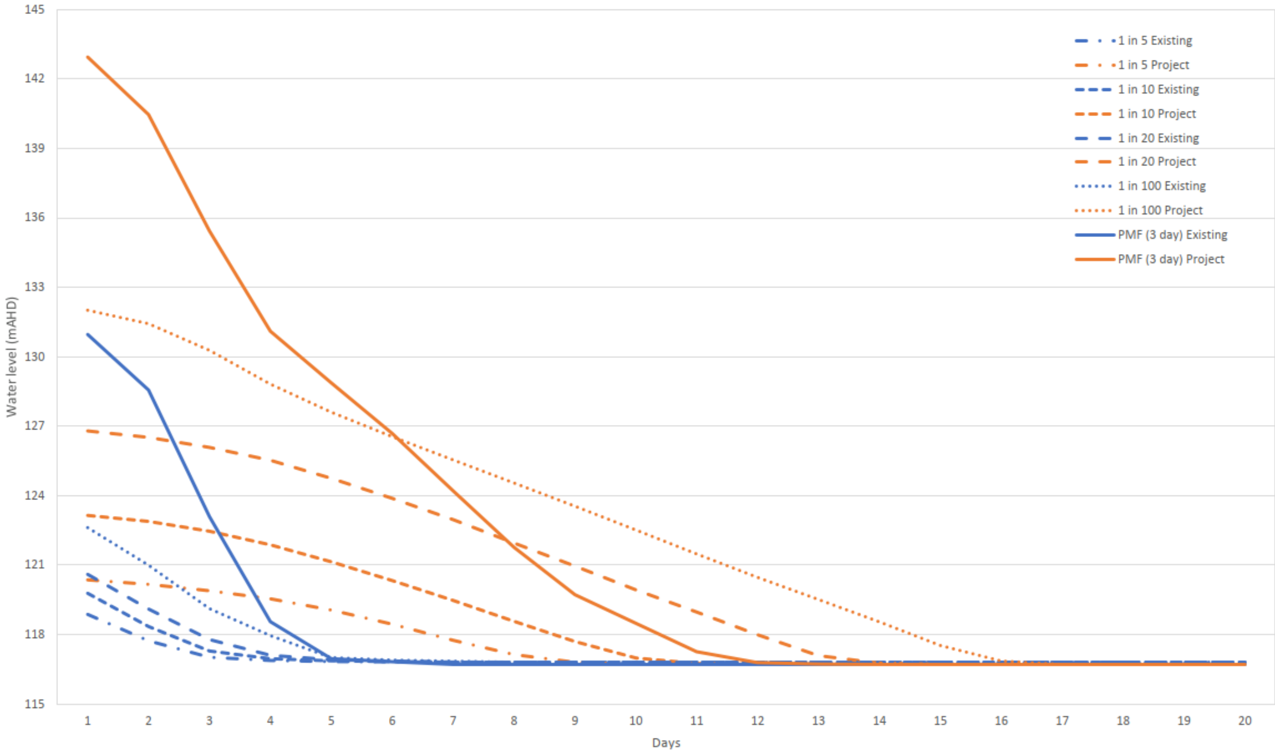
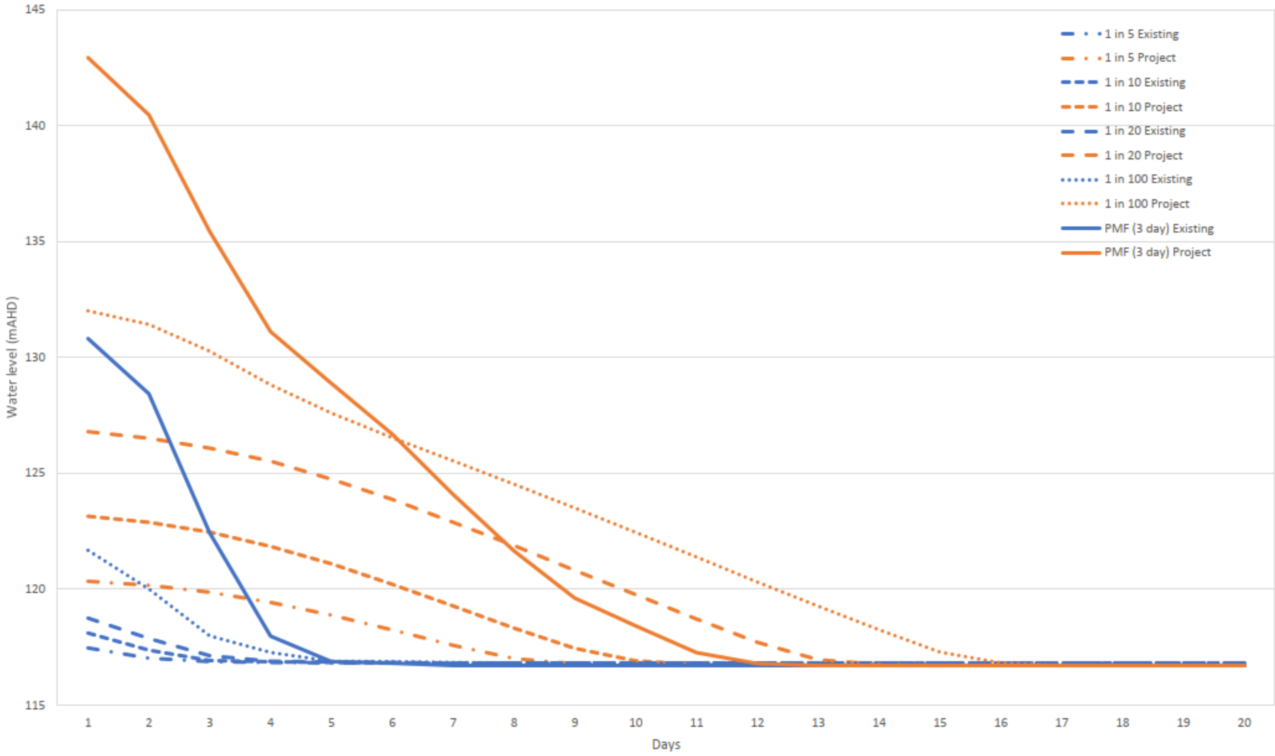


Figure 4-19. Depth-duration curves for NATTAI_5680



Kowmung River

The Kowmung River joins the Coxs River above cross-section COX_1475. Depth-duration curves were examined for two cross-sections on the Kowmung River as follows:

- KOWMUNG_10130 represents the approximate location of the Project PMF event, and the limit of Project influence on the Kowmung River.
- KOWMUNG_13130 is about three kilometres further downstream and represents the approximate location of the Project for the 1 in 100 chance in a year event.

The results of the analysis are summarised in Table 4-6 and the associated depth-duration curves shown in Figure 4-20 and Figure 4-21.

The table also includes the results for the dam wall to facilitate a comparison with the situation at the downstream-most location in the upstream study area, and for cross-section COXS_28800 as an intermediate location within Lake Burragorang.

The analysis indicates:

- increases in the depth and duration of temporary inundation for cross-section KOWMUNG_10130 are less than half a metre and half a day respectively for all events
- increases in the depth of temporary inundation for cross-section KOWMUNG_13130 are less than half a metre up to the 1 in 100 chance in a year event
- increases in the duration of temporary inundation for cross-section KOWMUNG_13130 are less than half a day up to the 1 in 20 chance in a year event, increasing up to 1-2 days for the larger events.

Table 4-6. Upstream changes in temporary inundation depth and duration with the Project: Kowmung River

Location (refer Figure 4-6)	Flood event (1 in x chance in a year)							
	1 in 5		1 in 10		1 in 20		1 in 100	
	E[1]	P[2]	E	P	E	P	E	P
KOWMUNG_10130								
Depth (m)	3.8	<0.5	4.9	<0.5	6.8	<0.5	7.4	<0.5
Duration (days)	5.9	<0.5	5.4	<0.5	6.1	<0.5	5.1	<0.5
KOWMUNG_13130								
Depth (m)	4.1	<0.5	5.6	<0.5	7.0	<0.5	9.4	<0.5
Duration (days)	5.9	<0.5	5.4	<0.5	6.1	<0.5	5.3	2.0
COXS_28800								
Depth (m)	0.7	2.5	1.3	5.1	2.2	9.1	5.1	10.8
Duration (days)	6.8	2.4	6.4	3.8	7.2	8.0	6.4	8.3
Dam wall								
Depth (m)	0.7	2.9	1.3	5.1	1.9	8.2	4.8	10.5
Duration (days)	2.8	4.6	3.4	6	4.0	8.6	4.0	10.8

Notes: 1 – E = existing; 2 – P = additional depth/duration with Project

Figure 4-20. Depth-duration curves for KOWMUNG_10130

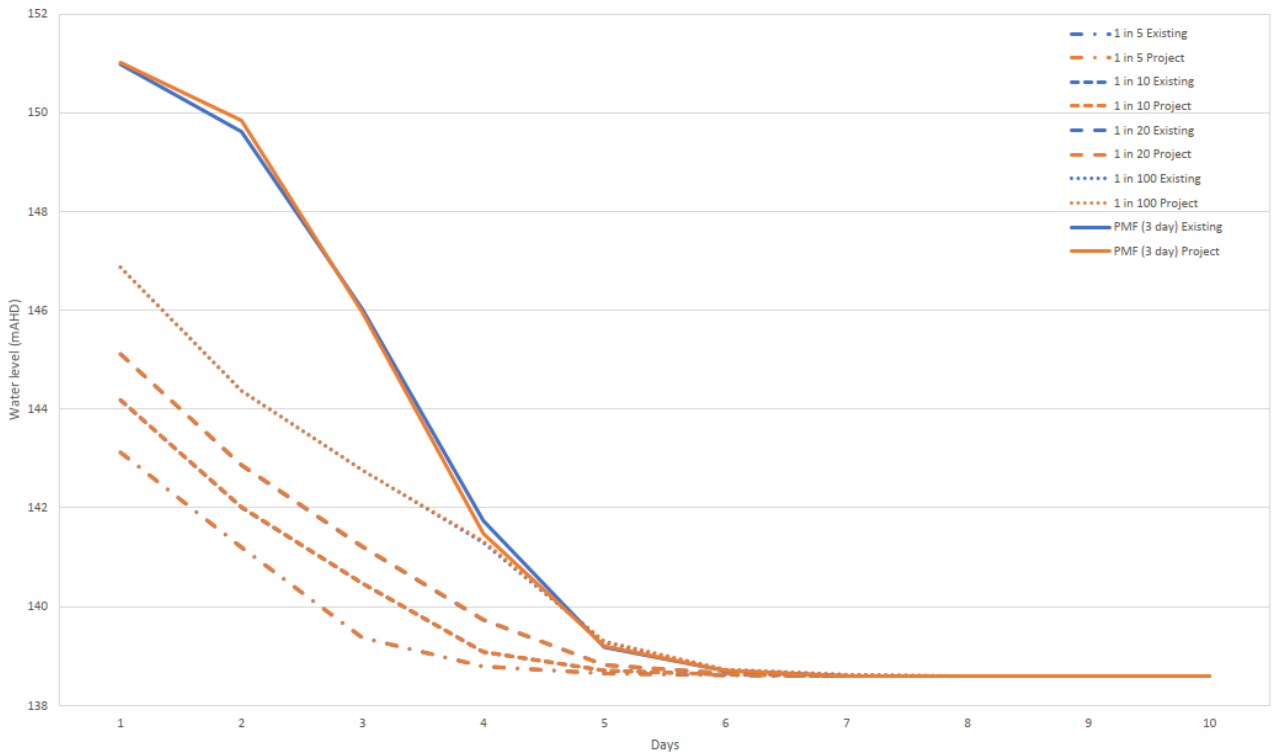
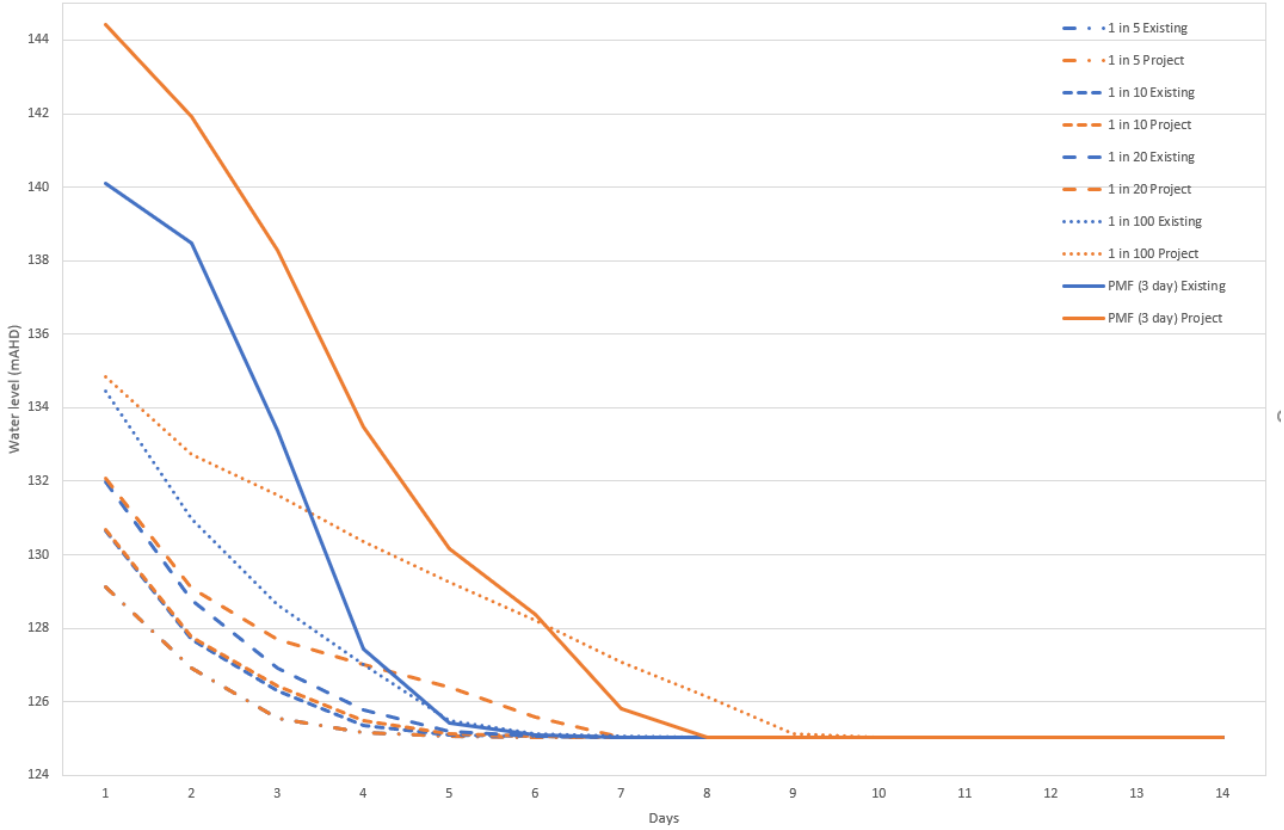


Figure 4-21. Depth-duration curves for KOWMUNG_13130



Summary

For the locations approximating the limit of the 1 in 100 chance in a year event, the analysis shows:

- Increases in the depth of temporary inundation with the Project for all events up to the 1 in 100 chance in a year event would be half a metre or less
- Increases in duration of temporary inundation for all events for the Nattai River and Wollondilly River would be less than half a day
- Increases in temporary inundation for the Kowmung River would be less than half a day up to the 1 in 20 chance in a year event, and about two days for the 1 in 100 chance in a year event
- Increases in temporary inundation for the Coxs River would be less than half a day for up to the 1 in 20 chance in a year event, and then slightly over half a day up to the 1 in 100 chance in a year event (these would not affect the GBMWHA).

There is an increasing influence of the Project moving downstream with the increase in temporary depth and duration of temporary inundation with locations within Lake Burragorang generally reflecting the pattern of changes in depth and duration of temporary inundation for the same flood events at the dam wall.

It should be noted that the analysis is based on individual events from the 20,000 scenarios used in the Monte Carlo analysis and therefore there will be variability across individual events. However, this is not expected to overly influence the trend showing the increasing influence of the Project moving down the catchment toward the dam wall.

4.2.2.2 Changes to flood frequencies

A frequency analysis of the peak flood levels in Lake Burragorang at the dam wall under both existing case and with Project scenarios is presented in Figure 4-22. The frequency analysis shows the increase in peak flood levels for all events considered.

The frequency analysis shows a change in the shape of the frequency curve, with a change in grade occurring between the 1 in 20 chance in a year event to the 1 in 100 chance in a year event. This shows that the relative impact during these smaller order design events is higher than that of the rarer events (that is, greater than the 1 in 100 chance in a year event).

The frequency analysis also shows a leftward shift in the frequency of flood events, with an increase in the frequency of all events of a specified magnitude. For example, a 1 in about 50 chance in a year event under existing conditions would be equivalent to about a 1 in 5 chance in a year event with the Project (that is, a water level that currently occurs on average about once every 50 years would occur on average once every five chance in a years with the Project).

However, the pattern of the leftward shift in the with Project flood frequency curve is not uniform across the upstream catchment and is substantially less further up the catchment as illustrated in Figure 4-22 to Figure 4-26.

These show that for the Wollondilly River and Nattai River there is effectively no material change in flood frequencies. For the Kowmung River, the flood frequency curves start to diverge at about the 1 in 50 chance in a year event. The current 1 in 100 chance in a year event would occur on average about once every 85 years with the Project. For the Coxs River, the curves start to diverge between the 1 in 10 chance in a year and the 1 in 20 chance in a year events. The current 1 in 100 chance in a year event would occur on average about once every 70 years with the Project.

The convergence of the flood frequency curves (reducing leftward shift) with distance up the catchment is better illustrated through Figure 4-27, Figure 4-28 and Figure 4-29. The pattern of the flood frequency curves in Figure 4-27 is very similar to the curves for the dam wall with the flood frequency curves progressively converging moving up the Nattai River.

Figure 4-22. Upstream flood frequency distributions: existing and with Project scenarios at the dam wall

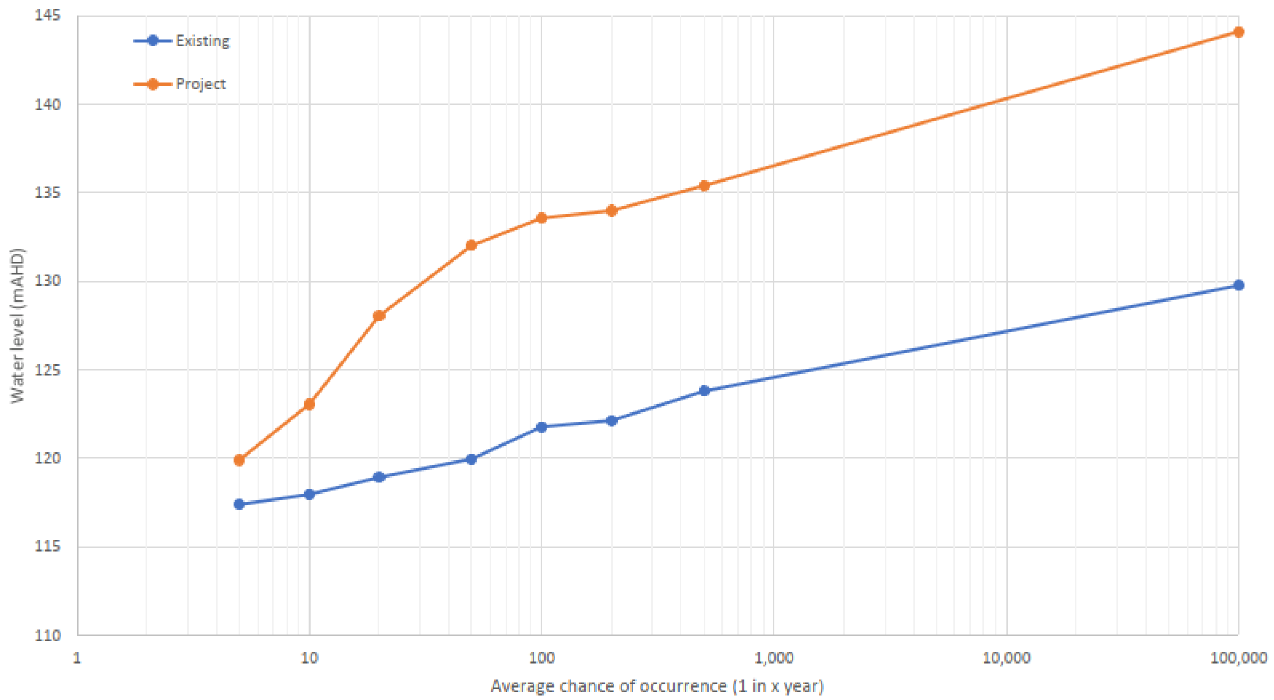


Figure 4-23. Upstream flood frequency distributions: existing and with Project scenarios at NATTAI_US_8700

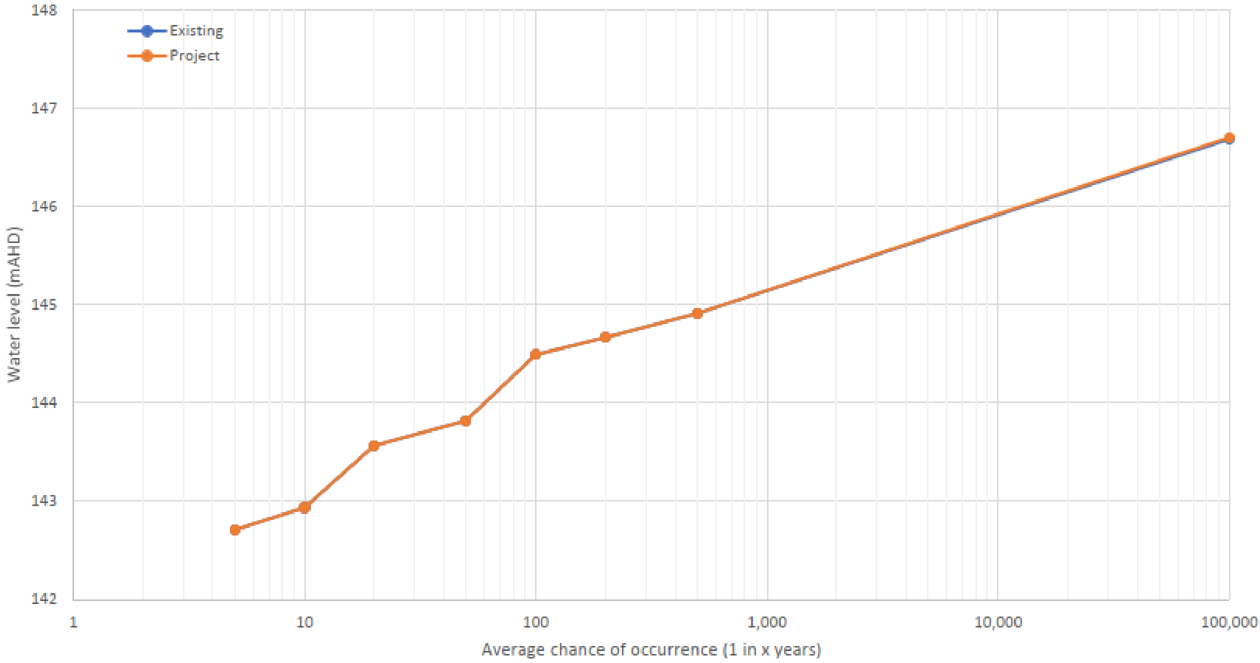


Figure 4-24. Upstream flood frequency distributions: existing and with Project scenarios at WOLLONDILLY_US_6720

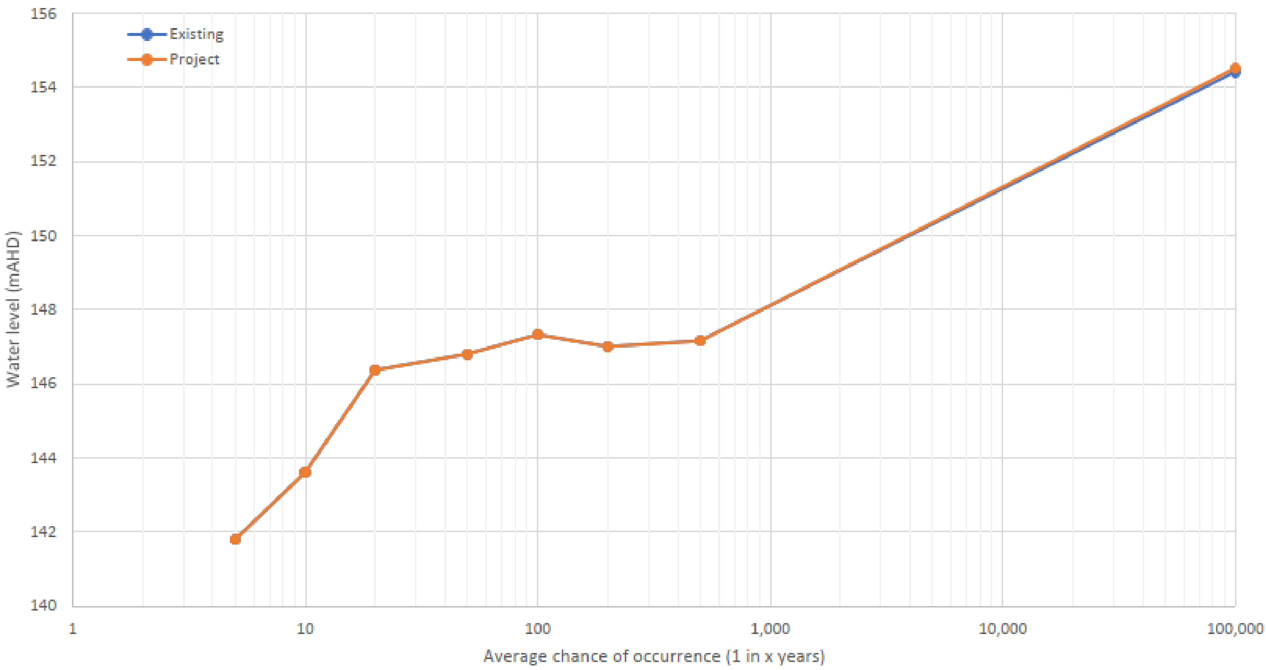


Figure 4-25. Upstream flood frequency distributions: existing and with Project scenarios at KOWMUNG_10130

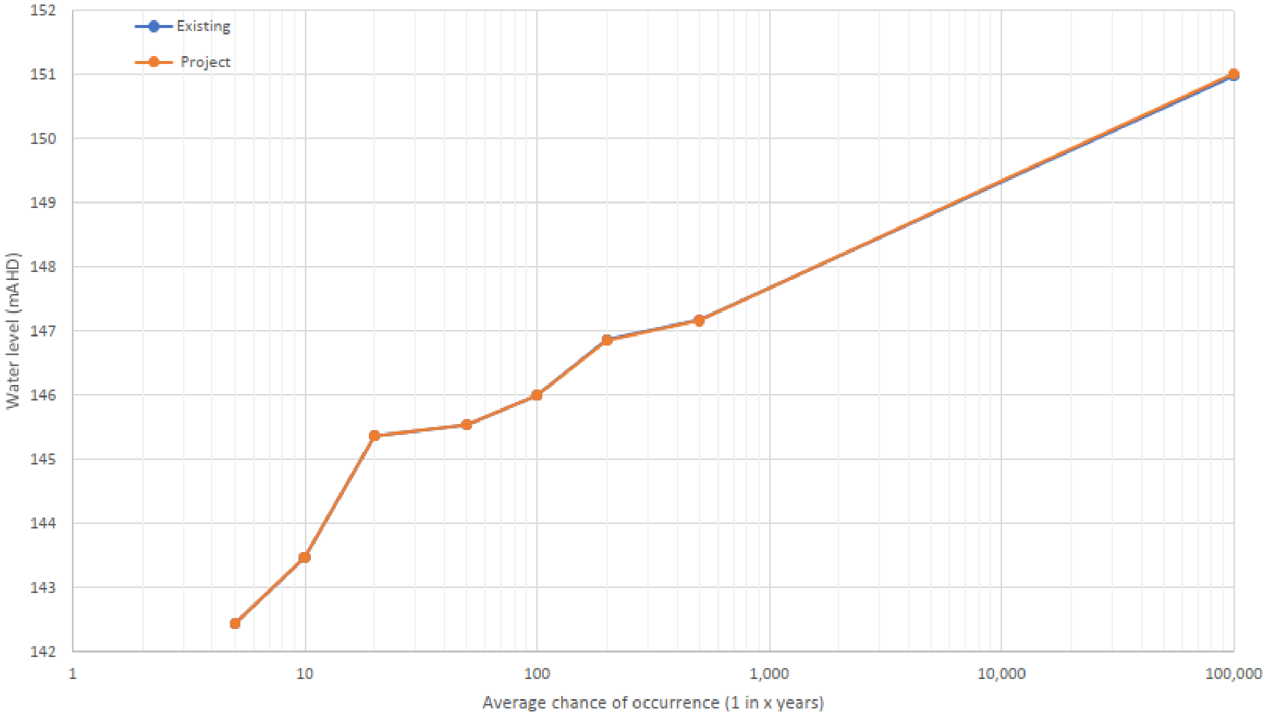


Figure 4-26. Upstream flood frequency distributions: existing and with Project scenarios at COX_US_7335

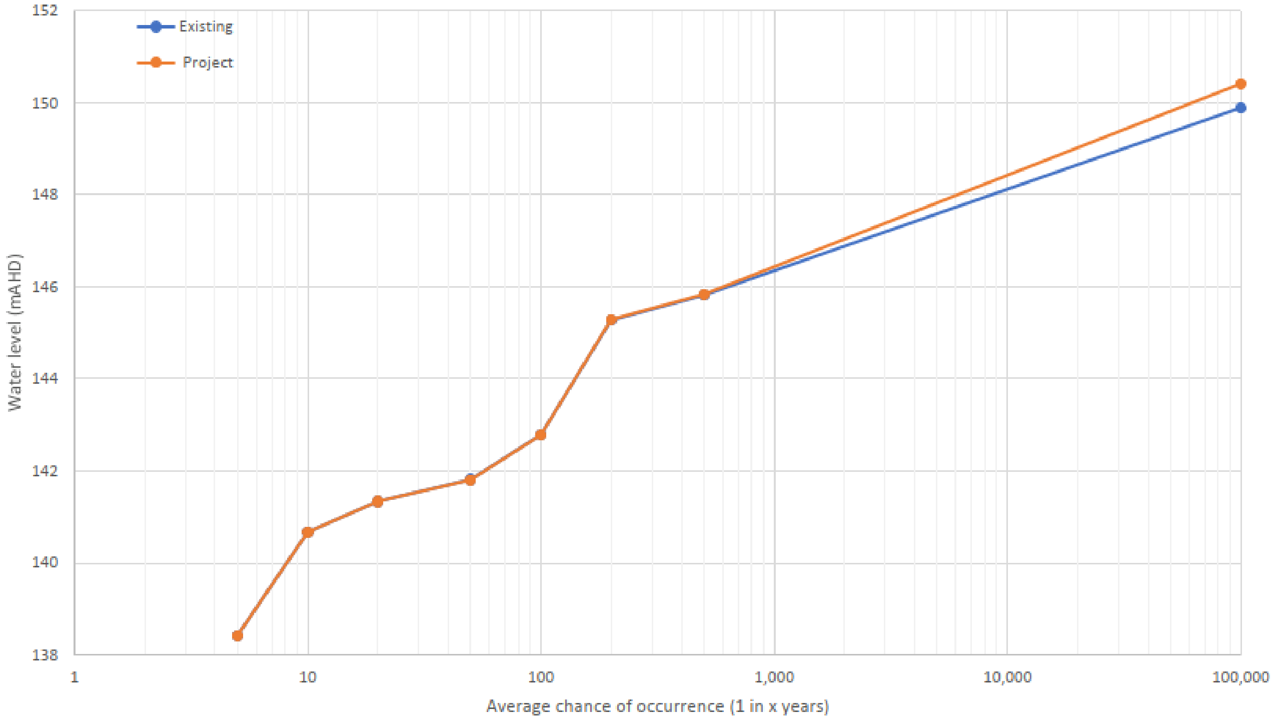


Figure 4-27. Upstream flood frequency distributions: existing and with Project scenarios at NATTAI_5680

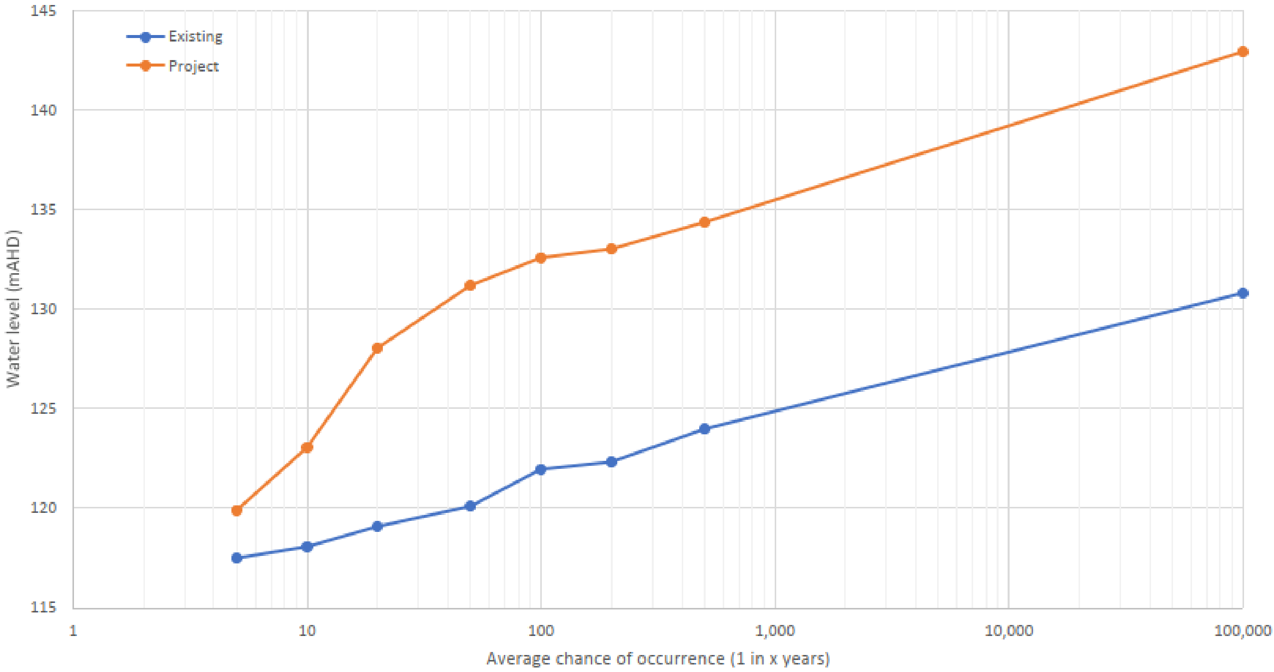


Figure 4-28. Upstream flood frequency distributions: existing and with Project scenarios at NATTAI_1880

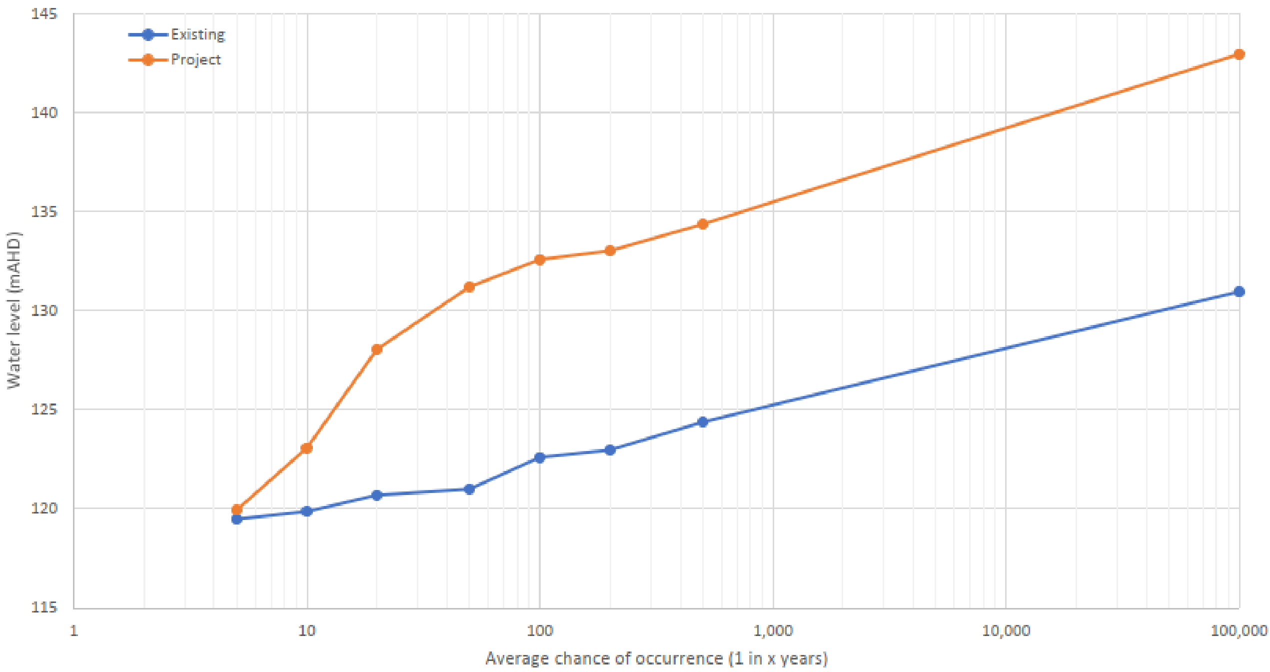
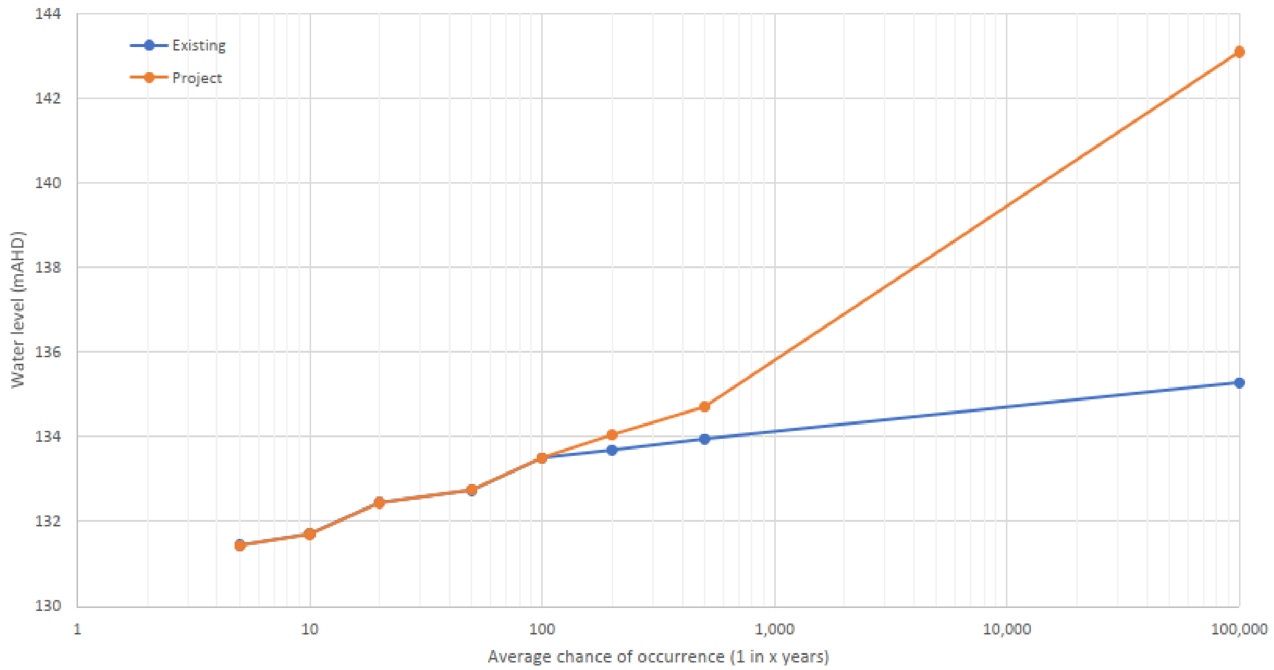


Figure 4-29. Upstream flood frequency distributions: existing and with Project scenarios at NATTAI_11066



4.2.2.3 Changes to flood extents

The inundation extent upstream of Warragamba Dam is controlled by the peak flood level at the dam wall and the topography across the upstream catchment. Areas with steep terrain would have minor increases in flood extent compared to the areas with flatter terrain. The steep valley terrain surrounding Lake Burragorang, which extends from the dam wall upstream for at least 20 kilometres results in the peak flood level inundation extent being contained to a small total land area. Further upstream where key tributaries the Wollondilly River and Coxs River enter Lake Burragorang is notable flatter terrain. As a result, the increase in peak flood level inundation extent from the existing to Project scenario encompasses a larger total area (as elevation increases more gradually).

A comparison of existing flood extent and with Project flood extent for individual flood events identified that the upstream flood extent in tributaries resulted from a combination of the Project and from contributions from the local catchment of the tributary. In order to accurately characterise the potential impacts of the Project, it was therefore necessary to remove the flood extent contributed from the local catchments. This was done through an analysis of depth-duration curves for individual cross sections for each tributary. This allowed identification of the cross-section where the Project started to contribute to the extent of inundation.

Approximate changes to the SEARs flood event extents for the Project study area are summarised in Table 4-7.

Table 4-7. Changes to flood extents within the Project study area

Flood event (1 in x chance in a year)	Flood affected area (ha)		Area change due to Project	
	Existing	Project	Area (ha)	%
5	560	843	283	51
10	754	1,589	835	111
20	926	2,313	1,387	150
100	998	2,910	1,912	192

4.2.3 Summary

The following is a summary of the changes to flooding and hydrology in the catchment upstream of Warragamba Dam. It is stressed that these should not be considered in isolation and it is necessary to consider them holistically when assessing potential impacts of the Project.

The PMF event is used principally as an input to design and, given the scale of the catchment of Lake Burragorang, is highly unlikely to occur in nature. Accordingly, more weight should be given to the flood events with a relatively greater chance of occurrence (and areas that would experience an increased risk of likely inundation due to the Project).

Depth and duration of temporary inundation

For the locations approximating the limit of the 1 in 100 chance in a year event, increases in the depth of temporary inundation with the Project for all events would be half a metre or less.

Increases in duration of temporary inundation for all events considered for the Nattai River and Wollondilly River would be less than half a day.

Increases in temporary inundation for the Kowmung River would be less than half a day up to the 1 in 5 and 1 in 10 chance in a year events, about 1.3 days for the 1 in 20 chance in a year event, and about two days for the 1 in 100 chance in a year event.

Increases in temporary inundation for the Coxs River would be less than half a day for up to the 1 in 20 chance in a year event and then slightly over half a day up to the 1 in 100 chance in a year event.

There is an increasing influence of the Project moving downstream with the increase in temporary depth and duration of temporary inundation, with locations within Lake Burragorang generally reflecting the pattern of changes in depth and duration of temporary inundation for the same flood events at the dam wall.

Flood frequencies

- The Project would result in a shift in the flood frequency curves resulting in events of a specified depth occurring more frequently than currently occurs; this is most pronounced at the dam wall and in Lake Burragorang, and decreases moving up the tributaries
- There is no material difference in the existing and Project flood frequency curves at upstream locations that approximate the extent of the Project PMF (as would be expected).

Flood extents

- The incremental increase in flooding extent due to the Project ranges from 283 hectares for the 1 in 5 chance in a year event (51 percent increase) to 1,912 hectares for the 1 in 100 chance in a year event (192 percent increase)
- The areas of the incremental flood extents are (as would be expected) concentrated around the perimeter of Lake Burragorang but also extend up the tributaries, the distance depending on the magnitude of the flood event; however, as previously noted, the influence of the Project decreases moving up the catchment.

Other Lake Burragorang tributaries

There are a number of other tributaries that drain to Lake Burragorang. The catchments for these tributaries represent very minor contributions to Lake Burragorang relative to the overall Warragamba Dam catchment and accordingly were not included in the upstream modelling. As such, information such as depth-duration curves is not available for any of these tributaries.

4.3 Downstream

4.3.1 Existing hydrology and flooding

Floodwaters flowing into the Hawkesbury-Nepean Valley come from several different river catchments. The largest of these is the Warragamba River catchment, which drains into Lake Burragorang and represents about 80 percent of the catchment at Penrith and 70 percent of the catchment at Windsor. Further inflows downstream of the dam originate from the Nepean River (up to 37 percent), the Grose River (up to 11 percent), South and Eastern Creeks (up to seven percent), and other tributaries (up to 12 percent). While floods can occur without contribution from the Warragamba catchment, larger floods (above the 1 in 100 chance in a year flood) would include significant floodwater inflows from the Warragamba River catchment. However, each flood event is unique due to the timing of rainfall across the Hawkesbury-Nepean Valley catchment.

The inundation extent is controlled by the topography across the floodplain, with floodwaters primarily contained within the channel and highly incised valley floor for some reaches, and widespread inundation in other sections of the floodplain. There are also significant step changes in inundation extents between flood events, for example the reach of the Nepean River from the dam wall to immediately upstream of Penrith is characterised by steep terrain with a highly incised channel, resulting in a narrow flood extent, while near the regional localities of Penrith, Windsor, and Richmond the floodplain is notably flatter and wider, and flood inundation extends over a greater area.

Flooding within the Hawkesbury-Nepean Valley has been described as a 'bathtub' effect, where floodwaters are constrained by river channel choke points to form three main floodplains around Wallacia, Penrith/Emu Plains, and Richmond/Windsor (including backwater flooding in South Creek and Eastern Creek). Downstream from the Richmond/Windsor floodplain, the river winds its way through around 100 kilometres of confined, sandstone gorges to Brooklyn. Along this stretch, numerous small floodplains form in the narrow areas between the river and the steep valley sides.

The Hawkesbury-Nepean Valley has one of the most significant flood risk exposures within Australia. The risk to property and life due to flood exposure is well known and has been the subject of numerous studies, including the Hawkesbury-Nepean Valley Flood Risk Management Strategy (INSW 2017), which was prepared on behalf of the NSW Government. Additional flood modelling was undertaken as part of the Project assessment and outcomes are presented in Appendix H1 (Section 3.20) and summarised below.

Since records began in the 1790s, there have been about 130 moderate to major floods in the valley. The largest flood in living memory was in November 1961 (about a 1 in 50 chance in a year flood), when the water reached 15.7 metres above normal river height at Windsor. The largest flood on record was in 1867 (about a 1 in 500 chance in a year flood), and reached 19.7 metres above normal river height at Windsor, causing massive damage and loss of life (Hawkesbury-Nepean Valley Regional Flood Study 2019). Palaeoflood investigations examined deposits from floods in Fairlight Gorge near the junction of the Nepean and Warragamba Rivers (Saynor & Erskine 1993). Analysis of minerals and radiocarbon dating found that a flood at least eight metres higher than the 1867 flood had occurred in the Holocene (within about the last 10,000 years).

The period from 1901 to 1948 had fewer and smaller floods compared to the period from 1857 to 1900. However, the period from 1949 to 1992 had more frequent and larger floods, despite the completion of Warragamba Dam for water supply in 1960. Six of the top nine flood events in the continuous period of record (1893–present) occur in the last 50 years. While 1867 is the highest ranking event 1961 is the highest in the continuous record. No moderate or major floods have been observed at Windsor since 1992.

Of interest is a recent significant rain event that occurred in February 2020. Downstream flooding was estimated to be about a 1 in 5 chance in a year event. At the time dam was less than 50 percent full, and all upstream inflow was trapped by the dam with no spill. Downstream flooding was therefore wholly a result of local flooding, with no contribution from the Warragamba Dam catchment. This highlights the importance of local downstream flooding in contributing to existing landforms, biodiversity and groundwater characteristics.

4.3.2 Potential flooding with the Project

4.3.2.1 Changes to flood levels and duration of temporary inundation

The FMZ would delay and attenuate the progression of inflows coming from the upstream Warragamba catchment, which in turn would reduce the severity of regional flood events impacting on the downstream Hawkesbury-Nepean Valley. While the Project would significantly reduce flood risk, it would not eliminate it completely. Flooding from other catchments such as the Nepean, Grose, Colo and South Creek can also contribute significantly to downstream flooding.

Peak dam outflows for existing and Project scenarios are given in Table 4-8 which shows a reduction in peak outflow at the dam wall for all modelled events.

Table 4-8. Peak dam outflows for existing and Project scenarios for a range of flood events

Flood event (1 in x chance in a year)	Existing scenario (m^3/s)	Project scenario (m^3/s)	Peak outflow change at dam wall (m^3/s)
5	2,271	810	-1,461
10	4,430	1,160*	-3,270
20	6,860	1,160*	-5,700
100	9,660	3,800	-5,860
200	11,061	5,943	-5,118
500	13,019	8,862	-4,157
PMF	40,950	36,390	-4,560

* Discharge rate of FMZ (100 gigalitres per day)

Figure 4-30 shows the discharge (outflow) hydrographs from Warragamba Dam for the 1 in 20 and 1 in 100 chance in a year events for existing and with Project. As can be seen, the FMZ substantially reduces the peak of the hydrographs but this is offset by an extended period where downstream flows remain above normal until the FMZ is emptied.

Figure 4-30. Discharge hydrographs at Warragamba Dam: 1 in 20 and 1 in 100 chance in a year flood events

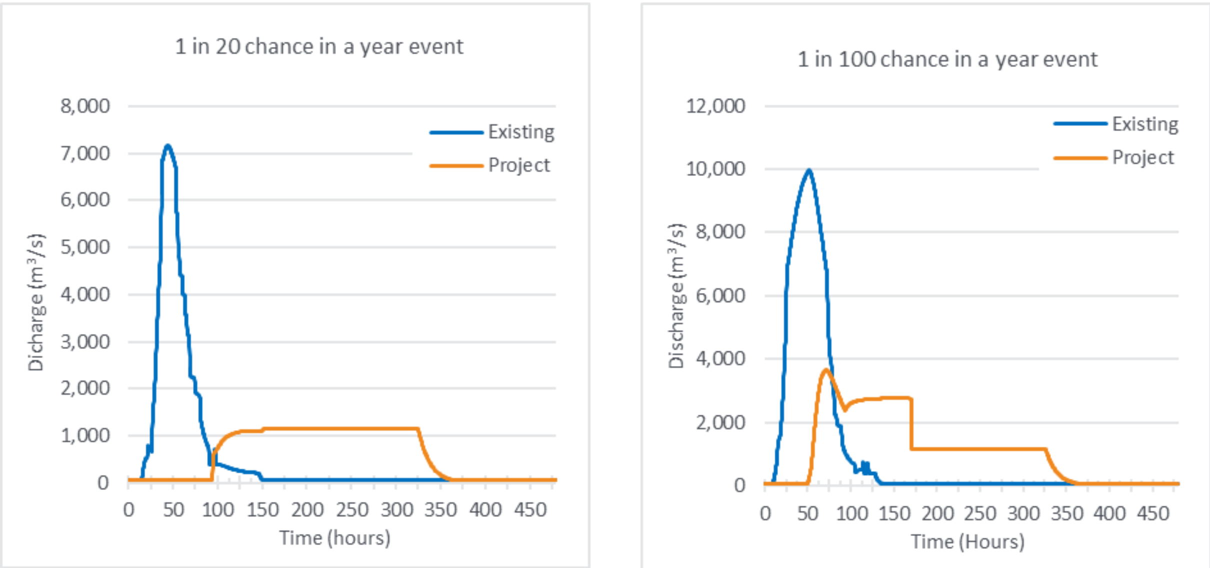
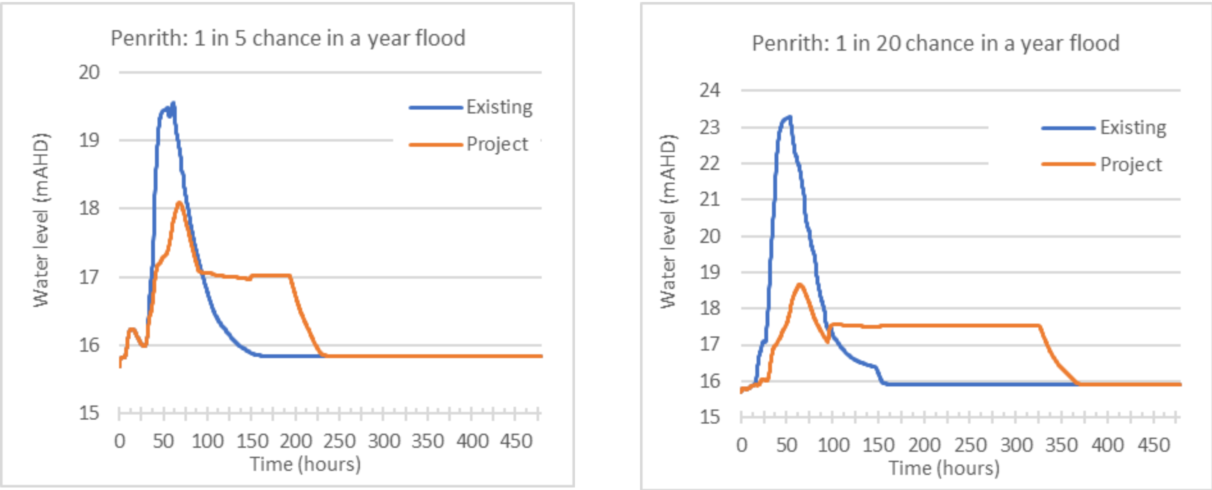


Figure 4-31 shows the hydrographs (as water levels) further downstream of the dam at Penrith for the 1 in 5 and 1 in 20 chance in a year events. As can be seen, the general shape of the existing and Project hydrographs are generally similar to the outflow hydrographs at Warragamba Dam shown in Figure 4-30.

Figure 4-31. Flood hydrographs at Penrith: 1 in 5 and 1 in 20 chance in a year floods

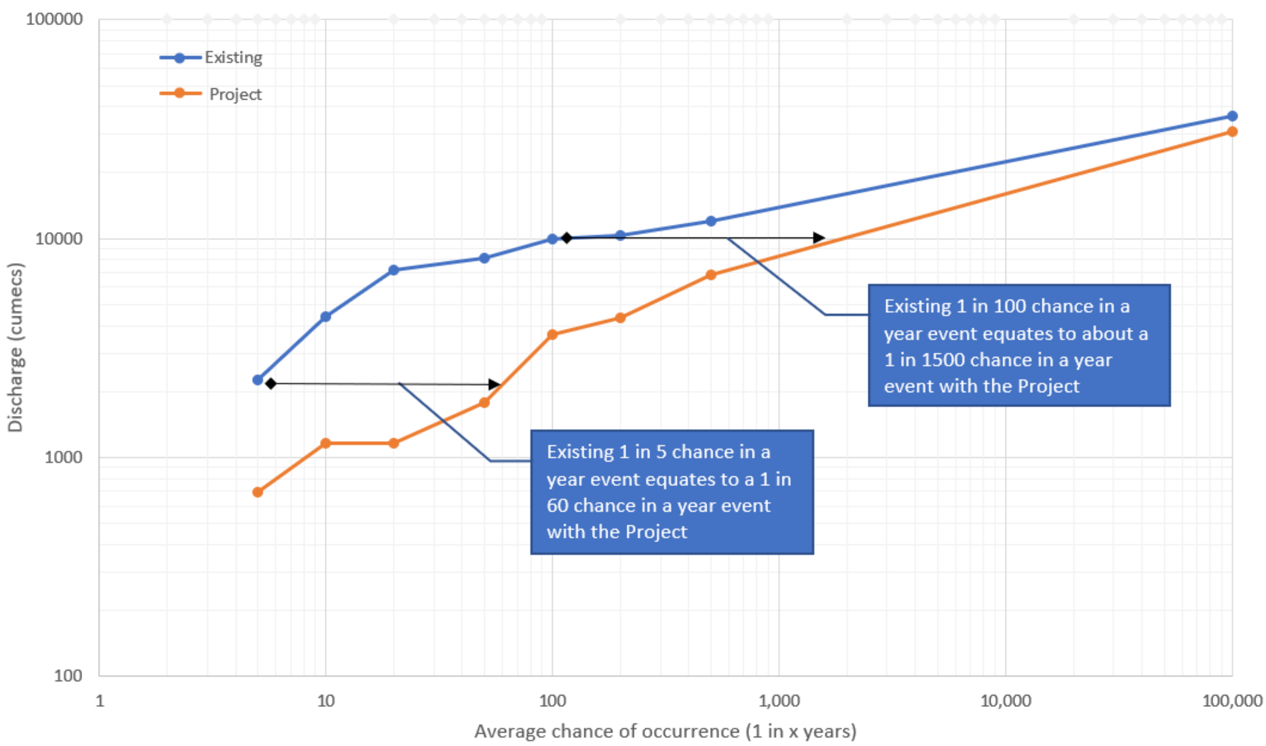


Operation of the FMZ is reflected in the 'plateau' in the falling limb of the Project hydrographs. For the 1 in 5 chance in a year event, the additional duration of elevated water level would be about 3.2 days; for the 1 in 20 chance in a year event, it would be about 8.8 days. These elevated flows would remain within the main channel of the Hawkesbury River and not spill onto the floodplain.

4.3.2.2 Changes to flood frequencies

Figure 4-32 shows the frequency distributions of dam outflows for the existing and Project scenarios (a nominal 1 in 100,000 chance in a year has been used to represent the PMF event).

Figure 4-32. Frequency distributions of dam outflows for existing and Project scenarios



This shows:

- A reduction in magnitude for an outflow event of a specific chance of occurrent; for example, a 1 in 5 chance in a year outflow event reduces from about 2,260 m^3/s (cubic metres per second or cumecs) to about 690 m^3/s while the 1 in 100 chance in a year outflow event reduces from about 9,970 m^3/s to about 3,650 m^3/s
- An overall shift to the right for the Project flood frequency curve representing a lesser chance of occurrence for an outflow event of a specific magnitude.

As illustrated by the annotations, the existing 1 in 5 chance in a year outflow event becomes a relatively less frequent event with the Project, having about a 1 in 60 chance in a year of occurring. Similarly, the existing 1 in 100 chance in a year outflow event becomes a rarer 1 in 1,500 chance in a year outflow event.

4.3.2.3 Changes to flood extents

Greater Blue Mountains World Heritage Area

The Project would result in the reduced extent and duration of large floods in both the Warragamba/Nepean River area and the Lower Colo area. Estimated changes in flooding extents for the SEARs floods events for the Nepean/Warragamba Rivers (Blue Mountains National Park) and the Lower Colo River (Yengo National Park) are presented in Table 4-9.

Table 4-9. Areas of downstream GBMWHA in the study area affected by flooding

Location	Flood event (chance in a year)	Existing area affected within study area (ha)	Area affected within study area with Project (ha)	Change in area (ha)
Blue Mountains National Park	1 in 5	80.5	32.1	-48.4
	1 in 10	87.3	51.4	-35.9
	1 in 20	120.8	75.8	-45.0
	1 in 100	177.0	147.8	-29.2
Yengo National Park	1 in 5	0.0	0.0	0.0
	1 in 10	0.0	0.0	0.0
	1 in 20	0.0	0.0	0.0
	1 in 100	0.4	0.1	-0.3

Old Great North Road World Heritage Area

The Old Great North Road World Heritage Area is currently unaffected by all SEARs events up to the 1 in 100 chance in a year event and this would not change with the Project

4.3.3 Summary

- the area downstream of Warragamba Dam would experience a reduction in the height of flood peaks compared to the existing situation
- operation of the FMZ would result in an increase in elevated water levels until the FMZ had been emptied; these flows would remain within the main channel of the Hawkesbury River and would not spill onto the floodplain
- downstream flood events would continue to be influenced by inflows from other catchments
- the frequency of flood events of a specific chance of occurrence in a given year would reduce, that is, they would be less frequent than currently occurs
- the downstream area of the GBMWHA would experience a reduction in the extent of flooding with the Project compared to the existing situation

- the Old Great North Road World Heritage area is currently unaffected by all the SEARs flood events with the exception of the PMF event; with regard to this event, the area of flooding would reduce by about half a hectare to about 0.6 hectares.

5 Upstream impact area

The upstream study area comprises the maximum extent of flood prone land estimated from the probable maximum precipitation and resultant inundation. The probabilistic nature of flooding in the upstream study area presents a challenge in identifying appropriate flood events to inform an assessment of potential impacts, and noting that for a specific flood event of a particular chance of occurrence, there is already an existing potential impact associated with that particular flood event.

For the upstream study area, potential impacts would be principally associated with the effects of temporary inundation from operation of the FMZ, the lower limit of which is the existing FSL. The exact nature of the impacts would be dependent on multiple factors such as:

- the timing and magnitude of the rainfall events
- catchment conditions at the time of the rainfall event
- the existing storage level
- the duration, depth and extent of inundation for an individual flood event
- the potential change in vegetation integrity as a result of the differing responses of individual plant species to different inundation regimes
- the type and condition of Aboriginal cultural heritage items and places.

These and other factors contribute to substantial uncertainty with regard to quantifying the potential impacts on World Heritage values, notably biodiversity values and Aboriginal cultural heritage.

In view of this, it was determined that a different approach to assessing potential impacts was required in order to provide relative greater certainty around potential impacts and importantly, to provide a more objective basis for identification and development of mitigation measures. The approach taken has been to identify an ‘impact area’ that takes account of the variability of flood events and their extent over time.

Floods are all uniquely different depending on the conditions in place when the event occurs. For example, if a flood occurs during a drought when a dam is half empty, upstream inundation levels would be lower than if the dam had been full. Conversely, if a flood occurs soon after previous rain then greater inflows would occur and with the dam being already quite full, more upstream inundation would result.

Flood behaviour in the Hawkesbury Nepean Valley has been shown to have distinct multi-decade wet and dry periods that have been quite consistent since records began in 1799 (Infrastructure NSW 2019). Table 5-1 lists the large flood events that have occurred over the life of Warragamba Dam. There have been about 37 flood events that have caused the lake level to rise above FSL. The November 1961 flood is the flood of record since the dam was constructed.

Table 5-1. Summary of large historical flood events for Warragamba Dam

Event	Peak dam level (mAHD)	Inundation depth above FSL (m)	Downstream probability of occurrence (1 in x chance in a year)
November 1961	119.51	2.79	37
June 1964	118.89	2.17	25
June 1975	118.15	1.43	13
March 1978	118.01	1.29	19
April 1988	118.06	1.34	13
August 1990	118.72	2.00	22
March 2021	118.26	1.54	10 to 20[1]

1. At the time of preparation of this report, the probability of occurrence for this event had still to be confirmed.

A review of the historical record identified at least one large flood above FSL would occur within a 20 year period. Building on previous hydrological modelling carried out for the Project, further modelling was undertaken to assess the likely level of inundation upstream of the dam. Around 20,000 Monte Carlo simulated events were used to generate a 200,000 year flood record. This included the full range of possible events based on the latest hydrology analyses. This was then analysed by selecting the maximum inundation level in 20 year periods to determine the 'average' or likely inundation level. This was also undertaken for the existing dam scenario so that a comparison of inundation extents could be made.

Since flood behaviour in the Hawkesbury Nepean Valley has distinct multi-decade wet and dry periods, the inundation assessment modelled potential outcomes considering:

- randomly selected periods
- half wet / half dry periods
- wet dominated periods
- dry dominated periods.

The results from all these hypothetical flood sequences were then analysed to determine what the average or likely inundation outcomes would be. In terms of predicted inundation, a sample of key results is provided in Table 5-2 for the existing and raised dam. Sensitivity assessments of the results for the 10^{th}, 50^{th} and 90^{th} percentiles, and the average of all probability outcomes are also provided in Table 5-2 for the existing and raised dam.

Table 5-2. Inundation depths for selected flooding scenarios

Percentile	Existing dam		Raised dam		Increase in depth of inundation (m)	
	Random sequence	Flood/drought sequence	Random sequence	Flood/drought sequence		
	Level (mAHD)	Level (mAHD)	Level (mAHD)	Level (mAHD)	Random sequence	Flood/drought sequence
10	117.94	117.10	122.77	119.12	4.83	2.02
50	119.11	118.77	129.10	128.04	9.99	9.27
90	122.77	122.70	133.09	133.05	10.32	10.35
Average	119.54	119.50	127.05	126.97	7.51	7.47

The average results for the flood/drought sequence were then used to define the upper and lower elevations for the impact area as these were considered to provide the most likely outcome on a statistical basis. These are:

- Lower extent: 2.78 metres above FSL (119.5 mAHD)
- Upper extent: 10.25 metres above FSL (126.97 mAHD).

The likely inundation level for the existing dam is also about the maximum recorded level since construction of Warragamba Dam. For the purposes of the Project, the area between these two levels has been adopted as the upstream impact area. The size of the upstream impact area is about 1400 hectares.

With regard to changes in duration of temporary inundation in the upstream impact area, this would be similar to Lake Burragorang, i.e. an additional duration of about eight and a half days.

The upstream impact area has been used as a means to offset the potential impacts of the Project. For the purposes of offsetting the potential impacts of the Project, it has been assumed that there would be a complete loss of values in this area. In reality, this is unlikely as sensitive areas/sites would have differing risks of impact depending on their respective locations in terms of elevation. Areas/sites at lower elevations would have a greater risk of temporary inundation than areas/sites at higher elevations within the upstream study area.

6 Methodology

The assessment of potential impacts to biodiversity-related MNES was informed by the terrestrial biodiversity and aquatic ecology technical assessments. These are provided in Appendix F1 (Biodiversity assessment report – upstream), Appendix F2 (Downstream ecological assessment), Appendix F3 (Biodiversity assessment report – construction area) and Appendix F4 (Aquatic ecology assessment report). These technical assessments provide specific detail on the assessment methodology for these aspects.

The methodology for the terrestrial and aquatic biodiversity assessments was informed by relevant legislation, policy and guidelines including:

- *Matters of National Environmental Significance Significant Impact Assessment Guidelines 1.1* (Department of the Environment (DoE) 2013)
- *Framework for Biodiversity Assessment*: NSW (OEH 2014a)
- *NSW Biodiversity Offsets Policy for Major Projects* (OEH 2014c)
- *Policy and Guidelines for Fish Habitat Conservation and Management* (Fairfull 2013)
- *Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings* (Fairfull & Witheridge 2003).

Prior to the biodiversity assessment commencing, concurrence was sought from the former OEH and DoEE with regard to the terrestrial biodiversity field survey extent and assessment parameters. Both agencies agreed that for the terrestrial biodiversity assessment:

- MNES would be assessed relative to the future PMF, that is, with a raised dam
- the survey extent would align with the 1 in 100 chance in a year (1% AEP) flood extent.

Subsequent to this, it was then agreed that offset requirements would be determined relative to the upstream impact area. As noted in Section 5, for the purposes of offsetting the potential impacts of the Project, a precautionary approach has been adopted in that it has been assumed that there would be a complete loss of values in this area.

For the purpose of the terrestrial biodiversity assessment, the Project study was split into:

- upstream: bounded by the full supply level and the upstream PMF extent with the Project
- construction: effectively the area at and immediately around the dam where construction activities would occur
- downstream: bounded generally by the downstream PMF extent with the Project.

A description of the existing environment of the Project study area was developed through a desktop assessment and field observations. The desktop assessment included interrogation of relevant databases, a review of relevant literature and technical reports. Field studies were conducted to record biodiversity information relevant to the Project, and to ground-truth the results from the desktop assessment.

The biodiversity assessments for the upstream and construction study areas were prepared in accordance with the FBA. The assessment of biodiversity values included database searches, a literature review, desktop vegetation mapping, and field studies.

The FBA does not provide for assessment of downstream impacts from changes to hydrology and environmental flows on surface vegetation or GDEs (refer Section 2.3.1.2 of the FBA). In view of this, the downstream biodiversity assessment was carried out in accordance with the draft *Threatened Biodiversity Survey and Assessment: Guidelines for Developments and Activities* (DECC 2004).

6.1 Framework for Biodiversity Assessment

The biodiversity assessment for the upstream and construction study areas was prepared in accordance with the FBA. The FBA:

- Underpins the Biodiversity Offsets Policy for Major Projects. It contains the assessment methodology that is adopted by the policy to quantify and describe the impact assessment requirements and offset guidance that apply to Major Projects.
- Sets out requirements for assessment of biodiversity values and measures required to offset unavoidable impacts and prepare a BOS. The BOS details a strategy the proponent would carryout post-approval in order

to satisfy any offset requirements for the Project, and would include the likely and prioritised actions to be taken for acquiring offsets in line with approved measures.

The FBA is undertaken in three stages:

- Stage 1 – Assessment of biodiversity values, comprising:
  - Landscape values of the development site. These include landscape features defined by their noted importance, Interim Biogeographic Regionalisation for Australia (IBRA) bioregions and subregions, Mitchell landscapes, waterways, wetlands, native vegetation extent in the assessment circles, biodiversity links and any other landscape features.
  - Biodiversity values of native vegetation on the development site: Includes mapping the extent of native vegetation, identify Plant Community Types (PCTs) and ecological communities, undertake floristic site surveys, identify any threatened ecological communities, identify vegetation zones, assess site value (vegetation condition), undertake plot & transect site surveys, and assess site value score.
  - Biodiversity values of threatened species. This includes interrogating the Threatened Species Profile Database, assessing species that can be predicted by habitat surrogates (ecosystem credits), assessing species that cannot be predicted by habitat surrogates (species credits), undertake threatened species survey.
- Stage 2 – Impact assessment (biodiversity values), comprising:
  - Avoid and minimise impacts on biodiversity values. Sets out the actions that must be undertaken to demonstrate that reasonable measures are taken to avoid and minimise the direct and indirect impacts of a proposal on biodiversity values.
  - Thresholds for the assessment and offsetting of unavoidable impacts of development. Sets out the impact thresholds for landscape features, native vegetation, and threatened species and populations, and impacts on biodiversity that require further consideration.
  - Determining offset requirement. Includes calculating: credit requirement, the future site value score for vegetation zones on the development site and the change in the site value score for vegetation zones on the development site; and implement offset rules for biodiversity values.
- Stage 3 – Biodiversity offsets strategy, comprising:
  - Deliver long-term conservation gain for threatened entities impacted by the Project. Includes sourcing credits from market, establishing an offset site, carrying out supplementary measures, payment into Biodiversity Conservation Trust Fund.

6.2 Database searches

Information relating to the terrestrial and aquatic biodiversity of the Project study area was obtained from a variety of sources including numerous State and Federal databases. These are summarised in the following table.

Table 6-1. Summary of database searches

Name and source	Description
Protected Matters Search Tool (DAWE)	The Protected Matters Search Tool (PMST) identifies MNES protected under the EPBC Act that may occur within or relate to the 'defined' Project study area. The PMST predicts the potential presence of species or ecological communities in an area based on bioclimatic modelling, known distribution and habitat preferences.
Directory of Important Wetlands in Australia (DAWE)	The Directory of Important Wetlands in Australia identifies nationally important wetlands and provides a substantial knowledge base of what defines wetlands, their variety, and the many flora and fauna species that depend on them. It also contains information about their social and cultural values and some of the ecosystem services and benefits they provide.
Species Profiles and Threats Database (DAWE)	The Species Profiles and Threats (SPRAT) database provides information about species and ecological communities listed under the EPBC Act. This includes descriptions of the species, population and distribution, habitat, movements, feeding, reproduction and taxonomic comments.

Name and source	Description
Mitchell Landscapes NSW OEH v3 2011 Bioregional Assessment Source Dataset (NSW Department of Environment, Climate Change and Water)	The Mitchell Landscapes database provides descriptions of Mitchell Landscapes for each recognised bioregion.
Atlas of NSW Wildlife (BioNet) (DPIE)	BioNet is the repository for biodiversity data and provides comprehensive, credible and robust information on biodiversity in NSW.
Threatened Biodiversity Profile Search (DPIE)	The Threatened Biodiversity Profile Search tool allows proponents to search for threatened flora, fauna, and communities with NSW.
BioNet Vegetation Classification	Information about the NSW vegetation communities is maintained in the BioNet Vegetation Classification database. This includes Plant Community Types (PCTs), the master community-level typology used in NSW's planning and assessment tools and vegetation mapping programs.
Biodiversity Values Map and Threshold tool (DPIE)	The Biodiversity Values Map and Threshold Tool provides information on areas of biodiversity value that would require application of the biodiversity assessment method should actions be proposed in the vicinity.
BioBanking Credit Calculator (DPIE)	The BioBanking Credit Calculator is a tool used to determine the credits associated with individual species or communities that require offsetting due to impacts associated with development projects.
Atlas of Groundwater Dependent Ecosystems (Bureau of Meteorology)	The Groundwater Dependent Ecosystems Atlas (GDE Atlas) was developed as a national dataset of Australian GDEs to inform groundwater planning and management. It is the first and only national inventory of GDEs in Australia.

6.3 Desktop vegetation mapping

Prior to field studies, a review of previously collated vegetation mapping and relevant literature was undertaken. This comprised the following information sources:

- Warragamba_VISmap_2380 (NPWS 2003b)
- the Native Vegetation of the Warragamba Special Area (NPWS 2003b)
- the Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands Version 1.0 (Tozer *et al.* 2010)
- BioNet Vegetation Classification System (OEH 2017)
- Spatial Information eXchange (DFS 2017)
- Remnant Vegetation of the western Cumberland subregion 2013 Update. VIS_ID 4207 (OEH (20122015: Covers the Western Sydney portion of the Project study area that occurs from the Warragamba Dam wall in the south-west, to Sackville in the north-east
- the natural vegetation of the St Albans 1:100,000 mapsheet (Ryan, Fisher & Schaeper 1996): Covers the Project study area north of Sackville and along the Colo River
- DECC (2008); The Native Vegetation of Yengo and Parr Reserves and Surrounds: Covers the area north of the Colo River.

6.4 Field studies

Field studies were undertaken to further refine the existing terrestrial and aquatic biodiversity values of the Project study area as determined through the desktop literature review and database searches, including verification of the likelihood of occurrence of EPBC Act listed flora, fauna and communities. Verification was based on observations of flora, fauna, fauna traces or suitable habitat for flora and fauna species. Prior to commencement of field studies, desktop information was reviewed to identify specific areas or species to be targeted for the surveys.

The field survey was limited to areas that were publicly accessible (for example, national parks and state conservation areas). Given the survey area encompassed hundreds of private lots, obtaining permission to access these lots presented a significant limitation. As such, field validation across the Cumberland Plain and the Colo region (from Warragamba Dam to Lower Colo) concentrated on publicly accessible land to inform vegetation mapping validation and fauna habitat assumptions.

6.4.1 Native vegetation surveys and mapping

Flora field surveys comprised vegetation mapping, plot and transect surveys as per the FBA. Survey details are provided in Appendix F1 of the EIS (Biodiversity assessment report – upstream), Appendix F2 of the EIS (Downstream ecological assessment), and Appendix F3 of the EIS (Biodiversity assessment report – construction area).

6.4.1.1 Upstream

- Vegetation surveys within the upstream study area were conducted between 11 October 2017 and 18 January 2019 over a period of approximately 39 non-consecutive weeks.
- PCTs occurring within the upstream study area were initially stratified into areas represented by the locally-defined vegetation communities. These were subsequently divided into different condition classes, which resulted in the creation of 19 vegetation zones. As per the FBA, floristic plots and plot and transect surveys were conducted to verify the PCTs and collect site value data from the identified vegetation zones.
- Vegetation mapping, PCT identification as well as floristic plots and plot transect surveys were undertaken concurrently, with periodic refinements during the survey period.
- Ninety-five plot and transects sites were surveyed. Plot and transect maps are provided in the Appendix F1 of the EIS (Biodiversity assessment report - upstream).
- Identification of the PCTs occurring within the upstream study area was guided by the information review, site surveys and a review of the PCTs held within the Vegetation Information System (VIS) Classification Database. Consideration was given to the following:
  - occurrence within the Sydney Basin and South Eastern Bioregions and relevant subregions
  - vegetation formation
  - landscape position
  - dominant upper, mid and ground strata species
  - Pedology and edaphics.
- PCTs occurring within the upstream study area were initially stratified into areas represented by the locally-defined vegetation communities. These were subsequently divided into different condition classes, which resulted in the creation of 19 vegetation zones. PCTs were matched to conforming TECs where relevant.

6.4.1.2 Construction area

- Field surveys were undertaken between October 2017 and October 2018.
- Floristic plots were conducted at 13 sites within and adjacent the construction study area to verify PCTs and collect site value data from the identified vegetation zones. These sites were also used for plot and transect surveys of each vegetation zone.
- Identification of PCTs occurring within the Project study area considered the following:
  - review of available information and site surveys
  - occurrence within the Wollemi, Burragorang, and Cumberland IBRA subregions
  - vegetation formation
  - landscape position
  - soil type and edaphics
  - dominant upper, mid and ground strata species.
- PCTs occurring within the construction study area were initially stratified into areas represented by the locally-defined vegetation communities. These were subsequently divided into different condition classes, which resulted in the creation of five vegetation zones. PCTs were matched to conforming TECs where relevant.

6.4.1.3 Downstream

- Field surveys were undertaken between November 2017 and April 2018.
- Twenty-four PCTs were identified that were then stratified across six different condition classes; where applicable, PCTs were matched to conforming TECs where relevant
- One hundred and four plot and transects sites were surveyed. Plot and transect maps are provided in the Appendix F2 of the EIS (Downstream ecological assessment).

6.4.2 Threatened species surveys

The type and occurrence of threatened species and populations that could potentially be impacted by the Project were appraised in accordance with the FBA, which includes assessment of:

- Existing data: develop a list of species and populations potentially occurring within the Project study area. This information was used to determine candidate ecosystem credit species and species credit species.
- Ecosystem credits: a measurement of the value of PCTs, endangered ecological communities (EECs), critically endangered ecological communities (CEECs), and threatened species habitat for species that can be reliably predicted to occur within a PCT. Ecosystem credits measure the loss in biodiversity values at a development site and the gain in biodiversity values at an offset site. Ecosystem credit species were determined using the following criteria:
  - Interim Biogeographical Regionalisation of Australia (IBRA) subregions
  - associated PCTs
  - condition of vegetation: moderate to good (all vegetation zones).
- Species credit species: the class of biodiversity credits created or required for the impact on threatened species that cannot be reliably predicted to use an area of land based on habitat surrogates. Species that require species credits are listed in the Threatened Species Profile Database. Candidate species were identified in accordance with Section 6.5.1.2 of the FBA. The BioBanking Credit Calculator generates a list of candidate species based on the distribution of the species occurring within the same IBRA subregion as the Project study area and the presence of habitat features and components associated with these species. A wide range of habitat features, and components have been used to assess the presence/absence of species within the Project study area.

Fauna field surveys were based on the survey effort recommendations of *Threatened Biodiversity Survey and Assessment: Guidelines for Developments and Activities - Working Draft* (DEC 2004) regarding the size of the survey sites, broad scale vegetation communities and major sampling stratification units.

Fauna habitat assessments were undertaken to:

- assess the likelihood of presence of threatened fauna species
- assess habitat characteristics including the presence of hollow bearing trees, fallen logs, leaf litter and other ground debris, drainage lines, ponds, the structure of vegetation communities and the presence of fruiting/flowering plant species to assess the habitat suitability for a range of fauna species
- search for signs of fauna activity such as tracks, scats, scratches and notches on trees, as well as any opportunistic sightings, to identify the presence of fauna species
- record habitat information at each sampling site including: height and density of vegetation layers, leaf litter, fallen timber, tree hollows (position on tree and size), stags, rock shelves, soil type, presence of water and any artificial habitats.

6.4.2.1 Upstream and construction areas

The targeted threatened fauna and flora surveys within the upstream and construction study areas comprised the following methodology:

- infrared cameras and hair funnels - targeting nocturnal and diurnal ground-dwelling and arboreal mammalian fauna
- microchiropteran bat surveys - locations chosen with suitable flyways to maximise the potential for bat detection
- diurnal bird surveys - surveys undertaken for woodland birds at dawn and dusk
- cage trapping – surveys undertaken for nocturnal arboreal mammalian fauna
- nocturnal spotlight surveys and call playback – including targeted surveys for the Greater Glider (*Petauroides volans*) and Squirrel Glider (*Petaurus norfolcensis*)
- koala scat assessment
- incidental observations
- parallel field traverse
- random meander surveys through suitable habitat.

A list of the threatened flora species surveyed, the methodologies utilised, and the required effort is provided in Table 6-2.

Table 6-2. Upstream and construction study area threatened flora survey effort

Scientific name	Common name	Survey type	Recorded	SMEC effort (km/hr)	Guidelines required effort (km/hrs)
Acacia clunies-rossiae	Kanangra Wattle	Parallel field traverse, Incidental	Yes	20/40	2,982/1,983
Bossiaea oligosperma	Few-seeded Bossiaea	Parallel field traverse, Incidental	Yes	20/40	2036/1,357
Callistemon linearifolius	Netted Bottle Brush	Parallel field traverse, Incidental	Yes	10/20	798/520
Eucalyptus benthamii	Camden White Gum	Parallel field traverse, Incidental	Yes	48/96	439/281
Eucalyptus glaucina	Slaty Red Gum	Incidental	Yes	5/10	298/199
Grammitis stenophylla	-	Incidental	Yes	0.25/1	41.14/54.72
Grevillea parviflora subsp. *parviflora*	Small-Flower Grevillea	Parallel field traverse, Incidental	Yes	5/10	55/37
Hakea dohertyi	Kowmung Hakea	Parallel field traverse, Incidental	Yes	10/20	1,638/1,092
Pomaderris brunnea	Brown Pomaderris	Parallel field traverse, Incidental	Yes	20/40	1642/1,025
Solanum amourense	-	Parallel field traverse, Incidental	Yes	15/30	2,555/1,563

A list of the threatened fauna species surveyed, the methodologies utilised, and the required effort is provided in Table 6-3.

Table 6-3. Upstream and construction study area threatened fauna survey effort

Method	Target species	Dates	Survey effort	Suggested survey effort
Spotlighting and call playback	Koala, Greater Glider, Squirrel Glider	2 Nov – 7 Dec 2017	15 hours	61 hours at 1 km/hr
Arboreal hair tubes	Squirrel Glider, Brush-tailed Phascogale	17 Oct 2017 – 31 Jan 2018	1,820 trap nights	3,224 trap nights
Ground hair tubes	Southern Brown Bandicoot, Spotted-tail Quoll	24 Oct 2017 – 30 Jan 2018	1,400 trap nights	2,083 trap nights
Arboreal cage traps	Squirrel Glider, Brush-tailed Phascogale	13 Nov – 8 Dec 2017	330 trap nights	656 trap nights
Amphibian surveys	Giant Burrowing Frog, Red-crowned Toadlet, Stuttering Frog	15-16 Nov 2017	40 mins with expert reports prepared for construction area only	Expert reports
Diurnal bird surveys	Regent Honeyeater	2 Nov – 13 Dec 2017	24 hours 40 mins	20 hours over 5 days targeting heavily flowering trees

Method	Target species	Dates	Survey effort	Suggested survey effort
Ultrasonic call detection	Large-eared Pied Bat	23 Oct – 13 Dec 2017	78 trap nights	864 trap nights
Remote sensing cameras	Southern Brown Bandicoot, Spotted-tail Quoll		1,083 nights	No guidelines
	Brush-tailed Rock-wallaby	13 Dec 2017 – 15 Mar 2018	184 nights	No guidelines
	Rosenberg's Goanna	14 Nov – 18 Dec 2017	157 nights	No guidelines
KSAT	Koala	9 Nov – 7 Dec 2017	3 hours 40 mins	No guidelines
Nest boxes	Eastern Pygmy-possum	9 Nov 2017 – 4 April 2018	1,220 trap nights	2,900 trap nights

6.4.2.2 Downstream

The targeted threatened flora and fauna surveys within the downstream study area comprised the following methodology:

- infrared cameras and hair funnels - targeting nocturnal and diurnal ground-dwelling and arboreal mammalian fauna
- microchiropteran bat surveys - locations chosen with suitable flyways to maximise the potential for bat detection
- diurnal bird surveys - surveys undertaken for woodland and wetland birds at dawn and dusk
- nocturnal spotlight surveys and call playback – including targeted surveys for Australasian Bittern (BioBanking Credit Calculator) and Eastern Grass Owl (BioBanking Credit Calculator
- koala scat assessment
- random meanders through suitable habitat and area of known occurrences.
- incidental observations.

Specifically, the survey effort for the threatened flora entailed the following;

- walking meanders through habitat types and PCTs associated with threatened species within the survey area, targeting the following species:
  - *Acacia pubescens*
  - *Dillwynia tenifolia*
  - *Cynanchum elegans*
  - *Epacris purpurascens var. purpurascens*
  - *Grevillea juniperina* subsp. *juniperina*
  - *Marsdenia viridiflora* subsp. *viridiflora*
  - *Micromyrtus minutiflora*
  - *Persoonia hirsuta*
  - *Persoonia nutans*
  - *Pimelea spicata*
- threatened flora population counts for *Acacia pubescens*
- recording of *Dillwynia tenuifolia* individuals.

The survey effort for threatened fauna species was more complex and utilised a variety of survey techniques and methodologies. A summary of the threatened fauna survey effort in the downstream study area is provided in Table 6-4.

Table 6-4. Downstream threatened fauna survey effort

Survey type	Target species	Dates	Survey effort	Description
Infrared cameras	Spotted-tail Quoll Southern Brown Bandicoot	11/4/18 - 1/6/18	408 trap nights	Four infrared camera traps were placed in two locations to target nocturnal and diurnal ground-dwelling mammalian fauna. Cameras (PC900 Hyperfire, Reconyx, USA) were placed 1 m from bait stations which consisted of a PVC pipe containing rolled oats and peanut butter staked to the ground.
Hair funnels	Southern Brown Bandicoot	11/4/18 - 1/6/18	112 trap nights	Next to each camera described above, a single hair funnel was placed using the same bait. This was to aid in the identification of species that are difficult to distinguish in a grey-scale image, should they be detected. Hair samples collected were sent to Barbara Triggs, a recognised expert on the identification of mammalian traces, for identification.
Ultrasonic call detection	Threatened microchiropteran bats with a moderate or high likelihood of occurrence.	17/1/18 - 12/4/18	30 nights	Ultrasonic call detectors (SongMeter4BAT FS, Wildlife Acoustics, USA) were deployed all night (minimum eight hours) for at least two nights per site at six sites to record the echolocation calls of microchiropteran bats (microbats). Locations were chosen as having suitable flyways to maximise the potential for bat detection. Recorded calls were converted to zero crossing using Kaleidoscope (Version 4.1.0a, Wildlife Acoustics, USA), sorted and sent to Dr Brad Law (Principal Research Scientist, NSW Primary Industries) for analysis
Diurnal bird surveys	Threatened wetland birds with a moderate or high likelihood of occurrence.	17/1/18 - 10/4/18	24 hours, 48 mins	Surveys were undertaken for both woodland and wetland birds, targeted wetlands, and vegetation along the Hawkesbury River. Dawn and dusk bird surveys were undertaken within three hours of sunrise and sunset, respectively, by two observers. Eleven sites were surveyed, with most sites being surveyed twice on two separate days. Surveys lasted at least 30 minutes and involved a random meander from the start point where suitable habitat occurred within a two-hectare area. Species were identified visually or by vocalisations using *The Morcombe and Stewart Guide to Birds of Australia* (Cool Ideas LLC, 2014) as a reference guide.
Call playback and spotlighting	Eastern Grass Owl Australasian Bittern	9/4/18 - 13/4/18	14 hours	Call playback was undertaken at three sites in the Colo River catchment. The sites were chosen based on the presence of intact wetland vegetation. The survey included at least two call playback events at each location on separate nights and was preceded by a 10-minute listening period. Recorded calls were then broadcast for five minutes using an MP3 player and megaphone, followed by a 10-minute period of listening for a response. This was followed by localised spotlight searches and subsequent intermittent call playback to check for individuals that may have moved closer to investigate but had not audibly responded. Calls played during the survey included the Australasian Bittern (*Botaurus poiciloptilus*) and Eastern Grass Owl (*Tyto longimembris*).
KSAT	Koala	11/4/18 - 12/4/18	3 sites (90 trees)	30 trees were sampled at each KSAT site. Three sites that provided suitable feed trees for the koala or had historical records of the species' occurrence and were not overgrown by exotic vegetation were surveyed on 11 and 12 April 2018. The following methods from Phillips and Callaghan (The Spot Assessment Technique: A tool for determining localised levels of habitat use by Koalas Phascolarctos cinereus, 2011) were adopted:

Survey type	Target species	Dates	Survey effort	Description
				1. Locate and mark with flagging tape one tree (the focal tree) that meets one or more of the following selection criteria: (a) a tree of any species, beneath which, one or more koala faecal pellets has been observed (b) a tree in which a koala has been observed; and/or (c) any other tree known to be potentially important for the koala (for example, recognised koala food trees). 1. Identify and uniquely mark the 29 nearest koala habitat trees to this tree. 2. Undertake a search for koala faecal pellets beneath each of the 30 marked trees, based on a cursory inspection of the undisturbed ground surface within a distance of 100 centimetres around the base of each tree, followed (if no faecal pellets are initially detected) by a more thorough inspection involving disturbance of the leaf litter and ground cover within the prescribed search area. Only trees greater than ten centimetres diameter at breast height (DBH) or four metres in height were selected. As no previous koala records were known, or evidence of scats observed upon commencement of the survey, a tree recognised as a koala feed tree (as described by 1 (c) above) was utilised as the focal tree. A maximum of two person-minutes per tree was dedicated to the faecal pellet search. The search concluded either once a faecal pellet was found or when the two person-minutes were expired, whichever came first. A brief search of each tree was also made to determine the presence or absence of Koalas. Scat samples collected were sent to Barbara Triggs, a recognised expert on the identification of mammalian traces, for identification.

6.5 Aquatic ecology

Aquatic habitats within the study area were characterised as follows:

- historical conditions assessed through review of 2013 River Styles® mapping; This assessment provides a geomorphological classification and assessment of physical habitat condition of streams within the Hawkesbury-Nepean catchment
- the boundaries of visible meso-habitat features (i.e. sand/gravel shoals, shallow rocky areas, macrophytes) were digitised using geo-rectified aerial photography (Nearmap – 2019)
- bank profiles were interpreted using a digital elevation model (DEM) produced by Shuttle Radar Topography Mission (SRTM - supplied by WaterNSW with 30 m accuracy)
- Strahler stream order was characterised using data obtained through the Australian Government (www.data.gov.au)
- habitat conditions of portions of the Nattai River, Little River, Wollondilly River, Kedumba River and Coxs River were characterised during site surveys undertaken in December 2017.

It is important to note the following mapping limitations: (i) many of the smaller tributary streams in confined (gorge) environments are narrow with a dense riparian canopy, and are therefore difficult to map from remote imagery; (ii) access to Lake Burragorang and its tributary streams is severely constrained (limited tracks, steep/rugged topography), and site inspections were limited to areas accessible by tracks. A mapping confidence level was applied to reflect these limitations.

The Project does not introduce any new obstructions to fish passage upstream or downstream. As such, this issue has not been considered as the Project does not introduce any material changes with regard to existing obstructions.

An aquatic habitat assessment was conducted to characterise the general habitat condition within the upstream reaches of Warragamba Dam. This also served to determine the appropriateness for threatened species habitat at each location. Potential impacts downstream relate mostly to flood flow, for which the main impacts would be within the floodplains of Penrith, Richmond and Windsor. In view of this, a dedicated aquatic habitat assessment was not conducted downstream.

Environmental DNA (eDNA) analysis was used to assess fish species diversity and the presence of Macquarie perch (*Macquaria australasica*) and Australian Grayling (*Prototroctes maraena*) in Lake Burragorang and its tributaries.

Material impacts to downstream habitat preferred by the Macquarie perch (clear, cool, rocky fast-flowing streams with deep holes and riffles) resulting from the project are considered unlikely. However, due to operation of the FMZ, material impacts to upstream habitats preferred by Macquarie perch may occur.

Nine sites were assessed: two on the Nattai River, one on Little River, three on the Wollondilly River, two on the Kedumba River, and one on the upper Coxs River. The aquatic habitat assessment considered:

- records of approximate water depth
- stream flow
- wetted stream width and length
- water clarity
- sediment and water odour
- mesohabitat structures (e.g., pool, riffle, run)
- bank conditions (e.g. undercutting, slope, erosion, overhanging roots)
- substrate composition (e.g. mud, sand, fine gravel, coarse gravel, cobble, rock, bedrock)
- composition and abundance of macrophyte species (e.g. floating, emergent, submerged)
- riparian and in-stream vegetation
- filamentous algae
- leaf litter
- presence of small (less than 15 cm diameter) and large woody debris (more than 15 cm diameter)
- animal activity (e.g. footprints, droppings)
- human activity (e.g. bridges, farms, weirs).

7 Existing ecological environment

The Project study area occurs within the Hawkesbury-Nepean catchment. The Hawkesbury-Nepean catchment covers 21,400 square kilometres[6], from Lithgow in the west, Goulburn in the south, south-east as the Illawarra escarpment and north to Gosford.

Upstream of Warragamba Dam are two major river systems that drain into the reservoir. In the north are the Coxs River and its tributaries, including the Kowmung River, Kedumba Creek, Butcher Creek and Green Wattle Creek. In the south are the Wollondilly river and its tributaries, including the Wingecarribee River, Nattai River, Tonalli River, Byrnes Creek and Jooriland Creek.

The Hawkesbury-Nepean River downstream of Warragamba River junction has been significantly modified with the building of Penrith Weir and subsequent weir pool, extensive historical sand and gravel mining from the river bed and surrounding areas, and the clearing of riparian vegetation. This has been exacerbated by human activity such as wave generated recreational water activities and remedial bank stability works that have redistributed flows (WaterNSW 2016).

The impact of urbanisation along the river and land use changes across the floodplain have altered geomorphic features and river flow characteristics. Between Yarramundi and Windsor, the Hawkesbury River is wide and shallow with numerous shoals restricting navigability. This segment of river is also notably straighter than the other downstream river reaches and includes numerous lagoons and wetlands across the floodplain and lowlands. The channel form and bank stability of the upper estuary at this location are largely influenced by the persistent low flows in the Hawkesbury River. Further downstream below Cattai, the floodplain is narrow and (typically less than 400 metres and non-existent where the river channel is bedrock-controlled (that is, steep sandstone gorge).

7.1 Database records

Table 7-1 provides a list of EPBC Act listed TECs identified through database and mapping information sources as potentially occurring in the Project study area.

Table 7-1. EPBC Act listed threatened ecological communities mapped within the Project study area

Ecological community EPBC Act alignment	EPBC Act status	Potential location
Castlereagh Scribbly Gum and Agnes Banks Woodlands of the Sydney Basin Bioregion	Endangered	Downstream
Cooks River/Castlereagh Ironbark Forest of the Sydney Basin Bioregion	Critically Endangered	Downstream
Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest	Critically Endangered	Downstream
River-flat eucalypt forest on coastal floodplains of southern New South Wales and eastern Victoria	Critically Endangered	Upstream, Downstream
Shale Sandstone Transition Forest of the Sydney Basin Bioregion	Critically Endangered	Construction, Downstream
Turpentine-Ironbark Forest of the Sydney Basin Bioregion	Critically Endangered	Downstream
Western Sydney Dry Rainforest and Moist Woodland on Shale	Critically Endangered	Downstream
White box - Yellow box - Blakely's red gum grassy woodlands and derived native grasslands	Critically Endangered	Upstream

The ecological community *Melaleuca dominated Temperate Swamp Sclerophyll Forests on Coastal Floodplains of Eastern Australia* was identified as potentially occurring in the downstream study area. The community was

[6] NSW Department of Planning, Industry and Environment

nominated for listing as a threatened ecological community in 2017 with the proposed conservation status of ‘endangered’. At the time of preparation of this report, this community was not listed under the EPBC Act.

Table 7-2 identifies EPBC Act listed flora species identified through desktop database and literature searches as potentially occurring in the Project study area.

Table 7-2. EPBC Act listed flora species potentially present within the Project study area

Scientific name	Common name	EPBC Act status
Acacia bynoeana	Bynoe’s Wattle	Vulnerable
Acacia flocktoniae	Flockton’s Wattle	Vulnerable
Acacia gordonii	Gordon’s Wattle	Endangered
Acacia pubescens	Downy Wattle	Vulnerable
Acacia terminalis subsp. *terminalis*	Sunshine Wattle	Vulnerable
Acrophyllum australe	–	Vulnerable
Allocasuarina glareicola	–	Endangered
Asterolasia elegans	–	Endangered
Astrotricha crassifolia	Thick-leaf Star-hair	Vulnerable
Baloskion longipes	Dense Cord-rush	Vulnerable
Bossiaea oligosperma[1]	Few-seeded Bossiaea	Vulnerable
Caladenia tessellata	Thick-lipped Spider Orchid, Daddy Long-legs	Vulnerable
Callistemon megalongensis	Megalong Valley Bottlebrush	Critically endangered
Callistemon purpurascens	–	Critically endangered
Commersonia prostrata	Dwarf Kerrawang	Endangered
Cryptostylis hunteriana	Leafless Tongue Orchid	Vulnerable
Cynanchum elegans	White-flowered Wax Plant	Endangered
Darwinia biflora	–	Vulnerable
Deyeuxia appressa	–	Endangered
Diuris aequalis	Buttercup Doubletail	Vulnerable
Epacris hamiltonii	–	Endangered
Epacris sparsa	Sparse Heath	Vulnerable
Eucalyptus aggregata	Black Gum	Vulnerable
Eucalyptus benthamii	Camden White Gum	Vulnerable
Eucalyptus camfieldii	Heart-leaved Stringybark	Vulnerable
Eucalyptus copulans	–	Endangered
Eucalyptus sp. Cattai	–	Critically endangered
Eucalyptus glaucina[1]	Slaty Red Gum	Vulnerable
Eucalyptus macarthurii	Paddys River Box	Endangered
Eucalyptus pulverulenta	Silver-leaved Mountain Gum, Silver-leaved Gum	Vulnerable
Euphrasia arguta	–	Critically endangered
Euphrasia bowdeniae	–	Vulnerable
Genoplesium baueri	Bauer’s Midge Orchid/Yellow Gnat-orchid	Endangered
Gentiana wingecarribiensis	Wingecarribee Gentian	Endangered

Scientific name	Common name	EPBC Act status
Grevillea cayleyi	Caley's Grevillea	Critically endangered
Grevillea evansiana	Evan's Grevillea	Vulnerable
Grevillea parviflora subsp. *parviflora*	Small-flower Grevillea	Vulnerable
Grevillea shiressii	–	Vulnerable
Hakea dohertyi	Kowmung Hakea	Endangered
Haloragis exalata subsp. *exalata*	Square Raspwort	Vulnerable
Haloragodendron lucasii	Hal	Endangered
Hibbertia puberula subsp. *glabrescens*	–	Critically endangered
Hibbertia spanantha	Julian's Hibbertia	Critically endangered
Homoranthus darwinioides	–	Vulnerable
Isopogon fletcheri	Fletcher's Drumstick	Vulnerable
Kunzea cambagei	Cambage Kunzea	Vulnerable
Kunzea rupestris	–	Vulnerable
Leionema lachnaeoides	–	Endangered
Leptospermum deanei	Deane's Tea-tree	Vulnerable
Leucopogon exolasius	Woronora Beath-heath	Vulnerable
Melaleuca biconvexa	Biconvex Paperbark	Vulnerable
Melaleuca deanei	Deane's Paperbark	Vulnerable
Micromyrtus blakelyi	–	Vulnerable
Micromyrtus minutiflora	–	Vulnerable
Microtis angusii	Angus's Onion Orchid	Vulnerable
Olearia cordata	–	Vulnerable
Pelargonium sp. *Striatellum*	Omeo Storksbill	Endangered
Persicaria elatior	Tall Knotweed	Vulnerable
Persoonia acerosa	Needle Geebung	Vulnerable
Persoonia bargoensis	Bargo Geebung	Vulnerable
Persoonia glaucescens	Mittagong Geebung	Vulnerable
Persoonia hirsuta	Hairy Geebung	Endangered
Persoonia marginata	Clandulla Geebung	Vulnerable
Persoonia mollis subsp. *maxima*	–	Endangered
Persoonia nutans	Nodding Geebung	Endangered
Pherosphaera fitzgeraldii	Dwarf Mountain Pine	Endangered
Phyllota humifusa	Dwarf Phyllota	Vulnerable
Pimelea curviflora var. *curviflora*	–	Vulnerable
Pimelea spicata	Spiked Rice-flower	Endangered
Pomaderris brunnea	Brown Pomaderris/ Rufous Pomaderris	Vulnerable
Pomaderris cotoneaster	Cotoneaster Pomaderris	Endangered
Pomaderris pallida	Pale Pomaderris	Vulnerable

Scientific name	Common name	EPBC Act status
Prasophyllum fuscum	Tawny Leek-orchid, Slaty Leek-orchid	Vulnerable
Prostanthera askania	Tranquillity Mintbush	Endangered
Prostanthera cineolifera	Singleton Mint Bush	Vulnerable
Prostanthera densa	Villous Mint-Bush	Vulnerable
Prostanthera junonis	Somersby Mintbush	Endangered
Prostanthera marifolia	Seaforth Mintbush	Critically endangered
Pterostylis gibbosa	Illawarra Greenhood, Rufa Greenhood, Pouched Greenhood	Endangered
Pterostylis pulchella	Waterfall Greenhood/ Pretty Greenhood	Vulnerable
Pterostylis saxicola	Sydney Plains Greenhood	Endangered
Pultenaea aristata	Prickly Bush-pea	Vulnerable
Pultenaea elusa	Elusive Bush-pea	Vulnerable
Pultenaea glabra	Smooth Bush-pea	Vulnerable
Pultenaea parviflora	–	Vulnerable
Rhizanthella slateri	Eastern Australian Underground Orchid	Endangered
Syzygium paniculatum	Magenta Lilly Pilly	Vulnerable
Rutidosis heterogama	Heath Wrinklewort	Vulnerable
Tetratheca juncea	Black-eyed Susan	Vulnerable
Thelymitra kangaloonica	Kangaloon Sun Orchid	Critically endangered
Thesium australe	Austral Toadflax	Vulnerable
Velleia perfoliata	–	Vulnerable
Wollemia nobilis	Wollemi Pine	Critically Endangered
Xerochrysum palustre	Swamp Everlasting, Swamp Paper Daisy	Vulnerable
Zieria covenyi	Coveny's Zieria	Endangered
Zieria involucrata	–	Vulnerable
Zieria murphyi	Velvet Zieria	Vulnerable

Table 7-3 identifies the EPBC Act listed fauna species identified through desktop database and literature searches as potentially occurring in the Project study area.

Table 7-3. EPBC Act listed fauna potentially present within the Project study area

Scientific name	Common name	EPBC Act status
Heleioporus australiacus	Giant Burrowing Frog	Vulnerable
Litoria aurea	Green and Golden Bell Frog	Vulnerable
Litoria booroolongensis	Booroolong Frog	Endangered
Litoria littlejohni	Littlejohns's Tree Frog	Vulnerable
Litoria raniformis	Growling Grass Frog, Southern Bell Frog, Green and Golden Frog, Warty Swamp Frog	Vulnerable
Mixophyes balbus	Stuttering Frog	Vulnerable
Mixophyes iteratus	Giant Barred Frog, Southern Barred Frog	Vulnerable

Scientific name	Common name	EPBC Act status
Anthochaera phrygia	Regent Honeyeater	Critically Endangered
Botaurus poiciloptilus	Australian Bittern	Endangered
Calidris ferruginea	Curlew Sandpiper	Critically Endangered
Dasyornis brachypterus	Eastern Bristlebird	Endangered
Grantiella picta	Painted Honeyeater	Vulnerable
Hirundapus caudacutus	White-throated Needletail	Vulnerable
Lathamus discolor	Swift Parrot	Critically endangered
Limosa lapponica baueri	Bar-tailed Godwit (*baueri*), Western Alaskan Bar-tailed Godwit	Vulnerable
Limosa lapponica menzbieri	Northern Siberian Bar-tailed Godwit, Bar-tailed Godwit (*menzbieri*)	Critically endangered
Numenius madagascariensis	Eastern Curlew, Far Eastern Curlew	Critically endangered
Polytelis swainsonii	Superb Parrot	Vulnerabe
Rostratula australis	Australian Painted-snipe, Australian Painted Snipe	Endangered
Chalinolobus dwyeri	Large-Eared Pied Bat	Vulnerable
Dasyurus maculatus	Spotted-Tailed Quoll	Endangered
Isoodon obesulus	Southern Brown Bandicoot (Eastern)	Endangered
Petauroides volans	Greater Glider	Vulnerable
Petrogale penicillata	Brush-Tailed Rock-Wallaby	Vulnerable
Phascolarctos cinereus	Koala	Vulnerable
Potorous tridactylus	Long-nosed Potoroo	Vulnerable
Pseudomys novaehollandiae	New Holland Mouse, Pookila	Vulnerable
Pteropus poliocephalus	Grey-Headed Flying-Fox	Vulnerable
Pommerhelix duralensis	Dural Land Snail	Endangered
Synemon plana	Golden Sun Moth	Critically endangered
Aprasia parapulchella	Pink-tailed Worm-lizard, Pink-tailed Legless Lizard	Vulnerable
Delma impar	Striped Legless Lizard	Vulnerable
Eulamprus leuraensis	Blue Mountains Water Skink	Endangered
Hoplocephalus bungaroides	Broad-headed Snake	Vulnerable

7.2 Native vegetation and plant communities

7.2.1 Upstream

Native vegetation within the upstream study area covers about 5,280 hectares. Eleven vegetation classes are identified (Keith 2004), which are mapped in Appendix F1 of the EIS (Biodiversity assessment report - upstream). Vegetation classes are:

- Northern Warm Temperate Rainforests
- Central Gorge Dry Sclerophyll Forests
- Sydney Sand Flats Dry Sclerophyll Forests
- Dry Rainforests
- Coastal Floodplain Wetlands

- Sydney Hinterland Dry Sclerophyll Forests
- Sydney Coastal Dry Sclerophyll Forests
- Eastern Riverine Forests
- North Coast Wet Sclerophyll Forests
- Western Slopes Grassy Woodlands
- Northern Hinterland Wet Sclerophyll Forests.

The upstream study area is centred around Lake Burragorang, which was created following construction of Warragamba Dam in 1960. Consequently, vegetation surrounding Lake Burragorang is not typical riparian or floodplain vegetation but comprises vegetation typical of ridgetops on skeletal soils and valley slopes.

Most of the upstream study area supports dry sclerophyll forest of shrubby sub-formation, as well as areas of wet sclerophyll forest, dry rainforest, warm temperate rainforest, grassy woodlands, and forested wetlands. General characteristics are summarised as follows:

- vegetation immediately west of Warragamba Dam on the walls of the Warragamba Gorge is dominated by species characteristic of ridgetop woodlands around the Sydney Basin, including *Angophora costata*, *Eucalyptus piperita*, *E. eugenioides*, *E. sieberi* and *Corymbia gummifera*
- pockets of Warm Temperate Rainforest are present in sheltered, south-facing gullies
- most of the area around Lake Burragorang is characterised by dry sclerophyll forest communities, which are dominated by *E. punctata*, *E. tereticornis*, *E. glaucina*, *E. eugenioides*, *E. fibrosa*, and *E. crebra*
- vegetation within drainage lines consists of tall wet forest dominated by *E. deanei* and dry rainforest dominated by *Backhousia myrtifolia* and *Melaleuca styphelioides*
- vegetation near the mouth of the Wollondilly River and along the river itself is dominated by grassy woodland consisting of *E. melliodora*, *E. tereticornis*, *E. glaucina*, *E. albens-moluccana intergrade*, and *Brachychiton populneus*. This vegetation conforms to White Box Yellow Box Blakely's Red Gum Woodland CEEC
- forested wetlands dominated by *E. deanei*, *E. elata*, *E. benthamii*, and *Casuarina cunninghamiana* are present along the Nattai River, Kedumba River, Coxs River, and many other smaller tributaries flowing into Lake Burragorang. Much of this vegetation conforms to River Flat Eucalypt Forest on Coastal Wetlands EEC
- extensive areas of dry rainforest dominated by *B. myrtifolia* are present along the Coxs River and Kowmung River. The dry sclerophyll forest within this area is dominated by *E. crebra*, *E. tereticornis*, *E. punctata*, and various stringybark species.

Vegetation within the upstream study area is aligned with 18 PCTs. These are described and mapped in Appendix F1 of the EIS (Biodiversity assessment report - Upstream) and summarised in Table 7-4.

Table 7-4. PCTs within the upstream study area

PCT code/ BVT[1] code	PCT name	Area within study area (ha)	Area within upstream impact area (ha)
PCT 769 HN517	Coachwood - Lilly Pilly warm temperate rainforest in moist sandstone gullies, Sydney Basin Bioregion	1.52	0.53
PCT 832 HN525	Forest Red Gum - Narrow-leaved Ironbark open forest of the southern Blue Mountains gorges, Sydney Basin Bioregion	544.90	143.14
PCT 840 HN527	Forest Red Gum - Yellow Box woodland of dry gorge slopes, southern Sydney Basin Bioregion and South Eastern Highlands[2]	490.47	127.75
PCT 860 HN532	Grey Gum - Broad-leaved Ironbark dry open forest on gorge slopes on the Blue Mountains, Sydney Basin Bioregion	963.64	226.04
PCT 862 HN533	Grey Gum - Hard Leaved Scribbly Gum woodland of the Cox River Valley	84.62	10.97
PCT 870 HN535	Grey Gum - Thin-leaved Stringybark grassy woodland of the southern Blue Mountain gorges, Sydney basin Bioregion	91.26	22.17
PCT 871 HN536	Grey Gum shrubby open forest on gorge slopes of the Blue Mountains, Sydney Basin Bioregion	800.41	212.92

PCT code/ BVT[1] code	PCT name	Area within study area (ha)	Area within upstream impact area (ha)
PCT 875 HN537	Grey Myrtle - Lilly Pilly dry rainforest in dry gullies of the Sydney Basin Bioregion and South East Corner Bioregion	16.07	5.62
PCT 877 HN538	Grey Myrtle dry rainforest of the Sydney Basin Bioregion and South East corner Bioregion	231.16	50.15
PCT 941 HN553	Mountain Blue Gum - Thin-leaved Stringybark open forest on river flat alluvium in the Sydney Basin Bioregion[3]	378.04	104.51
PCT 1081 HN564	Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion	7.37	1.92
PCT 1083 HN566	Red bloodwood -scribbly gum heathy woodland on sandstone plateaux of the Sydney basin Bioregion	25.14	6.57
PCT 1086 HN568	Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion	100.01	25.72
PCT 1105 HN574	River Oak open forest of major streams, Sydney Basin Bioregion and South East Corner Bioregion	368.15	84.23
PCT 1246 HN598	Sydney Peppermint - Grey Gum shrubby open forest of the western Blue Mountains, Sydney Basin Bioregion	33.10	9.71
PCT 1284 HN606	Turpentine - smooth-barked Apple moist shrubby forest of the lower Blue Mountains, Sydney Basin Bioregion	75.39	20.82
PCT 1292 HN607	Water Gum - Coachwood riparian scrub along sandstone streams, Sydney Basin Bioregion	36.58	14.66
PCT 1401 HN557	Narrow-leaved Ironbark - Forest Red Gum on rocky slopes of the lower Burragorang Gorge, Sydney Basin Bioregion[2]	957.26	302.81

1 Biometric vegetation type

2 Assessed as conforming to *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* (critically endangered under the EPBC Act)

3 Assessed as conforming to *River-flat eucalypt forest on coastal floodplains of southern New South Wales and eastern Victoria* (critically endangered under the EPBC Act).

7.2.2 Construction area

Native vegetation covers approximately 52 percent (55.38 hectares) of the construction study area and can be classified into three vegetation classes:

- Sydney Hinterland Dry Sclerophyll Forests
- Sydney Coastal Dry Sclerophyll Forests
- Northern Hinterland Wet Sclerophyll Forests.

The construction study area is centred around Warragamba Dam, which flooded Warragamba Gorge when it was constructed between 1948 and 1960. As such, vegetation surrounding Lake Burragorang is not typical riparian or flood plain vegetation. Instead, much of the site is comprised of vegetation typical of ridgetops on skeletal soils and most of the site supports dry sclerophyll forest of shrubby sub-formation, as well as a smaller area of wet sclerophyll forest.

Immediately upstream of Warragamba Dam and on both sides of Lake Burragorang, the vegetation is dominated by species characteristic of ridgetop woodlands around the Sydney Basin, including *Angophora costata*, *Eucalyptus piperita*, *E. eugenioides*, *E. sieberi* and *Corymbia gummifera*. To the north-east of Warragamba Dam there is an area of wet sclerophyll forest that extends through a drainage line from just below the ridge line down to the dam infrastructure at the base of the dam wall. The canopy in this area is dominated by *E. pilularis*, *Syncarpia glomulifera*, *E. punctata* and *Angophora costata*. This vegetation conforms to the Shale/Sandstone Transition Forest CEEC.

Analysis of desktop and field assessments determined that vegetation within the construction study area is aligned with four PCTs (refer Table 7-5).

Table 7-5. PCTS within the construction study area

PCT code/ BVT[1] code	PCT name	Development footprint (ha)	Study area (ha)
PCT 1081 HN564	Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion	2.76	16.96
PCT 1083 HN566	Red Bloodwood - Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion	12.25	24.78
PCT 1086 HN568	Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion	5.77	8.61
PCT 1281 HN604	Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion[2]	1.64	4.88

1 Biometric vegetation type

2 Assessed as conforming with *Shale/Sandstone Transition Forest* (endangered under EPBC Act)

7.2.3 Downstream

Vegetation across the downstream study area varies significantly in its structure, floristics, and condition. Within the Cumberland lowlands, much of the vegetation has been subject to clearing and disturbance due to historical land use practices such as agriculture and, more recently, urban development within Greater Western Sydney. Consequently, most native vegetation is found within National Parks and reserves, council managed land, and small remnant patches in farm areas.

Native vegetation on the Cumberland Plain is mostly listed as a threatened ecological community (TEC) under State and Commonwealth legislation. Much of this vegetation shows evidence of disturbance such as alterations to vegetation structure and floristics, as well as weed invasion. However, more intact areas exist in small pockets. The vegetation communities present on the Cumberland Plain are primarily driven by substrate and landform/drainage patterns. Grassy woodlands dominated by *Eucalyptus tereticornis* and *E. moluccana* are typically found on clay substrates on rolling hills above the water table. The Tertiary Alluvium soil landscapes of varying drainage support the Castlereagh Woodland Communities. River-flat Forests occur on the alluvial soils adjacent to creek lines, while small pockets of Aeolian sands support *Banksia* dominated heath communities, which are typical of coastal areas. Gullies have historically contained dry rainforest, however, much of this vegetation type has been cleared.

As the landscape rises towards the Hornsby Plateau and Blue Mountains Plateau, transitional communities such as Shale-Sandstone Transition Forest Critically endangered ecological community (CEEC) and Turpentine-Ironbark Forest are found on transitional soils where Wianamatta shale grades into Hawkesbury Sandstone. These communities contain a mix of species typically found on either sandstone substrates or clay substrates. As such, the composition and structure of these communities can differ significantly depending on the proportions of clay-sandstone in the area. Where the landscape is comprised of sandstone, sandstone heath, woodland, and forest communities are present. Species composition and structure within these communities are driven by exposure, aspect and landscape position. Sheltered forests typically occur on south facing slopes and within gullies, while woodland and heath generally occur closer or on top of ridges where the soils are shallow and the landscape position more exposed.

Twenty-four PCTs were identified within the downstream study area. These are detailed in Table 7-6.

Table 7-6. PCTs within the downstream study area boundary and the existing 10% AEP event

PCT code/ BVT [1]code	PCT name	Commonwealth-listed TEC and status	Area within existing 10% AEP flood event (ha)	Area within study area (ha)
PCT 724 HN512	Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain, Sydney Basin Bioregion	*Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest CEEC*	62.29	1,379.59
PCT 725 HN513	Broad-leaved Ironbark – *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain Sydney Basin Bioregion	*Cooks River/Castlereagh Ironbark Forest of the Sydney Basin Bioregion CEEC*	0.12	412.23
PCT 781 HN520	Coastal freshwater lagoons of the Sydney Basin Bioregion and South East Corner Bioregion	Not listed	1,086	1106.73
PCT 835 HN526	Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin Bioregion	*River-flat eucalypt forest on coastal floodplains of southern New South Wales and eastern Victoria CEEC*	437.73	3,209.28
PCT 849 HN528	Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion	*Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest CEEC*	275.67	2,165.45
PCT 850 HN529	Grey Box – Forest Red Gum grassy woodland on shale of the southern Cumberland Plain Sydney Basin Bioregion	*Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest CEEC*	0.08	148.19
PCT 866 HU554	Grey Gum - Smooth-barked Apple open forest of the dry hinterland of the Central Coast, Sydney Basin Bioregion	Not listed	3.02	3.02
PCT 877 HN538	Grey Myrtle dry rainforest of the Sydney Basin Bioregion and South East Corner Bioregion	*Western Sydney Dry Rainforest and Moist Woodland on Shale CEEC*	9.22	19.54
PCT 883 HN542	Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain, Sydney Basin Bioregion	*Castlereagh Scribbly Gum and Agnes Banks Woodlands of the Sydney Basin Bioregion EEC*	0.03	900.50
PCT 924 HN552	*Melaleuca linariifolia* alluvial melaleuca thicket of the lower Blue Mountains and Capertee Valley, Sydney Basin Bioregion	Not listed	36.46	36.63
PCT 1067 HN562	Parramatta Red Gum woodland on moist alluvium of the Cumberland Plain, Sydney Basin Bioregion	Not listed	3.62	437.42
PCT 1081 HN564	Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion	Not listed	0.62	51.96
PCT 1106 NR223	River Oak riparian woodland of the NSW North Coast Bioregion and northern Sydney Basin Bioregion	*River-flat eucalypt forest on coastal floodplains of southern New South Wales and eastern Victoria CEEC*	151.28	158.51

PCT code/ BVT [1]code	PCT name	Commonwealth-listed TEC and status	Area within existing 10% AEP flood event (ha)	Area within study area (ha)
PCT 1181 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.	Not listed	385.81	438.16
PCT 1183 HN587	Smooth-barked Apple - Sydney Peppermint – Turpentine heathy open forest on plateaux areas of the Sydney Basin Bioregion	*Turpentine-Ironbark Forest of the Sydney Basin Bioregion CEEC*	12.84	12.96
PCT 1284 HN606	Turpentine – Smooth-barked Apple moist shrubby forest of the lower Blue Mountains, Sydney Basin Bioregion.	*Turpentine-Ironbark Forest of the Sydney Basin Bioregion CEEC*	36.08	36.93
PCT 1292 HN607	Water Gum - Coachwood riparian scrub along sandstone streams, Sydney Basin Bioregion	Not listed	7.14	11.08
PCT 1327 HN612	Yellow Bloodwood – Ironbark shrubby woodland of the dry hinterland of the Central Coast, Sydney Basin Bioregion	Not listed	0.83	0.83
PCT 1328 HN613	Yellow Bloodwood – Narrow-leaved Apple heathy woodland on hinterland plateaux of the Central Coast, Sydney Basin Bioregion.	Not listed	0.36	1.03
PCT 1385 HN577	Rough-barked Apple - Grey Gum grassy open forest of the hinterland hills of the Central Coast, Sydney Basin Bioregion	Not listed	35.83	36.67
PCT 1395 HN556	Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion	*Shale Sandstone Transition Forest in the Sydney Basin Bioregion CEEC*	360.56	708.78
PCT 1504 HN647	Sydney Blue Gum - Deane's Gum - River Peppermint shrubby riparian tall forest of the lower Colo River, Sydney Basin Bioregion	*River-flat eucalypt forest on coastal floodplains of southern New South Wales and eastern Victoria CEEC*	59.93	60.94
PCT 1557 HN665	Rough-barked Apple – Forest Oak – Grey Gum grassy woodland on sandstone ranges of the Sydney Basin	Not listed	0.52	2.85
PCT 1718 HU932	Swamp Mahogany – Flax-leaved paperbark swamp forest on coastal lowlands of the Central Coast	Preliminary determination for *Melaleuca dominated Temperate Swamp Sclerophyll Forests on Coastal Floodplains of Eastern Australia*	0.02	5.90

Flora species assessed in the downstream biodiversity assessment are presented in Appendix F2 of the EIS. The review of existing studies and the database search results identified 105 threatened flora species as having a moderate or higher likelihood of occurring in the downstream study area. A total of 140 floristic plots and transects were conducted across the downstream study area recording a total of 422 species, of which 75 were identified as locally non-native. Targeted flora surveys were conducted for *Acacia pubescens* and *Dillwynia tenuifolia*. Both species were recorded during the survey effort along with one incidental observation of a *Grevillea juniperina* subsp*. juniperina* population.

Further flora surveys and vegetation mapping observed an additional four threatened flora species – *Eucalyptus benthamii*, *Persoonia nutans*, *Rhodamnia rubescens* and *Zieria involucrata*. All four threatened flora species had been previously recorded within a one-kilometre radius of their observed locations.

7.3 Fauna habitats

7.3.1 Upstream

Across the broader landscape of the upstream study area, different habitats provide specific features and resources that are key elements required by native fauna for the maintenance of life cycles, including breeding, sheltering and foraging. Fauna habitats recorded in the upstream study area are described in Table 7-7.

Table 7-7. Fauna habitat characteristics – upstream

Fauna habitat	Description
Alluvial woodland	The structure of the alluvial woodland consists of a tall canopy, dense mid-story and often sparse understory. Predominant canopy species are Deane's Gum (*Eucalyptus deanei*), River Peppermint (*E. elata*), Camden White Gum (*Eucalyptus benthamii*), Rough-barked Apple (*Angophora floribunda*), and River Oak (*Casuarina cunninghamiana)*. Common mid-story shrubs are Leptospermum and Acacia species and Coffee Bush (*Breynia oblongifolia*). The groundcover is dominated by species such as Lomandra species, *Lobelia purpurascens* and *Pteridium esculentum*. Alluvial woodland occurs on the banks of the major rivers in the upstream study area; the Wollondilly, Nattai, Kowmung, Coxs and Kedumba. The river banks are often steep with numerous rock outcrops. Other key habitat features present in the woodland areas include fallen timber, fragmented rock and hollow bearing trees. Sap feed trees for the Yellow-bellied Glider have been identified in this habitat. Alluvial woodland has been identified as a priority animal habitat within the Warragamba Special Area (DECC 2007). It provides important foraging habitat for some threatened species including the Large-eared Pied Bat. Alluvial woodland comprises about 15% (794 hectares) of the upstream study area.
Grassy box woodland	This habitat occurs on flat or undulating topography – predominantly in the south of the upstream study area around Jooriland, on the banks of the Wollondilly River. Only a small area of this habitat occurs in the upstream study area. There is a low distribution of canopy trees, predominately Grey Box (*Eucalyptus moluccana*) and Forest Red Gum (*Eucalyptus tereticornis*). The understory consists of perennial grasses and shrubs are rare. Low rock outcrops are common amongst the groundcover. Land previously cleared for agricultural purposes is beginning to regenerate but is still subject to continuous grazing pressure from large populations of native and introduced herbivores (for example, Eastern Grey Kangaroos, deer and goats). Grassy Box woodland has been identified in a study of the fauna of the Warragamba Special Area (DECC 2007) as the highest priority fauna habitat as it supports several threatened species that do not persist elsewhere in the region due to widespread clearing. Species include the critically endangered Regent Honeyeater and Swift Parrot (DECC 2007). Grassy box woodland comprises about 28% (1,468 hectares) of the upstream study area.
Dry sclerophyll forest	The canopy of the dry sclerophyll forest is typically up to 20 metres and is dominated by Red Bloodwood (*Corymbia gumifera*), Scribbly Gums (*Eucalyptus haemastoma* and *E. racemosa*), Narrow-leaved Stringybark (*E. oblonga*) and Grey Gum (*E. punctata*). The mid-storey includes Acacia, Banksia, Persoonia and Leptospermum species. Flooding of the Burragorang Valley has resulted in habitat that would usually occur only on ridgetops occurring close to the lake. Dry sclerophyll forest is the most common habitat within the upstream study area. It occurs throughout the upstream study area, close to the lake edges and adjacent to areas of alluvial woodland along the major rivers.

Fauna habitat	Description
	Fallen logs and leaf litter are common. Rocks are abundant throughout this habitat, providing sheltering habitat for small mammals and reptiles. Overhangs and cliffs also provide habitat for microbats. Hollow-bearing trees are present, although likely to occur at a lower abundance due to historical logging. Threatened woodland birds are likely to use this habitat for foraging, nesting and roosting. Suitable foraging habitat for microbats occurs. Dry sclerophyll forest comprises about 51% (2,689 hectares) of the upstream study area.
Wet sclerophyll forest	This tall, open forest occurs in patches across the upstream study area, particularly around Brereton Head. The canopy is dominated by Turpentine (*Syncarpia glomulifera*), Grey Gum (*Eucalyptus punctata*), Blackbutt (*E. pilularis*) and Smooth-barked Apple (*Angophora costata*). The mid-storey is open, comprising of shrubs and small trees including Pittosporum, Acacia, Allocasuarina and Leucopogon species. The understorey is formed by a diverse array of shrubs, grasses and graminoids. Within this habitat, fallen logs, leaf litter and rocks are common. As is the case with other habitats in the upstream study area, hollow-bearing trees are present, although likely to occur at a lower abundance due to historical logging. This vegetation provides suitable nesting, roosting and foraging habitat for threatened woodland birds and forging habitat for microchiropteran bats. Wet sclerophyll forest comprises about 1.5% (77 hectares) of the upstream study area.
Dry rainforest	The dry rainforest habitat found around Lake Burragorang has a moderately tall canopy (10-15 metres) dominated by Grey Myrtle (*Backhousia myrtifolia*), Lilly Pilly (*Acmena smithii*), Coachwood (*Ceratopetalum apetalum*) and Sassafras (*Doryphora sassafras*). Beneath the canopy, a sparse understory of scattered ferns, small shrubs and herbs occurs including Gristle Fern (*Blechnum cartilagineum*), Rough Treefern (*Cyathea australis*) and Necklace Fern (*Asplenium flabellifolium*). There is an abundance of leaf litter, fallen logs, rock outcrops and dry creek beds are often rocky. This habitat generally occurs in small patches in sandstone gullies where the sides are steep with a southerly aspect. Suitable locations generally occur on small tributaries of the Kowmung and Coxs Rivers. Dry rainforest provides suitable sheltering, breeding and foraging habitat for the threatened Eastern Pygmy-possum (*Cercartetus nanus*) and Brush-tailed Rock-wallaby (*Petrogale pencilliata*). Dry rainforest comprises about 4.8% (251 hectares) of the upstream study area.
Aquatic and wetlands	Riverine (for example, Wollondilly River) and lacustrine (Lake Burragorang) wetlands comprise the largest areas in the catchment. There are no Ramsar or nationally significant wetlands in the upstream study area (BMT 2018). Despite being an artificial environment, WaterNSW (2015) reports that Lake Burragorang supports an abundance of aquatic flora and fauna. Minimal aquatic vegetation occurs on the creeks flowing into Lake Burragorang due to shading, instability of substrates and high velocity flows (BMT 2018). Waterways within the upstream study area are mapped as Key Fish Habitat under the FM Act (BMT 2018). One threatened fish species, the Macquarie Perch (*Macquaria australasica*) has been recorded in Lake Burragorang. Tributary streams feeding into Lake Burragorang provide suitable habitat for two semi-aquatic invertebrate species: Adam's Emerald Dragonfly (*Archaeophya adamsi*) and Sydney Hawk Dragonfly (*Austrocordulia leonardi*) (DPI 2007). The upstream study area lies within a large area of native vegetation maintained for water supply. Most of the area has been relatively undisturbed since the construction of Warragamba Dam in 1960 and the establishment of a three-kilometre exclusion zone to protect Lake Burragorang. Parts of the upstream study area are in the Blue Mountains National Park, Kanangra-Boyd National Park, Nattai National Park and the Burragorang, Nattai and Yerranderie State Conservation Areas.

The upstream study area is within a much broader area of vegetation within the GBMWHA and other conservation areas, and there is extensive connectivity between habitat in the upstream study area and neighbouring areas. Physical barriers are formed by naturally occurring landscape features such as escarpments and gorges, and constructed trails for vehicle and pedestrian access. Lake Burragorang and major rivers also act as barriers to some terrestrial species.

Animals often use landscape features to guide their dispersal. Riparian vegetation is used by some species, such as the Spotted-tailed Quoll, to move through the landscape. These areas are important given the presence of escarpments and cliffs that most ground-dwelling species would be incapable of negotiating.

The Wollondilly Linkage forms an important corridor connecting Grassy Box Woodland environments, which occurs on a small part of the upstream study area around Jooriland. This link extends from Jooriland and south along the Wollondilly River to Bullio (DECC 2007). The northern end of this link falls within the upstream study area.

A small and steep rocky stream connects Warragamba River to Lake Burragorang, which provides an important pathway for juvenile eels to migrate around the dam wall (See Appendix F4 (Aquatic Ecology)).

7.3.2 Construction area

Fauna habitat assessments included consideration of important indicators of habitat condition and complexity including the occurrence of microhabitats such as tree hollows, fallen logs, bush rock and wetland/riparian areas and the presence of mistletoe and flowering trees for nectivorous bird species. Hollows were used as a general indication of habitat quality for arboreal fauna and for hollow dependent birds and bats.

Fauna habitats of the construction study area were assessed in two main categories:

- fauna habitat features and resources at a locality scale that form part of the broader landscape of the Project study area to a five-kilometre radius
- site-specific fauna habitat features and resources that provide the key elements required by native fauna for the maintenance of life cycles.

Fauna habitats identified in the construction study area are described in Table 7-8.

Table 7-8. Fauna habitat characteristics – construction area

Fauna habitat	Description
Dry sclerophyll forest	The canopy of the dry sclerophyll forest is typically up to 20 metres high and is dominated by Red Bloodwood (*Corymbia gumifera*), Scribbly Gums (*Eucalyptus haemastoma* and *E. racemosa*), Narrow-leaved Stringybark (*E. oblonga*) and Grey Gum (*E. punctata*). The mid-storey includes Acacia, Banksia, Persoonia and Leptospermum species. The flooding of the Burragorang Valley by Warragamba Dam has resulted in an atypical distribution of habitat that would normally occur around waterways, namely that habitat that would usually occur only on ridgetops, occurs close to the surface level of the lake. Dry sclerophyll forest is the most common fauna habitat within the Project study area, occurring throughout the area and to the lake edges. Fallen logs and leaf litter are common. Rocks are abundant throughout this habitat, providing sheltering habitat for small mammals and reptiles. Overhangs and cliffs also provide habitat for microbats. Hollow-bearing trees are present, although likely to occur at a lower abundance due to historical logging. Threatened woodland birds are likely to use this habitat for foraging, nesting and roosting as are hollow roosting microbats.
Wet sclerophyll forest	This tall, open forest occurs in patches across the construction study area, particularly around Brereton Head. The canopy is dominated by Turpentine (*Syncarpia glomulifera*), Grey Gum (*Eucalyptus punctata*), Blackbutt (*E. pilularis*) and Smooth-barked Apple (*Angophora costata*). The mid-storey is open, comprising of shrubs and small trees including Pittosporum, Acacia, Allocasuarina and Leucopogon species. The understorey is formed by a diverse array of shrubs, grasses and graminoids. Within this habitat, fallen logs, leaf litter and rocks are common. As is the case with other habitats in the construction study area, hollow-bearing trees are present, although likely to occur at a lower abundance due to historical logging. This vegetation provides suitable nesting, roosting and foraging habitat for threatened woodland birds and forging habitat for microchiropteran bats.
Cleared / modified habitat	Cleared and modified areas provide habitat where scattered canopy trees occur over grassland, including areas used for recreation and areas that have been impacted by construction and operation of the dam and spillway. Trees provide foraging and sheltering habitat for birds and microbats that can occupy disturbed habitat. The Large-eared Pied Bat was detected in modified vegetation near the auxiliary spillway.
Aquatic	WaterNSW (2015) reports that Lake Burragorang supports an abundance of aquatic flora and fauna (BMT 2018). Within the Project study area, a small, high gradient rocky stream connecting Warragamba River to Lake Burragorang occurs. This stream is important fish habitat, providing the only upstream movement corridor for juvenile eels into Lake Burragorang (BMT 2018). Immediately below the dam wall, some aquatic vegetation occurs amongst the rocky river bed. Flows are limited by the daily volumes released from the dam.

The Project would result in the removal of 22.42 hectares of native vegetation in the construction study area. This would take in 1.64 hectares of Shale Sandstone Transition Forest in the Sydney Basin Bioregion TEC (critically endangered), and 14.19 hectares of suitable habitat for *Grevillea parviflora* subsp. *parviflora* (vulnerable).

7.3.3 Downstream

Most of the downstream study area is highly disturbed by activities associated with cattle grazing and agriculture. Natural habitats are degraded and often unsuitable for native fauna species that are sensitive to disturbance. Agricultural land use and urbanisation have simplified and/or removed most of the ground habitat features such as logs and rocks. The resultant landscape has a simplified and fragmented habitat typical of many rural areas that support a subset of the pre-European fauna. The integrity of these habitats is further challenged by the abundance of feral animals such as foxes, pigs and rabbits, which prey upon or compete with native fauna for food and shelter.

Cumberland Plain native vegetation originally comprised of various forms of open forest and woodland. The best remaining fauna habitats within the downstream study area are associated with remnant areas of forest and woodland, with the highest quality habitat located within National Parks and Reserves. Outside of National Parks and Reserves, most remnants are mostly comprised of young trees with scattered older individuals. Tree hollows, particularly large hollows, are rare.

Despite the modified nature, the downstream study area still offers broad habitat features for native fauna. These include:

- regenerating woodland and scattered paddock trees that are likely to facilitate dispersal for woodland birds
- remnant open forest and woodland, and woodland margins that contain mixed age trees, deep litter, stags, tree hollows suitable as shelter and breeding habitat for some hollow-dependent fauna. These habitats also provide connectivity for woodland birds to the wider locality
- understorey vegetation and ground cover, leaf litter, fallen timber and rocky outcrops suitable as shelter for small terrestrial species
- blossom-producing trees suitable as forage habitat for a range of birds and Grey-headed Flying-foxes
- open grassland for foraging birds and microbats
- riparian vegetation along the Hawksbury-Nepean, Colo River and associated tributaries as well as small, ephemeral water bodies suitable for some common birds, frogs, reptiles and microbats
- farm dams suitable for some common birds, frogs and microbats.

Fauna habitats recorded in the downstream study area are described in Table 7-9.

Table 7-9. Fauna habitat characteristics - downstream

Fauna habitat	Description
Alluvial forests and woodlands	The woodland and open forest vegetation is predominantly contained within National Parks and Reserves. Elsewhere the woodland areas are relatively young, open and with a grassy groundcover. For more mobile species, the woodland patches provide connectivity between the more intact woodlands within the National Parks and Reserves. Other habitat values are associated with open forests and woodlands, which include: ▪ Bush rock, stags and fallen logs: Fallen timber and woody debris are an important feature for many woodland birds. Fallen logs, leaf litter and ground vegetation provide habitat features that would provide shelter for many of the small to medium sized terrestrial fauna species known from the locality. In addition, some bush rock, particularly in sandstone derived areas provides habitat for small terrestrial fauna species such as small mammals and reptiles. ▪ Understorey vegetation: Many native woodland bird species are strongly associated with shrub and tall tussock grass understorey. Understorey vegetation, and thus woodland structural complexity, provides nesting sites, refuge from predators and food. This vegetation is most diverse within National Parks, Reserves and State Conservation Areas. Outside of these areas and for much of the downstream study area, it generally lacks a diverse understorey structure, and shrubs are uncommon, despite localised areas of shrubby understorey that is largely represented by exotic shrubs such as *Ligustrum sinense* and *Ligustrum lucidum* (Large and Small-leaved Privet), and *Lantana camara* (Lantana). ▪ Tree hollows: Tree hollows are an essential resource for some fauna species that rely on them for breeding, refuge, roosting, and nesting. Tree hollows have been shown to be a key limiting resource for hollow-dependent fauna. Furthermore, many hollow-dependent species such as forest owls and Little Lorikeets are hollow specialists and will only occupy hollows with specific hollow characteristics. This means that many of the available hollows are unlikely to be usable or functional for all resident native fauna, which increases the demand on the remaining suitable hollows. Due to the disturbed nature of the downstream study area, tree hollows occur in low densities throughout the downstream study area, and are generally associated with large, mature box eucalypts (such as *Eucalyptus moluccana*) and angophoras (such as *Angophora costata*).

Fauna habitat	Description
	▪ Blossom-producing trees: All forest and woodland vegetation communities provide suitable foraging habitat for a range of nectarivorous birds during blossom periods. The downstream study area contains flowering eucalypts that blossom at different times of the year providing a year-round food resource to many resident native fauna species as well as migratory species. Tree species recorded and mistletoe plants (*Amyema sp.*) are known to produce abundant flowers and nectar. Nectar-dependent bird species and Grey-headed Flying-foxes are expected to utilise these resources during blossoming periods.
Grassy box woodland	Grassy Box Woodlands are important for conserving declining woodland birds that are found in the region, including the Diamond Firetail, Brown Treecreeper, Hooded Robin, Restless Flycatcher and Speckled Warbler. This habitat type was once extensive in the Region, occurring on higher-fertility soils of the Cumberland Plain, Illawarra Coastal Plain and in the rain-shadow valleys of the Southern Blue Mountains such as in the Burragorang, Nattai and Wollondilly valleys. The largest area of semi-intact Grassy Box Woodland occurs in the Burragorang Valley within the Warragamba Special Area and is the most significant landscape in the Region in terms of conservation of faunal diversity. Most Grassy Box Woodlands have experienced some degree of disturbance, and on the Cumberland Plain and Illawarra Coastal Plain they are heavily depleted and fragmented. In these areas, smaller isolated remnants are no longer utilised by species that are sensitive to fragmentation. Many Grassy Box Woodland species are locally extinct or close to extinction in the southern Cumberland Plain. The Cumberland Plain would have supported the largest expanse of Grassy Box Woodlands, though this has been vastly reduced to less than 15 percent of its original extent. The Grassy Box Woodland that remains in south-western Sydney mostly occurs in very small patches or on the peripheries of the plain where it grades into sandstone vegetation.
Grassland	Grassland habitat generally provides low fauna habitat due to the lack of woody vegetation and ground debris for cover. Most native fauna species are found in treed habitats, however native tussock grasslands can provide sparse habitat for native fauna species because they provide a degree of groundcover complexity and seed resources, even where the grasslands are still used for light grazing. Grassland vegetation is the most widespread habitat type in the downstream study area. A range of native and neutralised grass and forb species dominate these communities, and upper stratum layers are generally non-existent except for a few scattered trees that do not conform to woodland. The composition and diversity of native species varies as a result of ongoing grazing; however, a large portion of grassland is derived from the understorey of woodland communities that have been cleared in the past and so still retain a proportion of native groundcover species. Some areas of grassland include woody debris and leaf litter cover; however, other areas that were cropped or grazed are devoid of such habitat features. Open grasslands in the downstream study area generally provide suitable foraging habitat for large mammals, including macropods like the Eastern Grey Kangaroo (*Macropus giganteus*). The grassland can also provide shelter and forage for small mammals in areas where there is an adequate layer of tussock grass, and microhabitats under timber and rocks for reptiles. Large open areas provide ample foraging habitat for insectivorous and granivorous birds, and hunting resources for raptors, owls and some microbat species. At the time of field surveys, grassland comprised about 96% of the downstream study area.
Disturbed areas	The remaining terrestrial habitat in the downstream study area is highly disturbed and includes suburban areas, turf farms, quarries and industrial areas. These areas provide limited habitat for anything other than the most urban-tolerant species. Turf farms may provide some suitable foraging habitat for bird species; however, the rates of chemical use are likely to be higher than that of the surrounding natural environment.
Aquatic and wetlands	Throughout the downstream study area there are wetland areas that provide habitat for wetland birds and frogs. The most important wetlands in the downstream study area for shorebirds and waterbirds are Bakers Lagoon, Broadwater Swamp, Bushells Lagoon, Hobartville Swamp, Little Cattai Creek, Longneck Lagoon, McGraths Hill, McKenzies Creek, Pitt Town Lagoon, Powells/Triangle Lane, Pughs Lagoon, Rickabys Creek, Wheeny Lagoon and Yarramundi Lagoon. Most of the wetlands in the downstream study area are either tributary wetlands or depositional flats adjacent to the main channel and major drowned tributaries (Taylor-Wood & Warner 2003). Considerable changes to the wetlands of the Hawkesbury-Nepean River have occurred since European colonisation due to drainage, changes in land use, vegetation clearance and the construction of Warragamba Dam. Today, most wetlands rely on their own, local catchments for water as the construction of levy banks and flood mitigation devices have reduced or removed their connectivity to the Hawkesbury-Nepean River, with only overbank flows reaching them. Some wetlands have been partly drained and only hold water for short periods after flooding and heavy rain whilst others have been dammed and are now permanent swamps. In addition, farm dams provide some habitat for invertebrates, fish species, amphibians, reptiles and wetland birds. Some suitable habitat for Green and Golden Bell Frog occurs within the downstream study area in and around wetland areas, particularly in areas containing reeds, bulrushes (Typha spp.) or spike rushes

Fauna habitat	Description
	(Eleocharis spp.). Large dams and open waterways in the downstream study area also provide foraging habitat for raptors such as the White-bellied Sea-eagle (*Haliaeetus leucogaster*).

7.4 Threatened species

7.4.1 Upstream and construction area

The biodiversity assessments for the upstream and construction study areas were conducted in accordance with the FBA. This involved identification of 'ecosystem credit species' and 'candidate species credit species' as follows:

- ecosystem credit species: A measurement of the value of PCTs, EECs, CEECs, and threatened species habitat for species that can be reliably predicted to occur within a PCT. Ecosystem credits measure the loss in biodiversity values at a development site and the gain in biodiversity values at an offset site. A total of 29 ecosystem credit species were identified.
- candidate species credit species: The class of biodiversity credits created or required for the impact on threatened species that cannot be reliably predicted to use an area of land based on habitat surrogates. Species that require species credits are listed in the Threatened Species Profile Database. A total of 67 flora species or populations, and 19 fauna species were identified.

Ecosystem credit species recorded or assumed to occur within the upstream and construction Project study areas are listed in Table 7-10.

Table 7-10. Ecosystem credit species recorded or assumed to occur within the upstream and construction Project study areas

Scientific name	Common name	EPBC Act status	Study area[1]
Petauroides volans	Greater Glider	Vulnerable	U
Pteropus poliocephalus	Grey-headed Flying-fox	Vulnerable	U
Dasyurus maculatus	Spotted-tailed Quoll	Vulnerable	C
Grantiella picta	Painted Honeyeater	Vulnerable	U
Lathamus discolor	Swift Parrot	Critically Endangered	C
Pseudomys novaehollandiae	New Holland Mouse	Vulnerable	U, C

[1] U = upstream, C = Construction

Species credit species recorded or assumed to occur within the upstream and construction Project study areas are listed in Table 7-11.

Table 7-11. Species credit species recorded or assumed to occur within the upstream and construction Project study areas

Scientific name	Common name	EPBC Act status	Study area[1]
Flora			
Acacia bynoeana	Bynoe's Wattle	Vulnerable	U, C
Acacia flocktoniae	Flockton Wattle	Vulnerable	U, C
Acacia gordonii	-	Endangered	U, C
Acacia pubescens	Downy Wattle	Vulnerable	U, C
Acrophyllum australe	-	Vulnerable	U
Asterolasia elegans	-	Endangered	U, C
Astrotricha crassifolia	Thick-leaf Star-hair	Vulnerable	U, C
Baloskion longipes	Dense Cord-rush	Vulnerable	U
Bossiaea oligosperma	Few-seeded Bossiaea	Vulnerable	U*

Scientific name	Common name	EPBC Act status	Study area[1]
Callistemon megalongensis	Megalong Valley Bottlebrush	Endangered	U
Cryptostylis hunteriana	Leafless Tongue-orchid		C
Cynanchum elegans	White-flowered Wax Plant	Endangered	U
Darwinia biflora	-	Vulnerable	U, C
Epacris sparsa	Sparse Heath	Vulnerable	C
Eucalyptus benthamii	Camden White Gum	Vulnerable	U*
Eucalyptus glaucina	Slaty Red Gum	Vulnerable	U*
Genoplesium baueri	Bauer's Midge Orchid	Endangered	U, C
Grevillea evansiana	Evans Grevillea	Vulnerable	U, C
Grevillea parviflora subsp. *parviflora*	Small-flower Grevillea	Vulnerable	U*
Hakea dohertyi	Kowmung Hakea	Endangered	U*
Haloragodendron lucasii	Hal	Endangered	C
Haloragis exalata subsp. *exalata*	Square Raspwort	Vulnerable	U
Hibbertia puberula		Critically endangered	C
Kunzea cambagei	Cambage Kunzea	Vulnerable	U
Kunzea rupestris	-	Vulnerable	U, C
Leionema lachnaeoides	-	Endangered	U
Leucopogon exolasius	Woronora Beard-heath	Vulnerable	U, C
Melaleuca deanei	Deane's Paperbark	Vulnerable	U, C
Micromyrtus blakelyi	-	Vulnerable	U, C
Olearia cordata	-	Vulnerable	U, C
Persoonia acerosa	Needle Geebung	Vulnerable	U, C
Persoonia bargoensis	Bargo Geebung	Vulnerable	U
Persoonia hirsuta	Hairy Geebung	Endangered	U, C
Phyllota humifusa	Dwarf Phyllota	Vulnerable	U
Pimelea curviflora var. curviflora	-	Vulnerable	U, C
Pomaderris brunnea	Brown Pomaderris/Rufous Pomaderris	Vulnerable	U*, C
Pterostylis saxicola	Sydney Plains Greenhood	Endangered	U, C
Pultenaea glabra	Smooth Bush-pea	Vulnerable	U, C
Pultenaea parviflora	-	Vulnerable	U, C
Rhizanthella slateri	Eastern Australian Underground Orchid	Endangered	U
Syzygium paniculatum	Magenta Lilly Pilly	Vulnerable	C
Trachymene scapigera	Mountain Trachmene	Endangered	U
Velleia perfoliata	-	Vulnerable	U, C
Zieria covenyi	Coveny's Zieria	Endangered	U
Zieria involucrata	-	Vulnerable	U, C
Zieria murphyi	Velvet Zieria	Vulnerable	U, C

Scientific name	Common name	EPBC Act status	Study area[1]
Fauna			
Anthochaera phrygia	Regent Honeyeater	Critically Endangered	U*, C
Chalinolobus dwyeri	Large-eared Pied Bat	Vulnerable	U*
Heleioporus australiacus	Giant Burrowing Frog	Vulnerable	U, C
Hoplocephalus bungaroides	Broad-headed Snake	Vulnerable	U, C
Isoodon obesulus obesulus	Southern Brown Bandicoot (eastern)	Endangered	U, C
Litoria littlejohni	Littlejohn's Tree Frog	Vulnerable	U
Mixophyes balbus	Stuttering Frog	Vulnerable	U
Petauroides volans	Greater Glider	Vulnerable	U*
Petrogale penicillata	Brush-tailed Rock-wallaby	Vulnerable	U, C
Phascolarctos cinereus	Koala	Vulnerable	U, C
Pteropus poliocephalus	Grey-headed Flying-fox	Vulnerable	U*

1. U = upstream, C = Construction

* Recorded during field surveys for the Project.

7.4.2 Downstream

Threatened fauna species recorded within the downstream study area or identified from database searches are detailed in Table 7-12. Threatened flora recorded in downstream study area

Table 7-12. Threatened flora recorded in downstream study area

Scientific name	Common name	Habitat and distribution	EPBC Act status
Acacia bynoeana	Bynoe's Wattle	Grows mainly in heath and dry sclerophyll forest in sandy soils. Mainly south of Dora Creek-Morisset area to Berrima and the Illawarra region, west to the Blue Mountains, also recorded from near Kurri Kurri in the Hunter Valley and from Morton National Park.	Vulnerable
Acacia pubescens	Downy Wattle	Concentrated around the Bankstown-Fairfield-Rookwood area and the Pitt Town area, with outliers occurring at Barden Ridge, Oakdale and Mountain Lagoon. Occurs on alluviums, shales and at the intergrade between shales and sandstones. The soils are characteristically gravely soils, often with ironstone. Grows in open woodland and forest, in a variety of plant communities, including Cooks River-Castlereagh Ironbark forest, Shale-Gravel Transition forest and Cumberland Plain Woodland.	Vulnerable
Allocasuarina glareicola		Primarily restricted to the Richmond (NW Cumberland Plain) district, but with an outlier population found at Voyager Point, Liverpool. Grows in Castlereagh woodland on lateritic soil. Found in open woodland with Parramatta Red Gum, Broad-leaved Ironbark, Narrow-leaved Apple, Scribbly Gum and Paperbarks.	Endangered
Eucalyptus benthamii	Camden White Gum	Occurs on the alluvial flats of the Nepean River and its tributaries. There are two major subpopulations: the Kedumba Valley of the Blue Mountains National Park and at Bents Basin State Recreation Area. Several trees are scattered along the Nepean River around Camden and Cobbitty. At least five trees occur on the Nattai River in Nattai National Park. Requires a combination of deep alluvial soils and a flooding regime that permits seedling establishment. Occurs in open forest.	Vulnerable
Kunzea rupestris		Grows in shallow depressions on large flat sandstone rock outcrops. Characteristically found in short to tall shrubland or heathland.	Vulnerable

Scientific name	Common name	Habitat and distribution	EPBC Act status
Lasiopetalum joyceae		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. Grows in heath on sandstone.	Vulnerable
Micromyrtus minutiflora		Grows in Castlereagh Scribbly Gum woodland, Ironbark forest, Shale-Gravel Transition forest, open forest on tertiary alluvium and consolidated river sediments.	Vulnerable
Persoonia hirsuta	Hairy Geebung	Distributed from Singleton in the north, along the east coast to Bargo in the south and the Blue Mountains to the west. A large area of occurrence, but occurs in small populations, increasing the species' fragmentation in the landscape. Found in sandy soils in dry sclerophyll open forest, woodland and heath on sandstone. Usually present as isolated individuals or very small populations. Probably killed by fire (as other *Persoonia* spp. Are) but will regenerate from seed.	Endangered
Persoonia nutans	Nodding Geebung	Confined to aeolian and alluvial sediments and occurs in a range of sclerophyll forest and woodland vegetation communities, with the majority of individuals occurring within Agnes Banks woodland or Castlereagh Scribbly Gum woodland. Restricted to the Cumberland Plain in western Sydney, between Richmond in the north and Macquarie Fields in the south.	Endangered
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 Sock, Bellevue Hill and Manly. Occurs on shale-lateritic soils over sandstone and shale-sandstone transition soils on ridgetops and upper slopes amongst woodlands.	Vulnerable
Pimelea spicata	Spiked Rice-flower	Once widespread on the Cumberland Plain, the Spiked Rice-flower occurs in two disjunct areas: the Cumberland Plain (Narellan, Marayong, Prospect Reservoir areas) and the Illawarra (Landsdowne to Shellharbour to northern Kiama). In both the Cumberland Plain and Illawarra environments this species is found on well-structured clay soils. On the inland Cumberland Plain sites, it is associated with grey box and Ironbark. In the coastal Illawarra it occurs commonly in Coast Banksia open woodland with a better developed shrub and grass understorey.	Endangered
Pomaderris brunnea	Brown Pomaderris/ Rufous Pomaderris	The species is expected to live for 10-20 years, while the minimum time to produce seed is estimated to be 4-6 years. 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 Tableland and in far eastern Gippsland in Victoria.	Vulnerable
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 Sydney Plains Greenhood occurs are sclerophyll forest or woodland on shale-sandstone transition soils or shale soils.	Endangered
Pultenaea parviflora		Endemic to the Cumberland Plain. May be locally abundant, particularly within scrubby-dry heath areas within Castlereagh Ironbark forest and Shale Gravel Transition forest on tertiary alluvium or laterised clays. May also be common in transitional areas where these communities adjoin Castlereagh Scribbly Gum woodland.	Vulnerable
Zieria involucrata		Has a disjunct distribution in the Baulkham Hills, Hawkesbury, Hornsby and Blue Mountains LGAs. Recent records for the species come from 22 populations in the catchments of the Macdonald, Colo and Hawkesbury Rivers. Occurs on Hawkesbury sandstone,	Vulnerable

Scientific name	Common name	Habitat and distribution	EPBC Act status
		Narrabeen Group sandstone and on Quaternary alluvium. Found in sheltered forests on mid- to lower slopes and valleys, in or adjacent to gullies which support sheltered forest, although some populations extend up-slope into drier vegetation.	

Threatened fauna species recorded within the downstream study area or identified from database searches are detailed in Table 7-13.

Table 7-13. Threatened fauna recorded in the downstream study area

Scientific name	Common name	Location	EPBC Act status
Chalinolobus dwyeri	Large-eared Pied Bat	Detected on the Hawkesbury River at Yellomundee NP and Cattai NP	Vulnerable
Phascolarctos cinereus	Koala	Upper Colo Reserve and Blaxlands Ridge. Historical records from Lapstone north to the Colo River, predominantly to the west of the Nepean River. A record in South Windsor from 2014 and Wianamatta Regional Park from 2004 (*Robert Close, pers. coms*).	Vulnerable
Pteropus poliocephalus	Grey-headed Flying-fox	Detected on the Nepean River at Silverdale and Yarramundi	Vulnerable
Botaurus poiciloptilus	Australasian Bittern	Recorded occasionally, particularly between Richmond and Pitt Town Lagoon.	Endangered
Rostratula australisi	Australian Painted Snipe	Recorded very occasionally at wetlands in the downstream study area (Richmond/Pitt Town area)	Endangered
Calidris ferruginea	Curlew Sandpiper	Recorded once in the downstream study area. Very rare in the surrounding region. Little suitable habitat present in the study area, restricted to wetlands in the Richmond/Pitt Town area.	Critically Endangered
Heleioporus australiacus	Giant Burrowing Frog	Previously recorded in the downstream study area.	Vulnerable
Grantiella picta	Painted Honeyeater	Occasionally recorded in the downstream study area prior to the 1970s, very rarely recorded in the region since. Sole recent record from Pitt Town Lagoon in 2013.	Vulnerable
Anthochaera phrygia	Regent Honeyeater	Recorded in the downstream study area reasonably regularly until the late 1980s however there have been very few records from the study area since.	Critically Endangered
Lathamus discolour	Swift Parrot	Occasionally recorded in the downstream study area.	Critically Endangered

7.4.3 Aquatic species

Threatened ecological communities

The Protected Matters Search Tool search for the aquatic ecology assessment identified the TEC *Posidonia australis seagrass meadows of the Manning-Hawkesbury ecoregion* as likely to occur in estuarine habitats in the downstream study area. This TEC is listed as endangered under the EPBC Act. The downstream limit of the material influence of the Project is at Wisemans Ferry. Suitable habitat for this TEC (subtidal waters with salinity close to marine levels) is not present above this location.

Posidonia australis is listed as an endangered population under the NSW *Fisheries Management Act 1994* (FM Act). The Scientific Determination[7] noted that populations of *Posidonia australis* are found in Port Hacking, Botany Bay,

[7] https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/636503/FD44-Posidonia-australis.pdf

Sydney Harbour, Pittwater, Brisbane Waters, Lake Macquarie and Port Stephens. These locations are all outside the Project study area.

Macroinvertebrates

The aquatic ecology assessment (Appendix F4) identified the potential for the Project to impact on two semi-aquatic invertebrate species listed as endangered under the FM Act. These are the Adam's emerald dragonfly (*Archaeophya adamsi*) and Sydney hawk dragonfly (*Austrocordulia leonardi*). Neither species is listed under the EPBC Act.

Fish

Two threatened fish species that are indigenous to the Hawkesbury-Nepean catchment and occur in the study area were identified through a search of the EPBC Act protected matters search and BioNet search. These include the Macquarie perch (*Macquaria australasica*), which is listed as endangered under the EPBC Act and the Australian grayling (*Prototroctes maraena*) which is listed as vulnerable under the EPBC Act

At least three other threatened species may occur in the catchment, including trout cod (*Maccullochella macquariensis*), the Murray River cod (*Maccullochella peelii peelii*) and silver perch (*Bidyanus bidyanus*). These species are not indigenous to the catchment, but rather have historically been translocated to the catchment from elsewhere. There are no recent records of these species from the catchment, therefore it has been suggested that their introductions to the catchment have failed (DPI 2006).

Distribution modelling provided by the EPBC Act protected matters search tool indicates the black rockcod (*Epinephelus daemelii*) may occur in the lower reaches of the downstream study area; however, there have been no confirmed sightings of this species. This species is listed as Vulnerable under the EPBC Act.

Another fish species, that is likely related to the Macquarie perch, the Blue Mountains perch (*Macquaria sp. nov. 'hawkesbury taxon'*), is likely present within the study area. While not officially listed as threatened under the EPBC Act, the Blue Mountains perch has been included on the provisional list of animals requiring urgent management attention in the Australian Government's bushfire recovery package for wildlife and their habitat.

Table 7-14 provides a summary of potential threatened species occurring in the study area, with descriptions provided below for the species that are known or likely to occur – Macquarie perch (*Macquaria australasica*), Australia grayling (*Prototroctes maraena*) and Black rockcod (*Epinephelus daemelii*).

Table 7-14. Threatened fish species known to occur or possibly occurring in the Hawkesbury-Nepean catchment

Species name	Common name	EPBC Act status*	Habitat requirements	Potential habitat within the study area
Macquaria australasica	Macquarie perch	E	Cool clean water preferring deep slow flowing pools and lakes.	Yes – confirmed to occur in upstream study area
Macquaria sp. nov. 'hawkesbury taxon'	Blue Mountains perch	Priority listing	Restricted to the mid-reaches of small near pristine streams, at elevations of 35-420 m above sea level, mostly commonly at 100-175 m above sea level.	Yes – likely to occur in the study area
Prototroctes maraena	Australian grayling	V	Clear gravely coastal streams and rivers from the sea to the first barrier, up to 1,000 m	No – numerous barriers in downstream environments. Not known to occur in study area
Maccullochella macquariensis	Trout cod	E	Inhabits large rivers and streams in the upper Murray-Darling Basin often associated with cover such as large woody debris rock outcrops, boulders, and deep holes	No – known from translocated stocks within Cordeaux Dam
Maccullochella peelii peelii	Murray cod	V	Turbid, slow-flowing rivers and streams of the Murray-Darling Basin, often near deep holes with large woody debris. rocks and overhanging vegetation	No – stocked in the 19th century in the Coxs Nepean and Wollondilly rivers. Stock in Cataract Dam and several water storages (Rowland 1989)

Species name	Common name	EPBC Act status*	Habitat requirements	Potential habitat within the study area
Epinephelus daemelii	Black rockcod	V	Occurs in caves, gutters and rocky reefs in near shore environments, with juveniles potentially also occurring in estuaries.	Possible but no confirmed sightings. Habitat unlikely to occur within downstream limit of influence of Project (Wisemans Ferry).

*E: Endangered, V: Vulnerable.

7.5 Threatened ecological communities

The terrestrial vegetation within the study area was compared against the Approved Listing Advice and/or Conservation Advice for each TEC under the EPBC Act, especially in relation to relevant size and condition thresholds pertinent to EPBC Act listings.

Table 7-15 lists the EPBC Act listed TECs associated with PCTs recorded from the upstream study area including a summary of the key diagnostic characteristics that were relied upon as justification for the TECs presence. Detailed discussion of the TEC analysis undertaken for Commonwealth TECs in the upstream study area including detailed maps is provided in Appendix F1 of the EIS (Biodiversity assessment report – upstream) (Section 4.4.2, see maps in Appendix L of Appendix F1).

Table 7-15. EPBC Act listed TECs associated with PCTs - upstream study area

Federally listed TEC and status	PCT	Area (ha)		Summary of the key diagnostic characteristics present in vegetation in the study area
		Impact area	Study area	
White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland (Critically Endangered)	PCT 840 HN527 PCT 1401 HN557	142.16	1,447.73	▪ Grassy woodland dominated by *Eucalyptus albens – moluccana intergrade* and *E. melliodora* ▪ Subjected to rainfall of approximately 900 millimetres per annum with elevation between 116 metres and 190 metres ASL ▪ Shrub cover is generally low* ▪ Predominantly native understorey dominated by tussock grasses ▪ At least 12 native non-grass species present ▪ At least one important species is present ▪ Patch area thresholds are met ▪ Occurrence within Sydney Basin and South Eastern Highlands Bioregions.
River-flat eucalypt forest on coastal floodplains of southern New South Wales and eastern Victoria (Critically Endangered)	PCT 941 HN553	104.51	378.04	▪ Occurs in the South East Corner and Sydney Basin IBRA Bioregions, in eastern Victoria and south eastern New South Wales. ▪ Occurs within catchments of the eastern and southern watershed of the Great Dividing Range. ▪ Occurs at elevations up to 250 metres above sea-level (mASL), but most typically below 50 mASL. ▪ Occurs on alluvial landforms related to coastal river floodplains and associated sites where transient water accumulates, including floodplains, river-banks, riparian zones, lake foreshores, creek lines (including the floors of tributary gullies), floodplain pockets, depressions, alluvial flats, fans, terraces, and localised colluvial fans. ▪ Occurs on alluvial soils of various textures including silts, clay loams, sandy loams, gravel

Federally listed TEC and status	PCT	Area (ha)		Summary of the key diagnostic characteristics present in vegetation in the study area
		Impact area	Study area	
				and cobbles. Does not occur on soils that are primarily marine sands, or aeolian sands. ▪ Occurs as a tall closed-forest, tall open-forest, closed forest, open forest, tall woodland, or woodland. The canopy has a crown cover of at least 20 percent. ▪ Has a canopy dominated by one or a combination of the following species: *Angophora floribunda, A. subvelutina, Eucalyptus amplifolia, E. baueriana, E. benthamii, E. bosistoana, E. botryoides, E. botryoides* x *E. saligna, E. elata, E. grandis, E. longifolia, E. moluccana, E. ovata, E. saligna, E. tereticornis, E. viminalis.*

*Shrub cover has not been quantified across the study area in line with the recommended 0.1 hectare minimum measure.

Table 7-16 lists the EPBC Act listed TECs associated with PCTs recorded from the construction study area. Detailed discussion of the TEC analysis undertaken for Commonwealth TECs in the construction study area is provided in Appendix F3 of the EIS (Biodiversity assessment report – construction area) (Section 4.4 of the report).

Table 7-16. EPBC Act listed TECs associated with PCTs - construction study area

Federally listed TEC and status	PCT	Development footprint (ha)	Study area (ha)	Summary of the key diagnostic characteristics present in vegetation in the study area
Shale Sandstone Transition Forest of the Sydney Basin Bioregion (Critically Endangered)	PCT 1281 HN604	1.64	8.12	▪ Occurs within the Sydney Basin Bioregion ▪ Occurs near the transition between shales and sandstones of the Wianamatta and Hawkesbury Groups ▪ Occurs as a forest to woodland ▪ Canopy included a mix of species including *Eucalyptus punctata, E. crebra*, *E. fibrosa* and *E. resinifera* ▪ Mid layer variable across extent of community – *Persoonia linearis* present with *Allocasuarina torulosa* dominant in the small tree layer for some of the extent ▪ At least nine characteristic ground layer species present.

Table 7-17 lists the EPBC Act listed TECs associated with PCTs recorded from the downstream study area. The extent of each EPBC Act listed TEC in the downstream study area has not necessarily been ground-truthed and therefore has been inferred based on PCT associations.

Table 7-17. EPBC Act listed TECs associated with PCTs - downstream study area

Federally listed TEC and status	PCT	Existing 1 in 10 chance in a year flood (ha)	Study area (ha)	Summary of the key diagnostic characteristics present in vegetation in the study area
Castlereagh Scribbly Gum and Agnes Banks Woodlands of the Sydney Basin Bioregion (Endangered)	PCT 958 HN555	-	986.76	▪ Occurs within the Sydney Basin Bioregion ▪ Occurs on flat or gently undulating terrain ▪ Occurs on sandy soils, on deposits of Tertiary alluvium which are sometimes overlayed with aeolian deposits

Federally listed TEC and status	PCT	Existing 1 in 10 chance in a year flood (ha)	Study area (ha)	Summary of the key diagnostic characteristics present in vegetation in the study area
				▪ Occurs as a woodland less than 20 metres tall with a prominent shrub layer and a variable ground layer ▪ Canopy dominated by one or more of the diagnostic species in the Conservation Advice ▪ Each patch has not been individually assessed against the size and condition thresholds.
Cooks River/Castlereagh Ironbark Forest of the Sydney Basin Bioregion (Critically Endangered)	PCT 725 HN513	0.12	412.23	▪ Occurs within the Sydney Basin Bioregion ▪ Primarily occurs in elevations below 100 metres ASL ▪ Occurs in the Cumberland subregion with clay soils derived from predominantly Tertiary alluvium and on Wianamatta Shale derived soils found next to Tertiary alluvium ▪ Occurs as a dry sclerophyll open-forest to low woodland typically dominated by *Eucalyptus fibrosa* and *Melaleuca decora* ▪ Usually includes a moderate to dense mid layer with a variable and generally sparse ground layer ▪ Each patch has not been individually assessed against the size and condition thresholds.
Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest (Critically Endangered)	PCT 724 HN512 PCT 849 HN528 PCT 850 HN529	338.04	3,693.23	▪ Occurs within Sydney Basin Bioregion ▪ Most occurrences are on clay soils derived from Wianamatta Group geology ▪ Canopy typically dominated by *Eucalyptus moluccana, E. tereticornis* and/or *E. fibrosa* ▪ Sparse or lower tree layer may be present, typically with young eucalypts and species of *Acacia, Exocarpos* and *Melaleuca* ▪ Understorey typically comprises a variety of perennial native gramminoids and forbs ▪ Each patch has not been individually assessed against the size and condition thresholds.
River-flat eucalypt forest on coastal floodplains of southern New South Wales and eastern Victoria (Critically Endangered)	PCT 835 HN526 PCT 1504 HN647 PCT 1106 NR223	460.78	3,428.73	▪ Occurs in the South East Corner and Sydney Basin IBRA Bioregions, in eastern Victoria and south eastern New South Wales. ▪ Occurs within catchments of the eastern and southern watershed of the Great Dividing Range. ▪ Occurs at elevations up to 250 mASL, but most typically below 50 mASL. ▪ Occurs on alluvial landforms related to coastal river floodplains and associated sites where transient water accumulates, including floodplains, river-banks, riparian zones, lake foreshores, creek lines (including the floors of tributary gullies), floodplain pockets, depressions, alluvial flats, fans, terraces, and localised colluvial fans. ▪ Occurs on alluvial soils of various textures including silts, clay loams, sandy loams, gravel

Federally listed TEC and status	PCT	Existing 1 in 10 chance in a year flood (ha)	Study area (ha)	Summary of the key diagnostic characteristics present in vegetation in the study area
				and cobbles. Does not occur on soils that are primarily marine sands, or aeolian sands. ▪ Occurs as a tall closed-forest, tall open-forest, closed forest, open forest, tall woodland, or woodland. The canopy has a crown cover of at least 20 percent. ▪ Has a canopy dominated by one or a combination of the following species: *Angophora floribunda, A. subvelutina, Eucalyptus amplifolia, E. baueriana, E. benthamii, E. bosistoana, E. botryoides, E. botryoides* x *E. saligna, E. elata, E. grandis, E. longifolia, E. moluccana, E. ovata, E. saligna, E. tereticornis, E. viminalis.*
Shale Sandstone Transition Forest in the Sydney Basin Bioregion (Critically Endangered)	PCT 1395 HN556	360.56	708.78	▪ Occurs within the Sydney Basin Bioregion ▪ Occurs at the transition between shales and sandstones of the Wianamatta and Hawkesbury Groups including the transitional Mittagong Formation ▪ Occurs as forest or woodland ▪ Canopy dominated by a mix of species including two or more of the diagnostic species listed in the Conservation Advice ▪ Where present the mid layer of the understorey varies in structure and floristics ▪ Where present, the ground layer of the understorey is typically diverse ▪ Each patch has not been individually assessed against the size and condition thresholds.
Turpentine-Ironbark Forest of the Sydney Basin Bioregion (Critically Endangered)	PCT 1183 HN587 PCT 1284 HN606	48.92	49.89	▪ Occurs within the Sydney Basin Bioregion ▪ Open forest typically dominated or co-dominated by *Syncarpia glomulifera* ▪ Ironbark species commonly present such as *Eucalyptus crebra, E. paniculata and/*or *E. fibrosa* ▪ Small tree layer sometimes present ▪ Occurs predominantly on clay soils derived from Wianamatta shale, including clay lenses of Wianamatta shale within Hawkesbury sandstone ▪ Each patch has not been individually assessed against the size and condition thresholds.
Western Sydney Dry Rainforest and Moist Woodland on Shale (Critically Endangered)	PCT 877 HN538 PCT 830 HN524	9.22	26.41	▪ Occurs within the Sydney Basin Bioregion ▪ Occurences are typically on clay soils derived from Wianamatta Group shale geology ▪ Canopy is a simple, low closed forest (often with emergents) to a more open woodland, with a small tree layer forming a sub-canopy; ▪ Shrub layer usually present ▪ Ground layer is variable and generally sparse ▪ Vines and scramblers are typically present across the ecological community

Federally listed TEC and status	PCT	Existing 1 in 10 chance in a year flood (ha)	Study area (ha)	Summary of the key diagnostic characteristics present in vegetation in the study area
				▪ Each patch has not been individually assessed against the size and condition thresholds.
Nomination for *Melaleuca dominated Temperate Swamp Sclerophyll Forests on Coastal Floodplains of Eastern Australia* (Endangered)	PCT 1718 HU932	4.08	5.90	Detailed TEC analysis was not undertaken as this community has only been nominated for listing under the EPBC Act.

7.6 Groundwater dependent ecosystems

7.6.1 Upstream

Groundwater dependent ecosystems (GDEs) have been classified to a corresponding vegetation type and mapped by the Bureau of Meteorology and Kuginis *et al.* (2012) in the Groundwater Dependent Ecosystems Atlas (BOM 2019). Nineteen GDEs were identified within the upstream study area (Groundwater Dependent Ecosystem Atlas, BOM 2015). These are described and mapped in Appendix F1 of the EIS (Biodiversity assessment report - upstream) and summarised in Table 7-18.

Table 7-18. Groundwater dependent ecosystems – upstream study area

Vegetation type	GDE classification summary
Blue Mountains Heath	Low to moderate GDE
Burragorang Escarpment Forest	Low to moderate GDE for most areas
Burragorang Hillslope Forest	High GDE for most areas
Burragorang River Flat Forest*	Low to Moderate GDE
Burragorang Rocky Slopes Woodland	Low to Moderate GDE
Burragorang-Nepean Hinterland Woodland	Low to Moderate GDE
Coastal Sandstone Ridgetop Woodland	Low to Moderate GDE
Grey Myrtle Dry Rainforest	High GDE for most areas
Hinterland Sandstone Gully Forest	High GDE for most areas
Kowmung Dry Shrub/Herb Forest – *E. punctata*	Low GDE
Kowmung-Wollondilly Gorge Forest	High GDE for all areas
Lower Blue Mountains Wet Forest	High GDE for most areas
Megalong-Tonalli Sandstone Forest	High GDE for most areas
Riparian Acacia Shrub/Grass/Herb Forest: *Casuarina cunninghamiana*	High GDE for all areas
Riverbank Forest*	High GDE for most areas
Sandstone Riparian Scrub	High GDE for all areas
Sandstone Scarp Warm Temperate Rainforest	High GDE for most areas
Sydney Hinterland Transition Woodland	High GDE for all areas
Wollondilly-Cox-Shoalhaven Gorge Woodland*	Low to Moderate GDE

*Components of these GDEs may meet the listing advice for EPBC Act TECs

7.6.2 Construction area

Four GDEs were identified within the Project study area, all within the Greater Metropolitan Region Groundwater Sources – Sydney Basin area. These are described in Table 7-19.

Table 7-19. Groundwater dependent ecosystems – construction area

Vegetation type	GDE classification summary
Coastal Sandstone Ridgetop Woodland	Low to moderate potential GDE
Cumberland River Flat Forest*	High potential GDE
Hinterland Sandstone Gully Forest	High potential GDE
Sydney Hinterland Transition Woodland	High potential GDE

7.6.3 Downstream

Two of the thirteen groundwater management areas (GWMAs) identified in the State of the Catchments 2010 report for the Hawkesbury-Nepean region[8] are relevant to the Project, these being the Hawkesbury Alluvium (alluvial GWMA) and the Sydney Basin–Central (porous rock GWMA).

The hydrogeological characteristics of the Sydney Basin bioregion has been described by Herron *et al.* (2018) as follows:

> *The alluvial deposits of the Hawkesbury River, extending downstream of Warragamba Dam to the township of Spencer, are referred to as the Hawkesbury Alluvium Groundwater Source. Alluvial deposits are broadest in the Windsor to Wilberforce area with most bores drilled in thinner alluvia of minor tributaries. … The Hawkesbury alluvium is a significant alluvial groundwater system with reasonable levels of storage.*

The main hydrogeological unit in the Sydney Basin–Central area is the Wianamatta Group. Two other hydrogeological units in this area are Quaternary-Cenozoic and Hawkesbury Sandstone. With regard to the Wianamatta Group, Herron *et al.* (2018) note:

> *The Wianamatta Group consists of three units: the Ashfield Shale, the Minchinbury Sandstone and the Bringelly Shale, with the Minchinbury Sandstone of negligible thickness (McNally, 2004). This group has a maximum thickness in western Sydney of up to 300 m, but with more typical thicknesses in the range of 100 to 150 m. The Wianamatta Group occurs as scattered remnant areas in the Southern Highlands, with major outcrops predominantly over the Cumberland Plain south-west of Richmond.*
>
> *In western Sydney, two aquifer systems are associated with the shale formations of the Wianamatta Group. The upper aquifer system comprises residual soils and colluvium derived from the shales, floodplain alluvium and the weathered saprolite, and typically has a depth of 3 to 10 m. Hydraulic conductivities show a large variability and range between 0.01 and 10-5 m/day, with the higher end suggesting the presence of open fractures in weathered shales or ferricrete bands. The lower aquifer system occurs below the base of the weathering and comprises fine-grained mudrocks. This aquifer shows some degree of fracturing thus allowing some groundwater flows. Despite its low transmissivities, McNally (2004) refers to this system as an aquifer because it discharges small volumes of saline water to the surface. Hydraulic conductivities range between 0.001 and 10-8 m/day, with the lower end reflecting the intrinsic impermeability of the unfractured shale.*
>
> *Both aquifers show limited storage and low bore yields, typically less than 0.1 ML/day (McNally, 2004; Parsons Brinckerhoff, 2013). Water-bearing fractures are widely spaced and sometimes poorly interconnected. This results in boreholes being dry when first drilled, then slowly filling with water over several weeks, causing substantial head and salinity variations in piezometers. Water within fractures is generally brackish to saline, especially in low relief areas, with typical values in the range of 5,000 to 50,000 mg/L TDS (McNally, 2004).*

The nature of groundwater recharge in the Sydney Basis is described as follows in Herron *et al.* (2018):

> *The dominant recharge mechanism in the geological Sydney Basin is likely to be infiltration of rainfall and runoff through alluvial deposits in valleys, particularly where they are incised into weathered Hawkesbury Sandstone (Parsons Brinckerhoff, 2011). Similarly, recharge through infiltration takes place where the underlying units of the*

[8] https://www.environment.nsw.gov.au/soc/sydneymetro.htm

Narrabeen Group outcrop. … Recharge for deeper sandstone aquifers comes mainly from infiltration of rainfall over outcropping areas and through inter-aquifer leakage (SCA, 2012). In the Southern Coalfields, the deeper aquifers occurring in the Bulgo and Scarborough sandstones (Narrabeen Group) outcrop in the valleys of the Cordeaux and Avon reservoirs and thus recharge is expected at times of higher water level (SCA, 2012).

and

On a local scale, topography controls the groundwater flow near the ground surface in alluvial and shallow aquifers. In these systems, groundwater flow is likely to be localised and limited in extent, with occurrence of perched aquifers controlled by the presence of fine-grained materials. In general, these systems are responsive to rainfall and streamflow (SCA, 2012). On a regional scale, … groundwater flows for the geological Sydney Basin [are] *controlled by the basin geometry, topography and major hydraulic boundaries.*

There are approximately 50 floodplain wetlands that are associated with the Hawkesbury-Nepean River downstream of Pheasants Nest and Broughtons Pass Weirs to the confluence of the Colo River, with the majority found between Richmond and Wisemans Ferry. Important wetlands include Pitt Town Lagoon and Longneck Lagoon, which are examples of the Endangered Ecological Communities (EEC) Freshwater Wetlands on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions. There are no Ramsar listed wetlands, however some wetlands north of Agnes Banks are listed under State Environmental Policy (Coastal Management) 2018.

Groundwater dependent ecosystems (GDEs) have been classified to a corresponding vegetation type and mapped by the Bureau of Meteorology and Kuginis *et al.* (2012) in the Groundwater Dependent Ecosystems Atlas (BOM 2019). Sixty-two vegetation types within the downstream study area were identified and classified according to their groundwater dependency potential, groundwater management area, position in the landscape and bioregion. This classification is provided in Appendix F2 of the EIS (Downstream ecological assessment).

Appendix 4 to the background document for the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources* (NSW Office of Water 2011) lists identified high priority GDEs in the Greater Metropolitan Region. Of these, the following are relevant to the assessment:

- Pitt Town Lagoon (associated with the Hawkesbury Alluvium groundwater source)
- Long Swamp (associated with the Sydney Basin Central groundwater source)
- Longneck Lagoon (associated with the Sydney Basin Central groundwater source)
- O'Hares Creek (associated with the Sydney Basin Central groundwater source).

Downstream GDEs are considered to have limited reliance upon flows from the Warragamba catchment (Herron *et al.* (2018). Periodic inundation of floodplain areas under flood conditions represents only a minor contribution to groundwater, particularly compared with the contribution of infiltration from direct rainfall in the catchment. The recent flood in February 2020 demonstrated the extent of local flooding without flow contribution from the Warragamba Dam catchment.

7.7 Migratory species

The migratory species protected under section 209 of the EPBC Act comprise:

- migratory species which are native to Australia and are included in the appendices to the Bonn Convention (Convention on the Conservation of Migratory Species of Wild Animals – Appendices I and II)
- migratory species included in annexes established under the Japan-Australia Migratory Bird Agreement (JAMBA)
- migratory species included in annexes established under the China-Australia Migratory Bird Agreement (CAMBA)
- native, migratory species identified in a list established under, or an instrument made under, an international agreement approved by the Minister, such as the Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA).

Migratory species were not identified in Attachment A to the SEARs as a 'controlling provision' requiring assessment. However, Attachment A of the SEARs notes that

> *the list of controlling provisions may not be a complete list and that it is the responsibility of the proponent to undertake an analysis of the significance of the relevant impacts and ensure all protected matters that are likely to be significantly impacted are assessed*.

Migratory species with potential to occur in the Project study area were identified through literature review and database searches (refer Table 8-4). This section summarises the number of migratory species identified as potentially occurring within the upstream, construction and downstream study areas.

7.7.1 Upstream

The EPBC Protected Matters Report identified 18 migratory species potentially occurring within the upstream study area. The habitat for migratory species within the upstream study area primarily consists of wet and dry sclerophyll forest suitable for terrestrial species. Suitable habitat for some migratory wetland species occurs within the forested wetland vegetation types bordering the larger tributaries of Lake Burragorang. Most of the shoreline of Lake Burragorang does not provide suitable habitat for these species.

7.7.2 Construction area

The EPBC Protected Matters Report identified 16 migratory species potentially occurring within the construction study area. The habitat for migratory species within the construction study area is limited to the wet and dry sclerophyll forest suitable for terrestrial species. No suitable wetland or similar habitat is present onsite for migratory wetland species.

7.7.3 Downstream

The EPBC Protected Matters Report identified 18 migratory species potentially occurring within the downstream study area. The habitat for migratory species within the downstream study area is a mixture of wet and dry sclerophyll forest suitable for terrestrial species, and wetlands species for migratory wetland species. Large tracks of suitable wet and dry sclerophyll forest habitat occurs towards the northern portions of the downstream study area, north of Penrith and up towards the Colo River. The downstream study area also contains wetlands and riparian habitat, including mapped coastal wetlands. The most important wetlands in the downstream study area for shorebirds and waterbirds are Bakers Lagoon, Broadwater Swamp, Bushells Lagoon, Hobartville Swamp, Little Cattai Creek, Longneck Lagoon, McGraths Hill, McKenzies Creek, Pitt Town Lagoon, Powells/Triangle Lane, Pughs Lagoon, Rickabys Creek, Wheeny Lagoon and Yarramundi Lagoon. Most of the wetlands in the downstream study area are either tributary wetlands or depositional flats adjacent to the main channel and major drowned tributaries (Taylor-Wood & Warner 2003).

8 Likelihood of occurrence

The information gathered through the database searches and literature reviews was referenced against field data and observations to assess the likelihood of occurrence of each Protected Matter. This was used to focus the assessment on communities and species with a moderate or higher likelihood of occurrence, or where a community or species had been recorded in the study area.

Detailed assessments of likelihood of occurrence are provided as appendices in the separate terrestrial biodiversity assessments as follows:

- upstream study area: Appendix F1, Biodiversity assessment report – upstream (Appendix G of the report)
- downstream study area: Appendix F2, Downstream ecological assessment (Appendix A of the report)
- construction study area: Appendix F3, Biodiversity assessment report – construction area (Appendix F of the report).

Assessments of likelihood of occurrence for threatened aquatic species and communities are provided in Appendix F4, Aquatic Ecology Working Paper.

Table 8-1 provides definitions of likelihood of occurrence for the TECs listed in Table 8-2, threatened species listed in Table 8-3 and migratory species listed in Table 8-4.

Table 8-1. Definition of likelihood of occurrence for TECs and threatened species

Likelihood of occurrence	TEC	Species (non-migratory and migratory)
Recorded	TEC was observed during the recent surveys or has been previously recorded in the survey	The species was observed during the recent surveys or has been previously recorded in the survey area.
High	It is likely that a TEC occurs within the survey area	It is likely that a species inhabits or utilises habitat within the survey area
Moderate	There is potential for a TEC to occur within the survey area	Potential habitat for a species occurs within the survey area.
Low	It is unlikely that the TEC occurs within the survey area	It is unlikely that the species inhabits the survey area
None	TEC has not been recorded within the survey area	The species has not been recorded within the survey area and no suitable habitat occurs in the survey area.

8.1 Threatened ecological communities

Protected Matters searches were carried out for each of the three study areas using a 10-kilometre buffer. The search results for TECS are summarised in Table 8-2 including the conservation status of each TEC (vulnerable, V; endangered, E; or critically endangered CE). The table also identifies the likelihood of occurrence of each TEC within the individual study areas (upstream, construction, downstream).

TECs with a single asterisk (*) are Protected Matters identified in the SEARs as particularly likely to be significantly impacted; those with a double asterisk (**) are Protected Matters that have been identified as potentially being impacted.

Table 8-2. Likelihood of occurrence of TECs in Project study area

Common name	EPBC Act status	Likelihood of occurrence		
		Upstream	Downstream	Construction
Blue Gum High Forest of the Sydney Basin Bioregion	CE	Low	Low	Low
Castlereagh Scribbly Gum and Agnes Banks Woodlands of the Sydney Basin Bioregion**	E	Low	Recorded	Low
Coastal Swamp Oak (Casuarina glauca) Forest of New South Wales and South East Queensland ecological community	E	None	Low	Low
Central Hunter Valley Eucalypt Forest and Woodland Ecological Community	CE	Low	Low	Low
Coastal Upland Swamps in the Sydney Basin Bioregion	E	Low	Low	Low
Cooks River/Castlereagh Ironbark Forest of the Sydney Basin Bioregion**	CE	Low	Recorded	None
Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest**	CE	Moderate	Recorded	Low
Illawarra-Shoalhaven Subtropical Rainforest of the Sydney Basin Bioregion	CE	Low	Low	None
Littoral Rainforest and Coastal Vine Thickets of Eastern Australia	CE	None	Low	None
Natural Temperate Grassland of the South Eastern Highlands	CE	Low	None	None
Posidonia australis seagrass meadows of the Manning-Hawkesbury ecoregion	E	None	None	Low
River-flat eucalypt forest on coastal floodplains of southern New South Wales and eastern Victoria	CE	Recorded	Recorded	None
Shale Sandstone Transition Forest in the Sydney Basin Bioregion*	CE	Low	Recorded	Moderate
Southern Highlands Shale Forest and Woodland in the Sydney Basin Bioregion	CE	Low	Low	None
Subtropical and Temperate Coastal Saltmarsh	V	None	None	None
Temperate Highland Peat Swamps on Sandstone**	E	Low	Low	Low
Turpentine-Ironbark Forest of the Sydney Basin Bioregion**	CE	Low	High	Low
Upland Basalt Eucalypt Forests of the Sydney Basin Bioregion**	E	Low	Low	Low
Western Sydney Dry Rainforest and Moist Woodland on Shale**	CE	Moderate	Recorded	Low
White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland*	CE	Recorded	Low	Low

8.2 Threatened species

Protected matters searches were carried out for each of the three study areas using a 10-kilometre buffer. The search results are summarised in Table 7-2 and identify the conservation status of each species (vulnerable, V; endangered, E; critically endangered, CE).

The likelihood of occurrence and related descriptors are as described in Section 8.1.

Species with a single asterisk (*) are Protected Matters identified in the SEARs as particularly likely to be significantly impacted; those with a double asterisk (**) are Protected Matters that have been identified as potentially being impacted.

Table 8-3. Likelihood of occurrence of threatened species

Scientific name	Common name	EPBC Act status	Likelihood of occurrence		
			Upstream	Downstream	Construction
Birds					
Anthochaera phrygia	Regent Honeyeater*	CE	Recorded	Recorded	Moderate
Botaurus poiciloptilus	Australian Bittern**	E	Low	Recorded	None
Calidris ferruginea	Curlew Sandpiper	CE	Low	Recorded	None
Dasyornis brachypterus	Eastern Bristlebird**	E	Low	Low	Low
Grantiella picta	Painted Honeyeater**	V	Recorded	Moderate	Moderate
Hirundapus caudacutus	White-throated Needletail	V	Moderate	High	Moderate
Lathamus discolour	Swift Parrot**	CE	High	Recorded	Moderate
Limosa lapponica baueri	Bar-tailed Godwit (*baueri*), Western Alaskan Bar-tailed Godwit	V	None	None	None
Limosa lapponica menzbieri	Northern Siberian Bar-tailed Godwit, Bar-tailed Godwit (*menzbieri*)	CE	None	None	None
Numenius madagascariensis	Eastern Curlew, Far Eastern Curlew	CE	Low	Low	None
Polytelis swainsonii	Superb Parrot	V	Moderate	Low	Low
Rostratula australis	Australian Painted-snipe, Australian Painted Snipe	E	Low	Recorded	Low
Fish					
Epinephelus daemelii	Black Rockcod, Black Cod, Saddled Rockcod	V	None	None	None
Macquaria australasica	Macquarie Perch*	E	High	Low	Low
Prototroctes maraena	Australian Grayling**	V	Low	Low	Low
Frogs					
Heleioporus australiacus	Giant Burrowing Frog**	V	Moderate	High	High
Litoria aurea	Green and Golden Bell Frog**	V	Low	Recorded	None
Litoria booroolongensis	Booroolong Frog	E	Low	None	None

Scientific name	Common name	EPBC Act status	Likelihood of occurrence		
			Upstream	Downstream	Construction
Litoria littlejohni	Littlejohn's Tree Frog, Heath Frog**	V	Low	Low	Low
Litoria raniformis	Growling Grass Frog, Southern Bell Frog, Green and Golden Frog, Warty Swamp Frog	V	Low	None	None
Mixophyes balbus	Stuttering Frog**	V	Low	Low	Low
Mixophyes iteratus	Giant Barred Frog, Southern Barred Frog	E	None	None	None
Mammals					
Chalinolobus dwyeri	Large-Eared Pied Bat, Large Pied Bat*	V	Recorded	Recorded	Recorded
Dasyurus maculatus maculatus	Spot-tailed Quoll, Spotted-tail Quoll, Tiger Quoll**	E	High	Recorded	Moderate
Isoodon obesulus obesulus	Southern Brown Bandicoot**	E	High	Moderate	High
Petauroides volans	Greater Glider**	V	Recorded	Moderate	Low
Petrogale penicillata	Brush-tailed Rock-wallaby**	V	High	Low	High
Phascolarctos cinereus	Koala**	V	High	Recorded	Moderate
Potorous tridactylus tridactylus	Long-nosed Potoroo	V	Moderate	Low	Low
Pseudomys novaehollandiae	New Holland Mouse, Pookila	V	Moderate	Low	Low
Pteropus poliocephalus	Grey-headed Flying-fox*	V	Recorded	Recorded	High
Reptiles					
Aprasia parapulchella	Pink-tailed Worm-lizard, Pink-tailed Legless Lizard**	V	Low	Low	Low
Delma impar	Striped Legless Lizard	V	Low	Low	Low
Eulamprus leuraensis	Blue Mountains Water Skink	E	Low	Low	Low
Hoplocephalus bungaroides	Broad-headed Snake**	V	Moderate	Low	Moderate
Invertebrates					
Pommerhelix duralensis	Dural Land Snail**	E	Low	Recorded	Moderate
Synemon plana	Golden Sun Moth	CE	None	None	None

Scientific name	Common name	EPBC Act status	Likelihood of occurrence		
			Upstream	Downstream	Construction
Plants					
Acacia bynoeana	Bynoe's Wattle**	V	Moderate	Moderate	Moderate
Acacia flocktoniae	Flockton's Wattle	V	Moderate	None	Moderate
*Acacia qordonii***	–	E	Moderate	Low	Moderate
Acacia pubescens	Downy Wattle**	V	Moderate	Recorded	Moderate
Acacia terminalis ssp. terminalis	Sunshine Wattle	E	Low	Low	Low
*Acrophyllum australe***	–	V	High	Low	Low
*Allocasuarina glareicola***	–	E	Low	Moderate	Low
*Asterolasia elegans***	–	E	Moderate	Low	Low
Astrotricha crassifolia	Thick-leaf Star-hair	V	Low	Low	Moderate
Baloskion longipes	Dense Cord-rush	V	Moderate	Low	None
Boronia deanei	Deane's Boronia	V	Low	Low	Low
Bossiaea oligosperma	Few-seeded Bossiaea**	V	Recorded	Low	Low
Caladenia tessellata	Thick-lipped Spider Orchid, Daddy Long-legs	V	Low	Low	Low
Callistemon megalongensis	Megalong Valley Bottlebrush	CE	Moderate	Low	Low
Callistemon purpurascens	–	CE	Low	Low	Low
Commersonia prostrata	Dwarf Kerrawang	E	Low	Low	Low
Cryptostylis hunteriana	Leafless Tongue Orchid	V	Moderate	Low	Moderate
Cynanchum elegans	White-flowered Wax Plant**	E	Moderate	Moderate	Low
*Darwinia biflora***	–	V	Moderate	Moderate	Moderate
Deyeuxia appressa	–	E	Low	Low	Low
Diuris aequalis	Buttercup Doubletail	V	Low	Low	Low
Epacris hamiltonii	–	E	Low	Low	Low

Scientific name	Common name	EPBC Act status	Likelihood of occurrence		
			Upstream	Downstream	Construction
Epacris sparsa	Sparse Heath	V	Low	Moderate	Low
Eucalyptus aggregata	Black gum	V	Low	Low	Low
Eucalyptus benthamii	Camden White Gum*	V	Recorded	Recorded	Low
Eucalyptus camfieldii	Camfield's Stringybark	V	Low	Moderate	Low
Eucalyptus copulans	–	E	Low	Low	Low
Eucalyptus sp. Cattai	–	CE	Low	Moderate	Low
Eucalyptus glaucina	Slaty Red Gum	V	Recorded	Low	Moderate
Eucalyptus macarthurii	Paddy's River Box	E	Low	Low	Low
Eucalyptus pulverulenta	Silver-leaved Mountain Gum, Silver-leaved Gum	V	Low	Low	Low
Euphrasia arguta	–	CE	Low	Low	Low
Euphrasia bowdeniae	–	V	Moderate	Low	Low
Genoplesium baueri	Bauer's Midge Orchid/Yellow Gnat-orchid	E	Moderate	Low	Moderate
Gentiana wingecarribiensis	Wingecarribee Gentian	E	Low	Low	Low
Grevillea cayleyi	Caley's Grevillea	CE	None	Low	None
Grevillea evansiana	Evan's Grevillea	V	Low	Low	Low
Grevillea parviflora subsp. *parviflora*	Small-flower Grevillea	V	High	High	Recorded
Grevillea shiressii	–	V	Low	Moderate	Low
Hakea dohertyi	Kowmung Hakea*	E	Recorded	Low	Low
Haloragis exalata subsp. *exalata*	Wingless Raspwort, Square Raspwort	V	Low	Low	Low
Haloragodendron lucasii	Hal**	E	Low	Low	Low
Hibbertia puberula subsp. *glabrescens*	–	CE	None	Low	Low
Hibbertia spanantha	Julian's Hibbertia	CE	Low	Low	Low
Homoranthus darwinioides	–	V	Low	Low	Low

Scientific name	Common name	EPBC Act status	Likelihood of occurrence		
			Upstream	Downstream	Construction
Isopogon fletcheri	Fletcher's Drumstick	V	Moderate	Low	Low
Kunzea cambagei	Cambage Kunzea**	V	Moderate	Low	Low
*Kunzea rupestris***	–	V	Moderate	Moderate	Moderate
Leionema lachnaeoides	–	E	Moderate	Low	Low
Leucochrysum albicans var. *tricolor*	Hoary Sunray, Grassland Paper-daisy	E	Low	Low	Low
Leucopogon exolasius	Woronora Beard-heath	V	Moderate	Moderate	Moderate
Melaleuca biconvexa	Biconvex Paperbark	V	Low	Low	Low
Melaleuca deanei	Deane's Paperbark	V	Moderate	Moderate	Moderate
*Micromyrtus blakelyi***	–	V	Moderate	Low	Moderate
*Micromyrtus minutiflora***	–	V	Low	High	Low
Microtis angusii	Angus's Onion Orchid	E	Low	Low	Low
*Olearia cordata***	–	V	Moderate	Low	Moderate
Pelargonium sp. *Striatellum***	Omeo Storksbill	E	Low	Low	Low
Persicaria elatior	Tall Knotweed	V	Moderate	Low	Low
Persoonia acerosa	Needle Geebung**	V	Moderate	Low	Moderate
Persoonia bargoensis	Bargo Geebung	V	Moderate	Low	Low
Persoonia glaucescens	Mittagong Geebung	V	Moderate	Low	Low
Persoonia hirsuta	Hairy Geebung**	E	High	Moderate	Moderate
Persoonia marginata	Clandulla Geebung	V	Low	Low	Low
Persoonia mollis ssp. maxima	–	E	Low	Low	Low
Persoonia nutans	Nodding Geebung**	E	Low	Recorded	High
Pherosphaera fitzgeraldii	Dwarf Mountain Pine	E	Moderate	Low	Low
Phyllota humifusa	Dwarf Phyllota	V	Moderate	Low	Low

Scientific name	Common name	EPBC Act status	Likelihood of occurrence		
			Upstream	Downstream	Construction
Pimelea curviflora var. *curviflora***	–	V	Moderate	Recorded	Moderate
Pimelea spicata	Spiked Rice-flower**	E	Low	High	Low
Pomaderris brunnea	Brown Pomaderris/ Rufous Pomaderris**	V	Recorded	Recorded	Moderate
Pomaderris cotoneaster	Cotoneaster Pomaderris	E	Low	Low	Low
Pomaderris pallida	Pale Pomaderris	V	Low	Low	Low
Prasophyllum fuscum	Tawny Leek-orchid, Slaty Leek-orchid	V	Low	Low	Low
Prostanthera askania	Tranquillity Mintbush	E	Low	Low	Low
Prostanthera cineolifera	Singleton Mint Bush	V	Low	Low	Low
Prostanthera densa	Villous Mint-Bush	V	Low	Low	Low
Prostanthera junonis	Somersby Mintbush	E	Low	Low	Low
Prostanthera marifolia	Seaforth Mintbush	CE	Low	Low	Low
Pterostylis gibbosa	Illawarra Greenhood, Rufa Greenhood, Pouched Greenhood	E	Low	Low	Low
Pterostylis pulchella	Waterfall Greenhood/ Pretty Greenhood	V	Low	Low	Low
Pterostylis saxicola	Sydney Plains Greenhood**	E	Moderate	Moderate	Moderate
Pultenaea aristata	Prickly Bush-pea	V	Low	Low	Low
Pultenaea elusa	Elusive Bush-pea	E	Low	Low	Low
Pultenaea glabra	Smooth Bush-pea, Swamp Bush-pea**	V	High	Low	Moderate
*Pultenaea parviflora***	–	V	Moderate	Recorded	Moderate
Rhizanthella slateri	Eastern Australian Underground Orchid	E	Moderate	Low	Low
Rutidosis heterogama	Heath Wrinklewort	V	Low	Low	Low
Syzygium paniculatum	Magenta Lilly Pilly, Magenta Cherry, Daguba, Scrub Cherry, Creek Lilly Pilly, Brush Cherry	V	Moderate	Moderate	Moderate
Tetratheca juncea	Black-eyed Susan**	V	Low	Low	Low
Thelymitra kangaloonica	Kangaloon Sun Orchid	CE	Low	Low	Low

Scientific name	Common name	EPBC Act status	Likelihood of occurrence		
			Upstream	Downstream	Construction
Thesium australe	Austral Toadflax**	V	Moderate	Low	Low
Trachymene scapigera	Mountain Trachymene	E	Moderate	Low	Low
Triplarina imbricata	Creek Triplarina	E	Low	Low	Low
Velleia perfoliata	–	V	Moderate	Moderate	Moderate
Wollemia nobilis	Wollemi Pine	CE	Low	Low	None
Xerochrysum palustre	Swamp Everlasting, Swamp Paper Daisy	V	Low	Low	Low
Zieria covenyi	Coveny's Zieria	E	High	Low	Low
*Zieria involucrata***	–	V	Moderate	Recorded	Moderate
Zieria murphyi	Velvet Zieria	V	Moderate	Low	Low

8.3 Migratory species

Protected matters searches were carried out for the upstream and construction study areas using a 10-kilometre buffer, and a five kilometre buffer for the downstream study area. The search results are summarised in Table 8-4, which also identifies the conservation status of each species (vulnerable, V; endangered, E).

The likelihood of occurrence and related descriptors are as described in Section 8.1.

Table 8-4. Likelihood of occurrence of migratory species

Scientific name	Common name	EPBC Act status	Likelihood of occurrence		
			Upstream	Downstream	Construction
Marine species					
Anous stolidus	Common Noddy	–	None	None	None
Apus pacificus	Fork-tailed Swift	–	Moderate	Moderate	Moderate
Ardenna carneipes	Flesh-footed Shearwater, Fleshy-footed Shearwater	–	None	None	None
Ardenna grisea	Sooty Shearwater	–	None	None	None
Ardenna pacifica	Wedge-tailed Shearwater	–	None	None	None

Scientific name	Common name	EPBC Act status	Likelihood of occurrence		
			Upstream	Downstream	Construction
Ardenna tenuirostris	Short-tailed Shearwater	–	None	None	None
Calonectris leucomelas	Streaked Shearwater	–	None	None	None
Diomedea antipodensis	Antipodean Albatross	V	None	None	None
Diomedea epomophora	Southern Royal Albatross	V	None	None	None
Diomedea exulans	Wandering Albatross	V	None	None	None
Diomedea sanfordi	Northern Royal Albatross	E	None	None	None
Fregata ariel	Lesser Frigatebird, Least Frigatebird	–	None	None	None
Fregata minor	Great Frigatebird, Greater Frigatebird	–	None	None	None
Macronectes giganteus	Southern Giant-Petrel, Southern Giant Petrel	E	None	None	None
Macronectes halli	Northern Giant Petrel	V	None	None	None
Phoebetria fusca	Sooty Albatross	V	None	None	None
Sternula albifrons	Little Tern	–	None	Low	None
Thalassarche bulleri	Buller's Albatross, Pacific Albatross	V	None	None	None
Thalassarche cauta cauta	Shy Albatross, Tasmanian Shy Albatross	V	None	None	None
Thalassarche cauta steadi	White-capped Albatross	V	None	None	None
Thalassarche eremita	Chatham Albatross	E	None	None	None
Thalassarche impavida	Campbell Albatross, Campbell Black-browed Albatross	V	None	None	None
Thalassarche melanophris	Black-browed Albatross	V	None	None	None
Thalassarche salvini	Salvin's Albatross	V	None	None	None
Terrestrial species					
Cuculus optatus	Oriental Cuckoo, Horsfield's Cuckoo	–	Low	Low	Low
Monarcha melanopsis	Black-faced Monarch	–	Recorded	Moderate	Moderate
Monarcha trivirgatus	Spectacled Monarch	–	Moderate	Moderate	Moderate

Scientific name	Common name	EPBC Act status	Likelihood of occurrence		
			Upstream	Downstream	Construction
Motacilla flava	Yellow Wagtail	–	Low	Low	Low
Myiagra cyanoleuca	Satin Flycatcher	–	Recorded	Moderate	Moderate
Rhipidura rufifrons	Rufous Fantail	–	Recorded	Moderate	Moderate
Wetland species					
Actitis hypoleucos	Common Sandpiper	–	Low	Low	Low
Calidris acuminata	Sharp-tailed Sandpiper	–	Low	Moderate	Low
Calidris melanotos	Pectoral Sandpiper	–	Low	Moderate	Low
Gallinago hardwickii	Latham's Snipe, Japanese Snipe	–	High	High	None
Tringa nebularia	Common Greenshank, Greenshank	–	Moderate	None	None

9 World Heritage

Biodiversity values associated with the Outstanding Universal Value of the GBMWHA have been assessed separately in Appendix J. However, given the overlap with MNES related to biodiversity, relevant discussion from that report has been included in this report to cover matters that have not necessarily been addressed in the other biodiversity reports (Appendices F1, F2, F3, F4).

The location of the Project study area relative to the GBMWHA and to the Old Great North Road World Heritage Area is shown in Figure 9-1 on the following page.

9.1 Impacts on plant communities

The primary values for inscription of the GBMWHA on the World Heritage list relate to biodiversity. The principal potential impact of the Project with regard to plant communities relates to temporary inundation when the FMZ is in operation. Depending on the magnitude of the inflow event and the depth to which the FMZ fills, the incremental duration of temporary inundation would range from hours up to about two weeks. The incremental depth of temporary inundation would similarly relate to the magnitude of the inflow event.

Assessment of potential impacts on plant communities in the upstream and construction study areas was undertaken in accordance with the NSW Framework for Biodiversity Assessment (FBA). The FBA is the mechanism for implementing the NSW Biodiversity Offsets Policy for Major Projects (OEH 2014). The SEARs (6.1) make specific reference to assessing Project impacts in accordance with the FBA.

The FBA prescribes the methodology for the impact assessment and provides guidance for offsetting impacts. The FBA also sets out measures required to offset unavoidable impacts through a Biodiversity Offset Strategy (BOS), which is submitted with the Biodiversity Assessment Report (BAR) as part of the EIS and application for approval. The FBA is undertaken in three stages as follows.

- Stage 1: Assessment of biodiversity values: this comprises dentification of the biodiversity values that would be impacted, both directly and indirectly, by the Project focussing on affected landscape values, native vegetation, and threatened species.
- Stage 2: Impact assessment (biodiversity values): this comprises assessment of impacts on identified biodiversity values considering opportunities to avoid and minimise impacts, identification of thresholds for assessing and offsetting of unavoidable impacts and determining required offsets.
- Stage 3: development of a biodiversity offset strategy.

The FBA includes provisions for assessment where there are likely to be impacts on biodiversity that are infrequent, cumulative or difficult to measure over time. This was identified as being of relevance to the Project for assessment of impacts on biodiversity values in the upstream area in view of the uncertainty regarding potential temporary injunction, particularly for less frequent events.

Assessment of potential impacts on plant communities in the downstream study area was undertaken in accordance with the matters identified in Attachment B to the SEARs. This involved interrogation of publicly available databases, reviews of publicly available documents, vegetation mapping, and flora and fauna surveys.

A detailed breakdown of the plant communities within the upstream impact area (1,400 hectares) is presented in Table 9-1. The areas of the same plant communities within the broader upstream study area (5,280 hectares) are also provided for context.

The response of plant communities and individual plant species to temporary inundation is likely to be variable and would depend upon a number of factors including:

- inherent tolerance to temporary inundation impacts
- size and frequency of the flood event
- duration and depth of temporary inundation
- natural regeneration.

These are further discussed in the following sections. More detailed information on the research undertaken for the Project, the tolerance of individual communities and species and the methodology for assessment is presented in Appendix F1 (Biodiversity Assessment Report - Upstream) to the EIS.

Figure 9-1. Location of Project study area relative to the GBMWHA and to the Old Great North Road World Heritage Area

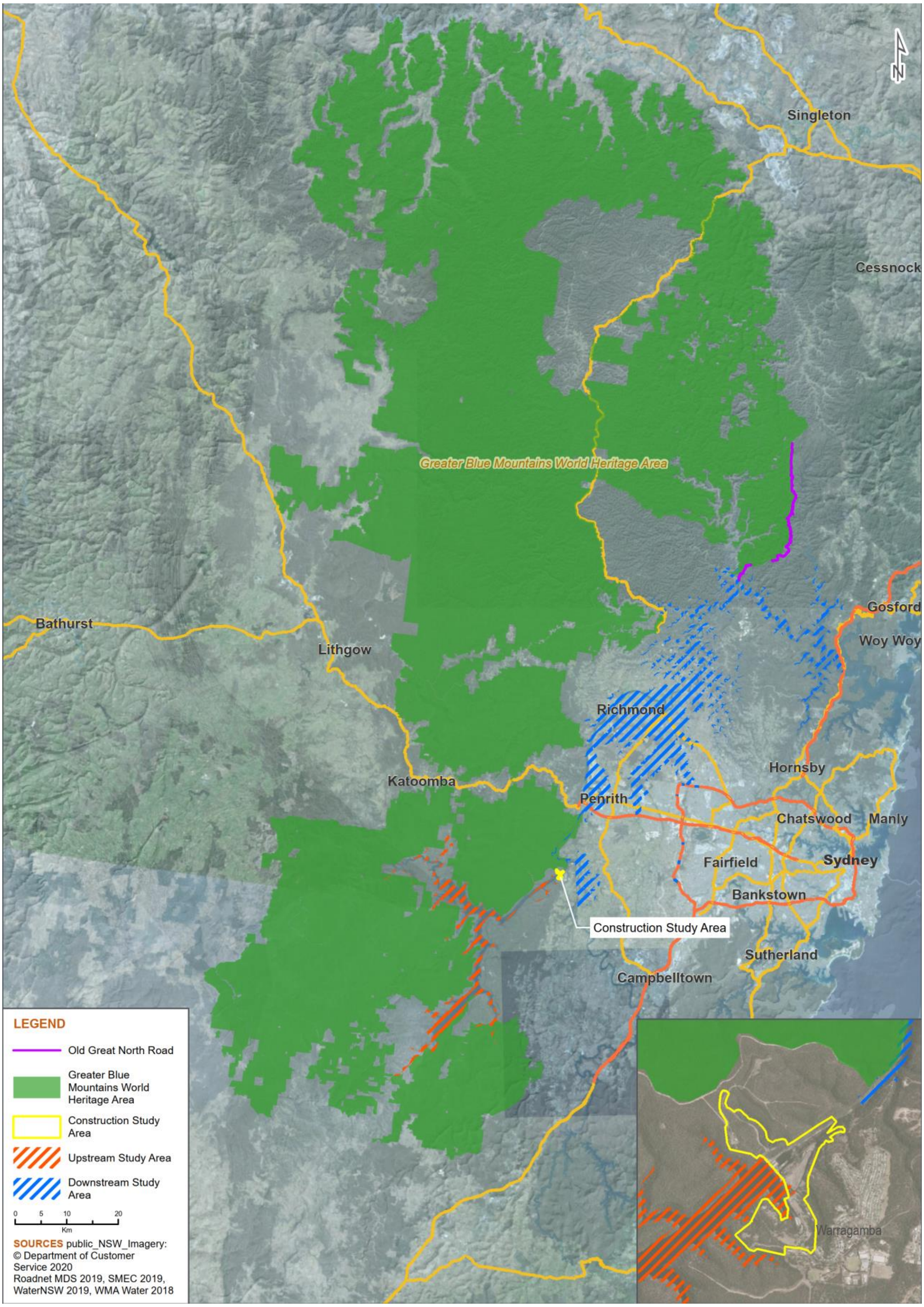


Table 9-1. Plant community types potentially impacted by temporary inundation

BVT Code	PCT Name	Area within upstream study area (ha)	Area within upstream impact area (ha)
HN517 (PCT 769)	Coachwood - Lilly Pilly warm temperate rainforest in moist sandstone gullies, Sydney Basin Bioregion	1.52	0.53
HN525 (PCT 832)	Forest Red Gum - Narrow-leaved Ironbark open forest of the southern Blue Mountains gorges, Sydney Basin Bioregion	544.90	143.14
HN527 (PCT 840)	Forest Red Gum - Yellow Box woodland of dry gorge slopes, southern Sydney Basin Bioregion and South Eastern Highlands	490.47	127.75
HN532 (PCT 860)	Grey Gum - Broad-leaved Ironbark dry open forest on gorge slopes on the Blue Mountains, Sydney Basin Bioregion	963.64	226.04
HN533 (PCT 862)	Grey Gum - Hard Leaved Scribbly Gum woodland of the Cox River Valley	84.62	10.97
HN535 (PCT 870)	Grey Gum - Thin-leaved Stringybark grassy woodland of the southern Blue Mountain gorges, Sydney basin Bioregion	91.26	22.17
HN536 (PCT 871)	Grey Gum shrubby open forest on gorge slopes of the Blue Mountains, Sydney Basin Bioregion	800.41	212.92
HN537 (PCT 875)	Grey Myrtle - Lilly Pilly dry rainforest in dry gullies of the Sydney Basin Bioregion and South East Corner Bioregion	16.07	5.62
HN538 (PCT 877)	Grey Myrtle dry rainforest of the Sydney Basin Bioregion and South East corner Bioregion	231.16	50.15
HN553 (PCT 941)	Mountain Blue Gum - Thin-leaved Stringybark open forest on river flat alluvium in the Sydney Basin Bioregion	378.04	104.51
HN557 (PCT 1401)	Narrow-leaved Ironbark - Forest Red Gum on rocky slopes of the lower Burragorang Gorge, Sydney Basin Bioregion	957.26	302.81
HN564 (PCT 1081)	Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion	7.37	1.92
HN566 (PCT 1083)	Red bloodwood -scribbly gum heathy woodland on sandstone plateaux of the Sydney basin Bioregion	25.14	6.57
HN568 (PCT 1086)	Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion	100.01	25.72
HN574 (PCT 1105)	River Oak open forest of major streams, Sydney Basin Bioregion and South East Corner Bioregion	368.15	84.23
HN598 (PCT 1246)	Sydney Peppermint - Grey Gum shrubby open forest of the western Blue Mountains, Sydney Basin Bioregion	33.10	9.71
HN606 (PCT 1284)	Turpentine - smooth-barked Apple moist shrubby forest of the lower Blue Mountains, Sydney Basin Bioregion	75.39	20.82
HN607 (PCT 1292)	Water Gum - Coachwood riparian scrub along sandstone streams, Sydney Basin Bioregion	36.58	14.66

1. Protection status: E = endangered; CE = critically endangered

9.1.1.1 Tolerance to temporary inundation

The inherent characteristics of individual plant species and some vegetation communities as a whole may allow them to tolerate temporary inundation. Generally riparian and wetland species and communities have a higher tolerance to inundation but other dryland species can also have specific tolerance characteristics.

A recent review of the environmental impacts of temporary inundation upstream of flood inundation dams in Queensland (Hydrobiology 2019) noted that temporary inundation may impact certain aspects of ecosystem health but that the extent to which this may occur is substantially dependent on a large range of independent variables such as geology, frequency and duration of flooding, geographic setting, ecosystem characteristics, land use, germination from flood-borne seeds, edge effects and similar matters. It further noted that the studies of Queensland dams did not suggest that temporary flood inundation would inevitably cause substantial environmental impact. The study did, however, note the limitations in extrapolating the findings of limited studies from one system to another, particularly when there are regional differences in (for example) geographic setting, climate, geology, species mix and inundation characteristics. The study also noted the following relevant issues from published literature:

- the duration of inundation can have a significant effect on survival, with naturally riparian species generally able to tolerate longer inundation than naturally up-slope species
- the frequency of inundation can affect soil chemistry and waterlogging, leading to changes in the vegetation supported
- successional changes in vegetation on the margins of dams can take decades to complete.

Along the tributaries of Lake Burragorang there is a greater variety of plant species and communities including riparian plants and communities which are more tolerant to inundation. Further discussion is provided in Appendix F1 Biodiversity Assessment Report – Upstream.

9.1.1.2 Size and frequency of flood events

The extent, duration and frequency of temporary inundation would vary across the impacted area, and noting that the area is already subject to inundation from flood events. Depending upon the frequency, duration and extent of temporary inundation, the vegetation communities in certain areas may be able to regenerate and recover between events.

9.1.1.3 Duration and depth of temporary inundation

While related to the size and frequency of flood events, the depth and duration of temporary inundation is also a separate consideration especially near the fringes of inundation extents for larger events. The fringes of the inundation extents would only be inundated for relatively short periods of time (hours to up to two days) and to relatively low depths (generally less than half a metre; refer Section 4.2.3). Plants and vegetation communities that are relatively inundation intolerant may be able to withstand or recover from short shallow inundation.

As noted in Section 5, changes in depth and duration of temporary inundation with regard to the upstream impact area, these would be similar to that for Lake Burragorang, i.e. the additional depth of inundation would be up to about eight metres and the additional duration of temporary inundation would be up to eight and a half days.

Many of the soils of the Blue Mountains and especially around the tributaries are alluvial in nature and drain rapidly after flooding. This reduces any impacts associated with waterlogging of soils that may affect plants and vegetation communities.

9.1.1.4 Natural regeneration

There would be natural regeneration of some plants and vegetation communities after temporary inundation. For areas that receive infrequent, short and shallow inundation, the regeneration potential would be higher compared to other areas which are subject to more frequent deeper and longer temporary inundation. Many areas around Warragamba Dam and Lake Burragorang have experienced disturbance in the past from clearing for dam construction, agricultural, access and mining, and these areas have successfully naturally regenerated. Bushfire is another example of an episodic impact on vegetation which experiences natural regeneration.

In areas where more frequent, deeper and longer temporary inundation occurs, there would still be regeneration, however it is likely that more inundation tolerant species would either dominate or colonise these areas. There is some evidence of this already around Lake Burragorang where flood tolerant *Casuarina* species have colonised areas that are subject to more frequent inundation from the current operations of the dam.

9.2 Scleromorphic species

The nomination for the World Heritage listing (Government of Australia 1998, p104) notes

> *Scleromorphic plants are those with a characteristic set of features: small, evergreen, tough leaves, thick cuticles, hairs, leaf rolling, succulent leaves and/or stems, sunken stomates and low transpiration rates. The leaves of scleromorphs are often stiff and pointed, containing a high proportion of sclerenchyma (increased fibre to protein ratio) and occasionally silica in the epidermal walls (Beadle 1981a, b). Soft-leaved xeromorphs frequently grow with the sclerophylls. Their leaves are less hard, but they usually possess thick cuticles, hairs and 'water storage' tissue.*

and (Government of Australia 1998, pp106-108)

> *The inherently infertile plateau soils of the Greater Blue Mountains have long been known to have a distinctive sclerophyllous vegetation (Hamilton 1912 1923 1932; Osborn 1930; Pidgeon 1937). The theory that xeromorphy and scleromorphy evolved primarily in response to poor soil fertility, particularly low phosphorus concentrations, within rainforests (rather than as an adaptation to an arid climate) is supported by the widespread occurrence of scleromorphs in wetter areas, for example in the Sydney district on low-fertility sands. Maximum sclerophyll development is attained in soils that are sandy, with minimal clay content and of acid reaction (pH 4.5-6.5). The nutrient status of such soil is very low, with phosphorus values of 30-70 ppm recorded for the types of soils that are most common in the Blue Mountains (Beadle 1981a). In comparison, phosphorus values for tall open-forest are 100-150 ppm and for rainforest 200-1000+ ppm.*
>
> *Scleromorphy occurs in about 20 plant families, notably Myrtaceae, Proteaceae and Epacridaceae (Beadle 1981b). Within the nominated area these families are all well represented, as well as the Fabaceae (including subfamilies Faboideae and Mimosoideae), Dilleniaceae (Hibbertia), Rutaceae (Boronia) and Euphorbiaceae (Tribe Stenolobeae).*
>
> *The family Myrtaceae, particularly the dry-fruited capsular genera, is prominent in Australian sclerophyll vegetation. Within the Greater Blue Mountains the Myrtaceae contain the second highest number of species within a plant family (156). These largely belong to dry-fruited groups, including Leptospermum, Baeckea, Darwinia and Eucalyptus.*

Vegetation potentially affected by the Project from temporary inundation occurs around the perimeter of Lake Burragorang and its associated tributaries. The upstream biodiversity assessment (Appendix F1 Biodiversity Assessment Report – Upstream) identified that about 51 percent of the upstream study area comprised dry sclerophyll forest and about 1.5 percent comprised wet sclerophyll forest.

Dry sclerophyll forest is the most common habitat within the study area, occurring throughout the study area, close to the lake edges and adjacent to areas of alluvial woodland along the major rivers. Dry sclerophyll forest is dominated by Red Bloodwood (*Corymbia gumifera*), Scribbly Gums (*Eucalyptus haemastoma* and *E. racemosa*), Narrow-leaved Stringybark (*E. oblonga*) and Grey Gum (*E. punctata*). The mid-storey includes *Acacia*, *Banksia*, *Persoonia* and *Leptospermum* species.

Wet sclerophyll forest is a tall, open forest occurring in patches across the study area, particularly around Brereton Head. The canopy is dominated by Turpentine (*Syncarpia glomulifera*), Grey Gum (*Eucalyptus punctata*), Blackbutt (*E. pilularis*) and Smooth-barked Apple (*Angophora costata).* The mid-storey is open, comprising shrubs and small trees including *Pittosporum, Acacia, Allocasuarina* and *Leucopogon* species. The understorey is formed by a diverse array of shrubs, grasses and graminoids.

Investigation of the effect of temporary inundation did not suggest that this would inevitably cause substantial environmental impact (refer Section 9.2). In summary therefore, it is not possible to make a precise statement of the effect of the Project on scleromorphic species. However, for the purpose of offsetting potential impacts of the Project, it has been assumed that there would be a total loss of biodiversity values within the upstream impact area.

9.3 Ant-adapted plants

The nomination for the World Heritage listing (Government of Australia 1998, p108) notes

> *Nearly all genera of ant-dispersed plants are Australian endemics of dry sclerophyll eucalypt forest, woodland or heathland. While the seeds of eucalypts lack specialised structures for ant dispersal, ants transport and consume these in great numbers (O'Dowd & Gill 1984; Wellington & Noble 1985). The delayed release of eucalypt seeds undoubtedly contributes to a stable food supply for ants over many years.*
>
> *The seeds of other genera within the eucalypt forests and associated heathlands display a unique combination of characteristics that suggest a long history of co-evolution of ant-plant interactions in Australia.*

Vegetation potentially affected by the Project from temporary inundation occurs around the perimeter of Lake Burragorang and its associated tributaries. The upstream biodiversity assessment (Appendix F1 Biodiversity Assessment Report – Upstream) identified that about 51 percent of the upstream study area comprised dry sclerophyll forest and about 1.5 percent comprised wet sclerophyll forest.

Dry sclerophyll forest is the most common habitat within the study area, occurring throughout the study area, close to the lake edges and adjacent to areas of alluvial woodland along the major rivers. Dry sclerophyll forest is dominated by Red Bloodwood (*Corymbia gumifera*), Scribbly Gums (*Eucalyptus haemastoma* and *E. racemosa*), Narrow-leaved Stringybark (*E. oblonga*) and Grey Gum (*E. punctata*). The mid-storey includes Acacia, Banksia, Persoonia and Leptospermum species.

Wet sclerophyll forest is a tall, open forest occurring in patches across the study area, particularly around Brereton Head. The canopy is dominated by Turpentine (*Syncarpia glomulifera*), Grey Gum (*E. punctata*), Blackbutt *(E. pilularis)* and Smooth-barked Apple (*Angophora costata*). The mid-storey is open, comprising shrubs and small trees including Pittosporum, Acacia, Allocasuarina and Leucopogon species. The understorey is formed by a diverse array of shrubs, grasses and graminoids.

As previously noted, the recent Queensland investigation of the effect of temporary inundation did not suggest that this would inevitably cause substantial environmental impact. In summary therefore, it is not possible to make a precise statement of the effect of the Project on scleromorphic species. For the purpose of offsetting potential impacts of the Project, it has been assumed that there would be a total loss of biodiversity values within the upstream impact area.

9.4 Diversity and characteristics of the flora as a whole

The nomination for the World Heritage listing (Government of Australia 1998, pp108 110) notes

> *The flora of the nominated area is very diverse at all taxonomic levels with at least 152 families, 484 genera and some 1500 species.*
>
> *The plant families with the highest number of species recorded from the nominated area are Fabaceae (149), Myrtaceae (150), Orchidaceae (77), Poaceae (57), Asteraceae (69), Proteaceae (77) and Cyperaceae (43). The largest genera in the nominated area are Eucalyptus and related genera (90 species) and Acacia (64 species).*
>
> *The importance of the Greater Blue Mountains for the representation of eucalypts has been described above. They also have a high degree of significance for the representation of Australia's other typical woody genus, Acacia. Acacia is the largest genus of vascular plant species in Australia, with over 900 species that are mostly endemic to Australia, out of 1200 species world-wide. The majority of the species in Australia (c99%) belong to subgenus Phyllodineae (syn. Heterophyllum) which is largely endemic to Australia (Ross 1981, Maslin & Pedley 1988).*
>
> *The nominated area contains a total of 64 species, located within a centre of high Acacia species diversity. The two principal centres of species richness are south-west Western Australia and the Great Dividing Range south of the Tropic of Capricorn in eastern Australia (Maslin & Hnatiuk 1987; Hnatiuk & Maslin 1988). The node of highest diversity in eastern Australia (with over 50 species in a grid) encompasses the Greater Blue Mountains and adjacent sandstone plateaus.*

The GBMWHA world heritage listing includes recognition of the diversity of Eucalypt species within the World Heritage Area. Based on field survey 22 different Eucalypt species were identified in the upstream study area. Not all of these species occur in the GBMWHA but do occur in adjacent areas that are not part of the GBMWHA. Extensive scientific literature reviews were also undertaken to identify information on the flood tolerance of each of the individual Eucalypt species. Also, WaterNSW commissioned CSIRO to undertake a controlled field experiment (CSIRO 2019) to assess the impacts of extended temporary inundation on the Camden White Gum. The results of this field experiment are discussed below.

For many species there was little or no information regarding their flood tolerance. The flood tolerance of species where information was available varied and was generally related to their typical occurrence in the landscape. Eucalypt species that were typically found in dry ridgetop areas were generally intolerant to flooding, whereas Eucalypts that were associated with riparian areas were flood tolerant.

A recent review of the environmental impacts of temporary inundation upstream of flood inundation dams in Queensland (Hydrobiology 2019) noted that temporary inundation may impact certain aspects of ecosystem health but that the extent to which this may occur is substantially dependent on a large range of independent variables such as geology, frequency and duration of flooding, geographic setting, ecosystem characteristics, land use, germination from flood-borne seeds, edge effects and similar matters. It further noted that the studies of Queensland dams did not suggest that temporary flood inundation would inevitably cause substantial environmental impact. Further discussion is provided in Appendix F1 Biodiversity Assessment Report – Upstream.

Apart from *Eucalyptus benthamii* (Camden White Gum) and *E. glaucina* (Slaty Red Gum), none of the Eucalypt species were listed as threatened or endangered under NSW and/or Commonwealth biodiversity protection legislation. All other Eucalypt species were common and widely distributed in the Blue Mountains and other areas in NSW, and some species in other States.

Eucalyptus benthamii (Camden White Gum)

Eucalyptus benthamii (Camden White Gum) is a tall tree up to 40 metres high with smooth, white bark and numerous long, loose bark ribbons, and a persistent, flaky bark stocking at the base. It occurs on the alluvial flats of the Nepean River and its tributaries. The Camden White Gum requires a combination of deep alluvial sands and a flooding regime that permits seedling establishment. Recruitment of juveniles appears to be most successful on bare silt deposits in rivers and streams. The recorded elevation range for the species is from 30 metres above sea level at Bents Basin to 750 metres above sea level in the Kedumba population. Most of the individuals have been recorded at between 60 and 300 metres above sea level[9].

The main identified threats to the Camden White Gum are land clearing, urban development, inappropriate fire regimes, changed hydrology, weed invasion, and inappropriate revegetation works (impacting genetic diversity) (OEH 2013). Populations are now isolated within fragmented habitat (NSW NPWS 2000) due to extensive pre-1840 land clearing (Benson *et al.* 1996, cited in Butcher *et al.* 2005). Regulation of flooding regimes, competition from weeds and inappropriate fire regimes limit natural regeneration (Butcher *et al.* 2005). The productive nature of alluvial flats make them particularly prone to weed invasion, and the following weeds threaten the Camden White Gum: honey locust (*Gleditsia triacanthos*), African olive (*Olea europaea* subsp. *cuspidata*), Privet (*Ligustrum vulgare*), Box Elder (*Acer negundo*), cactus (*Opuntia* spp.), Balloon Vine (*Cardiospermum grandiflorum*), Bridal Creeper (*Asparagus asparagoides*), blackberry (*Rubus* spp.) and exotic grasses such as couch (*Cynodon* spp.) and *Paspalum* spp. (OEH 2013). Other threats to the Camden White Gum include habitat degradation caused by feral pigs (*Sus scrofa*) at Kedumba (OEH 2013) and hybridisation with Manna Gum (*Eucalyptus viminalis*) (Butcher *et al.* 2005).

The propagation and planting of Camden White Gums has been and is currently being undertaken. This include trial plantation planting of Camden White Gums in Deniliquin and overseas – and local habitat restoration programs such 20 Million Trees: Creating Habitat for Camden White Gum project by local government organisations in the region.

There are two major subpopulations: in the Kedumba Valley of the Blue Mountains National Park and at Bents Basin State Recreation Area. Several trees are scattered along the Nepean River around Camden and Cobbitty, with a further stand at Werriberri (Monkey) Creek in The Oaks. At least five trees occur on the Nattai River in Nattai National Park. Large areas of habitat were inundated by the formation of Warragamba Dam in 1960. Logging and clearing of other stands for agriculture and urban development along the Nepean River are also likely to have impacted its distribution.

The Kedumba Camden White Gum population is confined to the lower Kedumba River and Valley. Only a small part of the lower Kedumba River and Valley is contained within the GBMWHA, however there are some Camden White Gums in the area of the GBMWHA within the Kedumba Valley. Overall about 15 percent of the area of Camden White Gums potentially impacted by the Project is contained within the GBMWHA.

The population of the Camden White Gum in the Kedumba Valley consists of about 6,500 to 7,000 trees of varying maturity and at varying locations within the landscape. Some trees are located within the river and riparian zone of the Kedumba River, whereas others are located on dryer locations on rocky valley walls.

The Camden White Gum is flood tolerant and relies on flooding for germination and recruitment. To assess the ability of the Camden White Gum to withstand sustained flooding, WaterNSW commissioned CSIRO to undertake a controlled field experiment (CSIRO 2019). The study used stands of planted relatively mature Camden White Gums in Deniliquin and subjected them to various periods of shallow flooding (between one and six weeks). Parameters measured during the experiment include tree mortality, growth, stress responses and soil conditions. Overall the experiment found that the shallow flooding had no measurable impact on the Camden White Gums. In fact with longer flooding periods (that is, six weeks), the growth of the Camden White Gums was significantly higher compared

[9] Camden White Gum species profile: https://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10284

to control plots and those had experienced shorter periods of flooding. The major limitations to the study were that it did not assess the impacts of deeper flooding or the impacts on flooding on juvenile individuals.

A CSIRO study to assess the impacts of partial and full inundation of juvenile Camden White Gums (CSIRO 1995) was undertaken for the 1995 EIS to raise Warragamba Dam by 23 metres (which did not proceed). The study included a range of different inundation regimes, water quality conditions and height of juvenile seedlings. The study found that there was little or no mortality of juvenile Camden White Gums with complete inundation for 15 days, providing that dissolved oxygen concentrations in the inundation water were moderate or high. With low dissolved oxygen concentrations in the inundation water 100 percent mortality was recorded. Flood waters generally have moderate or high dissolved oxygen concentrations. The major limitations to the study were that it did not assess the impacts of deeper flooding and it was undertaken in a laboratory/greenhouse which does not replicate natural conditions.

Based upon on the outcomes of the CSIRO studies, the infrequent nature of the operation of the FMZ, the distribution of the Kedumba Camden White Gum population across the landscape and the general tolerance and requirements of the Camden White Gums for flooding, the impacts on existing Camden White Gums within the GBMWHA may not be significant.

The EMP and the Warragamba Offset Program may include specific measures to mitigate any additional threats to the Camden White Gum population (for example, pest control of pigs) and measures to encourage the health and recruitment of the existing population.

Eucalyptus glaucina (Slaty Red Gum)

Eucalyptus glaucina (Slaty Red Gum) is a medium-sized tree to 30 metres tall which before field work undertaken for the Project, was only found on the North Coast and from Taree to Broke. Slaty Red Gum grows in a range of situations, from shallow soils or stony hillsides, but not on poor sandstones, to grassy woodland on deep, moderately fertile and well-watered soil to gentle slopes near drainage lines in alluvial and clayey soils[10]. Individuals and clusters of *E. glaucina* were found both inside and outside the Project study area and some juvenile individuals were found within the FSL. Active recruitment of the species was observed in many other locations outside the Project study area. While there is no available information on its flood tolerance, its range of habitats and its association with the Forest Red Gum suggest some degree of flood tolerance. Given its widespread presence both inside and outside the Project study area, its active recruitment and likely flood tolerance, this species is not considered at risk from the Project.

Acacia species

The biodiversity assessment noted that *Acacia* species form part of the mid-storey of wet and dry sclerophyll forest, this collectively occurring across just over half of the upstream study area. Only one threatened species, the Kanangra Wattle (*Acacia clunies-rossiae*), was recorded during field surveys, however, a further five threatened species (*A. baueri* subsp. *aspera*; Bynoes Wattle, *A. bynoeana*; Flockton's Wattle, *A. flocktoniae*; Gordon's Wattle, *A. gordonii*, and Downy Wattle, *A. pubescens*) were considered to have a moderate likelihood of occurrence in the upstream study area. The biodiversity assessment noted that these species could have limited tolerance to flood stress such as through temporary inundation or waterlogging. Areas with the greatest potential for this would be around the perimeter of Lake Burragorang, this reducing substantially moving up the tributaries.

9.5 Species diversity

The nomination for the World Heritage listing (Government of Australia 1998, pp110 112) notes:

> *Some of the highest species-richness values in the world have been recorded from particular vegetation communities on sandstone country adjacent to the nominated area. (It is likely that similar values would exist within the area, but detailed research has not yet taken place.) In the upland swamps of the Woronora Plateau, species richness was compared within floristic groups at scales of 1m^2 10m^2 and 15m^2. High values of species richness were recorded for open-forest, woodland and heathland with mean values of 57-66 for an area 400m^2 (Keith 1994). A heath community occurring on relatively dry sites within the swamps recorded up to 70 vascular plant species in 15m^2, a significantly high value relative to other shrub and sedge communities in temperate latitudes, both within Australia and internationally (Keith & Myerscough 1993). Species-richness values at the 1-15m^2 scales were higher than any other published record, including data for Kwongan (in Western Australia) and Fynbos (in South Africa), which are renowned for their high species diversity (George et al. 1979; Cowling 1983).*

[10] Slaty Red Gum species profile: https://www.environment.nsw.gov.au/threatenedSpeciesApp/profile.aspx?id=10295

Such high species richness values can be related to the low nutrient soils, the open vegetation structure and disturbance by fire.

The upstream impact area within the GBMWHA potentially impacted by the Project is located along peripheral areas of the GBMWHA bordering Lake Burragorang and related tributaries. The Project would not affect any upland swamp areas. The Project is considered unlikely to have a material impact on species diversity relative to the overall GBMWHA. However, For the purpose of offsetting potential impacts of the Project, it has been assumed that there would be a total loss of biodiversity values within the upstream impact area.

9.6 Vertebrates

The nomination for the World Heritage listing (Government of Australia 1998, pp122 124) notes

The Greater Blue Mountains and surrounding plateaus provide habitat for a wide variety of mammals, birds, amphibians and reptiles. The faunal diversity strongly reflects the floristic and structural diversity of the sclerophyll vegetation. Approximately 400 vertebrate species have been recorded, including one reptile endemic to the area.

Fifty-two native and 13 introduced species of mammals have been recorded from the area. All native species are endemic to Australia, and include such Australian 'icons' as koalas, kangaroos and wombats.

Birds are the most prominent and diverse component of the vertebrate fauna of the Greater Blue Mountains. Some 265 native and 10 introduced species of birds have been recorded in the nominated area, comprising approximately one third of the total number of species found in Australia. Ford (1985) noted that the highest concentration of honeyeaters in Australia is found on the east coast and tablelands of New South Wales. Twenty-five species of honeyeaters have been recorded within the nominated area, approximately one third of the Australian total.

Although the Greater Blue Mountains do not possess the reptile diversity characteristic of arid regions of Australia, a wide variety of reptiles has been recorded, including two tortoises and more than 60 lizard and snake species. One species is endemic and two are largely restricted to the area.

More than 30 species of frogs are found in the Greater Blue Mountains area. Relatively few species are found on the upper plateaus (Smith & Smith 1990), with the majority occurring in the lower Blue Mountains. Frogs are predominantly found in the swamp communities. Litoria littlejohni and two other species have significant proportions of their known distributions occurring within the Greater Blue Mountains.

The following discussion provides comment with regard to the above nomination text for a number of vertebrate species, and reptiles and amphibians more generally.

9.6.1 Platypus (*Ornithorhynchus anatinus*)

The Platypus is not listed as threatened under any current NSW or Commonwealth legislation and is classified as 'Near Threatened' on the IUCN Red List of Threatened Species (Woinarski and Burbidge 2016). The Platypus has been provisionally included on the list of animals requiring urgent management intervention following the 2019-2020 bushfires, citing that further information on the species is required (DAWE 2020).

The Platypus is endemic to Australia, occurring along the east coast and Tasmania. It is mainly solitary and occupies permanent freshwater streams, but also occurs in lakes and wetlands. Steep, vegetated banks are preferred for burrowing (Menkhorst and Knight 2011). Local population declines and extinctions have been noted across its range as a result of threats including habitat disturbance for urbanisation, construction of dams and predation by feral carnivores (Bino *et al.* 2015).

Platypi forage by repeatedly diving for aquatic invertebrates, which are stored in cheek pouches. Between dives, short periods are spent on the surface masticating food items. Platypus are crepuscular and nocturnal, travelling up to four kilometres to forage. When not foraging, platypus spend their time in burrows built into banks. Resting burrows are several metres in length while nesting burrows are up to 30 metres in length with side tunnels. In New South Wales, mating occurs in late winter or autumn and young emerge from burrows in January or February (Grant and Temple-Smith 1998). Juveniles disperse following each breeding season.

The platypus was observed upstream of the study area in the Wollondilly River. There are additional records for the Kedumba, Kowmung and Coxs Rivers as well as within Lake Burragorang downstream of the Kowmung River confluence. The species has also been recorded in the Nepean River. Flooding can result in the drowning of nestlings if they are to occur in the breeding season. Short term availability of macroinvertebrate prey can be reduced by flooding (Bino *et al.* 2015). Increased sedimentation and changes to macroinvertebrate assemblages associated with impacts to water quality due to the operation of the Project are potential threats to the Platypus in the lower reaches of the rivers flowing into Lake Burragorang (BMT 2020). Increased flow rates are unlikely to affect the species and reduced flooding downstream may stabilise the availability of prey.

9.6.2 Short-beaked Echidna (*Tachyglossus aculeatus*)

The Short-beaked Echidna is not listed as threatened under any current NSW or Commonwealth legislation and is classified as 'Least Concern' on the IUCN Red List of Threatened Species (Aplin *et al.* 2016).

Short-beaked Echidnas are widely distributed throughout Australia and also occur in Papua New Guinea. Echidnas occupy almost all terrestrial habitat types, feeding on ants, termites and other soil invertebrates that are exposed by digging. They are active at varying times of day to avoid extreme temperatures, otherwise sheltering in burrows, logs and crevices (Menkhorst and Knight 2011). Studies have identified that echidna home ranges follow patterns seen in solitary eutherian mammals. Both sexes are promiscuous and large male home ranges overlap with several small female's home ranges, with individuals displaying a high fidelity to their home-range. As is expected with their very low metabolic rate, home-range sizes are smaller than similar sized carnivorous or omnivorous mammals (Nicol *et al.* 2011).

Animals are generally solitary except during the breeding season when females may be pursued by several males. The echidna breeds in spring, when an egg is laid and transferred to the pouch where it is incubated for approximately 10 days. Maternity burrows are built for nesting, with the young left in the burrow while the mother forages. Young are ejected from the pouch about the time they develop spines. Care of the young in the burrow continues for about three months with dispersal occurring in late summer to early autumn (Griffiths 1972).

The echidna was observed upstream during recent surveys and although other records are scarce, this is likely due to the lack of survey and access to record sightings. There are widespread records of the species in the downstream study area (NSW Bionet 2020). The echidna is expected to occur in all PCTs given their tendency to occupy a wide variety of habitats. The Project would result in temporary inundation of habitat and possible loss of individuals that occupy flooded areas as a result of increased competition due to their high fidelity with small home ranges.

A list of animals requiring urgent management intervention following the 2019-2020 bushfires, does not include the echidna (DAWE 2020). It has been shown to use torpor as a response to fire by sheltering and lowering their energy needs during and after the fire (Nowack *et al.* 2016). This behaviour means the echidna is more likely to be able to survive fires and re-occupy the same home range once the fire has passed. Their ability to persist in a burnt habitat is dependent on the presence of shelter, so where the fire is high intensity resulting in the complete loss of logs and leaf litter, individuals may be displaced.

9.6.3 Macquarie Perch/Blue Mountains Perch

The Macquarie Perch (*Macquaria australasica*), which is listed as endangered under both the EPBC Act and the NSW FM Act, occurs within the upstream study area. The Blue Mountains Perch (*Macquaria sp. nov. 'Hawkesbury'*), which is likely related to the Macquarie Perch, is also likely present within the upstream study area. While not officially listed as threatened under the EPBC Act (or FM Act), the Blue Mountains Perch has been included on the provisional list of animals requiring urgent management attention in the Australian Government's bushfire recovery package for wildlife and their habitats.

The Macquarie Perch is known to prefer waterways with rocky substrate (Bruce *et al.* 2007) and has been recorded at several locations in the Hawkesbury-Nepean catchment. The distribution of this species within the study area is fragmented and they often occur in low numbers (Bruce *et al.* 2007, Knight 2010). Bruce *et al.* (2007) and Knight (2010) recorded this species in 20 of 48 water bodies sampled including the Colo River, lower Coxs River, Lake Burragorang and the Nepean River. This species was typically one of the most abundant species in locations where it was recorded (Bruce *et al.* 2007, Knight 2010). eDNA analysis undertaken to inform this assessment suggest this species also occurs in the Kedumba River within the upstream study area. Knight (2010) observed that all sites where Macquarie Perch occurred were in an undisturbed condition, suggesting that their distribution is limited by their sensitivity to in-stream habitat conditions.

The Blue Mountains Perch is thought to be restricted to the mid-reaches of small near-pristine streams, at elevations of 35-420 metres above sea level, mostly commonly at 100-175 metres above sea level. It occurs in complex boulder habitats near pristine, clear streams in rugged gorges, with minimal sediment and nutrient loads, and little or no instream vegetation. Historically the species was more widespread and has disappeared from areas such as the upper Kowmung River, Wollondilly River, and approximately 80 kilometres of the Nepean River between the Bargo River junction and Penrith weir (Bray 2020).

The aquatic ecology assessment (Appendix F4) noted that neither of these species would be likely to be impacted by construction activities due principally to their respective preferred habitats being upstream of the construction area. Potential impacts on habitat downstream is considered unlikely with the implementation of appropriate environmental management measures such as water quality controls. It was noted that there were likely to be areas within the FMZ that could potentially support preferred habitat of the Macquarie Perch but not for the Blue Mountains Perch.

Spawning of Macquarie Perch occurs above riffles (shallow running water), where adhesive eggs are deposited among small boulders, pebbles and gravel. It cannot be discounted that some of this type of habitat exists in the FMZ. The geomorphology assessment (Appendix N1) determined that changes in erosion and deposition in the upstream study area were unlikely to be significant, accordingly the risk of preferred habitat of the Macquarie Perch (rocky substrates) being altered through sediment deposition was low. Increases in turbidity would generally be temporary in nature and associated with flood events, and therefore unlikely to contribute to a permanent reduction in quality of habitat.

The rugged gorges that the Blue Mountains Perch prefers occur in the upper reaches of streams in the upstream catchment and below Yarramundi in the downstream catchment. As this species is thought to prefer streams with minimal sediment and nutrient loads, changes in sedimentation and turbidity could impact this species. However, such changes are not anticipated in areas where this species is likely to inhabit.

9.6.4 Reptiles

Five reptile species were recorded in the study area during field surveys: Eastern Water Dragon (*Intellagama lesueurii*), Red-bellied Black Snake (*Pseudechis porphyriacus),* Eastern Brown Snake (*Pseudonaja textilis*), Rosenberg's Goanna (*Varanus rosenbergi*) and the Lace Monitor (*Varanus varius*). The biodiversity assessment identified potential impacts on reptiles may include loss of important habitat components such as exfoliated rocks and hollows, and potential mortality during flood events. The risk of loss of habitat components is considered low as water velocities associated with rise and fall of temporary inundation would be very low with low potential to mobilise and move habitat material. Velocities would be relatively higher in the upper reaches of tributaries associated with inflows, however, this would be no different to the existing situation. The rate of rise of floodwaters is unlikely to be such that most animals could not move ahead of the rising water.

9.6.5 Amphibians

The upstream biodiversity assessment identified the potential occurrence of two frog species in the study area: the Giant Burrowing Frog (*Heleioporus australiacus*), and Littlejohn's Tree Frog (*Litoria littlejohni*). The Red-crowned Toadlet (*Pseudophryne australis*) was also identified as potentially occurring. The biodiversity assessment identified the principal potential impacts on amphibians would be related to loss of structural components of vegetation within areas of suitable breeding habitat, potential mortality of individuals, and loss of suitable foraging habitat. As noted in the upstream biodiversity assessment the likelihood of a loss of habitat from a change in vegetation composition is considered low.

Consideration was also given to the Green and Golden Bell Frog (*Litoria aurea*), Booroolong Frog (*Litoria booroolongensis*), Stuttering Frog (*Mixophyes balbus*), and the Giant Barred Frog (*Mixophyes iteratus*). None of these were considered likely to be impacted by the Project; in the case of the latter two species this was due to them being unlikely to occur in the study area.

9.7 Invertebrates

The nomination for the World Heritage listing (Government of Australia 1998, pp124 126) notes

> *The taxonomy of invertebrates and knowledge of their distribution is limited and fragmentary within the Greater Blue Mountains area. Studies to date indicate that diversity is generally high in sclerophyll communities (Taylor et al. 1993; New 1988) and that the Blue Mountains contain a diverse and rich invertebrate fauna, much of which is undescribed. Surveys on the Boyd Plateau recorded a high diversity of invertebrates, including several new genera of slater and the Hairy Cicada (Tettigarcta crinita) (Mosley 1989).*
>
> *The butterflies and moths (Order Lepidoptera) are a particularly diverse group within the nominated area. It is estimated that 110-120 species of butterflies and 4,000 species of moths are found in the Greater Blue Mountains (Edwards pers. comm.).*
>
> *Rodd (1987a 1987b) provided the most detailed listing, recording 59 species of butterflies and 160 species of moths for the Mount Tomah area alone. There is also a diverse range of dragonflies and damselflies (Order Odonata) in the nominated area (Theischinger pers. comm.).*

Rainforest communities are rich in invertebrates, often including many 'primitive' forms representative of the Gondwanan fauna, and of considerable scientific interest. The Phylum Onychophora, for example, is particularly significant because it is believed to represent the 'missing link' between annelids (earthworms, etc.) and arthropods (insects, etc.) and bears striking similarities, in external features, to fossil specimens. Tait (pers. comm.) notes that there are at least five species within the Blue Mountains out of less than two hundred found in the world. Also of evolutionary significance are the glowworms, particularly the primitive genus Arachnocampa. A. richardsae is a predator species which traps its prey in hanging mucilaginous threads and the larvae is 'self-luminescent'. The type locality for this species is the Glowworm Tunnel, near Newnes (Harrison 1966) which has become a tourist attraction within Wollemi National Park.

Also of significance within the area is the Family Gradunglidae (ground-dwelling spiders). A high proportion of this family is restricted to the east coast of Australia, and it is particularly well represented in the Greater Blue Mountains (Grey pers. comm.).

The upstream biodiversity assessment identified that the project could impact on important habitat features for fauna, including invertebrates, such as understorey vegetation, fallen logs, woody debris and leaf litter. While these features could be submerged due to temporary inundation, the project is considered unlikely to result in the permanent loss of these habitat features given that the maximum duration of temporary inundation would be about two weeks. It is also noted that these habitat features are potentially affected by upstream flooding from operation of the existing dam.

The aquatic ecology assessment (Appendix F4) noted that changes to macroinvertebrate assemblages associated with impacts on water quality due to the operation of the Project could impact on species that rely on aquatic macroinvertebrates, such as fish. It also considered potential impacts on two invertebrate species listed under the NSW *Fisheries Management Act 1994*, the Adam's Emerald dragonfly (*Archaeophya adamsi*) and Sydney Hawk dragonfly (*Austrocordulia leonardi*). Threats to both species (DPI 2007, 2013) include:

- habitat degradation resulting from removal of riparian vegetation, drainage works, sedimentation from road crossings, and similar activities
- water pollution and sedimentation from land clearing, waste disposal and stormwater runoff from urban, industrial and agricultural development in catchments
- chance events such as natural disasters including bushfire and drought.

River regulation and alteration of flows resulting in the disappearance of natural deep pools has been identified as threat to the Sydney Hawk dragonfly (DPI 2007) while low population sizes and a long larval period (indicating an extremely low rate of natural recruitment and therefore slow recovery from any population decline) has been identified as threat to the Adam's Emerald dragonfly (DPI 2007).

The likelihood of habitat degradation is considered low; while habitat utilised by these species may be subject to temporary inundation (and which is also an existing risk), the limited duration (a maximum of about two weeks) would be unlikely to have a material affect on riparian habitat utilised by these species. There would be no change to the operation of the Special Areas therefore there would be no change to the risk of water pollution and sedimentation. The Project would not have any effect on chance events that may affect these species. The Project would not result in the loss of natural deep pools. Accordingly, the assessment concluded that it was unlikely that the Project would have a material impact on either of these two species.

A small area of Wollemi National Park (about one hectare) near the Colo River would fall inside the downstream Project PMF. As such, the Project would not affect the Glowworm Tunnel within Wollemi National Park which occurs outside of the Project study area about 60 kilometres to the north on the Newnes Plateau.

10 Assessments of significant impact

Identification of potential significant impacts was undertaken for threatened communities and species with potential moderate or high likelihood, or known/recorded occurrence within the upstream (U), construction (C), and downstream (D) study areas.

The assessments were made with regard to the relevant significant assessment guidelines criteria (refer Section 3.3) and the findings are documented in Table 10-1 for listed threatened ecological communities, Table 10-2 for listed threatened species, and Table 10-3 for listed migratory species. Comment has been provided by way of exception with regard to the criteria, that is separate responses have not been made to each individual criterion for each TEC or species where the response is the same.

The complete significant impact assessments prepared in accordance with the Matters of National Environmental Significance Significant impact guidelines 1.1 are provided in Appendix A for each threatened species and ecological community identified as known/recorded, high or moderate likelihood of occurrence within the Project study area.

It should be noted that there is a practical challenge in applying the significant impact assessment guidelines for the Project, particularly for TECs and threatened flora, as the nature and magnitude of potential impact areas are uncertain and will be dependent on the frequency of the flood event, the depth and duration of inundation, and the associated tolerance of vegetation to inundation. The potential for inundation would be mostly associated with the more frequent 20% AEP flood event but the extent would be less than for other relatively less frequent events. While a precautionary approach has been taken in assessing significance of impacts, it should be noted that although the assessment may conclude there could be a significant impact on a TEC or threatened species, the potential for such impacts may in fact be less.

The Matters of National Environmental Significance Significant impact guidelines 1.1 discusses when is a significant impact likely. To be 'likely', it is not necessary for a significant impact to have a greater than 50% chance of happening; it is sufficient if a significant impact on the environment is a real or not remote chance or possibility.

If there is scientific uncertainty about the impacts of your action and potential impacts are serious or irreversible, the precautionary principle is applicable. Accordingly, a lack of scientific certainty about the potential impacts of an action will not itself justify a decision that the action is not likely to have a significant impact on the environment

Threatened ecological communities and species with a single asterisk (*) are Protected Matters identified in the SEARs as particularly likely to be significantly impacted; those with a double asterisk (**) are Protected Matters that have been identified as potentially being impacted.

Table 10-1. Assessment of potential significant impacts for listed threatened ecological communities

Common name	Likelihood of occurrence	Assessment of significance	Comment
Castlereagh Scribbly Gum and Agnes Banks Woodlands of the Sydney Basin Bioregion**	Recorded (D)	Unlikely significant impact	The Project has the potential to interfere with the recovery of the TEC. The Project is unlikely to have a significant impact with regard to other significant impact criteria for this threatened ecological community.
Cooks River/Castlereagh Ironbark Forest of the Sydney Basin Bioregion**	Recorded (D)	Unlikely significant impact	The Project has the potential to interfere with the recovery of the TEC. The Project is unlikely to have a significant impact with regard to other significant impact criteria for this threatened ecological community.
Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest**	Moderate (U) Recorded (D)	Likely significant impact	The Project is unlikely to cause a substantial change in the species composition of this TEC, otherwise it is likely to have a significant impact with regard to other significant impact criteria for this threatened ecological community.
River-flat eucalypt forest on coastal floodplains of southern New South Wales and eastern Victoria	Recorded (U) Recorded (D)	Likely significant impact	The Project has the potential to reduce the extent of the TEC, to modify or destroy abiotic factors necessary for the TEC's survival, and would not facilitate the recovery of the TEC. The Project is unlikely to have a significant impact with regard to other significant impact criteria for this threatened ecological community.
Shale Sandstone Transition Forest in the Sydney Basin Bioregion*	Recorded (D) Moderate (C)	Unlikely significant impact	The Project has the potential to reduce the extent of the TEC, to modify or destroy abiotic factors necessary for the TEC's survival, and would not facilitate the recovery of the TEC. The Project is unlikely to have a significant impact with regard to other significant impact criteria for this threatened ecological community.
Turpentine-Ironbark Forest of the Sydney Basin Bioregion**	High (D)	Unlikely significant impact	The Project has the potential to reduce the extent of the TEC, to modify or destroy abiotic factors necessary for the TEC's survival, and would not facilitate the recovery of the TEC. The Project is unlikely to have a significant impact with regard to other significant impact criteria for this threatened ecological community.
Western Sydney Dry Rainforest and Moist Woodland on Shale**	Moderate (U) Recorded (D)	Likely significant impact	The Project is likely to have a significant impact with regard to all significant impact criteria for this threatened ecological community.
White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland*	Recorded (U)	Likely significant impact	The Project is likely to have a significant impact with regard to all significant impact criteria for this threatened ecological community.

Table 10-2. Assessment of potential significant impacts for listed threatened species

Scientific name	Common name	Likelihood of occurrence	Assessment of significance	Comment
Birds				
Anthochaera phrygia	Regent Honeyeater*	Recorded (U,D), Moderate (C)	Likely significant impact	The Project is unlikely to fragment the existing population into two or more populations or result in the introduction of a disease which may cause species decline. However, the Project has the potential to significantly impact this species in the upstream study area with regard to all other significant impact criteria for critically endangered and endangered species.
Botaurus poiciloptilus	Australian Bittern**	Recorded (D)	Unlikely significant impact	The Project could potentially interfere with this species' recovery but is unlikely to have a significant impact with regard to the other significant impact criteria for critically endangered and endangered species.
Calidris ferruginea	Curlew Sandpiper	Recorded (D)	Unlikely significant impact	The Project could potentially interfere with this species' recovery but is unlikely to have a significant impact with regard to the other significant impact criteria for critically endangered and endangered species.
Grantiella picta	Painted Honeyeater**	Recorded (U), Moderate (D,C)	Unlikely significant impact	The Project may potentially fragment an important existing population of this species but is unlikely to have a significant impact with regard to the other significant impact criteria for vulnerable species.
Hirundpus caudacatus	White-throated Needletail	High (D), Moderate (U,C)	Unlikely significant impact	The Project is unlikely to have a significant impact on this species with regard to the significant impact criteria for vulnerable species.
Lathamus discolor	Swift Parrot**	Recorded (D), High (U), Moderate (C)	Unlikely significant impact	The Project could potentially interfere with this species' recovery and may cause the loss of suitable habitat but is unlikely to have a significant impact with regard to the other significant impact criteria for critically endangered and endangered species.
Polytelis swainsonii	Superb Parrot	Moderate (U)	Unlikely significant impact	The Project is unlikely to have a significant impact on this species with regard to the significant impact criteria for vulnerable species.
Rostratula australis	Australian Painted Snipe	Recorded (D)	Unlikely significant impact	The Project could potentially interfere with this species' recovery but is unlikely to have a significant impact with regard to the other significant impact criteria for critically endangered and endangered species.

Scientific name	Common name	Likelihood of occurrence	Assessment of significance	Comment
Fish				
Macquaria australasica	Macquarie Perch*	High (U)	Unlikely significant impact	The Project is unlikely to have a significant impact on this species with regard to the significant impact criteria for critically endangered and endangered species.
Frogs				
Heleioporus australiacus	Giant Burrowing Frog**	High (D,C), Moderate (U)	Unlikely significant impact	The Project is unlikely to have a significant impact on this species with regard to the significant impact criteria for vulnerable species.
Litoria aurea	Green and Golden Bell Frog**	Recorded (D)	Likely significant impact	The Project is unlikely to result in an invasive species that is harmful to the Green and Golden Bell Frog becoming established in its habitat and is unlikely to result in the introduction of a disease which may cause species decline. However, the Project could potentially a significant impact with regard to the other significant impact criteria for critically endangered and endangered species.
Mammals				
Chalinolobus dwyeri	Large-Eared Pied Bat, Large Pied Bat*	Recorded (U,D,C)	Unlikely significant impact	The Project is unlikely to have a significant impact with regard to the significant impact criteria for vulnerable species.
Dasyurus maculatus maculatus	Spot-tailed Quoll, Spotted-tail Quoll, Tiger Quoll**	Recorded (D), High (U), Moderate (C)	Likely significant impact	The Project could potentially have a significant impact on this species as it is likely to permanently remove the habitat of eight adult Spotted-tailed Quolls, resulting in a long-term decrease in the size of the population. The Project could also interfere with the species' recovery. The Project is unlikely to have a significant impact on this species with regard to the other significant impact criteria for critically endangered and endangered species.

Scientific name	Common name	Likelihood of occurrence	Assessment of significance	Comment
Isoodon obesulus obesulus	Southern Brown Bandicoot**	High (U,C), Moderate (D)	Likely significant impact	Given the large area of habitat potentially affected upstream, there is potential for the Project to contribute to a long-term decrease in the size of the Southern Brown Bandicoot populations associated with the upstream Project study area. The Project has the potential to fragment existing populations of the Southern Brown Bandicoot into two or more populations. The Project may affect the breeding cycle of the Southern Brown Bandicoot in the construction area. The Project may cause the local extinction of some populations upstream, resulting in the increased isolation of some remaining populations. However, this is not expected to affect the species to the extent it is likely to decline. The Project is unlikely to have a significant impact on this species with regard to the other significant impact criteria for critically endangered and endangered species.
Petauroides volans	Greater Glider**	Recorded (U), Moderate (D)	Unlikely significant impact	The Project would reduce an important population in the upstream study area and may reduce foraging habitat for this species. However, the Project is unlikely to have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
Petrogale penicillata	Brush-tailed Rock-Wallaby**	High (U,C)	Likely significant impact	The Project is not likely to affect the breeding cycle of an important population of Brush-tailed Rock-wallaby, to result in the introduction of any further harmful species, or to introduce disease with potential to cause the Brush-tailed Rock-wallaby to decline. However, the Project could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
Phascolarctos cinereus	Koala**	Recorded (D), High (U), Moderate (C)	Likely significant impact	The Project could adversely affect habitat critical to the survival of this species and the amount of habitat to be removed exceeds the amount recommended in the *EPBC Act referral guidelines for the vulnerable koala* (DoE 2014). The Project is unlikely to have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.

Scientific name	Common name	Likelihood of occurrence	Assessment of significance	Comment
Potorous tridactylus tridactylus	Long-nosed Potoroo	Moderate (U)	Unlikely significant impact	The Project could potentially adversely affect habitat critical to the survival of this species. However, the Project is unlikely to have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
Pseudomys novaehollandiae	New Holland Mouse	Moderate (U)	Likely significant impact	Removal of habitat may result in a decrease of the local population and interfere with the recovery of the New Holland Mouse. The Project is unlikely to have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
Pteropus poliocephalus	Grey-headed Flying-fox*	Recorded (U,D), High (C)	Unlikely significant impact	The Project may result in the removal of critical foraging habitat for the Grey-headed Flying-fox which could result in a long-term decrease of the size of an important population of the Grey-headed Flying-fox. The Project could also adversely affect habitat critical to the survival to an important population of Grey-headed Flying-fox and could would reduce the local and regional availability of Grey-headed Flying-fox foraging habitat, resulting in the loss of individuals. However, the Project is unlikely to have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
Reptiles				
Hoplocephalus bungaroides	Broad-headed Snake**	Moderate (U,C)	Likely significant impact	Removal of habitat may fragment habitat and interfere with breeding activity of the Broad-headed Snake, resulting in a population decline. The Project is unlikely to have a significant impact on with regard to the other significant impact criteria for vulnerable species.
Invertebrates				
Pommerhelix duralensis	Dural Land Snail**	Recorded (D), Moderate (C)	Unlikely significant impact	The Project is unlikely to have a significant impact on this species with regard to the significant impact criteria for critically endangered and endangered species.
Plants				
Acacia bynoeana	Bynoe's Wattle**	Moderate (U,D,C)	Likely significant impact	The Project could potentially have a significant impact on this species with regard to all significant impact criteria for vulnerable species.

Scientific name	Common name	Likelihood of occurrence	Assessment of significance	Comment
Acacia flocktoniae	Flockton's Wattle	Moderate (U,C)	Likely significant impact	The Project is unlikely to interfere with any known recovery plans or actions for this species, however, it could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
*Acacia gordonii***	–	Moderate (U,C)	Likely significant impact	No invasive species or diseases have been listed as a threat to *A. gordonii*, and the Project is unlikely to interfere substantially with the recovery of this species. However, the Project could potentially have a significant impact on this species with regard to the other significant impact criteria for critically endangered and endangered species.
Acacia pubescens	Downy Wattle**	Recorded (D), Moderate (U,C)	Likely significant impact	The Project is unlikely to introduce any disease(s) harmful to an important population of this species, however, it could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
*Acrophyllum australe***	–	High (U)	Likely significant impact	The Project is unlikely to introduce any disease(s) harmful to an important population of this species, however, it could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
*Allocasuarina glareicola***	–	Moderate (D)	Likely significant impact	The Project is unlikely to introduce any disease(s) that could cause the species to decline, however, it could potentially have a significant impact on this species with regard to the other significant impact criteria for critically endangered and endangered species.
*Asterolasia elegans***	–	Moderate (U)	Likely significant impact	The Project is unlikely to introduce any disease(s) that could cause the species to decline, however, it could potentially have a significant impact on this species with regard to the other significant impact criteria for critically endangered and endangered species.
Astrotricha crassifolia	Thick-leaf Star-hair	Moderate (C)	Likely significant impact	The Project is unlikely to introduce any disease(s) that could cause the species to decline or interfere with the recovery of this species, however, could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.

Scientific name	Common name	Likelihood of occurrence	Assessment of significance	Comment
Baloskion longipes	Dense Cord-rush	Moderate (U)	Likely significant impact	The Project is unlikely to introduce any disease(s) that could cause the species to decline or interfere with the recovery of this species, however, it could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
Bossiaea oligosperma	Few-seeded Bossiaea**	Recorded (U)	Likely significant impact	The Project is unlikely to introduce any disease(s) that could cause the species to decline or interfere with the recovery of this species. However, it could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
Callistemon megalongensis	Megalong Valley Bottlebrush	Moderate (U)	Likely significant impact	The Project could potentially have a significant impact on this species with regard to all significant impact criteria for critically endangered and endangered species.
Cryptostylis hunteriana	Leafless Tongue Orchid	Moderate (U,C)	Likely significant impact	The Project is unlikely to introduce any disease(s) that could cause the species to decline or interfere with the recovery of this species. However, it could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
Cynanchum elegans	White-flowered Wax Plant**	Moderate (U,D)	Likely significant impact	The Project is unlikely to introduce any disease(s) that could cause the species to decline or interfere with the recovery of this species. However, it could potentially have a significant impact on this species with regard to the other significant impact criteria for critically endangered and endangered species.
*Darwinia biflora***	–	Moderate (U,D,C)	Likely significant impact	The Project could potentially have a significant impact on this species with regard to all significant impact criteria for vulnerable species.
Epacris sparsa	Sparse Heath	Moderate (D)	Likely significant impact	The Project is unlikely to introduce any disease(s) that could cause the species to decline, however, it could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
Eucalyptus benthamii	Camden White Gum*	Recorded (U,D)	Likely significant impact	The Project could potentially have a significant impact on this species with regard to all significant impact criteria for vulnerable species.

Scientific name	Common name	Likelihood of occurrence	Assessment of significance	Comment
Eucalyptus camfieldii	Camfield's Stringybark	Moderate (D)	Likely significant impact	The Project could potentially have a significant impact on this species with regard to all significant impact criteria for vulnerable species.
Eucalyptus sp. Cattai	–	Moderate (D)	Likely significant impact	The Project is unlikely to result in invasive species or introduce any disease(s) that could cause the species to decline or interfere with the recovery of this species. However, it could potentially have a significant impact on this species with regard to the other significant impact criteria for critically endangered and endangered species.
Eucalyptus glaucina	Slaty Red Gum	Recorded (U), Moderate (C)	Likely significant impact	The Project could potentially have a significant impact on this species with regard to all significant impact criteria for vulnerable species.
Euphrasia bowdeniae	–	Moderate (U)	Unlikely significant impact	The Project may introduce disease that could cause the species to decline, however, it is unlikely to have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
Genoplesium baueri	Bauer's Midge Orchid/Yellow Gnat-orchid	Moderate (U,C)	Likely significant impact	The Project is unlikely to introduce any disease(s) that could cause the species to decline or interfere with the recovery of this species. However, it could potentially have a significant impact on this species with regard to the other significant impact criteria for critically endangered and endangered species.
Grevillea parviflora subsp. *parviflora*	Small-flower Grevillea	Recorded (C), High (U,D)	Likely significant impact	The Project is unlikely to introduce any disease(s) that could cause the species to decline or interfere with the recovery of this species. However, it could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
Grevillea shiressii	–	Moderate (D)	Unlikely significant impact	The Project may reduce the area of potential occupancy of an important population of this species and could modify or destroy habitat potentially important to a local population. However, the Project is unlikely to have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
Hakea dohertyi	Kowmung Hakea*	Recorded (U)	Likely significant impact	The Project is unlikely to introduce any disease(s) that could cause the species to decline, however, it could potentially have a significant impact on this species with regard to the other significant impact criteria for critically endangered and endangered species.

Scientific name	Common name	Likelihood of occurrence	Assessment of significance	Comment
Isopogon flethcheri	Fletcher's Drumstick	Moderate (U)	Unlikely significant impact	The Project is unlikely to have a significant impact on this species with regard to the significant impact criteria for vulnerable species.
Kunzea cambagei	Cambage Kunzea**	Moderate (U)	Unlikely significant impact	There are no records of this species in any of the study areas. If a population was to occur it would not be classed as an important population. The Project is unlikely to have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
*Kunzea rupestris***	–	Moderate (U,D,C)	Likely significant impact	The Project is unlikely to introduce disease that could cause the species to decline, however, it could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
Leionema lachnaeoides	–	Moderate (U)	Likely significant impact	In absence of targeted surveys, a population has been assessed as occurring in suitable habitat. The Project will impact this habitat, disrupt the breeding cycyle and interfer with the National Recovery Plan.
Leucopogon exolasius	Woronora Beard-heath	Moderate (U,D,C)	Likely significant impact	The Project is unlikely to introduce any disease(s) that could cause the species to decline or interfere with the recovery of this species. However, it could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
Melaleuca deanei	Deane's Paperbark	Moderate (U,D,C)	Likely significant impact	The Project is unlikely to introduce any disease(s) that could cause the species to decline or interfere with the recovery of this species. However, it could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
*Micromyrtus blakelyi***	–	Moderate (U,C)	Likely significant impact	The Project is unlikely to interfere with the recovery of this species. However, it could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
*Micromyrtus minutiflora***	–	High (D)	Likely significant impact	The Project is unlikely to introduce disease that could cause the species to decline. However, it could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.

Scientific name	Common name	Likelihood of occurrence	Assessment of significance	Comment
*Olearia cordata***	–	Moderate (U,C)	Likely significant impact	The Project is unlikely to introduce disease that could cause the species to decline. However, it could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species
Persicaria elatior	Tall Knotweed	Moderate (U)	Likely significant impact	The Project is unlikely to introduce disease that could cause the species to decline. However, it could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
Persoonia acerosa	Needle Geebung**	Moderate (U,C)	Likely significant impact	The Project is unlikely to interfere with the recovery of the species. However, it could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
Persoonia bargoensis	Bargo Geebung	Moderate (U)	Likely significant impact	The Project is unlikely to facilitate the spread and establishment of weed and exotic species harmful to an important population and would not interfere with the recovery of this species. However, it could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
Persoonia glaucescens	Mittagong Geebung	Moderate (U)	Likely significant impact	The Project is unlikely to interfere with the recovery of this species. However, it could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
Persoonia hirsuta	Hairy Geebung**	High (U), Moderate (D,C)	Likely significant impact	The Project could potentially have a significant impact on this species with regard to all significant impact criteria for critically endangered and endangered species.
Persoonia nutans	Nodding Geebung**	Recorded (D), High (C)	Likely significant impact	The Project could potentially have a significant impact on this species with regard to all significant impact criteria for critically endangered and endangered species.
Pherosphaera fitzgeraldii	Dwarf Mountain Pine	Moderate (U)	Likely significant impact	The Project could potentially have a significant impact on this species in that it would likely lead to a long-term decrease in the size of the population, reduce the area of occupancy of the species, especially in relation to key breeding habitat, adversely affect habitat critical to the survival of the species, disrupt the breeding cycle of the species, and interfere with the species recovery.

Scientific name	Common name	Likelihood of occurrence	Assessment of significance	Comment
Phyllota humifusa	Dwarf Phyllota	Moderate (U)	Likely significant impact	The Project is unlikely to interfere with the recovery of this species. However, it could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
*Pimelea curviflora var. curviflora***	–	Recorded (D), Moderate (U,C)	Likely significant impact	The Project is unlikely to introduce disease that could cause the species to decline. However, it could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
Pimelea spicata	Spiked Rice-flower**	High (D)	Likely significant impact	The Project is unlikely to introduce disease harmful to an important population of this species. However, it could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
Pomaderris brunnea	Brown Pomaderris/ Rufous Pomaderris**	Recorded (U,D), Moderate (C)	Likely significant impact	The Project is unlikely to interfere with the recovery of this species. However, it could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
Pterostylis saxicola	Sydney Plains Greenhood**	Moderate (U,D,C)	Likely significant impact	**Upstream**: the Project is unlikely to introduce any disease(s) that could cause the species to decline, however, it could potentially have a significant impact on this species with regard to the other significant impact criteria for critically endangered and endangered species. **Downstream**: the expert report prepared by Dr Weston for this species has determined that the species does not rely on periodic inundation, and the Project would be unlikely to impact populations of the species occurring within the PMF.
Pultenaea glabra	Smooth Bush-pea, Swamp Bush-pea**	High (U), Moderate (C)	Likely significant impact	The Project is unlikely to fragment an existing important population of this species into two or more populations but could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
*Pultenaea parviflora***	–	Recorded (D), Moderate (U,C)	Likely significant impact	The Project is unlikely to introduce disease that could cause the species to decline. However, it could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.

Scientific name	Common name	Likelihood of occurrence	Assessment of significance	Comment
Rhizanthella slateri	Eastern Australian Underground Orchid	Moderate (U)	Likely significant impact	The Project is unlikely to introduce disease that could cause the species to decline. However, it could potentially have a significant impact on this species with regard to the other significant impact criteria for critically endangered and endangered species.
Syzygium paniculatum	Magenta Lilly Pilly, Magenta Cherry, Daguba, Scrub Cherry, Creek Lilly Pilly, Brush Cherry	Moderate (U,D,C)	Likely significant impact	The Project could potentially have a significant impact on this species with regard to all significant impact criteria for vulnerable species.
Thesium australe	Austral Toadflax**	Moderate (U)	Likely significant impact	The Project is unlikely to interfere with the recovery of this species. However, it could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
Trachymene scapigera	Mountain Trachymene	Moderate (U)	Likely significant impact	The Project could potentially have a significant impact on this species in that it would likely lead to a long-term decrease in the size of the population, reduce the area of occupancy of the species, especially in relation to key breeding habitat, adversely affect habitat critical to the survival of the species, disrupt the breeding cycle of the species, and interfere with the species recovery.
Velleia perfoliata	–	Moderate (U,D,C)	Likely significant impact	The Project is unlikely to fragment an important population of this species into two or more smaller populations or to interfere with the recovery of the species. However, it could potentially have a significant impact on this species with regard to the other significant impact criteria for vulnerable species.
Zieria covenyi	Coveny's Zieria	High (U)	Likely significant impact	The Project could potentially have a significant impact on this species with regard to all significant impact criteria for critically endangered and endangered species.
*Zieria involucrata***	–	Recorded (D), Moderate (U,C)	Likely significant impact	The Project could potentially have a significant impact on this species with regard to all significant impact criteria for vulnerable species.
Zieria murphyi	Velvet Zieria	Moderate (U)	Likely significant impact	The Project could potentially have a significant impact on this species with regard to all significant impact criteria for vulnerable species.

Table 10-3. Assessment of potential significant impacts for migratory species

Scientific name	Common name	Agreement[1]			Likelihood of occurrence	Assessment of significance	Comment
		C	J	K			
Marine species							
Apus pacificus	Fork-tailed Swift	Y	Y	Y	Moderate (U, C, D)	Unlikely significant impact	The Project may have a potential impact on this species with regard to a decline in foraging habitat through modification of native vegetation. The Project is unlikely to have a significant impact on this species with regard to the other significant impact criteria for migratory species.
Terrestrial species							
Monarcha melanopsis	Black-faced Monarch	N	N	N	Recorded (U) Moderate (D, C)	Unlikely significant impact	The Project may have a potential impact on this species with regard to a substantially modifying habitat utilised by this species, however, this habitat is not regarded as important for the ongoing viability of this species. The Project is unlikely to have a significant impact on this species with regard to the other significant impact criteria for migratory species.
Monarcha trivirgatus	Spectacled Monarch	N	N	N	Moderate (U, C, D)	Unlikely significant impact	The Project may have a potential impact on this species with regard to a substantially modifying habitat utilised by this species, however, this habitat is not regarded as important for the ongoing viability of this species. The Project is unlikely to have a significant impact on this species with regard to the other significant impact criteria for migratory species.
Myiagra cyanoleuca	Satin Flycatcher	N	N	N	Recorded (U) Moderate (D, C)	Unlikely significant impact	The Project may have a potential impact on this species with regard to a substantially modifying habitat utilised by this species, however, this habitat is not regarded as important for the ongoing viability of this species. The Project is unlikely to have a significant impact on this species with regard to the other significant impact criteria for migratory species.
Rhipidura rufifrons	Rufous Fantail	N	N	N	Recorded (U) Moderate (D, C)	Unlikely significant impact	The Project may have a potential impact on this species with regard to a substantially modifying habitat utilised by this species, however, this habitat is not regarded as important for the ongoing viability of this species. The Project is

Scientific name	Common name	Agreement[1]			Likelihood of occurrence	Assessment of significance	Comment
		C	J	K			
							unlikely to have a significant impact on this species with regard to the other significant impact criteria for migratory species.
Wetland species							
Calidris acuminata	Sharp-tailed Sandpiper	Y	Y	Y	Moderate (D)	Unlikely significant impact	The Project is unlikely to have a significant impact on this species with regard to the significant impact criteria for migratory species.
Calidris melanotos	Pectoral Sandpiper	N	Y	Y	Moderate (D)	Unlikely significant impact	The Project is unlikely to have a significant impact on this species with regard to the significant impact criteria for migratory species.
Gallinago hardwickii	Latham's Snipe, Japanese Snipe	N	Y	Y	High (U,C,D)	Unlikely significant impact	The Project may have a potential impact on this species with regard to a substantially modifying habitat utilised by this species, however, this habitat is not regarded as important for the ongoing viability of this species. The Project is unlikely to have a significant impact on this species with regard to the other significant impact criteria for migratory species.
Tringa nebularia	Common Greenshank, Greenshank	Y	Y	Y	Moderate (U, C)	Unlikely significant impact	The Project is unlikely to have a significant impact on this species with regard to the significant impact criteria for migratory species.

1. C – CAMBA (China–Australia Migratory Bird Agreement); J – JAMBA (Japan–Australia Migratory Bird Agreement); K – ROKAMBA (Republic of Korea–Australia Migratory Bird Agreement)

11 Matters relevant to biodiversity in the EPBC Act and Regulations

11.1 Threatened species and communities

Section 139 of the EPBC Act identifies matters to be considered with regard to decision-making for proposals affecting threatened species and communities. The following table provides an assessment for each of these matters.

Table 11-1. Assessment of the Project against section 139 of the EPBC Act

Matter	Assessment
In deciding whether or not to approve for the purposes of a subsection of section 18 or section 18A the taking of an action, and what conditions to attach to such an approval, the Minister must not act inconsistently with:	
(a) Australia's obligations under:	
(i) the Biodiversity Convention[1]; or	The current mechanism to support Australia's obligations under the Biodiversity Convention is *Australia's Strategy for Nature 2019-2030* (Commonwealth of Australia 2019). The strategy identifies the following three goals: ▪ Goal 1: connect all Australians with nature ▪ Goal 2: care for nature in all its diversity ▪ Goal 3: share and build knowledge These goals are complemented by various objectives to guide achievement of each goal. Design development has sought to avoid, minimise and or mitigate impacts on biodiversity as far as practicable. Measures to offset residual impacts have been identified in accordance with the EPBC Environmental Offsets Policy (refer Section 13).
(ii) the Apia Convention[2]; or	The assessment has considered potential impacts on protected areas and the biodiversity values of these areas. Identified impacts have been avoided, minimised and/or mitigated where practicable. Measures to offset residual impacts have been identified in accordance with the EPBC Environmental Offsets Policy (refer Section 13).
(iii) CITES[3]; or	The Project does not include any matters that fall under CITES.
(b) a recovery plan or threat abatement plan.	Consideration of recovery plans or threat abatement plans is provided, where relevant, in Appendix A.

1 The United Nations Convention on Biological Diversity (CBD), or Biodiversity Convention, is one of three international environment agreements that emerged from the Rio Earth Summit held in 1992. The CBD is an international legally-binding treaty with three objectives: i) the conservation of biodiversity; ii) the sustainable use of its components; and iii) the fair and equitable sharing of the benefits arising from the use of genetic resources[11].

2 The Convention on Conservation of Nature in the South Pacific (Apia Convention) is a multilateral environmental agreement signed in Apia on 12 July 1976. The Convention entered into force on 26 June 1990. The main objective of the Convention is to commit the Parties to take action for the conservation, utilisation and development of the natural resources of the South Pacific region through careful planning and management for the benefit of present and future generations. The majority of the commitments under the Convention have been superseded by Parties' commitments under the CBD[12].

3 Convention on International Trade in Endangered Species of Wild Fauna And Flora

[11] Source: https://www.environment.gov.au/biodiversity/international/un-convention-biological-diversity

[12] Source: https://www.sprep.org/convention-secretariat/apia-convention

11.2 Migratory species

Section 140 of the EPBC Act identifies matters to be considered with regard to decision-making for proposals affecting migratory species. While migratory species have not been identified as a controlling provision in Attachment A to the SEARs, Table 11-2 provides an assessment for each of these matters.

Table 11-2. Assessment of the Project against section 140 of the EPBC Act

Matter	Assessment
In deciding whether or not to approve for the purposes of section 20 or 20A the taking of an action relating to a listed migratory species, and what conditions to attach to such an approval, the Minister must not act inconsistently with Australia's obligations under whichever of the following conventions and agreements because of which the species is listed:	
(a) the Bonn Convention;	None of the species listed in Table 10-3 are identified in Appendices I and II of the Convention on the Conservation of Migratory Species of Wild Animals (the Bonn Convention).
(b) CAMBA;	The assessment has consider potential impacts on species listed under CAMBA (refer Table 10-3). The Project is unlikely to have a significant impact on any of the identified species.
(c) JAMBA;	The assessment has consider potential impacts on species listed under JAMBA (refer Table 10-3). The Project is unlikely to have a significant impact on any of the identified species.
(d) an international agreement approved under subsection 209(4).	In addition to the above agreements, Australia is also a party to the Agreement on the Conservation of Albatrosses and Petrels. The Project would not impact any species listed under this agreement.

12 Summary of potential impacts

12.1 Construction

Construction works would require clearing 22.42 hectares of native vegetation. This may impact on four different vegetation communities, one of which (PCT 1281: Turpentine – Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion) conforms to the Shale Sandstone Transition Forest of the Sydney Basin Bioregion TEC, listed as critically endangered under the EPBC Act. This TEC has an extent of 8.12 hectares in the construction study area and immediate surrounding area. The Project would require clearing of 1.64 hectares.

While no targeted threatened flora species surveys were carried out in the construction study area, an incidental observation of *Grevillea parviflora* subsp. *parviflora*, listed as vulnerable under the EPBC Act, was recorded within the construction study area and may be affected by clearing during construction. This species can reproduce by suckering and may persist in disturbed areas. BioNet lists this species as being associated with the PCTs 1081 1083 and 1281. The combined clearing of these PCTs within the development site (the construction site) is 14.19 hectares.

The following fauna habitat features would be removed:

- understorey vegetation
- fallen logs, woody debris and leaf litter
- hollow-bearing living trees and stags
- nectar-producing trees and shrubs
- ephemeral drainage lines.

Suitable habitat (by PCT) for 26 protected matters (EPBC Act listed threatened fauna species) has also been identified within the Project study area and may be impacted by the development. A total of 22.42 hectares of suitable habitat for other threatened fauna species would be cleared.

Construction activities, including vegetation clearing may result in fauna mortality, including both vertebrates and invertebrates. The most likely causes of direct fauna mortality would be animals killed through injury or stress during active vegetation clearing or vehicle strike during construction.

Project construction activities may result in indirect impacts to protected matters through:

- loss or fragmentation of native vegetation
- edge effects
- degradation and changes to hydrology
- weed invasion and encroachment
- creating habitat conducive to invasive species
- introduction or spread of diseases or pathogens
- alteration of noise environment
- alteration of light environment
- dust impacts
- effects from blasting and vibration
- erosion and sedimentation
- changes to natural fire regimes.

These impacts are assessed in detail in Appendix F3 of the EIS (Biodiversity assessment report – construction area).

12.2 Operation

Construction of Warragamba Dam and the formation of Lake Burragorang in the 1960s resulted in significant changes to the upstream catchment flooding and inundation regime. The Project would result in reducing the peak rate of discharge through Warragamba Dam, which would change current temporary inundation extents, depths and durations, and rates of rising and receding flows. Some areas may also be affected by changes to sedimentation and erosion processes.

Changes to flood areas and durations and altered flow patterns can result in a reduction of suitable habitat, contribute to the degradation of riparian zones, increase conditions for invasive species and generally disrupt the maintenance of ecological functions and processes (NSW Scientific Committee 2002).

The inundation extent is controlled by the peak flood level at the dam wall and the topography across the upstream catchment. Steep terrain extends upstream from the dam wall for at least 20 kilometres, so that the extent of land inundated changes at a relatively small rate with increasing magnitude floods. However, the rate of change and inundated area increases as terrain flattens about where the Wollondilly River and Coxs River enter Lake Burragorang.

The modelling shows the increase in the duration of upstream inundation could be up to 10.4 days. The increase in temporary inundation impacts would decrease with distance upstream from Lake Burragorang and further in the upper tributaries.

Most terrestrial plant species cannot survive prolonged submergence or soil waterlogging: these stresses are collectively termed flood stress. Flooding results in the inundation of part or all of the above ground structures, while waterlogging occurs in the soils and rhizosphere (Colmer and Pedersen 2008; Parolin and Wittmann 2009). This can result in:

- changes to plant morphology
- disruption to life history processes
- changes to vegetation structure, composition and condition
- habitat changes.

However, a recent review of the environmental impacts of temporary inundation upstream of flood inundation dams in Queensland (Hydrobiology 2019) noted that temporary inundation may impact certain aspects of ecosystem health but that the extent to which this may occur is substantially dependent on a large range of independent variables such as geology, frequency and duration of flooding, geographic setting, ecosystem characteristics, land use, germination from flood-borne seeds, edge effects and similar matters. It further noted that the studies of Queensland dams did not suggest that temporary flood inundation would inevitably cause substantial environmental impact. Further discussion is provided in Appendix F1 Biodiversity Assessment Report – Upstream.

The Project would potentially impact native vegetation upstream when the FMZ is operating. The extent of flooding would depend on the magnitude of the inflow event and the level of the lake at the time. For a rare 1 in 100 chance in a year event, an additional area of 1,912 hectares would be temporarily inundated (2,910 hectares in total). For a relatively more frequent 1 in 5 chance in a year event, an additional area of 283 hectares would be temporarily inundated (843 hectares in total). Temporary inundation of the upstream impact area would affect about 1,400 hectares.

The estimated flood extents assumes that flood producing rainfall occurs when the dam is at full supply level, which would not always be the case. Therefore, quantifying how much native vegetation, if any, would be inundated during specific flood events, and the duration for which it would be inundated, is difficult.

Downstream impacts associated with operation of the FMZ would be influenced by the magnitude of the inflow event to the FMZ, with the level of the storage also having some influence. Hydrological modelling showed that the Project would reduce peak outflow rates and flood levels for all flood scenarios. Flood levels are substantially reduced for floods up to the 1 in 1,000 chance in a year event (0.1 %AEP event).

Operation of the FMZ following a major flood event would result in some sections of the floodplain being subjected to longer periods of inundation. Generally, the benefits of the Project in the reduction of flood extents and the impacts from the FMZ discharge extend downstream to Wisemans Ferry. While the benefits and impacts of the Project may still be detectable downstream of Wisemans Ferry, the changes in water levels would be minor and be substantially below the tidal range in the marine-influenced section of the Hawkesbury River.

12.2.1 Threatened flora

Based on consideration of relevant criteria in the EPBC Act significant impact guidelines, the Project would likely have a significant impact on 47 threatened flora species listed under the EPBC Act (refer Table 12-1). The table also identifies the conservation status of each species (vulnerable, V; endangered, E; or critically endangered CE). Impacts would principally relate to inundation based on associations with respective PCT(s). Areas have not been provided for the upstream impact area as it has been assumed that there would be a total loss of biodiversity values in this area.

Table 12-1. Threatened flora likely to be significantly impacted

Scientific name (Common name)	EPBC Act status	DS FMZ[1]	DS 10% AEP difference[1]	DS PMF difference[1]	Construction dev footprint[1]
Acacia bynoeana (Bynoe's Wattle)	V	137.48	282.09	683.08	20.78
Acacia flocktoniae (Flockton Wattle)	V	-	-	-	8.53
Acacia gordonii	E	-	-	-	15.01
Acacia pubescens (Downy Wattle)	V	400.84	277.82	86.57	22.42
Acrophyllum australe	V	-	-	-	12.25
Allocasuarina glareicola	E	0	28.75	535.67	-
Asterolasia elegans	E	-	-	-	-
Baloskion longipes (Dense Cord-rush)	V	-	-	-	-
Bossiaea oligosperma (Few-seeded Bossiaea)	V	-	-	-	-
Callistemon megalongensis (Megalong Valley Bottlebrush)	CE	-	-	-	-
Cryptostylis hunteriana (Leafless Tongue Orchid)	V	-	-	-	12.25
Cynanchum elegans (White-flowered Wax Plant)	E	0	0	0.39	-
Darwinia biflora	V	9.37	30.27	0	2.76
Epacris sparsa (Sparse Heath)	V	NA	NA	NA	-
*Eucalyptus benthamii** (Camden White Gum)	V	167.25	64.32	154.98	-
Eucalyptus sp. Cattai	CE	25.86	27.99	-	-
Eucalyptus glaucina (Slaty Red Gum)	V	-	-	-	-
Genoplesium baueri (Bauer's Midge Orchid)	E	-	-	-	22.42
Grevillea parviflora subsp. *parviflora* (Small-flower Grevillea)	V	0	0	11.79	4.40
Hakea dohertyi (Kowmung Hakea)	E	-	-	-	-
Isopogon fletcheri (Fletcher's Drumsticks)	V	-	-	-	-
Kunzea rupestris	V	0	0	0	15.01
Leionema lachnaeoides	E	-	-	-	-
Leucopogon exolasius (Woronora Beard-heath)	V	5.57	12.80	15.45	20.78
Melaleuca deanei (Deane's Paperbark)	V	1.06	49.72	37.48	15.01
Micromyrtus minutiflora	V	0	30.17	262.89	-
Olearia cordata	V	-	-	-	15.01
Persicaria elatior (Tall Knotweed)	V	-	-	540	-
Persoonia acerosa (Needle Geebung)	V	-	-	-	18.02
Persoonia bargoensis (Bargo Geebung)	V	-	-	-	-
Persoonia glaucescens (Mittagong Geebung)	V	-	-	-	-
Persoonia hirsuta (Hairy Geebung)	E	557.34	459.98	36.37	22.42

Scientific name (Common name)	EPBC Act status	DS FMZ[1]	DS 10% AEP difference[1]	DS PMF difference[1]	Construction dev footprint[1]
Persoonia nutans (Nodding Geebung)	E	5.56	44.99	622.11	-
Pherosphaera fitzgeraldii (Dwarf Mountain Pine)	E	-	-	-	-
Phyllota humifusa (Dwarf Phyllota)	V	-	-	-	-
Pimelea curviflora var. *curviflora*	V	107.42	179.46	52.40	-
Pomaderris brunnea (Brown Pomaderris)	V	-	-	-	2.76
Pterostylis saxicola (Sydney Plains Greenhood)	E	NA	NA	NA	NA
Pultenaea glabra (Smooth Bush-Pea)	V	-	-	-	18.02
Pultenaea parviflora	V	0.28	45.82	470.77	-
Rhizanthella slateri (Eastern Australian Underground Orchid)	E	-	-	-	-
Trachymene scapigera (Mountain Trachymene)	E	-	-	-	-
Velleia perfoliata	V	8.25	11.13	0	2.76
Zieria covenyi (Coveny's Zieria)	E	-	-	-	-
Zieria involucrata	V	56.19	58.17	0.31	-
Zieria murphyi (Velvet Zieria)	V	-	-	-	-

1 Area in hectares

12.2.2 Threatened fauna

Based on consideration of relevant criteria in the EPBC Act significant impact guidelines, the Project would likely have a significant impact on 11 threatened fauna species listed under the EPBC Act (refer Table 12-2). Impacts would principally relate to temporary inundation of habitat based on association with affected PCT(s). Areas have not been provided for the upstream impact area as it has been assumed that there would be a total loss of biodiversity values in this area.

Table 12-2. Threatened fauna likely to be significantly impacted

Scientific name (Common name)	EPBC Act status	DS FMZ[1]	DS 10% AEP difference[1]	DS PMF difference[1]	Construction dev footprint[1]
Anthochaera phrygia (Regent Honeyeater)	CE	-	-	-	NA – see AoS[2]
Dasyurus maculatus maculatus (Spotted-tail Quoll)	E	-	-	-	NA – see AoS
Hoplocephalus bungaroides (Broad-headed Snake)	V	-	-	-	21
Isoodon obesulus subsp. *obesulus* (Southern Brown Bandicoot (eastern))	E	NA – see AoS	NA – see AoS	0	12.00
Litoria aurea (Green and Golden Bell Frog)	V	NA – see AoS	NA – see AoS	NA – see AoS	-
Petrogale penicillata (Brush-tailed Rock-wallaby)	V	-	-	-	NA – see AoS
Phascolarctos cinereus (Koala)	V	858	805	909	-

Scientific name (Common name)	EPBC Act status	DS FMZ[1]	DS 10% AEP difference[1]	DS PMF difference[1]	Construction dev footprint[1]
Pommerhelix duralensis (Dural Land Snail)	V	121	197	38	-
Pseudomys novaehollandiae (New Holland Mouse)	V	-	-	-	-

1 Area in hectares

2 Assessment of Significance (refer Matters of National Environmental Significance Significant impact guidelines 1.1)

12.2.3 Threatened ecological communities

Eighteen PCTs conform to TECs listed under the EPBC Act that occur within the Project study area. Operational impacts on these are discussed as follows.

12.2.3.1 Upstream

The two affected TECs in the upstream study area are the critically endangered *White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland* and the critically endangered *River-flat eucalypt forest on coastal floodplains of southern New South Wales and eastern Victoria* which would be affected by temporary inundation during operation of the FMZ.

The two PCTs that conform to the first TEC are:

- 840, Forest Red Gum–Yellow Box woodland of dry gorge slopes, southern Sydney Basin Bioregion and South Eastern Highlands
- 1401, Narrow-leaved Ironbark–Forest Red Gum on rocky slopes of the lower Burragorang Gorge, Sydney Basin Bioregion.

The PCT that conforms to the second TEC is 941, Mountain Blue Gum–Thin-leaved Stringybark open forest on river flat alluvium in the Sydney Basin Bioregion.

The assessment of significance against the significant impact guidelines criteria concluded that the Project would likely have a significant impact on these communities (and noting that it has been assumed that there would be a total loss of biodiversity values in the upstream impact area).

Table 12-3 summarises the extent of inundation on these TECs for the upstream impact area. Detailed discussion of impacts is provided in section 7.3.3 of Appendix F1 of the EIS (Biodiversity assessment report – upstream).

Table 12-3. Extent of temporary inundation on affected TECs

Commonwealth listed TEC and status	Extent (ha)	
	Upstream impact area	Upstream study area
White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland (Critically Endangered)	430.56	1,447.73
River-flat eucalypt forest on coastal floodplains of southern New South Wales and eastern Victoria (Critically Endangered)	104.51	378.04

12.2.3.2 Construction area

The only affected TEC in the construction study area is the critically endangered *Shale Sandstone Transition Forest of the Sydney Basin Bioregion*. Construction activities would require clearing of 1.64 hectares of this TEC. Operation of the FMZ would not affect this TEC. However, additional extents of the TEC not directly being cleared may be indirectly impacted.

The assessment of significance against the significant impact guidelines criteria concluded that the Project would not likely have a significant impact on this community.

Table 12-4 summarises the extent of this TEC within the construction area, including extents that will be cleared and retained. Detailed discussion of the impacts to this TEC is provided in section 7.2.2 of Appendix F3 of the EIS (Biodiversity assessment report – construction area).

Table 12-4. Extent of affected Shale Sandstone Transition Forest of the Sydney Basin Bioregion

Federally listed TEC and status	Development footprint (ha)	Area to be retained (ha)	Study area (ha)	Summary of impacts
Shale Sandstone Transition Forest of the Sydney Basin Bioregion (Critically Endangered)	1.64	3.24	8.12	The clearing of native vegetation within the development footprint will result in loss and fragmentation of the TEC and habitat. Potential indirect impacts include degradation and changes to hydrology, edge effects, weed invasion and encroachment, introduction or spread of diseases or pathogens, and erosion, runoff and sedimentation.

12.2.3.3 Downstream

A total of seven TECs and one preliminary listed TEC in the downstream study area may be affected by the Project associated with operation of the FMZ:

- *Castlereagh Scribbly Gum and Agnes Banks Woodlands of the Sydney Basin Bioregion*
- *Cooks River/Castlereagh Ironbark Forest of the Sydney Basin Bioregion*
- *Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest*
- *River-flat eucalypt forest on coastal floodplains of southern New South Wales and eastern Victoria*
- *Shale Sandstone Transition Forest of the Sydney Basin Bioregion*
- *Turpentine-Ironbark Forest of the Sydney Basin Bioregion*
- *Western Sydney Dry Rainforest and Moist Woodland on Shale*
- Preliminary determination for *Melaleuca dominated Temperate Swamp Sclerophyll Forests on Coastal Floodplains of Eastern Australia*.

All the above TECs are currently affected by the operation of the existing dam during both normal operation and during flood events, with impacts associated with the latter being influenced by the magnitude of individual flood events. Flooding from other catchments such as the Nepean, Grose, Colo and South Creek also contribute to and influence downstream flooding, and this would not change with the Project.

Based on consideration of the criteria in the significant assessment guidelines, the Project could potentially have a significant impact on the following TECs:

- *Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest*
- *River-flat eucalypt forest on coastal floodplains of southern New South Wales and eastern Victoria*
- *Shale Sandstone Transition Forest of the Sydney Basin Bioregion*
- *Western Sydney Dry Rainforest and Moist Woodland on Shale*.

The Project would not likely have a significant impact on the following TECs:

- *Castlereagh Scribbly Gum and Agnes Banks Woodlands of the Sydney Basin Bioregion*
- *Cooks River/Castlereagh Ironbark Forest of the Sydney Basin Bioregion TEC*
- *Turpentine-Ironbark Forest of the Sydney Basin Bioregion TEC*.

Table 12-5 shows the extent of each TEC depending on a change in flood event for the FMZ, a 1 in 10 chance in a year (10% AEP) flood event, 1 in 20 chance in a year (5% AEP) flood event, the 1 in 100 chance in a year (1% AEP) flood event, and the PMF including a broad summary of associated impacts. Detailed discussion of the impacts to this TEC are provided in Section 6.4.1 of Appendix F2 of the EIS (Downstream ecological assessment).

Table 12-5. Extent of each TEC based on different modelled flood events as a result of operation of the FMZ

Federally listed TEC and status	FMZ	Change in 1 in 10 flood event	Change in 1 in 20 flood event	Change in 1 in 100 flood event	Change in PMF	Summary of potential impacts
Castlereagh Scribbly Gum and Agnes Banks Woodlands of the Sydney Basin Bioregion (Endangered)	-	0.3	3.78	50.05	287.90	This floodplain community does not occur in the FMZ. While it would be subject to reduced flooding extents in areas outside the FMZ, it is considered unlikely that these would result in modifications to the community.
Cooks River/Castlereagh Ironbark Forest of the Sydney Basin Bioregion (Critically Endangered)	-	0.1	2.78	16.28	126.26	This floodplain community does not occur in the FMZ. While it would be subject to reduced flooding extents in areas outside the FMZ, it is considered unlikely that these would result in modifications to the community.
Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest (Critically Endangered)	26.18	203.36	383.15	592.59	445.00	This floodplain community would be primarily subject to reduced flooding extents. Extended inundation would occur in some extents in the FMZ discharge area. Change in hydrological regimes may result in modifications to the community. Fringing vegetation and erosion impacts may result in temporary modifications to the community.
River-flat eucalypt forest on coastal floodplains of southern New South Wales and eastern Victoria (Critically Endangered)	0.43	1.45	482.44	255.70	75.99	This floodplain community would be subject to extended inundation in the FMZ discharge area and some areas would experience reduced flooding extents. Fringing vegetation and erosion impacts may result in temporary modifications to the community.
Shale Sandstone Transition Forest in the Sydney Basin Bioregion (Critically Endangered)	73.76	94.13	82.12	39.82	48.59	This floodplain community would be subject to extended inundation in the FMZ discharge area and some areas would experience reduced flooding extents. Fringing vegetation and erosion impacts may result in temporary modifications to the community.
Turpentine-Ironbark Forest of the Sydney Basin Bioregion (Critically Endangered)	5.10	3.91	2.04	0.99	0.07	This floodplain community would be subject to extended inundation in the FMZ discharge area and some areas would experience reduced flooding extents. Fringing vegetation and erosion impacts may result in temporary modifications to the community.
Western Sydney Dry Rainforest and Moist Woodland on Shale (Critically Endangered)	1.83	3.69	3.50	4.05	2.19	This floodplain community would be subject to extended inundation in the FMZ discharge area and some areas would experience reduced flooding extents. Fringing vegetation and erosion impacts may result in temporary modifications to the community.

Federally listed TEC and status	FMZ	Change in 1 in 10 flood event	Change in 1 in 20 flood event	Change in 1 in 100 flood event	Change in PMF	Summary of potential impacts
Preliminary determination *for Melaleuca dominated Temperate Swamp Sclerophyll Forests on Coastal Floodplains of Eastern Australia*	852.69	1.45	1.31	1.08	0.04	This floodplain community would be subject to extended inundation in the FMZ discharge area and some areas would experience reduced flooding extents. Fringing vegetation and erosion impacts may result in temporary modifications to the community.

12.2.4 Migratory species

While the Project may impact on areas of vegetation utilised by some migratory species, overall it would likely not have a significant impact on migratory species listed under the EPBC Act.

12.2.5 World Heritage

There are two areas of the GBMWHA downstream of Warragamba Dam that could potentially be impacted by the Project:

- catchment areas adjacent to the Warragamba River and Nepean River which are in the Blue Mountains National Park. The GBMWHA area adjacent to the Nepean River extends from its confluence with Warragamba River to Lapstone
- catchment areas of some tributaries of the lower Colo River near its confluence with the Hawkesbury River which are in the Yengo National Park.

The Project would have the following potential impacts or benefits on these areas:

- reduced extent and duration of large floods
- increased low level flooding impacts due to the discharge of water from the FMZ.

These are discussed in more detail in the following sections.

12.2.5.1 Reduced extent and duration of large floods

The Project would result in the reduced extent and duration of large floods in both the Warragamba/Nepean River area and the Lower Colo area. There would be a small decrease in flooding extents in both areas for the assessed flood events.

In the Nepean/Warragamba area, the rivers are contained within a gorge so any changes in spatial flood extents would be minimal unlike the downstream floodplain areas around the Penrith and Richmond/Windsor area. The Lower Colo River's confluence with the Hawkesbury River is about 75 kilometres downstream of Warragamba Dam. At this distance from the dam any changes in flooding extents due to the Project are negligible (about 0.7 hectares). Overall while there is likely to be some reduction in flood extents and durations in these areas of the GBMWHA, any benefits or impacts would be minimal.

12.2.5.2 Impacts from the operation of the FMZ

While peak flood levels and velocities would be lower due to the Project, there would be sustained lower level discharges from the FMZ which could potentially impact downstream areas, principally the Nepean/Warragamba River area of the GBMWHA. Once flood levels downstream of the dam had peaked, flood waters temporarily stored in the FMZ would be discharged.

The geomorphology assessment for the Project identified that the sandstone gorge areas in the Warragamba River and Nepean River within the GBMWHA are very stable and would not be impacted by operation of the FMZ.

12.2.5.3 Old Great North Road

The Old Great North Road is one of 11 places that make up the Australian Convict Sites World Heritage property. The 11 sites were given World Heritage listing in 2010. The Devines Hill and Finchs Line sections of the Old Great North Road, which lie in Dharug National Park, are included in this listing.

The cultural significance of the road is reflected through its inscription on the Australian National Heritage List (gazetted on 1 August 2007) as a nationally significant example of major public infrastructure developed using convict labour, and on the UNESCO World Heritage list as one of the Australian Convict Sites on 31 July 2010. The Old Great North Road was built between 1826 and 1836 to link Sydney with the Hunter Valley, running for some 250 kilometres and constructed using convict road gang labour.

The National Heritage List inscription notes:

> *The Old Great North Road is the best surviving example of an intact convict built road with massive structural works which remain undisturbed by later development on or around the road.*

and

Old Great North Road provides evidence of the transition of New South Wales from a penal colony to a permanent settlement and is an excellent representation of the extensive road building undertaken by Governor Ralph Darling to expand the colony, provide transportation and communication links with dispersed settlements, and provide harsh punishment for convicts.

The Old Great North Road World Heritage Area is currently unaffected by all SEARs events up to the 1 in 100 chance in a year event and this would not change with the Project. About 1.1 hectares is affected by the existing PMF and this would reduce to about 0.6 hectares with the Project. As has been noted elsewhere in this report, the PMF is event is used principally as an input to design and, given the scale of the catchment of Lake Burragorang, is highly unlikely to occur in nature.

While the Project would have a negligible material benefit on this World Heritage Area, an assessment with regard to the Old Great North Road conservation management plan and 2007 addendum is provided in Section 6.3 of Appendix J (World Heritage Assessment Report). An assessment of the Project against section 137 of the EPBC Act with regard to the Old Great North Road World Heritage Area is provided in Table 11-1 of Appendix J.

13 Mitigation and management of environmental impacts

The Project has sought to avoid and minimise impacts, as discussed below. Not all impacts can be avoided and as such, environmental management plans would be prepared for both construction and operation of the Project. These would provide a framework for management and mitigation of impacts to Protected Matters. Management of some Protected Matters would also be covered by the BOS. All safeguards and management measured to be implemented for the Project are summarised in Chapter 29 (EIS synthesis, Project justification and conclusion).

13.1 Avoid, minimise, and mitigate impacts

Under the FBA, there is a requirement for proponents to demonstrate how biodiversity impacts can be avoided or minimised. Similarly, the EPBC offsets policy requires consideration of offsets after application of measures to avoid, minimise and/or mitigate impacts. Full details are provided in the respective biodiversity assessments (Appendices F1, F2, F3), and the following is a summary of this process.

Actions have been undertaken to avoid and minimise potential direct and indirect impacts of the Project on biodiversity values. Chapter 4 of the EIS discusses the proposed alternatives that were considered for flood mitigation in the Hawkesbury-Nepean Valley, including:

- non-structural strategies: these do not alter flood levels but reduce the effects of flooding
- floodplain works: localised physical works in the floodplain could be used to divert floodwaters from properties
- drainage strategies: these lower flood levels by assisting floodwaters to escape from the floodplain
- flood detention strategies: these temporarily store floodwaters on contributing rivers and thereby lower peak levels downstream
- combined strategies: these combine some of the above approaches.

Table 13-1 identifies proposed actions to avoid impacts to biodiversity values where practicable in accordance with the FBA. Table 13-2 summarises how the Project has sought to avoid/minimise impacts to biodiversity values with regard to site selection considerations, as required under the FBA.

Table 13-1. Avoidance of impacts on biodiversity values

Impacts	Proposed avoidance mechanism
Impacts to endangered ecological communities (EECs) and critically endangered ecological communities (CEECs)	The scale and nature of the Project means that options to avoid impacts to TECs within the Project study area are limited to those detailed above. Impacts to the TEC within the construction study area have been minimised as far as practicable.
Impacts to areas that contain habitat for vulnerable, endangered or critically endangered threatened species or populations.	The scale and nature of the Project means that options to avoid impacts to areas that contain habitat for vulnerable, endangered or critically endangered threatened species or populations within the Project study area are limited to those detailed above.
Impacts to the riparian areas of 4th order or higher streams and rivers, important wetlands and estuaries.	Lake Burragorang is a 9th order stream and any impacts to the riparian buffers of a 4th order stream or higher cannot be avoided. Other than Lake Burragorang, there are no identified wetlands and estuaries.
Impacts to state significant biodiversity links.	The Project may impact upon the 50-metre riparian buffer for a 9th order stream. Under the FBA, riparian buffers for 6th order streams or higher are considered to be a state significant biodiversity link. Consequently, the Project may potentially impact a state significant biodiversity link. Given the fixed location of the dam, there is no practicable option to avoid this potential impact.

Table 13-2. Site selection assessment

FBA section	FBA criterion	Consideration for the Project
8.3.2.8 (a)	The major project should be located in areas where the native vegetation or threatened species habitat is in the poorest condition, or which avoid an EEC or CEEC	Due to the location, scale and nature of the development, construction impacts to Shale Sandstone Transition Forest of the Sydney Basin Bioregion cannot be avoided. However, when compared with building a new dam to achieve the same mitigation or alternatives such as dredging the Hawkesbury-Nepean River, impacts to biodiversity are lowest based on work undertaken to inform the Flood Strategy.
8.3.2.8 (b)	The major project and associated construction infrastructure should be located in areas that do not have native vegetation, or in areas that require the least amount of vegetation to be cleared, and/or in areas where other impacts to biodiversity will be lowest.	The development footprint is associated with the existing dam and locations of construction facilities have been selected to minimise the amount of clearing.
8.3.2.8 (c)	Major projects can impact on the connectivity and movement of species through areas of adjacent habitat. Minimisation measures may include providing structures that allow movement of species across barriers or hostile gaps.	Operational impacts will occur around Lake Burragorang and surrounding vegetation is intact with high levels of connectivity. Operation of the FMZ is unlikely to prevent movement of individuals through the landscape.
8.3.2.8 (d)	Any other constraints that the assessor has considered in determining the siting and layout of the major project.	A discussion of Project siting is included in Chapter 4 of the EIS.

13.2 Biodiversity Offset Strategy

The *NSW Biodiversity Offsets Policy for Major Projects* provides a standard method for assessing impacts of major projects on biodiversity and determining offsetting requirements (OEH 2014). The policy is underpinned by six principles, which must be considered when assessing offsets for major projects. These are:

1. Before offsets are considered, the impacts must first be avoided, and unavoidable impacts minimised through mitigation measures. Only then should offsets be considered for the remaining impacts.
2. Offset requirements should be based on reliable and transparent assessment of losses and gains.
3. Offsets must be target by the biodiversity values being lost or to higher conservation priorities.
4. Offsets must be additional to other legal requirements.
5. Offsets must be enduring, enforceable and auditable.
6. Supplementary measures can be used in lieu of offsets.

These principles have been addressed through the biodiversity assessments carried out for the upstream and construction study areas, and through the Biodiversity Offset Strategy (BOS) that has been developed for the Project (refer to Appendix F6 of the EIS) to offset biodiversity impacts in these areas.

The objective of the BOS is to provide guidance for the delivery of biodiversity offsets for the impacts expected as a result of the Warragamba Dam Raising Project and to achieve a long-term conservation gain for the threatened species, populations and communities, National Parks and World Heritage values impacted by the Project. The specific objectives for the BOS aim to:

- maintain ecological values: strategy aims to achieve the standard of ‘no-net-loss’ of biodiversity
- source local offsets: where feasible, offsets will be sourced as close to the impact as possible
- support heritage values: offsets will support or enhance World Heritage values, particularly those related to biodiversity.

The aspects of the BOS relating to the upstream study area would be delivered through the Warragamba Offset Program as described in Section 6 of the BOS (Appendix F6 to the EIS). The Program will include the establishment of an advisory committee which would comprise a group of core representatives from DAWE, DPIE, NPWS, Local Land

Services, Biodiversity Conservation Trust, Greater Blue Mountains World Heritage Area Management Committee, WaterNSW, and Infrastructure NSW, and would involve other parties such as local council and relevant subject matter experts where required. The advisory committee would be overseen by an independent chairperson.

The advisory committee would provide input into:

- consideration of compensatory options for both downstream and upstream that adhere to the NSW Biodiversity Offsets Policy for Major Projects, EPBC Environmental Offsets Policy, and OEH's Principles for the use of biodiversity offsets in NSW
- identification and prioritisation of potential compensatory options
- selection of final suite of biodiversity compensation package
- determining allocation of compensation funds to each action
- an annual Implementation Report to be issued to NSW and Commonwealth Governments outlining the actions taken and how compensatory obligations are being fulfilled.

13.3 National Parks Environmental Management Plan

WaterNSW is required to prepare an Environmental Management Plan (EMP) under Part 5A of the *Water NSW Act 2014* before the temporary inundation of any land protected by the *National Parks and Wildlife Act 1974* can occur. This would include all of the land in the GBMWHA within the upstream impact area potentially impacted by the Project.

The EMP would be separate to the BOS but would complement and support the strategy. The scope and content of the EMP has yet to be defined but would be consistent with the existing management plans for the national parks and the GBMWHA. The EMP would contribute to the maintenance and strengthening of protected lands values.

The EMP would be prepared in consultation with the NPWS (and require approval from the Minister administering the NPW Act). Other stakeholders such as the GBMWHA Management Committee and GBMWHA Advisory Committee would also be consulted. Funding for the EMP would be additional to the current funds used for management activities and would be agreed once the scope and requirements of the EMP are determined.

13.4 EPBC Act Environmental Offsets Policy

DAWE has advised that as the Department has endorsed the NSW Biodiversity Offsets Scheme, provided WaterNSW complies with the scheme, it is not required to simultaneously comply with the EPBC Act Environmental Offsets Policy.

14 Summary

The Warragamba Dam Raising Project is a controlled action (ref 2017/7940) requiring approval under the EPBC Act. This report has assessed impacts on biodiversity-related protected matters in accordance with the *Matters of National Environmental Significance Significant impact guidelines 1.1* (DoE 2013). This has drawn on the specialist biodiversity assessment reports prepared for the EIS.

It should be noted that there is a practical challenge in applying the significant impact assessment guidelines for the Project, particularly for TECs and threatened flora, as the nature and magnitude of potential impacts area uncertain and will be dependent greatly on the frequency of the flood event, the depth and duration of inundation, and the associated tolerance of vegetation to inundation. The potential for inundation would be greatest associated with the more frequent 20% AEP flood event but the extent would be less than for other relatively less frequent events. While a precautionary approach has been taken in assessing significance of impacts in that it has been assumed there would be a total loss of environmental values within the upstream impact area (including with regard to a TEC or threatened species), the potential for such impacts to actually occur may in fact be less.

Potential impacts relate principally to the changes in the flooding regime both upstream and downstream associated with the operation of the FMZ. Upstream impacts are related to an increase in the extent of temporary inundation while downstream impacts are generally associated with a reduction in the extent of flooding but with an increase in the duration of flooding in the river and some low lying areas such as the Richmond Lowlands. Impacts are also associated with construction activities which would require the clearing of native vegetation.

Assessment of impacts for the upstream and construction study areas has been carried out in accordance with the NSW FBA. Assessment of impacts in the downstream study area has been carried out in accordance with the provisions of the now repealed TSC Act through the effect of the transitional provisions of the Biodiversity Conservation (Savings and Transitional) Regulation 2017.

The assessment identified that the Project could have a significant impact on Protected Matters as follows:

- six threatened ecological communities:
  - upstream: White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland TEC, which would be affected by temporary inundation during operation of the FMZ
  - construction: through clearing of 1.64 hectares of Shale Sandstone Transition Forest of the Sydney Basin Bioregion TEC
  - downstream: Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest TEC, River-flat eucalypt forest on coastal floodplains of southern New South Wales and eastern Victoria TEC, Shale Sandstone Transition Forest of the Sydney Basin Bioregion TEC, and Western Sydney Dry Rainforest and Moist Woodland on Shale TEC.
- 46 threatened flora species, including the critically endangered Megalong Valley Bottlebrush (*Callistemon megalonensis)*
- eight threatened fauna species, including the critically endangered Regent Honeyeater (*Anthochaera phrygia*).

The Project was assessed as unlikely to have a significant impact on migratory species.

Impacts, including on biodiversity-related Protected Matters, would be offset principally through the BOS that has been developed for the Project. The BOS provides an offset strategy for construction-related impacts comprising:

- an assessment of BSA site options
- purchase of credits from the market
- contribution to the Biodiversity Conservation Fund.

Offsetting of impacts in the upstream study area would occur through a program of measures within the Warragamba Offset Program. The matters in the BOS relating to the upstream study area form part of the Program. The Program will include measures formally endorsed as part of the *NSW Biodiversity Offsets Policy for Major Projects* (NSW Government 2014), as well as additional measures where implementation of formally accepted measures may be difficult.

Development of the operational protocol for the FMZ would seek to minimise potential impacts on downstream vegetation from temporary inundation subject to meeting operational priorities for protection of life and property.

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Appendix A Assessments of significance

It should be noted that there is a practical challenge in applying the significant impact assessment guidelines for the Project, particularly for TECs and threatened flora, as the nature and magnitude of potential impacts are uncertain and will be dependent greatly on the frequency of the flood event, the depth and duration of inundation, contributions from other catchments downstream of Warragamba Dam, the effects of other land use activities on the Hawkesbury-Nepean floodplain, and the tolerance of vegetation to temporary inundation. The potential for inundation would be greatest associated with the more frequent 20% AEP flood event but the extent would be less than for other relatively less frequent events.

As detailed within the Matters of National Environmental Significance: Significance impact guidelines 1.1 (DoE 2013), it is not necessary for the significant impact to have a greater than 50 percent chance of happening for a significant impact to be considered ‘likely’, it is sufficient if a significant impact on an MNES is a real, or not remote chance, or possibility.

Threatened flora species

Acacia bynoeana (Bynoe's Wattle)

Vulnerable under the EPBC Act

Acacia bynoeana is a small wattle with a prostrate habit. The stems of *A. bynoeana* lie flat along the ground before rising towards the ends. These branches are ribbed and can rise to give an adult plant a height of up to 30 centimetres. Branchlets are hairy – a characteristic used to differentiate the species from the morphologically similar *Acacia trinervata*. *Acacia bynoeana* produces simple inflorescences of yellow-cream flowers. Flowering occurs after September, with flowers arranged in spheres that are supported by short hairy peduncles. Tapered seedpods - produced from September to January – contain oblong seeds about 4 millimetres long (DoE 2013; OEH 2017).

The distribution of *A. bynoeana* stretches from the Hunter Valley near Braxton, south to Morton National Park in the Southern Highlands, and as far west as the Blue Mountains. The Approved Conservation Advice for *Acacia bynoeana* (DoE 2013) states that as of 2013, there were only 30 known populations. Most populations were small, comprising of 1 to 5 individuals, with only a few sites supporting between 30 and 50. Most populations occur on land that is not reserved. A few populations are protected however, occurring in Marramarra National Park, the Blue Mountains National Park, and in Castlereagh Nature Reserve.

Acacia bynoeana occurs in heath and dry sclerophyll forest habitat. This includes open woodland with either a heathy understory, or open woodland with a sparse shrub layer with a layer of grasses and sedges (DoE 2013). Within this habitat, *A. bynoeana* is found in open situations that are caused by disturbances – anthropogenic or natural – such as fire, trail margins or road-sides. *Acacia bynoeana* habitat is supported by sand or a sand-clay mixture. This substrate often includes ironstone gravels and is well-draining and infertile (DoE 2013). Canopy species characteristic of *A. bynoeana* habitat include *Eucalyptus gummifera*, *E. haemastoma*, *E. parramattensis*, *E. sclerophylla*, *Banksia serrata*, and *Angophora bakeri.* Shrub species that are associated with *A. bynoeana* habitat include *B. spinulosa*, *Acacia oxycedrus*, *Acacia myrtifolia* and *Kunzea* spp.

According to OEH's BioNet system, *A. bynoeana* is associated with the following PCT mapped in the upstream study area:

- PCT 1081 (HN564): Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion
- PCT 1083 (HN566): Red Bloodwood – Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion
- PCT 1086 (HN568): Red Bloodwood – Sydney Peppermint – Blue-leaved Stringybark heathy forest of the southern Blue Mountains Sydney Basin Bioregion
- PCT 1292 (HN607): Water Gum – Coachwood riparian scrub along sandstone streams Sydney Basin Bioregion

Acacia bynoeana is associated with the following PCTs mapped in the downstream study area:

- PCT 724 (HN512): Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain Sydney Basin Bioregion.
- PCT 725 (HN513): Broad-leaved Ironbark - *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain Sydney Basin Bioregion.
- PCT 849 (HN528): Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion.
- PCT 883 (HN542): Hard-leaved Scribbly Gum - Parramatta Red Gum heathy woodland of the Cumberland Plain, Sydney Basin Bioregion.
- PCT 958 (HN555): Narrow-leaved Apple - Hard-leaved Scribbly Gum heathy woodland on sand at Agnes Banks, Sydney Basin Bioregion.
- PCT 1395 (HN556): Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain Sydney Basin Bioregion.
- PCT 1067 (HN562): Parramatta Red Gum woodland on moist alluvium of the Cumberland Plain, Sydney Basin Bioregion.
- PCT 1081 (HN564): Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion.

- PCT 1181 (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.
- PCT 1292 (HN607): Water Gum - Coachwood riparian scrub along sandstone streams, Sydney Basin Bioregion.
- PCT 1327 (HN612): Yellow Bloodwood - ironbark shrubby woodland of the dry hinterland of the Central Coast, Sydney Basin Bioregion.
- PCT 1328 (HN613): Yellow Bloodwood - Narrow-leaved Apple heathy woodland on hinterland plateaux of the Central Coast, Sydney Basin Bioregion.

Acacia bynoeana is associated with the following PCT mapped in the construction study area:

- PCT 1081 (HN564): Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion
- PCT 1083 (HN566): Red Bloodwood – Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion
- PCT 1086 (HN568): Red Bloodwood – Sydney Peppermint – Blue-leaved Stringybark heathy forest of the southern Blue Mountains Sydney Basin Bioregion

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) define an 'important population' of a Vulnerable species as being

> '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*
>
> - *key source populations either for breeding or dispersal.*
> - *populations that are necessary for maintaining genetic diversity.*
> - *populations that are near the limit of the species range.*

Targeted surveys for *A. bynoeana* were not undertaken in the upstream, downstream or construction study areas. Previous OEH records do however occur in the downstream study area. In the absence of targeted surveys in the three study areas, *A. bynoeana* has been assumed present in areas of suitable habitat – the previously listed PCTs. Using the precautionary principle, the population(s) residing within this habitat have been assessed as an important population(s) as they are key source populations for breeding and dispersal, are necessary for maintaining genetic diversity, and occur near the limit of the species range.

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**
As *Acacia bynoeana* has not been surveyed, areas of habitat have been used as a surrogate for the species occurrence. Within the upstream study area 132.53 hectares of habitat has been mapped. Of this 132.53 hectares, 14.45 hectares may be impacted by a 1 in 5 chance in a year flood event (20% AEP) and 68.63 hectares by a 1 in 100 chance in a year flood event (1% AEP). Impacts associated with all three events (the study area representing the PMF) may lead to long-term decreases in the important population. Within the downstream study area 282.09 hectares occurs between the existing and with Project 10% AEPs, 683.08 hectares between the existing and with project PMFs and 137.48 hectares within the FMZ discharge area. Approximately 20 hectares of habitat occurs within the Development Footprint associated with construction activities. The impacts to suitable habitat have the potential to lead to a long-term decrease in the size of the important populations of *A. bynoeana*.
• **reduce the area of occupancy of an important population**
The Project may reduce the potential area of occupancy for *Acacia bynoeana* across all three study areas. These reductions can be summarised according to the following impact scenarios:

Upstream Study Area

- 1% AEP (1 in 100 chance in a year flood): 68.63 hectares
- 20% AEP (1 in 5 chance in a year flood): 14.45 hectares

Downstream Study Area

- FMZ discharge area: 137.48 hectares
- Difference between the existing and with project 10% AEPs: 282.09 hectares
- Difference between the existing and with project PMFs: 683.08 hectares

Construction Study Area

- Development footprint: 20.78 hectares

- **fragment an existing important population into two or more populations**

Most of the *Acacia bynoeana* habitat within the downstream study area occurs across the central area of the Cumberland Plain and along the lower Nepean/upper Hawkesbury Rivers. This habitat has been previously fragmented through agricultural and residential development. The Project has the potential to increase the fragmentation of all the *A. bynoeana* habitat in the downstream study area. Fragmentation may be caused by the removal of native vegetation, the increased presence of invasive weed species, through increases to erosion and deposition and by modified fire regimes.

Not all *A. bynoeana* habitat is currently fragmented. The habitat in the upstream and construction study areas is mainly contiguous with the Blue Mountains National Park. The Project may impact the extents of this habitat in a similar manner to the habitat in the downstream study area– direct removal of vegetation, increased presence of invasive species, erosion and deposition - however its connectivity to larger extents of native vegetation may reduce the number of new edges and 'fragments' created.

- **adversely affect habitat critical to the survival of a species**

According to the *Matters of National Environmental Significance Significant impact guidelines* 1.1 (DoE 2013) habitat critical to the survival of a species refers to areas that are necessary for:

- activities such as foraging, breeding, roosting, or dispersal
- 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
- the reintroduction of populations or recovery of the species or ecological community.

The *A. bynoeana* habitat in the upstream, downstream and construction study areas has been assessed as critical habitat because it is important for dispersal, the long-term maintenance of the species, and for maintaining genetic diversity. The Project may potentially adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive species, erosion and deposition, and modifying the fire regime.

- **disrupt the breeding cycle of an important population**

The reproductive ecology of *Acacia bynoeana* is complex. This species of *Acacia* is clonal, that is, it is capable of reproducing vegetatively via underground stems (Driscoll 2006). This can result in populations comprised of clustered individuals of various levels of clonality. It is unknown if *A. bynoeana* is capable of self-pollination (DoE 2013). Cross-pollination however, is thought to be mediated by native bees and wasps (Bernhardt 1987). Regardless, the production of seed is low compared to other species of *Acacia*. Seedlings appear to be rare and seed dispersal seems to be limited (Benson and McDougall 1996).

Plants occur in open areas indicating that germination and/or establishment may require a disturbance. Apart from occurring in open areas that may have been created by fire, there is no evidence that the lifecycle of *A. bynoeana* is linked to heat, smoke or burning. However, the Approved Conservation Advice for *Acacia bynoeana* does state that this species cannot cope with fires occurring more frequently than 10 – 12 years (DoE 2013).

Fire, and its mismanagement, may be a risk to the breeding cycle of *A. bynoeana*. The Project may affect the fire regime within all three study areas by modifying the vegetation communities (and subsequently the fuel load). If

the modified vegetation is more susceptible to fire, then the frequency of fire events may be increased. If fire is too frequent (occurring more than every 10 years), it may kill the next generation of plants before they have reached reproductive maturity and replenished the seed bank. Increases in flooding may also impact the lifecycle of *A. bynoeana*, as flood waters may inundate habitat, destroy seed banks and removed surrounding vegetation. Flood waters may inundate *A. bynoeana* habitat and individuals which have not evolved to withstand frequent flooding and inundation. The sparse *A. bynoeana* soil-stored seed bank may also be impacted as flood water has the potential to erode it away or bury it in sediment and debris carried from upstream areas.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project may impact *Acacia bynoeana* habitat within the upstream, downstream and construction study areas. Habitat may be destroyed and/or directly impacted through the clearing of native vegetation, the loss of flora and fauna habitat, and a reduction in the extent of ecological communities. Habitat may be indirectly impacted (modified, reduced in quality etc.) through fragmentation, alteration to soil conditions, edge effects, weed invasion and incursion, through the spread of disease and pathogens, erosion and sedimentation, and thorough changes to the fire regime.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
The OEH threatened species profile for *Acacia bynoeana* states that '*weeds can invade the species habitat*'. The Project may result in the spread and establishment of invasive flora species into the habitat of A. bynoeana (OEH 2017). The OEH threatened species profile and SPRAT profile for *A. bynoeana* both identify browsing by the European Hare as a potential threat. It is unknown if the Project may increase the number or extent of the European Hare within *A.bynoeana* habitat (OEH 2017; DoEE 2019).
• **introduce disease that may cause the species to decline, or**
No diseases have been identified as a threat to *Acacia bynoeana*. As such, the approved Threat Abatement Plan for disease in natural ecosystems caused by *Phytophthora cinnamomi* (DoEE 2018) does not apply.
• **interfere substantially with the recovery of the species.**
No National Recovery Plan has been developed for *Acacia bynoeana* under the EPBC Act. The Approved Conservation Advice for *A. bynoeana* (DoE 2013) does provide the following 'Conservation Information' however: • Raise awareness of Bynoe's Wattle within the local community, and encourage community involvement in surveys. Build a network of government and non-government organisations and individuals to support management actions. • Engage interested nature conservation, land management and landholder groups in the activities of the program. Develop a fact sheet on this species including information on ecology, distribution and threats. • Support and encourage stakeholders across the region to actively develop skills and knowledge in managing this species. Use workshops to aid stakeholders in developing the skills and knowledge required to manage this species. • To manage the risk of losing genetic diversity, undertake appropriate seed collection and storage. Seeds from representative natural populations to be collected and stored • Implement national translocation protocols (Vallee *et al.* 2004) if establishing additional populations is considered necessary and feasible. • Develop and maintain a database to efficiently and securely store survey and monitoring data. The Project is unlikely to interfere with any of the actions listed above.

A targeted strategy for managing *Acacia bynoeana* has been developed under the Saving Our Species Program. Under the Saving Our Species Program, *A. bynoeana* has been assigned to the 'site-managed species' management stream. The following five priority management sites have been determined for *A. bynoeana*:

- Dora Creek in the Lake Macquarie LGA.
- Eastern Yengo in the Central Coast and Hawkesbury LGAs.
- Castlereagh in the Penrith LGA.
- Dharawal in the Campbelltown, Wollondilly and Wollongong LGAs.
- Colymea SCA in the Shoalhaven LGA.

The Project may potentially impact the Castlereagh priority management site. Specifically, the Project may not be inconsistent with the following management objectives set out for the Castlereagh priority management site:

- Minimise impacts of clearing/removal of key habitat.
- Maintain appropriate fire regime for the species/community.

Conclusion

The Project may potentially impact *Acacia bynoeana* habitat across the Project study areas. This habitat may become further fragmented, isolating occurrences of *A. bynoeana* from one another. The Project may impact the breeding cycle of *A. bynoeana* by clearing native vegetation (habitat), modifying the fire regime, and impacting the soil seedbank. The threat of invasive flora species may also be exacerbated by the Project. These impacts are expected to cause a decline of the important population of *A. bynoeana*.

The Project has been assessed as likely having a significant impact on *Acacia bynoeana.*

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Acacia flocktoniae

Vulnerable under EPBC Act

Acacia flocktoniae is listed as Vulnerable under the BC Act and EPBC Act. *A. flocktoniae* is an erect or spreading shrub growing 2-4 m high with golden yellow or creamy-white globular flower heads appearing between June and August (Harden 2002). *A. flocktoniae* has isolated occurrences in the central tablelands however primarily occurs in the Southern Blue Mountains (at Mt Victoria, Megalong Valley and Yerranderie) (OEH 2019). The species generally grows in dry sclerophyll forest on low nutrient soils derived from sandstone (Orchard and Wilson 2001). The species has also been found to occur at altitude of 500-1000 m above sea level and is often found growing in association with *Acacia stricta* and *Podolobium ilicifolium* (DEWHA 2008).

With regard to the Project, *A. flocktoniae* is considered likely to occur in the construction and upstream study areas however targeted surveys for this species were not undertaken. Additionally, *A. flocktoniae* was not incidentally encountered in the survey area during vegetation mapping investigations associated with the Project.

In the absence of targeted surveys, *A. flocktoniae* has been assumed present in areas of presumed suitable habitat. For this assessment, suitable habitat for *A. flocktoniae* includes the PCTs that are associated with the species (as per the TBDC), BioNet Atlas Records and any other known vegetation types (as per scientific literature) that the species is associated with that has been mapped within the construction and upstream study areas.

Suitable habitat includes the following PCTs that have been mapped within the construction study area:

- PCT1081: Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion (associated as per TBDC)
- PCT1086: Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains Sydney Basin Bioregion (associated as per TBDC).

Suitable habitat includes the following PCTs that have been mapped within the upstream study area:

- PCT1081: Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion (associated as per TBDC)
- PCT1086: Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains Sydney Basin Bioregion (associated as per TBDC)
- PCT1246: Sydney Peppermint - Grey Gum shrubby open forest of the western Blue Mountains Sydney Basin Bioregion (associated as per TBDC)
- PCT832: Forest Red Gum - Narrow-leaved Ironbark open forest of the southern Blue Mountains gorges Sydney Basin Bioregion (associated as per TBDC)
- PCT840: Forest Red Gum - Yellow Box woodland of dry gorge slopes southern Sydney Basin Bioregion and South Eastern Highlands Bioregion (associated as per TBDC)
- PCT862: Grey Gum - Hard Leaved Scribbly Gum woodland of the Cox River Valley (associated as per TBDC)
- PCT870: Grey Gum - Thin-leaved Stringybark grassy woodland of the southern Blue Mountain gorges Sydney Basin Bioregion (associated as per TBDC)
- PCT871: Grey Gum shrubby open forest on gorge slopes of the Blue Mountains Sydney Basin Bioregion (associated as per TBDC).

A. flocktoniae is considered to have a low likelihood of occurring in the downstream study area. Although some of these PCTs also occur in the downstream study area they are not considered likely to support a population of this species and are therefore not included in this assessment. Therefore, suitable habitat is limited to the construction and upstream study areas which comprises 1,374.64 hectares of suitable habitat.

This Assessment of Significance has been prepared in accordance with the *Matters of National Environmental Significance: Significant impact guidelines 1.1* (DoE 2013). According to these guidelines, the questions of relevance to the significance of a 'Vulnerable' species are related to the 'importance of the population'. The guidelines define an 'important population' of a Vulnerable species as being *'a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal*
- *populations that are necessary for maintaining genetic diversity, and/or*

- *populations that are near the limit of the species range.'*

According to distributional records of *A. flocktoniae* as per the NSW BioNet Atlas, records of the species occur around Yerranderie within the upstream study area. However, in the absence of targeted surveys, suitable habitat within the construction and upstream study areas are assumed to support the species. It is assumed that the construction and upstream study areas support an 'important population' of *A. flocktoniae* particularly as there few known records of the species in New South Wales and it can be reasonably expected that the population affected by the Project is either a '*key source population either for breeding or dispersal' and the 'population is necessary for maintaining genetic diversity'*

This species is included in Gallagher *et al.* (2020) and considered likely to occur in the upstream study area. Based on the FESM mapping, approximately 69% of the study area's habitat was burnt in the 2019-2020 bushfires. Within the 20% AEP, 83.25 hectares of the total 154.44 hectares of habitat has been mapped as burnt, within the 1% AEP, 494.05 hectares of the total 752.78 hectares of habitat has been mapped as burnt, and within the PMF, 943.12 hectares of the total 1366.12 hectares of habitat has been mapped as burnt. The species is sensitive to fire, with above ground plants likely dying during fire (DEWHA 2008), with seedling recruitment potentially following suitable fire disturbance. This species is likely sensitive to broad-scale and intense fire events such as the 2019-2020 fires; a suitable fire regime has not been determined for this species. Those criteria identified by Gallagher *et al.* (2020) that particularly relate to this species and the environmental impacts associated with the Project, particularly in relation to post-fire disturbance and cumulative impacts, include:

A. Interactive effects of fire and drought

B. Short fire intervals (impacts of high fire frequency)

C. Post-fire herbivore impacts

E. High fire severity

F. Weed invasion

H. Fire sensitivity

I. Post-fire erosion

J. Cumulative exposure to high risks

K. Other plausible threats or expert-driven nominations (in this case the combined impacts from project-associated inundation on the above 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 an important population of a species**
It is estimated that the Project may affect a maximum of about 1,374.64 hectares of suitable habitat presumed to support an important population of *A. flocktoniae* (the majority of this area is the upstream PMF which has an area of 1,366.11 hectares for this species). Of this, about 8.53 hectares of suitable habitat presumed to support *A. flocktoniae* may be permanently lost through vegetation clearance associated with the construction of the dam wall. A more realistic estimate of the total potentially affected area, based on the 1% AEP (1 in 100 chance in a year flood) is 761.21 hectares. The remaining area of suitable habitat in the upstream study area may be subjected to varying degrees of impact associated with a variable inundation frequency, duration and extent. These inundation scenarios could lead to changes to vegetation structure, floristic composition, fire ecology and soil structure and properties. 154.06 hectares will be impacted by a 1 in 5 chance in a year flood event, and 752.68 hectares by a 1 in 100 chance in a year flood event and 1,366.11 hectares occurs with the PMF (study area). Impacts on suitable habitat may potentially lead to a long-term decrease in the size of an important population of *A. flocktoniae* either by causing stress or death to individual plants, by negatively affecting recruitment and germination or by altering the suitability of the habitat.

• **reduce the area of occupancy of an important population**
The Project could potentially reduce the area of occupancy of an important population of *A. flocktoniae* by removing or modifying up to 1,374.64 hectares of suitable habitat across both the construction and upstream study areas. This area includes the upstream PMF area which is highly unlikely to occur in nature. Reductions in the area of occupancy can be summarised according to the following impact scenarios: Upstream Study Area: • 1% AEP (1 in 100 chance in a year flood): 752.68 hectares • 20% AEP (1 in 5 chance in a year flood): 154.06 hectares Construction Study Area: • Development footprint: 8.53 hectares
• **fragment an existing important population into two or more populations**
Given the variable nature and extent of impacts associated with various inundation scenarios in the upstream study area, it is precautionarily assumed that an existing important population could become fragmented. As no targeted surveys for this species were undertaken, it is also assumed that vegetation clearance associated with the construction of the dam may also fragment an existing important population. It is unlikely however, that known occurrences of *A. flocktoniae* outside the construction and upstream study areas would become fragmented by the Project.
• **adversely affect habitat critical to the survival of a species**
The Minister maintains a 'Register of Critical Habitat' under the EPBC Act in which habitat as identified as being critical to the survival of a listed threatened species is provided. To date, no critical habitat is listed for this species that occurs within or proximal to the construction or upstream study areas. In addition, there is no state of federal Recovery Plan that has been prepared for *A. flocktoniae.* However, the estimated 2,620 hectares of suitable habitat presumed to support an important population of *A. flocktoniae* is considered to be habitat critical to the survival of the species. This is because the habitat is likely important in maintaining the genetic diversity and long-term evolutionary development of the species and is important for maintaining ecological processes essential to the survival for the species (for example, pollinators). The Project may therefore potentially adversely affect habitat critical to the survival of *A. flocktoniae.*
• **disrupt the breeding cycle of an important population**
The breeding cycle of *A. flocktoniae* is not documented in scientific literature. However, there is research (albeit limited) that has been conducted on the pollination ecology of the Acacia genus more broadly. A study undertaken by Stone et. al. (2003) suggests that the most important pollinators of acacias are social and solitary bees, although other insects and nectar-feeding birds may be important in specific circumstances. According to Kodella et. al. (2012), acacia seeds are dispersed mostly by being ejected from a legume that has usually opened due to the heat of the sun. However, in some circumstances the seeds may remain hanging from the open legume attracting birds which may facilitate dispersal by eating the seeds (Kodella et. al. 2012). In accordance with the precautionary principle, the Project is assumed to have the potential to disrupt the breeding cycle of an important population of *A. flocktoniae.* This is considered a reasonable assumption as the variable nature of impacts could potentially disrupt one or more ecological functions and processes that are currently maintaining known populations of this species in the study area such as at Yerranderie.
• **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 estimated that the Project may affect a maximum of 1,374.64 hectares of suitable habitat presumed to support an important population of *A. flocktoniae.* Of this, about nine hectares of suitable habitat presumed to support *A. flocktoniae* would be permanently lost through vegetation clearance associated with the construction of the raising of the dam wall. The remaining area of suitable habitat in the upstream study area may be modified due to being subjected to a range of changed inundation scenarios. Over the long-term these modifications to the ecosystem

and habitat for *A. flocktoniae* may potentially lead to a decrease in the availability or quality of the habitat for the species.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
The invasive weed St Johns Wort (*Hypericum perforatum*) is a known threat to *A. flocktoniae* (DEWHA 2008). It is possible that machinery and equipment associated with the construction of the raising of the dam wall could lead to an introduction or spread of this invasive species. The risk of the introduction of invasive weeds during the construction phase can be effectively mitigated through hygiene controls and weed management. It has been assumed such controls will be implemented during construction. In this regard, it is considered unlikely that the project would result in this invasive species becoming established in the construction area. It is not known whether operation of the FMZ could lead to a spread of *Hypericum perforatum.*
• **introduce disease that may cause the species to decline, or**
There are no diseases that are known to specifically affect *A. flocktoniae*, however there are many gall-forming insects that attack specific acacia species (Kodella et. al. 2012). These insects are often specific to either the flower buds, foliage or stems and include wasps, mites and thrips where the latter may also inhabit the phyllode nectaries (Kodella et. al. 2012). The gall-midge (*Cecidomyidae*) produces a substance which stimulates the plant to produce the gall cells for the gall-midge to live. These primary gall-formers suck the cell contents, but they in turn may be parasitised by other insects, such as moth larva, wasps, weevils and beetles (Kodella et. al. 2012). Gall-formers can be fatal to host acacia species that are already undergoing stress due to other factors. In addition to galls, some acacia species are susceptible to fungal attack. Besides being formed by insects, galls may also be formed by some fungi, such as by the *Uromycladium* sp. fungus (Kodella et. al. 2012). This infestation is often observed on *Acacia implexa* and can be severe enough that it can debilitate the plant (Kodella et. al. 2012). Existing ecological functions and processes may be affected by the Project to the extent that such changes may potentially create an environment conducive to the introduction or spread of disease that may cause *A. flocktoniae* to decline. None of the described diseases are covered by an approved Threat Abatement Plan.
• **interfere substantially with the recovery of the species.**
There is no approved National Recovery Plan for *A. flocktoniae.* The Commonwealth Conservation Advice (DEWHA 2008) for *A. flocktoniae* notes recovery actions should be targeted towards research priorities, managing known threats such as invasive weeds and fire and minimising habitat loss, modification and disturbance to known populations. The Project currently does not support the action noted towards research priorities in managing threats such as invasive weeds or altered fire regime and other disturbance. The Project therefore does not interfere substantially with the recovery of the species due to no recovery plan prescribed in legislation.
Conclusion
The Project may reduce the area of occupancy and modify substantial extents of suitable habitat for *Acacia flocktoniae* and could potentially have an adverse effect on an important population such that it may cause it to decline. The Project has been assessed as likely having a significant impact on *A. flocktoniae*.

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Acacia gordonii

Endangered under the EPBC Act

Acacia gordonii is a small erect to spreading shrub growing up to 1.5 metres tall. It produces pubescent branchlets and phyllodes that are alternately arranged in either whorls or clusters. Flowers are produced in August and September and are arranged in singular golden/yellow globular heads across a branchlet. Flat, oblong-shaped seed pods containing between 5 and 8 hard-coated seeds are produced from October through to February (DoE 2014).

A. gordonii has been recorded from north-western Sydney and the lower eastern slopes of the Blue Mountains. In north-western Sydney, *A. gordonii* has been most commonly recorded in the Glenorie/Maroota area (Benson and McDougall 1996) with one record being made in Hornsby (Orchard and Wilson 2001). Within the north-western Sydney area of the *A. gordonii* distribution the species has been estimated at less than 2000 individuals (DoE 2014). Within the Blue Mountains, *A. gordonii* has been recorded at Linden, across the Kings Tableland, at Bilpin and at Faulconbridge. About 850 individuals occur throughout these localities (DoE 2014).

Acacia gordonii habitat includes dry sclerophyll forests and heathlands occurring on rock platforms or in areas supporting sandstone outcrops.

According to OEH's BioNet system, *A. gordonii* is associated with the following PCTs mapped in the upstream study area:

- PCT 1081 (HN564): Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion
- PCT 1083 (HN566): Red Bloodwood – Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion

A. gordonii is associated with the following PCT mapped in the construction study area:

- PCT 1081 (HN564): Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion
- PCT 1083 (HN566): Red Bloodwood – Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion

A. gordonii was assessed with a low likelihood of occurring in the downstream study area. As such it is not subject to this assessment.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines a 'population of a species' as an occurrence of the species in a particular area. In relation to critically endangered, endangered or vulnerable threatened species occurrences include but are not limited to:

- a geographically distinct regional population, or collection of local populations.
- a population, or collection of local populations that occur within a particular bioregion.

Targeted surveys for *A. gordonii* were not undertaken across the three study areas. In the absence of targeted surveys, *A. gordonii* has been assumed present in areas of suitable habitat – the previously listed PCTs and contiguous vegetation supporting known records. Using the precautionary principle, a population of the species has been assessed as occurring across the three study areas.

An action is likely to have a significant impact on an endangered or critically 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**
As *A. gordonii* has not been surveyed for within the Project study area, areas of suitable habitat have been used as a surrogate for the species occurrence. Within the Upstream Study Area 29.61 hectares of habitat has been mapped. Of this 29.61 hectares, 3.49 hectares may be impacted by a 1 in 5 chance in a year flood event (20% AEP) and 16.27 hectares by a 1 in 100 chance in a year flood event (1% AEP). Impacts associated with all three events (the study area representing the PMF) could lead to long-term decreases in the population. 15.01 hectares of habitat occurs within the Development Footprint associated with construction activities.

The impacts to suitable habitat have the potential to lead to a long-term decrease in the size of the populations of *A. gordonii*.
• **reduce the area of occupancy of the species**
The Project may reduce the potential area of occupancy for *A. gordonii* across two study areas. These can be summarised according to the following impact scenarios: Upstream Study Area • 1% AEP (1 in 100 chance in a year flood): 16.27 hectares • 20% AEP (1 in 5 chance in a year flood): 3.49 hectares Construction Study Area • Development footprint: 15.01 hectares
• **fragment an existing population into two or more populations**
The *A. gordonii* habitat within the downstream study area has been partially fragmented through agricultural and residential development. The extents of PCT 1081 (HN564) and PCT 1181 (HN586) are however often contiguous with larger areas of native vegetation that stretch outside of the Downstream study area. This has made the *A. gordonii* habitat comparatively less fragmented than other native vegetation occurring within the central part of the Cumberland Plain. Despite the *A. gordonii* habitat's connectivity with large areas of native vegetation, the Project may further fragment its extent. The further fragmentation of *A. gordonii* habitat may predominantly occur along the Nepean River, Kelly's Creek, Origma Creek and Little Cattai Creek. The habitat in the upstream and construction study areas is mainly contiguous with the Blue Mountains National Park. The Project may impact the extents of this habitat in a similar manner to the habitat in the downstream study area– direct removal of vegetation, increased presence of invasive species, erosion and deposition - however its connectivity to larger extents of native vegetation may reduce the number of new edges and fragments created.
• **adversely affect habitat critical to the survival of a species**
According to the *Matters of National Environmental Significance Significant impact guidelines* 1.1 (DoE 2013) habitat critical to the survival of a species refers to areas that are necessary for: • activities such as foraging, breeding, roosting, or dispersal • 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 • the reintroduction of populations or recovery of the species or ecological community. The *A. gordonii* habitat in the upstream, downstream and construction study areas has been assessed as critical habitat because it is important for dispersal, the long-term maintenance of the species, for maintaining genetic diversity, and for the potential reintroduction/recovery of the species. The Project could potentially adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive species, erosion and deposition, and modifying the fire regime.
• **disrupt the breeding cycle of a population**
Lifecycle processes in *A. gordonii* are largely influenced by fire. *A. gordonii* produces a hard-coated seed that forms a persistent soil-stored seedbank (OEH 2019). Benson and McDougall (1996) write that fire promotes the germination of the seedbank. Germination will not occur without fire as the seed's hard coating requires heat to break dormancy. Benson and McDougall also write that *A. gordonii* can re-sprout after fire, yet this was not consistent across all adult individuals in the observed population. Variability in this response to fire is not unusual for other species of *Acacia*. Potential changes to hydrology within the downstream study area could modify the floral assemblages between the existing 10% AEP and the proposed 10% AEPs. The change in floral assemblages may impact the fire regime within these impact boundaries. As germination is dependent on fire, the Project has the potential to impact the breeding cycle of *A. gordonii*. An increase in flooding extents and durations may also cause modifications to the upstream

fire regimes. A change to fire frequency and intensity within the upstream study area could potentially impact the breeding cycle of *A. gordonii*.

- **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**

The Project may impact up to 64.38 hectares of *A. gordonii* habitat within the upstream and construction study areas. Habitat may be destroyed and/or impacted through the clearing of native vegetation, the loss of flora and fauna habitat, and a reduction in the extent of ecological communities. Habitat may be also be impacted through fragmentation, alteration to soil conditions, edge effects, weed invasion and incursion, through the spread of disease and pathogens, erosion and sedimentation, and thorough changes to the fire regime.

- **result in invasive species that are harmful to an endangered or critically endangered species becoming established in the endangered or critically endangered species' habitat**

No invasive species have been listed as a threat to *A. gordonii* in either the SPRAT profile, Approved Conservation Advice or OEH threatened species profile (DoE 2014; DoEE 2019; OEH 2019). Despite this, invasive flora species are likely to provide competition for *A. gordonii* for space and light. The Project may promote the spread and establishment of invasive flora throughout *A. gordonii* habitat.

- **introduce disease that may cause the species to decline, or**

No diseases have been identified as a threat to *A. gordonii*. As such, the approved Threat Abatement Plan for disease in natural ecosystems caused by *Phytophthora cinnamomi* (DoEE 2018) does not apply.

- **interfere substantially with the recovery of the species.**

A National Recovery Plan for *A. gordonii* has not been developed under the EPBC Act. The approved Commonwealth Conservation Advice for *A. gordonii* does however outline Regional Priority Actions and Local Priority Actions to support the species' recovery. The Project interferes with the following Regional and Local Priority Actions:

- Ensure there is no disturbance in areas where *A. gordonii* occurs, excluding necessary actions to manage the conservation of the species/ecological community.
- Manage any other known, potential or emerging threats.
- Develop and implement a suitable fire management strategy for the habitat of *A. gordonii*
- Protect populations of the species through the development of conservation agreements and/or covenants.
- Implement an appropriate fire management regime for local populations

A targeted strategy for managing *A. gordonii* has been developed under the Saving Our Species Program. Under the Saving Our Species program *A. gordonii* has been assigned to the 'site-managed species' management stream. The following two priority management sites have been identified:

- Neich Road in The Hills Shire LGA
- Blue Mountains National Park in the Blue Mountains and Hawkesbury LGAs.

The Project is unlikely to impact either priority management sites.

Conclusion

The Project may impact up to 64.38 hectares of *A. gordonii* habitat across the upstream, downstream and construction study areas. This habitat may become further fragmented, isolating occurrences of *A. gordonii* from one another. The Project may also impact the breeding cycle of *A. gordonii* by clearing native vegetation (habitat), modifying the fire regime and impacting the soil seedbank. These impacts are expected to cause a decline of population of *A. gordonii*.

The Project has been assessed as likely having a significant impact on *A. gordonii.*

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Acacia pubescens

Vulnerable under EPBC Act

Acacia pubescens is listed as Vulnerable under the BC Act and EPBC Act. *A. pubescens* is a spreading shrub 1-5 m high with yellow flowers and bipinnate leaves with conspicuously hairy branchlets (OEH 2017). It is endemic to NSW and its distribution is concentrated around the Bankstown-Fairfield-Rookwood area and the Pitt Town area, with outliers at Barden Ridge, Oakdale and Mountain Lagoon (NPWS 2003a). The species has been recorded on a variety of geologies including Tertiary Alluvium, Holocene Alluvium and Wianamatta Shale. The soils at these sites where *A. pubescens* occur are characteristically gravely often with ironstone however the species has also been found at a few sites on the interface between sandstone and shale soils (NPWS 2003a). The topography of the habitat the species is found in is generally flat to gently undulating. Typically, the species is found in open woodland and forest in a variety of plant communities however most occurrences are within Cooks River/Castlereagh Ironbark Forest, Shale Gravel Transition Forest or Shale Plains Woodland (NPWS 2003a). Stands of *A. pubescens* have also been recorded in open, disturbed areas, surrounded by exotic species (NPWS 2003a). *A. pubescens* is a clonal species which appears to sucker at most sites it has been recorded (NPWS 2003a).

With regard to the Project, *A. pubescens* is considered likely to occur in the upstream, construction and downstream study areas however targeted surveys for this species were not undertaken. Despite targeted surveys not being undertaken, a total of 1,504 individuals of *A. pubescens* were incidentally recorded in the downstream survey area (that is, the 10% AEP Existing boundary) during the current survey.

In the absence of targeted surveys, *A. pubescens* has been assumed present in areas of presumed suitable habitat. For this assessment, suitable habitat for *A. pubescens* includes the PCTs that are associated with the species (as per the TBDC), BioNet Atlas Records and any other known vegetation types (as per scientific literature) that the species is associated with that has been mapped within the construction and upstream study areas.

Suitable habitat includes the following PCTs that have been mapped within the construction study area:

- PCT1081: Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion (associated as per TBDC)
- PCT1083: Red bloodwood - scribbly gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion (associated as per TBDC)
- PCT1086: Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains Sydney Basin Bioregion (associated as per TBDC)
- PCT1281: Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains Sydney Basin Bioregion (associated as per TBDC).

Suitable habitat includes the following PCTs that have been mapped within the upstream study area:

- PCT1081: Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion (associated as per TBDC)
- PCT1083: Red bloodwood - scribbly gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion (associated as per TBDC)
- PCT1086: Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains Sydney Basin Bioregion (associated as per TBDC).

Suitable habitat includes the following PCTs that have been mapped within the downstream study area includes:

- PCT724: Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain, Sydney Basin Bioregion (associated as per TBDC)
- PCT725: Broad-leaved Ironbark - *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain, Sydney Basin Bioregion (associated as per TBDC)
- PCT1081: Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion (associated as per TBDC)
- PCT1181: Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney, Sydney Basin Bioregion (associated as per TBDC)
- PCT1395: Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion (associated as per TBDC)

- PCT835: Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain Sydney Basin Bioregion (associated as per incidental records in this PCT).

A. pubescens is considered to have a moderate likelihood of occurring in the upstream and construction study areas and has a known occurrence in the downstream study area.

This Assessment of Significance has been prepared in accordance with the *Matters of National Environmental Significance: Significant impact guidelines* (DoE 2013). According to these guidelines, the questions for a 'Vulnerable' species is related to the 'importance of the population'. The guidelines define an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal*
- *populations that are necessary for maintaining genetic diversity, and/or*
- *populations that are near the limit of the species range.'*

According to distributional records of *A. pubescens* as per the NSW BioNet Atlas, records of the species occur primarily within the downstream study area. It is assumed that the downstream study area supports an 'important population' of *A. pubescens* and that these known occurrences are a 'key source population either for breeding or dispersal' and the 'population is necessary for maintaining genetic diversity'.

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**
As *A. pubescens* has not been surveyed, areas of habitat have been used as a surrogate for the species occurrence. Within the upstream study area approximately 132.52 hectares of habitat has been mapped. Of this 132.52 hectares, 14.44 hectares may be impacted by a 1 in 5 chance in a year flood event (20% AEP) and 68.63 hectares by a 1 in 100 chance in a year flood event (1% AEP). Within the Downstream Study Area about 277.82 hectares occurs between the existing and with project 10% AEPs, 86.57 hectares between the existing and with project PMFs and 400.84 hectares within the FMZ discharge area. 22.42 hectares of habitat occurs within the Development Footprint associated with construction activities. It is assumed that the modification or loss of suitable habitat could eventually lead to a long-term decrease in the size of an important population of *A. pubecens* either by causing stress or death to individual plants, by negatively affecting recruitment and germination potential or by negatively affective the integrity and suitability of preferred habitat.
• **reduce the area of occupancy of an important population**
The Project could potentially reduce the area of occupancy of suitable habitat for *A. pubescens* by removing or modifying suitable habitat across the three study areas, the extent of which is considered to support an important population. These reductions can be summarised according to the following impact scenarios: Upstream Study Area • 1% AEP (1 in 100 chance in a year flood): 68.63 hectares • 20% AEP (1 in 5 chance in a year flood): 14.44 hectares Downstream Study Area • FMZ discharge area: 423.92 hectares • Difference between the existing and with project 10% AEPs: 277.82 hectares • Difference between the existing and with project PMFs: 86.57 hectares Construction Study Area • Development footprint: 22.42 hectares

• fragment an existing important population into two or more populations
The Project could potentially reduce the area of occupancy of suitable habitat for *A. pubescens* across the three study areas. The Project is considered to have potential to result in the modification or loss of these extents of suitable habitat and may contribute to fragmentation of an existing important population of the species.
• adversely affect habitat critical to the survival of a species
The Minister maintains a 'Register of Critical Habitat' under the EPBC Act in which habitat as identified as being critical to the survival of a listed threatened species is provided. To date, no critical habitat is listed for this species that occurs within or proximal to the construction, downstream or upstream study areas. Additionally, according to the recovery plan (NPWS 2003), habitat critical to the survival of *A. pubescens* cannot be identified given the clonal nature of the species and a lack of genetic information about this clonality. However, according to the significant impact guidelines (DoE 2013), 'habitat critical to the survival of a species' may also include areas that are necessary: • for activities such as foraging, breeding, roosting, or dispersal • for the long-term maintenance of the species • to maintain genetic diversity and long term evolutionary development, or • for the reintroduction of populations or recovery of the species. On this basis, it is suggested that the habitat occupied by *A. pubescens* in the downstream study area comprises habitat critical to the survival of the species. This is because this habitat may precautionarily be necessary for breeding or dispersal, the long-term maintenance of the species, and to maintain the genetic diversity and long-term evolutionary development of the species.
• disrupt the breeding cycle of an important population
The breeding cycle of *A. pubescens* is poorly understood, and it has been recommended by the recovery plan (NPWS 2003) that the population dynamics, breeding system, fire ecology, distribution/species extent be further researched and investigated (NPWS 2003a; NPWS 2003b). Broadly, the breeding system has been found to vary from being highly self-incompatible to exhibiting a mixture of out-crossing and self-compatibility (NPWS 2003). With regard to the Project, it is not known if altered hydrological regimes and associated impacts such as erosion and sedimentation may have an immediate effect on *the breeding* cycle of A. pubescens. However, the Project is expected to alter (either directly or indirectly) the existing ecological processes and functions within the upstream, downstream and construction study areas which may disrupt the breeding cycle of an important population that is considered to exist within the downstream study area.
• modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline
The Project may affect suitable habitat presumed to support an important population of *A. pubecens.* Suitable habitat within the three study areas may be affected by the Project which could potentially lead to a decrease in the availability or quality of habitat suitable for the species. The potential modification or loss of habitat within the downstream study area is considered to be more detrimental to the survivability of the species which could contribute to the species decline.
• result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat
Invasive weeds that are considered harmful to *A. pubescens* and its habitat include African lovegrass (*Eragrostis curvula*), Whisky grass (*Andropogon virginicus*), Paddy's lucerne (*Sida rhombifolia*), Prickly Pear (*Opuntia spp*.), Mother-of-millions (*Bryophyllum delagoense*), Paspalum (*Paspalum dilatatum*), Kikuyu (*Pennisetum clandestinum*), Blackberry (*Rubus fruticosus sp. agg*.), Honeysuckle (*Lonicera japonica*) and African Olive (*Olea europea*) (NPWS 2003). It is possible that machinery and equipment associated with the construction of the raising of the dam wall could lead to an introduction or spread of this invasive species. The spread and establishment of weed species can be mitigated thorugh proper hygiene controls. It has been assumed these controls will be implemented throughout the construction phase of the Project.

It is also possible that impacts associated with the Project, particularly the main effect of altered hydrology (both upstream and downstream) may potentially create conditions conducive to the establishment and spread of these weed species throughout the study area. Measures to avoid, mitigate and minimise these impacts have not been undertaken.
• **introduce disease that may cause the species to decline, or**
It is noted in the National Recovery Plan (NPWS 2003) that a large proportion of individuals of *A. pubescens* appear to be suffering from an unknown disease which affects the leaves of plants. This is considered by the recovery plan (NPWS 2003) as being a threat to the survivability of the species and therefore research into the disease is considered as a high priority within the plan. Given the unknown nature and extent of this disease, including its unknown effects on the species, it is considered precautionarily that the Project may facilitate the spread of this disease throughout the study area such that it may cause the species to decline. However, it is not known whether other diseases such as *Phytophthora cinnamomi* or any other disease affects *A. pubescens*. It is unknown if hygiene controls can prevent the spread of the unknown disease affecting *A. pubescens*. The unknown disease – nor any other disease known to affect *A. pubescens* – are covered by an approved Threat Abatement Plan.
• **interfere substantially with the recovery of the species.**
A National Recovery Plan for *A. pubescens* was published in 2003 by the NSW National Parks and Wildlife Services (NPWS). The overall objective of the recovery plan is *'to prevent the status of A. pubescens from becoming endangered, by reducing habitat loss and by implementing management regimes aimed at maintaining representative populations across the species' range*' (NPWS 2003b). The plan consists of 13 recovery actions which aim to meet the overall objective (NPWS 2003b). Given that a substantial extent of habitat known to support *A. pubescens* in the downstream study area may be affected (either directly or indirectly) by the Project it is expected that this would interfere substantially with the recovery actions (as per the recovery plan) for the species. It is not expected that the Project would interfere substantially with the recovery of the species in the upstream and construction study areas.
Conclusion
The Project is considered to have potential to reduce the area of occupancy and modify substantial extents of suitable habitat for the species and could therefore have an adverse effect on an important population of *A. pubescens* such that it may cause it to decline. The Project has been assessed as likely having a significant impact on *A. pubescens*.

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Acrophyllum australe

Vulnerable under the EPBC Act

Acrophyllum australe is listed as Vulnerable under the BC Act and EPBC Act. *A. australe* is a small hairless shrub, growing 1-2 m high. Leaves have regularly toothed margins, occurring in whorls of three, four sometimes opposite and ovate (DEWHA 2008). The species flowers in November to December, producing small white flowers that are tinged with pink (DEWHA 2008). *A. australe* has a very restricted distribution and occurs only in the mid- Blue Mountains within the Wollemi sub-catchment area (DEWHA 2008). According to the conservation advice (DEWHA 2008), there are 27 known populations of which eight occur in NSW reserves and one within the Blue Mountains National Park (Briggs and Leigh 1996). The preferred habitat for *A. australe* includes damp crevices and rock faces with a south-east to south-west aspect, usually near waterfalls and drip zones (Benson and McDougall 1995). Generally, it prefers moist clayey soils on Hawkesbury sandstone with damp humus accumulation, low nutrients and permanent moisture (DEWHA 2008).

With regard to the Project, *A. australe* is considered likely to have a ‘high’ likelihood of occurring within the upstream study area and a ‘moderate’ likelihood of occurring within the construction study area, based on the presence of suitable habitat. Targeted surveys were not undertaken for *A. australe* and the species was not incidentally encountered in the survey area during vegetation mapping investigations associated with the Project.

In the absence of targeted surveys, *A. australe* has been assumed present in areas of presumed suitable habitat. For this assessment, suitable habitat for *A. australe* includes the PCTs that are associated with the species (as per the TBDC), BioNet Atlas Records and any other known vegetation types (as per scientific literature) that the species is associated with that has been mapped within the upstream and construction study areas.

Suitable habitat includes the following PCT that have been mapped within the construction study area:

- PCT1083: Red bloodwood - scribbly gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion (associated as per TBDC).

Suitable habitat includes the following PCTs that have been mapped within the upstream study area:

- PCT769: Coachwood - Lilly Pilly warm temperate rainforest in moist sandstone gullies Sydney Basin Bioregion (associated as per TBDC)
- PCT1083: Red bloodwood - scribbly gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion (associated as per TBDC)
- PCT1284: Turpentine - Smooth-barked Apple moist shrubby forest of the lower Blue Mountains Sydney Basin Bioregion (associated as per TBDC)

A. australe is considered to have a low likelihood of occurring in the downstream study area. This is based on a lack of suitable habitat in the form of PCTs and because the species has a restricted distribution for which there are no known populations in the downstream study area. Therefore, suitable habitat is limited to the construction and upstream study areas which comprises 57.19 hectares of suitable habitat.

This Assessment of Significance has been prepared in accordance with the *Matters of National Environmental Significance: Significant impact guidelines 1.1 (DoE 2013).* According to these guidelines, the questions for a ‘Vulnerable’ species are related to the ‘importance of the population’. The guidelines define an ‘important population’ of a Vulnerable species as being *‘a population that is necessary for a species’ long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal*
- *populations that are necessary for maintaining genetic diversity, and/or*
- *populations that are near the limit of the species range.’*

Given the separation between known sites occupied by *A. australe*, by both distance and geophysical features and given an unknown proportion of plants are clonal, there may be limited genetic diversity within populations (OEH 2019). On this basis, it is assumed that the construction and upstream study areas support an ‘important population’ as it can be reasonably expected that the population affected by the Project is a *‘population is necessary for maintaining genetic diversity’.*

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 Project may affect up to 57.19 hectares of suitable habitat presumed to support an important population of *A. australe.* Of this, 44.94 hectares is presumed to occur in the upstream study area. 5.64 hectares will be impacted by a 1 in 5 chance in a year flood event and 29.95 hectares by a 1 in 100 chance in a year flood event. About 12.25 hectares will be impacted by the clearing associated with construction (development footprint). There is potential for any form of inundation to result in the mortality of affected individuals either directly by causing flood stress or indirectly by other inundation impacts. While this species occurs in a constantly moist environment, it is not known if it can tolerate full or partial submergence. Flood stress could occur in this case as the plant would be starved of oxygen, carbon dioxide and sunlight. Other inundation associated impacts may include changes to the habitat this species persists in which could occur due to such things as erosion or sedimentation. In the construction study area, up to 12.25 hectares of suitable habitat may be impacted through habitat loss required for constructing a raised dam wall. These impacts may potentially lead to a long-term decrease in the size of an important population of *A. australe* either by causing stress or death to individual plants, by negatively affecting recruitment and germination or by altering the suitability of the habitat.
• **reduce the area of occupancy of an important population**
The Project could potentially reduce the area of occupancy of an important population of *A. australe* by removing or modifying up to about 57.19 hectares of suitable habitat across both the construction and upstream study areas. Reductions in the area of occupancy can be summarised according to the following impact scenarios: Upstream Study Area • 1% AEP (1 in 100 chance in a year flood): 29.95 hectares • 20% AEP (1 in 5 chance in a year flood): 5.64 hectares Construction Study Area • Development footprint: 12.25 hectares
• **fragment an existing important population into two or more populations**
Given the variable nature and extent of impacts associated with various inundation scenarios in the upstream study area, it is precautionarily assumed that an existing important population could become fragmented. As no targeted surveys for this species were undertaken, it is also assumed that vegetation clearance associated with the construction of the dam may also fragment an existing important population. It is unlikely however, that known occurrences of *A. australe* outside the construction and upstream study areas would become fragmented by the Project.
• **adversely affect habitat critical to the survival of a species**
The Minister maintains a 'Register of Critical Habitat' under the EPBC Act in which habitat is identified as being critical to the survival of a listed threatened species. To date, no critical habitat is listed for this species that occurs within or proximal to the construction or upstream study areas. In addition, there is no state of federal Recovery Plan that has been prepared for *A. australe*. However, the estimated 57.19 hectares of suitable habitat presumed to support an important population of *A. australe* is considered to be habitat critical to the survival of the species. This is because the habitat is likely important in maintaining the genetic diversity and long-term evolutionary development of the species and is important for maintaining ecological processes essential to the survival for the species. The Project could therefore potentially adversely affect habitat critical to the survival of *A. australe.*
• **disrupt the breeding cycle of an important population**
The breeding cycle of *A. australe* is not documented in scientific literature nor well-understood. However, an unknown proportion of plants are known to be clonal (OEH 2019). The species is also known to have a specific habitat requirements and flower November to December. Seed is known to be released when mature however recent surveys suggest that few plants had produced seed in recent years (OEH 2019). Recruitment occurs after fire and in the absence of fire and may episodic in response to certain conditions. Small plants are killed by fire however

larger plants may resprout from a lignotuber (OEH 2019). In accordance with the precautionary principle, the Project is assumed to have the potential to disrupt the breeding cycle of an important population of *A. australe*. This is considered a reasonable assumption as the variable nature of impacts is likely to disrupt one or more ecological functions and processes that are currently maintaining known populations of this species in the study area.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project may affect up to about 57.19 hectares of suitable habitat presumed to support an important population of *A. australe.* Of this, about 12 hectares would be permanently lost through vegetation clearance associated with the construction of the raising of the dam wall. The remaining area of suitable habitat in the upstream study area could potentially be modified due to being subjected to a range of changed inundation scenarios. Over the long-term these modifications to the ecosystem and habitat for *A. australe* could potentially lead to a decrease in the availability or quality of the habitat for the species.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
The establishment and spread of invasive weeds are potential threats to *A. australe* (DEWHA 2008). It is possible that machinery and equipment associated with the construction of the raising of the dam wall could lead to an introduction or spread of this invasive species. Similarly, potential changes to the upstream ecosystem as a result of various inundation scenarios could create an environment conducive to the spread and establishment of invasive weed species. The Project is therefore considered to have potential to result in invasive species harmful to *A. australe* becoming established in the species' habitat.
• **introduce disease that may cause the species to decline, or**
There are no diseases that are known to specifically affect *A. australe.* It is expected that the existing ecological functions and processes specific to *A. australe*, may be affected by the Project. It is reasonable to assume that such changes may create an environment conducive to the introduction or spread of disease that may cause *A. australe* to decline. No disease known to affect *A. australe* has been covered by an approved Threat Abatement Plan.
• **interfere substantially with the recovery of the species.**
There is no adopted or approved National Recovery Plan or Threat Abatement Plan for *A. australe*. The Commonwealth Conservation Advice (DEWHA 2008) for *A. australe* provides regional priority recovery and threat abatement actions to support the recovery of the species. The actions aim to minimise threats associated with habitat loss, disturbance and modification, invasive weeds, fire and a lack of community awareness of the species. Broadly, the actions involve managing road/track widening and maintenance activities, weed spraying and hydrological changes that could contribute to habitat loss, disturbance and modification; developing and implementing a management plan for invasive weeds in local regions where the species occurs, identify appropriate intensity and interval of fire to promote seed germination, raise awareness of *A. australe* within the local community and enable recovery of additional sites and/or populations by undertaking seed collection and storage, investigation options for linking, enhancing or establishing additional populations. The Project may interfere with the recovery of the species by contributing to habitat loss, disturbance and modification.
Conclusion
The Project has potential to reduce the area of occupancy and modify extents of suitable habitat for the *A. australe*, and could potentially have an adverse effect on an important population such that it may cause it to decline. The Project has been assessed as likely having a significant impact on *A. australe*.

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Allocasuarina glareicola

Endangered under the EPBC Act

Allocasuarina glareicola is a dioecious or monoecious shrub that grows to between 1 and 2 metres tall. *A. glareicola* has smooth bark with ascending branchlets that grow to 20 centimetres long. Branchlets support articles between 5 and 11 millimetres long, and 0.5 to 0.7 millimetres in diameter. These articles have 5 to 7 slightly spreading teeth. Branchlets support small cones on peduncles 4 to 7 millimetres long (PlantNET 1993).

The *A. glareicola* distribution is restricted to the Cumberland Plain of Western Sydney. Most records come from Castlereagh and Londonderry within an area of 27 square kilometres. An outlier population has been recorded in the southern extent of the Cumberland Plain at the Holsworthy Military Base (DEWHA 2008). Populations occurs within Castlereagh woodland where they are supported by tertiary alluvial gravels with a yellow clay sub-soil. The occurrence of *A. glareicola* can be associated with the occurrence of *Eucalyptus parramattensis*, *E. fibrosa*, *Angophora bakeri*, *E. sclerophylla* and *Melaleuca decora* (OEH 2019).

According to OEH's BioNet system, *A. glareicola* is associated with the following PCTs mapped in the downstream study area:

- PCT 724 (HN512): Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain Sydney Basin Bioregion
- PCT 725 (HN513): Broad-leaved Ironbark - *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain Sydney Basin Bioregion
- PCT 883 (HN542): Hard-leaved Scribbly Gum - Parramatta Red Gum heathy woodland of the Cumberland Plain Sydney Basin Bioregion
- PCT 1067 (HN562): Parramatta Red Gum woodland on moist alluvium of the Cumberland Plain Sydney Basin Bioregion
- PCT1081 (HN564): Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion

A. glareicola has been assessed with a low likelihood of occurrence in the upstream and construction study areas. As such, it is not considered to occur in these study areas or be impacted by the Project in these study areas.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines a 'population of a species' as an occurrence of the species in a particular area. In relation to critically endangered, endangered or vulnerable threatened species occurrences include but are not limited to:

- a geographically distinct regional population, or collection of local populations.
- a population, or collection of local populations that occur within a particular bioregion.

Targeted surveys for *A. glareicola* were not undertaken in the Downstream study area. In the absence of targeted surveys in the Downstream study area, a population of *A. glareicola* has been assumed present in the areas of suitable habitat – the previously listed PCT.

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**
As *A. glareicola* has not been surveyed, areas of habitat have been used as a surrogate for the species occurrence. 535.67 hectares of *A. glareicola* habitat occurs between the 'with Project' PMF and the 'existing' PMF. 28.75 hectares occurs between the existing and with project 10% AEPs, and zero hectares occurs within the FMZ discharge area. All the suitable habitat within these impact scenarios could potentially lead to a long-term decrease in the size of the population of *A. glareicola*.
• **reduce the area of occupancy of the species**
The Project may directly impact the area of occupancy of the species by 535.67 hectares between the 'with Project' PMF and the 'existing' PMF, by 28.75 hectares between the existing and with project 10% AEPs, and by zero hectares within the FMZ discharge area.

• **fragment an existing population into two or more populations**
The Project has the potential to further fragment the native forests and woodlands of the Cumberland Plain. However, stands of *A. glareicola* habitat are often contiguous with larger stands of habitat as is the case with Castlereagh Nature Reserve and Agnes Banks Nature Reserve, where many of the previous recording of this species are located. While the Project may fragment some of the native vegetation in within the previously outlined impact boundaries and scenarios, it is unlikely to fragment an existing population of *A. glareicola* into two or more smaller populations.
• **adversely affect habitat critical to the survival of a species**
According to the Matters of National Environmental Significance impact guideline (DoE 2013), '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'* (DoE 2013). *A. glareicola* has been identified in the Cumberland Plain Recovery Plan (NSW Department of Environment, Climate Change and Water 2010). This makes the habitat within the Downstream PMF critical to the survival of the species as defined in the Matters of National Significance impact guidelines. The Project may adversely impact this critical habitat.
• **disrupt the breeding cycle of a population**
A. glareicola has the means to spread vegetatively (reproduce asexually), with one individual being comprised of up to 100 stems. Sexual reproduction occurs in a similar manner to other species within the genus *Allocasuarina*, however comparative observations between burnt and unburnt stands of *A. glareicola* have identified that areas unburnt for longer periods of time produce large numbers of fruit (OEH 2019). Observation have also identified that *A. glareicola* is not killed by fire but re-sprouts from root stock (Fairley 2004). The Project has the potential to disrupt the breeding cycle of the population in the downstream study area. The fire regime – important to the species – may be impacted, through inundation-induced changes to the supporting vegetation community(s). Less frequent inundation of native vegetation may change the species composition to that of a community which burns more frequently. If current *A. glareicola* habitat was to burn more frequently it could impact the production of fruit and therefore the number of seed and individuals in the next generation.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project may impact *A. glareicola* habitat within the downstream study area. Habitat may be destroyed and/or directly impacted through the clearing of native vegetation, the loss of habitat and a reduction in the extent of ecological communities'. Habitat may be indirectly impacted (modified, reduced in quality etc.) through alteration to soil conditions, edge effects, weed invasion and incursion, through the spread of disease and pathogens, erosion and sedimentation, and thorough changes to the fire regime.
• **result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat**
The Approved Conservation Advice for *A. glareicola* states 'Weed invasion is also a major threat, with Weeping Lovegrass (*Eragrostis curvula*) and Whisky Grass (*Andropogon virginicus*) the major weed competitors'. The OEH threatened species profile adds *Ricinus communis* and Asparagus Fern (*Asparagus aethiopicus*) as weed species

threatening *A. glareicola.* The Project has the potential, through a reduced flooding extent, to facilitate the spread and establishment of these species into *A. glareicola* habitat.
• **introduce disease that may cause the species to decline, or**
No diseases have been identified as a threat to *A. glareicola* in either the Approved Commonwealth Conservation Advice or the OEH threatened species profile.
• **interfere substantially with the recovery of the species.**
No National Recovery Plan has been developed for *A. glareicola* under the EPBC Act. The Approved Commonwealth Conservation Advice for *A. glareicola* (DoE 2013) provides the following conservation and management actions: 1. Manage threats to areas of vegetation (namely Castlereagh Woodland) that contain populations/occurrences/remnants of *A. glareicola*. 2. Ensure chemicals or other mechanisms used to eradicate weeds do not have a significant adverse impact on *A. glareicola*. 3. Investigate formal conservation arrangements such as the use of covenants, conservation agreements or inclusion in reserve tenure. 4. Develop and implement a management plan for the control of Weeping Lovegrass and Whisky Grass in areas with *A. glareicola*. 5. Develop and implement a suitable fire management strategy for *A. glareicola*. 6. Identify appropriate intensity and interval of fire to promote fruit production and seed set. 7. Provide maps of known occurrences to local and state Rural Fire Services and seek inclusion of mitigative measures in bush fire risk management plans, risk register and/or operation maps. 8. Raise awareness of *A. glareicola* within the local community. Enable Recovery of Additional Sites and/or Populations 9. Investigate options for linking, enhancing or establishing additional populations, both to increase the overall population size and to maximise genetic diversity of the species. 10. Implement appropriate national translocation protocols (Vallee *et al.* 2004) if establishing additional populations is considered necessary and feasible. 11. Maintain ex-situ populations reported to be in cultivation at Adelaide Botanic Gardens (South Australia), Mt Annan Botanic Gardens (NSW) and Australian National Botanic Gardens (ACT) (CHABG 1994). No Approved Threat Abatement Plans listed by the EPBC Act are relevant to *A. glareicola*.
Conclusion
The Project may impact *A. glareicola* habitat across the downstream study area. The habitat may be impacted through changes to hydrology and potentially changes to the fire regime. Both impacts have the potential to impact the breeding cycle of *A. glareicola*. Additionally, the Project may interfere with the recovery the species and spread invasive weeds into its habitat. The Project is unlikely however, to impact any previously recorded occurrences of the species. The Project has been assessed as likely having a significant impact on *A. glareicola*.

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Asterolasia elegans

Endangered under the EPBC Act

Asterolasia elegans is listed as endangered under both the BC Act and EPBC Act. *A. elegans* is a slender erect shrub 1-3 m high with densely rusty-red stellate-tomentose young branches (PlantNet 2019). The species is found mainly on mid- to lower slopes of rolling to very steep terrain on the Hawkesbury or Gymea erosional soil landscape associated with Hawkesbury sandstone geology (OEH 2017). Generally, *A. elegans* grows in wet sheltered sclerophyll forests from 2 to 40 metres above the creek line (Scott 1994). Specifically, the species has been found inhabiting Sydney coastal dry sclerophyll forests, Sydney hinterland dry sclerophyll forests, rainforests and wet sclerophyll forests (OEH 2017). The canopy at known sites supporting *A. elegans* is dominated by *Syncarpia glomulifera* subsp. *glomulifera, Angophora costata, Eucalyptus piperita, Allocasuarina torulosa* and *Ceratopetalum gummiferum* (OEH 2017). The vegetation communities and geology preferred by *A. elegans* occur simultaneously over a large area of northern Sydney however only a small area around Maroota would contain the landscape features and specific micro-climate preferred by *A. elegans* (OEH 2011). It is therefore assumed that *A. elegans* has a restricted distribution with less than 10 known locations in this area (Auld 2001).

A. elegans was assessed with a moderate likelihood of occurring in the upstream study area and a low likelihood of occurring in the downstream and construction study areas. The assessment of this species is therefore limited to the upstream study area.

With regard to the Project, targeted surveys for this species were not undertaken. Additionally, *A. elegans* was not incidentally encountered in the upstream study area during vegetation mapping associated with the Project. In the absence of targeted surveys, *A. elegans* has been assumed present in areas of presumed suitable habitat within the upstream study area. For this assessment, suitable habitat for *A. elegans* includes the PCTs that are associated with the species (as per the TBDC), BioNet Atlas Records and any other known vegetation types (as per scientific literature) that the species is associated with that has been mapped within the upstream study area.

Suitable habitat includes the following PCTs that have been mapped within the upstream study area:

- PCT1081: Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion (associated as per TBDC)
- PCT1284: Turpentine - Smooth-barked Apple moist shrubby forest of the lower Blue Mountains Sydney Basin Bioregion (associated as per TBDC).

This Assessment of Significance has been prepared in accordance with the *Matters of National Environmental Significance: Significant impact guidelines* (DoE 2013). According to these guidelines, the questions for an 'Endangered' species is related to a 'population of a species'. The guidelines define a 'population of a species' of an Endangered species as being '*an occurrence of the species in a particular area. Occurrences include but are not limited to:*

- *a geographically distinct regional population, or collection of local populations, or*
- *a population, or collection of local populations, that occurs within a particular bioregion.'*

In the absence of targeted surveys, suitable habitat within the upstream study area is assumed to support a 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 a population**
The Project may affect up to an estimated 21.94 hectares of suitable habitat within the upstream study area, presumed to support a population of *A. elegans.* Up to10.89 hectares may be impacted by a 1 in 100 chance in a year flood event (1% AEP) and 2.30 hectares by a 1 in 5 chance in a year flood event (20% AEP). Impact to this habitat has the potential to lead to a long-term decrease in the population of *A. elegans*.
• **reduce the area of occupancy of the species**
An estimated 21.94 hectares of habitat suitable for occupancy occurs with the upstream study area. 10.89 hectares may be impacted by a 1 in 100 chance in a year flood event (1% AEP) and 2.30 hectares by a 1 in 5 chance in a year flood event (20% AEP).

• **fragment an existing population into two or more populations**
It is not known whether there is a population of *A. elegans* within the study areas as targeted surveys were not undertaken. However, suitable habitat was identified within the upstream study area. The Project could potentially contribute to fragmentation of an existing population that is presumed to be present as the variable nature of impacts has potential to result in the complete loss of suitable habitat.
• **adversely affect habitat critical to the survival of a species**
The Minister maintains a 'Register of Critical Habitat' under the EPBC Act in which habitat is identified as being critical to the survival of a listed threatened species. To date, no critical habitat is listed for this species that occurs within or proximal to the upstream study area. However the National Recovery Plan for *A. elegans* (OEH 2011) identifies the habitat features and locations that would contain habitat that is critical to the survival of the species as required by the EPBC Act. Habitat critical to the survival of the species includes all habitat currently known to support *A. elegans* (OEH 2011). The preferred landscape features include the presence of Hawkesbury sandstone, including rocky outcrops and boulders and wet sheltered sclerophyll forests from 2 to 40 m above the creek line (Scott 1994). Such habitat occurs in the upstream study area and may be adversely affected by the Project.
• **disrupt the breeding cycle of a population**
The breeding system (including pollination mechanisms) of *A. elegans* is largely unknown (OEH 2011). However, generally the species produces flowers in spring, from August to October, and fruit in November (OEH 2011). The pollinators of other *Asterolasia* species are mostly beetles, flies and bees however the specific pollinators for *A. elegans* are unknown (OEH 2011; Armstrong 1979). *Asterolasia elegans* is an obligate seeder where mature plants are killed by fire and regeneration is reliant upon soil-stored seed (OEH 2011). Seed dispersal in *Asterolasia* species is initially by forcible ejection from the fruit (OEH 2011). Due to the presence of an ant-attracting food body within the seed, it is possible that secondary dispersal is by ants (that is, myrmecochory) (OEH 2011). *Asterolasia elegans* has both dormant and non-dormant seeds at the time of release, where non-dormant seeds undergo rapid decay while dormant seeds showed no evidence of decay over a two year period, implying the establishment of a relatively long-lived persistent soil seedbank for this species (OEH 2011; Auld 2001). It has been found that seed dormancy is broken by heat, smoke or disturbance (OEH 2011). With regard to the Project, it is considered likely that the main potential impact of a changed hydrological regime is considered to be damage the soil seedbank, either directly through increased flooding, or through secondary impacts such as erosion or weed invasion and spread. Given that the seed dormancy is broken by heat, smoke or disturbance, a changed fire regime is also likely to affect the life cycle for this species. A changed fire regime is likely to occur where a changed hydrological regime associated with the Project could subsequently cause a change in the existing floristic structure and composition of vegetation communities within the study area. A change in floristic structure and composition means that the fire dynamics (that is, duration, intensity and frequency) could therefore be affected. Any one of these impacts (or a combination) could potentially disrupt the breeding cycle of a population of *A. elegans.*
• **modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project may affect up to 21.94 hectares of suitable habitat within the upstream study area, presumed to support a population of *A. elegans.* The condition, quality and integrity of this habitat could potentially be modified or in the worst case, destroyed as a result of the Project. Potential impacts associated with the upstream study area include possible changes to hydrology where there may be an increase in extent, duration and frequency of temporary inundation upstream, long-term erosion and sedimentation and changes to vegetation structure, composition and condition. Through any one of these potential impacts (or a combination) the condition, quality and integrity of suitable habitat could potentially be adversely affected to a point which could lead to a decline in the species.

• **result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat**
Competition from weeds is considered a threat to *A. elegans* (OEH 2011). Where there are known to be populations of *A. elegans,* such as Laughtondale Gully Road in Marramarra National Park, weeds such as crofton weed (*Ageratina adenophora*) and *Sonchus oleraceus* are known to be a threat. Additionally, the known population of *A. elegans* that occurs on the Putty Road is near a sewage pond affected by sewage outflow. The increased nutrients that are being expelled from the outlet have been found as promoting the growth of weed species threatening *A. elegans* habitat (OEH 2011). Potential impacts associated with the Project such as changes to inundation regimes, erosion and sedimentation may also create an environment that is conducive to the establishment and spread of invasive weeds and therefore the Project could potentially result in invasive species that are harmful to habitat of *A. elegans.*
• **introduce disease that may cause the species to decline, or**
There is no published evidence regarding the susceptibility of *A. elegans* to *phytophthora cinnamomi* even though other species from the Rutaceae family are known to be susceptible (Auld 2001). It is not known whether *P. cinnamomi* occurs in the upstream study area but given that human activity is a vector for spread, is possible that the Project could cause the disease to be introduced into the study area. There is no published evidence on the susceptibility of *A. elegans* to other types of disease that is commonly observed on Australian flora. The Approved Threat Abatement Plan for *Phytophthora cinnamomi* (DoEE 2018) is relevant to *A. elegans*. The Project interferes with Objective 2: Reduce the spread and mitigate the impacts of Phytophthora to protect priority biodiversity assets and susceptible landscapes.
• **interfere with the recovery of the species.**
A National Recovery Plan for *A. elegans* was published in 2011 by the OEH. The overall objective of the recovery plan is 'to ensure the continued and long-term survival of *A. elegans* in the wild by promoting the in-situ conservation of the species across its natural range'. The plan consists of seven sub-objectives accompanied by specific recovery actions and performance criteria which contribute to meeting the overall objective (OEH 2011). The Project may interfere with the following two objectives: (i) Identify and minimise threats where the species occurs. (ii) Minimise the loss and fragmentation of A. elegans habitat using land use planning mechanisms and increase the species legislative protection. The Project could potentially interfere with the recovery of the species.
Conclusion
The Project is considered to have potential to affect suitable habitat for the species. As targeted surveys were not conducted it is assumed that a population of *A. elegans* occurs in areas of mapped suitable habitat within the upstream study area. The potential impacts associated with the Project could have an adverse effect on a population of *A. elegans* such that it may cause the species to decline. The Project has been assessed as likely to have a significant impact on *A. elegans*.

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Astrotricha crassifolia

Vulnerable under the EPBC Act

Astrotricha crassifolia (Thick-leaf Star-hair) is a suckering shrub that grows up to 2.5 metres in height. This species of *Astrotricha* produces branchlets with a deep, firm indumentum, which support stiff, broad linear leaves between 2 and 6 centimetres long. Leaves have a blunt tip and revolute margins giving them a convex appearance. The adaxial surface of leaves are glabrous whereas the abaxial surface is covered in brown hairs. *Astrotricha crassifolia* produces small white or cream flowers with mauve anthers and 5 petals. Flowers are grouped on sparse inflorescences up to 10 centimetres long (OEH 2019; PlantNET 2019).

Astrotricha crassifolia is endemic to the Sydney Basin Bioregion. Its distribution is comprised of two metapopulations; one just north of Sydney in Brisbane Water National Park, and the second to the south of Sydney occurring on parts of the Woronora Plateau and through Royal National Park (Benson and McDougall 1993). There is also a record from near Glen Davis, in the Lithgow LGA.

The habitat of *A. crassifolia* includes dry sclerophyll forest, woodland and heath. *Astrotricha crassifolia* has been recorded growing along sandstone ridgetops, associated with the occurrence of *Hakea* spp., *Banksia* spp. and *Xylomelum pyriforme*. Within its sandstone ridgetop habitat, *A. crassifolia* grows in areas of partial shade in a number of small and isolated patches (Benson and McDougall 1993; Warman and Beckers 2011).

According to OEH's BioNet system, *A. crassifolia* is associated with the following PCTs mapped in the downstream study area:

- PCT 1181 (HN586): Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney Basin Bioregion
- PCT 1183 (HN857): Smooth-barked Apple – Sydney Peppermint – Turpentine heathy open forest on plateaux areas of the Sydney Basin Bioregion
- PCT 1292 (HN607): Water Gum – Coachwood riparian scrub along sandstone streams Sydney Basin Bioregion
- PCT 1327 (HN612): Yellow Bloodwood – Ironbark shrubby woodland of the dry hinterland of the Central Coast Sydney Basin Bioregion
- PCT 1328 (HN613): Yellow Bloodwood – Narrow-leaved Apple heathy woodland on hinterland plateaux of the Central Coast Sydney basin Bioregion.

A. crassifolia was assessed as not having a moderate or higher likelihood of occurring in the upstream and construction study areas.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal.*
- *populations that are necessary for maintaining genetic diversity.*
- *populations that are near the limit of the species range.*

Targeted surveys for *A. crassifolia* were not undertaken in the downstream study area and the species was not incidentally encountered during vegetation mapping associated with the Project. In the absence of targeted surveys, *A. crassifolia* has been assumed present in areas of presumed suitable habitat – the previously listed PCTs. Using the precautionary principle, the population(s) residing within this habitat have been assessed as an important population(s) as they are key source populations for breeding and dispersal, are necessary for maintaining genetic diversity, and are near the limit of the species range.

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**
As *Astrotricha crassifolia* has not been surveyed for, areas of habitat have been used as a substitute for the species occurrence and population size. The Project may impact up to about 142 hectares of *A. crassifolia* habitat and could potentially lead to a long-term decrease in the size of the important population of *A. crassifolia*.
• **reduce the area of occupancy of an important population**
The Project may directly impact the area of occupancy for the important population by up to about 142 hectares between the existing and proposed downstream 10% AEP flood extents.
• **fragment an existing important population into two or more populations**
With the exception of that occurring in the Blue Mountains and Wollemi National Parks, much of the *A. crassifolia* habitat considered in this assessment currently occurs in a fragmented condition. The habitat in the downstream study area could potentially become further fragmented by a modified flooding regime (hydrology) and the erosion caused by the discharge of the FMZ. Indirect impacts caused by the Project such as modification of the fire regime(s) and the facilitation of weed and exotic species could potentially contribute to habitat fragmentation.
• **adversely affect habitat critical to the survival of a species**
According to the *Matters of National Environmental Significance Significant impact guidelines* 1.1 (DoE 2013) habitat critical to the survival of a species refers to areas that are necessary for: • activities such as foraging, breeding, roosting, or dispersal • 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 • the reintroduction of populations or recovery of the species or ecological community. The *A. crassifolia* habitat in the downstream study area has been assessed as critical habitat because it is important for dispersal, the long-term maintenance of the species, for maintaining genetic diversity, and for the potential reintroduction/recovery of the species. The Project could potentially adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive species, erosion and deposition, and modifying the fire regime.
• **disrupt the breeding cycle of an important population**
A. crassifolia has a rhizomatous root system allowing it to sucker and reproduce asexually. It can re-sprout from this suckering root system (and from basal stems) after fire or mechanical damage such as slashing. Insects have been observed visiting flowers however a detailed understanding of pollination is still to be obtained. Although *A. crassifolia* produces fruit, there is no evidence that it contains viable seed. Warman and Beckers (2011) add that the reproductive capacity of *A. crassifolia* may be influenced by the density of the surrounding vegetation and the availability of light. As there is no evidence/research about the effects of flooding and inundation on this species, it has been been assumed that the Project has potential to impact the breeding cycle of *A. crassifolia* in the downstream study area
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project may impact up to about 142 hectares of habitat within the downstream study area.

• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
The Approved Conservation Advice, SPRAT profile and OEH species profile all list invasive grasses as a threat to *A. crassifolia* (DEWHA 2008; DoEE 2019; OEH 2019). The Project is likely to facilitate the spread and establishment of weed and exotic grasses downstream of Warragamba Dam within *A. crassifolia* habitat.
• **introduce disease that may cause the species to decline, or**
No diseases have been identified as a threat to *Astrotricha crassifolia*.
• **interfere substantially with the recovery of the species.**
No recovery plan has been developed for *Astrotricha crassifolia* under the EPBC Act. A recovery plan has however been developed for *A. crassifolia* under OEH's Saving Our Species program (NSW government). Within the Saving Our Species program, *A. crassifolia* has been assigned as a site-managed species. The following two priority management sites have been listed for *A. crassifolia*: • Brisbane Waters National Park in Central Coast LGA • Woronora in Wollongong LGA. The Project is unlikely to impact any of listed priority management sites. The Project therefore is unlikely to substantially interfere with the recovery of the *A. crassifolia*.
Conclusion
The Project may impact up to about 142 hectares of *A. crassifolia* habitat and could potentially disrupt the breeding cycle of *A. crassifolia* within this habitat. The Project could also potentially increase the fragmentation of *A. crassifolia* habitat in the downstream study area and promote the spread and establishment of invasive grasses. These impacts could potentially cause a decline of important population of *A. crassifolia*. The Project has therefore been assessed as having a potentially significant impact.

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Baloskion longipes (Dense Cord-rush)

Vulnerable under the EPBC Act

Baloskion longipes is a dioecious, rush-like perennial herb. It has a tufted habit, arising from shortly creeping rhizomes. *Baloskion longipes* produces erect culms that can get up to 1.5 metres tall and 2.5 millimetres in diameter. The sheaths produced by *B. longipes* are closely appressed with an acute apex and are between 20 to 30 millimetres long. Flowers arise from a loose raceme or narrow panicle that can get to 25 centimetres long (OEH 2019; PlantNET 2019).

Baloskion longipes is endemic to NSW where it has been recorded in the Blue Mountains and Kanangra-Boyd NPs west of Sydney, at Hanging Rock Swamp nine kilometres west of Bundanoon, in Morton NP west of Nowra, along the Braidwood-Nelligen Road, and the Clyde Mountain area south of Braidwood (DoEE 2019). No quantitative data has been collected on the size of the populations within this distribution, however all have been recorded as 'small' (OEH 2019).

The habitat of *B. longipes* includes seasonally inundated peat, sandy wetland swamps (Meney and Pate 1999) or depressions in sandy alluvium (Harden 1993). The OEH threatened species profile adds that *B. longipes* habitat also includes *swails within tall forest, and in Black Gum Woodland* (OEH 2019). According to OEH's BioNet system, *B. longipes* is associated with the following PCT mapped in the upstream study area:

- PCT 1105 (HN574): River Oak open forest of major streams, Sydney Basin Bioregion and South East Corner Bioregion.

B. longipes is not associated with any PCTs mapped in the downstream or construction study areas.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal.*
- *populations that are necessary for maintaining genetic diversity.*
- *populations that are near the limit of the species range.*

Targeted surveys for *B. longipes* were not undertaken in the upstream study area. Additionally, *B. longipes* was not incidentally encountered during vegetation mapping associated with the Project. In the absence of targeted surveys, *B. longipes* has been assumed present in areas of presumed suitable habitat – PCT 1105. Using the precautionary principle, the population(s) residing within this habitat have been assessed as an important population(s) as they are key source populations for breeding and dispersal and are necessary for maintaining genetic diversity.

This species is included in Gallagher *et al.* (2020) and considered likely to occur in the upstream study area. Based on the FESM mapping, approximately 54% of the study area's habitat was burnt in the 2019-2020 bushfires. Within the 20% AEP flood extent 19.78 hectares of the total 45.65 hectares of habitat has been mapped as burnt, within the 1% AEP flod extent, 39.98 hectares of the total 77.34 hectares of habitat has been mapped as burnt, and within the upstream study area, 77.8 hectares of the total 145.28 hectares of habitat has been mapped as burnt.

The species is sensitive to fire, and while the species may be able to re-shoot after appropriate fire (Meney and Pate 1991), (DEWHA 2008) adds there is a need to identify the 'intensity and interval of fire to promote seed germination'; precautionarily the scale and intensity of the 2019-2020 fires have been assessed as potentially outside preferable the matrix of a suitable scale and intensity. Those criteria identified by Gallagher *et al.* (2020) that particularly relate to this species and the environmental impacts associated with the Project, particularly in relation to post-fire disturbance and cumulative impacts, include:

A. Interactive effects of fire and drought

B. Short fire intervals (impacts of high fire frequency)

C. Post-fire herbivore impacts

E. High fire severity

F. Weed invasion

H. Fire sensitivity

I. Post-fire erosion

J. Cumulative exposure to high risks

K. Other plausible threats or expert-driven nominations (in this case the combined impacts from project-associated inundation on the above 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 an important population of a species**
As *B. longipes* was not surveyed, areas of habitat have been used as a surrogate for the species occurrence and population size. Within the upstream study area, 145.27 hectares of habitat has been mapped. Of this 145.27 hectares, 45.53 hectares may be impacted by a 1 in 5 chance in a year flood event (20% AEP) and 77.14 hectares by a 1 in 100 chance in a year flood event (1% AEP). Impacts associated with all three events (the study area representing the PMF) would lead to long-term decreases in the size of the important population.
• **reduce the area of occupancy of an important population**
Within the upstream study area, 145.27 hectares of habitat has been mapped; 45.53 hectares may be impacted by a 1 in 5 chance in a year flood event (20% AEP) and 77.14 hectares by a 1 in 100 chance in a year flood event (1% AEP). All flood events would reduce the area of occupancy of this species.
• **fragment an existing important population into two or more populations**
The Project may lead to the clearing of native vegetation, erosion and sedimentation, weed invasion and encroachment, and edge effects which could potentially contribute to fragmenting the occurrence of PCT 1105 within the upstream study area. Potential impacts within the upstream study area may fragment the population of *B. longipes*.
• **adversely affect habitat critical to the survival of a species**
According to the *Matters of National Environmental Significance Significant impact guidelines* 1.1 (DoE 2013) habitat critical to the survival of a species refers to areas that are necessary for: • activities such as foraging, breeding, roosting, or dispersal • 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 • the reintroduction of populations or recovery of the species or ecological community. The *B. longipes* habitat in the Project study area has been assessed as critical habitat because it is important for dispersal, the long-term maintenance of the species, for maintaining genetic diversity, and for the potential reintroduction/recovery of the species. The Project could potentially adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive species, erosion and deposition, modifying hydrology and modifying the fire regime.
• **disrupt the breeding cycle of an important population**
The reproductive ecology and breeding cycle of *B. longipes* is poorly understood. This species produces new shoots from rhizomes, and according to Meney and Pate (1991), can re-sprout after fire. The Approved Conservation Advice for *B. longipes* (DEWHA 2008) adds there is a need to identify the '*intensity and interval of fire to promote seed germination*'. A change to the fire regime therefore has the potential to disrupt the breeding cycle of *B. longipes,* specifically recruitment of new individuals into a population from seed and asexual reproduction. The Approved Conservation Advice for *B. longipes* identifies modifications to hydrology as a threat to its habitat. It states that fluctuations in hydrology may result in '*changes to the water table levels, increased run-off, sedimentation and pollution*'. As *B. longipes* habitat has evolved to match its current environmental conditions, any deviations from these conditions may have a detrimental impact. The Project could potentially alter the

hydrological environment within the upstream study area. Potential changes to hydrology caused by the Project therefore have the potential to disrupt the lifecyle of *B. longipes*.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project may potentially impact up to 145.27 hectares of *B. longipes* habitat within the upstream study area, 77.14 hectares within the 1% AEP and 45.53 hectares within the 20% AEP. Habitat may be destroyed and/or impacted through the clearing of native vegetation, the loss of flora and fauna habitat and a reduction in the extent of ecological communities. Habitat may be indirectly impacted (modified, reduced in quality etc.) through fragmentation, alteration to soil conditions, edge effects, weed invasion and incursion, through the spread of disease and pathogens, erosion and sedimentation, and thorough changes to the fire regime.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
No species of invasive flora are identified as a threat to *Baloskion longipes* in the Approved Commonwealth Conservation Advice, in the SPRAT profile or in OEH's threatened species profile (DEWHA 2008; DoEE 2019; OEH 2019). The Approved Commonwealth Conservation Advice does however state that sites (supporting the species) must be managed to '*prevent introduction of invasive weeds, which could become a threat to B. longipes*'. For this assessment invasive weeds have been identified as a general threat to *B. longipes*. The Project has the potential to facilitate the spread and establishment of invasive flora species in the habitat of *B. longipes*. Feral pigs are listed as a threat to *B. longipes* in the species Approved Commonwealth Conservation Advice, SPRAT profile and OEH threatened species profile (DEWHA 2008; DoEE 2019; OEH 2019). Feral pigs are a threat as they directly damage habitat when they are rooting for food (OEH 2019). However, feral pigs are already common throughout the upstream study area. There is an Approved Threat Abatement Plan for feral pigs (DoEE 2017) listed under the EPBC Act. It is unclear if the Project may further facilitate their spread and establishment in *B. longipes* habitat and therefore interfere with the Threat Abatement Plan for feral pigs.
• **introduce disease that may cause the species to decline, or**
No diseases have been identified as a threat to *B. longipes*.
• **interfere substantially with the recovery of the species.**
No National Recovery Plan has been developed for *B. longipes* under the EPBC Act. A recovery plan has however been developed for *B. longipes* under OEH's Saving Our Species program (NSW government). Within the Saving Our Species program, *B. longipes* has been assigned as a site-managed species. The following five priority management sites have been listed for *B. longipes*: • Kanangra-Boyd National Park in the Oberon LGA • Mount Werong in Oberon, in the Upper Lachlan Shire LGA • Hanging Rock in the Wingecarribee LGA • Clyde Mountain in the Eurobodalla and Queanbeyan-Palerang Regional LGAs • Ballalaba in the Queanbeyan-Palerang Regional LGA. The Project is unlikely to impact any of the five listed priority management sites. The Project therefore is unlikely to substantially interfere with the recovery of the *B. longipes*.
Conclusion
The Project may impact up to 145.27 hectares of *B. longipes* habitat in the upstream study area. This habitat may become fragmented, potentially isolating occurrences of the species from one another. The Project could potentially impact the breeding cycle of *B. longipes* by modifying the fire regime and modifying the hydrological environment. The threat of invasive flora species may also be exacerbated by the Project. These potential impacts could cause a decline of important population of *B. longipes*. The Project has been assessed as likely to have a significant impact on *Baloskion longipes.*

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Bossiaea oligosperma (Few-seeded Bossiaea)

Vulnerable under the EPBC Act

Bossiaea oligosperma (Few-seeded Bossiaea) is listed as vulnerable under the EPBC Act. *Bossiaea oligosperma* is an upright shrub to 2 metres with small almost circular green leaves to 5mm long. The pea flowers are 11mm long with a red keel and bright yellow wings and some red marking, during late winter and spring. Fruit is an elliptical pod up to 17mm long (PlantNet 2019; Bionet 2018).

This species is known to occur in two disjunct areas, on stony slopes or sandstone ridges in Yerranderie area of the Wollondilly, Allum and Tonalli River catchments in the lower Blue Mountains, as well as, the Windellama area, where it is locally abundant in low woodland on loamy soil (OEH 2018; DOE 2008). The distribution overlaps with two EPBC listed threatened ecological communities; White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland; and Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory (DoE 2008; BioNet 2018). There is little known about the ecology of *Bossiaea oligosperma* although it probably has hard-coated seeds that respond well to fire and soil disturbance (OEH 2018; DoE 2008).

Targeted surveys for *Bossiaea oligosperma* were not undertaken in the downstream, upstream or construction study areas for the Project. *Bossiaea oligosperma* was incidentally encountered in the survey area during the upstream vegetation mapping associated with the Project.

In the absence of targeted surveys, *Bossiaea oligosperma* has been assumed present in areas of presumed suitable habitat. For this assessment, suitable habitat for *Bossiaea oligosperma* includes the PCTs that are associated with the species (as per the TBDC), BioNet Atlas Records and any other known vegetation types (as per scientific literature) that the species is associated with that has been mapped within the study area.

Suitable habitat includes the following PCTs, according to OEH's BioNet, that have been mapped within the upstream study area (about 1,634.08 hectares):

- PCT1105 (HN574): River Oak open forest of major streams Sydney Basin Bioregion and South East Corner Bioregion
- PCT860 (HN532): Grey Gum - Broad-leaved Ironbark dry open forest on gorge slopes on the Blue Mountains Sydney Basin Bioregion
- PCT832 (HN525): Forest Red Gum - Narrow-leaved Ironbark open forest of the southern Blue Mountains gorges Sydney Basin Bioregion.

Bossiaea oligosperma was not assessed to have a moderate or higher likelihood of occurring in the downstream study area nor was any habitat assessed as occurring in the construction study area. As such, the potential for this species to be impacted by the Project in the downstream and construction study areas is not subject to this assessment.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal*
- *populations that are necessary for maintaining genetic diversity, and/or*
- *populations that are near the limit of the species range.*

The *B. oligosperma* recorded in the upstream study area have been assessed as key for breeding and dispersal, important for maintaining the genetic diversity of the species and occur at the northern limit of the species distribution. As such, the *B. oligosperma* occurring in the upstream study area have been assessed as 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**
As targeted surveys for *Bossiaea oligosperma* were not conducted, areas of habitat have been used as a surrogate for the species occurrence and population size. Within the upstream study area 1,634.08 hectares of habitat has been mapped. Of this area, 236.21 hectares may be impacted by a 1 in 5 chance in a chance in a year flood event (20% AEP) and 977.37 hectares by a 1 in 100 chance in a year flood event (1% AEP). Impacts associated with all

three events (the study area representing the PMF) could lead to long-term decreases in the size of the important population.

The northern limit of this species distribution is around the Nattai area. The Nattai occurrence is geographically isolated from the southern extent of the distribution that occurs around the Windellama area. Impacts to the Nattai population – the local population - would potentially impact plants supporting alleles not present in the southern part of the distribution. BioNet (2019) refers specifically to the Nattai population to be at risk from weeds, altered hydrology and potential increase in dam wall height at Warragamba. Impacts associated with the three described inundation scenarios would lead to a reduced size of an important population.

- **reduce the area of occupancy of an important population**

The area of occupancy within the upstream study area is 1,634.08 hectares of which 977.37 hectares occurs within the 1% AEP flood extent and 236.21 hectares within the 20% AEP. The Project may reduce these areas of occupancy according to the relevant inundation scenario.

- **fragment an existing important population into two or more populations**

The potential loss of habitat could further fragment the northern half of the *Bossiaea oligosperma* distribution from the southern half. The loss of genetic connectivity has the potential to cause inbreeding, genetic bottle-necks and a loss of genetic diversity in both the north and south of the distribution. Loss of genetic diversity increases the species susceptibility to environmental changes.

The loss of habitat has the potential to fragment occurrences of *B. oligosperma* within the Warragamba Special Area. Inter-population fragmentation may have similar adverse effects as distributional fragmentation only that these effects often occur sooner and are less likely to be survived.

- **adversely affect habitat critical to the survival of a species**

The Minister maintains a 'Register of Critical Habitat' under the EPBC Act in which habitat as identified as being critical to the survival of a listed threatened species is provided. To date, no critical habitat is listed for this species that occurs within or proximal to the construction, upstream or downstream study areas.

Suitable habitat presumed to support an important population of *B. oligosperma* has been assessed as habitat critical to the survival of the species. This habitat is important for dispersal, the long-term maintenance of the species and for maintaining genetic diversity. It is also important for maintaining ecological processes essential to the survival for the species. The Project may adversely affect this habitat through the removal of vegetation, increasing the presence of invasive species, erosion and deposition, and modifying hydrology and the fire regime. Accordingly, the Project could potentially adversely affect habitat critical to the survival of *B. oligosperma.*

- **disrupt the breeding cycle of an important population**

There is a lack of information and scientific literature about the breeding cycle of this species. The seeds have a hard coating requiring fire to germinate. If fire becomes less frequent, recruitment of new individuals into a population becomes less likely and less frequent. Modification of the fire regime within *Bossiaea oligosperma* habitat therefore has the potential to disrupt its breeding cycle.

- **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**

The Project may potentially impact up to 1,634.08 hectares of *Bossiaea oligosperma* habitat within the upstream study area, 977.37 hectares within the 1% AEP and 236.21 hectares within the 20% AEP. Habitat may be destroyed and/or impacted through the clearing of native vegetation, the loss of flora and fauna habitat and a reduction in the extent of ecological communities. Habitat may be indirectly impacted (modified, reduced in quality etc.) through fragmentation, alteration to soil conditions, edge effects, weed invasion and incursion, through the spread of disease and pathogens, erosion and sedimentation, and thorough changes to the fire regime.

• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
The conservation advice does not list any invasive species or weeds that are harmful to this species. BioNet lists weeds as a threat to the norther population of *B. oligosperma* mentioning the Nattai population as a result of this Project.
• **introduce disease that may cause the species to decline, or**
There are no diseases identified specifically which may affect *B. oligosperma* within the conservation advice or SPRAT database (DOEE 2008)
• **interfere substantially with the recovery of the species.**
There is currently no National Recovery Plan for *B. oligosperma*. However, the Approved Commonwealth Conservation Advice and SPRAT database has identified too frequent fires as a threat to this species. The Project has the potential to modify the fire regime within the Upstream Study Area and subsequently increase the frequency and intensity of fires. No Approved Threat Abatement Plans listed under the EPBC Act are relevant to *B. oligosperma*.
Conclusion
The *B. oligosperma* population within the study area including the Nattai is an important population as it is the northern extent of its known range, it is likely to contain genetic diversity form the southern population near to Windellama. BioNet specifically refers to this Project as increasing the threat of weeds and hydrological changes with the potential raising of the dam wall. The Project has been assessed as likely to have a significant impact on *Bossiaea oligosperma.*

References

Department of the Environment (DoE) (2013) Matters of National Environmental Significance: Significant impact guidelines 1.1 *Environment Protection and Biodiversity Conservation Act 1999,* Commonwealth of Australia.

Callistemon megalongensis (Megalong Valley Bottlebrush)

Critically endangered under the EPBC Act

Callistemon megalongensis is a large shrub, growing up to 2.5 metres tall. It has sub-papery bark and glabrescent leaves. The leaves are narrow – elliptical with an acute apex, ranging from 35 to 55 millimetres long and 3.5 to 5 millimetres wide. Spike-like inflorescences are produced supporting between 40 and 50 single flowers. Each flower has numerous stamens with pink - dark red filaments and anthers (PlantNET 2012). This species is difficult to distinguish when not in flower from the morphologically similar *Callistemon citrinus* (OEH 2019).

Callistemon megalongensis only occurs in a small area in the eastern section of the Megalong Valley, NSW. Within this restricted distribution, *C. megalongensis* has been recorded on both private and Crown land (Blue Mountains National Park. This species is known only from 8 sites which are considered a single population (DoE 2015).

Callistemon megalongensis occurs in swampy habitat, primarily in the swampy shrublands and/or swampy woodlands beneath the sandstone plateau of the Blue Mountains (DoE 2015). Individuals have been recorded on rare occasions below this habitat, where they have been restricted to drainage line habitat. The swampy habitat varies in structure, with the western most swamp habitat being more open compared to the swampy woodlands to the east (Douglas 2013).

According to OEH's BioNet system, *C. megalongensis* is associated with the following PCT mapped in the upstream study area:

- PCT 862 (HN533): Grey Gum - Hard Leaved Scribbly Gum woodland of the Cox River Valley.

Callistemon megalongensis has been assessed with a low likelihood of occurrence in the downstream and construction study areas.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines a 'population of a species' as an occurrence of the species in a particular area. In relation to critically endangered, endangered or vulnerable threatened species occurrences include but are not limited to:

- a geographically distinct regional population, or collection of local populations
- a population, or collection of local populations that occur within a particular bioregion.

Targeted surveys for *C. megalongensis* were not undertaken in the upstream study area. In the absence of targeted surveys in the upstream study area, a population of *C. megalongensis* has been assumed present in the areas of suitable habitat – the previously listed PCT.

This species is included in Gallagher *et al.* (2020) and considered likely to occur in the upstream study area. Based on the FESM mapping, approximately 93% of the study area's habitat was burnt in the 2019-2020 bushfires. Within the 20% AEP 19.78 hectares of the total 45.65 hectares of habitat has been mapped as burnt, within the 1% AEP, 39.98 hectares of the total 77.34 hectares of habitat has been mapped as burnt, and within the PMF, 77.8 hectares of the total 145.28 hectares of habitat has been mapped as burnt.

The species is thought to reshoot from suitable fire regimes, the fire regime is important to the breeding cycle of *C. megalongensis*, with low to moderate intensity fires every 10 to 20 years thought to be important (Douglas 2013 Precautionarily the scale and intensity of the 2019-2020 fires have been assessed as potentially outside preferable the matrix of a suitable scale and intensity.

Those criteria identified by Gallagher *et al.* (2020) that particularly relate to this species and the environmental impacts associated with the Project, particularly in relation to post-fire disturbance and cumulative impacts, include:

A. Interactive effects of fire and drought

B. Short fire intervals (impacts of high fire frequency)

C. Post-fire herbivore impacts

E. High fire severity

F. Weed invasion

H. Fire sensitivity

I. Post-fire erosion

J. Cumulative exposure to high risks

K. Other plausible threats or expert-driven nominations (in this case the combined impacts from project-associated inundation on the above 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**
As *Callistemon megalongensis* was not surveyed, areas of habitat have been used as a surrogate for the species occurrence. Within the upstream study area 57.04 hectares of habitat has been mapped. Of this 57.04 hectares 1.77 hectares may be impacted by a 1 in 5 chance in a year flood event (20% AEP) and 14.13 hectares by a 1 in 100 chance in a year flood event (1% AEP). Impacts associated with all three events (the study area representing the PMF) would lead to long-term decreases in the size of the population.
• **reduce the area of occupancy of the species**
The area of occupancy within the upstream study area is 57.04 hectares of which 14.13 hectares occurs within the 1% AEP flood extent and 1.77 hectares within the 20% AEP flood extent. The Project may reduce these areas of occupancy according to the relevant inundation scenario.
• **fragment an existing population into two or more populations**
The *C. megalongensis* habitat in the upstream study area is not in a fragmented condition, being contiguous with the native vegetation of the Blue Mountains National Park. The Project could potentially impact this habitat, however its connectivity to larger extents of native vegetation may reduce the number of new edges and 'fragments' created. The Project is therefore unlikely to fragment the existing population into two or more smaller populations.
• **adversely affect habitat critical to the survival of a species**
No critical habitat has been listed for *Callistemon megalongensis* under the EPBC Act.
• **disrupt the breeding cycle of a population**
Callistemon megalongensis is thought to reach reproductive maturity at approximately seven years with individuals thought to live for several decades (DoE 2015). Adult plants flower from November to December with pollination most likely being facilitated by insects, birds and possibly small mammals. Resprouting can occur after fire or after mechanical damage. The fire regime is important to the breeding cycle of *C. megalongensis*, with low to moderate intensity fires every 10 to 20 years thought to be important (Douglas 2013). The Project could potentially disrupt the breeding cycle of the population in the upstream study area. The fire regime – important to the species – may be impacted, through inundation-induced changes to the supporting vegetation community(s). Changes to the vegetation community supporting the *C. megalongensis* population may modify the fire regime therefore impacting the populations breeding cycle.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project could potentially impact up to 57.04 hectares of *C. megalongensis* habitat within the upstream study area 14.13 hectares within the 1% AEP and 1.77 hectares within the 20% AEP. Habitat may be destroyed and/or directly impacted through the clearing of native vegetation, the loss of flora and fauna habitat, and a reduction in the extent of ecological communities. Habitat may be indirectly impacted (modified, reduced in quality etc.) through alteration to soil conditions, edge effects, weed invasion and incursion, through the spread of disease and pathogens, erosion and sedimentation, and thorough changes to the fire regime.

• **result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat**
The OEH threatened species profile for *Callistemon megalongensis* states that '*weed invasion, particularly Japanese honeysuckle and blackberry*' is a threat. The Project could potentially contribute to the spread and establishment of invasive flora species – such as Japanese honeysuckle and Blackberry - into the habitat of *C. megalongensis* (OEH 2017).
• **introduce disease that may cause the species to decline, or**
No diseases have been identified as a threat to *Callistemon megalongensis* in either the Approved Commonwealth Conservation Advice or the OEH threatened species profile.
• **interfere substantially with the recovery of the species.**
No National Recovery Plan has been developed for *Callistemon megalongensis* under the EPBC Act. The following reason is provided: *Recovery Plan not required, the approved conservation advice for the species provides sufficient direction to implement priority actions and mitigate against key threats.* The Approved Commonwealth Conservation Advice for *C. megalongensis* (DoE 2015) provides the following conservation and management actions: 1. Protect individuals and habitat from damage caused by the maintenance of infrastructure. 2. Install signs and provide advice to developers, consultants and approval authorities about the existence of the species and its significance and the need to protect from damage 3. Investigate options for linking, enhancing or establishing additional populations. In particular, investigate the possibility of establishing a revegetated corridor to reconnect the somewhat isolated western area of habitat. Where possible, implement these links. 4. Maintain swamp hydrology and water quality within the species' habitat. In particular, manage sediment and stormwater movement to protect habitat and reduce weed facilitation. 5. Implement an appropriate fire management regime for the species' key habitat. Where appropriate, provide maps of known occurrences to local and state Rural Fire Services and seek inclusion of mitigating measures in bush fire risk management plan/s, risk register and/or operation maps. 6. Control and reduce the spread of invasive species occurring within the species' habitat, such as Japanese honeysuckle and blackberry. Identify and remove new weeds in the local area that could become a threat to the species using appropriate methods. 7. Manage sites to monitor and identify, control and reduce the spread of feral animal species. 8. Ensure land owners/managers use an appropriate livestock grazing management regime in the area to ensure livestock grazing does not detrimentally affect this species. Use exclusion fencing or other barriers to manage total grazing pressure at important sites. 9. Engage with private landholders and land managers responsible for the land on which the species occurs and encourage these key stakeholders to contribute to the implementation of conservation management actions. 10. Investigate formal conservation arrangements, management agreements and covenants on private land with known occurrence. 11. Raise awareness among the local community and planning authorities about the risk of genetic contamination with more common varieties of callistemon (for example, with varieties planted in nearby gardens). 12. Where necessary and appropriate, suitably constrain public access to important sites by installing gates, fencing and signs. In particular, prevent access by horse riders, recreational 4WD vehicles and trail bikes to informal tracks intersecting the species' habitat. The Project may interfere with conservation and management actions 1, 4, 5, and 6.

The following Approved Threat Abatement Plans are relevant to *C. megalongensis*: • - Threat abatement plan for competition and land degradation by unmanaged goats (DEWHA 2008). • - Threat abatement plan for predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*) (DoEE 2017).
Conclusion
The Project could potentially impact *Callistemon megalongensis* habitat in the upstream study area. The species swamp habitat could potentially be impacted through changes to hydrology and to the fire regime. Both impacts have the potential to adversely affect the breeding cycle of *C. megalongensis*. Additionally, the Project could potentially interfere with the recovery the species. The Project has been assessed as likely to have a significant impact on *C. megalongensis*.

References

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Cryptostylis hunteriana (Leafless Tongue Orchid)

Vulnerable under the EPBC Act

Cryptostylis hunteriana is an upright perennial herb that can grow up to 75 centimetres tall. As the common name implies, *C. hunteriana* does not produce leaves. This orchid species does produce upright stems that support between five and 10 flowers. Flowers are comprised of small narrow green sepals and petals that get to 22 millimetres long. The visual appeal of this orchid is given by a hairy labellum, which is around 33 millimetres long, maroon at the margins and black through the centre (DEWHA 2008; OEH 2018).

Cryptostylis hunteriana has a large yet scattered distribution from south-east Queensland, down through eastern NSW, all the way to east Gippsland in Victoria. In NSW *C. hunteriana* is known from 39 sites. The most populated site is at Bulahdelah, comprising of two sub-populations of 359 and 104 plants respectively (DEWHA 2008; DoEE 2019). Aside from the population at Bulahdelah, *C. hunteriana* most commonly occurs in the Shoalhaven region south of Sydney. There are 25 populations recorded in the Shoalhaven region most of which comprising of 30 individuals or fewer. Further south of the Shoalhaven region, *C. hunteriana* has only been recorded at Ben Boyd National Park. North of Sydney, *C. hunteriana* has been recorded near Nowendoc State Forest, in Gibraltar Range National Park, at Washpool National Park, at Munmorah State Conservation Area, and near Nelson Bay. Within Sydney, this species of orchid has primarily been recorded to the north, at Ku-Ring-Gai Chase National Park.

The habitat of *C. hunteriana* is variable. This orchid has been recorded in habitat types such as coastal heaths, wet heaths, Spotted Gum forests, Stringybark forests, Paperbark forests, Banksia scrubs, and even rainforests. OEH states that larger populations typically occur in forests dominated by Scribbly Gums (*Eucalyptus sclerophylla*), Silvertop Ash (*E. sieberi*), Red Bloodwood (*Corymbia gummifera*) and Black Sheoak (*Allocasuarina littoralis*) (OEH 2018). For a species that extends from southeast Queensland through to east Gippsland, and from the Great Dividing Range down to coastal area, the OEH habitat description would seem somewhat limited.

According to OEH's BioNet system, *C. hunteriana* is associated with the following PCT mapped in the upstream study area:

- PCT 1083 (HN566): Red Bloodwood – Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion.

C. hunteriana is associated with the following PCT mapped in the construction study area:

- PCT 1083 (HN566): Red Bloodwood – Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion.

Cryptostylis hunteriana has been assessed with a low likelihood of occurrence in the downstream study area. As such, potential impacts to *C. hunteriana* in the downstream study area are not subject to this assessment.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal.*
- *populations that are necessary for maintaining genetic diversity.*
- *populations that are near the limit of the species range.*

Targeted surveys for *C. hunteriana* were not undertaken in the upstream, downstream or construction study areas. Additionally, *C. hunteriana* was not incidentally encountered during the vegetation mapping associated with the Project. In the absence of targeted surveys, *C. hunteriana* has been assumed present in areas of presumed suitable habitat – the previously listed PCTs. Using the precautionary principle, the population(s) residing within this habitat have been assessed as an important population(s) as they are key source populations for breeding and dispersal, are necessary for maintaining genetic diversity, and occur near the limit of the species range.

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**

As *C. hunteriana* was not surveyed, areas of habitat have been used as a surrogate for the species occurrence and population size. Within the Upstream Study Area 22.24 hectares of habitat has been mapped. Of this 2.60 hectares may be impacted by a 1 in 5 chance in a year flood event (20% AEP) and 12.39 hectares by a 1 in 100 chance in a year flood event (1% AEP). 12.25 hectares of habitat occurs within the Development Footprint associated with construction activities. Impacts associated with the upstream flooding events could lead to long-term decreases in the important population.

- **reduce the area of occupancy of an important population**

The Project may reduce the potential area of occupancy for *C. hunteriana* across the upstream and construction study areas. These reductions can be summarised according to the following impact scenarios:

Upstream Study Area

- 1% AEP (1 in 100 chance in a year flood): 12.39 hectares
- 20% AEP (1 in 5 chance in a year flood): 2.60 hectares

Construction Study Area

- Development footprint: 12.25 hectares

- **fragment an existing important population into two or more populations**

The *C. hunteriana* habitat within the three study areas is in a partially fragmented condition. In the downstream study area, *C. hunteriana* habitat occurs along waterways or to the side of wetlands or small flood plains that have been developed for agricultural use. Up-slope of this habitat lies native vegetation which is often contiguous with either Wollemi National Park, Parr State Conservation Area or Maroota Ridge State Conservation area. The *C. hunteriana* habitat within the upstream and construction study areas occurs near Warragamba Dam. While contiguous with the native vegetation of the Blue Mountains National Park, the *C. hunteriana* habitat has also been fragmented by the previous construction works associated with the original construction of Warragamba Dam.

The Project could potentially increase the fragmentation and degradation of the *C. hunteriana* habitat within the upstream, downstream and construction study areas. Habitat within the upstream 1% AEP flood extent may be fragmented by native vegetation loss caused by flooding and inundation. Within the downstream study area habitat may be fragmented by increases to flooding with the FMZ discharge boundary and decreases in flooding between the current and proposed 10% AEP flood extents. Habitat with the construction study area may be fragmented though direct vegetation clearing required for the construction works. In all study areas, fragmentation could potentially be exacerbated through the increased presence of invasive weeds and through erosive processes.

- **adversely affect habitat critical to the survival of a species**

According to the *Matters of National Environmental Significance Significant impact guidelines* 1.1 (DoE 2013) habitat critical to the survival of a species refers to areas that are necessary for:

- activities such as foraging, breeding, roosting, or dispersal
- 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
- the reintroduction of populations or recovery of the species or ecological community.

The *C. hunteriana* habitat in the upstream, downstream and construction study areas has been assessed as critical habitat because it is important for dispersal, the long-term maintenance of the species, for maintaining genetic diversity, and for the potential reintroduction/recovery of the species. The Project could potentially adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive species, erosion and deposition, modifying hydrology and modifying the fire regime.

• **disrupt the breeding cycle of an important population**
The lifecycle ecology of *Cryptostylis hunteriana* is unusual. Lacking leaves, *C. hunteriana* has a limited capacity to photosynthesise. Instead, this species of orchid most likely relies on a fungal association to obtain nutrients from either live of decaying organic material (DEWHA 2008; OEH 2018; DoEE 2019). *C. hunteriana* is only visible above ground when it flowers – between November and February in NSW and Victoria, and between June and August in Queensland. This species of orchid does not flower every year, however, when it does it produces between 5 and 10 flowers. As well as reproducing via seed, *C. hunteriana* can also reproduce vegetatively. This has allowed the species to form colonies at some locations (OEH 2018). Within the downstream 10% AEP flood extent, a reduction in peak flood extents and durations, along with a reduction in peak flood flows could potentially impact the lifecycle of *C. hunteriana*. The reductions in flood extents, durations and flows may change the drainage and hydrological conditions within the *C. hunteriana* habitat. These changed hydrological conditions may modify the micro-climatic conditions within the soil, potentially leading to the loss of the mycorrhizal fungi associated with *C. hunteriana*. Impacts to the associated mycorrhizal fungi may disrupt the breeding cycle of the local population due to the Project. Within the downstream and upstream study areas, increases in flooding caused by a flood event or by the discharge of the FMZ may impact the lifecycle of *C. hunteriana*. The increases to flooding may change the soil micro-climate which again, may impact the fungal association (although this time the fungi may be impacted by too much water as opposed to not enough). *C. hunteriana* habitat and individuals may be flooded, neither of which have evolved to withstand inundation. Additionally, if *C. hunteriana* produces a soil-stored seedbank, it could potentially be impacted by the increased flooding. Frequent fire and 'inappropriate fire regimes' have been identified in the OEH threatened species profile (OEH 2018) and in the Approved Conservation Advice for *C. hunteriana* (DEWHA 2008) as a threat to the breeding cycle of this species. The Project may affect the fire regime within all three study areas by modifying the vegetation communities (and subsequently the fuel load) within them. If the modified vegetation is more susceptible to fire then the frequency of fire may be increased. The increased frequency of fire may disrupt the breeding cycle of the important population of *C. hunteriana*.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project could potentially impact *C. hunteriana* habitat within the upstream and construction study areas. Habitat may be destroyed and/or directly impacted through the clearing of native vegetation, the loss of flora and fauna habitat, and a reduction in the extent of ecological communities. Habitat may be indirectly impacted (modified, reduced in quality etc.) through fragmentation, alteration to soil conditions, edge effects, weed invasion and incursion, through the spread of disease and pathogens, erosion and sedimentation, and thorough changes to the fire regime.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
Competition from weeds and exotic species may place additional pressure on the local population of *C. hunteriana*. Exotic plants such as Lantana, African Olive and a number of non-native grasses become established in disturbed areas quickly. Such plants can out-compete native plants, especially seedlings and juveniles. If seedlings and juveniles are outcompeted, recruitment of new individuals into a population cannot take place.
• **introduce disease that may cause the species to decline, or**
No diseases have been identified as a threat to *C. hunteriana*.
• **interfere substantially with the recovery of the species.**
No National Recovery Plan has been developed for *C. hunteriana* under the EPBC Act. However, a targeted strategy for managing *C. hunteriana* has been developed under the Saving Our Species Program (NSW Government). Under the Saving Our Species Program, *C. hunteriana* has been assigned to the 'site-managed species' management

stream. The Saving Our Species Program for *C. hunteriana* has identified the following three priority management sites to manage critical threats to the species: • Bulahdelah in the Mid-Coast LGA • Tomaree Head in the Port Stephens LGA • Meroo National Park. All three of the listed priority management sites are located over 100 kilometres from the Project study area. The Project is unlikely to impact these priority management sites, making it consistent with the Saving Our Species program for *C. hunteriana*. No Approved Threat Abatement Plans are relevant to the occurrence of *C. hunteriana* in the study areas.
Conclusion
The Project could potentially impact *Cryptostylis hunteriana* habitat across the upstream and construction study areas. This habitat may become fragmented, potentially isolating occurrences of the species from one another. The Project may impact the breeding cycle of *C. hunteriana* by clearing native vegetation (habitat), modifying the fire regime and modifying the hydrological environment. The threat of invasive flora species may also be exacerbated by the Project. These impacts could cause a decline of important population of *C. hunteriana*. The Project has been assessed as likely to have a significant impact on *Cryptostylis hunteriana.*

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Cynanchum elegans (White-flowered Wax Plant)

Endangered under the EPBC Act

Cynanchum elegans is a climbing or twining plant with a highly variable vegetative morphology. As the common name implies, the White-flowered Wax Plant produces white flowers that are tubular in shape. This plant produces fruit that can be described as a pointed pod about 8 centimetres long and containing up to 45 seeds (OEH 2018). *C. elegans* has been recorded flowering between August and May with a 'peak flowering' in November. Seed production has been described by OEH as being unreliable with dispersal being facilitated by the wind. A soil-stores seedbank is considered by OEH to be unlikely. This is unusual considering NPWS (2002) lists 'damage to the soil seedbank' as a potential risk to the lifecycle of the species.

C. elegans has been recorded in the Hawkesbury-Nepean, Hunter-Central Rivers, Northern Rivers, Southern Rivers and Sydney Metro Natural Resource Management Regions (OEH 2008). Within these management regions Harden and Williams (1992) have the species recorded from the Gloucester district to the Illawarra and inland to Mt Dangar.

C. elegans has primarily been recorded growing in the ecotones between dry subtropical rainforest and sclerophyll forests and woodlands. Harden and Williams (1992) add that it also grows in rainforest gullies, scrub and scree slopes. According to OEH's BioNet system, *C. elegans* is associated with the following PCT mapped in the downstream study area:

- PCT 835 (HN526): Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin Bioregion
- PCT 849 (HN528): Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion
- PCT 877 (HN538): Grey Myrtle dry rainforest of the Sydney Basin Bioregion and South East Corner Bioregion
- PCT 1183 (HN587): Smooth-barked Apple - Sydney Peppermint - Turpentine heathy open forest on plateaux areas of the Sydney Basin Bioregion
- PCT 850 (HN529): Grey Box - Forest Red Gum grassy woodland on shale of the southern Cumberland Plain, Sydney Basin Bioregion

Cynanchum elegans was assessed as not having a moderate or higher likelihood of occurrence in the upstream study area. No PCTs associated with the presence of *C. elegans* were recorded in the construction study area.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines a 'population of a species' as an occurrence of the species in a particular area. In relation to critically endangered, endangered or vulnerable threatened species occurrences include but are not limited to:

- a geographically distinct regional population, or collection of local populations.
- a population, or collection of local populations that occur within a particular bioregion.

Targeted surveys for *C. elegans* were not undertaken across the upstream and downstream study areas. In the absence of targeted surveys, *C .elegans* has been assumed present in areas of suitable habitat – the previously listed PCTs and contiguous vegetation supporting known records. Using the precautionary principle, a population of the species has been assessed as occurring across the upstream and downstream study areas.

An action is likely to have a significant impact on an endangered or critically 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**
As *Cynanchum elegans* was not surveyed, areas of habitat have been used as a surrogate for the species occurrence and population size. Within the downstream study area no habitat between the existing and with-project 10% AEPs or within the FMZ discharge area would be impacted. There is 0.39 hectares of *C. elegans* habitat between the existing and with Project PMF extents. Given the very low likelihood of occurrence of this event, there is not considered to be a real chance or possibility that the Project will likely to lead to a long-term decrease in the size of a population.

• reduce the area of occupancy of a species
Within the downstream study area no habitat between the existing and with-project 10% AEPs or within the FMZ discharge area would be impacted. There is 0.39 hectares of *C. elegans* habitat between the existing and with Project PMF extents. Given the very low likelihood of occurrence of this event, there is not considered to be a real chance or possibility that the Project will likely reduce the area of occupancy of this species.
• fragment an existing population into two or more populations
C. elegans habitat could potentially become fragmented from impacts associated with the Project. Habitat within the downstream 10% AEP flood extent and FMZ discharge boundary may be fragmented by more frequent flooding and changes to groundwater availability. Additionally, the risk of erosion of river banks may increase, and invasive plant species could become more common, potentially contributing to fragmenting habitat in the downstream study area.
• adversely affect habitat critical to the survival of a species
According to the *Matters of National Environmental Significance Significant impact guidelines* 1.1 (DoE 2013) habitat critical to the survival of a species refers to areas that are necessary for: • activities such as foraging, breeding, roosting, or dispersal • 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 • the reintroduction of populations or recovery of the species or ecological community. The *C. elegans* habitat in the downstream study area has been assessed as critical habitat because it is important for dispersal, the long-term maintenance of the species, for maintaining genetic diversity, and for the potential reintroduction/recovery of the species. The Project could potentially adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive species, erosion and deposition, modifying hydrology and modifying the fire regime.
• disrupt the breeding cycle of a population
The reproductive ecology and breeding cycle of *Cynanchum elegans* is poorly understood. The OEH species profile (2018) states that *C. elegans* is capable of suckering from rootstock after slashing or grazing however little research has been conducted on how this species responds to fire. *Cynanchum elegans* has been recorded re-shooting after fire however annual burning has led to the decline of one known population (OEH 2018). NPWS (2002) suggests ‘damage to the soil seedbank’ as a potential risk to the lifecycle of this species. If a soil seedbank was to occur within the study area it would likely be damaged by the Project. A changing erosive and depositional environment may move seed or prevent it from germinating. OEH (2018) states a soil seed bank is unlikely to occur however. If this is true, then the soil seedbank most likely occurs within the pods of mature plants. The Project would likely still impact an aerially stored seedbank. Regardless of where the seed of *C. elegans* is stored, its habitat is likely important and likely to be impacted. Impacts associated with the Project could potentially modify the soils and alter the fire regimes within the upstream and downstream study areas. As the reproductive ecology and fire-dependence (or lack there-of) of *C. elegans* is poorly understood, the Project has been precautionarily assessed as potentially impacting the lifecycle of the local population.
• modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline
The Project could potentially impact *Cynanchum elegans* habitat within the downstream study area. Habitat would be destroyed and/or directly impacted through the clearing of native vegetation, the loss of flora and fauna habitat, and a reduction in the extent of ecological communities. Habitat would be indirectly impacted (modified, reduced

in quality etc.) through fragmentation, alteration to soil conditions, edge effects, weed invasion and incursion, through the spread of disease and pathogens, erosion and sedimentation, and thorough changes to the fire regime.
• **result in invasive species that are harmful to an endangered or critically endangered species becoming established in the endangered or critically endangered species' habitat**
The Project may increase the threat of invasive weeds and exotic fauna to *C. elegans*. A reduction in the coverage of native flora could create opportunities for the further spread and establishment of invasive plants such as African Olive, Lantana, and a number of perennial grasses. The Environmental Impact Assessment Guidelines for *C. elegans* lists grazing by the feral European Rabbit (*Oryctolagus cuniculus*) as a threat (NPWS 2002). It is unknown if the Project would increase the presence or spread of the European Rabbit.
• **introduce disease that may cause the species to decline, or**
No diseases have been identified as a threat to *Cynanchum elegans*.
• **interfere substantially with the recovery of the species.**
No National Recovery Plan has been developed for *Cynanchum elegans* under the EPBC Act. However, a targeted strategy for managing *C. elegans* has been developed under the Saving Our Species Program. Under the Saving our Species Program, *C. elegans* has been assigned to the 'Keep-watch species management stream'. OEH's justification for placing *C. elegans* under this management stream is as follows; *Relatively large populations of this species occur within reserves (for example, at least 40 populations on conservation reserves) where current management is sufficient to ensure their long-term security*. As these populations are located in reserves no key management sites have been identified by OEH. While the Project may impact a number of reserves and National Parks, none of them have been recorded to support *C. elegans*. The Project is therefore likely consistent with the objectives and actions (or lack there-of) set out in the Saving Our Species Program. No Approved Threat Abatement Plans are relevant to the occurrence of *C. elegans* in the Upstream or Downstream Study Areas.
Conclusion
The Project could potentially impact *C. elegans* habitat across the downstream study area. This habitat could potentially become fragmented, isolating occurrences of *C. elegans* from one another. The Project may impact the breeding cycle of *C. elegans* by clearing native vegetation (habitat), modifying the fire regime, modifying the hydrological environment and impacting the soil seedbank. The threat of invasive flora species may also be exacerbated by the Project. These impacts are expected to cause a decline of the population of *C. elegans*. The Project has been assessed as likely to have a significant impact on *Cynanchum elegans.*

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Darwinia biflora

Vulnerable under the EPBC Act

Darwinia biflora (Cheel) B.G.Briggs is listed as Vulnerable under both the BC Act and EPBC Act. *Darwinia biflora* is an erect or spreading shrub to 80 centimetres high (PlantNET 2019). The leaves are laterally compressed, often appressed to branchlets (PlantNET 2019). Flowers are green, surrounded by two red bracteoles, and are mostly in pairs (Harden 1991). Generally, it occurs in the northern and north-western suburbs of Sydney, from Maroota in the north, North Ryde in the south, Cowan in the east and Kellyville in the west (DEC 2004). Preferred habitat for the species includes the edges of weather shale-capped ridges, where these intergrade with Hawkesbury Sandstone (DEC 2004). The associated soils are largely described as being the edges of residual soil landscapes where these intergrade with colluvial or erosional soil landscapes. Specifically, this includes most sites that are on the Lucas Heights Soil Landscape where this intergrades with either the Gymea or the Hawkesbury Soil Landscapes (DEC 2004). Generally, the species has been found on gentle slopes near the crests of ridges and on sheet rock which often contains moss beds. Associated vegetation broadly includes Sandstone Ridgetop Woodland (NPWS 2002), which is equivalent to Sydney Sandstone Ridge-top Woodland/Open Forest (community 10ar in Benson 1992) and Sydney Sandstone Scrub-heath complex (NPWS 1997). *Darwinia biflora* appears to be most successful at sites with a canopy cover ranging from 0% (that is, full sun) to 30% (DEC 2004). The species is an obligate seeder and as such fire is important factor in the life cycle of the species (DEC 2004). The species has also been found in high numbers at sites that have been subject to disturbances other than fire, such as sites under power lines that have been cleared and along tracks – wherever the amount of light reaching the ground layer is increased (DEC 2004).

With regard to the Project, *D. biflora* is considered likely to have a 'moderate' likelihood of occurring within the construction and downstream study areas, based on the presence of suitable habitat and known records as per BioNet Atlas. Targeted surveys were not undertaken for *D. biflora* and the species was not incidentally encountered in the survey area during vegetation mapping investigations associated with the Project.

In the absence of targeted surveys, *D. biflora* has been assumed present in areas of presumed suitable habitat. For this assessment, suitable habitat for *D. biflora* includes the PCTs that are associated with the species (as per the TBDC), BioNet Atlas Records and any other known vegetation types (as per scientific literature) that the species is associated with that has been mapped within the construction and downstream study areas.

Suitable habitat includes the following PCTs that have been mapped within the construction study area includes:

- PCT1081: Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion (associated as per TBDC).

Suitable habitat includes the following PCTs that have been mapped within the downstream study area includes:

- PCT1181: Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney Basin Bioregion (associated as per TBDC)
- PCT1081: Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion (associated as per TBDC)
- PCT1328: Yellow Bloodwood - Narrow-leaved Apple heathy woodland on hinterland plateaux of the Central Coast Sydney Basin Bioregion (associated as per TBDC).

However, the true extent of suitable habitat for this species within the study area is likely to be greater as a small proportion of vegetation communities that has been mapped by the Ryan *et al.* (1996) in The natural vegetation of the St Albans 1:100,000 mapsheet project could not be assigned to a PCT. Vegetation communities as mapped by Ryan *et al.* (1996) were adopted for parts of the study area north of Sackville and along the Colo River where time constraints limited the ability for SMEC to complete vegetation mapping in these areas.

D. biflora is considered to have a low likelihood of occurring in the upstream study area. This is because the species has a restricted distribution for which there are no known populations in the upstream study area.

This Assessment of Significance has been prepared in accordance with the *Matters of National Environmental Significance: Significant impact guidelines 1.1* (DoE 2013). According to the guidelines, the questions for a 'Vulnerable' species are related to the 'importance of the population'. The guidelines define an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal*

- *populations that are necessary for maintaining genetic diversity, and/or*
- *populations that are near the limit of the species range.'*

There are no NSW BioNet Atlas records within the construction and downstream study areas. Additionally, targeted surveys were not conducted for this species and therefore it cannot confirmed whether the species is present in either study area. Presumed suitable habitat in the form of associated PCTs do occur within the study area and are therefore assumed to support a population of the species. As this population would be key for breeding and dispersal, and maintaining the species genetic diversity it has been assessed as 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**
About 2.76 hectares of habitat (used as a surrogate for the important population's size) would likely be permanently lost through vegetation clearance associated with the construction of the raising of the dam wall. The remaining suitable habitat in the downstream study area could potentially be modified due to changed hydrological regimes and other related impacts. Within the downstream study area, some areas of suitable habitat may be subjected to changed flooding conditions, such as 9.37 hectares which occurs in the FMZ. Within the FMZ there is likely to be extended periods of inundation more regularly and for longer periods of time with on average inundation lasting five to eight days longer than existing flood events. While the habitat in the downstream study area is not likely to change in the short-term, over the long-term floristic structure and composition and soil properties may change. These changes could potentially lead to other ecosystem changes such that a changed floristic structure and composition could affect fire frequency, extent, intensity and duration while changed soil properties may contribute to erosion and sedimentation. In the worst case scenario, it is considered the project could potentially lead to a long-term decrease in the size of an important population of *D. biflora.*
• **reduce the area of occupancy of an important population**
The Project may reduce the potential area of occupancy for *D.biflora* across the downstream and construction study areas. These reductions can be summarised according to the following impact scenarios: Downstream Study Area • FMZ discharge area: 9.37 hectares • Difference between the existing and with project 10% AEPs: 30.27 hectares • Difference between the existing and with project PMFs: 0 hectares Construction Study Area • Development footprint: 2.76 hectares
• **fragment an existing important population into two or more populations**
The Project could potentially impact suitable habitat presumed to support an important population of *D. biflora.* Of this, about 21 hectares would likely be permanently lost through vegetation clearance associated with the construction of the raising of the dam wall. Suitable habitat in the downstream study area could potentially be modified due to changed hydrological regimes and other related impacts. Within the downstream study area, some areas of suitable habitat may be subjected to changed flooding conditions, such as about 89 hectares which occurs in the FMZ. As it has been precautionarily assumed that the construction and downstream study areas contain an important population, the Project could potentially contribute to fragmentation by contributing to the loss and modification of suitable habitat.
• **adversely affect habitat critical to the survival of a species**
The Minister maintains a 'Register of Critical Habitat' under the EPBC Act in which habitat as identified as being critical to the survival of a listed threatened species is provided. To date, no critical habitat is listed for this species that occurs within or proximal to the construction, upstream or downstream study areas. In addition, there is no

adopted or made federal Recovery Plan for *D. biflora.* According to the Species Profile and Threats Database (SPRAT) (DoE 2019) a Recovery Plan is not required because the approved conservation advice for the species provides sufficient direction to implement priority actions and mitigate against key threats. According to the approved conservation advice (DoE 2014), regional priority recovery and threat abatement actions include minimising habitat loss, disturbance and modification by monitoring known populations and identifying key threats including known, potential or emerging threats, developing and implementing a management plan for the control of weeds across the species' distribution, developing and implementing a suitable fire management strategy for the species' habitat and raising awareness of the species within the local community. It is important to note that under state legislation, a Recovery Plan for *D. biflora* has been prepared. The state Recovery Plan (DEC 2004), describes habitat features and species distribution that would contain habitat critical to the survival of this species. However, the state Recovery Plan notes that further survey work is required to understand the full distribution of the species and specific habitat critical to the survival of the species (DEC 2004).

It is therefore assumed that the suitable habitat identified in the construction and downstream study area is critical to the survival of the species. However, it is recognised that small portions of this total estimate are likely to be preferable based on the presence of the specific habitat components preferred by the species such as those related to landform and geology, climate and associated vegetation.

- **disrupt the breeding cycle of an important population**

The breeding cycle of *D. biflora* is poorly understood. However, the species has bisexual flowers and self-pollination is thought to occur more frequently than outcrossing due to the mode of floral development (DEC 2004). Furthermore, the small, inconspicuous flowers are reported to be rarely visit by insects and as such, outcrossing, although not entirely excluded, is likely a rare occurrence (DEC 2004). Flowers and fruit are produced at 18 months after germination, though at this stage few fruits reach maturity. Once mature, the fruit is released from the plant and seed is subsequently stored in a soil seedbank (Auld *et al.* 1993). Seed viability is high and most seeds are released in a dormant state (Auld *et al.* 1993). Ants are known to disperse seeds (Auld and Scott 1995). Fire is generally required to break seed dormancy, although a proportion of the dormant seed becomes non-dormant with time (Auld *et al.* 2000). Fire is an important factor in the life cycle of the species and the long-term persistence of the species at a site (Auld 1986; DEC 2004). Aspects related to fire such as frequency, intensity, duration and seasonality are also important whereby an inappropriate fire regime could be detrimental to the species (DEC 2004).

In accordance with the precautionary principle, the Project could potentially disrupt the breeding cycle of an important population of *D. biflora,* as the variable nature of impacts of changed hydrology affecting habitat occupied by the species in the downstream area could disrupt one or more ecological functions and processes that are currently known to be vital to the long-term survivability and viability of a population.

- **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**

About 2.76 hectares of suitable habitat presumed to support a *D. biflora* would be permanently lost through vegetation clearance associated with the construction of the raising of the dam wall. Approximately 30.27 hectares of suitable habitat in the downstream study area would be modified due to a changed hydrological regime (difference between the existing and with-project 10% AEPs). Additionally, a total of 9.37 hectares of suitable habitat for *D. biflora* which occurs in the FMZ. Within the FMZ there is likely to be extended periods of inundation more regularly and for longer periods of time with on average inundation lasting five to eight days longer than existing flood events. The FMZ represents an area of habitat for *D. biflora* which would experience permanent change in floristic structure and composition as well as changes to soil properties, erosion and sedimentation.

- **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**

The establishment and spread of invasive weeds are a potential threat the *D. biflora* (DoE 2014). It is possible that machinery and equipment associated with the construction of the raising of the dam wall could lead to an introduction or spread of this invasive species. Similarly, changes to the upstream ecosystem as a result of various inundation scenarios could create an environment conducive to the spread and establishment of invasive weed species. Accordingly, the Project could potentially result in invasive species that are harmful to *D. biflora* becoming established in the species' habitat.

• **introduce disease that may cause the species to decline, or**
D. biflora is expected to be susceptible to *Phytophora cinnamomi,* a soil borne pathogen belonging to the water mould group (Oomycetes). An infestation of *P. cinnamomi* may adversely affect populations of this species. *P. cinnamomi* can be spread in water, soil or plant material that contains the pathogen and dispersal, whether active or passive, is favoured by moist or wet conditions (OíGara *et al.* 2005). While there is a number of mechanisms for spread of this disease, humans are considered by far to be the most significant vector (OíGara *et al.* 2005). Humans can spread the disease by construction works where soil is moved, soil on vehicles and maintenance machinery, on footwear and camping equipment. There is a risk during the construction phase of the Project that machinery and equipment may introduce *P. cinnamomi* to the construction study area. Similarly, a change to the existing hydrological environment in the downstream study area which may create conditions conducive to spread of this disease.
• **interfere substantially with the recovery of the species.**
There is no current National Recovery Plan or Threat Abatement Plan for *D. biflora*. According to the EPBC Act Species Profile and Threat Database (SPRAT), a Recovery Plan is not required as the approved conservation advice for the species provides sufficient direction to implement priority actions and mitigate against key threats (DoEE 2019). The approved conservation advice (DoE 2014) recommends regional priority recovery and threat abatement actions to support the recovery of the species. Such actions include monitoring known populations to identify key threats associated with habitat loss, disturbance and modification, developing and implementing a management plan for controlling invasive weeds, developing and implementing a fire management strategy at sites where the species is known to occur as well as raising awareness of the species and encouraging landholders, land managers and key stakeholders to contribute to the implementation of conservation management strategies (DoE 2014). The main identified threats to *D. biflora* are habitat loss, habitat degradation, increased fragmentation and inappropriate fire regimes (DoE 2014). The Project may interfere with the recovery of the species by contributing to habitat loss, disturbance and modification.
Conclusion
The Project could potentially reduce the area of occupancy and modify extents of suitable habitat for *D. biflora*. These impacts could potentially have an adverse effect on an important population of *D. biflora* such that it may cause it to decline. The Project has been assessed as likely to have a significant impact on *D. biflora.*

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Epacris sparsa (Sparse Heath)

Vulnerable under the EPBC Act

Epacris sparsa is a an erect to spreading shrub that can reach 90 centimetres in height. Its leaves are elliptic to ovate, ranging from 11 to 17 millimetres long and up to four millimetres wide. Cream, tubular flowers 15 to 19 millimetres long are produced in groups towards the end of the branches. A capsule-like fruit about 3 millimetres long is formed (NSW NPWS 2000; OEH 2017).

Epacris sparsa has a distribution that is currently recognised as being restricted to the lower Grose River (NSW NPWS 2000; OEH 2017). *Epacris sparsa* habitat occurs just above the riparian zone with most records coming from shaded, damp, south facing claystone (NSW NPWS 2000). The *E. sparsa* threatened species profile adds that habitat includes riparian sandstone scrub, where it is found on the base of cliffs, rock faces, on rock ledges or among rock in the riparian flood zone (OEH 2017). The Environmental Impact Assessment Guidelines for *Epacris sparsa* (NSW NPWS 2000) made the following assessment of habitat with regards to population viability:

> *Significant fluctuations in population size over time may be related to extreme environmental events. The riparian habitat of E. sparsa is an unpredictable environment with alternating periods of flooding and dry spells. Populations may build up over years of relative stability to be significantly reduced or destroyed by a major flood or fire.*

According to OEH's BioNet system, *E. sparsa* is associated with the following PCTs mapped in the downstream study area:

- PCT 1292 (HN607): Water Gum – Coachwood riparian scrub along sandstone streams, Sydney Basin Bioregion
- PCT 99996: Water bodies, rivers, lakes, streams (not wetlands) – mapped as 'water bodies' throughout the EIS.

Epacris sparsa was not assessed as having a moderate or higher likelihood of occurring in the upstream or construction study areas.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal.*
- *populations that are necessary for maintaining genetic diversity.*
- *populations that are near the limit of the species range.*

Targeted surveys for *E. sparsa* were not undertaken in the downstream study area. Additionally, *E. sparsa* was not incidentally encountered during the vegetation mapping associated with the Project. In the absence of targeted surveys, *E. sparsa* has been assumed present in areas of presumed suitable habitat – the previously listed PCTs. Using the precautionary principle, the population(s) residing within this habitat have been assessed as an important population(s) as they are key source populations for breeding and dispersal, are necessary for maintaining genetic diversity, and occur near the limit of the species range.

According to the OEH records no *E. sparsa* have been recorded in the downstream study area. The downstream study area however abruptly ends five kilometres up the Grose River – a river with no man-made structures such as weirs that may explain this interruption. Numerous records of *E. sparsa* occur a further two kilometres up the Grose River from where the Downstream study area 10% AEP and FMZ discharge boundary end. These individuals have been precautionarily assessed as occurring within these boundaries. The important population therefore incorporates all occurrences of PCT 1292, and the *E. sparsa* records occurring within 100 metres of the Grose River - regardless of their occurrence outside the downstream study area.

An action is likely to have a significant impact on an endangered or critically 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**
As *Epacris sparsa* was not surveyed, areas of habitat and the previously made records along the Gross River have been used as a surrogate for the species occurrence and population size. Given that the flood modelling abruptly ends about 5 kilometres up the Grose River, it has been precautionarily assessed that changes to the existing PMF and 10% AEP along with impacts associated with the discharge of the FMZ will impact the important population. These impacts are likely to lead to a long-term decrease in the size of the important population.
• **reduce the area of occupancy of an important population**
Given that the flood modelling abruptly ends about 5kilometres up the Grose River, it has been precautionarily assessed that changes to the existing PMF and 10% AEP along with impacts associated with the discharge of the FMZ will impact the important population. These impacts will reduce the area of occupancy of the important population.
• **fragment an existing important population into two or more populations**
Epacris sparsa habitat is fragmented in the downstream study area, consisting of isolated stands of vegetation and suitable riparian terrain. The Project could potentially further fragment this habitat. In the downstream study area, PCT 1292 primarily occurs near Bents Basin and north of the lower Grose River. The occurrence near Bents Basin may become fragmented, primarily through edge effects, native vegetation removal, a modified fire regime and a modified erosion profile. The habitat along to the north of the Grose River and along the lower Grose River may become degraded and could also become fragmented by the Project.
• **adversely affect habitat critical to the survival of a species**
According to the *Matters of National Environmental Significance Significant impact guidelines* 1.1 (DoE 2013) habitat critical to the survival of a species refers to areas that are necessary for: • activities such as foraging, breeding, roosting, or dispersal • 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 • the reintroduction of populations or recovery of the species or ecological community. The *E. sparsa* habitat in the downstream study area has been assessed as critical habitat because it is important for dispersal, the long-term maintenance of the species and for maintaining genetic diversity. The Project may adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive species, erosion and deposition, and modifying the fire regime.
• **disrupt the breeding cycle of an important population**
The lifecycle ecology and breeding cycle of *Epacris sparsa* is poorly understood. The poor soil development in the *E. sparsa* riparian zone habitat likely limits the size of any soil-stored seed bank. A smaller soil-stored seed bank would limit the ability for a population to recover via a mass germination event following a disturbance (NSW NPWS 2000). However, re-sprouting from lignotubers after low to moderate intensity fires may occur. High intensity fires likely kill plants however, as has been observed in other Epacris species (Meney et al 1994). The Project could potentially affect the breeding cycle of *E. sparsa* by changing the fire regime within its habitat, by flooding the soil seedbank, and by facilitating the spread and establishment of weed species. The fire regime within *E. sparsa* habitat may be changed by the altered vegetation dynamics and the species assemblages within riparian zones. *Epacris sparsa* is thought to be able to re-sprout after low to moderate intensity fires from an underground lignotuber, however, like most Epacris species the *E. sparsa* is unlikely to be able to re-sprout after high-intensity fires. A high-intensity fire may also disrupt the soil seedbank. The Environmental Impact Assessment Guidelines for *E. sparsa* (NSW NPWS 2000) acknowledge this, writing that due to poor soil development the limited soil seed bank may be destroyed readily by high temperatures.

The occurrences of PCT 1292 and the *E. sparsa* records along the Grose River could potentially be placed at risk of flooding by the Project. The Environmental Impact Assessment Guidelines for *E. sparsa* (NSW NPWS 2000) acknowledges flooding as a threat stating *'seedlings and immature plants are the most susceptible to dislodgment during flooding… the survival of seedlings depends largely on the location of plants and the timing and intensity of rising water levels or fire events'*. Accordingly, the Project could potentially disrupt the breeding cycle of the important population of *E. sparsa*.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project could potentially impact *E. sparsa* habitat within the downstream study area and impact the habitat occluding along the Grose River. *Epacris sparsa* habitat may be destroyed and/or directly impacted through the clearing of native vegetation. Habitat may be indirectly impacted (modified, reduced in quality etc.) through fragmentation, alteration to soil conditions, edge effects, weed invasion and incursion, erosion and sedimentation, and thorough changes to the fire regime.
• **result in invasive species that are harmful to an endangered or critically endangered species becoming established in the endangered or critically endangered species' habitat**
The OEH species profile for *E. sparsa* identifies riparian weeds as a threat. It states, 'invasion and habitat loss from herbaceous riparian weeds including gorse, blackberry, crofton weed and mist flowerer' are threats, which are 'exacerbated when water/sediment levels are higher' (OEH 2019). The Project may provide opportunities for the spread and establishment of herbaceous riparian weeds throughout *E. sparsa* habitat. The spread and establishment of these weeds may be exacerbated as the Project raises the water and sediment levels when flood events occur.
• **introduce disease that may cause the species to decline, or**
No diseases have been identified as a threat to *E. sparsa*.
• **interfere substantially with the recovery of the species.**
No National Recovery Plan has been developed for *Epacris sparsa* under the EPBC Act. However, a targeted strategy for managing *Epacris sparsa* has been developed under the Saving Our Species Program. Under the Saving Our Species program, *E. sparsa* has been assigned to the 'site-managed species' management stream. The following three priority management sites (all along the Grose River) have been identified: • Brown's Ridge Road in the Hawkesbury LGA: a small 0.5 hectare patch along the banks of the Grose River. • Grose River in the Hawkesbury LGA: occurs along the Grose river, extending to Burralow Creek. • Faulconbridge Point: surrounding the Grose River and Linden Creek in the Blue Mountains National Park. The Project may impact the Grose River priority management site and has the potential to impact the Brown's Ridge Road and Faulconbridge Point priority management sites. No Approved Threat Abatement Plans are relevant to E. sparsa in context of impacts caused by the Project.
Conclusion
The Project could potentially impact *E. sparsa* habitat and impact the previously recorded occurrences along the Grose River. The Project may impact the breeding cycle of *E. sparsa* by clearing native vegetation (habitat), modifying the fire regime, modifying the hydrological environment and impacting the soil seedbank. The threat of invasive flora species may also be exacerbated by the Project. These impacts may cause a decline of important population of *E. sparsa*. T The Project has been assessed as likely to have a significant impact on *Epacris sparsa.*

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Eucalyptus benthamii (Camden White Gum)

Vulnerable under the EPBC Act

Eucalyptus benthamii is a large tree that can reach 40 metres in height. It has smooth, white bark that covers most of an individual, a persistent flaky bark stocking, and numerous long ribbons of bark. Mature leaves are 8-12 centimetres long and 1.5-2 centimetres wide, with elliptic to ovate margins. Juvenile leaves are opposite, rounded and glaucous. Seven-flowered umbellasters are produced upon terete peduncle. *Eucalyptus benthamii* produces white flowers in summer and autumn although sporadic flowering has been observed throughout the year (PlantNET 2019; OEH 2019).

The *E. benthamii* distribution is restricted to the Kedumba Valley and to the Nepean River at Bents Basin and Wallacia. It occurs along river banks and flats that support deep alluvial sands, silts, and are prone to flooding. This habitat supports open forest and riparian vegetation often consisting of *Eucalyptus elata*, *E. deanei*, *E. amplifolia*, *Angophora floribunda* and *A. subvelutina* (NSW NPWS 2000; OEH 2019).

According to OEH's BioNet system, *E. benthamii* is associated with the following PCTs mapped in the downstream study area:

- PCT 1106 (NR223): River Oak riparian woodland of the NSW North Coast Bioregion and northern Sydney Basin Bioregion
- PCT 835 (HN526): Forest Red Gum – Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain Sydney Basin Bioregion
- PCT 849 (HN528): Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain Sydney Basin Bioregion
- PCT 883 (HN542): Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain Sydney Basin Bioregion

E. benthamii is associated with the following PCTs mapped in the upstream study area:

- PCT 1105 (HN574): River Oak open forest of major streams Sydney Basin Bioregion and South East Corner Bioregion
- PCT 860 (HN532): Grey Gum – Broad-leaved Ironbark dry open forest on gorge slopes on the Blue Mountains Sydney Basin Bioregion
- PCT 941 (HN553): Mountain Blue Gum – Thin-leaved Stringybark open forest on river flat alluvium in the Sydney Basin Bioregion

Eucalyptus benthamii was assessed with a low likelihood of occurring in the constructing study area.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal.*
- *populations that are necessary for maintaining genetic diversity.*
- *populations that are near the limit of the species range.*

Most of the known occurrence of *E. benthamii* occurs within the Upstream and Downstream study areas or in vegetation contagious with these study areas. As such, the *E. benthamii* occurring within the upstream and Downstream study areas – subject to this assessment – are key sources for breeding and dispersal, are necessary for maintaining the genetic diversity of the species, and are near the limit of the species range. *The E. benthamii* subject to this assessment have been classed as 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**
The occurrence (or sub-population) of *E. benthamii* in the Kedumba Valley comprises about 6,550 individuals (Butcher *et al.* 2005) or 4000 individuals (OEH 2019) depending on the source of information. The size of the sub-population in the downstream study area includes the 300 individuals at Bents Basin and nine trees along the Nepean River near Wallacia (Benson 1985; Butcher *et al.* 2005; OEH 2019). Within the upstream study area, the 1% AEP and 20% AEP flood scenarios have the potential to impact the important population. The Project could potentially impact the *E. benthamii* sub-populations upstream and downstream of the dam wall. Accordingly, the Project has been assessed as having potential to contribute to a long-term decrease in the size of the important population.
• **reduce the area of occupancy of an important population**
The occurrence of the important population of *Eucalyptus benthamii* is confined to the Kedumba Valley, to Bents Basin and to the banks of the Nepean River at Wallacia. Within the Kedumba Valley, *E. benthamii* occupies about 107.39 hectares within the 1% AEP flood extent and 10.73 hectares within the 20% AEP. The Project could potentially reduce these areas of occupancy by modifying the available habitat within these areas. Within the downstream study area, 64.11 hectares occurs between the existing and with-project 10% AEP flood extents 154.98 hectares between the existing and with-project PMFs and 167.25 hectares within the FMZ discharge boundary. The Project could potentially reduce these areas of occupancy by modifying the available habitat within these areas.
• **fragment an existing important population into two or more populations**
Structurally, the upstream occurrence or sub-population of *Eucalyptus benthamii* is different to that occurring downstream. Apart from the presence of Lake Burragorang, the upstream sub-population is much larger and occurs in relatively undisturbed habitat. The Project may reduce the number of individuals within this sub-population by degrading the habitat through the Kedumba River. It is however unlikely to completely isolate the remaining individuals on either side of the degraded habitat. The downstream sub-population occurs within the remnant vegetation along the western edge of the Cumberland Plain. This sub-population is already fragmented with the individuals at Bents Basin occurring about seven kilometres from those at Wallacia. Older records of *E. benthamii* have also been made from near Agnes Banks and at the confluence of the Nepean and Grose Rivers. This may indicate a historically larger distribution that has since declined through fragmentation and the subsequent isolation of remaining individuals. The Project has the potential to further fragment the occurrence of *E. benthamii* occurring downstream of the dam wall.
• **adversely affect habitat critical to the survival of a species**
According to the *Matters of National Environmental Significance Significant impact guidelines* 1.1 (DoE 2013) habitat critical to the survival of a species refers to areas that are necessary for: • activities such as foraging, breeding, roosting, or dispersal • 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 • the reintroduction of populations or recovery of the species or ecological community. The *E. benthamii* habitat in the upstream and downstream study areas has been assessed as critical habitat because it is important for dispersal, the long-term maintenance of the species and for maintaining genetic diversity. The Project could potentially adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive species, erosion and deposition, and modifying hydrology and the fire regime.

- **disrupt the breeding cycle of an important population**

Germination and recruitment of new individuals into a population of *Eucalyptus benthamii* is dependent on flooding and the substrate (alluvial sands and silts) in which seeds have been stored (Benson 1985; Butcher *et al.* 2005). For seeds to geminate periodic flooding of the soil-stored seedbank is required. Changes to the flooding and inundation regimes upstream and downstream of the dam wall may affect germination of the *E. benthamii* soil-stored seed bank. Additionally, the erosion caused by the changes to hydrology and the flooding regime may erode away the soil-stored seedbank. Both the erosion of the soil-stored seed bank and the flood-related impacts to seed germination may disrupt the breeding cycle of the important population.

In addition to out-crossing (reproduction involving the transfer of pollen from one individual to another), *E. benthamii* is known to self-pollinate, producing offspring genetically similar to the parent in context of the wider population. This may indicate that populations naturally support lower levels of genetic diversity compared to species that only out-cross. It also highlights the sensitivity of the species to disruptions to out-crossing between individuals when it does occur. The Project could potentially impact a variety of possible pollinators such as the little lorikeet (*Glossopsitta pusilla*) and the native stingless bee (*Tetragonula carbonari*).

- **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**

The Project could potentially impact (modify or destroy) up to 107.39 hectares of habitat within the upstream 1% AEP and 10.73 hectares within the 20% AEP. The modification and/or destruction of this habitat is expected to cause the population of *E. benthamii* in the upstream study area to decline.

The Project may impact (modify or destroy) up to 154.98 hectares between the existing and with-project PMF, 64.11 hectares between the existing and with-Project 10% AEPs and 167.25 hectares within the FMZ discharge area. The modification and/or destruction of this habitat is expected to cause the population of *E. benthamii* in the upstream study area to decline.

- **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**

Both invasive flora and fauna are harmful to *Eucalyptus benthamii* and its habitat. The OEH threatened species profile for *E. benthamii* identifies the following invasive flora species as a threat:

- *Gleditsia tricanthos*
- *Olea europaea* subsp. *cuspidata* (African olive)
- *Ligustrum sinense* (Small-leaf Privet)
- *Ligustrum lucidum* (Large-leaved Privet)
- *Acer negundo* (Box-elder Maple)
- *Opuntia* spp.
- *Cardiospermum grandiflorum* (Balloon Vine)
- *Asparagus asparagoides* (Bridal Creeper)
- *Rubus* spp. (Blackberry)
- *Cynodon* spp.
- *Paspalum* spp.
- Other annual weeds.

The Project could potentially facilitate the spread and establishment of these invasive flora species both upstream and downstream of the dam wall. This may occur through water moving seed and propagules, and by erosion and flooding creating disturbances that is, establishment opportunities. These invasive species would be harmful to an important population of *E. benthamii*.

The OEH threatened species profile for *E. benthamii* identifies feral pigs as a threat, specifically to the Kedumba sub-population. It is unknown if the Project may increase the size of the feral pig population in the Kedumba Valley.

• **introduce disease that may cause the species to decline, or**
No diseases have been listed as a threat to *Eucalyptus benthamii* in the Environmental Impact Assessment Guidelines, SPRAT profile, Approved Conservation Advice or OEH species profile.
• **interfere substantially with the recovery of the species.**
No National Recovery Plan has been developed for *Eucalyptus benthamii* under the EPBC Act. A recovery plan has however been developed for *E. benthamii* under OEH's Saving Our Species program (NSW government). Within the Saving Our Species program, *E. benthamii* has been assigned as a site-managed species. The following three priority management sites have been listed for *E. benthamii*: • Kedumba in the Blue Mountains and Wollondilly LGAs • Bent's Basin in the Liverpool, Penrith and Wollondilly LGAs • Camden Airport in the Camden and Wollondilly LGAs. The Project may impact the Kedumba and Bents Basin priority management sites. Specifically, the Project may exacerbate the following threats identified for these priority management site: • Changes to fire intensity and frequency • Potential for removal of key habitat via urban development • Competition from weeds. The impacts to these priority management sites could potentially interfere with the recovery of *E. benthamii*. There is an Approved Threat Abatement Plan for feral pigs (DoEE 2017) listed under the EPBC Act. It is unclear if the Project may further facilitate their spread and establishment in *E. benthamii* habitat and therefore interfere with the Threat Abatement Plan for feral pigs. Observations made during the field-based assessment identified that feral pigs were already having an impact on *E. benthamii* habitat.
Conclusion
The Project could potentially impact *E. benthamii*. habitat. The number of individuals occurring both upstream and downstream of the dam wall could decrease as a result of the Project. Along with potential impacts on habitat, the decline in the important population of *E. benthamii* may occur as the Project may facilitate the spread and establishment of invasive weed species and disrupt the population's breeding cycle. The Project has been assessed as likely to have a significant impact on *E. benthamii*.

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Eucalyptus camfieldii (Camfield's Stringybark)

Vulnerable under the EPBC Act

Camfield's Stringybark (*Eucalyptus camfieldii*) is listed as Vulnerable under the BC Act and EPBC Act. *Eucalyptus camfieldii* is mostly a mallee between 4-9 m tall with rough, fibrous and stringy bark. Juvenile leaves are described as round to heart-shaped and roughly hairy (OEH 2019). Adult leaves are broadly lance-shaped, to 10 x 3 centimetres, glossy green while the flowers are creamy-white (OEH 2019). The fruit is in clusters of 11 or more and is flattened, globe-shaped, to 9 mm across with valves enclosed or with protruding tips (OEH 2019). The species has a restricted distribution in a narrow band with the most northerly records in the Raymond Terrace and Norah Head, on the Central Coast to Waterfall and the Royal National Park in the south (DEWHA 2008). Preferred habitat for the species includes poor coastal country in shallow sandy soils overlying Hawkesbury sandstone and coastal heath mostly on exposed sandy ridges (OEH 2019; DEWHA 2008). Associated species include narrow-leaved stringybark (*E. oblonga*), brown stringybark (*E. capitellata*), scribbly gum *(E. hamastoma*), silvertop ash (*E. sieberi*), smooth-barked apple (*Angophora costata*), dwarf apple (*A. hispida*), red bloodwood (*Corymbia gummifera*), scrub she-oak (*Allocasuarina distyla*), slender tea tree (*Leptospermum trinervium*) and fern-leaved banksia (*Banksia oblongifolia*) (OEH 2019; DEWHA 2008).

According to OEH's BioNet system, *E. camfieldii* is associated with the following PCTs mapped in the downstream study area:

- PCT1183: Smooth-barked Apple - Sydney Peppermint - Turpentine heathy open forest on plateaux areas of the Sydney Basin Bioregion (associated as per TBDC)
- PCT1292: Water Gum - Coachwood riparian scrub along sandstone streams Sydney Basin Bioregion (associated as per TBDC).

Eucalyptus camfieldii is considered to have a moderate likelihood of occurring in the downstream study area. It was assessed with a low likelihood of occurrence in the upstream and construction study areas. As such, this assessment is only relevant to potential impacts to *E. camfieldii* in the Downstream study area.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal.*
- *populations that are necessary for maintaining genetic diversity.*
- *populations that are near the limit of the species range.*

Targeted surveys for *C. camfieldii* were not undertaken in the Downstream study area. In the absence of targeted surveys, *C. camfieldii* has been assumed present in areas of suitable habitat – the previously listed PCTs. Using the precautionary principle, the population(s) residing within this habitat have been assessed as an important population(s) as they would be necessary for maintaining genetic diversity and occur near the limit of the species range.

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**
As *E. camfieldii* was not surveyed, areas of habitat have been used as a surrogate for the species' occurrence. Within the downstream study area, no habitat is likely to be impacted by changes to the PMF and 10% AEP, or by impacts associated with the discharge of the FMZ. The important population is not expected to be reduced due to impacts associated with the Project.
• **reduce the area of occupancy of an important population**
Within the downstream study area, no habitat is likely to be impacted by changes to the PMF and 10% AEP, or by impacts associated with the discharge of the FMZ. The Project is unlikely to reduce the area of occupancy of the important population.

• **fragment an existing important population into two or more populations**
The *E. camfieldii* habitat in the downstream study area is in a partially fragmented condition, being partly contiguous with the native vegetation of the Blue Mountains and Yengo National Parks and Parr State Conservation Area. The Project may impact *E. camfieldii* habitat, however its connectivity to larger extents of native vegetation may reduce the number of new edges and 'fragments' created. The Project is therefore unlikely to fragment the existing population into two or more smaller populations.
• **adversely affect habitat critical to the survival of a species**
No critical habitat has been listed for *Eucalyptus camfieldii* under the EPBC Act.
• **disrupt the breeding cycle of an important population**
The breeding cycle ecology of *E. camfieldii* is poorly understood. However, the following information has been provided by the state and federal government which is relevant to understanding the breeding cycle of this eucalypt: • *E. camfieldii* populations appear to respond poorly to infrequent fire. • *E. camfieldii* flowers throughout the year. • The sizes of populations can be difficult to estimate as *E. camfieldii* can produce extensive lignotubers (up to 20 metres across), each with numerous stems. This can give the appearance that there are more individuals in a population than there are. Given the lack of understanding surrounding the breeding-cycle of E. camfieldii, the Project has been precautionarily assessed as acting as a disrupting force.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project could potentially impact *E. camfieldii* habitat within the downstream study area. Habitat may be destroyed and/or directly impacted through the clearing of native vegetation, the loss of habitat, and a reduction in the extent of ecological communities. Habitat may be indirectly impacted (modified, reduced in quality etc.) through alteration to soil conditions, edge effects, weed invasion and incursion, through the spread of disease and pathogens, erosion and sedimentation, and thorough changes to the fire regime.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
The OEH threatened species profile and Approved Conservation Advice for *E. camfieldii* both identify weed invasion as a threat. The Project may result in the spread and establishment of invasive flora species (weeds) into the habitat of *E. camfieldii*.
• **introduce disease that may cause the species to decline, or**
Eucalyptus species are known to be susceptible to infection by myrtle rust (*Austropuccinia psidii*), a disease caused by the exotic fungus *Uredo rangelii* (Makinson 2018; OEH 2011) and *E. camfieldii* has been proven to be susceptible to the disease (Morin *et al.* 2011). Myrtle rust was first detected in Australia in 2010 on the NSW Central Coast however it has since established along the entire mainland eastern seaboard, in parts of the Northern Territory and marginally in parts of Tasmania and Victoria (Makinson 2018; OEH 2011). Myrtle rust has already proved capable of infecting 258 native species or subspecies and has already led to serious declines of particular species (Makinson 2018). The myrtle rust pathogen favours moist habitats and human or human-related vectors seem more likely to have contributed to the spread of the disease (Makinson 2018). Myrtle Rust likely occurs within the downstream study area. Currently there is no Approved Threat Abatement Plan for Myrtle Rust listed under the EPBC Act.
• **interfere substantially with the recovery of the species.**
There is no Approved National Recovery Plan or threat abatement plan for *Eucalyptus camfieldii*. However, the Approved Conservation Advice (DEWHA 2008) provides a list of priority recovery and threat abatement actions that

can support the recovery of the species. Priority recovery and threat abatement actions involve monitoring known populations to identify threats, identifying populations of high conservation priority, ensuring that infrastructure, development and maintenance activities do not impact known habitat, investigate further formal conservation arrangements such as covenants and conservation agreements, implementing weed management or control, developing and implementing a fire management strategy, raise awareness of the species within the local communities in which it occurs and enabling recovery of additional sites and/or populations (TSSC 2015). The Project is not expected to interfere with the recovery of known populations of the species however it may impact upon habitat considered suitable and presumed to support an important population of *E. camfieldii* within the construction and downstream study areas.
Conclusion
The Project could potentially impact *E. camfieldii* habitat in the downstream study area. The species habitat may be impacted through changes to hydrology and potentially changes to the fire regime. The Project has been assessed as likely to have a significant impact on *E. camfieldii*.

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Eucalyptus sp. Cattai

Critically Endangered under the EPBC Act

Eucalyptus sp. Cattai is listed as Critically Endangered under the EPBC Act. It is a small, often mallee-form tree to 4.5 m with thick, somewhat fibrous, furrowed bark which is loose on the lower trunk. Adult leaves are lance-shaped (but can be broader) 4 - 12 centimetres long and 1 - 4 centimetres wide (OEH 2015). *Eucalyptus* sp. Cattai grows as isolated trees or small groups of trees in scrub, heath and low woodland, on sandstone-derived soils, sites which it occurs are generally flat and on ridge tops. This species is also associated with the edges of the Mittagong Formation, which may include Mittagong sandstone and shale, and at some sites with the presence of laterised loose stones (NSW SC 2015).

Eucalyptus sp. Cattai geographic distribution is very highly restricted, only known or predicted to occur in the following sub-regions of the Hawkesbury-Nepean Interim Biogeographic Regionalisation of Australia and is endemic to NSW (OEH 2019; TSSC 2018). The populations occur within the area bounded by Kellyville, Maraylya and Glenorie (OEH 2015) it is not known west of the Nepean river. Its extent of occurrence is approximately 40 square kilometres with the area of occupancy was estimated to be 32 square kilometres (NSW SC 2015). This species occurs is highly urbanised and the remnant vegetation is fragmented due to expanding urban development. One of the key threats to this species, across the geographic range, is the ongoing clearing and fragmentation, road works, disturbance to habitat from urban and rural-residential land use, clearing and understorey suppression for bushfire management, an altered fire regime and apparent lack of recruitment (NSW SC 2015). The two main reasons for the EPBC Act listing is a very highly restricted geographic range with an extent of occurrence, and, continuing decline is estimated in area and extent and quality of habitat and the number of mature individuals through ongoing clearing, too frequent fire and habitat degradation, as well as, severe fragmentation (TSSC 2018).

Targeted surveys for *Eucalyptus* sp*.* Cattai were not undertaken in the downstream, upstream or construction study areas for the Project. Additionally, *Eucalyptus* sp*.* Cattai was not incidentally encountered in the survey area during vegetation mapping associated with the Project.

In the absence of targeted surveys, *Eucalyptus* sp*.* Cattai has been assumed present in areas of presumed suitable habitat. For this assessment, suitable habitat for *Eucalyptus* sp*.* Cattai includes the PCTs that are associated with the species (as per the TBDC), BioNet Atlas Records and any other known vegetation types (as per scientific literature) that the species is associated with that has been mapped within the study area.

Suitable habitat includes the following PCTs, according to OEH's BioNet, that have been mapped within the downstream study area:

- PCT1181 (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
- PCT1183 (HN587) Smooth-barked Apple - Sydney Peppermint - Turpentine heathy open forest on plateaux areas of the Sydney Basin Bioregion
- PCT1081 (HN564) Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion.

Eucalyptus sp. Cattai was assessed as not having a moderate or higher likelihood of occurrence in the upstream or construction study areas. As such, it is only subject to this assessment within the downstream study area.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines a 'population of a species' as an occurrence of the species in a particular area. In relation to critically endangered, endangered or vulnerable threatened species occurrences include but are not limited to:

- a geographically distinct regional population, or collection of local populations.
- a population, or collection of local populations that occur within a particular bioregion.

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**
As *E.* sp. *Cattai* was not surveyed, areas of habitat have been used as a surrogate for the species occurrence. Within the downstream study area 27.99 hectares of habitat occurs between the existing and with-project 10% AEP flood extents, 0.14 hectares between the existing and with-project PMFs and 25.86 hectares within the FMZ discharge boundary. Impacts to this habitat has the potential to lead to a long-term decrease in the size of the population of *E*. sp. *Cattai*.
• **reduce the area of occupancy of a population of the species**
Within the downstream study area 27.99 hectares of habitat occurs between the existing and with-project 10% AEP flood extents, 0.14 hectares between the existing and with-project PMFs and 25.86 hectares within the FMZ discharge boundary. The Project has the potential to reduce the area of occupancy of the population within these areas.
• **fragment an existing population into two or more populations**
Habitat is assumed to be fragmented as 3.5% of the known habitat where the species has been recorded could potentially be removed or modified within the downstream study area of the Project. No fragmentation is expected in the construction study area or the upstream study areas.
• **adversely affect habitat critical to the survival of a species**
The Minister maintains a 'Register of Critical Habitat' under the EPBC Act in which habitat as identified as being critical to the survival of a listed threatened species is provided. To date, no critical habitat is listed for this species that occurs within or proximal to the construction, upstream or downstream study areas.   Suitable habitat presumed to support a population of *Eucalyptus* sp. Cattai has been assessed as habitat critical to the survival of the species. This habitat is important for dispersal, the long-term maintenance of the species and for maintaining genetic diversity. It is also important for maintaining ecological processes essential to the survival for the species. The Project may adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive species, erosion and deposition, and modifying hydrology and the fire regime. Accordingly, the Project may adversely affect habitat critical to the survival of *Eucalyptus* sp. Cattai.
• **disrupt the breeding cycle of a population**
Eucalyptus sp. Cattai has viable seeds although it infrequently is seen with juveniles in the wild. Any modification to the landscape can only be assumed to have a negative effect on the breeding cycle for this species. An increase in frequency of the fire regime between the 10% AEP existing and the 10% AEP in the downstream study area may destroy viable seed in the seed bank. The increase in the flooding of the FMZ zone may hamper the viability of the seed bank for the habitat within this zone due to the extended inundation time.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project could potentially impact *Eucalyptus* sp. Cattai habitat in the downstream study area which could potentially modify, destroy, remove or isolate or decrease the availability or quality of habitat comprising Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney, Sydney Basin Bioregion (PCT1181) and Smooth-barked Apple - Sydney Peppermint - Turpentine heathy open forest on plateaux areas of the Sydney Basin Bioregion (PCT1183) to the extent that the species may decline
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
Potential increases in weeds due to disturbance of the vegetation in the downstream inundation and FMZ areas and also the drying out of the change between the existing and with Project 10% AEP is expected. Increased of fire

frequencies and intensities caused by the Project could impact on the distribution and occurrence of certain weed species – for example *Cirsium vulgare is* an early coloniser after fire. Early colonising weed species may outcompete seedling and juvenile *E*. sp. *Cattai* after fire events.
• **introduce disease that may cause the species to decline, or**
There are no diseases that are known to specifically affect *Eucalyptus* sp. Cattai listed under the conservation advice or the SPRAT database. The Myrtaceae family is known to be affected by Myrtle Rust and some eucalyptus species can be affected by Eucalyptus Rust. Myrtle Rust is not currently covered by an Approved Threat Abatement Plan.
• **interfere with the recovery of the species.**
There is currently no National Recovery Plan for *Eucalyptus* sp. Cattai. The SPRAT database and the Approved Commonwealth Conservation Advice for *Eucalyptus* sp. Cattai refers to the Saving Our Species Program as adequate for the recovery plan. OEH has developed a recovery plan and objectives for various threatened species as part of the Saving Our Species (SoS) Program, with the aim to use site managed sites for *Eucalyptus* sp. Cattai. Two priority management sites were identified in NSW, *Eucalyptus* sp. Cattai Translocation site and the Hills Shire Site. These sites have no overlap on the local population in the study area. The Project has no impacts on the objectives of the SoS program. It is unlikely to be any interactions between the local population in the study area and the populations within these two key priority management sites. Therefore, the Project is not inconsistent with achieving the management aspects of these two priority management sites. No currently approved Threat Abatement plans apply to *Eucalyptus* sp. Cattai in context of the Project impacts.
Conclusion
The local population of *Eucalyptus* sp. Cattai has been assessed as occurring within the study area from the PCT associated with its habitat, however, no records of the species occur within the 10% AEP event changed flood extent or within the Project study area. Records for the species occur immediately outside the Project study area, within the main known distribution of the species occurring on surrounding ridgetops. The Project is unlikely to result in a significant impact on *Eucalyptus* sp. Cattai within the 10% AEP event changed flood extent.

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Eucalyptus glaucina (Slaty Red Gum)

Vulnerable under EPBC Act

Slaty Red gum (*Eucalyptus glaucina*) is listed as Vulnerable under the EPBC Act. *E. glaucina* is a small to medium sized tree, between 18 to 30 metres high (Brooker and Kleinig 2006). The bark sheds over the whole trunk in large plates or flakes to leave a smooth of granular, mottled surface of white or various shades of grey (Brooker and Kleinig 2006). The species was originally known from the Rappville district, south of Casino, and in a number of localities in the Taree, Stroud, Dungog and Paterson districts of NSW (Johnson 1962). This species occurs within the Hunter Central Rivers and the Northern Rivers (NSW) Natural Resource Management Regions. *E. glaucina* grows in a range of situations, from shallow soils or stony hillsides to grassy woodland on deep, moderately fertile and well watered soil and gentle slopes near drainage lines in alluvial and clayey soils (Chippendale 1988; Harden 1991).

E. glaucina was incidentally recorded in the upstream study area, representing a geographical range extension for the species. The species is considered to have a 'low' likelihood of occurring within the construction and downstream study areas due to a lack of suitable habitat or known records. Targeted surveys were not undertaken in any study area and records of the species occurrence are limited to incidental observations. *E. glaucina* was recorded along all the major rivers feeding into Lake Burragorang including the Coxs River, Wollondilly River and Nattai River in the upstream study area. However, an estimation on the number of individuals within the local population is difficult to establish considering the enormity of the study area and the limitations to which it was surveyed.

E. glaucina has been assumed present in areas of presumed suitable habitat. For this assessment, suitable habitat for *E. glaucina* includes the PCTs that the species was recorded in or are associated with the species (as per the TBDC) that have been mapped within the upstream study area.

Suitable habitat includes the following PCTs that have been mapped within the upstream study area:

- HN557 (PCT 1401) Narrow-leaved Ironbark - Forest Red Gum on rocky slopes of the lower Burragorang Gorge, Sydney Basin Bioregion.
- HN525 (PCT 832) Forest Red Gum - Narrow-leaved Ironbark open forest of the southern Blue Mountains gorges, Sydney Basin Bioregion.
- HN527 (PCT 840) Forest Red Gum - Yellow Box woodland of dry gorge slopes, southern Sydney Basin Bioregion and South Eastern Highlands.
- HN532 (PCT860) Grey Gum - Broad-leaved Ironbark dry open forest on gorge slopes on the Blue Mountains, Sydney Basin Bioregion.
- HN535 (PCT870) Grey Gum - Thin-leaved Stringybark grassy woodland of the southern Blue Mountains gorges, Sydney Basin Bioregion.
- HN536 (PCT 871) Grey Gum shrubby open forest on gorge slopes of the Blue Mountains, Sydney Basin Bioregion.
- HN538 (PCT 877) Grey Myrtle dry rainforest of the Sydney Basin Bioregion and South East corner Bioregion
- HN553 (PCT 941) Mountain Blue Gum - Thin-leaved Stringybark open forest on river flat alluvium in the Sydney Basin Bioregion.

Therefore, suitable habitat for the species is approximately 4,163.71 hectares.

This Assessment of Significance has been prepared in accordance with the *Matters of National Environmental Significance: Significant impact guidelines* (DoE 2013). According to these guidelines, the questions for an 'Vulnerable' species is related to 'an important population of a species'. The guidelines define an 'important population of a species' as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal*
- *populations that are necessary for maintaining genetic diversity, and/or*
- *populations that are near the limit of the species range.'*

As the *E. glaucina* in the upstream study area represents a geographical range extension for the species, the suitable habitat within the upstream study area is considered to support an important population of this 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: • **lead to a long-term decrease in the size of an important population of a species**
Prior to SMEC recording *E. glaucina* in the upstream study area, most recent records of the species have primarily been north of Sydney near Casino and from Taree to Broke (according to the AVH 2020). The occurrences of *E. glaucina* within the upstream study area are therefore considered to be an 'important population' as they represent a 'population that is near the limit of the species range' and they are therefore likely to be key source population either for breeding or dispersal and necessary to maintaining genetic diversity. The Project is estimated as potentially affecting up to about 4,163.71 hectares of suitable habitat within the PMF presumed to support an important population of *E. glaucina* within the upstream study area. Within the 1% AEP 2,243.09 hectares of habitat occurs and within the 20% AEP about 473.67 hectares occurs. Impact to this habitat may lead to a long-term decrease in the size of the important population.
• **reduce the area of occupancy of an important population**
The Project could potentially affect up to about 4,163.71 hectares of suitable habitat within the upstream study area. Within the 1% AEP flood extent 2,243.09 hectares of habitat occurs and within the 20% AEP flood extent about 473.67 hectares occurs. The Project has the potential to reduce the area of occupancy of the important population.
• **fragment an existing important population into two or more populations**
The current state of habitat for *E. glaucina* in the upstream study area is intact and contiguous with adjoining national parks with minimal to no fragmentation. The Project has the potential to fragment the important population into two or more smaller populations through associated with alterations to habitat (upstream study area).
• **adversely affect habitat critical to the survival of a species**
The Minister maintains a 'Register of Critical Habitat' under the EPBC Act in which habitat as identified as being critical to the survival of a listed threatened species is provided. To date, no critical habitat is listed for this species that occurs within or proximal to the upstream study area. It is therefore assumed that all habitat is critical to the survival of the species and that the Project has the potential to adversely affect this habitat.
• **disrupt the breeding cycle of an important population**
The breeding cycle specific to *E. glaucina* is not well-documented in scientific literature. *E. glaucina* likely has a pollinator assemblage comprising of different insects, birds (primarily honeyeaters and lorikeets), mega-chiropteran bats, arboreal marsupials and rodents as these animals are known to pollinate plants of the genus Eucalyptus (OEH 2016). The Project has been precautionarily assessed as having potential to disrupt the breeding-cycle processes within an important population.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project could potentially affect suitable habitat within the upstream study area, presumed to support an important population of *E. glaucina*. The condition, quality and integrity of this habitat could be modified or in the worst case, destroyed as a result of the impacts associated with the Project. Potential impacts associated with the upstream study area include changes to hydrology associated with an increase in extent, duration and frequency of temporary inundation upstream, long-term erosion and sedimentation and changes to vegetation structure, composition and condition. Through any one of these impacts (or a combination) the condition, quality and integrity of suitable habitat may be adversely affected to a point in which it could lead to a decline in the species.

• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
Within the upstream study area, potential impacts associated with the Project such as changes to inundation regimes, erosion and sedimentation may create an environment that is conducive to the establishment and spread of invasive weeds harmful to the important population. As the habitat in the construction study area is contiguous with the upstream study area, there is potential for invasive species to move into this area. The risk of the introduction of invasive weeds during the construction phase can be effectively mitigated through hygiene controls and weed management. It has been assumed such controls will be implemented during construction. In this regard, it is considered unlikely that the Project would result in invasive species becoming established in this species' area of habitat.
• **introduce disease that may cause the species to decline, or**
There are two exotic rusts currently known to constitute a major threat to native Australian plants of the Myrtaceae family (including species of the genus Eucalyptus). These are Myrtle Rust (*Austropuccinia psidii*) and Eucalyptus Rust (*Puccinia psidii*). Myrtle rust is known to occur in Australia however Eucalyptus Rust has not yet been detected in Australia but is identified as having a high potential for entry to Australia (NSW Scientific Committee 2011). In addition, a soil-borne pathogen, root-rot fungus (*Phytophthora cinnamomi*) is known to affect Eucalypt species by causing dieback. There is considerable evidence that increasing levels of human activity can facilitate the establishment and spread of myrtle rust and root-rot fungus. As the habitat in the construction study area is contiguous with the upstream study area, increased vehicular movements associated with vegetation clearance and construction activities may facilitate the spread and establishment of the pathogens into the upstream study areas. Myrtle Rust is not currently covered by an Approved Threat Abatement Plan.
• **interfere substantially with the recovery of the species.**
It was determined by the Commonwealth that a National Recovery Plan was not required for this species (DAWE 2020). However, the Approved Conservation Advice (2008) provides a number of regional and local priority recovery and threat abatement actions that can be done to support the recovery of Slaty Red Gum. The Project would interfere substantially with the recovery of the species particularly as it may modify and destroy suitable habitat known to be occupied by the species. No currently approved Threat Abatement plans apply to *Eucalyptus glaucina* in context of the Project impacts.
Conclusion
The Project will likely have a significant impact on *E. glaucina* as it may affect up to about 4,163.71 hectares of habitat supporting an important population of the species. The species was recorded incidentally by SMEC in the upstream study area representing a geographical range extension for the species and is therefore likely to constitute an 'important population'. The Project has been assessed as likely to have a significant impact on *E. glaucina.*

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Euphrasia bowdeniae

Vulnerable under the EPBC Act

Euphrasia bowdeniae is a semi-parasitic herb – their rootlets may connect to other plants - that grows to between 7 and 20 centimetres tall when fully grown (OEH 2019). Adult plants have ascending branches each with two rows of stiff recurved non-glandular hairs. Leaves are elliptic to obovate, 4 to 7.5 millimetres long and 1.2 to 3.2 millimetres wide. Racemes usually support between 4 and 10 flowers but have been observed with twice this amount on rare occasions. Flowers are between 7 and 10.5 millimetres long, mauve to violet with deeper colouration at the throat (PlantNET 1992).

The *Euphrasia bowdeniae* distribution is restricted to the Upper Blue Mountains, NSW. The species occurs only at Wentworth Falls but previously occurred at Blackheath and the Jamieson Valley in 1982 (Barker 1982). Habitat occurs at altitudes between 600 and 750 metres, usually as wet vertical sandstone rock faces on south or eastern facing cliffs. Individuals grow in small pockets of sandy soil that is associated with the Hassans Walls soil landscape. Individuals have also been observed in damp sandy sites at the tops of cliffs (OEH 2019).

According to OEH’s BioNet system, *E. bowdeniae* is associated with the following PCT mapped in the upstream study area:

- PCT 769 (HN517): Coachwood - Lilly Pilly warm temperate rainforest in moist sandstone gullies Sydney Basin Bioregion

E. bowdeniae was assessed with a low likelihood of occurring in the construction and downstream study areas. As such, it was not considered likely to be impacted by the Project in these study areas and therefore not subject to assessment in these study areas.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an ‘important population’ of a Vulnerable species as being ‘*a population that is necessary for a species’ long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal.*
- *populations that are necessary for maintaining genetic diversity.*
- *populations that are near the limit of the species range.*

Targeted surveys for *E. bowdeniae* were not undertaken in the upstream study area. In the absence of targeted surveys, *E. bowdeniae* has been assumed present in areas of suitable habitat – the previously listed PCT. Using the precautionary principle, the population(s) residing within this habitat have been assessed as an important population(s) as they would be necessary for maintaining genetic diversity, and occur near the limit of the species range.

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**
As *Euphrasia bowdeniae* was not surveyed, areas of habitat have been used as a surrogate for the species occurrence. Within the upstream study area 10.89 hectares of habitat has been mapped. Of this 10.89 hectares, 1.01 hectares may be impacted by a 1 in 5 chance in a year flood event (20% AEP) and 5.60 hectares by a 1 in 100 chance in a year flood event (1% AEP). It is unlikely that impacts to these areas of habitat will lead to a long-term decrease in the size of the important population.
• **reduce the area of occupancy of an important population**
The Project may impact the area of occupancy of the important population by 5.60 hectares within the upstream 1% AEP and 1.01 hectares within the 20% AEP. However, it is considered unlikely that it would reduce the area of occupancy of this population.

• **fragment an existing important population into two or more populations**
The *Euphrasia bowdeniae* habitat within the upstream study area may have already been fragmented through the construction of the original dam wall. The Project may further fragment this habitat. The further fragmentation of this habitat is however unlikely to fragment the assessed population into two or more smaller populations.
• **adversely affect habitat critical to the survival of a species**
No critical habitat has been listed for *Euphrasia bowdeniae* under the EPBC Act.
• **disrupt the breeding cycle of an important population**
Euphrasia bowdeniae flowers from September to December, with fruiting occurring shortly thereafter. Seeds are only dispersed a short distance, with seed accumulation being restricted to nearby soil/sand pockets on ledges or at the bases of cliffs. This indicates that soil storage – the seed bank – is limited to those small pockets of sandy soil making colonisation of new habitat niches difficult. The Project may impact the breeding cycle of *E. bowdeniae* by damaging the seed bank. *Euphrasia bowdeniae* is likely to be fire-sensitive (OEH 2019). The Project has the potential to alter the fire regime within the upstream study area. Being restricted to permanently wet sandstone cliff-faces, it is however less likely that *E. bowdeniae* habitat would be altered to the same extent – if at all. While possible, it is therefore unlikely that an altered fire regime may impact on *E. bowdeniae* habitat such that it disrupts the breeding cycle of the important population.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project has the potential to impact *E, bowdeniae* habitat (PCT 769) within the upstream study area. Habitat may be destroyed through the clearing of native vegetation, the loss of habitat, and a reduction in the extent of ecological communities. Habitat may be indirectly impacted (modified, reduced in quality etc.) through fragmentation, alteration to soil conditions, erosion and sedimentation, and thorough changes to the fire regime.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
Invasive species have not been identified as a threat to *E. bowdeniae* in either the Approved Conservation Advice (DEWHA 2008) or the OEH threatened species profile (OEH 2019). Regardless, the Project is unlikely to result in invasive species becoming established in the habitat of *E. bowdeniae*.
• **introduce disease that may cause the species to decline, or**
No diseases have been identified as a threat to *E. bowdeniae*.
• **interfere substantially with the recovery of the species.**
No National Recovery Plan has been developed for *E. bowdeniae* under the EPBC Act. The following reason was provided: *Recovery Plan not required, included on the Not Commenced List* The Approved Conservation Advice for *E. bowdeniae* (DoEWAH 2008) does provide the following conservation 'priority actions' however: 1. Identify populations of high conservation priority. 2. Manage threats to areas of vegetation that contain populations/occurrences of Euphrasia bowdeniae. 3. Ensure recreational walking track use, construction and maintenance activities do not adversely impact on known populations of Euphrasia bowdeniae. 4. Manage any changes to hydrology that may result in changes to the water table levels, increased run-off, sedimentation or pollution. 5. Investigate formal conservation arrangements for populations outside the national park, such as the use of covenants, conservation agreements or inclusion in reserve tenure.

6. Develop and implement a suitable fire management strategy for Euphrasia bowdeniae.
7. Provide maps of known occurrences to local and state Rural Fire Services and seek inclusion of mitigative measures in bush fire risk management plans, risk register and/or operation maps.
8. Raise awareness of E. bowdeniae within the local community.
9. Review conservation status if targeted surveys for the species fail to locate significant new populations.
10. Investigate options for linking, enhancing or establishing additional populations.
11. Implement appropriate national translocation protocols (Vallee *et al.* 2004) if establishing additional populations is considered necessary and feasible.
12. Undertake seed collection and storage.

The Project could interfere with priority action 4.

No currently approved Threat Abatement plans apply to *E. bowdeniae* in context of the Project impacts.

Conclusion

The Project has the potential to impact *E. bowdeniae* habitat across the upstream study area. This impact is not expected to lead to a long-term decrease in the important population. The Project is not expected to fragment the important population or disrupt its breeding cycle. The Project may interfere with one conservation management action.

The Project has been assessed as having a likely minimal impact on *E. bowdeniae*.

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Genoplesium baueri (Bauer's Midge Orchid)

Endangered under the EPBC Act

Genoplesium baueri (Bauer's Midge Orchid) is a brittle terrestrial orchid that can grow to 15 centimetres tall. This orchid species produces a sparsely flowered inflorescence (1-6 flowers) that can get to three centimetres long. The flowers are yellowish-green and red in colour with the petals reaching 3 millimetres long, the lateral sepals 10 millimetres long, the dorsal sepal 3.5 millimetres long and labellum 4 millimetres long. The Conservation Advice for *G. baueri* states that flowering occurs between December and April (DoE 2014) however the NSW Scientific Committee's final determination writes that flowering is between December and March (OEH 2012), while flowering is said to occur in February and March according to OEH's threatened species profile (OEH 2018).

G. baueri is endemic to NSW. It has been recorded in coastal areas from Ulladulla on the NSW South Coast to Port Stephens on the NSW Mid-North Coast. Outlier records have been made further west at Woodford in the Blue Mountains and Penrose State Forest in the Southern Highlands (OEH 2012; DoE 2014). Within its recognised distribution about half of the recorded sightings of *G. baueri* were made before 1960. Most of the older records are from suburbs in Sydney such as Asquith, Cowan, Gladesville, Longueville and Wahroonga (OEH 2018). Remaining populations are now contained within Berowra Valley Regional Park, Royal National Park and Lane Cove National Park. These populations support about 200 plants over 13 sites. OEH (2018) acknowledges however that populations unknown to science may occur within the Woronora, O'Hares, Metropolitan and Warragamba catchments.

The habitat of *G. baueri* seems to be variable. It is written in the Conservation Advice for *G. baueri* (DoE 2014) that habitat includes heathland and shrubby woodland supported by sands or sandy loams, or in open forest, shrubby forest and heathy forest occurring on well-drained sandy and gravelly soils. The NSW Scientific Committee's final determination (OEH 2012) adds that *G. baueri* has been recorded in moss gardens occurring over sandstone.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines a 'population of a species' as an occurrence of the species in a particular area. In relation to critically endangered, endangered or vulnerable threatened species occurrences include but are not limited to:

- a geographically distinct regional population, or collection of local populations.
- a population, or collection of local populations that occur within a particular bioregion.

Targeted surveys for *G. baueri* were not undertaken in the upstream, downstream or construction study areas and it was not incidentally encountered during the vegetation mapping associated with the Project. In the absence of targeted surveys and taking into consideration the limited ecological understanding of *G. baueri* habitat, this orchid has been assumed to have a moderate likelihood of occurrence within the upstream and construction study areas. This species has been assessed with a low likelihood of occurring in the downstream study area. Using the precautionary principle, the occurrence within the upstream and construction these two study areas has been assessed as comprising a population of the species.

An action is likely to have a significant impact on an endangered or critically 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 of a species**
As *G. baueri* was not surveyed for and its habitat preferences are unknown, the areas of native vegetation within the study areas has been used as a surrogate for the species occurrence and population size. Within the upstream study area 953.48 hectares of habitat has been mapped. Of this area, 93.92 hectares may be impacted by a 1 in 5 chance in a year flood event (20% AEP) and 470.95 hectares by a 1 in 100 chance in a year flood event (1% AEP). 223 hectares occurs in the upstream impact area. For the purpose of the assessment, it has been assumed that there would be a total loss of biodiversity values in the upstream impact area. 22.42 hectares of habitat occurs within the Development Footprint associated with construction activities. Impacts associated with all scenarios could lead to long-term decrease(s) in the size of the population.

• **reduce the area of occupancy of a species**
The Project may reduce the potential area of occupancy for *G. baueri* across two study areas. These reductions can be summarised according to the following impact scenarios: Upstream Study Area • 1% AEP (1 in 100 chance in a year flood): 470.95 hectares • 20% AEP (1 in 5 chance in a year flood): 93.92 hectares • Upstream impact area: 223.00 hectares For the purpose of the assessment, it has been assumed that there would be a total loss of biodiversity values in the upstream impact area. Construction Study Area • Development footprint: 22.42 hectares The Project is considered to have the potential to reduce the occupancy of this species.
• **fragment an existing population into two or more populations**
The habitat of *G. baueri* has been assessed as all the native vegetation occurring within the upstream, downstream and construction study areas. Within the downstream study area, most of the native vegetation occurs as remnant stands of the forests and woodlands that once covered the Cumberland Plain. The degree to which these stands of native vegetation have been degraded varies from substantial (for example, the riparian vegetation along the Lower Nepean River) to minor (for example, the ridges and mid-slopes of Maroota Ridge State Conservation Area). These stands of native vegetation are often isolated (or partially) from one another through agricultural and residential development and/or public infrastructure. The Project has the potential to further fragment the native vegetation in the downstream study area. The native vegetation in the upstream and construction study areas is comparatively contiguous and undisturbed. The potential impacts of the Project on native vegetation could contribute to fragmentation of *G. baueri* habitat.
• **adversely affect habitat critical to the survival of a species**
According to the *Matters of National Environmental Significance Significant impact guidelines* 1.1 (DoE 2013) habitat critical to the survival of a species refers to areas that are necessary for: • activities such as foraging, breeding, roosting, or dispersal • 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 • the reintroduction of populations or recovery of the species or ecological community. The *G. baueri* habitat in the upstream, downstream and construction study areas has been assessed as critical habitat because it is important for dispersal, the long-term maintenance of the species and for maintaining genetic diversity. The Project could potentially adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive species, erosion and deposition, and modifying hydrology and the fire regime.
• **disrupt the breeding cycle of a population**
Unlike some other orchids, *G. baueri* does not produce a new tuber after every time it emerges from the ground. Instead *G. baueri* persists from a single tuber-like perennial root (DoE 2014). *G. baueri* individuals may not emerge every year though, and when they do, they are only visible for about two months before dying back to their tuber-like roots. It is not known what triggers the emergence of individuals, but it has been reported that the species is most often seen shortly after fire (Riley and Banks 2002). The local population of *G. baueri* has been assessed using the precautionary principle as occurring across the entirety of the study areas. The local population could potentially be impacted through changes to the fire regime

(potentially important to the breeding cycle of *G. baueri*) and modifications to the hydrology. The Project could potentially disrupt the breeding cycle of the population.

- **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**

The Project could potentially impact *G. baueri* habitat within the upstream and construction study areas. *G. baueri* habitat could potentially be destroyed and/or directly impacted through the clearing of native vegetation. Habitat could be indirectly impacted (modified, reduced in quality etc.) through fragmentation, alteration to soil conditions, edge effects, weed invasion and incursion, erosion and sedimentation, and thorough changes to the fire regime. The impacts caused by the Project to the *G. baueri* habitat could potentially cause the species to decline.

- **result in invasive species that are harmful to an endangered or critically endangered species becoming established in the endangered or critically endangered species' habitat**

The OEH species profile for *G. baueri* identifies the European Rabbit as a possible threat. It states, 'browsing by swamp wallabies and possibly rabbits is known to have removed flowering and fruiting stems at the site in the Ku-Ring-Gai Wildflower Garden. Whilst this damage is not expected to kill plants it may adversely impact future recruitment potential' (OEH 2019). It is unknown if the Project would promote the spread of the European Rabbit throughout *G. baueri* habitat.

- **introduce disease that may cause the species to decline, or**

No diseases have been identified as a threat to *G. baueri*.

- **interfere substantially with the recovery of the species.**

No National Recovery Plan has been developed for *G. baueri* under the EPBC Act. The Approved Commonwealth Conservation Advice for *G. baueri* outlines the following conservation objectives, required management actions and required information:

Conservation objectives

1. Population increases so that the species is secure in the wild to the point of being delisted.
2. Expanded area of occupancy.

Information required

1. All individuals located in intensive surveys of nearby potential habitat.
2. Status assessed across historical and potential new locations.
3. Design and implement a monitoring program or, if appropriate, support and enhance existing programs.

Management actions required

1. Ensure sites where species occurrences are protected from disturbance by trail bike riding, rubbish dumping and track and road maintenance by barriers and/or fencing.
2. Maintain natural habitat of the species.
3. As the species exists in well-drained habitat types, any alteration to hydrology at all sites should be avoided.

A targeted strategy for managing *G. baueri* has been developed under the Saving Our Species Program (NSW Government). Under the Saving Our Species Program *G. baueri* has been assigned to the 'site-managed species' management stream. The following four priority management sites have been identified in the Saving Our Species Program for *G. baueri*:

- Ku-Ring-Gai Chase National Park in the Hornsby LGA
- Ku-Ring-Gai Wildflower Garden in the Ku-Ring-Gai LGA
- Bombaderry Creek in the Shoalhaven LGA
- Callala in the Shoalhaven LGA.

The Project would not impact any of the identified priority management sites.

No currently approved Threat Abatement plans apply to *G. baueri* in context of the Project impacts.

Conclusion
The Project could potentially impact *G. baueri* habitat and reduce the size of the population(s). The Project may impact the breeding cycle of *G. baueri* by clearing native vegetation (habitat), modifying the fire regime and modifying the hydrological environment. These impacts could potentially cause a decline of *G. baueri*. The Project has been assessed as likely to have a significant impact on *G. bauera.*

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Grevillea parviflora subsp. *parviflora* (Small-flower Grevillea)

Vulnerable under the EPBC Act

Grevillea parviflora subsp*. parviflora* is a small flowering grevillea with a spindly habit that can be low spreading or erect in habit. The leaves are crowded, narrow and 2-3.5 centimetres long with a shortly pointed apex and silky hairs on the underside with recurved leaf margins. The flowers are spider like in groups of 6-12 in white to pinkish in July to December, and in April and May. The fruit is a capsule 8-10mm long. The flowers are pollinated by insects and one or two seeds are produced although dispersal is possibly less than 2m.

Grevillea parviflora subsp*. parviflora* occurs on ridges, crests, upper slopes or flat plains in exposed slightly disturbed sites close to tracks and roads. They are found on soils derived from tertiary sands and alluvium form the Mittagong formations where their soils consist of sands, light clays over thin shales with lateritic ironstone gravel. The vegetation types that this species is associated with vary from heath to scrubby woodland and open forest. Canopy species can include *Acacia suaveolens, Eucalyptus oblonga, E. piperita, E. racemosa, Grevillea diffusa, G.* mucronulata and *Persoonia pinifolia*. Communities that this species is known in association with are Kurri Sand Swamp Woodland, in open forest of Spotted Gum, Sydney Sandstone Ridgetop Woodland at Wedderburn and Castlereagh Ironbark Woodland at Kemps Creek. *Grevillea parviflora* subsp*. parviflora* is associated with three threatened ecological communities listed under the EPBC Act: Shale/Sandstone Transition Forest (Endangered), White Box-Yellow Box-Blakely's Red Gum Grassy Woodland (Critically Endangered) and Turpentine-Ironbark Forest (Critically Endangered).

G. parviflora subsp*. parviflora* is endemic to NSW with possibly 21 populations around the Sydney basin. This subspecies is known from Picton, Appin, Bargo where the species is associated with the Nepean and Georges Rivers, prospect to Woronora plateau and kemps creek to voyager point, as well as other areas in the Hunter Valley, Central Coast, Lake Macquarie. The exact number of the *Grevillea parviflora* subsp*. parviflora* is not known due to its suckering nature the number of plants on site are difficult to accurately determine. Significant sites are considered to include more than 50 plants, with varying age, structure and have active recruitment of seedlings.

Habitat loss and degradation is a threat to *G. parviflora* subsp*. parviflora*, as well as weed invasion, and recruitment and disturbance frequency. Urban development road maintenance and mining are activities leading to habitat loss, resulting from overshading, altered hydrology, grazing pressure, mowing, rubbish dumping and increased levels of nutrients in the soils. This can lead to the isolation on populations, reduced gene flow and lower genetic diversity affecting the longer-term viability of the species. This species suckers after fire regeneration from root stock although seedling recruitment is uncommon, altered fire regimes can reduce the local population’s viability.

While no targeted threatened flora species surveys were carried out in the study area, incidental observations of *G. parviflora* subsp. *parviflora*, listed as Vulnerable under both the BC Act and EPBC Act, were recorded within the construction development site and may be affected by clearing. As this species can reproduce by suckering, the species may persist in disturbed areas as well as more intact extents of native vegetation.

In the absence of targeted surveys, *G. parviflora* subsp*. parviflora* has been assumed present in areas of presumed suitable habitat across the upstream, downstream and construction study areas. For this assessment, suitable habitat for *G. parviflora* subsp*. parviflora* includes the PCTs that are associated with the species (as per the TBDC), BioNet Atlas Records and any other known vegetation types (as per scientific literature) that the species is associated with that has been mapped within the study area.

Suitable habitat includes the following PCTs that have been mapped within the study areas:

- 724 Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain, Sydney Basin Bioregion
- 725 Broad-leaved Ironbark - *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain, Sydney Basin Bioregion
- 883 Hard-leaved Scribbly Gum - Parramatta Red Gum heathy woodland of the Cumberland Plain, Sydney Basin Bioregion
- 1081 Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion
- 1281 Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion
- 1395 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) define an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal*
- *populations that are necessary for maintaining genetic diversity, and/or*
- *populations that are near the limit of the species range.*

The *G. parviflora* subsp. *parviflora* occurring across the three study areas would be large enough to represent a key source population for breeding and dispersal. The occurrence across the three study areas would also represent the most south-westerly extent of the species' range. The *G. parviflora* subsp. *parviflora* occurring across all three study areas has subsequently been assessed as 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**
Within the upstream study area approximately 32.52 hectares of habitat has been mapped. Of this 32.52 hectares, 3.66 hectares may be impacted by a 1 in 5 chance in a year flood event (20% AEP) and 17.49 hectares by a 1 in 100 chance in a year flood event (1% AEP). Nine hectares would be removed in the upstream impact area. A general reduction in the peak flood events and duration is expected within the downstream study area outside of the FMZ. This equates to about 11.79 hectares of suitable habitat occurring between the existing and with PMFs. No suitable habitat occurs within the FMZ discharge area or between the existing and with-Project 10% AEPs. 4.40 hectares of habitat occurs within the development footprint associated with construction activities. The Project is considered unlikely to lead to a long term decrease of an important population in the downstream study area given the absence of the species in the FMZ area and the changed 10% AEP flood event area. The Project has the potential to lead to a long term decrease of an important population in the upstream and construction study areas.
• **reduce the area of occupancy of an important population**
The Project may reduce the potential area of occupancy for *Grevillea parviflora* subsp. *parviflora* across the upstream and construction study areas. These reductions can be summarised according to the following impact scenarios: Upstream Study Area • 1% AEP (1 in 100 chance in a year flood): 17.49 hectares • 20% AEP (1 in 5 chance in a year flood): 3.66 hectares • Upstream impact area: 9.00 hectares Downstream Study Area • FMZ discharge area: 0 hectares • Difference between the existing and with project 10% AEPs: 0 hectares • Difference between the existing and with project PMFs: 11.79 hectares Construction Study Area • Development footprint: 4.40 hectares
• **fragment an existing important population into two or more populations**
Fragmentation has the potential to occur across the downstream study area. However, limits to the extent of the mapping in the downstream study area is likely to underestimate the area of land that could potentially be affected by fragmentation. On the other hand, the construction and upstream study areas have high-quality well-connected habitat as they are adjoining the Blue Mountains National Park. Impacts to habitat in the upstream and

construction study areas are therefore less likely to cause habitat fragmentation and isolate occurrence of *G. parviflora* subsp. *parviflora* from one another.

- **adversely affect habitat critical to the survival of a species**

The Minister maintains a 'Register of Critical Habitat' under the EPBC Act in which habitat as identified as being critical to the survival of a listed threatened species is provided. To date, no critical habitat is listed for this species that occurs within or proximal to the construction, upstream or downstream study areas.

- **disrupt the breeding cycle of an important population**

G. parviflora subsp. *parviflora* is a small flowering grevillea with a spindly habit, flowering between July and December. This species is cross-pollinated by insects although the seed dispersal is usually less than 2m. Changes to the hydrology of sites containing this species could potentially reduce the genetic diversity for this species if it occurs during the flowering period or when the seedlings germinate before they become established.

- **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**

The habitat potentially affected by the Project appears to be in good condition from desktop searches as the majority of the vegetation with any potential impact is within the gullies and creek lines. Changes to the pattern and frequency of inundation may increase the time this species may be inundated within the upstream and downstream study areas. There may be a drying out of the area between the 10% AEP with Project compared to the existing 10% AEP in the downstream study area, however, as noted previously no suitable habitat occurs in this area.

- **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**

Competition with weeds and exotic species may impact the local population of *Grevillea parviflora* subsp. *parviflora*. Exotic plants such as Lantana and African Olive become established in disturbed areas quickly. Such plants can out-compete native plants, especially seedlings and juveniles. If seedlings and juveniles are outcompeted, recruitment of new individuals into a population cannot take place.

- **introduce disease that may cause the species to decline, or**

The dispersal of *Phytophthora cinnamomi* can be mediated through water and through eroded soil. The Project has the potential to facilitate the spread of *P. cinnamomi* throughout the study area and therefore contribute to this key threatening process listed under the EPBC Act. An approved Threat Abatement Plan has been developed for *P. cinnamomi* under the EPBC Act (DoEE 2017). The Project interferes with Objective 2 of the plan - Reduce the spread and mitigate the impacts of Phytophthora to protect priority biodiversity assets and susceptible landscapes.

- **interfere substantially with the recovery of the species.**

No National Recovery Plan has been developed for *Grevillea parviflora* subsp. *parviflora*. OEH (now DPIE) however, has developed a recovery plan and objectives for various threatened species as part of the Saving Our Species (SoS) Program. This species is data deficient with the SoS objectives identified to undertake a threat assessment to determine sensitivity to pathogens (for example, Phytophthora). Assess recruitment and pollination success, impacts of fire and use genetics to determine the diversity of individuals.

Conclusion

The Project could potentially impact *G. parviflora* subsp. *parviflora* habitat across the upstream, downstream and construction study areas. The Project may impact this species by clearing native vegetation in the construction impact area, by reducing the area of occupancy (habitat), and by modifying the fire regime and hydrological environment. This may have an affect on the breeding cycle for this species. The threat of invasive flora species could also be exacerbated by the Project. These impacts could potentially cause a decline of important population of *Grevillea parviflora* subsp. *parviflora*.

The Project has been assessed as likely to have a significant impact on *Grevillea parviflora* subsp. *parviflora*.

References

Department of the Environment (DoE) (2013) Matters of National Environmental Significance: Significant impact guidelines 1.1 *Environment Protection and Biodiversity Conservation Act 1999,* Commonwealth of Australia.

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Grevillea shiressii

Vulnerable under the EPBC Act

Grevillea shiressii is listed as vulnerable under the EPBC Act. This species is a tall shrub from 2-5m high with entire, lanceolate leaves 8-19 centimetres long and up to 3 centimetres wide. The flower is distinctively coloured starting green, becoming blue-grey to cream in spring 2-9 flowers in the inflorescence (PlantNet 2019; OEH 2019). Birds pollinate the flowers. The seed is released in October at maturity and the seeds are dispersed by ants (OEH 2019). This species is a fire sensitive obligate seeded making it highly susceptible to local extinction due to fire. Seed germination occurs without fire although physical disturbance likely promotes seed germination (DOEE 2013).

G. shiressii grows along creek banks in wet sclerophyll forest; sandy soil on Hawkesbury sandstone (PlantNet 2019). Vegetation community of moist open forests include *Eucalyptus deanei, Syncarpia glomulifera, Angophora floribunda* and also riparian vegetation community's with *Tristaniopsis laurina, Lomatia myricoides* Known from two populations near Gosford, on tributaries of the lower Hawkesbury River north of Sydney (Mooney Mooney Creek and Mullet Creek). Both populations occur within the Gosford Local Government Area (DOEE 2013).

Targeted surveys for *G. shiressii* were not undertaken in the downstream, upstream or construction study areas for the Project. Additionally, *G. shiressii* was not incidentally encountered in the survey area during vegetation mapping associated with the Project.

In the absence of targeted surveys, *G. shiressii* has been assumed present in areas of presumed suitable habitat. For this assessment, suitable habitat for *G. shiressii* includes the PCTs that are associated with the species (as per the TBDC), BioNet Atlas Records and any other known vegetation types (as per scientific literature) that the species is associated with that has been mapped within the study area.

Suitable habitat includes the following PCTs, according to OEH's BioNet, that have been mapped within the downstream study area:

- PCT1181 (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
- PCT1183 (HN587): Smooth-barked Apple - Sydney Peppermint - Turpentine heathy open forest on plateaux areas of the Sydney Basin Bioregion
- PCT1284 (HN606): Turpentine - Smooth-barked Apple moist shrubby forest of the lower Blue Mountains Sydney Basin Bioregion
- PCT1292 (HN607): Water Gum - Coachwood riparian scrub along sandstone streams Sydney Basin Bioregion.

Grevillea shiressii was not assessed to have a moderate or higher likelihood of occurring in the upstream and construction study areas. As such, the potential for this species to be impacted by the Project in the upstream and construction study areas is not subject to this assessment.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal*
- *populations that are necessary for maintaining genetic diversity, and/or*
- *populations that are near the limit of the species range.*

By using habitat as a surrogate for the occurrence of *G. shiressii*, we have assessed the occurrence of a population in the downstream study area. The occurrence of a population in the downstream study area would represent the southern-most limit of the species distribution. Depending on the size of the population, it may also be important for breeding, dispersal and maintaining genetic diversity. We have subsequently assessed the population occurring in the downstream study area as 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**
As *G. shiressii* was not surveyed areas of habitat (associated PCTs) have been used as a surrogate for the species occurrence and population size. Within the downstream study area, no habitat is likely to be impacted by changes to the PMF and 10% AEP, or by impacts associated with the discharge of the FMZ. The important population is not expected to be reduced due to impacts associated with the Project. Known records of this species are restricted to the Gosford local government area. The Project will have no effect on this area. One record is noted to occur in the Blue Mountains although this is atypical. Given that the known records of this species will not be impacted and only marginal habitat will be, the Project is unlikely to lead to a long-term decrease in the size of the important population.
• **reduce the area of occupancy of an important population**
Within the downstream study area, no habitat is likely to be impacted by changes to the PMF and 10% AEP, or by impacts associated with the discharge of the FMZ. The Project is unlikely to reduce the area of occupancy of the important population.
• **fragment an existing important population into two or more populations**
The Project has the potential to fragment the habitat of the local population. This is unlikely to impact upon the known occurrences of this species in the Gosford LGA.
• **adversely affect habitat critical to the survival of a species**
The Minister maintains a 'Register of Critical Habitat' under the EPBC Act in which habitat as identified as being critical to the survival of a listed threatened species is provided. To date, no critical habitat is listed for this species that occurs within or proximal to the construction, upstream or downstream study areas. Suitable habitat presumed to support an important population of *G. shiressii* has been assessed as habitat critical to the survival of the species. This habitat is important for dispersal, the long-term maintenance of the species and for maintaining genetic diversity. It is also important for maintaining ecological processes essential to the survival for the species. The Project will adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive species, erosion and deposition, and modifying hydrology and the fire regime. It is therefore expected that the Project will adversely affect habitat critical to the survival of *G. shiressii.*
• **disrupt the breeding cycle of an important population**
Seed maturation and release can take longer compared to other species of Grevillea. *Grevillea shiressii* is understood to flower in spring with seeds maturing and being released in October. If disturbances were to become more frequent – through modified fire and hydrological regimes – and released seed disturbed, the breeding cycle of a population may be adversely impacted.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
Any habitat within the downstream study area is likely to be modified, destroyed, isolated which may cause *G. shiressii* to decline if it was present.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
Threat from exotic weeds inhibiting recruitment of *G. shiressii* is identified as a threatening process. The Project is unlikely to have an effect on invasive species becoming established in *G. shiressii* habitat.

• **introduce disease that may cause the species to decline, or**
Given restricted distribution of *G. shiressii*, it is susceptible to local extinction due to environmental and demographic uncertainty and pathogens such as *Phytophthora cinnamomi*. The Project would not introduce disease harmful to the important population located in the Gosford LGA. The Approved Threat Abatement Plan for Phytophthora does not apply to the Project with regards to G. shiressii as an important population does not occur in any of the study areas.
• **interfere substantially with the recovery of the species.**
A National Recovery Plan has not been written for *Grevillea shiressii*. However, the Approved Commonwealth Conservation Advice identifies threats that may interfere with the recovery of the species. Activities that could substantially interfere with the recovery of *G. shiressii* include, Track maintenance causing physical damage and loss of some plants, potential for hazard reduction burns and wildfires to occur and alter habitat and threat from exotic weeds inhibiting recruitment (DoE 2008). Considering the known location of the species occurring around the Gosford area, The Project is unlikely to interfere with the recovery of *G. shiressii*.
Conclusion
While an important population has been assessed as occurring in the downstream study area it is unlikely to be impacted such that it would become extinct. The Project has been assessed as unlikely to have a significant impact on *Grevillea shiressii*.

References

Department of the Environment (DoE) (2013) Matters of National Environmental Significance: Significant impact guidelines 1.1 *Environment Protection and Biodiversity Conservation Act 1999,* Commonwealth of Australia.

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Department of the Environment (2019). *Grevillea shiressii* in Species Profile and Threats Database, Department of the Environment, Canberra. Available from: http://www.environment.gov.au/sprat.

Office of Environment and Heritage (OEH), (2019) *Grevillea shiressii* - profile, https://www.environment.nsw.gov.au/threatenedSpeciesApp/profile.aspx?id=10380

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Hakea dohertyi (Kowmung Hakea)

Endangered under the EPBC Act

Hakea dohertyi is an erect shrub that can grow up to 6 metres tall. It has flexible, thread-like leaves that are between 20 and 40 centimetres long and triangular in cross-section. Small, cream to white flowers are produced in groups of 4 to 6, growing from the axils of the leaves. A woody fruit about 3 centimetres long with a small warty beak is produced. The OEH threatened species profile for *Hakea dohertyi* add that *plants mature relatively young and may live for many decades* (OEH 2019).

The *H. dohertyi* distribution is confined to four sites across eastern NSW; along the Kowmung River in Kanangra Boyd National Park, across a small peninsula at the edge of Lake Burragorang in the Blue Mountains National Park, a smaller population just outside of Yerranderie in the Yerranderie Regional Park, and in a small population 15 kilometres west of Nowra. Within its distribution, *H. dohertyi* has been previously recorded growing in dry sclerophyll forest that is dominated by *Eucalyptus punctata* (Grey Gum) and *Eucalyptus sieberi* (Silvertop Ash).

According to OEH's BioNet system, *H. dohertyi* is associated with the following PCTs mapped in the upstream study area:

- PCT 1401 (HN557): Narrow-leaved Ironbark - Forest Red Gum on rocky slopes of the lower Burragorang Gorge Sydney Basin Bioregion
- PCT 832 (HN525): Forest Red Gum - Narrow-leaved Ironbark open forest of the southern Blue Mountains gorges Sydney Basin Bioregion
- PCT 840 (HN527): Forest Red Gum – Yellow Box woodland of dry gorge slopes southern Sydney Basin Bioregion and South Eastern Highlands Bioregion
- PCT 870 (HN535): Grey Gum - Thin-leaved Stringybark grassy woodland of the southern Blue Mountain gorges Sydney Basin Bioregion
- PCT 871 (HN536): Grey Gum shrubby open forest on gorge slopes of the Blue Mountains Sydney Basin Bioregion

H. dohertyi was not assessed with a moderate or higher likelihood of occurring in the downstream or construction study areas. As such, its potential occurrence in these study areas is not subject to this assessment.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines a 'population of a species' as an occurrence of the species in a particular area. In relation to critically endangered, endangered or vulnerable threatened species occurrences include but are not limited to:

- a geographically distinct regional population, or collection of local populations.
- a population, or collection of local populations that occur within a particular bioregion.

Targeted surveys for *H. dohertyi* were not undertaken across the upstream study area, although individuals with NSW Herbarium tags were noted at one of the record locations near Tonali Point. In the absence of targeted surveys, *H. dohertyi* has been assumed present in areas of suitable habitat – the previously listed PCTs and contiguous vegetation supporting known records. Using the precautionary principle, a population of the species has been assessed as occurring within the upstream study area.

This species is included in Gallagher *et al.* (2020) and known to occur in the upstream study area. Based on the FESM mapping, approximately 81% of the study area's habitat was burnt in the 2019-2020 bushfires. Within the 20% AEP: 70.97 of the total 87.13 hectares of habitat has been mapped as burnt, within the 1% AEP: 330.65 hectares of the total 393.77 hectares of habitat has been mapped as burnt, and within the PMF, 559.58 hectares of the total 648.41 hectares of habitat has been mapped as burnt.

Plants of this species die in fire. It is not known if plants known to occur in the study area have burnt, if plant-held seeds survived the fire's intensity or if any germination occurred. This species is also identified as likely to be very susceptible to inundation or waterlogging. The project may inundate any recruiting plants from the current or future fires, or killed by inundation, that are not old enough to have set seed.

Those criteria identified by Gallagher *et al.* (2020) that particularly relate to this species and the environmental impacts associated with the Project, particularly in relation to post-fire disturbance and cumulative impacts, include:

A. Interactive effects of fire and drought

B. Short fire intervals (impacts of high fire frequency)

C. Post-fire herbivore impacts

E. High fire severity

F. Weed invasion

H. Fire sensitivity

I. Post-fire erosion

J. Cumulative exposure to high risks

K. Other plausible threats or expert-driven nominations (in this case the combined impacts from project-associated inundation on the above 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**
As *Hakea dohertyi* was not surveyed, areas of habitat have been used as a surrogate for the species occurrence. Within the upstream study area 648.41 hectares of habitat has been mapped. Of this 648.41 hectares, 86.93 hectares may be impacted by a 1 in 5 chance in a year flood event (20% AEP) and 393.77 hectares by a 1 in 100 chance in a year flood event (1% AEP). 199 hectares occurs in the upstream impact area. It is important to note that the population includes the records (confirmed in the field by SMEC) of less than 100 individuals on the southern shore of Tonalli Cove. It is expected that all these records would be impacted by the Project. Impacts to habitat caused by the Project are also likely to lead to a long-term decrease in the size of the population.
• **reduce the area of occupancy of the species**
Within the Upstream Study Area approximately 648.41 hectares of habitat has been mapped. Of this 648.41 hectares, 86.93 hectares may be impacted by a 1 in 5 chance in a year flood event (20% AEP) and 393.77 hectares by a 1 in 100 chance in a year flood event (1% AEP). 199 hectares occurs in the upstream impact area. For the purpose of offsetting biodiversity impacts in the upstream study area, it has been assumed that there would be a total loss of biodiversity values in the upstream impact area. Accordingly, it is likely that the Project will reduce the area of occupancy for the population.
• **fragment an existing population into two or more populations**
The population has been identified as the *H. dohertyi* occurring along the southern edge of Tonalli Cove and the associated habitat throughout the upstream study area. The Tonalli Cove occurrence occurs about 10 kilometres from the next closest recorded population at Yerranderie Regional Park, about 25 kilometres from the population along the Kowmung River and over 90 kilometres from the population in the Shoalhaven region. An inundation event would be unlikely to fragment the local population of *H. dohertyi* as it could potentially negatively impact the entire population occurring at Tonalli Cove.
• **adversely affect habitat critical to the survival of a species**
According to the *Matters of National Environmental Significance Significant impact guidelines* 1.1 (DoE 2013) habitat critical to the survival of a species refers to areas that are necessary for: • activities such as foraging, breeding, roosting, or dispersal • 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 • the reintroduction of populations or recovery of the species or ecological community. The *H. dohertyi* habitat in the upstream study area has been assessed as critical habitat because it is important for dispersal, the long-term maintenance of the species and for maintaining genetic diversity. The Project could potentially adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive species, erosion and deposition, and modifying hydrology and the fire regime.

• **disrupt the breeding cycle of a population**
H. dohertyi is an obligate seeding, bradysporous species. Seeds are non-dormant and will begin to germinate between 5 and 100 days after they have been released from the fruit of a mature plant. An unpublished study by Steenbeeke (1995) states that at room temperature, fresh seeds are almost 100% viable, however this viability decreases over time with seeds being dead after 10 years. Recruitment of new individuals into a population of *H. dohertyi* is therefore more likely facilitated through germination after seed release from a mature plant (they have an aerial seedbank) rather than from seed contained in a soil-stored seedbank. The temporary inundation of *H. dohertyi* habitat at Tonalli Cove is unlikely to remove a soil-stored seed bank important to recruitment, principally as the species does not have a soil-stored seedbank. Fire is likely important to the lifecycle of *H. dohertyi*. It may not be the trigger of germination as is the case in many Australian flora species, however it likely enables the release of seed stored in a population's aerial seed bank – seed stored in the fruit of mature individuals. A change to the fire regime within *H. dohertyi* habitat could affect a population's ability to release seed Fire interval is important for the species' breeding cycle, with too-frequent fire, to plants not old enough to support viable branch-held seed, or fire of such intensity that death of branch-held seed occurs, would threaten local extinction as the species does not store seed in the soil and the plants die after fire. The Project could potentially change the fire regime within the upstream study area (and therefore the habitat of the Tonalli Cove *H. dohertyi* population). The Project could potentially disrupt the breeding cycle of the population of *H. dohertyi*.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
H. dohertyi has been described as growing in dry sclerophyll forests occurring on steep, dry, north-facing slopes and open rocky ridge tops (Barker *et al.* 1999; Benson and McDougall 2000; Harden 2002). This habitat description partly matches that of the *H. dohertyi* habitat recorded by SMEC. During the recent surveys SMEC recorded *H. dohertyi* on slopes of various aspects, in dry sclerophyll forest. No rocky outcrops were observed nor were the slopes particularly steep. It is important to note however, that this population was recorded close to the edge of the man-made lake Burragorang meaning that steeper and rockier habitat could have occurred prior to the existence of the lake. The *H. dohertyi* recorded by SMEC occurred in PCT 840 (HN527), however its occurrence is associated with four other PCTs according to BioNET. PCT 840 (HN527) occurs frequently throughout the study area. As all the vegetation within the entire upstream study area was not surveyed, the potential habitat for this species has been precautionarily assessed as all the occurrences of PCTs 1401 (HN557), 832 (HN525), 840 (HN527), 870 (HN535) and 871 (HN536).
• **result in invasive species that are harmful to an endangered or critically endangered species becoming established in the endangered or critically endangered species' habitat**
No invasive flora species have been listed in the SPRAT profile, or OEH profile as a threat to *H. dohertyi* (DoEE 2019; OEH 2019). Goats are however listed in the OEH profile as a threat to *H. dohertyi* They have been listed as they are *noted to browse the foliage and bark of plants, leading to their death and potentially reducing seed availability* (OEH 2019). It is unknown if the Project could result in the spread and further establishment of goats throughout the potential habitat of *H. dohertyi.*
• **introduce disease that may cause the species to decline, or**
No diseases have been identified in the SPRAT profile, Approved Conservation Advice or OEH threatened species profile as a threat to *H. dohertyi*.
• **interfere substantially with the recovery of the species.**
No National Recovery Plan has been developed for *Hakea dohertyi* under the EPBC Act. Regional and local priority actions to enable the recovery of additional sites and/or populations have however been identified in the Approved Commonwealth Conservation Advice for *H. dohertyi*. The following priority actions have been identified: • Undertake appropriate seed collection and storage. Germination and ex situ seed storage has been studied for this species and seed viability after storage is high

- Investigate options for linking, enhancing or establishing additional populations.
- Implement national translocation protocols if establishing additional populations is considered necessary and feasible.

The Project could potentially interfere with all three of the listed priority actions.

Feral goats have been identified in the Approved Commonwealth Conservation Advice as a threat to *H. dohertyi.* While an Approved Threat Abatement Plan has been written for competition and land degradation caused by unmanaged goats, the Project is unlikely to exacerbate impacts caused by goats within the Upstream Study Area (feral goats were incidentally observed in the Upstream Study Area.

Conclusion

The Project could potentially inundate and impact the entire occurrence of *H. dohertyi* at Tonalli Cove though rapidly killing of this species that is likely very sensitive to inundation and waterlogging. The species is a bradysporous obligate seeder that would need favourable germination conditions post plant death and associated seed release. Inundation or waterlogging as the disturbance event that kills plants and effects seed release would likely create unfavourable germination conditions. If the effects of inundation and bushfire are combined, or multiple affecting flood events occur within a short period of time before adequate mature seed set occur, it would likely cause the local extinction of this population. These impacts would be expected across the remainder of the suitable habitat within the other three impact scenarios. These impacts could cause a decline of the population of *H. dohertyi*.

The Project has been assessed as likely to have a significant impact on *H. dohertyi*.

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Isopogon fletcheri (Fletcher's Drumsticks)

Vulnerable under EPBC Act

Fletcher's Drumsticks (*Isopogon fletcheri*) is listed as Vulnerable under the EPBC Act. *Isopogon fletcheri* is an erect, stout shrub growing up to about 1-1.5 metres high (Fairley 2004). Yellowish or creamy-green flowers occur in spring and are crowded into dense globular drumstick-like heads (Fairley 2004). Leaves are leathery, entire, narrow lance-shaped, approximately 12 centimetres long and two centimetres wide and have a blunt point. Fruit is a rounded woody cone about two centimetres across (Fairley 2004). The species is restricted to a small area in the Blackheath district of the Blue Mountains, NSW. The entire known population occurs within the Blue Mountains National Park (DECC 2005 cited in DEWHA 2008). The species grows in moist sheltered cliffs within the spray zone of a waterfall. It also occurs in sheltered, moist locations of dry sclerophyll forest and heath on sandstone (DEWHA 2008).

Isopogon fletcheri is considered to have a low likelihood of occurring within the construction and downstream study areas due to a lack of suitable habitat or known records. However, the species is considered to have a moderate likelihood of occurring within the upstream study area based on the presence of suitable habitat. However, targeted surveys were not undertaken in the upstream study area and the species was not incidentally observed. The species has been assessed as having a 'moderate' likelihood of occurring in areas of suitable habitat, and for the purposes of this assessment, has been assumed to be present within the upstream study area. For this assessment, suitable habitat for *I. fletcheri* includes the PCTs that the species is associated with (as per the TBDC) that have been mapped within the upstream study area.

Suitable habitat includes the following PCTs that have been mapped within the upstream study area:

- HN536 (PCT 871) Grey Gum shrubby open forest on gorge slopes of the Blue Mountains, Sydney Basin Bioregion.

This Assessment of Significance has been prepared in accordance with the *Matters of National Environmental Significance: Significant impact guidelines* (DoE 2013). According to these guidelines, the questions for an 'Vulnerable' species is related to 'an important population of a species'. The guidelines define an 'important population of a species' as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal*
- *populations that are necessary for maintaining genetic diversity, and/or*
- *populations that are near the limit of the species range.'*

The species has been assessed as having a 'moderate' likelihood of occurring based on the presence of suitable habitat and therefore a population is presumed present. If the species was found to be present in the study area then it is likely that it would constitute an 'important population' as it would be a range extension for this species. The population would also be considered distinct from the known population in Blackheath. As detailed within (Keith 1998), populations are considered to be distinct (geographically or otherwise) if they separated by discontinuities of greater than one kilometre.

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**
As *I. fletcheri* has not been surveyed, the species has been assumed present within areas of suitable habitat within the upstream study area. As detailed within Section 7.3.4 of Appendix F1, suitable habitat for the species was defined as HN536 within 500 metres of south-facing cliff lines. 10.22 hectares of suitable habitat for *I. fletcheri* is present within the upstream study area; of this 3.00 hectares occurs in the upstream impact area and, for the purposes of offsetting, it has been assumed there would be a total loss of biodiversity values in this area. Consequently, it is considered likely that the Project would to lead to a long-term decrease in the size of an important population of *I. fletcheri*, should one be present within the upstream study area.

• **reduce the area of occupancy of an important population**
The Project could potentially impact 10.11 hectares of *I. fletcheri* habitat within the upstream study area. Of this, 0.9 hectares occurs within the 20% AEP, 5.13 hectares occurs within the 1% AEP, and 3.00 hectares occurs in the upstream impact area. For the purposes of offsetting, it has been assumed there would be a total loss of biodiversity values in the upstream impact area. Consequently, it is considered likely that the Project would lead to a reduction in the area of occupancy of the species, should it be present within the upstream study area.
• **fragment an existing important population into two or more populations**
The current state of habitat for *I. fletcheri* in the upstream study area is intact and contiguous with adjoining national parks with minimal to no fragmentation. However, as noted above, a population within the upstream study area would also be considered distinct from the known population in Blackheath. Given the nature of the potential impacts associated with the Project (i.e. non-linear), it is unlikely to fragment the existing population into two or more smaller populations.
• **adversely affect habitat critical to the survival of a species**
The Minister maintains a 'Register of Critical Habitat' under the EPBC Act in which habitat as identified as being critical to the survival of a listed threatened species is provided. To date, no critical habitat is listed for this species that occurs within or proximal to the upstream study area. Habitat critical to the survival of a species is defined as areas which are: • Necessary for activities such as foraging, breeding, roosting, or dispersal • Necessary for the long-term maintenance of the species • To maintain genetic diversity and long term evolutionary development • For the reintroductions of the species Given its relative isolation within the national park away from urbanisation, a disjunct population of *I. fletcheri* within the upstream area would likely be necessary for the long-term maintenance of the species. Consequently, the suitable habitat occurring within the upstream study area would meet the requirements for 'habitat critical to the survival of' under the DoE (2013) guidelines. The Project could potentially impact 10.11 hectares of important habitat for *I. fletcheri* within the upstream study area. Of this, approximately 0.9 hectares occurs within the 20% AEP, and 5.13 hectares occurs within the 1% AEP.
• **disrupt the breeding cycle of an important population**
The breeding cycle of *I. fletcheri* is not well-documented in scientific literature. Typically, the species has been observed flowering in spring and summer producing seed that is dispersed by gravity (OEH 2019). The species is documented as being a fire tolerant species capable of resprouting from the base following fire (OEH 2019). However, this also means that too frequent fire can present a threat to the species existence. Impacts associated with temporary inundation resulting from the Project has the potential to change the ecosystem in ways that may influence the fire regime. For example, altered hydrology can influence floristic assemblages which in turn could change overall vegetation structure and community. As fire dynamics are influenced by vegetation, there could be a change to the current fire regime.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project could potentially impact 10.11 hectares of important habitat for *I. fletcheri* within the upstream study area. Of this, 0.9 hectares occurs within the 20% AEP, 5.13 hectares occurs within the 1% AEP, and 3.00 hectares occurs in the upstream impact area. The 3.00 hectares in the upstream impact area equates to approximately 30 percent of suitable habitat for the species. Consequently, it is considered likely that the Project would modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline, should it be present within the upstream study area.

• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
Within the upstream study area, potential impacts associated with the Project such as changes to inundation regimes, erosion and sedimentation may create an environment that is conducive to the establishment and spread of invasive weeds harmful to the important population. As the habitat in the construction study area is contiguous with the upstream study area, increased vehicular movements associated with vegetation clearance and construction activities could potentially facilitate the spread and establishment of weed and exotic species.
• **introduce disease that may cause the species to decline, or**
Isopogon fletcheri is known to be sensitive to a soil-borne pathogen, root-rot fungus (*Phytophthora cinnamomi*) which causes dieback (ANBG and CANBR 2012). The *Threat abatement plan for disease in natural ecosystems by Phytophthora cinnamomi* (DoEE 2018) has been adopted for this species under the EPBC Act. As the habitat in the construction study area is contiguous with the upstream study area, increased vehicular movements associated with vegetation clearance and construction activities may facilitate the spread and establishment of pathogens (including *Phytophthora*) into the upstream study areas. Temporary inundation associated with the Project would facilitate the spread of the pathogen into area which are currently not subject to temporary inundation. Actions associated the Project are therefore inconsistent with the Approved Threat Abatement Plan for Phytophthora (DoEE 2018).
• **interfere substantially with the recovery of the species.**
It was determined by the Commonwealth that a National Recovery Plan was not required for this species (DAWE 2020). However, the Approved Commonwealth Conservation Advice (2008) provides a number of regional and local priority recovery and threat abatement actions that can be implemented to support the recovery of *I. fletcheri*. The Project will interfere with the following two recovery and threat abatement actions: 1. Manage threats to areas of vegetation that contain populations/occurrences/remnants of Fletcher's Drumsticks. 2. Manage any changes to hydrology that may result in changes to the water table levels, increased run-off, sedimentation or pollution.
Conclusion
The Project has the potential to impact 10.11 hectares *I. fletcheri* habitat within the upstream study area. Of this, 0.9 hectares occurs within the 20% AEP, 5.13 hectares occurs within the 1% AEP, and 3.00 hectares occurs in the upstream impact area. This habitat is considered to be habitat critical to the survival of an important population of the species, should one occur within the upstream study area. The impacts to this habitat, and a population should it occur, associated with the Project are expected to have an adverse effect on an important population of *I. fletcheri* such that it may cause the species to decline. The Project has been assessed as likely to have a significant impact on *Isopogon fletcheri*.

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Kunzea cambagei

Vulnerable under the EPBC Act

Kunzea cambagei is a prostrate or ascending shrub that forms dense clumps or thickets. While only reaching 0.6 metres in height, *K. cambagei* is a long-lived species (like many Kunzea species) (OEH 2019). *Kunzea cambagei* produces elliptic to obovate leaves from 3 to 8 millimetres long 1.5 to 3 millimetres wide, with an obtuse apex. Foliage is hairy when young before becoming glaucous with age. This species of *Kunzea* produces cream to yellow flowers which occur in head-like clusters towards the ends of branches. Flowers produce indehiscent fruit about 3 millimetres long and 1. 5 millimetres in diameter.

Kunzea cambagei occurs in the western and southern parts of the Blue Mountains, NSW. Specifically, populations of K. cambagei have been recorded along the Oberon-Colong Stock Route, the Wanganderry Plateau, along the Wingecarribee River and on the Loombah Plateau (DEWHA 2008). All recorded populations support between 20 and 150 individuals. Within its distribution, K. cambagei occurs in wet heath and woodland habitat. It grows in coarse sandy soils overlying a sandstone and quartzite geology (Benson and McDougall 1998).

Kunzea cambagei has been assessed with a moderate likelihood of occurring in the upstream study area. However, according to OEH's BioNet system, *K. cambagei* is not associated with any PCTs mapped in the upstream study area. *Kunzea cambagei* has been assessed with a low likelihood of occurrence in the downstream and construction study areas. As such, it is not considered to occur in these study areas or be impacted by the Project in these study areas.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal.*
- *populations that are necessary for maintaining genetic diversity.*
- *populations that are near the limit of the species range.*

Targeted surveys for *K. cambagei* were not undertaken in the upstream study area. In the absence of targeted surveys in the study area, *K. cambagei* has been assumed present in areas of suitable habitat – its associated PCTs. As no associated PCTs occur within the upstream study area it is unlikely that an important population of *K. cambagei* occurs.

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**
An important population of *Kunzea cambagei* does not occur in the upstream study area.
• **reduce the area of occupancy of an important population**
An important population of *Kunzea cambagei* does not occur in the upstream study area.
• **fragment an existing important population into two or more populations**
The original construction of Warragamba Dam and the subsequent creation of Lake Burragorang fragmented the native vegetation within the Burragorang Valley. Raising Warragamba Dam will further fragment this native vegetation. The raising of Warragamba Dam is unlikely to fragment a population of *K. cambagei* into two or more smaller populations. If this species does occur in the study area, the original building of Warragamba Dam would have been the action that fragmented a population.
• **adversely affect habitat critical to the survival of a species**
No critical habitat has been listed for *Kunzea cambagei* under the EPBC Act.
• **disrupt the breeding cycle of an important population**
An important population of *Kunzea cambagei* does not occur in the upstream study area.

• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
No PCTs associated with the occurrence of *Kunzea cambagei* were recorded in the upstream study area. As such (and because targeted surveys were not conducted), all the native vegetation within the Upstream study area could support the species. The native vegetation within the Upstream study area will be partly destroyed and modified by the Project.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
Invasive species have not been identified as a threat to *Kunzea cambagei* in either the Approved conservation advice (DEWHA 2008) or the OEH threatened species profile (OEH 2019). However, the spread and establishment of invasive species is likely to be facilitated through impacts associated with the Project. If *Kunzea cambagei* was to occur in the upstream study area it could be impacted by the spread of invasive species.
• **introduce disease that may cause the species to decline, or**
No diseases have been identified as a threat to *Kunzea cambagei*.
• **interfere substantially with the recovery of the species.**
No National Recovery Plan has been developed for *Kunzea cambagei* under the EPBC Act. A targeted strategy for managing *Kunzea cambagei* has been developed under DPIE's Saving Our Species Program. Under the Saving Our Species Program, *Kunzea cambagei* has been assigned to the 'site-managed species' management stream. The following three priority management sites have been determined for *Kunzea cambagei:* • Mount Werong within Kanangra Boyd National Park • Nattai National Park • Medway near Berrima The Project could potentially impact the Nattai National Park priority management site. The Approved Commonwealth Conservation Advice for *K. cambagei* identifies high frequency fire as a threat (DEWHA 2008). Given that an important population of K. cambagei does not occur within any of the study areas, changes to the fire regime caused by the Project will not interfere with the recovery of the species. No Approved Threat Abatement Plans listed under the EPBC Act are relevant to *K. cambagei* in context of the Project.
Conclusion
The Project may impact suitable *Kunzea cambagei* habitat within the upstream study area. However, the Project would not result in a decrease in the size of an important population, reduce the area of occupancy of an important population, or adversely affect habitat critical to the survival of the species. The Project is unlikely to have a significant impact on *K. cambagei*.

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Kunzea rupestris

Vulnerable under the EPBC Act

Kunzea rupestris is a colonial shrub to 1.5 metres high with leaves 6-11mm long and white to cream flowers that are sessile in clusters at the end of branches. The this walled fruit which is up to 5mm long do not open to release seed at maturity (PlantNet 2019; Tierney & Wardle 2005). *K. rupestris* has been known to cross pollinate with *K. capitata*, the hybridised fruit partly dehisce, but retain their seeds and have a thicker seed coat (Tierney 2003; Tierney & Wardle 2005). *K. rupestris* grows in the shallow depressions on the large flat sandstone outcrops (OEH 2017).

K. rupestris is restricted to locations in Maroota, Sackville and Glenorie area, there is one record in the Ku-ring-gai Chase National Park. These areas contain the 20 known populations, of which 6 are reserved (OEH 2017). This species grows in shallow depressions on a large flat sandstone rock outcrops typically found in shrubland and heathlands. Flowers occur in the spring where afterwards the indehiscent fruits resist entrapment by the soil and disperse meters per week. After flowers the base of the plant's re-sprout after fire or mechanical damage, the seedlings have been observed germinating after fire (BioNet 2019). Of the six reserved populations one is within the Maroota Ridge State Conservation Area (SCA), one of the four priority management sites identified in NSW (SoS 2017). The PMF boundary in south Maroota falls within 45.3 hectares of the Maroota Ridge SCA.

Suitable habitat includes the following PCTs that have been mapped within the study areas.

Upstream study area:

- PCT1081 (HN564): Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion
- PCT1083 (HN566): Red bloodwood - scribbly gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion

Construction study area:

- PCT1081 (HN564): Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion
- PCT1083 (HN566): Red bloodwood - scribbly gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion.

Downstream study area:

- PCT1081 (HN564): Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal*
- *populations that are necessary for maintaining genetic diversity, and/or*
- *populations that are near the limit of the species range.*

Targeted surveys for *K. rupestris* were not undertaken in the downstream, upstream or construction study areas for the Project. Additionally, *K. rupestris* was not incidentally encountered in the survey areas during vegetation mapping associated with the Project. There are however, several records within one kilometre of the downstream study area. There are no known records on the NSW atlas near the construction zone or the upstream study areas.

In the absence of targeted surveys, *K. rupestris* has been assumed present in areas of presumed suitable habitat. For this assessment, suitable habitat for *K. rupestris* includes the PCTs that are associated with the species (as per the TBDC), BioNet Atlas Records and any other known vegetation types (as per scientific literature) that the species is associated with that has been mapped within the study area. As the K. rupestris population presumed to occur across the three study areas would be at the southern and western limits of the species range, it has been assessed as 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**
As *Kunzea rupestris* has not been surveyed, areas of habitat have been used as a surrogate for the species occurrence. Within the upstream study area 29.61 hectares of habitat has been mapped. Of this 29.61 hectares, 3.49 hectares may be impacted by a 1 in 5 chance in a year flood event (20% AEP) and 16.27 hectares by a 1 in 100 chance in a year flood event (1% AEP). Within the downstream study area no habitat has been mapped between the existing and with-project PMF and 10% AEP, or within the FMZ discharge impact boundary. Approximately 15.01 hectares of habitat occurs within the Development Footprint associated with construction activities. The impacts to suitable habitat across the construction and upstream study areas have the potential to lead to a long-term decrease in the size of the important population of *K. rupestris*.
• **reduce the area of occupancy of an important population**
The Project may reduce the potential area of occupancy for *Kunzea rupestris* across all three study areas. These reductions can be summarised according to the following impact scenarios: Upstream Study Area • 1% AEP (1 in 100 chance in a year flood): 16.27 hectares • 20% AEP (1 in 5 chance in a year flood): 3.49 hectares Downstream Study Area • FMZ discharge area: 0 hectares • Difference between the existing and with project 10% AEPs: 0 hectares • Difference between the existing and with project PMFs: 0 hectares Construction Study Area • Development footprint: 15.01 hectares
• **fragment an existing important population into two or more populations**
Habitat occurring within the upstream and construction study areas is contiguous with the native vegetation of the Blue Mountains National Park. This makes it unlikely that the Project will fragment habitat within these two study areas as the amount of new edges created will be minimal.
• **adversely affect habitat critical to the survival of a species**
The Minister maintains a 'Register of Critical Habitat' under the EPBC Act in which habitat as identified as being critical to the survival of a listed threatened species is provided. To date, no critical habitat is listed for this species that occurs within or proximal to the construction, upstream or downstream study areas. The NSW OEH recovery plans were referred where there are four Priority management sites are identified in NSW. Of this one site, Maroota Ridge State Conservation Area in South Maroota overlaps the PMF boundary by 45.3 hectares. There are insufficient literature references to flooding tolerances for *K. rupestris,* re sprouting was noted after fire or mechanical damage but not flooding. Changes in inundation could potentially adversely affect habitat critical to the survival of the species.
• **disrupt the breeding cycle of an important population**
K. rupestris flowers in spring, the fruits are indehiscent and resist soil entrapment which allows them to disperse metres per week. This species also re-sprouts from the base after fire or other mechanical damage. Seedlings have also been seen after fire (BioNet 2019). The increased discharge of the FMZ could potentially affect the breeding cycle by burying seed under an increased sediment load. A modified fire regime caused by changes to hydrology also has the potential to disrupt the breeding cycle of the important population of *K. rupestris*.

• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
Habitat with the upstream and construction study areas will be modified and destroyed by the Project. The destruction and modification of this habitat is likely to cause a decline in the species.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
Weed encroachment is identified (BioNet 2019) as a threat to *K. rupestris* although no specific invasive species have been identified. The Project has the potential to facilitate the further spread and establishment of invasive weed species throughout the *K. rupestris* habitat.
• **introduce disease that may cause the species to decline, or**
There are no known diseases that are known to affect *K. rupestris*. *Phytophthora cinnamomi* is however known to affect Kunzea genus. Taking a precautionary position, it has been assumed that the Project could potentially cause a decline in *K. rupestris* through alteration of hydrology and inundation increasing the spread of *Phytophthora cinnamomi.* With regards to *K. rupestris*, the Project is therefore inconsistent with the Approved Threat Abatement Plan for Phytophthora.
• **interfere substantially with the recovery of the species.**
A National Recovery Plan has not been developed for *Kunzea rupestris*. The Approved Commonwealth Conservation Advice does however list threats to the recovery of the species. The main threats to *K. rupestris* are track maintenance, fire suppression activities, sedimentation, encroachment of weeds, damage to plants by the cut flower industry, destruction of habitat by bush rock removal, soil and sand extraction, hybridisation with *Kunzea capitate*, local extinction from stochastic events such as drought, recreational users damaging habitat, threat of land clearing for rural residential (DoEE 2008; OEH 2017). The Project has the potential to exacerbate the impacts of fire and sedimentation to the important population. No currently approved Threat Abatement plans apply to *Kunzea rupestris* in context of the Project impacts.
Conclusion
The Project could potentially have a significant impact on *Kunzea rupestris* by impacting habitat and exacerbating the effect of fire and sedimentation. The Project has been assessed as likely to have a significant impact on *K. rupestris.*

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Leionema lachnaeoides

Endangered under the EPBC Act

Leionema lachnaeoides is a tall shrub in the Rutaceae family. It has white stems with pubescent new growth that becomes glabrous with age. Stems support terete leaves about 8 millimetres long and 1 millimetre wide. Leaves curve upwards ending with an acute apex. Solitary flowers form in the upper leaf axils, comprised of yellow petals approximately 5 millimetres long (PlantNET 1991).

Leionema lachnaeoides has been assessed with a moderate likelihood of occurrence in the upstream study area and a low likelihood of occurrence in the downstream and construction study areas. Targeted surveys for *L. lachnaeoides* were not undertaken in the Upstream Study Area. In the absence of targeted surveys for *L. lachnaeoides*, a population has been assumed present in areas of suitable habitat – the following PCTs occurring in the Upstream Study Area:

- PCT 769: Coachwood - Lilly Pilly warm temperate rainforest in moist sandstone gullies, Sydney Basin Bioregion
- PCT 1246: Sydney Peppermint - Grey Gum shrubby open forest of the western Blue Mountains, Sydney Basin Bioregion

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines a 'population of a species' as an occurrence of the species in a particular area. In relation to critically endangered, endangered or vulnerable threatened species, occurrences include but are not limited to:

- a geographically distinct regional population, or collection of local populations.
- a population, or collection of local populations that occur within a particular bioregion.

In the absence of targeted surveys, a population *of L. lachnaeoides* has been assumed present in occurrences of PCTs 769 and 1246 in the Upstream Study Area. As *L. lachnaeoides* has not been recorded in the Warragamba Special Area before, this occurrence represents a geographical distinct population.

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**
As *L. lachnaeoides* has not been surveyed, areas of habitat (PCTs 769 and 1246) have been used as a surrogate for the species occurrence. The Project could potentially impact up to 0.22 hectares of *L. lachnaeoides* habitat within the upstream study area. Within the 1% AEP about 0.13 hectares of suitable habitat has been recorded and within the 20% AEP, about 0.03 hectares. Given that this habitat represents the only occurrence of the species in the Warragamba Special Area, any impact has the potential to lead to a long-term decrease in the size of the population of *L. lachnaeoides*.
• **reduce the area of occupancy of the species**
The Project could potentially impact up to 0.22 hectares of *L. lachnaeoides* habitat within the upstream study area. Within the 1% AEP about 0.13 hectares of suitable habitat has been recorded and within the 20% AEP, about 0.03 hectares. Impact to the habitat within these boundaries will reduce the area of occupation of the species.
• **fragment an existing population into two or more populations**
The *L. lachnaeoides* habitat in the upstream study area is not in a fragmented condition, being contiguous with the native vegetation of the Blue Mountains National Park. The Project may impact this habitat, however its it is unlikely to create any new edges or fragments. The Project is therefore unlikely to fragment the existing population into two or more smaller populations.
• **adversely affect habitat critical to the survival of a species**
No critical habitat has been listed for *L. lachnaeoides* under the EPBC Act.

• **disrupt the breeding cycle of a population**
The lifecycle and breeding cycle ecology of *L. lachnaeoides* is poorly understood. Individuals have a life-span greater than 10 years, and fire likely plays an important role in reproduction. In most circumstances, fire kills all plants but triggers germination from soil-stored seed. Pollination is thought to be facilitated by insects however the viability of the resulting seed is unknow (DoE 2016). The Project has the potential to disrupt the breeding cycle of the population in the Upstream Study Area. The fire regime could be impacted, through inundation-induced changes to the supporting vegetation community(s). Changes to the vegetation communities supporting the *L. lachnaeoides* population could modify the fire regime therefore impacting the populations breeding cycle. The Project also has the potential to impact the soil-stored seed bank. Erosion and inundation caused by the Project may remove, destroy, and bury seed in habitat unsuitable for germination.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project could potentially impact up to 0.22 hectares of *L. lachnaeoides* habitat within the Upstream Study Area, 0.13 hectares within the 1% AEP and 0.03 hectares within the 20% AEP. Given the extent of potential impacts, the Project is likely to modify, destroy, and decrease the availability and quality of habitat. This has the potential to cause a decline in the population of *L. lachnaeoides*.
• **result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat**
The OEH threatened species profile and Approved Commonwealth Conservation Advice for *L. lachnaeoides* identify weed invasion as a threat (DoE 2016; OEH 2019). Given the limited extent of potential impacts, the Project is unlikely to result in the spread and establishment of invasive flora species into the habitat of *L. lachnaeoides*.
• **introduce disease that may cause the species to decline, or**
No diseases have been identified as a threat to *L, lachnaeoides* in either the Approved Commonwealth Conservation Advice or the OEH threatened species profile.
• **interfere substantially with the recovery of the species.**
A National Recovery Plan has been developed for *L, lachnaeoides* under the EPBC Act. The National Recovery Plan for *Leionema lachnaeoides* (NSW NPWS 2001) outlines the following recovery objectives: 1. Ensure the long-term protection of currently known populations of *L. lachnaeoides*. 2. Establish the full extent of *L. lachnaeoides* distribution. 3. Enhance future management of *L. lachnaeoides* by furthering our understanding of essential aspects of the biology and ecology of the species. 4. Safeguard extinction of *L. lachnaeoides* by investigating the potential for ex situ cultivation. 5. Raise awareness of the conservation status of *L. lachnaeoides* and involve the community in the recovery program. 6. Carry out re-evaluation of the conservation status of *L. lachnaeoides*. Assuming *L. lachnaeoides* occurs in the Upstream Study Area, the Project interferes with objective 2. In addition to the National Recovery Plan the Approved Commonwealth Conservation Advice for *L. lachnaeoides* (DoE 2016) provides the following conservation and management actions: 1. Focus efforts at three sites (Shipley Plateau, Bonnie Doon and Narrow Neck) identified as priority by the NSW government for the conservation of this species (NSW OEH 2016). 2. Ensure best practice mitigation is in place for any proposed up slope development activities to maintain suitable drainage and hydrological regimes.

3. Control Radiata pine (Pinus radiata) seedlings establishing at sites. 4. Minimise the impacts of recreational disturbance at sites through improved education and access constraints. 5. Minimise the frequency of fire through acknowledgement of *L. lachnaeoides* sites and habitat in Bushfire management plans developed by the NSW National Parks and Wildlife Service, City of Blue Mountains Council, Blue Mountains Bush Fire Risk Management Committee and the NSW Rural Fire Service. Given the limited extent of potential impacts to *L. lachnaeoides* habitat, the Project is unlikely to interfere with any of these actions. No currently approved Threat Abatement plans apply to *L. lachnaeoides* in context of the Project impacts.
Conclusion
The Project will impact *L. lachnaeoides* habitat, habitat used as a surrogate for the occurrence of the species in the absence of targeted surveys. The Project has the potential to interfere with the breeding cycle of the species and the National Recovery Plan. The Project has been assessed as likely to have a significant impact on *L. lachnaeoides.*

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Leucopogon exolasius (Woronora Beard-heath)

Vulnerable under the EPBC Act

Woronora Beard-heath (*Leucopogon exolasius*) is listed as Vulnerable under the EPBC Act. *L. exolasius* is an erect shrub growing to one metre in height. It has pubescent branchlets with sharp pointed leaves about 15 millimetres long and 2.5 millimetres wide. Tubular, white, drooping flowers are produced in groups of three on spikes originating from where leaves meet the stem. The Woronora Beard Heath however also has smaller hairs on the outside of the corolla tube (DEWHA 2008).

Leucopogon exolasius is endemic to the Sydney region and central coast of NSW (Fairley and Moore 2000). The species occurs along the upper Georges River and in Heathcote National Park (NP) and Royal NP (Powell 2007) and is also known from the Blue Mountains along the Grose River (Harden 1992). Preferred habitat includes woodland on sandstone and prefers rocky hillsides along creek banks up to 100 m altitude (Powell 2007). Associated species include *Eucalyptus piperita* and *E. sieberi* and the shrubs *Pultenaea flexilis*, *Leptospermum trinervium* and *Dillwynia retorta* (Powell 2007).

Leucopogon exolasius is considered to have a 'moderate' likelihood of occurring within the upstream, construction and downstream study areas. However, targeted surveys were not undertaken in either of these study areas and the species was not incidentally observed during survey work. The species is therefore assumed moderately likely to be present in areas of suitable habitat. For this assessment, suitable habitat for *L. exolasius* includes the PCTs that the species is associated with (as per the TBDC) that have been mapped within the upstream, construction and downstream study areas.

Suitable habitat includes the following PCTs that have been mapped within the upstream study area:

- HN564 (PCT 1081): Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion
- HN566 (PCT 1083): Red bloodwood -scribbly gum heathy woodland on sandstone plateaux of the Sydney basin Bioregion
- HN568 (PCT 1086): Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion
- HN607 (PCT 1292): Water Gum - Coachwood riparian scrub along sandstone streams, Sydney Basin Bioregion.

Suitable habitat includes the following PCTs that have been mapped within the construction study area:

- HN564 (PCT 1081): Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion
- HN566 (PCT 1083): Red Bloodwood – Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion
- HN568 (PCT 1086): Red Bloodwood – Sydney Peppermint – Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion.

Suitable habitat includes the following PCTs that have been mapped within the downstream study area:

- HN562 (PCT 1067): Parramatta Red Gum woodland on moist alluvium of the Cumberland Plain, Sydney Basin Bioregion
- HN564 (PCT 1081): Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion
- HN586 (PCT 1181): Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney, Sydney Basin Bioregion
- HN587 (PCT 1183): Smooth-barked Apple - Sydney Peppermint - Turpentine heathy open forest on plateaux areas of the Sydney Basin Bioregion (12.78 hectares)
- HN607 (PCT 1292): Water Gum - Coachwood riparian scrub along sandstone streams, Sydney Basin Bioregion.

This Assessment of Significance has been prepared in accordance with the *Matters of National Environmental Significance: Significant impact guidelines* (DoE 2013). According to these guidelines, the questions for an 'Vulnerable' species is related to 'an important population of a species'. The guidelines define an 'important population of a species' as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal*
- *populations that are necessary for maintaining genetic diversity, and/or*
- *populations that are near the limit of the species range.'*

The majority of known records for this species are east of Lake Burragorang between Camden and Campbelltown with outliners at Richmond and Taralga (AVH 2020). Due to the small range and population size it is likely that all known individuals are considered part of 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**
As *Leucopogon exolasius* has not been surveyed, areas of habitat have been used as a surrogate for the species occurrence. Within the upstream study area 169.10 hectares of habitat has been mapped. Of this 169.10 hectares 16.53 hectares may be impacted by a 1 in 5 chance in a year flood event (20% AEP) and 95.13 hectares by a 1 in 100 chance in a year flood event (1% AEP). Within the downstream study area approximately 12.80 hectares occurs between the existing and with project 10% AEPs, 15.45 hectares between the existing and with project PMFs and 5.57 hectares within the FMZ discharge area. Approximately 20.78 hectares of habitat occurs within the Development Footprint associated with construction activities. The impacts to suitable habitat across all three study areas have the potential to lead to a long-term decrease in the size of the important population of *L. exolasius*.
• **reduce the area of occupancy of an important population**
The Project may reduce the potential area of occupancy for *Leucopogon exolasius* across all three study areas. These reductions can be summarised according to the following impact scenarios: Upstream Study Area • 1% AEP (1 in 100 chance in a year flood): 95.13 hectares • 20% AEP (1 in 5 chance in a year flood): 16.53 hectares Downstream Study Area • FMZ discharge area: 5.57 hectares • Difference between the existing and with project 10% AEPs: 12.80 hectares • Difference between the existing and with project PMFs: 15.45 hectares Construction Study Area • Development footprint: 20.78 hectares
• **fragment an existing important population into two or more populations**
The current state of habitat for *L. exolasius* in the upstream and construction study areas is intact and contiguous with adjoining national parks and minimal to no fragmentation. However, the current state of habitat for *L. exolasius* in the downstream study area varies from highly fragmented patches of disturbed vegetation to intact vegetated areas contiguous with national parks or reserves. The Project has the potential to fragment the important population into two or more smaller populations either directly (vegetation clearance in the construction study area) or indirectly (through changed hydrological regimes modifying the suitability of habitat).
• **adversely affect habitat critical to the survival of a species**
The Minister maintains a 'Register of Critical Habitat' under the EPBC Act in which habitat as identified as being critical to the survival of a listed threatened species is provided. To date, no critical habitat is listed for this species that occurs within or proximal to the upstream, construction or downstream study area. It is therefore assumed

that all habitat is critical to the survival of the species and that the Project has the potential to adversely affect this habitat.
• **disrupt the breeding cycle of an important population**
The breeding cycle specific to *L. exolasius* is not well-documented in scientific literature. However, many studies have documented the fire response and seedling emergence of *L. exolasius* (Ooi 2002; Ooi *et al.* 2006; Ooi 2019). It is understood that germination of dormant seeds is prompted by seasonal changes rather than fire, although fire may enhance germination once it has begun (Ooi *et al.* 2006). Based on the current limited understanding of the ecology of this species, the Project may disrupt the breeding cycle by changing the existing fire regime. In a study undertaken by Ooi (2019), it was found that fire caused a slower growth rate and potentially reduced seed production of *L. exolasius* (smaller plants produce fewer seeds), which would reduce the capacity for fast seed bank recovery post-fire. The impacts associated with the Project, particularly an altered hydrology is likely to lead to a change in the existing fire regime. This is because a changed hydrology may influence the vegetation present whereby there may be structural and floristic assemblage changes. Vegetation structure and floristic assemblage are known to influence the intensity, frequency and seasonality of fire.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
Habitat within all three study areas is likely to be modified and destroyed. About 18 hectares of suitable habitat may be removed to facilitate the construction of the dam wall while the remaining area could potentially be modified or destroyed due to the associated changes in hydrology. Potential impacts associated with the upstream study area include changes to hydrology where there would be an increase in extent, duration and frequency of temporary inundation upstream, long-term erosion and sedimentation and changes to vegetation structure, composition and condition. Potential impacts to the downstream study area broadly include a reduction in peak flood extents and durations and a reduction in peak flood flows and an increase in low level flooding and flows during the discharge of the FMZ. Other potential impacts to all study areas include changes in fire regimes, the spread and establishment of weed and exotic flora species, changes to the chemical composition of soils, transmission of diseases and plant pathogens and erosion or sedimentation. Through any one of these impacts (or a combination) the condition, quality and integrity of suitable habitat could be adversely affected to a point in which it could potentially lead to a decline in the species.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
Within the upstream study area, potential impacts associated with the Project such as changes to inundation regimes, erosion and sedimentation may create an environment that is conducive to the establishment and spread of invasive weeds harmful to the important population. As the habitat in the construction study area is contiguous with the upstream study area, increased vehicular movements associated with vegetation clearance and construction activities may facilitate the spread and establishment of weed and exotic species that may be harmful to the important population into the upstream study area. The current condition of the downstream study area is that most areas are highly disturbed with numerous invasive species and hence the Project could facilitate the spread of invasive seed propagules through mobilisation (via changes to hydrology) or by creating an environment conducive to weed growth where there are reduced flows.
• **introduce disease that may cause the species to decline, or**
Leucopogon exolasius is known to be affected by the soil-borne pathogen, root-rot fungus (*Phytophthora cinnamomi*) which causes dieback. There is considerable evidence that increasing levels of human activity can facilitate the establishment and spread of root-rot fungus. As the habitat in the construction study area is contiguous with the upstream study area, increased vehicular movements associated with vegetation clearance and construction activities may facilitate the spread and establishment of the pathogens into the upstream study areas. It is assumed that root-rot fungus occurs in the downstream study area however it is not known how the Project may affect it's spread. The Project could potentially introduce or facilitate the spread of root-rot fungus such that it may impact any *L. exolasius* that may be present. The Project has subsequently been assessed as inconsistent with the Approved Threat Abatement Plan for Phytophthora.

• **interfere substantially with the recovery of the species.**
It was determined by the Commonwealth that a National Recovery Plan was not required for this species (DAWE 2020). However, the Approved Commonwealth Conservation Advice (2008) provides a number of regional and local priority recovery and threat abatement actions that can be implemented to support the recovery of *L. exolasius*. The Project would interfere substantially with the recovery of the species particularly as it will modify and destroy suitable habitat likely to be occupied by the species.
Conclusion
The Project will have a likely significant impact on *L. exolasius* as it could potentially habitat presumed to support an important population of the species. Due to the small range and population size, the impacts associated with the Project may cause the species to decline. The Project has been assessed as likely to have a significant impact on *Leucopogon exolasius.*

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Melaleuca deanei (Deane's Paperbark)

Vulnerable under the EPBC Act

Melaleuca deanei is a shrub to 3 metres high with fibrous flaky bark, narrow smooth leaves and many white flowers occurring on 6-metre-long spikes (OEH 2019; DoE 2010; PlantNet 2019). This species grows in wet heath on sandstone and in coastal districts from Berowra to Nowra (PlantNet 2019). There is limited evidence of regeneration after disturbance with *M. deanei* relying on clonal reproduction. Additionally, *M. deanei* produces seed infrequently. Seed release is triggered by fire, and on occasion, frost or drought.

There are two distinct areas within the *M. groveana* distribution; in the Ku-ring-gai/Berowra area and in the Holsworthy/Wedderburn area. There are also more isolated occurrences at Springwood (in the Blue Mountains), Wollemi National Park, Yalwal (west of Nowra) and the Central Coast (Hawkesbury River) (BioNet 2019; DoE 2010). These occurrences are thought to comprise of a total of 95 populations, very few of which are considered secure and reproductively viable. These 95 populations are fragmented throughout the landscape, comprising of between 1000-3000 individuals. *Melaleuca deanei* has been assessed with a moderate likelihood of occurring across all three study areas (upstream, downstream and construction).

According to OEH's BioNet system, *M. deanei* is associated with the following PCT mapped in the upstream study area:

- PCT 1081 (HN564): Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion
- PCT 1083 (HN566): Red Bloodwood – Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion.

M. deanei is associated with the following PCT mapped in the construction study area:

- PCT 1081 (HN564): Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion
- PCT 1083 (HN566): Red Bloodwood – Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion.

M. deanei is associated with the following PCTs mapped in the downstream study area:

- PCT 1081 (HN564): Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion
- PCT 1181 (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
- PCT 1183 (HN587): Smooth-barked Apple - Sydney Peppermint - Turpentine heathy open forest on plateaux areas of the Sydney Basin Bioregion
- PCT 1328 (HN1328): Yellow Bloodwood - Narrow-leaved Apple heathy woodland on hinterland plateaux of the Central Coast, Sydney Basin Bioregion
- PCT 1395 (HN556): Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal.*
- *populations that are necessary for maintaining genetic diversity.*
- *populations that are near the limit of the species range.*

Targeted surveys for *M. deanei* were not undertaken across the three study areas. In the absence of targeted surveys, *M. deanei* has been assumed present in areas of suitable habitat – the previously listed PCTs. Using the precautionary principle, the population(s) residing within this habitat have been assessed as an important population(s) as they are key source populations for breeding and dispersal, are necessary for maintaining genetic diversity, and occur near the limit of the species range.

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**
As *Melaleuca deanei* has not been surveyed, areas of habitat have been used as a surrogate for the species occurrence. Within the upstream study area 35.52 hectares of habitat has been mapped. Of this 35.52 hectares, 3.65 hectares may be impacted by a 1 in 5 chance in a year flood event (20% AEP) and 17.49 hectares by a 1 in 100 chance in a year flood event (1% AEP). Within the downstream study area approximately 49.72 hectares occurs between the existing and with project 10% AEPs 1.06 hectares between the existing and with project PMFs and 37.48 hectares within the FMZ discharge area. 15.01 hectares of habitat occurs within the Development Footprint associated with construction activities. The impacts to suitable habitat across all three study areas have the potential to lead to a long-term decrease in the size of the important population of *M. deanei*.
• **reduce the area of occupancy of an important population**
The Project may reduce the potential area of occupancy for *Melaleuca deanei* across all three study areas. These reductions can be summarised according to the following impact scenarios: Upstream Study Area • 1% AEP (1 in 100 chance in a year flood): 17.49 hectares • 20% AEP (1 in 5 chance in a year flood): 3.65 hectares Downstream Study Area • FMZ discharge area: 37.48 hectares • Difference between the existing and with project 10% AEPs: 49.72 hectares • Difference between the existing and with project PMFs: 1.06 hectares Construction Study Area • Development footprint: 15.01 hectares
• **fragment an existing important population into two or more populations**
The *M. deanei* distribution is currently fragmented with isolated occurrences recorded from the Ku-ring-gai/Berowra area, the Holsworthy/Wedderburn area, from the Lower Blue Mountains (Springwood) and from the hills and escarpment west of the Illawarra area. The *M. deanei* habitat within the downstream study area is also fragmented. This habitat occurs as the remnant forests and woodlands that once covered the Cumberland Plain. These forest and woodlands were historically cleared for agricultural use but have more recently been cleared for urban and residential developments. The Project could potentially further increase the fragmentation of the *M. deanei* within the Downstream study area. Not all *M. deanei* habitat is in a heavily fragmented and degraded condition. The habitat in the Upstream and construction study areas is mainly contiguous with the Blue Mountains National Park. However, the Project may impact the extents of this habitat in a similar manner to the habitat in the downstream study area– direct removal of vegetation, increased presence of invasive species, erosion and deposition - however its connectivity to larger extents of native vegetation may reduce the number of new edges created.
• **adversely affect habitat critical to the survival of a species**
According to the *Matters of National Environmental Significance Significant impact guidelines* 1.1 (DoE 2013) habitat critical to the survival of a species refers to areas that are necessary for: • activities such as foraging, breeding, roosting, or dispersal • 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

- the reintroduction of populations or recovery of the species or ecological community.

The *M. deanei* habitat in the upstream, downstream and construction study areas has been assessed as critical habitat because it is important for dispersal, the long-term maintenance of the species and for maintaining genetic diversity. The Project could potentially adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive species, erosion and deposition, and modifying hydrology and the fire regime.

- **disrupt the breeding cycle of an important population**

Recruitment is limited in the recorded populations of *M. deanei*. Flowering appeared to be limited, subsequently leading to the production of a low amount of viable seed. Flowering – and viable seed - was noted as more common along roadside populations, in populations that had been recently burnt, and proportionately more common in larger populations (DoEE 2019). Seed is held on an adult plant for several years until dehydration or fire allows the capsules to open (Benson and McDougall 1998). Seed is wind-dispersed with the length of viability after dispersal unknown.

The most common form of reproduction observed in *M. deanei* is asexual reproduction via suckering with some populations have been recorded consisting over 100 ramets. A study into the population genetics of the *M. groveana* distribution would be required to determine the prevalence of asexual reproduction.

Within the upstream and downstream study areas, increases in flooding frequencies (and in the upstream study area, extents) may impact the lifecycle of *M. groveana*. Occurrences of *M. groveana* will be inundated by flood waters and any of the limited soil-stored seed could be washed away and/or buried under deposited material. Given the species occurrence on slopes and ridges away from water-ways, it is also unlikely that adult plants can tolerate flooding.

Fire has been identified in the *M. deanei* SPRAT profile as associated with seed release, flowering and recruitment DoEE 2019). A modified fire regime would then stand to reason, impact the breeding cycle of *M. deanei*. Any modification of this fire regime caused by the Project could impact recruitment of new individuals into the population.

- **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**

The Project could potentially impact *M. deanei* habitat within the upstream, downstream and construction study areas. Habitat could potentially be destroyed and/or directly impacted through the clearing of native vegetation, the loss of flora and fauna habitat, and a reduction in the extent of ecological communities. Habitat may be indirectly impacted (modified, reduced in quality etc.) through fragmentation, alteration to soil conditions, edge effects, weed invasion and incursion, through the spread of disease and pathogens, erosion and sedimentation, and thorough changes to the fire regime.

- **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**

The Project could potentially likely result in the spread and establishment of invasive flora species into the habitat of *M. deanei*. The SPRAT profile and OEH Threatened Species Profile of *M. deanei* both identify weeds or weed encroachment as a threat.

No invasive fauna has been identified as a threat to *M. deanei*.

- **introduce disease that may cause the species to decline, or**

No diseases have been identified as a threat to *Melaleuca deanei*.

- **interfere substantially with the recovery of the species.**

A National Recovery Plan for *M. deanei* has been written under the EPBC Act. The National Recovery Plan for *Melaleuca deanei* (DECCW 2010) identifies the following recovery objectives:

1. Coordinate the recovery of *M. deanei*.
2. Protect known occurrences of *M. deanei* using land use and conservation planning mechanisms.
3. To identify and minimise the threats operating at *M. deanei* sites.

4. To improve awareness of *M. deanei* amongst operational staff working within easements, walking tracks and fire trails.
5. To promote surveys, research and monitoring that will assist with the management of *M. deanei.*
6. To provide stakeholders with information that assist in conserving *M. deanei.*
7. To raise awareness about the threats to the species and involve the community in the recovery program.
8. To coordinate an ex-situ conservation program to safeguard genetic material from extinction.

The Project is inconsistent with objectives 2 and 3 thereby interfering with the recovery of the species.

A targeted strategy for managing *M. deanei* has been developed under the NSW Government's Saving Our Species Program. Under the Saving Our Species Program, *M. deanei* has been assigned to the 'site-managed species' management stream. The following 5 priority management sites have been identified for this species:

- Ku-Ring-Gai Chase National Park in the Hornsby LGA.
- Berowra Valley National Park in the Hornsby LGA.
- Holsworthy in the Campbelltown, Liverpool and Sutherland Shire LGAs.
- Nepean-Avon Plateau in the Wollondilly LGA.
- Nepean Dam in the Wingecarribee LGA.

The Project would not impact any of the listed priority management sites.

Conclusion

The Project could potentially impact *M. deanei* habitat across the upstream, downstream and construction study areas. This habitat may become further fragmented, increasing the isolation between occurrences of *M. deanei.* The Project may impact the breeding cycle of *M. deanei* by clearing native vegetation (habitat), modifying the fire regime, and impacting the soil seedbank. The threat of invasive flora species would also be exacerbated by the Project further threatening *M. deanei*. These impacts are expected to cause a decline of important population of *M. deanei*.

The Project has been assessed as likely to have a significant impact on *Melaleuca deanei.*

References

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Micromyrtus minutiflora

Vulnerable under the EPBC Act

Micromyrtus minutiflora is listed Vulnerable under the EPBC Act. *M. minutiflora* is a slender spreading shrub to 2 metres high. The leaves are 1-4 millimetres long and 0.5-1 millimetres wide with ciliate margins. The flowers are white and solitary on a peduncle (stalk) 0.5 millimetres long (DEWHA 2008). The species exhibits sporadic flowering between June and March (OEH 2017). The species is endemic to the Cumberland Plain with a distribution largely restricted to the general area between Richmond and Penrith in western Sydney. Generally, *M. minutiflora* occurs on sandy clay or gravelly soils of Tertiary alluvium (Benson and McDougall 1998). Typically, *M. minutiflora* is found in Castlereagh Scribbly Gum Woodland, Ironbark Forest, Shale/Gravel Transition Forest, open forest on tertiary alluvium and consolidated river sediments (OEH 2017). According to the Final Determination for this species, the total number of individuals is estimated to be as low as 1,800 (NSW Scientific Committee 2002). Of this, approximately 50 individuals are known to occur within a conservation reserve (Castlereagh Nature Reserve) (NSW Scientific Committee 2002).

According to OEH's BioNet system, *M. minutiflora* is associated with the following PCT mapped in the downstream study area:

- PCT724 (HN512): Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain, Sydney Basin Bioregion
- PCT 725 (HN513): Broad-leaved Ironbark - *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain Sydney Basin Bioregion (associated as per TBDC)
- PCT 1067(HN562): Parramatta Red Gum woodland on moist alluvium of the Cumberland Plain Sydney Basin Bioregion (associated as per TBDC).

Micromyrtus minutiflora was not assessed with a moderate or higher likelihood of occurring in either the upstream or construction study areas. As such the potential for this species to be impacted by the Project in these study areas is not subject to this assessment.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal.*
- *populations that are necessary for maintaining genetic diversity.*
- *populations that are near the limit of the species range.*

Targeted surveys for *M. minutiflora* were not undertaken across Downstream study area. In the absence of targeted surveys, *M. minutiflora* has been assumed present in areas of suitable habitat – the previously listed PCTs. Using the precautionary principle, the population(s) residing within this habitat have been assessed as an important population(s) as they are key source populations for breeding and dispersal, are necessary for maintaining genetic diversity, and occur near the limit of the species range.

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**
As *M. minutiflora* has not been surveyed, areas of habitat have been used as a surrogate for the species occurrence. The Project could potentially impact up to 262.89 hectares of *M. minutiflora* habitat between the existing and with-project PMFs, 30.17 hectares occurring between the existing and with-project 10% AEPs and zero hectares within the FMZ discharge boundary. Impacts to this habitat has the potential to lead to a long-term decrease in the size of the important population.
• **reduce the area of occupancy of an important population**
The Project could potentially impact up to 262.89 hectares of *M. minutiflora* habitat between the existing and with-project PMFs, 30.17 hectares occurring between the existing and with-project 10% AEPs and zero hectares within the FMZ discharge boundary. These impacts are expected to reduce the area of occupancy of the important population.

• **fragment an existing important population into two or more populations**
Most of the *M. minutiflora* habitat within the downstream study area has been partially fragmented through agricultural, public and residential development. Through a changed hydrological regime, a further 2,354 hectares of suitable habitat within the study area could potentially be modified. This may cause fragmentation and isolation of this habitat from other areas of presumed suitable or known habitat for the species. The pollen vectors of *M. minutiflora* are unknown. The distance apart that two populations need to be to become isolated from one another is subsequently unknown. The Project has been precautionarily assessed as potentially causing isolation between occurrences of *M. minutiflora* within the downstream study area and isolating them from occurrences outside the study area.
• **adversely affect habitat critical to the survival of a species**
According to the *Matters of National Environmental Significance Significant impact guidelines* 1.1 (DoE 2013) habitat critical to the survival of a species refers to areas that are necessary for: • activities such as foraging, breeding, roosting, or dispersal • 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 • the reintroduction of populations or recovery of the species or ecological community. The *M. minutiflora* habitat in the downstream study area has been assessed as critical habitat because it is important for dispersal, the long-term maintenance of the species, and for maintaining genetic diversity. Some of the habitat in the downstream study area is also suitable for habitat for the reintroduction and translocation of the species in the future. The Project could potentially adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive species, erosion and deposition, and modifying the fire regime.
• **disrupt the breeding cycle of an important population**
The breeding cycle and reproductive ecology of *M. minutiflora* - including the pollination and breeding mechanisms - is poorly documented in the scientific literature. However, it is known that *M. minutiflora* has specific habitat requirements based on its limited distribution where it is found in Castlereagh Scribbly Gum Woodland, Ironbark Forest, Shale/Gravel Transition Forest, open forest on tertiary alluvium and consolidated river sediments (OEH 2017). It is suggested that regeneration of the species occurs via re-sprouting or germination of soil-stored seed (OEH 2019). Based on the above information, it is assumed that the Project could potentially have an adverse effect on the breeding cycle of the *M. minutiflora* population that occurs within the downstream study area. This is because habitat for the species occurs within the study area and is expected to be modified by the Project. The main effect of a changed hydrological regime may alter the floristic structure and composition of suitable habitat while secondary impacts such as erosion could deplete the seedbank of any soil-stored seed.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project could potentially impact *M. minutiflora* habitat within the downstream study area. Habitat may be destroyed and/or directly impacted through the clearing of native vegetation, the loss of flora and fauna habitat, and a reduction in the extent of ecological communities. Habitat may be indirectly impacted (modified, reduced in quality etc.) through fragmentation, alteration to soil conditions, edge effects, weed invasion and incursion, through the spread of disease and pathogens, erosion and sedimentation, and thorough changes to the fire regime.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
Invasive flora – '*weed invasion including African lovegrass'* - has been identified as a threat to *M. minutiflora* in the OEH Threatened Species Profile. The OEH Threatened Species Profile adds however, that the development of a large woody overstory is also a threat to existing occurrences. Disturbance would seem to be importance to the

ecology of *M. minutiflora*, however it is important that the earlier colonisers of the disturbed vegetation are not invasive species.
• **introduce disease that may cause the species to decline, or**
No diseases have been identified in the *M. minutiflora* SPRAT profile, Approved Commonwealth Conservation Advice or OEH Threatened Species Profile.
• **interfere substantially with the recovery of the species.**
M. minutiflora is included in the Cumberland Plain Recovery Plan that was published in 2011 by the NSW Department of Environment, Climate Change and Water (DECCW). The Cumberland Plain Recovery Plan identifies actions for implementation by local, State and Australian government authorities which are grouped under the following recovery objectives: 1. To build a protected area network, comprising public and private lands, focused on the priority conservation lands, 2. To deliver best practice management for threatened species, populations and ecological communities across the Cumberland Plain, with a specific focus on the priority conservation lands and public lands where the primary management objectives are compatible with conservation, 3. To develop an 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, and 4. To increase knowledge of the threats to the survival of the Cumberland Plain's threatened species, populations and ecological communities, and thereby improve capacity to manage these in a strategic and effective manner. This Cumberland Plain Recovery Plan seeks to focus recovery efforts on those lands which represent the best opportunities to secure viable, long-term conservation outcomes in the region (DECCW 2011). These lands, have been identified as 'Priority Conservation Lands (PCLs)' (DECCW 2011). According to mapped extents of PCLs, *M. minutiflora* is known to occur within the 'Castlereagh' PCL which is likely to be impacted by the Project (as it is within the study area). Therefore, the Project is inconsistent with the management objectives for this PCL that contains *M. minutiflora*. In addition to this approved recovery plan, OEH has developed management objectives and plans for various threatened species as part of its Saving Our Species (SoS) program. The stated management objective for *M. minutiflora* under the program is '*The SoS strategy aims to secure the species in the wild for 100 years and maintain its conservation status under the BC Act*' (OEH 2019). The SoS program has identified one key management site, namely, Wianamatta Nature Reserve in Penrith LGA. This management site does not fall within the study area and therefore the proposed action is not inconsistent with the SoS management objectives and actions for *M. minutiflora* under the SoS program. A National Recovery Plan has not been developed for *M. minutiflora*. No Approved Threat Abatement Plans are relevant to M. minutiflora in context of the Project.
Conclusion
The Project could potentially impact *M. minutiflora* habitat across the downstream study area. This habitat may become further fragmented, increasing the isolation between occurrences of *M. minutiflora.* The Project may impact the breeding cycle of *M. minutiflora* by clearing native vegetation (habitat), modifying the fire regime and modifying the hydrological environment. The threat of invasive flora species may also be exacerbated by the Project. These impacts could potentially cause a decline of important population of *M. minutiflora*. The Project has been assessed as likely to have a significant impact on *M. minutiflora.*

References

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Olearia cordata

Vulnerable under the EPBC Act

Olearia cordata is a shrub that grows to 2 metres high with alternately arranged leaves which are linear to narrow-lanceolate 10-40 mm long 2-8 mm wide (PlantNET 2019). The apex of the leaves are acute or rounded, finely mucronate and the base of the leaves are broad-cordate (PlantNET 2019). The species has typical daisy-like flowers that can be mauve to deep blue (rarely white) with a yellow centre (OEH 2019).

Olearia cordata is endemic to New South Wales with a scattered distribution from the south-western Hunter Plateau, eastern Colo Plateau, and the far north-west of the Hornsby Plateau near Wisemans Ferry (OEH 2019). Most known populations occur within conservation reserves including Wollemi National Park, Yengo National Park and the Wisemans Ferry Historic Site.

Olearia cordata has been recorded in open forest and shrubland associated with sandstone ridges. The species generally grows in shallow or skeletal soils that are neutral to slightly acidic derived from Hawkesbury Sandstone. It has been recorded at altitudes from 150-500 m on steep to gentle slopes (DEWHA 2008). According to OEH's BioNet system, *O. cordata* is associated with the following PCT mapped in the upstream study area:

- PCT 1081 (HN564): Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion
- PCT 1083 (HN566): Red Bloodwood – Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion.

Olearia cordata is associated with the following PCT mapped in the construction study area:

- PCT 1081 (HN564): Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion
- PCT 1083 (HN566): Red Bloodwood – Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion.

Olearia cordata was assessed with a low likelihood of occurring in the downstream study area. As such, the subject of this assessment is limited to its occurrence in the upstream and construction study areas.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal.*
- *populations that are necessary for maintaining genetic diversity.*
- *populations that are near the limit of the species range.*

Targeted surveys for *O. cordata* were not undertaken across the Upstream, Downstream and construction study areas. In the absence of targeted surveys, *O. cordata* has been assumed present in areas of suitable habitat – the previously listed PCTs. Using the precautionary principle, the population(s) residing within this habitat have been assessed as an important population(s) as they are key source populations for breeding and dispersal, are necessary for maintaining genetic diversity, and occur near the limit of the species range.

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**
As *O. cordata* has not been surveyed, areas of habitat have been used as a surrogate for the species occurrence and the important population's size. Up to 3.49 hectares may be impacted by a 1 in 5 chance in a year flood event and up to 16.27 hectares by a 1 in 100 chance in a year flood event. About 15.01 hectares will be directly impacted by the clearing associated with construction (development footprint). The impacts to *O. cordata* habitat within the upstream and construction study areas are expected to lead to a long-term decrease in the size of the important population.
• **reduce the area of occupancy of an important population**
The Project could potentially reduce the area of occupancy of the important population of *O. cordata* by removing or modifying up to about 31.28 hectares of suitable habitat across both the construction and upstream study areas. Reductions in the area of occupancy can be summarised according to the following impact scenarios: Upstream Study Area • 1% AEP (1 in 100 chance in a year flood): 16.27 hectares • 20% AEP (1 in 5 chance in a year flood): 3.49 hectares Construction Study Area • Development footprint: 15.01 hectares
• **fragment an existing important population into two or more populations**
The *O. cordata* habitat occurring in the upstream and construction study areas is largely contiguous with the native vegetation of the Blue Mountains National Park. However, the original construction of Warragamba Dam and the subsequent creation of Lake Burragorang fragmented this habitat. Within the construction study area, habitat could become fragmented by the Project through the direct clearing of vegetation associated with the construction works, by introduced edge effects and by the spread and establishment of invasive flora species. In the upstream study area, the Project may increase the fragmentation of habitat predominantly through the direct clearing of vegetation associated with inundation from higher flood events. The habitat occurring in the downstream study area is in a more fragmented condition compared to that in the Upstream and construction study areas. It occurs as remnant stands of forest and woodland that once covered the Cumberland Plain but has since been degraded through agricultural and residential uses. The Project may increase the fragmentation of these remnant stands of forest and woodland – some of which is *O. cordata* habitat – through the direct removal of vegetation, the spread of weeds and exotic species, by modifying the fire regime, and by increasing erosion and sedimentation along the Hawkesbury-Nepean system. The creation of new sub-populations - in either of the three study areas - through fragmentation cannot be conclusively proved without demonstrating new barriers to gene flow. A population genetic analysis would be required to demonstrate the existence of new sub-populations and the creation of barriers to gene flow.
• **adversely affect habitat critical to the survival of a species**
According to the *Matters of National Environmental Significance Significant impact guidelines* 1.1 (DoE 2013) habitat critical to the survival of a species refers to areas that are necessary for: • activities such as foraging, breeding, roosting, or dispersal • 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 • the reintroduction of populations or recovery of the species or ecological community. The *O. cordata* habitat in the upstream, downstream and construction study areas have been assessed as critical habitat. This is because it is important for dispersal, the long-term maintenance of the species (due to its restricted distribution), for maintaining genetic diversity, and for the potential reintroduction/recovery of the species. The

Project will adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive and exotic species, erosion and deposition, and modifying the fire regime.

- **disrupt the breeding cycle of an important population**

Olearia cordata has been recorded flowering from November to May, with seed released from February to May - dependent on environmental conditions. Seed is wind dispersed and may adhere to the fur of browsers such as wallabies (OEH 2019). Adult plants have been recorded re-sprouting after fire. Germination is not dependent on fire – seeds are unable to remain dormant for long periods after release – however, large numbers of seedlings are more commonly recorded after fire. Germination also occurs after significant rain events (OEH 2019).

The Project may disrupt the breeding cycle of *O. cordata* in the following ways:

- Direct clearing of adult plants
- Modified fire regimes impacting germination events.

- **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**

The Project could potentially impact *O. cordata* habitat within the upstream and construction study areas. Habitat may be destroyed and/or directly impacted through the clearing of native vegetation, the loss of flora and fauna habitat, and a reduction in the extent of ecological communities. Habitat may be indirectly impacted (modified, reduced in quality etc.) through fragmentation, edge effects, weed invasion and establishment, through the spread of disease and pathogens, erosion and sedimentation, and thorough changes to the fire regime.

- **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**

The OEH Threatened Species Profile identifies 'infestation by weeds' as a threat to *O. cordata* (OEH 2019), and the Approved Conservation Advice adds that 'competition from weeds' is a main threat (DEWHA 2008). The Project may facilitate the spread and establishment of weeds and invasive flora species – such as *Rubus fruticosus* spp. agg. and *Lantana camara* – by creating new edges within the Upstream, Downstream and construction study areas. The spread and establishment of invasive flora species will also be promoted through the movement of plant and people during the construction phase and by the raised flood extents carrying plant material from upslope.

- **introduce disease that may cause the species to decline, or**

No diseases have been identified as a threat to *Olearia cordata* in the Approved Commonwealth Conservation Advice, SPRAT Profile or OEH Threatened Species Profile.

- **interfere substantially with the recovery of the species.**

A National Recovery Plan for *O. cordata* has yet to be developed under the EPBC Act. The Approved Commonwealth Conservation Advice for *Olearia cordata* however, outlines several regional and local priority actions to assist in the conservation of the species. The Project interferes with the following priority actions:

- Manage threats to areas of native vegetation that contain populations of *O. cordata*.
- Manage any changes to hydrology that may result in changes to the water table levels, increased run-of, sedimentation or pollution.
- Manage any disruption to water flows.
- Develop and implement a management plan for the control of weeds in the local region.

A targeted strategy for managing *O. cordata* has been developed under the Saving Our Species Program (NSW Government). Under the Saving Our Species Program, *O. cordata* has been assigned to the 'site-managed species' management stream. The following priority management site has been identified in the Saving Our Species Program for *O. cordata*:

- Greater Yengo in the Central Coast, Cessnock, Hawkesbury, Lithgow City, Singleton and The Hills Shire LGAs.

The Project may impact this priority management site where it runs along the Hawkesbury and Colo Rivers.

No currently approved Threat Abatement plans apply to *O. cordata* in context of the Project impacts.
Conclusion
The Project could potentially impact *Olearia cordata* habitat across the upstream, downstream and construction study areas. This habitat may become further fragmented, potentially increasing the isolation between occurrences of *O. cordata.* The Project may impact the breeding cycle of *O. cordata* by directly clearing adult plants and modifying the fire regime. The Saving Our Species recovery program and the conservations initiatives set out in the Approved Conservation Advice may be impeded by the Project. The threat of invasive flora species and weeds may also be exacerbated by the Project. These impacts could cause a decline of important population of *O. cordata*. The Project has been assessed as likely to have a significant impact on *Olearia cordata.*

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Persicaria elatior (Tall Knotweed)

Vulnerable under the BC Act and EPBC Act

Tall Knotweed (*Persicaria elatior*) is listed as Vulnerable under the BC Act and EPBC Act. *Persicaria elatior* is an erect herb with glandular hairs growing to 90 centimetres tall (DEWHA 2008). Leaves are 3–11 centimetres long and 1–3 centimetres wide with a sheath encircling the stem at the base of each leaf. *Persicaria elatior* contains small pink flowers are arranged in long, narrow spikes up to 5 centimetres long (DEWHA 2008). The species is known from the North Coast, Central Coast and South Coast botanical subdivisions of NSW as well as the Moreton Pastoral District in south-east Queensland (Wilson 1990). The species is known to prefer sandy, alluvial soil in swampy areas and riparian herblands along watercourses and lake edges often occurring in association with species such as *Melaleuca linearifolia, M. quinquenervia, Pseudognaphalium luteoalbum, Persicaria hydropiper, Floydia praealta* and *Cyperus semifertilis* (Wilson 1990; Quinn *et al.* 1995; Benson and McDougall 1999).

With regard to the Project, *P. elatior* is considered likely to occur in the upstream and downstream study area although targeted surveys for this species were not undertaken. Additionally, *P. elatior* was not incidentally encountered in the survey area during vegetation mapping associated with the Project.

In the absence of targeted surveys, *P. elatior* has been assumed present in areas of presumed suitable habitat. For this assessment, suitable habitat for *P. elatior* includes the PCTs that are associated with the species (as per the TBDC), BioNet Atlas Records and any other known vegetation types (as per scientific literature) that the species is associated with that has been mapped within the upstream and downstream study areas.

No suitable habitat has been mapped within the upstream or construction study areas, however the following PCTs presumed to be suitable habitat for *P. elatior* have been mapped within the downstream study area:

- PCT781: Coastal freshwater lagoons of the Sydney Basin Bioregion and South East Corner Bioregion (associated as per TBDC)
- PCT835: Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain Sydney Basin Bioregion (associated as per TBDC)

This Assessment of Significance has been prepared in accordance with the *Matters of National Environmental Significance: Significant impact guidelines* (DoE 2013). According to these guidelines, the questions for a 'Vulnerable' species is related to the 'importance of the population'. The guidelines define an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal*
- *populations that are necessary for maintaining genetic diversity, and/or*
- *populations that are near the limit of the species range.'*

In the absence of targeted surveys, taking a precautionary position based on the mapped PCTs, it is assumed that the downstream study area supports an 'important population' of *P. elatior* particularly as there few known records of the species in New South Wales and it can be reasonably expected that the population affected by the Project is either a '*key source population either for breeding or dispersal*' and the '*population is necessary for maintaining genetic diversity*'.

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 Project could potentially impact up to about 540 hectares in the downstream study area between the existing 10% AEP and the proposed 10% AEP flood extents through less flooding over the long-term potentially leading to a greater level of change in ecosystem functioning, ecological processes, vegetation structure and floristic assemblages. Changes to habitat that may occur as a result of the Project could potentially to lead to a long-term decrease in the size of an important population of *P. elatior* in the downstream study area.

• **reduce the area of occupancy of an important population**
The Project could potentially reduce the area of occupancy of an important population of *P. elatior* by removing or modifying up to 540 hectares of suitable habitat in the downstream study area.
• **fragment an existing important population into two or more populations**
As no targeted surveys were undertaken it has been assumed that the suitable habitat supports an important population of *P. elatior.* The Project could potentially remove or modify up to 540 hectares of suitable habitat from the downstream study area which may to lead to fragmentation.
• **adversely affect habitat critical to the survival of a species**
The Minister maintains a 'Register of Critical Habitat' under the EPBC Act in which habitat as identified as being critical to the survival of a listed threatened species is provided. To date, no critical habitat is listed for this species that occurs within or proximal to the construction, upstream or downstream study areas. In addition, there is no state of federal Recovery Plan that has been prepared for *P. elatior.* However, the estimated 540 hectares of suitable habitat presumed to support an important population of *P. elatior* is considered to be habitat critical to the survival of the species. This is because the habitat is likely important in maintaining the genetic diversity and long-term evolutionary development of the species and is important for maintaining ecological processes essential to the survival for the species. The Project could potentially adversely affect habitat critical to the survival of *P. elatior.*
• **disrupt the breeding cycle of an important population**
The breeding cycle of *P. elatior* is not documented in scientific literature. However, changes to existing ecosystem functioning and ecological processes as a result of the Project could potentially disrupt the breeding cycle of an important population. Particularly where habitat requirements for plants are changed to the extent that plants would experience increased levels of stress.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project could potentially impact up to about 540 hectares of suitable habitat presumed to support an important population of *P. elatior.* Over the long-term these modifications to the ecosystem and habitat for *P. elatior* could potentially lead to a decrease in the availability or quality of the habitat for the species.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
There are no invasive species that are known to be harmful to *P. elatior.* However, it is well-understood that invasive species such as weeds pose a threat to the suitability, quality and integrity of suitable habitat for threatened species through such things as increasing competition for resources.
• **introduce disease that may cause the species to decline, or**
There are no diseases that are known to specifically affect *P. elatior.*
• **interfere substantially with the recovery of the species.**
There is no National Recovery Plan for *P. elatior.* The Approved Commonwealth Conservation Advice (DEWHA 2008) for *P. elatior* notes recovery actions should be targeted towards research priorities and managing known threats such road and track maintenance activities, clearing and hydrological changes to wetlands. The Project may cause hydrological changes to wetlands therefore interfering with the recovery of *P. elatior*. No currently approved Threat Abatement plans apply to *Persicaria elatior* in context of the Project impacts. Feral Pigs (which are covered by an Approved Threat Abatement Plan) may impact *P. elatior* but it is unknown how the Project might exacerbate this these impact.

Conclusion
The Project could potentially impact up to about 540 hectares of suitable habitat presumed to support an important population of *Persicaria elatior* habitat. This may an adverse effect on an important population of *P. elatior* such that it may cause it to decline. The Project has been assessed as likely to have a significant impact on *P. elatior*.

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Persoonia acerosa (Needle Geebung)

Vulnerable under the EPBC Act

Persoonia acerosa, the Needle Geebung, is an erect or spreading shrub growing up to two metres tall. It has distinct leaves that are bright green and sub-teret. The distinctive leaves are 12 to 23 millimetres long with a prominent channel on the adaxial side (DEWHA 2005; OEH 2019). Tubular yellow flowers about 10 millimetres long are produced in the summer and autumn. Inflorescences form in leafy shoots, not at the end of branches, as is common in most other species of *Persoonia* (DEWHA 2005; OEH 2019). This species of *Persoonia* produces yellow to green pear-shaped fruits with brown or red markings. Most *P. acerosa* fruit is about 14 millimetres long and 10 millimetres in diameter (PlantNET 1995).

P. acerosa is endemic to the Sydney Basin Bioregion. Historically, the distribution of *P. acerosa* occurred between Newnes Plateau, Hilltop, Lithgow and Springwood (NSW NPWS 2000). This distribution has contracted, with recent surveys determining that the population at Hilltop is now extinct (NSW NPWS 2000). The Environmental Impact Assessment Guidelines for *Persoonia acerosa* do acknowledge however, that large areas of potential - though low quality habitat - remain unsurveyed.

Within its known distribution, *P. acerosa* has been recorded growing in heath, low woodland and dry sclerophyll forest. Habitat is supported by low nutrient well-draining soils, that are derived from underlying sandstone. The Approved Conservation Advice for *Persoonia acerosa* adds that it has also been recorded growing in lateritic, and gravelly soils (DEWHA 2008). Most observations of *P. acerosa* have been recorded along ridgetops and plateaus between 500 and 1000 metres above sea level. Other species typically associated with *P. acerosa* include *Eucalyptus sieberi*, *E. piperita*, *E. sclerophylla*, *Lambertia formosa*, *Leptospermum trinervium*, *Hakea dactyloides* and *Platysace linearifolia* (DEWHA 2008).

According to OEH's BioNet system, *P. acerosa* is associated with the following PCT mapped in the upstream study area:

- PCT 1083 (HN566): Red Bloodwood – Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion
- PCT 1086 (HN568): Red Bloodwood – Sydney Peppermint – Blue-leaved Stringybark heathy forest of the southern Bleu Mountains Sydney basin Bioregion

P. acerosa is associated with the following PCT mapped in the construction study area:

- PCT 1083 (HN566): Red Bloodwood – Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion
- PCT 1086 (HN568): Red Bloodwood – Sydney Peppermint – Blue-leaved Stringybark heathy forest of the southern Blue Mountains Sydney basin Bioregion.

Persoonia acerosa was not assessed as having a moderate or higher likelihood of occurring in the Downstream study area. As such, the potential for this species to be impacted by the Project in this study area is not subject to this assessment.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal.*
- *populations that are necessary for maintaining genetic diversity.*
- *populations that are near the limit of the species range.*

Targeted surveys for *P. acerosa* were not undertaken across the Upstream and construction study areas. In the absence of targeted surveys, *P. acerosa* has been assumed present in areas of suitable habitat – the previously listed PCTs. Using the precautionary principle, the population(s) residing within this habitat have been assessed as an important population(s) as they are key source populations for breeding and dispersal, are necessary for maintaining genetic diversity, and occur near the limit of the species range.

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**
As *P. acerosa* has not been surveyed, areas of habitat have been used as a surrogate for the species occurrence and the important population's size. Up to 13.56 hectares of habitat may be impacted by a 1 in 5 chance in a year flood event, and up to 64.76 hectares by a 1 in 100 chance in a year flood event. About 18.02 hectares of habitat will be directly impacted by the clearing associated with construction (development footprint). The impacts to *P. acerosa* habitat within the upstream and construction study areas are expected to lead to a long-term decrease in the size of the important population.
• **reduce the area of occupancy of an important population**
The Project could potentially reduce the area of occupancy of the important population of *P. acerosa* by removing or modifying up to about 82.78 hectares of suitable habitat across both the construction and upstream study areas. Reductions in the area of occupancy can be summarised according to the following impact scenarios: Upstream Study Area • 1% AEP (1 in 100 chance in a year flood): 64.76 hectares • 20% AEP (1 in 5 chance in a year flood): 13.56 hectares Construction Study Area • Development footprint: 18.02 hectares
• **fragment an existing important population into two or more populations**
The *P. acerosa* habitat occurring in the upstream and construction study areas is largely contiguous with the native vegetation of the Blue Mountains National Park. However, the original construction of Warragamba Dam and the subsequent creation of Lake Burragorang fragmented this habitat. Within the construction study area, habitat may become increasingly fragmented by the direct clearing of vegetation associated with the construction works, by introduced edge effects and by the spread and establishment of invasive flora species. In the upstream study area, the Project may increase the fragmentation of habitat predominantly through the direct clearing of vegetation associated with higher flood events. The creation of new sub-populations through fragmentation cannot be conclusively proved without demonstrating new barriers to gene flow. A population genetic analysis would be required to demonstrate the existence of new sub-populations.
• **adversely affect habitat critical to the survival of a species**
According to the *Matters of National Environmental Significance Significant impact guidelines* 1.1 (DoE 2013) habitat critical to the survival of a species refers to areas that are necessary for: • activities such as foraging, breeding, roosting, or dispersal • 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 • the reintroduction of populations or recovery of the species or ecological community. The *P. acerosa* habitat in the Upstream and construction study areas has been assessed as critical habitat because it is important for dispersal, the long-term maintenance of the species, for maintaining genetic diversity, and for the potential reintroduction/recovery of the species. The Project could potentially adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive species, erosion and deposition, and modifying the fire regime.
• **disrupt the breeding cycle of an important population**
The breeding cycle of *P. acerosa* is reliant on disturbances created by fire and on the spread of genetic material by native fauna. Native bees from the genera *Leioproctus* and *Exoneura* have been recorded as the primary visitors of

P. acerosa flowers (Bernhardt and Weston 1996). Seeds are contained within a fleshy fruit, likely being dispersed by birds and/or small mammals (NSW NPWS 2000). Fire is important in both facilitating germination of the seedbank and reducing competition (for space and light) allowing for the recruitment of new individuals into a population. The Project may impact the occurrence of native bees within the Upstream and Constructions Study Areas. Nest and hive habitat – occurring either in trees or in the ground – may be impacted by prolonged periods of inundation, direct clearing of vegetation, erosion and disposition caused by the Project. Impacting native bees may interfere with the pollination of *P. acerosa* and the subsequent setting of seed. Habitat for native fauna – agents of seed dispersal – may be impacted by the Project in a similar manner to native bee habitat. A decrease in the occurrence of seed-dispersers may impact gene-flow and the recruitment of new individuals in to populations. A restriction on the exchange of genetic material between populations may cause these populations to become inbred and limit their ability to withstand changes to their environment. Restricting seed dispersal may impact the breeding cycle of *P. acerosa*. The Project may modify the assemblage of species within the impacted areas of vegetation. A different set of species will change the fuel load and subsequently, the fire regime. As fire is important for seed germination and providing opportunities for seedling growth, less frequent fire - or too frequent – would be detrimental to the breeding cycle of *P. acerosa*.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project could potentially impact *P. acerosa* habitat within the upstream and construction study areas. Habitat may be destroyed and/or directly impacted through the clearing of native vegetation, the loss of flora and fauna habitat, and a reduction in the extent of ecological communities. Habitat may be indirectly impacted (modified, reduced in quality etc.) through fragmentation, alteration to soil conditions, edge effects, weed invasion and incursion, through the spread of disease and pathogens, erosion and sedimentation, and thorough changes to the fire regime.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
The OEH Threatened Species Profile identifies 'weed invasion' as a threat to *P. acerosa*, especially on the edges and margins of bushland (OEH 2019). The Project may facilitate the spread and establishment of weeds and invasive flora species – such as *Rubus fruticosus* spp. agg. and *Lantana camara* – by creating new edges within the upstream and construction study areas. The spread and establishment of invasive flora species will also be promoted through the movement of plant and people during the construction phase and by the raised flood extents carrying plant material upslope. Although not identified in the SPRAT profile, Approved Conservation Advice or OEH Threatened Species Profile, the European Honey Bee (*Apis mellifera*) is a threat to *P. acerosa*. The European Honey Bee competes with native bees for access to flowers. This is problematic when species – such as *P. acerosa* – are reliant on these native bees to transfer pollen. European Honey Bees were incidentally observed in both the Upstream and construction study areas. It is unknown if the Project may increase their numbers throughout these Study Areas.
• **introduce disease that may cause the species to decline, or**
Persoonia acerosa has been identified as susceptible to *Phytophora cinnamomi,* a soil borne pathogen belonging to the water mould group (Oomycetes). An infestation of *P. cinnamomi* may adversely affect the important population(s) of *P. acersoa*. *Phytophora cinnamomi* can be spread in water, soil or plant material that contains the pathogen. Successful dispersal appears to be more common in moist or wet conditions (OíGara *et al.* 2005). While there is a number of mechanisms for spread of this disease, humans are considered by far to be the most significant vector (OíGara *et al.* 2005). Humans can spread the disease by construction works where soil is moved, soil on vehicles and maintenance machinery, on footwear and camping equipment. There is a risk during the construction phase of the Project that machinery and equipment may introduce *P. cinnamomi* to the construction study area. Similarly, a change to the existing hydrological environment in the upstream study area may create conditions conducive to spread of this disease. The Project has therefore been assessed as inconsistent with the Approved Threat Abatement Plan for Phytophthora.

• **interfere substantially with the recovery of the species.**
A National Recovery Plan for *P. acerosa* has yet to be developed under the EPBC Act. The Approved Commonwealth Conservation Advice for *P. acerosa* however, outlines several regional and local priority actions to assist in the conservation of the species. The Project interferes with the following priority actions: • manage threats to areas of vegetation that contain populations/occurrences/remnants of *P. acerosa* • Ensure road widening and maintenance activities (or other infrastructure or development activities) involving substrate and vegetation disturbance do not adversely impact on known populations. • Implement appropriate management recommendations outlined in the Threat Abatement Plan for Dieback Caused by Root-rot Fungus Phytophthora cinnamomi to protect known sites from further outbreaks of dieback. • Investigate options for linking, enhancing or establishing additional populations. • Protect known habitat from clearing and disturbance • Manage sites to prevent introduction of invasive weeds, which could become a threat to P. acerosa, using appropriate methods. A targeted strategy for managing *P. acerosa* has been developed under the Saving Our Species Program (NSW Government). Under the Saving Our Species Program, *P. acerosa* has been assigned to the 'site-managed species' management stream. The following priority management site has been identified in the Saving Our Species Program for *P. acerosa*: • Great Western Highway in the Blue Mountains LGAs. The Project will not impact this priority management site.
Conclusion
The Project could potentially impact *P. acerosa* habitat across the upstream and construction study areas. This habitat may become further fragmented increasing the isolation between occurrences of *P. acerosa.* The Project may impact the breeding cycle of *P. acerosa* by clearing native vegetation (habitat), modifying the fire regime, interfering with native pollinators and disturbing the soil seed bank. The threat of invasive flora species may also be exacerbated by the Project. These impacts are expected to cause a decline of important population of *P. acerosa*. The Project has been assessed as likely to have a significant impact on *Persoonia acerosa.*

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Persoonia bargoensis (Bargo Geebung)

Vulnerable under the EPBC Act

Persoonia bargoensis is an erect shrub varying in height from 0.6 metres to 2.5 metres in height. This species has slender branches with new growth being lightly covered in brownish hairs. The leaves are small, thin, slightly discolours and lanceolate in shape. The flowers are yellow, tubular appearing in summer in pedicels in the leaf axils (PlantNET 2019; OEH 2017).

The *P. bargoensis* distribution is restricted to a small area south-west of Sydney on the northern edge of the Southern Highlands. The limits of this distribution are Picton and Douglas park to the north, Yanderra to the south, Cataract River to the east and Thirlmere to the west. This species of *Persoonia* prefers the soil between Blacktown Soil Landscape and the complex Mittagong Formation soils (BioNet 2017). As populations sizes are small and typically absent from NPWS estates, any area of known habitat should be regarded as significant (NSW NPWS 2000).

This species is known to occur in woodland or dry sclerophyll forest supported by sandstone or well drained loamy, gravelly soils. Some of the vegetation the species occurs in is recognised as Shale/Sandstone Transition Forest, a listed TEC (BioNet 2017).

According to OEH's BioNet system, *P. bargoensis* is associated with the following PCTs mapped in the upstream study area:

- PCT 1081 (HN564): Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion
- PCT 1083 (HN566): Red bloodwood - scribbly gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion
- PCT 1086 (HN568): Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains Sydney Basin Bioregion
- PCT 1284 (HN606): Turpentine - Smooth-barked Apple moist shrubby forest of the lower Blue Mountains Sydney Basin Bioregion
- PCT 1292 (HN607): Water Gum - Coachwood riparian scrub along sandstone streams Sydney Basin Bioregion.

Persoonia bargoensis was not assessed as having a moderate or higher likelihood of occurring in the downstream or construction study areas. As such, its potential occurrence in these tow study areas is not subject to this assessment.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal.*
- *populations that are necessary for maintaining genetic diversity.*
- *populations that are near the limit of the species range.*

Targeted surveys for *P. bargoensis* were not undertaken in the upstream study area. Additionally, *P. bargoensis* was not incidentally encountered during vegetation mapping associated with the Project. In the absence of targeted surveys, *P. glaucescens* has been assumed present in areas of presumed suitable habitat – the previously listed PCTs. Using the precautionary principle, the population(s) residing within this habitat have been assessed as an important population(s) as they are key source populations for breeding and dispersal, are necessary for maintaining genetic diversity, and are near the limit of the species range.

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**
As explained in the introduction, because *Persoonia bargoensis* has not been surveyed, areas of habitat have been used as a surrogate for occurrence and population size. The Project could potentially impact up to about 41.13 hectares of *P. bargoensis* habitat within the 1% AEP flood extent and 5.08 hectares within the 20% AEP flood extent. Impacts to the habitat of *P. bargoensis* have the potential to lead to a long-term decrease in the size of the important population.

• **reduce the area of occupancy of an important population**
The Project could potentially impact up to about 41.13 hectares of *P. bargoensis* habitat within the 1% AEP flood extent and 5.08 hectares within the 20% AEP flood extent. The impacts to habitat within these boundaries may reduce the area of occupancy of the important population.
• **fragment an existing important population into two or more populations**
Persoonia bargoensis habitat is currently in a fragmented condition as result of the original construction of Warragamba Dam. The Environmental Impact Assessment Guidelines for *Persoonia bargoensis* provides the following information with regards to assessing isolation and fragmentation: Because the dynamics of metapopulations of *P. bargoensis* are unknown, the specific parameters needed to assess fragmentation effects are also unknown. In light of this information and given the scale of the Project and its impacts, the important population has been precautionarily assessed as likely to become fragmented.
• **adversely affect habitat critical to the survival of a species**
According to the *Matters of National Environmental Significance Significant impact guidelines* 1.1 (DoE 2013) habitat critical to the survival of a species refers to areas that are necessary for: • activities such as foraging, breeding, roosting, or dispersal • 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 • the reintroduction of populations or recovery of the species or ecological community. The *P. bargoensis* habitat in the upstream area has been assessed as critical habitat because it is important for dispersal, the long-term maintenance of the species and for maintaining genetic diversity. The Project will adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive species, erosion and deposition, and modifying hydrology and the fire regime.
• **disrupt the breeding cycle of an important population**
Fire is important to the reproductive ecology of *Persoonia bargoensis*. Fire kills adult plants making changes to the fire regime harmful to the important population. The Environmental Impact Assessment Guidelines for *Persoonia bargoensis* identify the threat of fire to its breeding cycle stating that 'if a proposal is likely to result in fire frequencies less than 10-15 years, this may lead to a decline of the affected population, since an adequate seedbank will not be able to develop between fires' (NSW NPWS 2000). The Project may change the fire regime – both increasing and decreasing fire frequency depending on the existing vegetation and landform – upstream and downstream of the dam wall. The Project has subsequently been assessed as potentially disrupting the breeding cycle of the important population of *P. bargoensis*. Native bees have been observed as the primary pollinators of *P. glaucescens* (Bernhardt and Weston 1996). Species in the genus *Leioproctus* that have been observed visiting *Persoonia* flowers, make tunnels in sandy ground. This makes bees from the genus *Leioproctus* that make tunnel nests in the upstream study area, vulnerable to the increased flooding extent caused by the Project. Bees from the genus *Exoneura* – also observed visiting *Persoonia* flowers - nest in the hollow stems of plants. Bees nesting in the plants within the upstream 1% AEP flood extent may be impacted by the Project. Modifying the vegetation has the potential to limit habitat for bees in the genus *Exoneura*. Impacting the native bees of these two genera has the potential to impact the breeding cycle of *P. bargoensis*.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project could potentially impact *Persoonia bargoensis* habitat within the upstream study area. Habitat may be destroyed and/or directly impacted through the clearing of native vegetation, the loss of flora and fauna habitat, and a reduction in the extent of ecological communities. Habitat may be indirectly impacted (modified, reduced in

quality etc.) through fragmentation, alteration to soil conditions, edge effects, weed invasion and incursion, through the spread of disease and pathogens, erosion and sedimentation, and thorough changes to the fire regime.

- **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**

No invasive flora species have been listed in the SPRAT profile, Environmental Impact Assessment Guidelines or OEH profile as a threat to *Persoonia bargoensis* (NSW NPWS 2000; DoEE 2019; OEH 2019). The European Honey Bee - *Apis mellifera* - is however listed as a threat by all three sources. *Apis mellifera* is a threat to *P. bargoensis* as it can outcompete native bee pollinators for pollen. Additionally, while *A. mellifera* is able to collect pollen, its method of pollen transport makes effective pollination of other *P. bargoensis* individuals unlikely (OEH 2019).

Apis mellifera was commonly observed throughout the upstream study area. The Project is therefore unlikely to further facilitate its spread.

- **introduce disease that may cause the species to decline, or**

Many species in the genus *Persoonia* are killed by the soil-borne pathogen *Phytophthora cinnamomi* (OEH 2019). *Phytophthora cinnamomi* is common in coastal forests, occurring around the roots of plants in warm and moist conditions. The OEH key threatening process for *P. cinnamomi* states that it 'may contribute to plant death where there are other stresses present (for example, waterlogging, drought, and wildfire)'. Waterlogging of previously un-inundated soils will occur in the upstream 1% AEP flood extent. This may facilitate the spread of *P. cinnamomi* and/or exacerbate its impact. Increasing the spread and impact of *P. cinnamomi* upstream of the dam wall has the potential to lead to the decline of *P. bargoensis*. The Project has been assessed as inconsistent with the Approved Threat Abatement Plan for Phytophthora.

- **interfere substantially with the recovery of the species.**

No National Recovery Plan has been developed for *Persoonia bargoensis* under the EPBC Act. A recovery plan has however been developed for *P. bargoensis* under OEH's Saving Our Species program (NSW government). Within the Saving Our Species program, *P. bargoensis* has been assigned as a site-managed species. The following three priority management sites have been listed for *P. bargoensis*:

- Bargo in Wingecarribee, in the Wollondilly LGA.
- Wilton in the Wollondilly LGA.
- Hume Highway in the Wingecarribee and Wollondilly LGAs.

The Project would not impact any of the three listed priority management sites. The Project therefore would not substantially interfere with the recovery of *P. bargoensis*.

Conclusion

The Project could potentially impact *Persoonia bargoensis* habitat. This habitat may become further fragmented, potentially isolating remaining stands from one another. The Project may impact the breeding cycle of *P. bargoensis* by modifying the fire regime and destroying the habitat of its native bee pollinators. The spread and establishment the pathogen *Phytophthora cinnamomi* – a threat to *P. bargoensis* – will also be facilitated by the Project. These impacts may cause a decline of important population of *P. bargoensis*.

The Project has been assessed as likely to have a significant impact on *Persoonia bargoensis*.

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Persoonia glaucescens (Mittagong Geebung)

Vulnerable under the EPBC Act

Persoonia glaucescens is a shrub with an erect habitat that can reach up to three metres tall. It has a mottled stem that produces reddish or brown branches. This species of *Persoonia* has erect leaves that are greyish green, are three to eight centimetres long, and have an oblanceolate or narrow-spatulate margin. These leaves are sparsely hairy and are waxy when young. Yellow flowers between 11 to 12 millimetres long emerge from the leaf axils from January to May.

Persoonia glaucescens has a restricted distribution, occurring between Berrima and Picton just to the south of Sydney (DEWHA 2008). This species has been recorded in woodland and open dry sclerophyll forest occurring along ridgetops, plateaux and upper slopes (OEH 2018). Habitat is supported by soils with a large clay component and often consist of lateritic gravels.

According to OEH's BioNet system, *P. glaucescens* is associated with the following PCTs mapped in the upstream study area:

- PCT 1081 (HN564): Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion
- PCT 1083 (HN566): Red bloodwood - scribbly gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion
- PCT 1086 (HN568): Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains Sydney Basin Bioregion.

Persoonia glaucescens was not assessed with a moderate or higher likelihood of occurring in the downstream or construction study areas.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal.*
- *populations that are necessary for maintaining genetic diversity.*
- *populations that are near the limit of the species range.*

Targeted surveys for *P. glaucescens* were not undertaken in the upstream study area. Additionally, *P. glaucescens* was not incidentally encountered during vegetation mapping associated with the Project. In the absence of targeted surveys, *P. glaucescens* has been assumed present in areas of presumed suitable habitat – the previously listed PCTs. Using the precautionary principle, the population(s) residing within this habitat have been assessed as an important population(s) as they are key source populations for breeding and dispersal, are necessary for maintaining genetic diversity, and are near the limit of the species range.

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**
As explained in the introduction, because *Persoonia glaucescens* has not been surveyed, areas of habitat have been used as a surrogate for occurrence and population size. The Project could potentially impact up to about 17.05 hectares of *P. bargoensis* habitat within the 1% AEP flood extent and 3.27 hectares within the 20% AEP flood extent. Impacts to the habitat of *P. glaucescens* have the potential to lead to a long-term decrease in the size of the important population.
• **reduce the area of occupancy of an important population**
The Project could potentially impact up to about 17.05 hectares of *P. bargoensis* habitat within the 1% AEP flood extent and 3.27 hectares within the 20% AEP flood extent. The impacts to habitat within these boundaries will reduce the area of occupancy of the important population.

• **fragment an existing important population into two or more populations**
Throughout its distribution, *Persoonia glaucescens* has been previously recorded occurring as fragmented, linear populations (OEH 2018). Due to the scale of the Project, it is possible that more than one of these populations could be impacted. These populations have however been defined as a single important population for purpose of this assessment. The scale of the Project and its potential impact in the upstream study area, may further fragment the occurrences of the previously listed PCTs used to define the important population. The important population could potentially therefore become further fragmented.
• **adversely affect habitat critical to the survival of a species**
According to the *Matters of National Environmental Significance Significant impact guidelines* 1.1 (DoE 2013) habitat critical to the survival of a species refers to areas that are necessary for: • activities such as foraging, breeding, roosting, or dispersal • 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 • the reintroduction of populations or recovery of the species or ecological community. The *P. glaucescens* habitat in the upstream study area has been assessed as critical habitat because it is important for dispersal, the long-term maintenance of the species and for maintaining genetic diversity. The Project may adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive species, erosion and deposition, and modifying hydrology and the fire regime.
• **disrupt the breeding cycle of an important population**
Fire and disturbance are important to the reproductive ecology of *Persoonia glaucescens*. Fire kills adult plants making changes to the fire regime harmful to the important population of *P. glaucescens*. The lifespan of a *P. glaucescens* individual is thought to be at least 20 years however most plants do not make it to this age because of frequent fire (NSW NPWS 2000). The Environmental Impact Assessment Guidelines for *Persoonia glaucescens* identify the threat of fire to its breeding cycle stating that *if a proposal is likely to result in fire frequencies less than 10-15 years, this may lead to a decline of the affected population, since an adequate seedbank will not be able to develop between fires* (NSW NPWS 2000). These guidelines then identify a decrease in fire frequency as a threat to the breeding cycle - *if a proposal is likely to reduce the incidence of fire beyond 20 years, this may also lead to population decline from reduced opportunity for recruitment* (NSW NPWS 2000). The Project will change the fire regime – both increasing and decreasing fire frequency depending on the existing vegetation and landform – upstream of the dam wall. The Project has subsequently been assessed as potentially disrupting the breeding cycle of the important population of *P. glaucescens*. Native bees from the genera *Leioproctus* and *Exoneura*, have been observed as the primary pollinators of *P. glaucescens* (Bernhardt and Weston 1996). Species in the genus *Leioproctus* such as *Leioproctus plumosus*, make tunnels in sandy ground. Bees from the genus *Leioproctus* that make tunnel nests in the upstream study area may be impacted by the increased flooding extent caused by the Project. Bees from the genus *Exoneura* nest in the hollow stems of plants. Bees nesting in the plants within the upstream 1% AEP flood extent may be impacted by the Project. Modifying the vegetation has the potential to limit habitat for bees in the genus *Exoneura*. Impacting the native bees of these two genera has the potential to impact the breeding cycle of *P. glaucescens*.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project could potentially impact *Persoonia glaucescens* habitat within the upstream study area. Habitat may be destroyed and/or directly impacted through the clearing of native vegetation, the loss of flora and fauna habitat, and a reduction in the extent of ecological communities. Habitat may be indirectly impacted (modified, reduced in quality etc.) through fragmentation, alteration to soil conditions, edge effects, weed invasion and incursion, through the spread of disease and pathogens, erosion and sedimentation, and thorough changes to the fire regime.

• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
Both invasive flora and fauna were observed in *Persoonia glaucescens* habitat. The European honey bee (*Apis mellifera*) can outcompete native bee pollinators for *P. glaucescens* pollen. Additionally, while *A. mellifera* is able to collect pollen, its method of pollen transport makes effective pollination of other *P. glaucescens* individuals unlikely (OEH 2018). However, *Apis mellifera* was commonly observed throughout the upstream study area. The Project is therefore unlikely to further facilitate its spread.
• **introduce disease that may cause the species to decline, or**
Many species in the genus *Persoonia* are killed by the soil-borne pathogen *Phytophthora cinnamomi* (OEH 2018). Dieback caused by the root-rot fungus (*Phytophthora cinnamomi*) is listed as a key threatening process under the EPBC Act. *Phytophthora cinnamomi* is common in coastal forests, occurring around the roots of plants in warm and moist conditions. The OEH key threatening process for *P. cinnamomi* states that it *may contribute to plant death where there are other stresses present (for example, waterlogging, drought, and wildfire)*. Waterlogging of previously un-inundated soils may occur in the upstream 1% AEP flood extent as a result of the Project. This may facilitate the spread of *P. cinnamomi* and/or exacerbate its impact. Increasing the spread and impact of *P. cinnamomi* upstream of the dam wall has the potential to lead to the decline of *P. glaucescens*. The Project has been assessed as inconsistent with the Approved Threat Abatement Plan for Phytophthora.
• **interfere substantially with the recovery of the species.**
No National Recovery Plan has been developed for *Persoonia glaucescens* under the EPBC Act. A recovery plan has however been developed for *P. glaucescens* under OEH's Saving Our Species program (NSW government). Within the Saving Our Species program, *P. glaucescens* has been assigned as a site-managed species. The following four priority management sites have been listed for *P. glaucescens*: • Bargo in Wingecarribee, in the Wollondilly LG. • Cordeaux record in the Wollongong LGA • Mt Alexandra, Welby and Jellore in the Wingecarribee LGA • Upper Nepean State Conservation Area in the Wingecarribee LGA. The Project would not impact any of the four listed priority management sites. The Project therefore would not substantially interfere with the recovery of the *P. glaucescens*.
Conclusion
The Project could potentially impact *Persoonia glaucescens* habitat. This habitat may become further fragmented, isolating remaining stands from one another. The Project may impact the breeding cycle of *P. glaucescens* by modifying the fire regime and destroying the habitat of its native bee pollinators. These impacts may cause a decline of important population of *P. glaucescens*. The Project has been assessed as likely to have a significant impact on *Persoonia glaucescens*.

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Persoonia hirsuta (Hairy Geebung)

Endangered under the EPBC Act

Persoonia hirsuta, the Hairy Geebung, is a decumbent to spreading shrub that can grow up to one metre tall. As the common name suggests, *P. hirsuta* can be distinguished from other species of *Persoonia* by its indumentum or hair-coverage. It has long coarse hairs on its flowers and branches and smaller stiffer hairs on its leaves (OEH 1998; DoE 2014). Small leaves between 6 and 12 millimetres are produced which are oblong to narrow in shape and clustered along the length of a stem. Leaves are curled or slightly revolute along their margins (PlantNET 1995; OEH 1998; DoE 2014). Tubular flowers about one centimetre long that are either yellow or orange are produced in summer.

Persoonia hirsuta has a scattered distribution throughout the Sydney Basin Bioregion. It occurs as 21 small populations - mostly between 1 and 5 individuals- from Cessnock in the north, to the Blue Mountains in the west, and down to Bargo in the south (OEH 1998; DoE 2014). Only two populations are comprised of over 10 individuals, the one in the Baulkham Hills Shire being of noted importance by OEH (1998) because of the comparatively high density of plants.

Persoonia hirsuta has been recorded in woodlands, heaths, and dry sclerophyll forest. Its habitat is usually supported by sand-based soils, however rare occurrences of the species have recorded it growing in soils with a large shale influence (OEH 1998; DoE 2014).

According to OEH's BioNet system, *P. hirsuta* is associated with the following PCT mapped in the upstream study area:

- PCT 1081 (HN564) Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion.
- PCT 1083 (HN566): Red Bloodwood – Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion
- PCT 1086 (HN568): Red Bloodwood – Sydney Peppermint – Blue-leaved Stringybark heathy forest of the southern Blue Mountains Sydney Basin Bioregion.

Persoonia hirsuta is associated with the following PCTs mapped in the construction study area.

- PCT 1081 (HN564) Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion.
- PCT 1083 (HN566): Red Bloodwood – Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion
- PCT 1086 (HN568): Red Bloodwood – Sydney Peppermint – Blue-leaved Stringybark heathy forest of the southern Blue Mountains Sydney Basin Bioregion
- PCT 1281 (HN604): Turpentine – Grey Ironbark open forest on shale in the lower Blue Mountains Sydney Basin Bioregion

Persoonia hirsuta is associated with the following PCTs mapped in the downstream study area:

- PCT 835 (HN526): Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin Bioregion
- PCT 1081 (HN564) Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion
- PCT 1181 (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
- PCT 1183 (HN587): Smooth-barked Apple - Sydney Peppermint - Turpentine heathy open forest on plateaux areas of the Sydney Basin Bioregion
- PCT 1327 (HN612): Yellow Bloodwood - ironbark shrubby woodland of the dry hinterland of the Central Coast, Sydney Basin Bioregion
- PCT 1328 (HN613): Yellow Bloodwood - Narrow-leaved Apple heathy woodland on hinterland plateaux of the Central Coast, Sydney Basin Bioregion
- PCT 1395 (HN556): Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain Sydney Basin Bioregion.

OEH records of *P. hirsuta* occurred in one PCT mapped within the downstream study area yet was not listed in the BioNet system as being an associated PCT - PCT 883 (HN542): Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain Sydney Basin Bioregion. This PCT will be considered as associated with the occurrence of *P. hirsuta* for the purposes of this assessment.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'population of a species' as '*an occurrence of the species in a particular area'. In relation to critically endangered, endangered or vulnerable threatened species, occurrences include but are not limited to:*

- *a geographically distinct regional population, or collection of local populations, or*
- *a population, or collection of local populations, that occurs within a particular bioregion.*

Targeted surveys for *P. hirsuta* were not undertaken in the upstream, downstream or construction study areas, and *P. hirsuta* was not incidentally encountered during the vegetation mapping associated with the Project. In the absence of targeted surveys, *P. hirsuta* has been assumed present in areas of presumed suitable habitat – the previously listed PCTs. Using the precautionary principle, a population of *P. hirsuta* has been assessed as occurring in areas of suitable habitat (the previously listed PCTs).

An action is likely to have a significant impact on an endangered or critically 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 of a species**

As *Persoonia hirsuta* has not been surveyed, areas of habitat have been used as a surrogate for the species occurrence and population size. Within the upstream study area 132.53 hectares of habitat has been mapped. Of this 132.53 hectares, 14.45 hectares may be impacted by a 1 in 5 chance in a year flood event (20% AEP) and 68.63 hectares by a 1 in 100 chance in a year flood event (1% AEP).

Within the downstream study area approximately 459.98 hectares occurs between the existing and with project 10% AEPs, 36.37 hectares between the existing and with project PMFs and 557.34 hectares within the FMZ discharge area.

22.42 hectares of habitat occurs within the Development Footprint associated with construction activities.

The impacts to suitable habitat have the potential to lead to a long-term decrease in the size of the populations of *P. hirsuta*.

- **reduce the area of occupancy of a species**

The Project may reduce the potential area of occupancy for *Persoonia hirsuta* across all three study areas. These reductions can be summarised according to the following impact scenarios:

Upstream Study Area

- 1% AEP (1 in 100 chance in a year flood): 68.63 hectares
- 20% AEP (1 in 5 chance in a year flood): 14.45 hectares

Downstream Study Area

- FMZ discharge area: 557.34 hectares
- Difference between the existing and with project 10% AEPs: 459.98 hectares
- Difference between the existing and with project PMFs: 36.37 hectares

Construction Study Area

- Development footprint: 22.42 hectares

- **fragment an existing population into two or more populations**

Much of the *Persoonia hirsuta* habitat within the downstream study area is fragmented. This habitat occurs as the remnant forests and woodlands that once covered the Cumberland Plain. These forest and woodlands were historically cleared for agricultural use but have more recently been cleared for urban and residential developments. The PCTs making up the *P. hirsuta* habitat within the downstream study area include PCTs; 835 (HN526); 883(HN542) 1181(HN586) 1327(HN612) 1328 (HN613) and 1395 (HN556). The Project may increase the fragmentation of these PCTs within the Downstream study area. The *P. hirsuta* habitat in the downstream study area may be fragmented by the Project through changes to hydrology, increases in erosion and deposition, changes to the fire regime and the increased presence of invasive weed species.

The *P. hirsuta* habitat in the Upstream and construction study areas occurs in the eastern extent of Warragamba Gorge – PCTs 1081 (HN564) 1083 (HN566) 1086 (HN568) and 1281 (HN604) in the case of the construction study area. This habitat is contiguous with the native vegetation of the surrounding Blue Mountains National Park. The Project will lead to the direct removal of native vegetation and habitat in the eastern section of the Warragamba Gorge. The removal of this vegetation may fragment the *P. hirsuta* habitat in the Upstream and construction study areas. Potential indirect impacts caused by the Project such as promoting the spread and establishment of invasive flora species may also contribute to habitat fragmentation.

- **adversely affect habitat critical to the survival of a species**

According to the *Matters of National Environmental Significance Significant impact guidelines* 1.1 (DoE 2013) habitat critical to the survival of a species refers to areas that are necessary for:

- activities such as foraging, breeding, roosting, or dispersal
- 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
- the reintroduction of populations or recovery of the species or ecological community.

The *P. hirsuta* habitat in the upstream study area has been assessed as critical habitat because it is important for dispersal, the long-term maintenance of the species and for maintaining genetic diversity. The Project may adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive species, erosion and deposition, and modifying hydrology and the fire regime.

- **disrupt the breeding cycle of a population**

The breeding cycle of *Persoonia hirsuta* is influenced by fire, the European Honey Bee (*Apis mellifera*), and unstable population dynamics. *Persoonia hirsuta* – like most *Persoonia* species – is likely killed by fire with the regeneration of a population occurring from a soil-stored seedbank (OEH 1998; DoE 2014). As previously mentioned, the *P. hirsuta* distribution is comprised of 21 populations, none of which consist of more than 20 individuals. This makes the species susceptible to demographic shifts. The Approved Conservation Advice for *Persoonia hirsuta* explains that the European Honey Bee may contribute to the small size of *P. hirsuta* occurrences. The European honey bee is able to collect pollen, however the way in which it transports this pollen prohibits the subsequent pollination of other individuals in the population (DoE 2014).

The Project may modify the fire regime within the *P. hirsuta* habitat. If fire becomes too frequent it can disrupt the breeding cycle of the population. The Project may directly impact the population dynamics of the population through the direct clearing of vegetation, and indirectly impact them by promoting completion with invasive flora, increasing erosion and sedimentation, creating edge effects and spreading *Phytophthora cinnamomi*. While the European Honey Bee may contribute to the instability of population dynamics, it is unknown if this will be exacerbated by the Project.

- **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**

The Project could potentially impact *Persoonia hirsuta* habitat within the upstream, downstream and construction study areas. Habitat may be destroyed and/or directly impacted through the clearing of native vegetation, the loss of flora and fauna habitat, and a reduction in the extent of ecological communities. Habitat may be indirectly impacted (modified, reduced in quality etc.) through fragmentation, alteration to soil conditions, edge effects, weed invasion and incursion, through the spread of disease and pathogens, erosion and sedimentation, and thorough changes to the fire regime.

- **result in invasive species that are harmful to an endangered or critically endangered species becoming established in the endangered or critically endangered species' habitat**

The European Honey Bee has the potential to impact gene flow within and between populations of *P. hirsuta.* However, it is unknown if the Project could promote the occurrence of the European Honey Bee. It is important to note though, that the Project may promote the spread and establishment of weed and exotic flora species - many from Europe and Africa – which could increase pollen and nectar availability for the European Honey Bee. If pollen and nectar availability increase, the occurrence of the European Honey Bee may also rise. If the European Honey Bee is able to further outcompete the native bee pollinators of *P. hirsuta*, pollination and the subsequent recruitment of new individuals may not occur.

- **introduce disease that may cause the species to decline, or**

The pathogen *Phytophthora cinnamomi* is a recognised threat to many species of Persoonia, so it stands to reason that it may also be a threat to *Persoonia hirsuta*. *Phytophthora cinnamomi* can be spread through water making the Project a potential facilitator of its spread throughout the upstream study area and parts of the downstream study area. The spread of *Phytophthora cinnamomi* as a result of the Project may cause the occurrence of *P. hirsuta* to decline. The Project has been assessed as inconsistent with the Approved Threat Abatement Plan for Phytophthora.

- **interfere substantially with the recovery of the species.**

No National Recovery Plan has been developed for *Persoonia hirsuta* under the EPBC Act. The SPRAT profile for *P. hirsuta* provides the following justification for the absence of a recovery plan; recovery plan not required, the approved conservation advice for the species provides sufficient direction to implement priority actions and mitigate against key threats. The following priority actions outlined in the Approved Commonwealth Conservation Advice (DoE 2014) will be inhibited by the Project:

Habitat Loss, Disturbance and Modification

- Ensure there is no disturbance in areas where Persoonia hirsuta occurs, excluding necessary actions to manage the conservation of the species.
- Manage any other known, potential or emerging threats.

Fire

- Develop and implement a suitable management strategy for the habitat of Persoonia hirsuta.

Enable recovery of additional sites and/or populations

- Undertake appropriate seed collection and storage.
- Investigate options for linking, enhancing or establishing additional populations.

In addition to the Approved Conservation Advice, a targeted strategy for managing *Persoonia hirsuta* has been developed under the Saving Our Species Program (NSW Government). Under the Saving Our Species Program, P. hirsuta has been assigned to the 'site-managed species' management stream. The following 7 priority management sites have been identified for this species:

- Yengo in the Central Coast, Cessnock and Hawkesbury LGAs.
- Parr in the Hawkesbury and The Hills Shire LGAs.
- Maroota Ridge in the Hawkesbury, Hornsby and The Hills Shire LGAs.
- Fred Caterson Reserve in The Hills Shire LGA.
- Cromer in the Northern Beaches LGA.
- WestCliff Mine in the Wollondilly LGA.
- Bargo in the Wingecarribee and Wollondilly LGAs.

The Project may impact areas of the Yengo, Parr and Maroota Ridge priority management sites. The *P. hirsuta* SOS management plan outlines management objectives for these priority management sites, of which the following may be impeded by the Project:

- Maintain appropriate fire regime for the species/community.

Conclusion

The Project could potentially impact *Persoonia hirsuta* habitat across the upstream, downstream and construction study areas. This habitat may become fragmented, potentially isolating occurrences of *P. hirsuta* from one another. The Project may impact the breeding cycle of *P. hirsuta* by clearing native vegetation (habitat), modifying the fire regime and impacting the soil seed bank. The threat of *Phytophthora cinnamomi* may also be exacerbated by the Project. These impacts could interfere with the recovery of the population and cause a decline of the species.

The Project has been assessed as likely to have a significant impact on *P. hirsute.*

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Persoonia nutans (Nodding Geebung)

Endangered under the EPBC Act

Persoonia nutans is a spreading shrub that can grow up to 2. 5 metres in height. A distinguishing characteristic of this species of *Persoonia* is its hairy young stems. *P. nutans* produces linear leaves between 1 and 3 centimetres long 1 to 1.8 millimetres wide, have recurved margins, and are sparsely arranged upon mature stems. Like most Persoonias, *P. nutans* has yellow flowers. The flowers of *P. nutans* hang from drooping peduncles that are about 12 millimetres long. Flowering occurs from November to March (OEH 2019; PlantNET 2019).

P. nutans is restricted to the Cumberland Plain in western Sydney, between Richmond in the north and Macquarie Fields in the south. This species has a disjunct distribution, with the majority of populations (and almost all individuals) occurring in the north of the species' range in the Agnes Banks, Londonderry, Castlereagh, Berkshire Park and Windsor Downs areas. Core distribution occurs within the Penrith, and to a lesser extent Hawkesbury, LGAs, with isolated and small populations also occurring in the Liverpool, Campbelltown, Bankstown and Blacktown LGAs (OEH 2019).

Its southern and northern populations have distinct habitat differences. Northern populations of *P. nutans* are confined to aeolian and alluvial sediments and occur in a range of sclerophyll forest and woodland vegetation communities, with the majority of individuals occurring within Agnes Banks Woodland or Castlereagh Scribbly Gum Woodland, and a smaller number occurring in Cooks River/Castlereagh Ironbark Forests. Southern populations also occupy tertiary alluvium but extend onto shale sandstone transition communities and into Cooks River/Castlereagh Ironbark Forest (OEH 2019).

According to OEH's BioNet system, *P. nutans* is associated with the following PCTs mapped in the downstream study area:

- PCT 724 (HN512): Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain Sydney Basin Bioregion
- PCT 725 (HN513): Broad-leaved Ironbark - *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain Sydney Basin Bioregion
- PCT 883 (HN542): Hard-leaved Scribbly Gum - Parramatta Red Gum heathy woodland of the Cumberland Plain Sydney Basin Bioregion
- PCT 958 (HN555): Narrow-leaved Apple - Hard-leaved Scribbly Gum heathy woodland on sand at Agnes Banks Sydney Basin Bioregion
- PCT 1395 (HN556): Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain Sydney Basin Bioregion
- PCT 1067 (HN562): Parramatta Red Gum woodland on moist alluvium of the Cumberland Plain Sydney Basin Bioregion

Persoonia nutans is not associated with any PCTs mapped in the upstream study area or construction footprint. As such, impacts to *P. nutans* in these two study areas has not been considered in this assessment.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'population of a species' as '*an occurrence of the species in a particular area). In relation to critically endangered, endangered or vulnerable threatened species, occurrences include but are not limited to:*

- *a geographically distinct regional population, or collection of local populations, or*
- *a population, or collection of local populations, that occurs within a particular bioregion.*

Targeted surveys for *P. nutans* were not undertaken in the upstream, downstream or construction study areas. In the absence of targeted surveys, *P. nutans* has been assumed present in areas of presumed suitable habitat – the previously listed PCTs. Using the precautionary principle, a population of *P. nutans* has been assessed as occurring in areas of suitable habitat (the previously listed PCTs).

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**
As *Persoonia nutans* has not been surveyed, areas of habitat have been used as a surrogate for occurrence and population size. The Project could potentially impact up to about 622.11 hectares of *P. nutans* habitat between the existing and with-project PMFs, 44.99 hectares between the existing and with-project 10% AEPs and 5.56 hectares within the FMZ discharge boundary. Impacts to this habitat has the potential to lead to a long-term decrease in the size of the *P. nutans* population.
• **reduce the area of occupancy of the species**
According to SMEC's mapping and the NPWS's mapping of the Cumberland Plain (NPWS 2002), *Persoonia nutans* occurs predominantly in woodland communities just east of the Nepean and Hawkesbury Rivers within the Penrith and Hawkesbury LGAs. Approximately 99% of previously recorded individuals occur in either Agnes Banks Woodland or Castlereagh Scribbly Gum Woodland (NSW DEC 2005) that fall within these LGAs. Smaller occurrences of *P. nutans* have also been recorded in in Cooks River Castlereagh Ironbark Forest, Shale Gravel Transition Forest and Shale Sandstone Transition Forest.   Within the downstream study area, the Project could potentially impact up to about 622.11 hectares of *P. nutans* habitat between the existing and with-project PMFs, 44.99 hectares between the existing and with-project 10% AEPs and 5.56 hectares within the FMZ discharge boundary. These impacts are expected to reduce the area of occupancy of the *P. nutans* population.
• **fragment an existing population into two or more populations**
The Project may further fragment the native forests and woodlands of the Cumberland Plain and fragmenting vegetation in the comparatively undisturbed Warragamba Special Area. The remnant forests and woodlands on the Cumberland Plain occur as isolated stands of varying sizes, condition and level of protection. The Project may further impact these stands of forest and woodland – of which much has been assessed as *P. nutans* habitat. Specifically, the Project may fragment the *P. nutans* habitat in the Agnes Banks Nature Reserve, Windsor Downs Nature Reserve, Castlereagh Nature Reserve, Wianamatta Nature Reserve and Wianamatta Regional Park.
• **adversely affect habitat critical to the survival of a species**
No critical habitat has been listed for *Persoonia nutans* under the EPBC Act. The Environmental Impact Assessment Guidelines for *Persoonia nutans* however, defines areas of significant habitat. In the south of its known distribution significant habitat has been defined as *any area of known habitat.* In the north of known distribution – where most recorded individuals occur – significant habitat will need to be assessed according to the following factors: • the area and condition of habitat on the site.   • the area, condition and security, of other, nearby habitat.   • Connectivity with other areas of habitat.   • The impact of the loss of that habitat on potential seed dispersal among P. nutans populations particularly those in conservation reserves.   As the Project may impact Agnes Banks Nature Reserve, Windsor Downs Nature Reserve, Castlereagh Nature Reserve, Wianamatta Nature Reserve and Wianamatta Regional Park, it has been assessed as adversely affecting significant habitat.
• **disrupt the breeding cycle of a population**
Persoonia nutans is an obligate seed regenerator with the regeneration of a population occurring from a soil-stored seed bank after fire (Benson and McDougall 2000). Peak flowering in *P. nutans* occurs from December to January however intermittent flowering has been observed throughout the year (Benson and McDougall 2000; Bernhardt and Weston 1996). Bernhardt and Western observed bees and wasps as the most frequent visitors to *Persoonia* flowers in Eastern Australia indicating they likely visit the flowers of *P. nutans*. *Persoonia nutans* sets fleshy fruit containing one or two seeds. Individual plants are able to set a large quantity of this fruit – one plant observed to

produce over 1000 (NPWS 1996). Seed dispersal is likely carried out by large birds and mammals such as possums (Benson and McDougall 2000).

The Project may modify the fire regime both upstream and downstream of the dam wall, subsequently affecting seed germination. Populations of the native bee pollinators may be impacted by the Project through inundation of nests and hives. Impacting pollinators will inhibit recruitment of new individuals into the population and prevent the exchange of genetic material between extant occurrences. Erosion caused by the Project also has the potential to affect the seedbank by burying it in debris carried from upstream and upslope. The Project has therefore been assessed as potentially disrupting the breeding cycle of the population of *P. nutans*.

- **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**

Within the downstream study area, the Project could potentially impact up to about 622.11 hectares of *P. nutans* habitat between the existing and with-project PMFs, 44.99 hectares between the existing and with-project 10% AEPs and 5.56 hectares within the FMZ discharge boundary. These impacts are expected modify and/or destroy the habitat of the *P. nutans* population.

- **result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat**

The following invasive flora have been listed as a threat to *Persoonia nutans* in the OEH threatened species profile:

- Grasses: *Andropogon virginicus* (Whisky Grass), *Eragrostis curvula* (African Lovegrass), *Cenchrus clandestinus* (Kikuyu).
- *Acacia baileyana.*
- Other non-native and native woody invasive species.

The Project may facilitate the spread of these species and create opportunities for their establishment in previously un-colonised areas.

The European Honey Bee - *Apis mellifera* - is listed as a threat in the P. nutans SPRAT profile, Environmental Impact Assessment Guidelines and threatened species profile. *Apis mellifera* is a threat to *P. nutans* as it can outcompete native bee pollinators for pollen. Additionally, while *A. mellifera* is able to collect pollen, its method of pollen transport makes effective pollination of other *P. nutans* individuals unlikely (NSW NPWS 2000, DoEE 2019, OEH 2019).

Apis mellifera was commonly observed throughout the downstream, upstream and construction study areas. The Project is therefore unlikely to further facilitate its spread.

- **introduce disease that may cause the species to decline, or**

Many species in the genus *Persoonia* are killed by the soil-borne pathogen *Phytophthora cinnamomi* (OEH 2019). *Phytophthora cinnamomi* is common in coastal forests, occurring around the roots of plants in warm and moist conditions. Dieback caused by the root-rot fungus (Phytophthora cinnamomi) is listed as a key threatening process under the EPBC Act. The OEH key threatening process for *P. cinnamomi* states that it *may contribute to plant death where there are other stresses present (for example, waterlogging, drought, and wildfire)*. Waterlogging of previously un-inundated soils may occur in the upstream 1% AEP flood extent as a result of the Project. This may facilitate the spread of *P. cinnamomi* and/or exacerbate its impact. The Project may decrease the flooding frequency within the downstream 10% AEP flood extent. This may exacerbate the impact of *P. cinnamomi* by promoting drought-like conditions. Increasing the spread and impact of *P. cinnamomi* upstream and downstream of the dam wall has the potential to lead to the decline of *P. nutans*. The Project has been assessed as inconsistent with the Approved Threat Abatement Plan for Phytophthora

- **interfere substantially with the recovery of the species.**

A National Recovery Plan was developed for *P. nutans* by the Department of Environment and Conservation in January of 2006. The Approved *Persoonia nutans* Recovery Plan outlines the following recovery objectives:

- Specific Objective 1: To minimise the loss and fragmentation of *P. nutans* habitat using land use planning mechanisms.

- Specific Objective 2: To identify and minimise the threats operating at sites where the species occurs.
- Specific Objective 3: Develop and implement a survey & monitoring program that will provide information on the extent and viability of *P. nutans*.
- Specific Objective 4: To provide public authorities with information that assists in conserving the species.
- Specific Objective 5: To raise awareness of the species and involve the community in the recovery program.
- Specific Objective 6: To promote research projects that will assist future management decisions.

The Project directly opposes objectives 1 and 2, while neither promoting nor opposing objectives 3 to 6. The Project has therefore been assessed as having the potential to interfere with the recovery of *P. nutans*.

Conclusion

The Project could potentially impact habitat within *P. nutans'* known area of occupancy and could further fragment habitat, potentially isolating remaining stands from one another. The Project may impact the breeding cycle of *P. nutans* by modifying the fire regime and destroying the habitat of its native bee pollinators. The spread and establishment the pathogen *Phytophthora cinnamomi* may also be facilitated by the Project. These impacts are expected to cause a decline of population of *P. nutans*.

The Project has been assessed as likely to have a significant impact on *P. nutans*.

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Pherosphaera fitzgeraldii (Dwarf Mountain Pine)

Endangered under the EPBC Act

Pherosphaera fitzgeraldii is drooping shrub to 1 metre tall with hanging and straggling branches that can get to 2 metres long. These branches support leaves 2.5 to 3.5 millimetres long that have a narrow, in-curved shape. These leaves are pale on the adaxial surface and green on the abaxial surface. Male cones are ovate to globose and about 6 millimetres long, while the female cones are only 3 millimetres long with 4 to 8 scales (PlantNET 1990).

Pherosphaera fitzgeraldii occurs in the Blue Mountains west of Sydney, NSW. Its distribution currently supports 10 populations, all known from a 9 kilometre stretch of cliff-line between Wentworth Falls and Katoomba. The most recent survey of six of these populations identified a total of 445 plants (Jones 1994). Records of the species prior to 1950 show that individuals also occurred at Katoomba Falls, Leura Falls and Bonnie Doon Falls (DoE 2014).

The habitat of *P. fitzgeraldii* includes the spray zones, drip lines and seepage areas of waterfalls. This habitat is associated with sandstone cliffs at altitudes between 680 and 1,000 metres above sea level (OEH 2019). Populations all occur on south-east to south-west facing cliffs that are vertical (or near vertical) and often support caves and overhangs.

Pherosphaera fitzgeraldii has been assessed with a moderate likelihood of occurring in the Upstream Study area. However, according to OEH's BioNet system, *P. fitzgeraldii* is not associated with any PCTs mapped in the upstream study area. *P. fitzgeraldii* has been assessed with a low likelihood of occurrence in the downstream and construction study areas. As such, it is not considered to occur in these study areas or be impacted by the Project in these study areas.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) define a 'population of a species' as an occurrence of the species in a particular area. In relation to critically endangered, endangered or vulnerable threatened species occurrences include but are not limited to:

- a geographically distinct regional population, or collection of local populations.
- a population, or collection of local populations that occur within a particular bioregion.

Targeted surveys for *P. fitzgeraldii* were not undertaken in the upstream study area. In the absence of targeted surveys in the study area, *P. fitzgeraldii* would be assumed to be present in areas of suitable habitat (its associated PCTs). As no associated PCTs occur within the upstream study area, *P. fitzgeraldii* has been assessed as occurring in areas of suitable terrain – cliffs and rock faces.

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**
As *P. fitzgeraldii* was not surveyed, cliff habitat known to occur in the upstream study area has been used as a surrogate for the species occurrence. The Project has the potential to impact cliff-line habitat in the upstream study area through temporary inundation associated with operation of the FMZ. This habitat (much of it south-facing) mostly occurs in the Warragamba Gorge immediately upstream of Warragamba Dam. If *P. fitzgeraldii* does occur on the south-facing cliffs of the Warragamba Gorge, they may be impacted by the Project. The Project therefore has the potential to lead to a long-term decrease in the size of a population.
• **reduce the area of occupancy of the species**
The Project has the potential to reduce the availability of south-facing cliff-line habitat within the Warragamba Gorge through temporary inundation associated with operation of the FMZ.
• **fragment an existing population into two or more populations**
P. fitzgeraldii habitat is associated with cliff-lines, waterfalls, drip-lines and seepage lines. While the Project has the potential to reduce habitat from bottom of a cliff to the top of a cliff, it will not isolate habitat on a horizontal plane. As the flow of genetic material most likely occurs vertically and the Project will not introduce horizontal barrier to gene flow, it is unlikely to fragment and existing population into two or more smaller populations.

• **adversely affect habitat critical to the survival of a species**
No critical habitat has been listed for *P. fitzgeraldii* under the EPBC Act.
• **disrupt the breeding cycle of a population**
P. fitzgeraldii appears to be long-lived and slow-growing species with low mortality rates (OEH 2019). Plant produce either male or female cones with female plants being more common than male. Female cones are abundant on some individuals, containing well developed seed. Young plants are rare however, with the few observed likely originating vegetatively. The Project has the potential to limit the extent to which new individuals can become established. Temporary inundation may also remove seed from lower cliff-line areas in the Warragamba Gorge and potentially drown newly germinated individuals. The Project has the potential to disrupt the breeding cycle of any population occurring on the lower cliff-lines of the Warragamba Gorge.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project has the potential to modify, destroy and remove cliff-line habitat in the upstream study area. This habitat primarily occurs on the south-facing side of the Warragamba Gorge. If a population of *P. fitzgeraldii* utilises this habitat the species could potentially decline.
• **result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat**
The Approved Conservation advice for *Pherosphaera fitzgeraldii* states '*weed invasion including English ivy (Hedera helix); blackberry (Rubus spp.); montbretia (Crocosmia X crocosmiiflora); and Japanese honeysuckle (Lonicera japonica)*', is a threat to the species. The Project has the potential to facilitate the spread and establishment of these species through the movement of water further up *P. fitzgeraldii*'s cliff-line habitat.
• **introduce disease that may cause the species to decline, or**
No diseases have been identified as a threat to *Pherosphaera fitzgeraldii*.
• **interfere substantially with the recovery of the species.**
No National Recovery Plan has been developed for *Pherosphaera fitzgeraldii* under the EPBC Act. The SPRAT profile for *P. fitzgeraldii* does state however that a recovery plan is required (DoE 2020). Despite the lack of a recovery plan, the Approved Commonwealth Conservation Advice for *Pherosphaera fitzgeraldii* (DoE 2014) includes the following priority conservation actions: 1. Identify populations of high conservation priority. 2. Ensure there is no disturbance in areas where the dwarf mountain pine occurs, excluding necessary actions to manage the conservation of the species. 3. Manage any changes to hydrology that may result in changes to water table levels, sedimentation, pollution, rates of erosion or ground and surface water flows. 4. Ensure that bores within the area do not deplete water supplies that are essential to the persistence of the species. 5. Assess adequacy of existing up-stream sediment and sewage control measures. 6. Control access routes to suitably constrain public access to known sites on public land. 7. Suitably control and manage access on private land and other land tenure. 8. Undertake survey work in suitable habitat and potential habitat, such as the southern escarpment, Radiata Plateau and Narrowneck Plateau, to locate any additional populations/occurrences/remnants. 9. Investigate formal conservation arrangements, management agreements and covenants on private land, and for crown and private land investigate and/or secure inclusion in reserve tenure if possible. 10. Identify and remove weeds in the local area that could become a threat to the dwarf mountain pine, using appropriate methods.

11. Manage site/s to prevent introduction of invasive weeds that could become a threat to the dwarf mountain pine, using appropriate methods.
12. Implement the Blue Mountains National Park fire management strategy, which recommends low fire frequency and exclusion of fire from the species' habitat (NSW NPWS 2004).
13. Where appropriate provide maps of known occurrences to local and state Rural Fire Services and seek inclusion of mitigative measures in bush fire risk management plan/s, risk register and/or operation maps.

The Project could potentially interfere with priority conservation actions 2, 3 and 11.

No Approved Threat Abatement Plans listed under the EPBC Act are relevant to *P. fitzgeraldii* in context of the Project.

Conclusion
The Project has the potential to modify and destroy *Pherosphaera fitzgeraldii* cliff-line habitat along the Warragamba Gorge. The Project also has the potential to introduce invasive weed species to this area. Additionally, impacts associated with the Project will interfere with the priority conservation actions outlined in the Approved Commonwealth Conservation Advice. The Project has been assessed as likely to have a significant impact on *Pherosphaera fitzgeraldii*.

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Phyllota humifusa (Dwarf Phyllota)

Vulnerable under the EPBC Act

Phyllota humifusa (Dwarf Phyllota) is listed as vulnerable under the EPBC Act. This species is a prostrate shrub with foliage that is hairy when young (PlantNet 2019; TSSC 2008). Its small threadlike leaves are up to 10 mm long and 0.75 mm wide, with a small, pointed tip. Its small pea-shaped flowers are few, or solitary, growing in leafy spikes towards the ends of branches (OEH 2018). The standard (the broad top petal) is orange-yellow to reddish-brown, the wing-petals in front are yellow and the keel-petals, are reddish-brown. Flowers appear in late spring and summer. Pod not seen, plants apparently re-sprout following fire.

P. humifusa is known from the southern Blue Mountains, the Joadja area west of Mittagong and Penrose area near Paddys River (TSSC 2008). This species occurs in dry sclerophyll forest, in deep sandy soils or gravely loams over a sandstone substrate, sometimes near swamps. Associate species include *Eucalyptus mannifera*, *E. radiate*, or *E. piperita* (OEH 2018; TSSC 2008). Distribution of *P. humifusa* overlaps with following EPBC Act-listed ecological communities, White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland, and, Temperate Highland Peat Swamps on Sandstone (TSSC 2008).

Targeted surveys for *P. humifusa* were not undertaken in the downstream, upstream or construction study areas for the Project. Additionally, *P. humifusa* was not incidentally encountered in the survey area during vegetation mapping associated with the Project.

In the absence of targeted surveys, *P. humifusa* has been assumed present in areas of presumed suitable habitat. For this assessment, suitable habitat for *P. humifusa* comprises the PCTs that are associated with the species (as per the TBDC), BioNet Atlas Records and any other known vegetation types (as per scientific literature) that the species is associated with that has been mapped within the study area.

Suitable habitat includes the following PCTs, according to OEH's BioNet, that have been mapped within the upstream study area:

- PCT1086 (HN568): Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains Sydney Basin Bioregion

P. humifusa was not assessed to have a moderate or higher likelihood of occurring in the downstream study area or construction study area. Although some of these PCTs also occur in the downstream study area they are not considered likely to support a population of this species. As such, the potential for this species to be impacted by the Project in the downstream study area or construction study area is not subject to this assessment.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal*
- *populations that are necessary for maintaining genetic diversity, and/or*
- *populations that are near the limit of the species range.*

P.humifusa was assessed as having a low likelihood to occur within the Construction area, a moderate likelihood of occurring in the Upstream study area and not applicable to the downstream study area, therefore, only the upstream study area of 118.7 hectares will be considered in the assessment of significance. Two records exist in the NSW Atlas from 1990 within the upstream study area according to distributional records of *P.humifusa* as per the NSW BioNet Atlas, the majority records of the species occur primarily to the south of the upstream study area. It is assumed that the upstream study area supports an 'important population' of *P.humifusa* and that these known occurrences are a '*key source population either for breeding or dispersal*' and the *'population is necessary for maintaining genetic diversity*'.

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**
As *P. humifusa* has not been surveyed, areas of habitat have been used as a surrogate for the species occurrence and the important population's size. Up to 3.10 hectares of habitat may be impacted by a 1 in 5 chance in a year flood event, up to 15.82 hectares by a 1 in 100 chance in a year flood event, and 8.00 hectares in the upstream impact area. The impacts to *P. humifusa* habitat within the upstream study area are expected to lead to a long-term decrease in the size of the important population.
• **reduce the area of occupancy of an important population**
The conservation advice identified "*any changes to hydrology which may result in changes to the water table levels, increased run-off, sedimentation or pollution*". Within the upstream study area up to 3.10 hectares of habitat may be impacted by a 1 in 5 chance in a year flood event and up to 15.82 hectares by a 1 in 100 chance in a year flood event. This habitat could potentially be lost due to flooding events. For the purposes of offsetting impacts, it has been assumed that the 8.00 hectares in the upstream impact area would be removed completely. Outside of these areas the remaining study area may experience impacts of modification and further fragmentation of the suitable habitat.
• **fragment an existing important population into two or more populations**
The connectivity of the *P. humifusa* habitat with the native vegetation of the Blue Mountains National Park makes it unlikely that additional edges will be created as a result of the Project. With no new edges expected to result from the Project impacts, it is unlikely that the important population will be further fragmented into two or more populations.
• **adversely affect habitat critical to the survival of a species**
The Minister maintains a 'Register of Critical Habitat' under the EPBC Act in which habitat as identified as being critical to the survival of a listed threatened species is provided. To date, no critical habitat is listed for this species that occurs within or proximal to the construction, upstream or downstream study areas. In addition, there is no state of federal Recovery Plan that has been prepared for *P. humifusa.* However, the 119 hectares of suitable habitat presumed to support an important population of *P. humifusa* is habitat critical to the survival of the species. This is because the habitat is likely important in maintaining the genetic diversity and long-term evolutionary development of the species and is important for maintaining ecological processes essential to the survival for the species. It is therefore expected that the Project could potentially adversely affect habitat critical to the survival of *Phyllota humifusa.*
• **disrupt the breeding cycle of an important population**
The breeding cycle of *P. humifusa* is poorly understood. Too frequent fire is likely to remove individuals and disrupt reproduction (TSSC 2008). It is not known if altered hydrological regimes and associated impacts of the Project, such as erosion and sedimentation and altered fire regime will have an immediate effect on the breeding cycle of *P. humifusa*. However, the Project could potentially alter (either directly or indirectly) the existing ecological processes and functions within the upstream study area which may disrupt the breeding cycle of an important population.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The principal impact associated with the Project is the raising of the dam wall where the water level is increased during flood events, will cause temporary inundation of fringing vegetation although the extent, frequency and duration will be variable. Of the 119 hectares in the study area it is not identified how inundation could affect the habitat long-term, though there is potential that it could change. Further impacts associated with temporary inundation such as erosion and sedimentation may occur. Over the long-term, vegetation structure and composition may change and affect other ecological processes such as fire frequency, extent, intensity and duration. The Project could potentially lead to a decrease in the availability or quality of habitat for *Phyllota humifusa*.

- **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
Habitat invasion and competition by pine wildings is understood to reduce the habitat fitness and also constrains population growth for *P. humifusa,* invasion by various herbaceous weeds, often on roadsides or patches opened up by fire are also identified as being harmful to this species habitat.
- **introduce disease that may cause the species to decline, or**
Phytophthora cinnamomi is a soil borne pathogen belonging to the water mould group (Oomycetes). The reproductive structures that spread *P. cinnamomi* on vegetative mycelia in soil and plant roots in warm, moist conditions. Reproduction and infection occur entirely within soil or plants and there is no airborne transmission of the pathogen. Infection of native plants by *P. cinnamomi* has been identified as a threat to several species and communities listed in Schedule 1 or 2 of the TSC Act, including adversely affecting *P. humifusa*.
- **interfere substantially with the recovery of the species.**
The main identified threats to the *P. humifusa* include loss and degradation of habitat by sand and sandstone mining, both directly and through changes to hydrology and forestry activities (DECC 2005). Existing Management Prescription relevant to the species is Blue Mountains Fire Management Strategy (NSW NPWS 2004) and Plan of Management (NSW NPWS 2001). No National Recovery Plan has been developed for *P. humifusa*. Recovery conservation objectives and a management program have however been written in the Approved Commonwealth Conservation Advice and the NSW Government's Saving Our Species Program. The Office of Environment and Heritage (2018) Saving our Species program has identified four priority management sites were identified in NSW (ordered north to south and including local government area (LGA)). They comprise Bimlow Tableland, Jellore in Wingecarribee, Stingray Swamp in Wingecarribee and Morton National Park. The species is likely to be more widespread than is known, its distribution in some areas is poorly known. The SOS management sites do not overlap the study area upstream, although the Blue Mountains Fire Management Strategy 2004 includes the Upstream study area, this is a 5 chance in a year fire management plan which has since expired but it still referred to by TSSC (2008) in the conservation advice. No Approved Threat Abatement Plans listed under the EPBC Act are relevant to *P. humifusa* in context of the Project.
Conclusion
As targeted surveys were not conducted it is assumed that an important population of *P. humifusa* occurs in areas of mapped suitable habitat within the upstream study area. As the Project could potentially reduce the area of occupancy and modify substantial extents of suitable habitat for the species this may have an adverse effect on an important population of *Phyllota humifusa* such that it may cause it to decline. The Project has been assessed as likely to have a significant impact on *P. humifusa*.

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Pimelea curviflora var. *curviflora*

Vulnerable under the EPBC Act

Pimelea curviflora var. curviflora is listed as vulnerable under the EPBC Act. This species is a well branched shrub up to 1.2 metres but is often 20 centimetres-50 centimetres (PlantNet 2019; BioNet 2019; NSW SC 1998). It has an inconspicuous cryptic habit as it is fine and scraggly and often grows amongst dense grasses and sedge (NSW SC 1998). The leaves are up to 10mm long and 4mm wide which area sparsely hairy with coarse appressed hairs (PlantNet 2019). It has red to yellow flowers with long coarse hairs of 6 to 20 in terminal heads (PlantNet 2019; BioNet 2019). Flowers may occur year-round, mostly recorded October to January, occasionally until May (BioNet 2019; NSW SC 1998; DoE 2013). The species can survive for some period deprived of any foliage after fire or grazing, dependent on energy reserves in its tuberous roots for regrowth (NSW SC 1998). Likely to be fire tolerant species capable of re-sprouting following fire due to the presence of a tap root. Seedlings have been observed following fire.

Pimelea curviflora var. curviflora is restricted to the northern area of Sydney on sandstone soils and laterite soils (PlantNet 2019; BioNet 2019). Habitat features include ridge tops and upper slopes in open forest and woodlands (NSW CS 1998). Populations are known between northern Sydney and Maroota in the north-west from approximately 20 locations. It is found in the Baulkham Hills, Blacktown, Hornsby, Parramatta and Warringah Local Government Areas. In 2011 a new population was detected at Croom Reserve near Albion Park in the Shellharbour LGA (OEH 2019; BioNet 2019; DoE 2013)

Targeted surveys for *Pimelea curviflora var. curviflora* were not undertaken in the downstream, upstream or construction study areas for the Project. Additionally, *Pimelea curviflora var. curviflora* was not incidentally encountered in the survey area during vegetation mapping associated with the Project.

In the absence of targeted surveys, *Pimelea curviflora var. curviflora* has been assumed present in areas of presumed suitable habitat. For this assessment, suitable habitat for *Pimelea curviflora var. curviflora* includes the PCTs that are associated with the species (as per the TBDC), BioNet Atlas Records and any other known vegetation types (as per scientific literature) that the species is associated with that has been mapped within the study area.

Suitable habitat includes the following PCTs, according to OEH's BioNet, that have been mapped within the downstream study area:

- PCT1081 (HN564): Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion
- PCT724 (HN512): Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain Sydney Basin Bioregion
- PCT849 (HN528): Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain Sydney Basin Bioregion
- PCT883 (HN542): Hard-leaved Scribbly Gum - Parramatta Red Gum heathy woodland of the Cumberland Plain Sydney Basin Bioregion
- PCT1181 (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
- PCT1395 (HN556): Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain Sydney Basin Bioregion.

Pimelea curviflora var. curviflora was not assessed to have a moderate or higher likelihood of occurring in the upstream or construction study areas. As such, the potential for this species to be impacted by the Project in the Upstream or construction study area is not subject to this assessment.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal*
- *populations that are necessary for maintaining genetic diversity, and/or*
- *populations that are near the limit of the species range.*

The *P. curviflora var. curviflora* assessed as occurring in the downstream study area are likely to be part of a population that is key for both breeding, dispersal and maintaining genetic diversity. This meets the criteria of 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**
As *Pimelea curviflora var. curviflora* has not been surveyed, areas of habitat have been used as a surrogate for occurrence and population size. The Project could potentially impact up to about 52.40 hectares of *P. curviflora var. curviflora* habitat between the existing and with-project PMFs 179.74 hectares between the existing and with-project 10% AEPs and 118.65 hectares within the FMZ discharge boundary. Impacts to this habitat have the potential to lead to a long-term decrease in the size of the important population.
• **reduce the area of occupancy of an important population**
Within the downstream study area, the Project could potentially impact up to about 52.40 hectares of *P. curviflora var. curviflora* habitat between the existing and with-project PMFs, 179.74 hectares between the existing and with-project 10% AEPs and 118.65 hectares within the FMZ discharge boundary. These impacts may reduce the area of occupancy of the important population.
• **fragment an existing important population into two or more populations**
As no targeted surveys were undertaken it has been assumed that the suitable habitat supports an important population of *Pimelea curviflora var. curviflora*. The downstream study area is already highly fragmented due to the urban sprawl in western Sydney, industrial areas and also agricultural land. Further fragmentation may further limit the population dispersal and breeding mechanisms, further reduce genetic diversity and reduce the limited range of the species.
• **adversely affect habitat critical to the survival of a species**
The Minister maintains a ‘Register of Critical Habitat’ under the EPBC Act in which habitat as identified as being critical to the survival of a listed threatened species is provided. To date, no critical habitat is listed for this species that occurs within or proximal to the construction, upstream or downstream study areas. Suitable habitat presumed to support an important population of *Pimelea curviflora var. curviflora* has been assessed as habitat critical to the survival of the species. This habitat is important for dispersal, the long-term maintenance of the species and for maintaining genetic diversity. It is also important for maintaining ecological processes essential to the survival for the species. The Project may adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive species, erosion and deposition, and modifying hydrology and the fire regime. Accordingly, the Project may adversely affect habitat critical to the survival of *Pimelea curviflora var. curviflora.*
• **disrupt the breeding cycle of an important population**
The breeding cycle for *Pimelea curviflora var. curviflora* has limited literature available. It is generally understood that flowering occurs between October to January, occasionally until May. Changes to ecosystem function and processes because of the Project may disrupt the breeding cycle of the important population. This species has been observed re-sprouting after fire, it is understood that the tap root survives underground and relies on the energy reserves. Occasionally after fire *Pimelea curviflora var. curviflora* seedlings have been observed but it has not been identified as an obligate seeder. The changed hydrological regime may damage the soil seedbank, either directly through reduced or increased flooding, or by secondary impacts such as erosion or weed invasion and spread. A change in floristic structure and composition means that the fire dynamics (that is, duration, intensity and frequency) would therefore be affected. Any one of these impacts (or a combination) could potentially disrupt the breeding cycle of a population of *Pimelea curviflora var. curviflora.*

• modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline
The Project may affect suitable habitat within the downstream study area where it is presumed to support a population of *Pimelea curviflora var. curviflora*. The habitat condition may be modified or a decrease in the quality of the habitat, or worse case destroyed due to the Project. Impacts associated with the downstream study area outside of the FMZ may include changes to hydrology including a reduction in peak flood extents, durations and flows, long-term erosion and sedimentation, disruption to existing ecological processes and functions and changes to soil chemistry. Through any of these impacts, the condition, quality and integrity of suitable habitat may be adversely affected to a point in which it could reasonably lead to a decline in the species.
• result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat
Habitat degradation due to weed invasion is listed as a threat to *Pimelea curviflora var. curviflora* (OEH 2019). Also noted as harmful activities include recreational activities, road and trail maintenance and bush rock removal. The scientific determination also identifies grazing by pest fauna including the European Rabbit (*Oryctolagus cuniculus*), the Goat (*Capra hircus*) and the Pig (*Sus scrofa*) (NSW SC 1998). The Project may interfere with the recovery of the species by contributing to habitat loss, disturbance and modification.
• introduce disease that may cause the species to decline, or
There are no diseases that have been identified as a threat to *Pimelea curviflora var. curviflora.*
• interfere substantially with the recovery of the species.
Activities that have been identified as interfering substantially with the recovery of the species include; habitat loss due to clearing for urban development, habitat degradation due recreational activities, and bush rock removal, and also risk of too frequent or too intense fires inhibiting growth or reproduction. The Threat Abatement and Recovery program identifies the NSW Office of Environment and Heritage (2012) priority actions to assist in protection of the species, manage weed infestation, introduce measures to prevent habitat degradation related to unrestricted access and/or trail maintenance and protect areas of known and potential habitat from clearing and further fragmentation. The Project may interfere with the recovery of the species by contributing to habitat loss, disturbance and modification. A National Recovery Plan has not been developed for *P. curviflora* var. *curviflora*.
Conclusion
The Project may result in minor modifications to areas of known *Pimelea curviflora var*. *curviflora* habitat in the 10% AEP event; areas which are currently inundated every 10 years on average are predicted to be inundated every 20 years on average with the Project. Some potential habitat is expected to experience longer inundation in the FMZ discharge area, however vegetation damage as a result of this is expected to be temporary. The species persistence in habitats outside the Project study area suggests that the species is not reliant on regular flooding regimes. The Project is unlikely to result in a significant impact on *Pimelea curviflora var. curviflora* within the 10% AEP event changed flood extent.

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Pimelea spicata (Spiked Rice-flower)

Endangered under the EPBC Act

Pimelea spicata (Spiked Rice-flower) is listed as Endangered under both the BC Act and EPBC Act. This species is a low growing shrub to 50 centimetres tall with the habit varying from spreading to erect. The leaves are opposite, elliptical to 20mm. The flowers are white with a pink tinge in compact racemes when they are young, elongating with age (OEH 2019; PlantNet 2019). The mostly flower in summer, especially after rainfall but may flower at any time of the year. The mature plants may spread over short distance with an underground rhizome which may assist them in recovery from fire, occasional grazing and chemical spraying and help in weed invasion from matt forming species such as *Pennisetum clandestinum* (Kikuyu) (OEH 2019; SPRAT SHEET; Matarczyk 1999). Flowers may self-pollinate, but the seed production appears to be variable, seeds also have a poor dispersal with most seedlings germinating close to the adult. The soil seedbank is therefore important and is maintained with suitable irregular disturbance (BioNet 2019; NPWS 2000). It is estimated that *P. spicata* can take at least three years to develop a taproot enough for regeneration, after disturbance a substantial depletion of the tap root can take time to recover before future disturbances.

P.spicata grows on the coast in the Illawarra from Lansdowne to Shellharbour, and inland to Penrith (PlantNet 2019). It occurs in remnant bushland on Wiannamatta shales and well-structured clay soils in open woodlands (particularly Cumberland Plain Woodland variants and Moist Shale Woodland grey box communities) and grasslands of *Eucalyptus moluccana, E. crebra, E. tereticornis, Bursaria spinosa* and *Themeda triandra* in the Western Sydney and Cumberland Plains (SPRAT SHEET; NPWS 2000). It was once widespread across the Cumberland Plains, but it is now known around Camden, Narellan, Marayong, Douglas Park, Bankstown and Prospect Reservoir areas (OEH 2019; BioNet 2019).

Targeted surveys for *P.spicata* were not undertaken in the downstream, upstream or construction study areas for the Project. Additionally, *P.spicata* was not incidentally encountered in the survey area during vegetation mapping associated with the Project.

In the absence of targeted surveys, *P.spicata* has been assumed present in areas of presumed suitable habitat. For this assessment, suitable habitat for *P.spicata* includes the PCTs that are associated with the species (as per the TBDC), BioNet Atlas Records and any other known vegetation types (as per scientific literature) that the species is associated with that has been mapped within the study area.

Suitable habitat includes the following PCTs that have been mapped within the downstream study area:

- PCT830 (HN524) Forest Red Gum - Grey Box shrubby woodland on shale of the southern Cumberland Plain Sydney Basin Bioregion
- PCT 835 (HN526) – Forest Red Gum – Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin Bioregion
- PCT849 (HN528) Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain Sydney Basin Bioregion
- PCT850 (HN529) Grey Box - Forest Red Gum grassy woodland on shale of the southern Cumberland Plain Sydney Basin Bioregion

This equates to an estimated 2,148 hectares of habitat for this species in the downstream study area.

P.spicata was assessed as having a low likelihood of occurrence in the upstream and construction study areas. As such, the potential for this species to be impacted by the Project in these area is not subject to this assessment.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) define a 'population of a species' as '*an occurrence of the species in a particular area). In relation to critically endangered, endangered or vulnerable threatened species, occurrences include but are not limited to:*

- *a geographically distinct regional population, or collection of local populations, or*
- *a population, or collection of local populations, that occurs within a particular bioregion.*

Using the precautionary principle, a population of *P. spicata* has been assessed as occurring in areas of suitable habitat (the above listed PCTs).

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**
As there were no surveys for *P. spicata* the precautionary principle has been applied to assume that this species has a population in the downstream study area. About 145.63 hectares of *P.spicata* habitat occurs between the existing and with-Project PMFs, however, given the extreme unlikely occurrence of the PMF, this is not considered to be a material factor with regard to leading to a long term decrease in the size of the downstream population of this species. An estimated 71.47 hectares of suitable habitat occurs in the changed 10% AEP flood extent and an estimated 95.96 hectares occurs in the FMZ area. This equates to 3.3% and 4.5% respectively of the estimated habitat for this species in the downstream study area. Adopting a precautionary position, the Project is considered to have the potential to lead to a long term decrease in the size of the downstream population of this species.
• **reduce the area of occupancy of the species**
About 145.63 hectares of *P.spicata* habitat occurs between the existing and with-project PMFs, however, given the extreme unlikely occurrence of the PMF, this is not considered to be a material factor with regard to reducing the area of occupancy of this species. An estimated 71.47 hectares of suitable habitat occurs in the changed 10% AEP flood extent and an estimated 95.96 hectares occurs in the FMZ area. This equates to 3.3% and 4.5% respectively of the estimated habitat for this species in the downstream study area. Adopting a precautionary position, the Project is considered to have the potential to reduce the area of occupancy of this species in the downstream study area.
• **fragment an existing population into two or more populations**
The native vegetation of the floodplain in the Hawkesbury-Nepean catchment is currently subject to high fragmentation due to land use and vegetation clearance due to agriculture and suburban development. The known records of *P. spicata* occur within a range of disturbed and intact habitats on the floodplain. It is likely that the previous extent of the species has been reduced and fragmented through clearance in relation to agricultural and residential expansion. It is unlikely that the changed flooding regime will increase fragmentation for this species.
• **adversely affect habitat critical to the survival of a species**
The Minister maintains a 'Register of Critical Habitat' under the EPBC Act in which habitat as identified as being critical to the survival of a listed threatened species is provided. To date, no critical habitat is listed for this species that occurs within or proximal to the construction, upstream or downstream study areas. Suitable habitat presumed to support a population of *P.spicata* has been assessed as habitat critical to the survival of the species. This habitat is important for dispersal, the long-term maintenance of the species and for maintaining genetic diversity. It is also important for maintaining ecological processes essential to the survival for the species. The Project may adversely affect this habitat through the removal of vegetation (due to the effects of temporary inundation), increasing the presence of invasive species, erosion and deposition, and modifying hydrology and the fire regime.
• **disrupt the breeding cycle of a population**
The key impacts for this species as a result of the Project is the predicted reduction of flooding extent and an increased inundation period in the FMZ discharge when flood events occur. It is not known whether the species relies on specific hydrological regimes for its life cycle.

• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project may affect *P.spicata* habitat in the downstream study area within the changed 10% AEP flood extent and within the FMZ area due to temporary inundation. Adopting a precautionary position, the Project is considered to have the potential to modify habitat utilised by this species, potentially leading to a decline in the species in the downstream study area.
• **result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat**
The Conservation Advice for this species identifies weed invasion as a threat for the species. It notes that certain invasive weed species that form dense thickets or ground-covers are known to outcompete and displace spiked rice-flower populations. Weed invasion and competition is likely to reduce the reproductive capacity of adult plants, reduce the ability of adult plants to resprout following disturbance, and inhibit seedling recruitment. It is unclear whether this would necessarily result in invasive species becoming established, particularly for the FMZ area, as their tolerance to temporary inundation would be a factor.
• **introduce disease that may cause the species to decline, or**
There are no diseases that have been identified as a threat to *P.spicata.*
• **interfere substantially with the recovery of the species.**
Threats to *P.spicata* include generally habitat loss and fragmentation, clearing for agriculture and urban development, habitat degradation due to inappropriate fire regimes, grazing and weed invasion. Most populations of *Pimelea spicata* are threatened by the competition of environmental weeds such as Bridal Creeper, Bitou Bush, Lantana, Blackberry, Olive and Kikuyu (SPRAT SHEET and OEH 2019; Nash 1993). This species has poor tolerance to herbicide exposure with only the mature plants with established root systems sprouting after chemical application, seedlings are killed outright by glyphosate (SPRAT SHEET; Matarczyk 1999). A National Recovery Plan has been developed for *P.spicata*. The recovery plan outlined the following recovery objectives: 1. Conserve P. spicata using land use and conservation planning mechanisms. 2. Identify and minimise the operation of threats at sites where *P. spicata* occurs. 3. Develop and implement a survey and monitoring program that will provide information on the extent and viability of *P. spicata*. 4. Provide the community with information that assists in conserving the species. 5. Raise awareness of the species and involve the community in the recovery program. 6. Conduct research that will assist future management decisions. The Project has the potential to interfere with recovery objectives 1 and 2.
Conclusion
The Project may result in minor modifications to areas of known *P.spicata* habitat in the 10% AEP event; areas which are currently inundated every 10 years on average are predicted to be inundated every 20 years on average with the Project. The Project has the potential to result in a significant impact on *P.spicata* within the changed 10% AEP event flood extent and within the FMZ area.

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Pomaderris brunnea (Brown Pomaderris)

Vulnerable under the EPBC Act)

Pomaderris brunnea is a medium to large shrub growing between 2 and 4 metres tall. Elliptic to ovate leaves from 15 to 40 millimetres long and 8 -15 millimetres wide are arranged alternatively along a plant's stems. These stems are covered by a dense indumentum of simple pale hairs whereas the abaxial surface of the leaves are covered by an indumentum of stellate hairs and red to brown simple hairs. Small cream flowers covered by brown hairs occur in dense bracteate clusters (Sutter 2011).

Pomaderris brunnea is endemic to south-eastern Australia with records from as far north as the New England Tablelands near Walcha, and as far south as the Snowy Mountains National Park in Victoria (Sutter 2011; OEH 2017). Majority of the recorded individuals (prior to the recent surveys around Lake Burragorang) however occur in Western Sydney along the upper Colo and Nepean Rivers (Harden 2000). Prior to the recent surveys of the Warragamba Special area the known distribution of *P. brunnea* comprised 16 populations comprising of about 100 individuals (Sutter 2011).

Pomaderris brunnea occurs in a variety of habitats. Records of this species have been made in moist woodlands and forests on clay soils, in more open woodlands, on alluvial floodplains, and along creek lines (Sutter 2011; OEH 2017). The population on the New England Tableland is associated with canopy species such as *Eucalyptus laevopinea* (Silver-top Stringybark), *E. saligna* (Sydney Blue Gum) and *E. campanulata* (New England Blackbutt) (Sutter 2011). Populations further to the south have been noted to occur in association with *E. amplifolia* (Cabbage Gum), *Allocasuarina* spp. and *Bursaria* spp. (Sutter 2011). In the Sydney Basin Bioregion, populations occurring on alluvial flood plains occur in association with *E. elata* (River Peppermint), *E. piperita* (Sydney Peppermint), *E. punctata* (Grey Gum), *Bursaria spinosa* and *Pteridium esculentum* (Bracken).

According to OEH's BioNet system, *P. brunnea* is associated with the following PCT mapped in the upstream study area:

- PCT 1081 (HN564): Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion
- PCT 1105 (HN574): River Oak open forest of major streams Sydney Basin Bioregion and South East Corner Bioregion
- PCT 1292 (HN607): Water Gum – Coachwood riparian scrub along sandstone streams Sydney Basin Bioregion
- PCT 860 (HN532): Grey Gum – Broad-leaved Ironbark dry open forest on gorge slopes on the Blue Mountains Sydney Basin Bioregion

Pomaderris brunnea is associated with the following PCT mapped in the construction study area:

- PCT 1081 (HN564) Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion.

Pomaderris brunnea was not assessed with a moderate or higher likelihood of occurring in the downstream study area. As such, the potential for this species to be impacted by the Project in the downstream study area is not subject to this assessment.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal.*
- *populations that are necessary for maintaining genetic diversity.*
- *populations that are near the limit of the species range.*

Targeted surveys for *P. brunnea* were not undertaken across the entirety of the Upstream, Downstream and construction study areas – they were conducted along the south western shore of Lake Burragorang near Tonalli Cove. In the absence of targeted surveys across the entirety of the three study areas, *P. brunnea* has been assumed present in areas of suitable habitat – the previously listed PCTs. Using the precautionary principle, the population(s) residing within this habitat have been assessed as an important population(s) as they are key source populations for breeding and dispersal, are necessary for maintaining genetic diversity, and occur near the limit of the species range.

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**
As *Pomaderris brunnea* was not surveyed, areas of habitat have been used as a surrogate for the species occurrence. Up to 511.91 hectares of habitat may be impacted by a 1 in 5 chance in a year flood event and up to 2,374.86 hectares by a 1 in 100 chance in a year flood event. About 2.76 hectares of habitat would be directly impacted by the clearing associated with construction (development footprint). The impacts to *P. brunnea* habitat within the upstream and construction study areas may lead to a long-term decrease in the size of the important population.
• **reduce the area of occupancy of an important population**
Up to 511.91 hectares of *P. brunnea* habitat may be impacted by a 1 in 5 chance in a year flood event and up to 2,374.86 hectares by a 1 in 100 chance in a year flood event. About 2.76 hectares of habitat would be directly impacted by the clearing associated with construction (development footprint). Impacts to this habitat may reduce the area of occupancy of the important population.
• **fragment an existing important population into two or more populations**
The habitat in the upstream and construction study areas is mainly contiguous with the Blue Mountains National Park. The Project may impact the extents of this habitat through the direct removal of vegetation, increased presence of invasive species, erosion and deposition - however its connectivity to larger extents of native vegetation may reduce the number of new edges created.
• **adversely affect habitat critical to the survival of a species**
According to the *Matters of National Environmental Significance Significant impact guidelines* 1.1 (DoE 2013) habitat critical to the survival of a species refers to areas that are necessary for: • activities such as foraging, breeding, roosting, or dispersal • 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 • the reintroduction of populations or recovery of the species or ecological community. The *P. brunnea* habitat in the upstream and construction study areas has been assessed as critical habitat because it is important for dispersal, the long-term maintenance of the species and for maintaining genetic diversity. The Project may adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive species, erosion and deposition, and modifying hydrology and the fire regime.
• **disrupt the breeding cycle of an important population**
The lifecycle of *Pomaderris brunnea* is thought to take between 10 and 20 years to complete with the time to reproductive maturity taking about four to six years (OEH 2017). Seeds are likely dispersed by ants (Myrmecochorous dispersal) a distance no greater three meters (Gomez and Espadaler 1998). This could explain why *P. brunnea* is often observed growing in dense stands or groups. *Pomaderris brunnea* was observed around the south-western edge of Lake Burragorang reproducing asexually by suckering – a method of reproduction that could also produce dense stands of individuals. Genetic testing has not been conducted on any population of *P. brunnea* so reproduction via suckering cannot be confirmed. There has been little research conducted into germination and pollination in *P. brunnea* however other species of *Pomaderris* have been shown to produce seed requiring fire for germination (Patykowski *et al.* 2016). Within the upstream study area increases in flooding frequencies may impact the breeding cycle of *P. brunnea*. Occurrences of the *P. brunnea* may be inundated by the flood waters and any soil-stored seed could be washed or eroded away and/or buried under deposited material. Fire is a demonstrated requirement for seed germination in some species of *Pomaderris* (Patykowski *et al.* 2016). The relationship between fire and germination has been precautionarily assumed to occur in *P. brunnea* because no

such studies have been conducted on the species. A modified fire regime would then stand to reason, impact the lifecycle of *P. brunnea*. Any modification of this fire regime could impact recruitment of new individuals into the population. In summary, the Project may impact the breeding cycle of *P. brunnea* occurring within the upstream and construction study areas.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project could potentially impact *Pomaderris brunnea* habitat within the upstream and construction study areas. Habitat may be destroyed and/or directly impacted through the clearing of native vegetation, the loss of flora and fauna habitat, and a reduction in the extent of ecological communities. Habitat may be indirectly impacted (modified, reduced in quality etc.) through fragmentation, alteration to soil conditions, edge effects, weed invasion and incursion, through the spread of disease and pathogens, erosion and sedimentation, and thorough changes to the fire regime.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
The Project may result in the spread and establishment of invasive flora species into the habitat of *Pomaderris brunnea*. The Recovery Plan for *Pomaderris brunnea* states that '*several populations in NSW are threatened by weeds, particularly Cape Ivy (Delairea odorata) and Afican Olive (Olea europaea* subsp*. africana)*' (Sutter 2011). The OEH threatened species profile adds that African Lovegrass (*Eragrostis curvula*) is a threat especially around the southern part of the Cumberland Plain (OEH 2017). The OEH threatened species profile for *P. brunnea* also adds that '*deer grazing causes pugging and erosion and promotes weed invasion*' (OEH 2017). It is unknown if the Project would promote the establishment and spread deer throughout the study areas. It is important to note that deer were recorded in the upstream study area.
• **introduce disease that may cause the species to decline, or**
No diseases have been identified as a threat to *Pomaderris brunnea*.
• **interfere substantially with the recovery of the species.**
A national recovery plan for *Pomaderris brunnea* was developed in to recover and '*minimise the probability of extinction of P. brunnea in the wild and to increase the probability of populations becoming self-sustaining in the long term*'. The national recovery plan sets out the following recovery objectives: 1. Determine current status and threats. 2. Determine habitat requirements. 3. Protect and manage populations on public and private land. 4. Monitor response of populations to active management. 5. Identify key biological functions. 6. Establish a population in cultivation. 7. Build community support of conservation. The Project may interfere with objective 3 – protect and manage populations on public and private lands. In addition to the national recovery plan, a targeted strategy for managing *Pomaderris brunnea* has been developed under the NSW Government's Saving Our Species Program. Under the Saving Our Species Program, *P. brunnea* has been assigned to the 'site-managed species' management stream. The following 4 priority management sites have been identified for this species: • Oakwood property in the Mid-Western Regional LGA. • Gundengarra Reserve/Spring Farm in the Camden LGA. • Wirrumburra Wildlife Sanctuary in Wollondilly LGA. • Upper Nepean State Conservation Area in the Wingecarribee LGA.

The Project would not impact any of the listed priority management sites.
Conclusion
The Project could potentially impact *Pomaderris brunnea* habitat across the upstream and construction study areas. This habitat may become fragmented, potentially isolating occurrences of *P. brunnea* from one another. The Project may impact the breeding cycle of *P. brunnea* by clearing native vegetation (habitat), modifying the fire regime, modifying the hydrological environment and impacting the soil seedbank. The threat of invasive flora species may also be exacerbated by the Project. These impacts may cause a decline of important population of *P. brunnea*. The Project has been assessed as likely to have a significant impact on *Pomaderris brunnea.*

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Pterostylis saxicola (Sydney Plains Greenhood)

Endangered under the EPBC Act

Pterostylis saxicola is a perennial, deciduous herb that can only be identified with confidence when flowering in Spring (late September to early November) and the timetable of the Project precluded surveying for this species at that time of year. Plants of *Pterostylis saxicola* are usually gregarious, with most collectors and observers noting multiple plants co-occurring together. Counts of the number of individual plants at sites vary from one to 280, with a mean population size of 82.

Records for *Pterostylis saxicola* are widely distributed across the Cumberland Plain and lower Blue Mountains in an area bounded by Scheyville, Freemans Reach, Euroka Campground, Douglas Park, Picnic Point, and Cattai, with two outlying records from the Gingra Range in Kanangra Boyd National Park and Anvil Hill in the Hunter Valley. It has been recorded at altitudes ranging from 30 to 440 metres. It is very sporadically distributed, partly because much of this land has been cleared for agriculture and suburban development but large parts of the Warragamba catchment are remote and inaccessible. However, the outlying records suggest that any habitat model is unlikely to be a powerful predictor of the presence of populations at particular locations.

According to Weston (2019a), *Pterostylis saxicola* is associated with the following PCTs and substrates mapped in the upstream study area:

- PCT 832 on Lambie Group metasediments: 130.31 hectares
- PCT 860 on Lambie Group metasediments: 5.44 hectares
- PCT 870 on Lambie Group metasediments: 28.08 hectares
- PCT 1081 on Hawkesbury Sandstone: 3.87 hectares

According to Weston (2019b), *Pterostylis saxicola* is associated with the following PCTs and substrates mapped in the construction study area:

- PCT 1081 on Hawkesbury Sandstone: 16.96 hectares

According to Weston (2019c), *Pterostylis saxicola* is associated with the following PCTs and substrates mapped in the downstream study area:

- PCT 849 on Ashfield Shale: 108 hectares
- PCT 1181 on Hawkesbury Sandstone: 332 hectares
- PCT 1385 on Ashfield Shale – Mittagong Formation – Hawkesbury Sandstone: 310 hectares

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**
Weston (2019a) estimates that there is a 50 percent chance of *Pterostylis saxicola* occurring within the upstream study area. Using predictive habitat modelling, Weston (2019a) also estimates that there may be at least two individual *Pterostylis saxicola* occurring within the 1% AEP flood extent. Weston (2019a) estimates that there is a one percent chance of *Pterostylis saxicola* occurring within the construction study area. Using predictive habitat modelling, Weston (2019a) also estimates that there may be less than one *Pterostylis saxicola* occurring within the construction study area. The Project could potentially result in the long-term decrease of a *Pterostylis saxicola* population in the upstream study area.
• **reduce the area of occupancy of a species**
The Project could potentially impact up to about 631 hectares of habitat (potential area of occupancy) identified by (Weston 2019a, Weston 2019b). Of this, about 619 hectares occur within the upstream study area and about 12 hectares occur within the construction study area. The Project could potentially reduce the area of occupancy for the species.

• **fragment an existing population into two or more populations**
Weston (2019a) notes that *Pterostylis saxicola* is a gregarious species, with a mean population size of 82 individuals. It is usually sporadically distributed throughout its range but notes that this because much of range has been cleared for agriculture and suburban development. The Project has the potential to fragment existing populations into two or more populations.
• **adversely affect habitat critical to the survival of a species**
According to the *Matters of National Environmental Significance Significant impact guidelines* 1.1 (DoE 2013) habitat critical to the survival of a species refers to areas that are necessary for: • activities such as foraging, breeding, roosting, or dispersal • 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 • the reintroduction of populations or recovery of the species or ecological community. Given the upstream study occurs at the edge of the species range, and the known populations are disjunct from populations within the core distributional range on the Cumberland Plain, it is possible that any individuals within the upstream area would be important for the maintenance of genetic diversity and long-term evolutionary development of the species. Therefore, the Project may impact upon habitat critical for the survival of *Pterostylis saxicola*.
• **disrupt the breeding cycle of a population**
Pterostylis saxicola is a perennial, deciduous, tuberous herb that germinates from a minute, dust-like seed. Like all other orchids, germination is reliant on invasion of the seed by the hyphae of a specific fungal associate. Plants of *Pterostylis saxicola* are deciduous, with the whole shoot system growing anew every year from a dormant tuber. The new shoot usually starts growing from an apical meristem on the tuber in late summer, with new shoots usually breaking the soil surface by March. The shoot develops into a "rosette" of crowded leaves just above ground level and in late winter a terminal raceme starts growing from the centre of the rosette, reaching anthesis in spring. While the shoot is growing above ground, a new replacement tuber is growing below ground, from the base of the shoot. Some species of *Pterostylis* multiply and spread vegetatively by producing additional new tubers on the ends of long roots but this trait does not occur within *Pterostylis saxicola*. Almost all species of *Pterostylis* are deceptively pollinated by male flies that attempt to copulate with the labellum of the flower. The Project could potentially disturb mycorrhizal associations and pollinator patterns such that the breeding cycle of *Pterostylis saxicola* would be disrupted.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
Suitable habitat for *P. saxicola* within the upstream and construction study areas is described by Weston (2019a 2019b) as: • thin accumulations of humus-rich sandy soil on sheets and rock shelves of Hawkesbury Sandstone, on the rims and sides of river valleys, growing in PCT 1081 Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain; • Lambie group metasediments, in PCT 870 Grey Gum - Thin-leaved Stringybark grassy woodland of the southern Blue Mountains gorges, in PCT 832 Forest Red Gum - Narrow-leaved Ironbark open forest of the southern Blue Mountains gorges, Sydney Basin Bioregion, and in PCT 860 Grey Gum - Broad-leaved Ironbark dry open forest on gorge slopes on the Blue Mountains, Sydney Basin Bioregion. The Project could potentially impact habitat suitable for *P. saxicola* either through construction or temporary inundation.

• **result in invasive species that are harmful to an endangered or critically endangered species becoming established in the endangered or critically endangered species' habitat**
Invasion of weed species are listed as a threat to *P. saxicola*. The Project may result in increased weed invasion across the species habitat.
• **introduce disease that may cause the species to decline, or**
It is unlikely that the Project would introduce a disease that may cause the species to decline.
• **interfere substantially with the recovery of the species.**
No National Recovery Plan has been developed for *P. saxicola* under the EPBC Act. Regional and local priority actions to enable the recovery of additional sites and/or populations have however been identified in the Approved Conservation Advice for *Pterostylis saxicola*. The following priority actions have been identified: • Design and implement a monitoring program • Undertake survey work in suitable habitat and potential habitat to locate any additional populations • More precisely assess population size, distribution, ecological requirements and the relative impacts of threatening processes • Undertake seed germination and/or vegetative propagation trials to determine the requirements for successful establishment, including mycorrhizal association trials • Identify pollinating agents. The Project could potentially interfere with all of the listed priority actions.
Conclusion
The Project could potentially: • Lead to a long-term decrease in the size of a population • Reduce the area of occupancy • Adversely affect the habitat critical to the survival of *P. saxicola*. The Project has been assessed as likely to have a significant impact on *P. saxicola.*

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Pultenaea glabra (Smooth Bush-Pea)

Vulnerable under the EPBC Act

Pultenaea glabra (Smooth Bush-Pea) is listed as Vulnerable under the EPBC Act (OEH 2019). This species is an erect shrub to 1.5 m tall with smooth hairless stems and alternate concave linear leaves. The yellow/orange pea-like flowers are borne in dense sub terminal or apparently terminal inflorescences followed by a swollen pod to 5mm long (BioNet 2019; PlantNet 2019). *Pultenaea* sp. are ecologically important, often forming a dominant or sub-dominant shrub layer in dry and wet sclerophyll forest and heathlands (OEH 2019).

Pultenaea glabra complex is composed of some geographically disjunct entities which exhibit morphological variation that appears to intergrade from the Dandenong Ranges in Victoria, the NSW Central Western Slopes and Tablelands (DoE 2019). De Kok and West (2002) describe *Pultenaea glabra* as a species with continuous morphological variation between southern Victoria and central eastern Queensland (including *Pultenaea weindorferi, Pultenaea* sp. Genowlan Point, *Pultenaea villosa* var. *glabrescens*, *Pultenaea* sp. E). De Kok and West also realise both *Pultenaea villosa* var. *glabrescens* and *Pultenaea weindorferi* are within the variation of the *Pultenaea glabra* description. Whereas the BC Act and the EPBC Act treats *Pultenaea glabra* as restricted to the Blue Mountains area in New South Wales (DoE 2019; OEH 2019).

Pultenaea glabra is restricted to the higher Blue Mountains and has been recorded from the Katoomba-Hazelbrook and Mount Victoria areas. This species is primarily associated with riparian or swamp habitat areas in the mid to upper altitudes of the central Blue Mountains on sandstone derived soils. It grows in swamp margins, hillslopes, gullies and creekbanks and occurs within dry sclerophyll forest and tall damp heath on sandstone (BioNet 2019). Select locations include Lawson, Wentworth Falls, Leura and Glen Davis, all known populations occur within the Blue Mountains Local Government Area.

Targeted surveys for *Pultenaea glabra* were not undertaken in the downstream, upstream or construction study areas for the Project. Additionally, *Pultenaea glabra* was not incidentally encountered in the survey area during vegetation mapping associated with the Project.

In the absence of targeted surveys, *Pultenaea glabra* has been assumed present in areas of presumed suitable habitat. For this assessment, suitable habitat for *Pultenaea glabra* includes the PCTs that are associated with the species (as per the TBDC), BioNet Atlas Records and any other known vegetation types (as per scientific literature) that the species is associated with that has been mapped within the study area.

Suitable habitat includes the following PCTs, according to OEH's BioNet, that have been mapped within the study areas:

Upstream study area

- PCT1083 (HN566): Red bloodwood - scribbly gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion
- PCT1086 (HN568): Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains Sydney Basin Bioregion

Construction study area

- PCT1083 (HN566): Red bloodwood - scribbly gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion
- PCT1086 (HN568): Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains Sydney Basin Bioregion.

Pultenaea glabra was not assessed to have a moderate or higher likelihood of occurring in the downstream study area. As such, an assessment of the Project's impacts to *P. glabra* have not been considered in the downstream study area.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal*
- *populations that are necessary for maintaining genetic diversity, and/or*
- *populations that are near the limit of the species range.*

An important population has been assessed as occurring within the Project Area conforming to the occurrence of the previously listed PCTs. This population meets all three requirements of an 'important population' as defined in the MNES Significant Impact Guidelines (above).

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**
As *Pultenaea glabra* was not surveyed, areas of habitat have been used as a surrogate for its occurrence. Up to 13.56 hectares of habitat may be impacted by a 1 in 5 chance in a year flood event and up to 64.76 hectares by a 1 in 100 chance in a year flood event. About 18.02 hectares of habitat will be directly impacted by the clearing associated with construction (development footprint). The impacts to *P. glabra* habitat within the upstream and construction study areas may lead to a long-term decrease in the size of the important population.
• **reduce the area of occupancy of an important population**
Up to 13.56 hectares of *P. glabra* habitat may be impacted by a 1 in 5 chance in a year flood event and up to 64.76 hectares by a 1 in 100 chance in a year flood event. About 18.02 hectares of habitat will be directly impacted by the clearing associated with construction (development footprint). Impacts to this habitat may reduce the area of occupancy of the important population.
• **fragment an existing important population into two or more populations**
Limits to the extent of the mapping is likely to underestimate the hectares of land that is fragmented or isolated. Due to the geographic distribution of NSW Atlas records and the known population distribution the Project is unlikely to fragment an existing important population of *Pultenaea glabra* into two or more populations.
• **adversely affect habitat critical to the survival of a species**
The Minister maintains a 'Register of Critical Habitat' under the EPBC Act in which habitat as identified as being critical to the survival of a listed threatened species is provided. To date, no critical habitat is listed for this species that occurs within or proximal to the construction, upstream or downstream study areas. Suitable habitat presumed to support an important population of *Pultenaea glabra* has been assessed as habitat critical to the survival of the species. This habitat is important for dispersal, the long-term maintenance of the species and for maintaining genetic diversity. It is also important for maintaining ecological processes essential to the survival for the species. The Project may adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive species, erosion and deposition, and modifying hydrology and the fire regime. Accordingly, the Project may adversely affect habitat critical to the survival of *Pultenaea glabra.*
• **disrupt the breeding cycle of an important population**
The breeding cycle has limited information listed under the conservation advice or the SPRAT profile, it is assumed that the breeding cycle could be disrupted as a result of the Project. This species is understood to flower in spring between September and November. This species is generally within 100m of water bodies. Flowering during a period of flooding may affect the breeding cycle of this species.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
Habitat that could potentially be removed or modified appears to be in good condition from desktop searches as much of the vegetation with any potential impact is within the gullies and creek lines. It is not likely to have a significant impact of the population in the locality. Modification to the habitat including the frequency of fires, either too frequent or not frequent enough, may cause a decline in this species.

• result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat
Habitat degradation due to weed invasion (mainly Scotch broom, privet and honeysuckle) was identified on the BioNet profile. The conservation advice for this species lists weed invasion as a threat.
• introduce disease that may cause the species to decline, or
The species is identified in the Approved Commonwealth Conservation Advice as being susceptible to infection by the disease *Phytophthora cinnamomi*. The dispersal of *Phytophthora cinnamomi* can be mediated through water and through eroded soil. The Project has the potential to facilitate the spread of *Phytophthora cinnamomic* throughout the study area and therefore contribute to the EPBC listed key threatening process dieback caused by the root-rot fungus (*Phytophthora cinnamomi*). The Project is therefore inconsistent with the Approved Threat Abatement Plan for Phytophthora.
• interfere substantially with the recovery of the species.
There is no National Recovery Plan listed on the SPRAT profile for *Pultenaea glabra.* OEH has developed a recovery plan and objectives as part of the Saving Our Species (SoS) Program, with the aim to use site managed sites for *Pultenaea glabra*. One priority management site was identified in NSW - Mid-upper Blue Mountains (Blue Mountains LGA) - which covers 12,194.8 hectares. The Project will impact this management site and therefore interfere with the recovery of the species. Existing Plans/Management Prescriptions that are Relevant to the Species • Blue Mountains National Park Fire Management Strategy (NSW NPWS 2004) and Plan of Management (NSW NPWS 2001), and • Threat Abatement Plan for Dieback Caused by the Root-Rot Fungus *Phytophthora cinnamomi* (EA 2001).
Conclusion
The Project could potentially impact *Pultenaea glabra* habitat in the upstream and construction study areas. Alteration to this habitat may increase the risks of weed invasion and hydrological changes may affect the fire regime. The Project has been assessed as likely to have a significant impact on *Pultenaea glabra*.

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Pultenaea parviflora

Vulnerable under the EPBC Act

Pultenaea parviflora is a small erect shrub about one metre tall. It produces alternately arranged leaves that are between 2 and 6 millimetres long, and 1 to 1.5 millimetres wide. Leaves are narrow to broadly obovate or cuneate, with an obtuse or slightly notched apex. Distinctive stipules, about 2 millimetres long are produced by *P. parviflora*. Yellow flowers between 5 and 7 millimetres long are clustered towards the end of branches. The calyx is hairy with slender lobes and is sub-tended by bracteoles about 4 millimetres long (OEH 2019; PlantNET 2019).

Pultenaea parviflora is endemic to the Cumberland Plain west of Sydney. Within its Cumberland Plain distribution, *P. parviflora* primarily occurs between Kemps Creek, Wilberforce, Penrith, and Dean Park (Benson and McDougall 1996; DEWHA 2008). The sizes of populations vary considerably, with some populations comprising of 10 individuals and others comprising over 5,000 (OEH 2019). Some of the species distribution is conserved in reserve areas such as Scheyville National Park, Windsor Downs Nature Reserve, Castlereagh Nature Reserve and Wianamatta Nature Reserve. Large occurrence of *P. parviflora* occur outside of conservation reserves however, with records from Shane's Park and Riverstone Bushlands.

Pultenaea parviflora habitat includes dry sclerophyll forest, woodlands, and grasslands supported by either Wianamatta Shale, laterite or Tertiary alluvium. Habitat is found on infertile sandy clay soils where the water table is low, and the supply of moisture is intermittent (Benson and McDougall 1996; DEWHA 2008). Canopy species associated with *P. parviflora* habitat include *Eucalyptus fibrosa*, *E. sclerophylla, E. sideroxylon, Angophora bakeri, Allocasuarina littoralis* and *Melaleuca decora*. Shrubs that have been recorded alongside *P. parviflora* include *Melaleuca nodosa*, *Acacia decurrens*, *Acacia elongata*, *Bursaria spinosa*, *Davesia genistifolia*, *Hakea sericea*, *Kunzea ambigua* and *Olearia microphylla*.

According to OEH's BioNet system, *P. parviflora* is associated with the following PCTs mapped in the downstream study area:

- PCT 724 (HN512): Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain Sydney Basin Bioregion.
- PCT 725 (HN513): Broad-leaved Ironbark - *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain Sydney Basin Bioregion.
- PCT 883 (HN542): Hard-leaved Scribbly Gum - Parramatta Red Gum heathy woodland of the Cumberland Plain, Sydney Basin Bioregion.

The OEH records also show *P. parviflora* occurring in vegetation mapped by SMEC as PCT 849 (HN528): Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain Sydney basin Bioregion. This PCT has been included as habitat for *P. parviflora* and has been used to define the important population. Conversely, *P. parviflora* was not assessed as having a moderate or higher likelihood of occurring in the upstream or construction study areas. As such, the potential for this species to be impacted by the Project in these study areas is not subject to this assessment.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal.*
- *populations that are necessary for maintaining genetic diversity.*
- *populations that are near the limit of the species range.*

Targeted surveys for *P. parviflora* were not undertaken across the downstream study area. In the absence of targeted surveys, *P. parviflora* has been assumed present in areas of suitable habitat – the previously listed PCTs. Using the precautionary principle, the population residing within this habitat has been assessed as an important population as it is a key source population for breeding and dispersal, is necessary for maintaining genetic diversity, and occurs near the limit of the species range.

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**
As *Pultenaea parviflora* was not surveyed, areas of habitat have been used as a surrogate for the species occurrence and the important population's size. The Project could potentially impact up to about 470.77 hectares of *P. parviflora* habitat between the existing and with-project PMFs, 199.04 hectares between the existing and with-project 10% AEPs and 24.79 hectares within the FMZ discharge boundary. Impacts to this habitat have the potential to lead to a long-term decrease in the size of the important population.
• **reduce the area of occupancy of an important population**
Within the downstream study area, the Project could potentially impact up to about 470.77 hectares of *P. parviflora* habitat between the existing and with-project PMFs, 199.04 hectares between the existing and with-project 10% AEPs and 24.79 hectares within the FMZ discharge boundary. These impacts may reduce the area of occupancy of the important population.
• **fragment an existing important population into two or more populations**
All of the *Pultenaea parviflora* habitat within the downstream study area occurs across the central area of the Cumberland Plain and along the lower Nepean/upper Hawkesbury Rivers. This habitat has been previously fragmented through agricultural, residential and public development. The Project may increase the fragmentation of the *P. parviflora* habitat. Fragmentation may be exacerbated by the spread of weed and exotic species through the creation of new edges. Erosion caused by the discharge of the FMZ and the modified hydrology within the proposed and existing 10% AEP flood extents may also cause fragmentation, especially to habitat occurring along the lower Nepean/upper Hawkesbury Rivers.   Most of the *P. parviflora* habitat within the downstream study area occurs as remnant stands of native vegetation. Because this habitat occurs as remnants, some form of physical isolation is already present between these stands. The Project may exacerbate the edge effects experienced by stands of habitat, further reducing their size and increasing their isolation from one another. The reduced size of these habitat stands is likely to decrease the exchange of genetic material - and hence increase genetic isolation. The Approved Conservation Advice for *Pultenaea parviflora* adds that 'seed dispersal is localised so interaction between populations via this mechanism is unlikely' (NSW NPWS 2002). To maintain connectivity between populations it is important that all existing habitat is conserved.   Although isolation and fragmentation may increase as a result of the Project, without a genetic analysis it cannot be comprehensively concluded that the important population of *P. parviflora* will fragmented into smaller sub-populations. Barrier(s) to gene flow would need to be demonstrated to prove the existence of smaller sub-populations.
• **adversely affect habitat critical to the survival of a species**
According to the *Matters of National Environmental Significance Significant impact guidelines* 1.1 (DoE 2013) habitat critical to the survival of a species refers to areas that are necessary for: • activities such as foraging, breeding, roosting, or dispersal   • 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   • the reintroduction of populations or recovery of the species or ecological community.   The *Pultenaea parviflora* habitat in the downstream study area has been assessed as critical habitat because it is important for dispersal, the long-term maintenance of the species, for maintaining genetic diversity, and for the potential reintroduction/recovery of the species. The Project may adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive species, erosion and deposition, modifying the area's hydrology and modifying the fire regime.

• **disrupt the breeding cycle of an important population**
Individual *Pultenaea parviflora* live for about 20 years, with estimates having individuals reaching reproductive maturity between 3 and 6 years (Benson and McDougall 1996; OEH 2019). Flowering occurs between August and November however the vectors of pollination are unknown (DEWHA 2008). Reproduction is understood to occur only from the out-crossing of two individuals as there are no recorded observations of self-pollination or vegetative spread (suckering) (OEH 2019). Fire and ants play an important role in the lifecycle of *P. parviflora*. The presence of an elaiosome on seeds indicates that ants are a factor in their dispersal. *Pultenaea parviflora* – with the help of ants - produces a soil-stored seedbank, a seedbank that requires fire to germinate. Fire induces recruitment of new individuals from the seedbank after it kills adult plants. OEH notes that germination from the soil-stored seedbank can be 'prolific after a moderate to high intensity fire' (OEH 2019). In the downstream study area, a reduction in peak flood extents and durations, along with a reduction in peak flood flows is unlikely to impact the lifecycle of *P. parviflora*. This is because *P. parviflora* occurs in dry habitat where the water-table is already low. A reduction to the extent and duration that this habitat is flooded is therefore unlikely to further reduce the water-table in *P. parviflora* habitat, or further dry out the habitat. Increases in low-level flooding caused by the discharge of the FMZ – affecting an area within the downstream study area but outside the difference between the proposed and existing 10% AEP flood extents may impact the lifecycle of *P. parviflora*. The discharged water will inundate *P. parviflora* habitat and individuals which have not evolved to withstand frequent flooding and inundation. The *P. parviflora* soil-stored seedbank – critical to the lifecycle of P. parviflora - may also be impacted, as the water discharged from the FMZ has the potential to erode it away or bury it in sediment and debris carried from upstream areas. This may also impact ant communities – facilitators of seed dispersal – in a similar manner. Fire is important to the breeding cycle of *P. parviflora*, making mismanagement of fire and a modification of the fire regime a risk. The Project may affect the fire regime within the downstream study area by modifying the vegetation communities - and subsequently the fuel load - within this area. If the modified vegetation is more susceptible to fire, then it is likely the frequency of fire will be increased. If fire is too frequent, it may kill the next generation of plants before they have reached reproductive maturity and replenished the seed bank.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project could potentially impact *Pultenaea* habitat within the downstream study area. Habitat may be impacted (modified, reduced in quality etc.) through fragmentation, alteration to soil conditions, edge effects, weed invasion and incursion, through the spread of disease and pathogens, erosion and sedimentation, and thorough changes to the fire regime.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
Weed invasion has been identified as a threat to *Pultenaea parviflora*. The OEH Threatened Species Profile for *P. parviflora* identifies 'African Lovegrass and other invasive grasses' as a threat because they 'increase biomass which fuels fires, as well as resulting in competition and shading' (OEH 2019). The Project may facilitate the spread and establishment of invasive flora species that are harmful to the important population of *P. parviflora*.
• **introduce disease that may cause the species to decline, or**
No diseases have been identified as a threat to *Pultenaea parviflora* in the species' SPRAT profile, Approved Commonwealth Conservation Advice, Environmental Impact Assessment Guidelines or OEH Threatened Species Profile (DoEE 2019; DEWHA 2008; NSW NPWS 2002; OEH 2019).

• **interfere substantially with the recovery of the species.**
Pultenaea parviflora has been included in the Cumberland Plain Recovery Plan, a plan that provides the foundation for future biodiversity protection in western Sydney (DECCW 2010). The Cumberland Plain Recovery Plan outlines the following four recovery objectives: 1. To build a protected area network, comprising public and private lands, focused on the priority conservation lands. 2. 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 primary objectives are compatible with biodiversity conservation. 3. To develop an understanding and enhanced awareness in the community of the Cumberland Plain's threatened biodiversity, the best practise standards for its management, and the recovery program. 4. 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 Project may not be consistent with objectives 1 and 2 of the Cumberland Plain Recovery Plan. The Project may impact protected areas - for example, Scheyville National Park, Windsor Downs Nature Reserve, Agnes Banks Nature Reserve, Wianamatta Regional Park - along with public and private lands that provide habitat for the biodiversity of the Cumberland Plain. This impact would be inconsistent with the building or even maintenance of a protected area network. Impacting the protected, public and private lands that support biodiversity do not align with best practise management of threatened species, communities and ecological communities. The Project therefore substantially interferes with the objectives of the Cumberland Plain Recovery Plan. A targeted strategy for managing *Pultenaea parviflora* has also been developed under the Saving Our Species Program (NSW Government). Under the Saving Our Species Program, *P. parviflora* has been assigned to the 'site-managed species' management stream. The following four priority management sites have been determined for *P. parviflora*: • Scheyville in the Hawkesbury LGA. • Castlereagh Nature Reserve in the Penrith LGA. • Wianamatta Nature Reserve in the Penrith LGA. • Colebee in the Blacktown LGA. The Project may impact the Scheyville priority management site. Specifically, the Project is inconsistent with the following management objectives set out for the Scheyville priority management site: • Reduce and maintain weed densities at low levels. • Maintain appropriate fire regime for the species/community. The Project may interfere with the Saving Our Species Program for P. parviflora and subsequently the species' recovery.
Conclusion
The Project could potentially impact *Pultenaea parviflora* habitat across the downstream study area. This habitat may become further fragmented, increasing the isolation between occurrences of *P. parviflora.* The Project may impact the breeding cycle of *P. parviflora* by modifying the fire regime, interfering with native pollinators and disturbing the soil seed bank. The threat of invasive flora species may be exacerbated by the Project. The Project may interfere with the Cumberland Plain Recovery Plan and Saving Our Species Program – two programs with the aim of recovering *P. parviflora*. The Project has been assessed as likely to have a significant impact on *Pultenaea parviflora.*

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Rhizanthella slateri (Eastern Australian Underground Orchid)

Vulnerable under the EPBC Act

Rhizanthella slateri (Eastern Australian Underground Orchid) is listed as Vulnerable under the BC Act and Endangered under the EPBC Act. This species is an orchid with a fleshy underground stem to 15 centimetres, the flower matures under the soil but may extent up to 2 centimetres above the ground and has 30 purplish tubular flowers from October to November. The pollination mechanism is not well understood for underground orchids (OEH 2019; TSSC 2003). The CSIRO in 2012 recorded swamp wallaby and long nosed bandicoot attracted to the site of mature seed heads that were emitting a vanilla scent at the Mt Allum sites near Bulahdelah. It is understood that these mammals aid in the dispersal of the seed (CSIRO 2009). *Rhizanthella slateri* is a saprophytic terrestrial herb that grows in sclerophyll eucalypt forests in shallow to deep loams where it grows on dead and decaying organic matter along the Great Dividing Range (PlantNet 2019; DoE 2019). There is no assessment to inform the preferred habitat for this species (DoE 2019). *Rhizanthella spp* are known to have a fungal association with *Rhizoctonia* spp which assists the orchid with carbon and nitrogen uptake in association with other trees and shrubs (Murasdiwati 2004; Bougoure et al 2010).

Rhizanthella slateri is restricted to New South wales and is currently known to occur in ten locations. The records for this species tend to be accidental, this makes determining the exact distribution problematic. This species has been recorded from the Blue Mountains, Bulahdelah, Watagan Mountains, Dharung National Park, Wisemans Ferry area, Agnes Banks and near Nowra (PlantNet 2019; TSSC 2003). While this species has a large extent of occurrence, it is understood it has a restricted area of occupancy with isolated populations. However, there is insufficient data to quantify the species distribution adequately (DoE 2019; TSSC 2003).

Suitable habitat includes the following PCTs that have been mapped within the study areas.

Upstream study area:

- PCT769 (HN517): Coachwood - Lilly Pilly warm temperate rainforest in moist sandstone gullies Sydney Basin Bioregion
- PCT1284 (HN606): Turpentine - Smooth-barked Apple moist shrubby forest of the lower Blue Mountains Sydney Basin Bioregion
- PCT1292 (HN607): Water Gum - Coachwood riparian scrub along sandstone streams Sydney Basin Bioregion

The occurrence of *R. slateri* was not associated with any PCTs mapped in the construction study area. This species was also assessed with a low likelihood of occurring in the downstream study area. As such, impacts to *R. slateri* in the construction and downstream study areas have not been considered in this assessment.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal*
- *populations that are necessary for maintaining genetic diversity, and/or*
- *populations that are near the limit of the species range.*

Targeted surveys for *Rhizanthella slateri* were not undertaken in the downstream, upstream or construction study areas for the Project. Additionally, *Rhizanthella slateri* was not incidentally encountered in the survey area during vegetation mapping associated with the Project.

In the absence of targeted surveys, *Rhizanthella slateri* has been assumed present in areas of presumed suitable habitat. For this assessment, suitable habitat for *Rhizanthella slateri* includes the PCTs that are associated with the species (as per the TBDC), BioNet Atlas Records and any other known vegetation types (as per scientific literature) that the species is associated with that has been mapped within the study area.

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**
As *Rhizanthella slateri* was not surveyed, areas of habitat have been used as a surrogate for the species occurrence and the important population's size. Within the upstream study area 80.97 hectares of habitat has been mapped. Of this 80.97 hectares, up to 9.65 hectares may be impacted by a 1 in 5 chance in a year flood event (20% AEP) and up to 45.08 hectares by a 1 in 100 chance in a year flood event (1% AEP). Impacts associated with all three events (the study area representing the PMF) would lead to long-term decreases in the important population. Impacts to the habitat of the important population is likely to lead to a long-term decrease in its size.
• **reduce the area of occupancy of an important population**
The Project may reduce the potential area of occupancy for *Rhizanthella slateri* across the upstream study areas. These reductions can be summarised according to the following impact scenarios: Upstream Study Area • 1% AEP (1 in 100 chance in a year flood): 45.08 hectares • 20% AEP (1 in 5 chance in a year flood): 9.65 hectares
• **fragment an existing important population into two or more populations**
As no targeted surveys were undertaken it has been assumed that the suitable habitat supports an important population of *Rhizanthella slateri*. The Project could potentially impact up to about to 80.97 hectares of suitable habitat from the upstream study area, and may lead to fragmentation.
• **adversely affect habitat critical to the survival of a species**
The Minister maintains a 'Register of Critical Habitat' under the EPBC Act in which habitat as identified as being critical to the survival of a listed threatened species is provided. To date, no critical habitat is listed for this species that occurs within or proximal to the construction, upstream or downstream study areas. In addition, there is no state of federal Recovery Plan that has been prepared for *Rhizanthella slateri*. Habitat that has been identified as critical in literature includes the area of occupancy of the known population, area of similar habitat within 200 m of a known population and additional similar habitat in adjoining or adjacent remnant bushland to known populations but not containing currently known individuals.
• **disrupt the breeding cycle of an important population**
There is little understanding of the *Rhizanthella slateri* breeding cycle. It is understood that the underground orchid flowers during October and November (OEH 2019). Within the upstream impact area an increase in flooding with the Project could interrupt the flowering period and possibly reduce the genetic diversity for this species. Downstream of the Project the change in the existing 10% AEP area to the 10% AEP with the Project is expected to have reduced inundation events, leading to a drying out of the habitat and increasing the potential for fires. Unplanned fires are identified by OEH (2019) as reducing the reproductive potential as the seed capsules are retained for up to 12 months of the year.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The cryptic nature of *Rhizanthella slateri* and the inability to detect it throughout much of the year (OEH 2019) means any potential habitat must be considered and the decline in quality could cause the population to decline. Any change in the fire regime has been identified as a threat to *Rhizanthella slateri* survival.

• result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat
Where invasive species such as exotic perennial grass are identified as harmful to *Rhizanthella slateri* (OEH 2019). Therefor this species the anticipated invasive species may be harmful to *Rhizanthella slateri* becoming established in suitable habitat.
• introduce disease that may cause the species to decline, or
There are no diseases that are known to specifically affect *Rhizanthella slateri.*
• interfere substantially with the recovery of the species.
Threats to *Rhizanthella slateri* include clearing for infrastructure such as roads as well as housing and other developments. The altered drainage and hydrological changes in soil moisture and weed invasions has the potential to remove, modify and fragments the populations possibly disturbing pollination and seed dispersal have been identified in literature for the population at Bulahdelah with the Pacific Highway upgrades (DoE 2019: TSSC 2003). Other threats include weed invasion, risk of visitation from orchid enthusiasts, loss of pollinators and small mammals and insects possibly dispersing seeds and vulnerable to changes in fire regimes (DoE 2019). Recovery strategy from the NSW Department of Environment and Climate Change (DECC) include protecting areas of known habitat, investigating alternative road placement, raising awareness among orchid collectors, fencing or restricting access to the known populations (DoE 2019; OEH 2019: TSSC 2003; DoE 2005). There is no National Recovery Plan for *Rhizanthella slateri.* The Approved Commonwealth Conservation Advice (TSSC 2003) for *Rhizanthella slateri* notes recovery actions should be targeted towards research priorities and managing known threats such as land clearing, stochastic events and inappropriate fire regimes. The loss and modification of suitable habitat within the Project study areas is likely to negatively affect the survivability and recoverability of this species into the future. The Project has therefore been assessed as interfering within the recovery of the species.
Conclusion
The Project could potentially reduce suitable habitat presumed to support an important population of *Rhizanthella slateri.* Flooding may reduce the habitat and functional ecosystem that *Rhizanthella slateri* exists in the upstream study area. This is because there is a complex mycorrhizal fungi relationship that is critical to the survival of the species and the seeds can take up to 12 months to mature after flowering. Increase in fire frequency in the upstream impact zone may impact on this species in terms of the reproduction and survival of the population. Due to the lack of scientific knowledge and a thorough understanding of *Rhizanthella slateri* the precautionary principle has been applied for this assessment. The Project has been assessed as likely to have a significant impact on *Rhizanthella slateri.*

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Syzygium paniculatum (Magenta Lilly Pilly)

Vulnerable under the EPBC Act

Syzygium paniculatum is a small to medium sized tree that grows to about 10 metres tall – although records of older trees get at tall as 20 metres. The bark is pinkish to reddish brown, flaky or platy, generally flaky on younger bark and platy on older bark. Leaves are oppositely arranged, simple, entire and lanceolate to slightly obovate (PlantNET 2019; OEH 2012; OEH 2019). *Syzygium paniculatum* leaves are about 10 centimetres in length and 3 centimetres wide, with a dark green upper surface and slightly sunken midribs. White flowers are produced in both terminal and upper axillary panicles. Flowers consist of four rounded petals and numerous stamens between 6 and 16 millimetres long. As the common name implies, magenta ovoid berries – although they can be white or pink – between 12 and 25 millimetres long are produced. The seed of *S. paniculatum* is polyembryonic, consisting of one to nine embryos (PlantNET 2019; OEH 2012; OEH 2019).

The *S. paniculatum* distribution occurs along a 400-kilometre extent of coastal NSW from Upper Lansdown to Conjola National Park (OEH 2012 2019). As of January 2011, this distribution was comprised of 44 sub-populations and 5 meta-populations. Estimates have these populations supporting approximately 1,200 individuals.

Syzygium paniculatum has been recorded in a variety of coastal rainforest habitats. Littoral rainforest and subtropical rainforest supported by sandy soils or sand dunes are the habitat where most *S. paniculatum* have been recorded. Additionally, *S. paniculatum* is often associated with gently sloping sites on floodplains, creek banks or on perched sand dunes (OEH 2012; OEH 2019).

According to OEH's BioNet system, *S. paniculatum* is associated with the following PCT mapped in the downstream study area:

- PCT 1504 (HN647): Sydney Blue Gum – Deane's Gum – River Peppermint shrubby riparian tall forest of the lower Colo River Sydney Basin Bioregion.

No PCTs associated with the occurrence of *S. paniculatum* were recorded in the upstream study area. Additionally, *S. paniculatum* was not assessed as having a moderate or higher likelihood of occurring in the construction study area. As such, the potential for the Project to impact this species in the construction study area is not subject to this assessment.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal.*
- *populations that are necessary for maintaining genetic diversity.*
- *populations that are near the limit of the species range.*

Targeted surveys for *S. paniculatum* were not undertaken across the Downstream study area. In the absence of targeted surveys, *S. paniculatum* has been assumed present in areas of suitable habitat – the previously listed PCTs. Using the precautionary principle, the population(s) residing within this habitat have been assessed as an important population(s) as they are key source populations for breeding and dispersal, are necessary for maintaining genetic diversity, and occur near the limit of the species range.

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**
As *Syzygium paniculatum* was not surveyed, areas of habitat have been used as a surrogate for the species occurrence. No habitat (occurrences of PCT 1504) was recorded between the existing and with-project PMFs and 10% AEPs, or within the FMZ discharge boundary. The Project is therefore unlikely to lead to a long-term decrease in the size of the local population.
• **reduce the area of occupancy of an important population**
The Project is unlikely to impact any *S. paniculatum* habitat within the downstream study area. The Project is therefore unlikely to reduce the area of occupancy of the important population.

• fragment an existing important population into two or more populations
Most of PCT 1504 (HN647) within the downstream study area has been partially fragmented through agricultural, public and residential development. Some extents of PCT 1504 (HN647) are however contiguous with larger areas of native vegetation that stretch outside of the Downstream study area. The Project may increase the fragmentation of both the currently degraded habitat and the habitat contiguous with native vegetation occurring outside the downstream study area.
• adversely affect habitat critical to the survival of a species
According to the *Matters of National Environmental Significance Significant impact guidelines* 1.1 (DoE 2013) habitat critical to the survival of a species refers to areas that are necessary for: • activities such as foraging, breeding, roosting, or dispersal • 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 • the reintroduction of populations or recovery of the species or ecological community. The *S. paniculatum* habitat in the downstream study area has been assessed as critical habitat because it is important for dispersal, the long-term maintenance of the species and for maintaining genetic diversity. The Project could potentially adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive species, erosion and deposition, and modifying hydrology and the fire regime.
• disrupt the breeding cycle of an important population
Syzygium paniculatum has an interesting breeding cycle and reproductive ecology. This rainforest tree is estimated to live between 75 and 200 years (OEH 2012) – not unusual for a tree of its size, however what is unusual about *S. paniculatum* is that it produces polyembryonic seed (OEH 2012 2019). As the name implies, polyembryonic seed, is seed that contains more than one embryo. The seed of *S. paniculatum* can contain up to 9 embryos. A study by Thurlby (2010) demonstrated that *S. paniculatum* also has the ability to produce fertile seed both sexually (out-crossing) and asexually (apomixis). The dispersal of seed is more straightforward. Two mechanisms are thought to disperse seed; dispersal of seed through water such as creeks and rivers that are subject to periodic flooding, and through fauna such as the Grey-headed Flying-fox (OEH 2012). Germination of seed has been reported to be greatest in moist conditions and conditions with a greater canopy cover (Payne 1997). A reduction in peak flood extents and durations, along with a reduction in peak flood flows within the existing and proposed downstream 10% AEP flood extents may impact the breeding cycle of *S. paniculatum*. The breeding cycle of *S. paniculatum* may be impacted as one method of seed dispersal relies on the flow of water, and because seed germination may be benefited by moist conditions. As the Project may result in reduced flood extents, durations and flows, the seed – and therefore breeding cycle - of the population of *S. paniculatum* will be impacted. Increases in low-level flooding caused by the discharge of the FMZ (within the downstream study area) is unlikely to impact the breeding cycle of *S. paniculatum*. As established, *S. paniculatum* benefits from the flow of water within its habitat and the extra moisture that this flow may bring. It is unlikely that the extra water discharged from the FMZ will benefit the local population of *S. paniculatum*, but it is unlikely to negatively impact it. *Syzygium paniculatum* is a rainforest plant and is therefore unlikely to have evolved to withstand frequent burning and fire. Fire, and its mismanagement, may therefore be a risk to the lifecycle of *S. paniculatum*. The Project will affect the fire regime within the downstream study area by modifying the vegetation communities (and subsequently the fuel load) within them. If the modified vegetation is more susceptible to fire, then it is likely the frequency of fire will be increased. If fire is too frequent, it may destroy any *S. paniculatum* in the burnt area. The potential increased frequency of fire has been assessed as impacting the breeding cycle of *S. paniculatum*.

• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project could potentially impact *Syzygium paniculatum* habitat within the downstream study area. Habitat may be destroyed and/or directly impacted through the clearing of native vegetation, the loss of flora and fauna habitat, and a reduction in the extent of ecological communities. Habitat may be indirectly impacted (modified, reduced in quality etc.) through fragmentation, alteration to soil conditions, edge effects, weed invasion and incursion, through the spread of disease and pathogens, erosion and sedimentation, and thorough changes to the fire regime.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
Invasive flora and fauna have been identified as threats to *Syzygium paniculatum* in the National Recovery Plan and OEH Threatened Species Profile. The OEH Threatened Species Profile identifies trampling by grazing stock – many of which are now feral and invasive – as a threat (OEH 2019a). Feral fauna such as horses, cows and deer were all observed during the field surveys, and all have the potential to threatened *S. paniculatum* and its habitat. Whether or not the Project will contribute to the spread and establishment of these fauna is inconclusive. The National Recovery Plan and OEH Threatened Species Profile for *S. paniculatum* identify '*mixed weeds, including Lantana, Bitou Bush, Asparagus spp., and various vines and scramblers*' as a threat (OEH 2012; OEH 2019a). These plants are already common in the downstream study area and could potentially be further spread and established as a result of the Project.
• **introduce disease that may cause the species to decline, or**
Myrtle Rust has been identified as a threat to *Syzygium paniculatum*. Myrtle Rust is a disease that affects some plants within the Myrtaceae family, which is cause by an invasive fungus (*Austropuccinia psidii*). Within Australia, Myrtle Rust has been recorded in a range of ecosystems including tropical rainforest, subtropical rainforest, littoral rainforest, coastal heath, and sclerophyll forests. OEH notes that '*spores are spread by wind (as well as some animals and human activities) and the pathogen probably already occupies its full bioclimatic suitability envelope in mainland NSW*' (OEH 2019b). *Rhodamnia rubescens*, a threatened shrub was observed at Maroota Ridge State Conservation Area (the extent within the Downstream study area) infected with Myrtle Rust, making it likely that the disease already extensively occurs throughout the downstream study area. The Project is unlikely to further spread Myrtle Rust throughout the downstream study area.
• **interfere substantially with the recovery of the species.**
A National Recovery Plan has been developed under the EPBC Act for *S. paniculatum* – the National Recovery Plan for Magenta Lilly Pilly *Syzygium paniculatum* (OEH 2012). The following seven recovery objectives have been identified for *S. paniculatum* under this plan: 1. To ensure a coordinated and efficient approach to the implementation of recovery efforts. 2. To establish the full extent of the distribution of Magenta Lilly Pilly 3. To increase the understanding of Magenta Lilly Pilly biology and ecology 4. To minimise the decline of Magenta Lilly Pilly through in situ habitat protection and management 5. To reduce impacts of Myrtle Rust on Magenta Lilly Pilly and its habitat. 6. To maintain a representative ex situ collection of Magenta Lilly Pilly 7. To raise awareness of the conservation significance of Magenta Lilly Pilly and involve the broader community in the recovery program. The Project may not be consistent with objectives 4 and 5 of the National Recovery Plan for *Syzygium paniculatum*. A targeted strategy for managing *Syzygium paniculatum* has also been developed under the Saving Our Species Program (NSW Government). Under the Saving Our Species Program, *S. paniculatum* has been assigned to the 'site-managed species' management stream. The following three priority management sites have been identified in the Saving Our Species Program for S. paniculatum: • Great Lakes in the Mid Coast and Port Stephens LGAs. • Wyrrabalong in the Central Coast LGA.

- Wamberal Lagoon in the Central Coast LGA. The Project will not impact any of the three listed priority management sites. Introduced vertebrate pests have been identified as a threat to *S. paniculatum* in the National Recovery Plan for Magenta Lilly Pilly. There are two Approved Threat Abatement Plans relevant to introduced vertebrate pests which may impact *S. paniculatum - Threat abatement plan for competition and land degradation by unmanaged goats* (DEWHA 2008), and *Threat abatement plan for competition and land degradation by rabbits* (DoEE 2016). It is unknown if the Project will increase the impact of goats or deer.
Conclusion
The Project is unlikely impact *Syzygium paniculatum* habitat across the downstream study area. The threat of invasive flora species may also be exacerbated by the Project however it is unclear if this will impact *S. paniculatum*. The Project has been assessed as unlikely to have a significant impact on *Syzygium paniculatum.*

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Trachymene scapigera (Mountain Trachymene)

Endangered under the EPBC Act

Trachymene scapigera is a robust, perennial herb growing to between 10 and 50 centimetres tall. This species produces 3 to 5 lobed leaves from 0.8 to 2 centimetres long and 1 to 3.5 centimetres wide, that form in a basal rosette. Leaf lobes are ovate to cuneate and covered by sparse hairs. *Trachymene scapigera* produces umbels that can support from 20 to 50 flowers. Flowers are white or pinkish, bisexual or female and have petals 1 to 1.2 millimetres in length (PlantNET 2002).

The known *T. Scapigera* distribution is restricted to Kanangra Boyd National Park and Gurnang State Forest, part of the Blue Mountains region west of Sydney NSW. There are two known populations within the Kanangra Boyd National Park extent its distribution, separated by about 4 kilometres (DEWHA 2008). *Trachymene scapigera* habitat is broadly restricted to flat or gently sloping terrain near riparian areas. Apart from this description habitat can be variable; at one of the Kanangra Boyd National Park populations *T. scapigera* grows alongside a *Leptospermum* thicket within a woodland, while at the second population *T. scapigera* grows throughout a gravel patch (Mackenzie 1996).

According to OEH's BioNet system, *T. scapigera* is associated with the following PCTs mapped in the upstream study area:

- PCT 941 (HN5353): Mountain Blue Gum - Thin-leaved Stringybark open forest on river flat alluvium in the Sydney Basin Bioregion
- PCT 1105 (HN574): River Oak open forest of major streams Sydney Basin Bioregion and South East Corner Bioregion
- PCT 1401 (HN557): Narrow-leaved Ironbark - Forest Red Gum on rocky slopes of the lower Burragorang Gorge Sydney Basin Bioregion.

Trachymene scapigera has been assessed with a low likelihood of occurrence in the downstream and construction study areas. As such, it is not considered to occur in these study areas or be impacted by the Project in these study areas.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines a 'population of a species' as an occurrence of the species in a particular area. In relation to critically endangered, endangered or vulnerable threatened species occurrences include but are not limited to:

- a geographically distinct regional population, or collection of local populations.
- a ppopulation or collection of local populations that occur within a particular bioregion.

Targeted surveys for *T. scapigera* were not undertaken in the upstream study area. In the absence of targeted surveys in the upstream study area, a population of *T. scapigera* has been assumed present in the areas of suitable habitat – the previously listed PCTs.

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**
As *Trachymene scapigera* was not surveyed, areas of habitat have been used as a surrogate for the species occurrence. The Project could potentially impact up to about 36.05 hectares within the 1% AEP boundary and 21.09 hectares within the 20% AEP boundary. Impacts to this habitat have the potential to lead to a long-term decrease in the size of the *T. scapigera* population.
• **reduce the area of occupancy of the species**
The Project could potentially impact up to about 36.05 hectares within the 1% AEP boundary and 21.09 hectares within the 20% AEP boundary. These impacts may reduce the area of occupancy of *Trachymene scapigera*.

• **fragment an existing population into two or more populations**
The *T. scapigera* habitat in the upstream study area is not in a fragmented condition, being contiguous with the native vegetation of the Blue Mountains National Park. The Project may impact this habitat, however its connectivity to larger extents of native vegetation will reduce the number of new edges and 'fragments' created. The Project is therefore unlikely to fragment the existing population into two or more smaller populations.
• **adversely affect habitat critical to the survival of a species**
No critical habitat has been listed for *Trachymene scapigera* under the EPBC Act.
• **disrupt the breeding cycle of a population**
Trachymene scapigera can reproduce asexually via rhizomes, making population census assessments difficult. Additionally, despite being perennial species, the above-ground parts of the plant die down over Winter. In the Spring, regrowth of the vegetative parts of a plant has recommenced. Seedlings also emerge at this time. Adults will flower from December to March with seed release occurring in April. Seed viability declines rapidly after dispersal with almost no viable seed remaining after 12 months (DEWHA 2008). The Project could potentially disrupt the breeding cycle of the population in the upstream study area. The short-lived seed bank may be impacted through inundation and erosion. Inundation and erosion could potentially impact adult plants as well, most likely leading to their death if inundated for any prolonged period of time.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project could potentially impact *Trachymene scapigera* habitat within the upstream study area. Habitat may be destroyed and/or directly impacted through the clearing of native vegetation, the loss of flora and fauna habitat, and a reduction in the extent of ecological communities. Habitat may be indirectly impacted (modified, reduced in quality etc.) through alteration to soil conditions, edge effects, weed invasion and incursion, erosion and sedimentation, and potentially thorough changes to the fire regime.
• **result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat**
The Approved Conservation advice for *Trachymene scapigera* states that feral pigs are a threat. While feral pigs already occur within the upstream study area, it is unknown whether the Project could increase their abundance.
• **introduce disease that may cause the species to decline, or**
No diseases have been identified as a threat to *Trachymene scapigera*.
• **interfere substantially with the recovery of the species.**
No National Recovery Plan has been developed for *Trachymene scapigera* under the EPBC Act. The SPRAT profile for *T. scapigera* states that 'no recovery plan is required'. Despite the lack of a recovery plan, the Approved Commonwealth Conservation Advice for *Trachymene scapigera* (DoE 2008) includes the following priority conservation actions: 1. Monitor known populations to identify key threats. 2. Monitor the progress of recovery, including the effectiveness of management actions and the need to adapt them if necessary. 3. Undertake targeted bush regeneration works, where required. 4. Identify populations of high conservation priority. 5. Ensure road widening and maintenance activities (or other infrastructure activities) involving substrate or vegetation disturbance in areas where T. scapigera occurs do not adversely impact on known populations. 6. Control access routes to suitably constrain public access to known sites on public land. 7. Prepare and implement a species management plan for the site that is located within Gurnang State Forest (DECC NSW 2005b).

8. Implement a management plan for the control and eradication of the feral pigs in the region.
9. Fence off known populations to minimise trampling.
10. Develop and implement a suitable fire management strategy for T. scapigera. The NSW Rural Fire Service recommends no fire for this species (NSW RFS 2004).
11. Provide maps of known occurrences to local and state Rural Fire Services and seek inclusion of mitigative measures in bush fire risk management plans, risk register and/or operation maps.

The Project does not interfere with any of the listed priority conservation actions.

Feral pigs have been listed in the Approved Commonwealth Conservation Advice as a threat to *T. scapigera*. An Approved Threat Abatement Plan for feral pigs - *Threat abatement plan for predation, habitat degradation, competition and disease transmission by feral pigs* (*Sus scrofa*) (DoEE 2017) – has been developed however it is unclear if the Project will increase impacts from feral pigs.

Conclusion
The Project could potentially impact *Trachymene scapigera* habitat throughout the upstream study area. The species habitat may be impacted through changes to hydrology and erosion which have the potential to impact the breeding cycle of *T. scapigera*. The Project has been assessed as likely to have a significant impact on *Trachymene scapigera*.

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Velleia perfoliata

Vulnerable under the EPBC Act

Velleia perfoliata is listed as Vulnerable under the BC Act and the EPBC Act. It is a small perennial herb with light green narrow-ovate leaves to 12mm long with toothed or entire margins. The flower stalk is up to 50 centimetres high with yellow flowers in spring. Below the flower stalk there are fused leaf-like structures forming a funnel. The capsule is globose to 4 millimetres (PlantNet 2019; BioNet 2018). This species is found in shallow depressions in Hawkesbury sandstone shelves, rocky hill sides, cliffs and along tracks and trails growing on moss and lichen mats formed on rock (BioNet 2018).

Velleia perfoliata is only known from the Hawkesbury area and upper Hunter Valley in nine populations, five are in reserved and four populations are situated along fire trails (NSW SC 2015). It is associated with heath and open forest over sandstone, other species in the communities are *Angophora bakeri, Corymbia eximia, Backhousia myrtifolia, Eucalyptus sparsifolia, E. crebra, E. notabilis, Allocasuarina torulosa* and *Leptospermum attenuatum* (BioNet 2018). There are estimated to be less than 1000 individuals across seven of the populations with no one population containing more than 300 plants (NSW SC 2015).

Targeted surveys for *Velleia perfoliata* were not undertaken in the downstream study area for the Project. There were no opportunistic recordings of this species in any field surveys for this Project. In the absence of targeted surveys, *Velleia perfoliata* has been assumed present in areas of known suitable habitat. For this assessment, suitable habitat for this species includes the PCTs that the species was identified as habitat by BioNet, PCTs that are associated with the species (as per the Threatened Biodiversity Data Collection) and any other known vegetation types (as per scientific literature) that the species is associated with that occur within the study area.

Suitable habitat includes the following PCTs that have been mapped within the study areas.

Upstream:

- PCT1081 (HN564): Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion

Construction

- PCT1081 (HN564): Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion

Downstream:

- PCT1081 (HN564): Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion
- PCT1181 (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
- PCT1183 (HN587): Smooth-barked Apple - Sydney Peppermint - Turpentine heathy open forest on plateaux areas of the Sydney Basin Bioregion
- PCT1327 (HN612): Yellow Bloodwood - ironbark shrubby woodland of the dry hinterland of the Central Coast, Sydney Basin Bioregion
- PCT1328 (HN613): Yellow Bloodwood - Narrow-leaved Apple heathy woodland on hinterland plateaux of the Central Coast, Sydney Basin Bioregion
- PCT1385 (HN577): Rough-barked Apple - Grey Gum grassy open forest of the hinterland hills of the Central Coast, Sydney Basin Bioregion

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal*
- *populations that are necessary for maintaining genetic diversity, and/or*
- *populations that are near the limit of the species range.*

An important population has been assessed as occurring in the Project area as it would be important for maintaining genetic diversity and would be at the limit of the species range.

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**
As *Velleia perfoliata* has not been surveyed, areas of habitat have been used as a surrogate for the species occurrence. Within the upstream study area 64.04 hectares of habitat has been mapped. Of this 64.04 hectares, 7.31 hectares may be impacted by a 1 in 5 chance in a year flood event (20% AEP) and 35.04 hectares by a 1 in 100 chance in a year flood event (1% AEP). Associated impacts could lead to long-term decreases in the important population. Within the downstream study area approximately 11.13 hectares occurs between the existing and with project 10% AEPs, zero hectares between the existing and with project PMFs and 8.25 hectares within the FMZ discharge area. Approximately 2.76 hectares of habitat occurs within the Development Footprint associated with construction activities. The impacts to suitable habitat have the potential to lead to a long-term decrease in the size of the important populations of *V. perfoliata*.
• **reduce the area of occupancy of an important population**
The Project may reduce the potential area of occupancy for *Velleia perfoliata* across all three study areas. These reductions can be summarised according to the following impact scenarios: Upstream Study Area • 1% AEP (1 in 100 chance in a year flood): 35.04 hectares • 20% AEP (1 in 5 chance in a year flood): 7.31 hectares Downstream Study Area • FMZ discharge area: 8.25 hectares • Difference between the existing and with project 10% AEPs: 11.13 hectares • Difference between the existing and with project PMFs: 0 hectares Construction Study Area • Development footprint: 2.76 hectares
• **fragment an existing important population into two or more populations**
The Project could potentially fragment *Velleia perfoliata* habitat, largely within the downstream study area. Given that the downstream area of habitat is not one large area but a mosaic of native vegetation, patches of habitat may become fragmented through loss of connecting corridor habitat and the formation of new edges. The potential for fragmentation in the upstream and construction study areas is lower, as the *V. perfoliata* habitat in these study areas is contiguous with the native vegetation of the Blue Mountains National Park.
• **adversely affect habitat critical to the survival of a species**
The Minister maintains a 'Register of Critical Habitat' under the EPBC Act in which habitat as identified as being critical to the survival of a listed threatened species is provided. To date, no critical habitat is listed for this species that occurs within or proximal to the construction, upstream or downstream study areas. Suitable habitat presumed to support an important population of *Velleia perfoliata* has been assessed as habitat critical to the survival of the species. This habitat is important for dispersal, the long-term maintenance of the species and for maintaining genetic diversity. It is also important for maintaining ecological processes essential to the survival for the species. The Project may adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive species, erosion and deposition, and modifying hydrology and the fire regime. The Project may therefore adversely affect habitat critical to the survival of *Velleia perfoliata.*

• **disrupt the breeding cycle of an important population**
Disruption to the breeding cycle may occur with the increased fire due to the changes in the hydrology downstream and the lower flood levels between the 10% AEP Existing and with the Project. In the upstream impact area, the vegetation may be most affected in spring and summer while its flowering and during the period of seed production.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
There is limited habitat in the upstream study area that could be modified, destroyed or removed. Up to three hectares of potential habitat in the construction area could be removed through clearing of vegetation. The habitat recorded in the downstream study area will be modified and/or destroyed by impacts caused by the Project.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
Weed encroachment is listed as a threatening process for *Velleia perfoliata*. Any invasive weeds that are likely to be early colonisers after disturbance may pose a threat to this species. Weed encroachment is considered to be a greater threat to *V. perfoliata* in the downstream study area. The diversity and abundance of weeds in the downstream study area is greater making their spread through a disturbance more likely.
• **introduce disease that may cause the species to decline, or**
No diseases have been identified as a threat to *Velleia perfoliata.*
• **interfere substantially with the recovery of the species.**
The main threats to *Velleia perfoliata* include track and road maintenance, weed encroachment, weed eradication and back burning activities carried out too frequently. To assist this species OEH (2018) listed protecting sites on private land and adapting park management where it is known. An Approved National Recovery Plan has not been developed for *V. perfoliata*. The Approved Commonwealth Conservation Advice (DEWHA 2008) does however outline local and regional priority actions to assist in the recovery of the species. The priority actions are organised under the following management themes: • Habitat Loss, Disturbance and Modification • Invasive Weeds • Fire • Conservation Information • Enable Recovery of Additional Sites and/or Populations The Project interferes with priority actions listed under the management theme *Habitat Loss, Disturbance and Modification*. Specifically, the Project is inconsistent with these actions: • Manage threats to areas of vegetation that contain populations/occurrences/remnants of *Velleia perfoliata*. • Manage any changes to hydrology, which may result in changes to the water table levels, increased run off, sedimentation or pollution.
Conclusion
Velleia perfoliata may be potentially significantly impacted by the Project as habitat with in the upstream, downstream and construction study areas could experience impacts leading to removal, fragmentation, modification and isolation of the habitat for this species. The Project may impact the breeding cycle of *Velleia perfoliata* by clearing native vegetation (habitat), modifying the fire regime, modifying the hydrological environment and impacting the soil seedbank. The threat of invasive flora species may also be exacerbated by the Project. These impacts may cause a decline of important population of *Velleia perfoliata*. The Project has been assessed as likely to have a significant impact on *Velleia perfoliate.*

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Zieria covenyi

Endangered under the EPBC Act

Zieria covenyi is an erect branching shrub up to 2 metres proliferating from root suckers (OEH 2019; PlantNet 2019). This species has leaves with 3 leaflets which area dark green, dotted with oil glands and is strongly aromatic, the underside is grey green with stellate hairs (PlantNet 2019). *Z. covenyi* conspicuous white to pale pink flowers 10-13 millimetres in diameter (BioNet 2019). Inflorescences usually about as long as leaves, 3–21-flowered, petals to 6 millimetres long, valvate, white to pale pink, pubescent or glabrous (PlantNet 2019). Fruit never observed (DOEE 2008).

Zieria covenyi grows in eucalypt woodland on sandy soils on south facing slopes (BioNet 2019; DOEE 2008), with associated vegetation includes *Eucalyptus sieberi, Leptospermum attenuatum, Telopea speciosissima, Banksia serrata, Hakea dactyloides, Olearia erubescens* and *Brachyloma daphnoides* (DOEE 2008). The species has a very restricted distribution and is known only from two populations several kilometres apart on Narrow Neck Peninsula in the Blue Mountains NP, NSW, although potential habitat of Z. covenyi is widespread in the local area, the known habitat is currently restricted to an area of only about. 1.2ha. (OEH 2019: BioNet 2019). Given this species poor genetic diversity any activities that result in change or reduce the resistance or adaptability of the population will have a negative impact on the regeneration potential and the genetic viability if the species (DOEE 2008).

Targeted surveys for *Zieria covenyi* were not undertaken in the downstream, upstream or construction study areas for the Project. Additionally, *Zieria covenyi* was not incidentally encountered in the survey area during vegetation mapping associated with the Project.

In the absence of targeted surveys, *Zieria covenyi* has been assumed present in areas of presumed suitable habitat. For this assessment, suitable habitat for *Zieria covenyi* includes the PCTs that are associated with the species (as per the TBDC), BioNet Atlas Records and any other known vegetation types (as per scientific literature) that the species is associated with that has been mapped within the study area.

Suitable habitat includes the following PCTs, according to OEH's BioNet, that have been mapped within the upstream study area:

- PCT1246 (HN598) Sydney Peppermint - Grey Gum shrubby open forest of the western Blue Mountains Sydney Basin Bioregion
- PCT1083 (HN566) Red bloodwood - scribbly gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion

Zieria covenyi was assessed as having a low likelihood of occurring in the construction and downstream study areas. As such, an assessment of impacts to Z. covenyi in these study areas has not been considered in this assessment.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'population of a species' as '*an occurrence of the species in a particular area). In relation to critically endangered, endangered or vulnerable threatened species, occurrences include but are not limited to:*

- *a geographically distinct regional population, or collection of local populations, or*
- *a population, or collection of local populations, that occurs within a particular bioregion.*

Targeted surveys for *Z. covenyi* were not undertaken in the upstream, downstream or construction study areas. In the absence of targeted surveys, *Z. covenyi* has been assumed present in areas of presumed suitable habitat – the previously listed PCTs. Using the precautionary principle, a population of *Z. covenyi* has been assessed as occurring in areas of suitable habitat (the previously listed PCTs).

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 of a species**
As *Zieria covenyi* has not been surveyed, areas of habitat have been used as a surrogate for the species occurrence. The Project could potentially impact up to 19.82 hectares of *Zieria covenyi* habitat within the 1% AEP flood extent and 3.71 hectares within the 20% AEP flood extent. These impacts have the potential to lead to a long-term decrease in the size of the *Z. covenyi* population.
• **reduce the area of occupancy of the species**
The Project could potentially impact up to 19.82 hectares of *Zieria covenyi* habitat within the 1% AEP flood extent and 3.71 hectares within the 20% AEP flood extent. Impacts to this habitat may reduce the area of occupancy of the species.
• **fragment an existing population into two or more populations**
The habitat in the upstream study area is contiguous with the native vegetation of the surrounding Blue Mountains National Park. The Project may result in the removal of native vegetation and habitat in the eastern section of the Warragamba Gorge. The removal of this vegetation could fragment *Zieria covenyi* habitat in the upstream study areas. Other impacts such as promoting the spread and establishment of invasive flora species could also contribute to habitat fragmentation.
• **adversely affect habitat critical to the survival of a species**
The Minister maintains a 'Register of Critical Habitat' under the EPBC Act in which habitat as identified as being critical to the survival of a listed threatened species is provided. To date, no critical habitat is listed for this species that occurs within or proximal to the construction, upstream or downstream study areas. Suitable habitat presumed to support a population of *Zieria covenyi* has been assessed as habitat critical to the survival of the species. This habitat is important for dispersal, the long-term maintenance of the species and for maintaining genetic diversity. It is also important for maintaining ecological processes essential to the survival for the species. The Project may adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive species, erosion and deposition, and modifying hydrology and the fire regime. The Project therefore could adversely affect habitat critical to the survival of *Zieria covenyi.*
• **disrupt the breeding cycle of a population**
This species flowers from September to December. It is completely pollen sterile and produces no fruit or seed. Numerous nectar-seeking insects have been observed visiting the blossoms, but none carrying fertile pollen. Reproduces vegetatively by root suckering. The taxon probably arose following hybridisation between two other *Zieria* species. The biology and life cycle of *Z. covenyi* is poorly known. It is possible that the current gene pool of *Z. covenyi* is a relic of the original genetic diversity. Species with poor genetic diversity are more prone to extinction through disease and rapid environmental change.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
With about 105 hectares of *Zieria covenyi* habitat in the upstream study area, any habitat destroyed or directly impacted by clearing native vegetation, the loss of habitat for fauna and flora or a reduction in the extent of ecological communities could cause fragmentation. Fragmentation of a population into two or more populations is however considered to be less likely as the habitat occurring upstream is contiguous with the native vegetation of the Blue Mountains National Park. Altered soil conditions, edge effects, weed invasion and spread of disease pathogens could potentially contribute to cause a decline in the species.

• **result in invasive species that are harmful to an endangered species becoming established in the endangered species' habitat**
Competition with weeds and exotic species could impact the local population of *Z. covenyi*. Exotic plants such as Lantana and African Olive become established in disturbed areas quickly. Such plants can out-compete native plants, especially seedlings and juveniles. If seedlings and juveniles are outcompeted, recruitment of new individuals into a population cannot take place.
• **introduce disease that may cause the species to decline, or**
The dispersal of *Phytophthora cinnamomi* can be mediated through water and through eroded soil. The Project has the potential to facilitate the spread of *Phytophthora cinnamomi* throughout the Project area and therefore contribute to the EPBC listed key threatening process Dieback caused by the root-rot fungus (*Phytophthora cinnamomi*). An Approved Threat Abatement Plan has been developed for the threat of *Phytophthora cinnamomi* (DoEE 2018). The Project has been assessed as inconsistent with the Approved Threat Abatement Plan for *Phytophthora*.
• **interfere with the recovery of the species.**
Too frequent fire, over abundant herbivores and road or track works are listed in the conservation advice for this species as threats, along with, low genetic diversity, lack of knowledge and understanding and *Phytophthora* (DOEE 2008). Changes to the hydrological regime may affect the soil moisture levels, creating positive conditions for *Phytophthora cinnamomic* during flooding events, or if there is damaged habitat though altered processes, this may increase fire frequency with the rise in dead matter as fuel. An Approved National Recovery Plan has not been developed for *Z. covenyi*. The Approved Commonwealth Conservation Advice (DEWHA 2008) does however outline local and regional priority actions to assist in the recovery of the species. The priority actions are organised under the following management themes: • Habitat Loss, Disturbance and Modification • Fire • Conservation Information • Enable Recovery of Additional Sites and/or Populations The Project interferes with the following priority action listed under the management theme *Habitat Loss, Disturbance and Modification*. Specifically, the Project is inconsistent with the actions: • Minimise adverse impacts from changed land use at known sites.
Conclusion
The Project has potential to have a significant impact on *Zieria covenyi* habitat. Any loss of habitat that is suitable for this species is considered potentially significant. The Project has been assessed as likely to have a significant impact on *Zieria covenyi.*

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Zieria involucrata

Vulnerable under the EPBC Act

Zieria involucrata is a small shrub about 1 or 2 metres high, with a sparse yet erect habit. It produces branches and leaves that are covered in a dense indumentum. Most of these hairs are stellate (star-shaped), with simple and bifurcating hairs occurring less commonly. The leaves of *Z. involucrata* are arranged oppositely, either occurring as a single leaflet or as three leaflets – both of which can occur on the same branch. The adaxial surface of the leaflets are dark green whereas the abaxial surface is pale-green to grey. Leaflets are oblong to elliptic or lance-shaped, about 3.6 centimetres long and 10-15 millimetres wide. Flowers occur in clusters of between 3 and 21 that are enclosed by numerous leaf-like bracts. The bracts are between 7 and 12 millimetres long and covered by a dense indumentum. Flowers are white with some pink, and like the rest of the plant, covered by an indumentum – although not as dense (OEH 2017; PlantNET 2019).

Zieria involucrata is endemic to the Sydney Basin Bioregion where it has been records from the hills and escarpments to the north-west and west of the Sydney Metropolitan area. According to the Draft Recovery Plan for *Zieria involucrata*, the species is known from 22 extant populations (NSW NPWS 2004). The size of populations ranges from a single plant to over 500, although 13 of the 22 known populations have fewer than 100 individuals. The exact size of the combined 22 populations is unknown, however estimates have the entire population being comprised of between 5,000 and 8,000 individuals (NSW NPWS 2004).

Within its distribution, *Z. involucrata* occurs on the mid – to lower slopes of rolling hills or steeper terrain. Within this terrain it usually occurs in neutral to slightly acid, sandy soils, often amongst sandstone outcrops and boulders. All but three populations occur in habitat supported by Hawkesbury Sandstone. Two of the outlier populations occur in habitat supported by a mix of Hawkesbury and Narrabeen Sandstone geologies. The third outlier population occurs on Quaternary alluvium of the Wiseman's Ferry soil landscape (NSW NPWS 2004). Canopy species characteristic of *Z. involucrata* habitat include *Syncarpia glomulifera* subsp. *glomulifera*, *Eucalyptus agglomerate*, *Allocasuarina torulosa* and *Angophora costata. Zieria involucrata* habitat usually supports a dense sub-canopy and shrub layer including species such as *Ceratopetalum gummiferum, Backhousia myrtifolia*, *Leptosperum trinervium* and *Elaeocarpus reticularis.* Smaller shrubs such as *Entolasia stricta, Lepidosperma laterale,* and *Dianella caerulea*, are common in *Z. involucrata* habitat.

Field survey conducted for the Project confirmed the occurrence of *Z. involucrata* within Scheyville National Park. The occurrence of these individuals corresponded to PCT 1557 (HN665) and PCT 1292 (HN607), neither of which are listed in BioNet. They have been included as habitat in this assessment.

Numerous records of *Z. involucrata* occur within the study area according to OEH's records. However, as targeted surveys for *Z. involucrata* were conducted by SMEC, nor was it incidentally recorded during other survey work, the occurrence of the local population has been precautionarily defined by the known occurrences of the species and the previously listed PCTs occurring in the study area identified as associated habitat through TBDC or other associated PCT's observed in the field. Areas of habitat occurring outside the study that is contiguous with habitat occurring inside the study area has been included in this definition.

In the absence of targeted surveys, *Z. involucrata* has been assumed present in areas of presumed suitable habitat. For this assessment, suitable habitat for *Z. involucrata* includes the PCTs that are associated with the species (as per the TBDC), BioNet Atlas Records and any other known vegetation types (as per scientific literature) that the species is associated with that has been mapped within the study area.

Suitable habitat includes the following PCTs, according to OEH's BioNet, that have been mapped within the study areas

Upstream study area:

- PCT1284 (HN606): Turpentine - Smooth-barked Apple moist shrubby forest of the lower Blue Mountains Sydney Basin Bioregion
- PCT1292 (HN607): Water Gum - Coachwood riparian scrub along sandstone streams Sydney Basin Bioregion

Downstream study area

- PCT1504 (HN647): Sydney Blue Gum - Deane's Gum - River Peppermint shrubby riparian tall forest of the lower Colo River Sydney Basin Bioregion

- PCT1181 (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
- PCT1183 (HN587): Smooth-barked Apple - Sydney Peppermint - Turpentine heathy open forest on plateaux areas of the Sydney Basin Bioregion
- PCT1284 (HN606): Turpentine - Smooth-barked Apple moist shrubby forest of the lower Blue Mountains Sydney Basin Bioregion
- PCT1328 (HN613): Yellow Bloodwood - Narrow-leaved Apple heathy woodland on hinterland plateaux of the Central Coast Sydney Basin Bioregion
- PCT1292 (HN607): Water Gum - Coachwood riparian scrub along sandstone streams Sydney Basin Bioregion
- PCT1557 (HN665): Rough-barked Apple - Forest Oak - Grey Gum grassy woodland on sandstone ranges of the Sydney Basin

Zieria involucrata was not assessed to have a moderate or higher likelihood of occurring in the construction study area. As such, the potential for this species to be impacted by the Project in the construction study area is not subject to this assessment.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal*
- *populations that are necessary for maintaining genetic diversity, and/or*
- *populations that are near the limit of the species range*

The *Z. involucrata* occurring in the upstream and downstream study area has been assessed as an important population because it is likely a key source population for breeding and dispersal and it is likely necessary for maintaining the species genetic diversity.

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**
As *Zieria involucrata* has not been surveyed, areas of habitat have been used as a surrogate for the species occurrence. The Project could potentially impact up to about 41.36 hectares within the 1% AEP flood extent and 9.13 hectares within the 20% AEP flood extent. Within the downstream study area, the Project may impact 0.31 hectares of habitat occurring between the existing and with-project PMFs, 59.22 hectares between the existing and with-project 10% AEPs and 54.76 hectares within the FMZ discharge zone. The impact to *Z. involucrata* habitat across all impact boundaries/scenarios has the potential to lead to a long-term decrease in the size of the important population.
• **reduce the area of occupancy of an important population**
The Project could potentially impact up to 41.36 hectares within the 1% AEP flood extent and 9.13 hectares within the 20% AEP flood extent. Within the downstream study area, the Project may impact 0.31 hectares of habitat occurring between the existing and with-project PMFs, 59.22 hectares between the existing and with-project 10% AEPs and 54.76 hectares within the FMZ discharge zone. These impacts are expected to reduce the area of occupancy of the important population.
• **fragment an existing important population into two or more populations**
The *Zieria involucrata* habitat within the downstream study area has been partially fragmented through agricultural and residential development. The extents of PCT 1284 (HN606) and PCT 1181 (HN586) are however often contiguous with larger areas of native vegetation that stretch outside of the study area. This makes the *Z. involucrata* habitat comparatively less fragmented than other native vegetation occurring within the central part of the Cumberland Plain. Despite the *Z. involucrata* habitat's partial connectivity with large areas of native vegetation, the Project may further fragment its extent.

• **adversely affect habitat critical to the survival of a species**
The Minister maintains a 'Register of Critical Habitat' under the EPBC Act in which habitat as identified as being critical to the survival of a listed threatened species is provided. To date, no critical habitat is listed for this species that occurs within or proximal to the construction, upstream or downstream study areas. Suitable habitat presumed to support an important population of *Zieria involucrata* has been assessed as habitat critical to the survival of the species. This habitat is important for dispersal, the long-term maintenance of the species and for maintaining genetic diversity. It is also important for maintaining ecological processes essential to the survival for the species. The Project may adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive species, erosion and deposition, and modifying hydrology and the fire regime. It is therefore expected that the Project may adversely affect habitat critical to the survival of *Zieria involucrata.*
• **disrupt the breeding cycle of an important population**
The lifespan of *Z. involucrata* is uncertain however the Draft Recovery Plan for *Zieria involucrata* describes that it may live between 10 and 15 years (NSW NPWS 2004). *Zieria involucrata* produces both dormant and non-dormant seed. A study by Auld *et al.* (2000) estimated that dormant seed reached its half-life 4.9 years after release and raised the possibility that some seed may be viable up to 2 decades after the plant it was released from had died. Seed is dispersed via 'forcible ejection' from a coccus (Armstrong 2002). Seeds have elaiosomes indicating that secondary dispersal via ants is also likely. Regardless, seed dispersal is likely to be limited to a few metres (Auld 2001). Fire is important to the reproductive ecology of *Z. involucrata. Zieria involucrata* has been described as a fire sensitive species that is capable of limited re-sprouting (Auld 2000; Armstrong 2002). Fire has been suggested as important to the germination of the seed bank. Heat or smoke – or a combination of the two- may be important to breaking seed dormancy and ensuring germination success (NSW NPWS 2004). A reduction in peak flood extents and durations, along with a reduction in peak flood flows is unlikely to impact the lifecycle of *Z. involucrata*. Increases in low-level flooding caused by the discharge of the FMZ may however impact the lifecycle of *Z. involucrata*, as the discharged water will reach occurrences of PCT 1504 (H647), PCT 1181 (HN586), PCT 1284 (HN606), PCT 1328 (HN613), PCT 1292 (HN607), and PCT 1557 (HN665). Releases from the FMZ may inundate *Z. involucrata* habitat and individuals neither of which have evolved to withstand flooding. The soil-stored seed bank produced by *Z. involucrata* may also be impacted as the water discharged from the FMZ has the potential to erode it away or bury it in sediment and debris carried from upstream areas. The increased flood frequency may also impact ant communities which are important vectors for the dispersal of seed.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project could potentially impact *Z. involucrata* habitat within the upstream and downstream study areas. *Zieria involucrata* is endemic to the hills and escarpments that surround the north-west and west of the Sydney Metropolitan area. For a species with such a limited distribution it is vital that all possible habitat is conserved. All the habitat occurring in the study area has undergone some form of anthropogenic disturbance. Despite this, habitat was found to support occurrences of *Z. involucrata*. The habitat within the study areas is likely to support a soil-stored seed-bank and communities of ants – vectors of seed dispersal. The habitat within the study area is important to the lifecycle of the local population. The habitat within the study area has therefore been assessed as important. The Project may increase the isolation and inhibit the connectivity of the remaining habitat. The Project may also increase the isolation of the habitat occurring on the western side of the Nepean River from that occurring around the Colo River and the smaller creeks feeding into the Hawkesbury River.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
Competition with weeds and exotic species may impact the local population of *Z. involucrata*. Exotic plants such as Lantana and African Olive become established in disturbed areas quickly. Such plants can out-compete native

plants, especially seedlings and juveniles. If seedlings and juveniles are outcompeted, recruitment of new individuals into a population cannot take place.
• **introduce disease that may cause the species to decline, or**
The dispersal of *Phytophthora cinnamomi* can be mediated through water and through eroded soil. The Project has the potential to facilitate the spread of *Phytophthora cinnamomi* throughout the study area and therefore contribute to the EPBC listed key threatening process Dieback caused by the root-rot fungus (Phytophthora cinnamomi). An Approved Threat Abatement Plan has been developed for the threat of *Phytophthora cinnamomi* (DoEE 2018). The Project has been assessed as inconsistent with the Approved Threat Abatement Plan for *Phytophthora*.
• **interfere substantially with the recovery of the species.**
A National Recovery Plan has been developed for *Zieria involucrata - Zieria involucrata* Recovery Plan (DEC 2006). The recovery plan outlines the following 6 recovery objectives: 1. Conserve *Z. involucrata* using land use and conservation planning mechanisms 2. Implement a survey and monitoring program 3. Identify and minimise the threats operating at sites where the species occurs 4. Provide public authorities and the community with information that assists in conserving the species 5. Raise awareness of the species and involve the community in the recovery program 6. Promote investigations into the ecology and biology of the species in order to provide information to assist future management decisions The Project interferes with objectives 1 and 3. A targeted strategy for managing *Zieria involucrata* has been developed under the Saving Our Species Program. Under the Saving Our Species Program, *Z. involucrata* has been assigned to the ‘site-managed species’ management stream. The following priority management sites have been identified in the Saving Our Species program for *Z. involucrata*: • Yengo – Parr, in the Hawkesbury LGA. • Marramarra National Park in the Hornsby LGA. • Maroota Ridge in The Hills Shire LGA. • Blue Mountains in the Blue Mountains and Hawkesbury LGAs. The Project may impact the Yengo- Parr and Maroota Ridge priority management sites, and may not be consistent with the following management objectives: • Maintain appropriate fire regime. • Prevent weed invasion of the site.
Conclusion
The local population has been assessed as occurring within the study area from the individuals recorded during the surveys, from OEH records, and from the PCTs associated with its habitat. The Project has been assessed as potentially impacting the lifecycle of the important population such that it could be significantly impacted. The Project has been assessed as likely to have a significant impact on *Zieria involucrata*.

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Zieria murphyi (Velvet Zieria)

Vulnerable under the EPBC Act

Zieria murphyi is a small slender shrub 1 or 2 metres high, with velvety glabrescent scent branches (PlantNet 2019; BioNet 2019). It is closely related to Boronia with four petaled flowers and aromatic foliage (OEH 2019). The leaves typically have two forms 1-foliate or 3-foliate with the leaflets that are linear to oblong-lanceolate. The upper leaf surface is darker with simple hairs while the underside is grey-green with mainly stellate hairs giving it the velvety effect. The inflorescence is shorter than the leaves, typically containing 2-9 flowers, petals are 4-5.5 millimetres long with a white to pink colouration (PlantNet 2019; BioNet 2019; OEH 2019). This species flowers in spring, from September to November and fruit in summer (OEH 2019; PlantNet 2019; DOEE 2008). Zieria species are an obligate seeder where they are killed by fire and only regenerate from seed, any increase in fire is a potential threat (OEH 2019).

Zieria murphyi grows in dry sclerophyll eucalypt forests on sandy soils of sheltered positions, often below cliff lines, in the Blue Mountains at Mt Tomah and in the southern highlands. This species has been recorded in Morton National Park in the Bundanoon area, and at Penrose (PlantNet 2019; BioNet 2019). It is Associated species include *Eucalyptus stricta*, *Dillwynia sericea*, and *Lomandra longifolia* (DOEE 2008). Several populations of fewer than 1000 plants are known to occur in both the Blue Mountains and Morton National Parks (BioNet 2019; OEH 2019). The distribution of this species is not known to overlap with any EPBC Act-listed threatened ecological communities (DOEE 2008). There is a lack of knowledge providing uncertainty about the status and distribution of the population at all known locations (OEH 2019). Fire management for the habitat of this species is prescribed no more frequent than 10 years and no slashing or trittering or tree removal to occur (BioNet 2019). OEH (2019) and DECC (2005) advice is to monitor populations recovery following fire as well as mapping and surveying during the monitoring.

Targeted surveys for *Zieria murphyi* were not undertaken in the downstream, upstream or construction study areas for the Project. Additionally, *Zieria murphyi* was not incidentally encountered in the survey area during vegetation mapping associated with the Project.

In the absence of targeted surveys, *Zieria murphyi* has been assumed present in areas of presumed suitable habitat. For this assessment, suitable habitat for *Zieria murphyi* includes the PCTs that are associated with the species (as per the TBDC), BioNet Atlas Records and any other known vegetation types (as per scientific literature) that the species is associated with that has been mapped within the study area.

Suitable habitat includes the following PCTs, according to OEH's BioNet, that have been mapped within the upstream study area.

- PCT1246 (HN598) Sydney Peppermint - Grey Gum shrubby open forest of the western Blue Mountains Sydney Basin Bioregion
- PCT1083 (HN566) Red bloodwood - scribbly gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion

Zieria murphyi was not assessed to have a moderate or higher likelihood of occurring in the construction study area or the downstream study area. Although some of these PCTs also occur in the construction study area they are not considered likely to support a population of this species. As such, the potential for this species to be impacted by the Project in the construction study area or the downstream study area is not subject to this assessment.

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal*
- *populations that are necessary for maintaining genetic diversity, and/or*
- *populations that are near the limit of the species range.*

The Mt Tomah population is approximately 40 kilometres to the north of the construction and upstream areas. This known population is isolated from the Project study area although there is similar habitat and therefore using the known PCTs it is assumed an important population could be present.

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**
As *Zieria murphyi* has not been surveyed, areas of habitat have been used as a surrogate for the species occurrence. The Project could potentially impact up to 12.39 hectares within the 1% AEP flood extent and up to 2.60 hectares within the 20% AEP flood extent. Impact to this habitat has the potential to lead to a long-term decrease in the size of the important population.
• **reduce the area of occupancy of an important population**
The Project could potentially impact up to 12.39 hectares within the 1% AEP flood extent and up to 2.60 hectares within the 20% AEP flood extent.. Impacts to this habitat is expected to reduce the area of occupancy of the important population.
• **fragment an existing important population into two or more populations**
The habitat in the upstream and construction zones are contiguous with the native vegetation of the surrounding Blue Mountains National Park. The Project may lead to the direct removal of native vegetation and habitat in the eastern section of the Warragamba Gorge. This may fragment the *Zieria murphyi* habitat in the upstream and construction study areas. Consequential impacts caused by the Project such as promoting the spread and establishment of invasive flora species may also contribute to habitat fragmentation.
• **adversely affect habitat critical to the survival of a species**
The Minister maintains a 'Register of Critical Habitat' under the EPBC Act in which habitat as identified as being critical to the survival of a listed threatened species is provided. To date, no critical habitat is listed for this species that occurs within or proximal to the construction, upstream or downstream study areas.   Suitable habitat presumed to support an important population of *Zieria murphyi* has been assessed as habitat critical to the survival of the species. This habitat is important for dispersal, the long-term maintenance of the species and for maintaining genetic diversity. It is also important for maintaining ecological processes essential to the survival for the species. The Project may adversely affect this habitat through the direct removal of vegetation, increasing the presence of invasive species, erosion and deposition, and modifying hydrology and the fire regime. It is therefore expected that the Project may adversely affect habitat critical to the survival of *Zieria murphyi.*
• **disrupt the breeding cycle of an important population**
Spring flowering September to November fruit in summer (PlantNet 2019; OEH 2019). The Mt Tomah population starts flowering in late August, at this site, nectar-seeking beetles were observed effectively pollinating the blossoms, whilst at Bundanoon, nectar-seeking and pollen-feeding flies were the pollinators. The species is capable of setting fruit following self-pollination DOEE (2008). Any alterations to the inundation during this time is likely to have a significant effect on 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**
With about 22.24 hectares of *Zieria murphyi* habitat in the upstream study area, any habitat destroyed or directly impacted by clearing native vegetation, the loss of habitat for fauna and flora or a reduction in the extent of ecological communities will cause fragmentation. Altered soil conditions, edge effects, weed invasion and spread of disease pathogens may all cause a decline in the species.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
Competition with weeds and exotic species may impact the local population of *Zieria murphyi*. Exotic plants such as Lantana and African Olive become established in disturbed areas quickly. Such plants can out-compete native plants, especially seedlings and juveniles. If seedlings and juveniles are outcompeted, recruitment of new individuals into a population cannot take place.

• **introduce disease that may cause the species to decline, or**
The species is potentially susceptible to infection by the disease *Phytophthora cinnamomic* (OEH 2019). The dispersal of *Phytophthora cinnamomi* can be mediated through water and through eroded soil. The Project has the potential to facilitate the spread of *Phytophthora cinnamomi* throughout the study area and therefore contribute to the EPBC listed key threatening process Dieback caused by the root-rot fungus (*Phytophthora cinnamomi*). An Approved Threat Abatement Plan has been developed for the threat of *Phytophthora cinnamomi* (DoEE 2018). The Project has been assessed as inconsistent with the Approved Threat Abatement Plan for *Phytophthora*.
• **interfere substantially with the recovery of the species.**
No Approved National Recovery Plan has been developed for *Zieria murphyi*. The Approved Commonwealth Conservation Advice (DEWHA 2008) does however outline local and regional priority actions to assist in the recovery of the species. The priority actions are organised under the following management themes: • Habitat Loss, Disturbance and Modification • Fire • Conservation Information • Enable Recovery of Additional Sites and/or Populations The Project does not specifically interfere with any priority actions listed in the Approved Commonwealth Conservation Advice. SoS - Three priority management sites were identified in NSW (ordered north to south and including local government area (LGA)). They are: Mount Tomah in Blue Mountains, Morton National Park in Goulburn Mulwaree, and Monkey Gum in the Shoalhaven. This list does not necessarily encompass all actions that may be of benefit to *Z. murphyi*, but highlights those that are of highest priority at the time of preparing the conservation advice. Existing Plans/Management Prescriptions that are Relevant to the Species: • Blue Mountains National Park Plan of Management (NSW NPWS 2001a), • Final Fire Management Strategy Blue Mountains National Park (NSW NPWS 2004), • Blue Mountains Region Draft Pest Management Strategy (NSW NPWS 2007), and • Morton National Park, Budawang National Park Plan of Management (NSW NPWS 2001b).
Conclusion
The Project could potentially impact *Zieria murphyi* habitat occurring in the upstream and construction areas. This may fragment, possibly isolate or modify the quality of habitat through inappropriate changes in fire regime due to the alteration of hydrology or changes in invasive flora species. These impacts could cause a decline of an important population of *Zieria murphyi*. The Project has been assessed as likely to have a significant impact on *Zieria murphyi.*

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Threatened fauna species

Anthochaera phrygia (Regent Honeyeater)

Critically Endangered under the EPBC Act

The Regent Honeyeater inhabits dry open forest and temperate woodland particularly Box-Ironbark woodland and riparian forests of River Sheoak (*Casuarina cunninghamiana*) at scattered locations in south-eastern and eastern Australia (Higgins *et al.* 2001). Key tree species include Mugga Ironbark (*Eucalyptus sideroxylon*), Yellow Box (*Eucalyptus melliodora*), White Box (*Eucalyptus albens*), Broad-leaved Apple (*Angophora floribunda*) Swamp Mahogany (*Eucalyptus robusta*) and Spotted Gum (*Corymbia maculata*). The Regent Honeyeater has undergone a substantial, long-term decline and the total population currently comprises approximately 350-400 individuals (DoE 2016). Within the Regent Honeyeater's current distribution there are less than five key breeding areas (DoE 2016 Crates *et al.* 2018). The loss, fragmentation and degradation of breeding and foraging habitat for agriculture and residential development is the Regent Honeyeater's main threat. The loss of the majority of fertile Yellow Box-White Box-Blakely's Red Gum Woodlands in south-eastern Australia has been particularly detrimental for this species (DoE 2016). Competition with the Noisy Miner (*Manorina melanocephala*) is another key threat whilst breeding and foraging.

Upstream and construction study areas

The Regent Honeyeater was formerly a widespread and relatively common species in the Burragorang Valley and greater region. Historically, the fertile valley floors and lower slopes of the Burragorang Valley region provided extensive suitable breeding and foraging habitat. Much of this habitat in Burragorang Valley and throughout the rest of the Regent Honeyeater's range was lost due to vegetation clearance following European colonisation. The vast majority of remaining suitable habitat in the Burragorang Valley was then flooded as a result of the construction of the Warragamba Dam in 1960.

Large sections of suitable habitat in the Warragamba Special Area have not been surveyed for Regent Honeyeater since the construction of Warragamba Dam. Hence, the Regent Honeyeater's distribution and abundance around the majority of Lake Burragorang and nearby valleys has remained poorly understood. Surveys during the past three decades have been focussed on the southern Burragorang Valley and have indicated that this species 'visits the Warragamba Special Area mostly in winter, when preferred Eucalypt species are in flower' (DECC 2007), however SMEC's findings from surveys undertaken in November 2017 indicate that this rarely surveyed area supports a significant breeding population.

The Regent Honeyeater had been recorded at 27 locations in the Warragamba Special Area as of 2007. The number of individuals counted annually varied between nil and 250 individuals (DECC 2007). Notable observations in the 1% AEP flood extent in the upstream study area prior to SMEC's 2017 survey include a record of four individuals including juveniles on the Nattai River in November 1989, four individuals on the western shore of Lake Burragorang in December 2000, four individuals on the south-eastern shore of Lake Burragorang in October 1991 and six individuals at the same location in October 2002. A record of 25 Regent Honeyeater beside the Wollondilly River in May 2006 represents the highest count of Regent Honeyeater between the Full Supply Level (FSL) and the upstream study area boundary. Notable observations from adjacent to the impact area include a record of 57 individuals in July 1997 and a record of 26 individuals in May 2001 in a patch of White Box (*E. albens*) in the Burragorang Valley.

SMEC conducted targeted Regent Honeyeater surveys in the Burragorang Valley during 20-24 and 28-30 November 2017 using an approach developed by researchers at the Australian National University (ANU) to monitor Regent Honeyeater in the Capertee Valley, Goulburn River region, Hunter Valley and Northern Tablelands of NSW. During the 2017 surveys, 21-25 individuals were detected in the upstream study area, the majority of which were breeding adults, recently fledged dependent young or nestlings. The Regent Honeyeater has subsequently been recorded during species monitoring surveys in 2018 and 2020.

The 2019-2020 Burragorang Valley fires affected an estimated 4,525 hectares of habitat for the Regent Honeyeater in the study area. Burnt habitat included the area where breeding activity of Regent Honeyeaters was observed in 2017. In this area, the majority of vegetation has sustained 'high' or 'extreme' damage. It is likely that breeding in this area will not occur again until the vegetation has recovered. The species is also included on a list of animals requiring urgent management intervention as a result of these fires due to the extent of habitat loss, extinction risk and vulnerability to fire (Wildlife and Threatened Species Bushfire Recovery Expert Panel 2020).

Downstream study area

The Regent Honeyeater was once a widespread and relatively common species on the Cumberland Plain. However, it has since declined considerably and is now rarely recorded in the downstream study area or elsewhere on the Cumberland Plain. The most recent records of this species in the downstream study area were in 1982 and 1983 (Pitt Town Bottoms) and 1985 (near Wallacia). Recent records from the region include three individuals at Agnes Bank Nature Reserve in 1998, seven at Castlereagh Nature Reserve in 2009 and eight at Windsor Downs Nature Reserve in 2010. In addition, two breeding events were recorded within one kilometre of the study area during the 2019-2020 breeding season, thought to be related to prolific blossom east of the Blue Mountains. This breeding event resulted three fledged juveniles; one juvenile fledged from the Mulgoa area, and two fledged from around the South Maroota area (R. Crates, pers comm). No targeted Regent Honeyeater surveys were conducted in the downstream study area by SMEC.

For this assessment, it was assumed that the Regent Honeyeater could occur in any suitable habitat that occurs within the upstream and construction study areas. Downstream potential habitat is limited to suitable PCTs within a five kilometre radius of records, as per the downstream BAR methodology. Suitable habitat includes areas that have been mapped as the following PCTs:

- 724: Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain Sydney Basin Bioregion
- 725: Broad-leaved Ironbark - *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain Sydney Basin Bioregion
- 830: Forest Red Gum - Grey Box shrubby woodland on shale of the southern Cumberland Plain Sydney Basin Bioregion
- 835: Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain Sydney Basin Bioregion
- 849: Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain Sydney Basin Bioregion
- 850: Grey Box - Forest Red Gum grassy woodland on shale of the southern Cumberland Plain Sydney Basin Bioregion
- 877: Grey Myrtle dry rainforest of the Sydney Basin Bioregion and South East Corner Bioregion
- 883: Hard-leaved Scribbly Gum - Parramatta Red Gum heathy woodland of the Cumberland Plain Sydney Basin Bioregion
- 924: *Melaleuca linariifolia* alluvial melaleuca thicket of the lower Blue Mountains and Capertee Valley Sydney Basin Bioregion
- 958: Narrow-leaved Apple - Hard-leaved Scribbly Gum heathy woodland on sand at Agnes Banks Sydney Basin Bioregion
- 1395: Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain Sydney Basin Bioregion
- 1067: Parramatta Red Gum woodland on moist alluvium of the Cumberland Plain Sydney Basin Bioregion
- 1081: Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion
- 1106: River Oak riparian woodland of the NSW North Coast Bioregion and northern Sydney Basin Bioregion
- 1557: Rough-barked Apple - Forest Oak - Grey Gum grassy woodland on sandstone ranges of the Sydney Basin
- 1385: Rough-barked Apple - Grey Gum grassy open forest of the hinterland hills of the Central Coast Sydney Basin Bioregion
- 1181: Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney Basin Bioregion
- 1183: Smooth-barked Apple - Sydney Peppermint - Turpentine heathy open forest on plateaux areas of the Sydney Basin Bioregion
- 1718: Swamp Mahogany - Flax-leaved Paperbark swamp forest on coastal lowlands of the Central Coast
- 1284: Turpentine - Smooth-barked Apple moist shrubby forest of the lower Blue Mountains Sydney Basin Bioregion
- 832: Forest Red Gum - Narrow-leaved Ironbark open forest of the southern Blue Mountains gorges Sydney Basin Bioregion (BVT: HN525)

- 840: Forest Red Gum - Yellow Box woodland of dry gorge slopes southern Sydney Basin Bioregion and South Eastern Highlands Bioregion (BVT: HN527)
- 860: Grey Gum - Broad-leaved Ironbark dry open forest on gorge slopes on the Blue Mountains Sydney Basin Bioregion (BVT: HN532)
- 862: Grey Gum - Hard Leaved Scribbly Gum woodland of the Cox River Valley (BVT: HN533)
- 870: Grey Gum - Thin-leaved Stringybark grassy woodland of the southern Blue Mountain gorges Sydney Basin Bioregion (BVT: HN535)
- 871: Grey Gum shrubby open forest on gorge slopes of the Blue Mountains Sydney Basin Bioregion (BVT: HN536)
- 875: Grey Myrtle - Lilly Pilly dry rainforest in dry gullies of the Sydney Basin Bioregion and South East Corner Bioregion (BVT: HN537)
- 941: Mountain Blue Gum - Thin-leaved Stringybark open forest on river flat alluvium in the Sydney Basin Bioregion (BVT: HN553)
- 1401: Narrow-leaved Ironbark - Forest Red Gum on rocky slopes of the lower Burragorang Gorge Sydney Basin Bioregion (BVT: HN557)
- 1083: Red bloodwood - scribbly gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion (BVT: HN566)
- 1086: Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains Sydney Basin Bioregion (BVT: HN568)
- 1105: River Oak open forest of major streams Sydney Basin Bioregion and South East Corner Bioregion (BVT: HN574)
- 1246: Sydney Peppermint - Grey Gum shrubby open forest of the western Blue Mountains Sydney Basin Bioregion (BVT: HN598)
- 1281: Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains Sydney Basin Bioregion (BVT: HN604).

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 of a population**
A review of the Conservation Advice (Department of the Environment 2015), Species Profile and Threats Database, Threat abatement plans and National Recovery plans has identified different potential impacts to the Regent Honeyeater between the upstream and construction area to the downstream area. UPSTREAM and CONSTRUCTION The Project has significant potential to lead to a long-term decrease in the size of a Regent Honeyeater population. A substantial breeding population that is present in the Burragorang Valley could be adversely impacted through inundation of critical breeding habitat. The population that could be directly impacted by the Project comprises a minimum of 21-25 individuals. This includes the number of adult and juvenile birds detected during targeted Regent Honeyeater surveys conducted in November 2017 (21), and the number of nestlings observed at two nests at the time of surveys (4), assuming each fledged successfully. This figure represents 5 to 7 % of the estimated global population of the Regent Honeyeater (DoE 2016, Kvistad *et al.* 2015) and this breeding population represents one of less than five remaining breeding populations known to currently support at least 20 individuals (DoE 2016, Crates *et al.* 2018). There is potential for the number of individuals occupying the upstream and construction study areas to be higher than 21-25 individuals noted given: ▪ the relatively low spatial and temporal survey coverage of the upstream and construction study areas during targeted Regent Honeyeater surveys in November 2017 ▪ the extent of mapped potential or likely breeding habitat in the unsurveyed areas of the upstream and construction study area ▪ the presence of records of up to 50 individuals during the non-breeding season in the past 20 years in the Burragorang Valley (OEH 2018) and a past breeding record in the impact area on the Nattai River (OEH 2018). On the other hand, recent fires have reduced the availability of habitat within the upstream study area by an estimated 94%. Given the species' reliance on the probability of individual trees flowering the remaining six percent of the habitat may not support any Regent Honeyeaters because flowering events would become rare and lack seasonal continuity. Flower availability may return to pre-fire levels in one to three years for many Eucalypt species (Law *et al.* 2000), suggesting food supply may not limit the species after a few years. However, the fire response may be influenced by vegetation structure, which may recover on longer timeframes. Moreover, altered vegetation may be prone to colonisation by Noisy Miners, a listed KTP known to threaten the Regent Honeyeater. If they become established in the short-term it may be possible for them to persist in the longer-term, preventing re-establishment by the Regent Honeyeater. While this is useful background, it does not constitute a project impact. The significance assessment assumes that recolonization by the Regent Honeyeater does occur. The size of the population that could be indirectly impacted is difficult to estimate. There is evidence from colour banding studies that the remaining greater Blue Mountains population of Regent Honeyeaters functions as a metapopulation (R. Crates, unpublished data). However, due to a lack of colour-banding and monitoring of Regent Honeyeaters in the Burragorang Valley, the extent to which individuals move between the Burragorang Valley and other regional sites is unknown. Assuming that the Burragorang Valley forms a component of the Greater Blue Mountains metapopulation, which is reasonable, it is estimated that the local population that could be indirectly impacted by the Project could range from 21 to 200 individuals (that is, corresponding to about 5-50% of the global population). The Regent Honeyeater population is likely to be adversely impacted by the loss and degradation of breeding and foraging habitat as the majority of suitable breeding habitat in the Warragamba Special Area is located in the impact area. This is discussed further in response to criteria b, d, e and f below. Due to the reasons outlined in this assessment the Project is highly likely to result in a long-term decline of a substantial breeding population of Regent Honeyeater. Given that a high proportion of suitable breeding available in the Warragamba Special Area is located in the impact area it is reasonable to consider that the Project could result in the loss of the entire local breeding population. This breeding location likely plays a critical role in the survival of the Regent Honeyeater in the wild. A severe decline or the extinction of a breeding population of this size would constitute a significant adverse impact on the Regent Honeyeater.

DOWNSTREAM

Very few Regent Honeyeaters have been recorded in the downstream study area during the past two decades. However, we note that some recent records have been obtained in this area, suggesting that foraging and breeding are likely to occur at least in some years. The annual frequency of use will depend on the availability of foraging resources and the presence of pest species (e.g. Noisy Miners) in relation to their availability and presence in other parts of their range.

Potential downstream impacts due to the Project would potentially arise due to a decrease in the frequency and/or extent of flooding. However, Regent Honeyeater foraging habitat (drier Eucalypt forest and woodland) is not dependent on flooding regimes to persist. Thus, minimal effects on the Regent Honeyeater's habitat are expected downstream. Given the nature of the predicted impact of the Project, it is unlikely that it would lead to a long-term decrease of a Regent Honeyeater population..

- **reduce the area of occupancy of the species**

UPSTREAM and CONSTRUCTION

Loss or degradation of breeding and foraging habitat within the Burragorang Valley is likely to considerably reduce the area of occupancy of the Regent Honeyeater at the local scale and potentially at the regional or larger scale.

Given that this breeding population represents the southernmost breeding population in NSW and one of less than five remaining breeding populations known to support at least 20 individuals (DoE 2016) the loss of this population would represent a major reduction in the species' entire area of occupancy.

The Regent Honeyeater's area of occupancy around Lake Burragorang may be reduced by up to an estimated 4,806 hectares as a result of the Project given the extent of known or potential breeding and foraging habitat present in the impact area (see response to criterion f). Further targeted Regent Honeyeater surveys during the breeding and non-breeding seasons would be required to gain a better understanding of their area of occupancy throughout the impact area.

DOWNSTREAM

The Project is unlikely to reduce the area of occupancy of a Regent Honeyeater population given that very few individuals have been recorded in the study area during the past two decades.

- **fragment an existing population into two or more populations**

UPSTREAM and CONSTRUCTION

Whilst Regent Honeyeaters are known to exhibit a degree of breeding site fidelity when conditions allow (Geering and French 1998), the species is highly mobile and depends on a network of breeding habitat patches that they exploit irregularly in space and time (DoE 2016). Due to their high mobility it is unlikely that the Project will result in an existing population fragmenting into two or more populations.

However, the likely loss and degradation of breeding habitat situated adjacent to Lake Burragorang as a result of inundation may considerably fragment the areas of remaining breeding habitat available in the Burragorang Valley which may have flow on effects on the total breeding output of this population.

DOWNSTREAM

The Project is unlikely to fragment an existing Regent Honeyeater population into two or more populations given that no suitable habitat is likely to degraded or lost as a result of the reduction of the flow regime of the Hawkesbury-Nepean River.

- **adversely affect habitat critical to the survival of a species**

UPSTREAM and CONSTRUCTION

The Project is likely to adversely affect habitat critical to the survival of the Regent Honeyeater.

Habitat critical to the survival of the Regent Honeyeater includes any breeding or foraging areas where the species is likely to occur and any newly discovered breeding or foraging locations (DoE 2016). Hence, suitable habitat present in the Burragorang Valley constitutes habitat critical to the survival of the species.

The Regent Honeyeater specialises on tree species that grow in low-lying areas when breeding (Geering and French 1998, Oliver *et al.* 1998, DoE 2016, Crates *et al.* 2017a). The majority of suitable breeding habitat in the

Burragorang Valley is located within the impact area close to the edge of Lake Burragorang or along tributaries. Such areas would be subject to periodic inundation resulting in the loss or degradation of suitable breeding habitat. Even highly infrequent inundation is likely to alter habitat characteristics (that is, vegetation structure and species composition) such that it must be assumed that these areas would not be suitable for Regent Honeyeater.

Considering that the local population likely forms an important component of the Greater Blue Mountains metapopulation, the cessation of successful breeding events in the Burragorang Valley may have significant implications for the Regent Honeyeater overall. The survival of the Regent Honeyeater population is dependent on the long-term viability of the few remaining breeding areas throughout their range due to the high degree of spatial and temporal variation in key breeding resources such as flowering of key Eucalyptus species (DoE 2016). Importantly, in any given year, only one or two key breeding areas may provide conditions suitable for breeding. Hence, the reduction in size or loss of a critical breeding area such as the Burragorang Valley is likely to have a significant adverse impact on the global Regent Honeyeater population.

The Burragorang Valley is unique in that it contains breeding habitat where:

a) the Noisy Miner, a key competitor, is scarce and in many areas apparently absent. It is noted that Noisy Miner were not recorded at any of locations where Regent Honeyeater were recorded breeding in November 2017. This is significant because the majority of breeding habitat elsewhere in the Regent Honeyeater's range is occupied by Noisy Miner.
b) No habitat clearance has occurred for half a century and ongoing or future habitat clearance is not a major threat. Elsewhere in this species' range breeding habitat is subject to ongoing degradation and loss and threatened by further habitat clearance. Due to the restrictions imposed on the Warragamba Special Zone it is likely that the breeding habitat present will continue to improve through time in the absence of such threats (barring the risk of inundation associated with the Project).

Inundation of suitable habitat in the Burragorang Valley will likely constitute an adverse impact on habitat critical to the survival of, and possibly essential to, any future recovery of the Regent Honeyeater's wild population.

DOWNSTREAM

No habitat critical to the survival of the Regent Honeyeater is likely to be present in the impact area.

- **disrupt the breeding cycle of a population**

UPSTREAM and CONSTRUCTION

The Project is very likely to seriously disrupt each component of the breeding cycle of a population of Regent Honeyeater.

Each active Regent Honeyeater nest detected in November 2017 was located in the impact area. Loss or degradation of habitat in such areas is likely to significantly reduce nesting success through the loss of known nest trees and critical foraging resources required by breeding pairs. Importantly, it is likely that the majority of breeding attempts in the Burragorang Valley and surrounding region are initiated in the impact area as this area largely mirrors or corresponds to the distribution of the highest quality breeding habitat in the Warragamba Special Area. There is indirect evidence that survival and breeding success of Regent Honeyeaters declines with decreasing flock size (Crates *et al.* 2017 b). Thus, any reduction in breeding output or local population size brought about by the Project is likely to create positive feedbacks to further reduce survival and breeding success of the remaining population.

DOWNSTREAM

The Project is unlikely to disrupt the breeding cycle of Regent Honeyeater given that:

- very few individuals have been recorded in the study area during the past two decades
- no suitable habitat is likely to be adversely impacted by the Project.

- **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**

UPSTREAM and CONSTRUCTION

The Project may modify, destroy, remove and decrease the availability and quality of Regent Honeyeater breeding habitat to the extent that the species is likely to decline. The estimated spatial extent of Regent Honeyeater habitat present in the upstream study area is presented in Table 1.

About 760 hectares of breeding habitat known to support a breeding population of at least 21-25 individuals is subject to inundation during a 1% AEP flood event, and which is expected to render such areas unsuitable for breeding Regent Honeyeater. An estimated 1,489 hectares of potential breeding habitat is located below the 1% AEP level. Overall, a total of approximately 2,663 hectares of known or potential breeding habitat may be adversely impacted in the event of a 1% AEP flood.

Table 1. Spatial extent of Regent Honeyeater habitat present in the impact area.

	Area (ha) FSL - 1% AEP	Area (ha) FSL – US study area boundary
A	761	1,620
B	1,489	2,999
C	2,662	5,280

Descriptions of the rows labelled 'A', 'B' and 'C' are as follows:

A: the spatial extent of confirmed breeding habitat in the Burragorang Valley.

This comprises the spatial extent of the five PCTs in the Burragorang Valley in which Regent Honeyeaters were observed breeding beside Lake Burragorang during November 2017.

This area is bound to the north-east by a west-east aligned vector positioned across the Burragorang Valley connecting a point at UTM 56 (256655E, 6222353N) to a point at (258807E, 6222312N) and bound elsewhere in the Burragorang Valley by either the 1% Annual Exceedance Probability (AEP) level or the upstream study area boundary.

B: the spatial extent of confirmed and potential breeding habitat.

This comprises areas of confirmed breeding habitat (detailed above) plus potential breeding habitat (727 hectares) located elsewhere around Lake Burragorang. This potential breeding habitat comprises unsurveyed areas which contain the same PCTs that Regent Honeyeaters were recorded breeding in during November 2017.

C: the spatial extent of confirmed and potential breeding and foraging habitat. This comprises the spatial extent of confirmed and potential breeding habitat (as described above) plus the spatial extent of PCTS that Regent Honeyeater are known to occur in (as per the list of associated PCTs on the NSW OEH Regent Honeyeater profile page).

The Regent Honeyeater is highly likely to decline as a result of the modification, destruction, removal, isolation or decline in the availability and quality of the habitat in the Burragorang Valley. The decline or loss of a breeding population of the size of the Burragorang Valley population, irrespective of the degree of connectivity with the Greater Blue Mountains metapopulation size, would have serious ramifications for the entire Regent Honeyeater's entire population.

DOWNSTREAM

An estimated 8,418 hectares of suitable or potential breeding and/or foraging habitat is present in the study area, of which an estimated 723 hectares is located in the impact area. The Project is unlikely to modify, destroy, remove or isolate or decrease habitat availability or quality to the extent that the Regent Honeyeater is likely to decline because:

- the Regent Honeyeater is a very rare visitor in the study area and is unlikely to breed in the impact area following this species' significant decline on the Cumberland Plain.
- Habitat in the impact area is unlikely to become degraded as a result of the Project.

- **result in invasive species that are harmful to an endangered or critically endangered species becoming established in the endangered or critically endangered species' habitat**

UPSTREAM and CONSTRUCTION

Project impacts in the upstream study area is likely to result in alterations to the vegetation, including the creation of new edges and the thinning of vegetative cover. Impacts in the construction area are also likely to result in the creation of new habitat edges. Noisy Miners are known to become established or to increase their dominance along habitat edges and in areas with reduced canopy cover and for these reasons are a KTP listed under the EPBC Act. More particularly, they are known to impact on habitat use and breeding success of the Regent Honeyeater (Crates

et al. 2018). Therefore, the Project is unlikely to result in the introduction invasive species that are harmful to the Regent Honeyeater becoming established in Regent Honeyeater habitat.. DOWNSTREAM The Project is not likely to alter the Regent Honeyeaters habitat downstream. Therefore, it is unlikely to result in the introduction of invasive species that are harmful to the Regent Honeyeater becoming established in Regent Honeyeater habitat.
• **introduce disease that may cause the species to decline**
UPSTREAM and CONSTRUCTION The Project is unlikely to introduce disease that may cause the Regent Honeyeater to decline. DOWNSTREAM The Project is unlikely to introduce disease that may cause the Regent Honeyeater to decline.
• **interfere substantially with the recovery of the species**
A National Recovery Plan has been prepared for the Regent Honeyeater (DoE 2016), which identifies threats, populations under particular pressure and objectives and strategies to assist in the recovery of this species. UPSTREAM and CONSTRUCTION The Project is likely to substantially interfere with the recovery of the species given that: • the proposed action constitutes a key threat, namely the loss of critical habitat. • the proposed action breaches one the chief Regent Honeyeater recovery plan objectives namely, ‘enhancement of the condition of habitat across the regent honeyeaters range to maximise survival and reproductive success and provide refugia during periods of extreme environmental fluctuation’. (DoE 2016) • the impact area supports a substantial breeding population of Regent Honeyeater and represents one of less than five remaining breeding populations known to support at least 20 individuals • habitat impacts may favour the presence and/or abundance of the Noisy Miner, a known pest species • as detailed in response to criterion d, the breeding habitat in the Burragorang Valley generally lacks certain threats that are highly influential in other key breeding areas. Hence, the Burragorang Valley is likely a crucial location for the recovery of the Regent Honeyeater. Furthermore, the Project is likely to interfere with the following recovery actions which have been specifically recommended for the Regent Honeyeater in the Warragamba Special Area (DECC 2007): • The protection and enhancement of Grassy Box Woodlands, particularly in the Burragorang and Wollondilly Valleys. • Any sites containing suitable winter-flowering Eucalypts (identified in the habitat model), particularly those known to have been utilised by Regent Honeyeaters in the past, should be protected from disturbance, including felling and hot fires. • Replanting and regeneration of appropriate feed trees is recommended for the most important area, the Burragorang Valley. • Retaining or restoring connectivity between remnants of habitat is probably important for this species. Particularly important may be the Wollondilly Linkage of grassy woodland that runs south along the Wollondilly River. The Project would not be consistent with several Regent Honeyeater recovery actions and is likely to substantially interfere with the recovery of the species. DOWNSTREAM The Project is unlikely to substantially interfere with the recovery of the species given that: • Very few individuals have been recorded in the study area during the past two decades • No suitable habitat is likely to be adversely impacted by the Project.

Conclusion
UPSTREAM and CONSTRUCTION The Project is likely to have a significant impact on the Regent Honeyeater upstream of the Warragamba Dam. DOWNSTREAM The Project is unlikely to have a significant impact on the Regent Honeyeater downstream of the Warragamba Dam.

References

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Botaurus poiciloptilus (Australasian Bittern)

Endangered under the EPBC Act

The Australasian Bittern is listed as endangered under both the EPBC Act and the BC Act. It inhabits permanent freshwater wetlands which support a dense cover of reeds, rushes, sedges and/or rice in south-east and south-west Australia (Marchant and Higgins 1990). The Australasian Bittern has declined markedly since the mid-20th century. The Australian population was estimated to consist of 250 – 800 individuals in 2010 (DSEWPaC 2011). The Australasian Bittern's key threat is the loss and degradation of wetlands as a result of drainage, overgrazing and salinization. In eastern Australia, cessation of floodplain inundation due to water harvesting and alteration of drainage systems has destroyed much of the Australasian Bittern's seasonal habitat (Jaensch 2004).

The Australasian Bittern is an occasional/rare visitor in the downstream study area. Most records are of single birds or pairs at wetlands on the Hawkesbury-Nepean River floodplain in the Richmond/Windsor area. The Australasian Bittern has been recorded at Pitt Town Lagoon (50+ records of single birds or pairs during the past 30 years), Longneck Lagoon (2012), McGraths Hill STP (2003 2013), Little Wheeney Lagoon (2008), Leets Vale (2005), Penrith Lakes (1985), Bushells Lagoon (1981 1992), Bakers Lagoon (1981). No breeding has been documented in the study area. No Australasian Bitterns were detected during surveys conducted by SMEC at wetlands on the Colo River in 2018. No targeted Australasian Bittern surveys were conducted by SMEC at wetlands in the Richmond/Windsor area.

Assessing the impact of the Project on the Australasian Bittern and the estimated 1,486 hectares of suitable habitat located in the impact area is difficult given the Australasian Bittern is threatened by the damming of rivers, diversion of water and drainage of wetlands in Australia though the sensitivity of this species to past anthropogenic changes to the flow regime of the Hawkesbury-Nepean River has not been studied and is hence, largely unknown. Negative impacts associated with reduced flow area are likely (Garnet and Crowley 2000) however the degree to which the habitat condition of key sites such as Pitt Town Lagoon depends on upstream flows (as opposed to purely local rainfall) is poorly understood and requires detailed examination. The magnitude, frequency and duration of potential environmental flow releases is unknown.

The Australasian Bittern is associated with the following PCTs mapped in the downstream study area:

- 1106: River Oak riparian woodland of the NSW North Coast Bioregion and northern Sydney Basin Bioregion
- 835: Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain Sydney Basin Bioregion
- 781: Coastal freshwater lagoons of the Sydney Basin Bioregion and South East Corner Bioregion.

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 of a population**
While up to about 160 hectares of suitable habitat could be impacted by the Project, this is unlikely to lead to a long-term decrease of a population of Australasian Bittern given that: • the Australasian Bittern is an occasional, non-breeding visitor in low numbers in the study area • suitable habitat at the key sites in the study area such as Pitt Town Lagoon is unlikely to be negatively impacted to the point that such sites become unsuitable for Australasian Bittern.
• **reduce the area of occupancy of the species**
The Project is unlikely to reduce the area of occupancy of the Australasian Bittern as sites such as Pitt Town Lagoon are likely to continue to provide suitable habitat for this species despite changes to the Hawkesbury-Nepean River's flood regime as a result of the Project.
• **fragment an existing population into two or more populations**
The Project is unlikely to fragment an existing Australasian Bittern population into two or more populations given the high mobility of this species.

• adversely affect habitat critical to the survival of a species
Habitat critical to the survival of the Australasian Bittern has been identified in the draft recovery plan for the species. It includes: • any wetland habitat where the species is known or likely to occur (breeding or foraging habitat) within the indicative distribution map (Figure 1 of the draft recovery plan); and • any location with suitable habitat outside the above area that may be periodically occupied by Australasian Bittern' (DoEE 2019). No habitat critical to the survival of the Australasian Bittern has been identified in the study area given that the species is an occasional, non-breeding visitor.
• disrupt the breeding cycle of a population
The Project is unlikely to disrupt the breeding cycle of a population of Australasian Bittern. Pitt Town Lagoon supports potential breeding habitat; however, no breeding events have been documented at this location.
• modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline
An estimated 1,486 hectares of suitable or potential habitat is located in the study area of which about 160 hectares is located in the changed 10% AEP flood extent. A reduction in the magnitude, frequency and duration of flood events may negatively impact suitable Australasian Bittern habitat at wetlands and lagoons in the Richmond/Windsor/Pitt Town area. Changes to the frequency of inundation of suitable habitat could lead to temporary, prolonged or permanent reductions in the extent of dense reeds and other thick aquatic vegetation (that is, key components of Australasian Bittern habitat). It is possible that certain areas of wetland on the edge of the floodplain will be significantly impacted, specifically areas that are only occasionally inundated under the current flood regime, but are likely to receive flows far less frequently as a result of the Project. Such areas may dry more frequently which could lead to the temporary or permanent loss of important wetland features such as sedges and rushes. The Project is unlikely to modify, destroy, remove or isolate or decrease habitat availability or quality to the extent that the Australasian Bittern is likely to decline because: • the Australasian Bittern is an occasional, non-breeding visitor in low numbers in the study area and, • suitable habitat at sites such as Pitt Town Lagoon is unlikely to be impacted to the point that such sites become unsuitable for Australasian Bittern.
• result in invasive species that are harmful to an endangered or critically endangered species becoming established in the endangered or critically endangered species' habitat
The Project is unlikely to result in invasive species that are harmful to the Australasian Bittern becoming established in Australasian Bittern habitat. Introduced predators that may pose a risk to the Australasian Bittern such as European Red Fox and Feral Cat are currently present in the study area.
• introduce disease that may cause the species to decline
The Project is unlikely to introduce disease that may cause the Australasian Bittern to decline.
• interfere substantially with the recovery of the species
A Draft National Recovery Plan has been prepared for the Australasian Bittern (*Botaurus poiciloptilus*). The Plan identifies threats to the species, the distributions in Australia, critical habitat to the survival of the Australasian Bittern and populations under particular pressure. The Project may result in the loss and degradation of wetland habitat, a key threat to this species, though this is not expected to interfere substantially with the recovery of the Australasian Bittern as it is an occasional non-breeding visitor in the study area.

Conclusion
Although suitable habitat is likely to be impacted by the alteration of the Hawkesbury-Nepean River flow regime, the Project is unlikely to have a significant impact on the Australasian Bittern.

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Calidris ferruginea (Curlew Sandpiper)

Critically Endangered and Migratory under the EPBC Act

The Curlew Sandpiper is listed as migratory under the EPBC Act 1999 and has large non-breeding area distributions which encompass large parts of coastal, near-coastal and/or inland Australia. The Curlew Sandpiper is also listed as critically endangered under the EPBC Act 1999 and endangered under the BC Act 2016. This shorebird species has been recorded either regularly, occasionally or rarely in the vicinity of lagoons and wetlands on the Hawkesbury-Nepean River floodplain in the Richmond/Windsor/Pitt Town/Wilberforce area. Bushells Lagoon, Bakers Lagoon and Pitt Town Lagoon provide the highest quality foraging habitat for this species in the study area and the broader north-west Sydney region. This shorebird faces threats in its breeding range in the Northern Hemisphere, along their migration pathway, the East Asian-Australasian Flyway (EAAF), which spans 23 countries, and in their foraging habitat and roosting sites in Australia. Threats to this shorebird includes habitat loss and degradation at staging areas in East Asia through land reclamation and other factors (Murray *et al.* 2014, Piersma *et al.* 2016), hunting in East Asia, disturbance and habitat degradation in their non-breeding habitat (that is, from recreational activities such as fishing, boating, walking dogs, night lighting) (Priest *et al.* 2002, Glover *et al.* 2011), and global warming (Wauchope *et al.* 2016). No targeted Curlew Sandpiper surveys were conducted in the study area by SMEC.

'Coastal freshwater lagoons of the Sydney Basin Bioregion and South East Corner Bioregion' (PCT781) is the only associated habitat mapped in the study area. An estimated 380 hectares of this PCT mapped downstream is considered to be suitable habitat for the Curlew Sandpiper based on the presence of records, with seven hectares of this to be impacted. There is likely significantly more appropriate habitat within the study area, but impacted area is difficult to calculate in this circumstance as not all area within a 'forested wetland' is appropriate wetland habitat. Assessing the impact of the Project on these shorebird species and the large area of suitable habitat located in the impact area is difficult given:

- The sensitivity of this species to a reduction in flows in the Hawkesbury-Nepean River is largely unknown. This is partly because the degree to which habitat condition at key sites (for example, Pitt Town Lagoon, Bakers Lagoon, Bushells Lagoon) relies on upstream flows (as opposed to local rainfall) during flood events to is not well understood. However, it is likely that given their preference for shallow water and exposed mudbanks, this species may be less vulnerable to reductions in flows to key lagoons than other waterbirds. Indeed, a reduction in flows in the Hawkesbury-Nepean River may enhance the habitat quality of certain wetlands in the impact area such as Pitt Town Lagoon (Pressey 1979) whilst potentially reducing the quality of others depending on the physical nature (that is, factors such as depth, shape, extent, proximity to the Hawkesbury-Nepean River) of individual wetlands.
- The magnitude, frequency and duration of potential environmental flow releases post-development is unknown.

The Curlew Sandpiper occurs at a range of inland wetlands and sheltered coastal habitat types. It typically occurs on intertidal mudflats in sheltered coastal areas, such as estuaries, bays, inlets and lagoons, and also around non-tidal swamps, lakes and lagoons near the coast, and ponds in saltworks and sewage farms (Higgins and Davies 1996). The Curlew Sandpiper's EAAF population is estimated to comprise 90,000 individuals and is in steep decline (Department of Environment 2015, Hansen *et al.* 2016). This species also occasionally utilises inland ephemeral and permanent lakes, dams and bore drains. The Curlew Sandpiper is an occasional visitor (October – February) in the study area which has been recorded most often at Pitt Town Lagoon but also infrequently observed at nearby wetlands and lagoons such as Bushells Lagoon and Bakers Lagoon. Notable observations include 20 at McGraths Hill in 1982 and 12 at Pitt Town Lagoon in 2002.

Important shorebird habitat and ecologically significant proportions of shorebird populations

The number of individual birds that corresponds to an ecologically significant proportion (0.1%) of the total population in accordance with the latest population estimates (Hansen *et al.* 2016) is as follows: Curlew Sandpiper (90).

Shorebird habitat for migratory shorebirds listed under the EPBC Act 1999 is considered internationally important according to the EPBC Act Policy Statement 3.21 (Commonwealth of Australia 2017) if it regularly supports:

- 1 percent of the individuals in a population of one species or subspecies of waterbird or

  Available data suggest that the study area does not regularly support 1% of Curlew Sandpiper populations.
- a total abundance of at least 20,000 waterbirds.

Available data suggest that the study area does not regularly support at least 20,000 waterbirds.

Shorebird habitat for migratory shorebirds listed under the EPBC Act 1999 is considered nationally important according to the EPBC Act Policy Statement 3.21 (Commonwealth of Australia 2017) if it regularly supports:

- 0.1 percent of the flyway population of a single species of migratory shorebird or

  Existing records of this species in the study area suggests that the Curlew Sandpiper is unlikely to occur in nationally significant numbers in the study area.

- 2000 migratory shorebirds or

  Available data suggest that the study area does not regularly support 2000 migratory shorebirds.

- 14 migratory shorebird species

  Available data suggest that the study area does not regularly support 14 migratory shorebird 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 of a population**
Given the nature of the predicted impact of the Project (that is, the alteration of the Nepean-Hawkesbury River flooding regime downstream of Warragamba Dam) it is unlikely that the proposed action will lead to a long-term decrease in the Curlew Sandpiper's population size.
• **reduce the area of occupancy of the species**
The Project is unlikely to but may reduce the area of occupancy of the Curlew Sandpiper at the local scale given that the Project could reduce the availability of suitable foraging habitat at wetlands in the Windsor/Richmond area.
• **fragment an existing population into two or more populations**
The Project is unlikely to fragment an existing Curlew Sandpiper population into two or more populations given the high mobility of this species.
• **adversely affect habitat critical to the survival of a species**
No critical habitat has been declared for this species.
• **disrupt the breeding cycle of a population**
The Project is unlikely to disrupt the breeding cycle of a population of Curlew Sandpiper, given that Australia provides non-breeding 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**
'Coastal freshwater lagoons of the Sydney Basin Bioregion and South East Corner Bioregion' (PCT781) is the only associated habitat mapped in the study area. An estimated 380 hectares of this PCT mapped downstream is considered to be suitable habitat for the Curlew Sandpiper with seven hectares of this to be impacted. There is likely significantly more appropriate habitat within the study area, but the impacted area is difficult to calculate in this circumstance as not all area within a 'forested wetland' is appropriate wetland habitat. The Project may modify or decrease habitat availability or quality in the impact area. However, this is unlikely to cause the Curlew Sandpiper to decline given the number of birds that utilise the impact area annually and considering that the alteration of the flow regime is unlikely to render areas of foraging habitat unsuitable.

• **result in invasive species that are harmful to an endangered or critically endangered species becoming established in the endangered or critically endangered species' habitat**
Dogs are known to disturb roosting and feeding sites of the Curlew Sandpiper. Given that the downstream study area is heavily populated, dogs are already present. The Project is unlikely to result in invasive species that are harmful to the Curlew Sandpiper becoming established in Curlew Sandpiper habitat.
• **introduce disease that may cause the species to decline**
The Project is unlikely to introduce disease that may cause the Curlew Sandpiper to decline.
• **interfere substantially with the recovery of the species**
A Conservation Advice prepared for the Curlew Sandpiper identified that no recovery plan is required for the species as sufficient direction is included in the Conservation Advice. None of the conservation objectives identified in the conservation advice for the species are considered relevant to the Project. Therefore, it is unlikely the Project would substantially interfere with the recovery of the species given the number of individuals that utilise the impact area.
Conclusion
The Project is unlikely to have a significant impact on the Curlew Sandpiper.

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Chalinolobus dwyeri (Large-eared Pied Bat)

Vulnerable under the EPBC Act

The Large-eared Pied Bat is listed as vulnerable under the EPBC Act. Little is known about the Large-eared Pied Bat. It requires a combination of sandstone (rarely volcanic) cliff/escarpment to provide roosting sites within several kilometres of higher fertility valleys that are used for foraging. It occurs in a variety of forest types and does not appear to forage in cleared area (Department of Environment and Resource Management 2011). Due to the extensive areas of sandstone escarpment within the Sydney Basin, some of the largest populations of the Large-eared Pied Bat occur in this region, although it is still uncommon and patchy (Department of Environment and Energy 2018a).

The area required for foraging, or the extent of overlap between individuals, is not known. The Large-eared Pied Bat is insectivorous, but further details of the diet have not been described. Their wing morphology suggests that it flies relatively slowly and is quite manoeuvrable, consistent with observations that it forages below the canopy (Churchill 1998). The population size, local density or population trend is not known. However, colonies rarely exceed 50 individuals and the extent of any interaction between colonies is not known (Department of Environment and Energy 2018a).

Daytime roosts have been observed in disused mine shafts, caves, overhangs and disused Fairy Martin (*Hirundo ariel*) nests (Hoye and Dwyer 1995; Schulz 1998). During breeding, large caves with highly specific characteristics are required: arched caves with dome roofs with indentations that presumably capture heat (Pennay 2008). Caves with the necessary combination of features are not common and are likely to be limiting. Only four maternity caves have ever been located, all in NSW. Of these, one (the type location in a mine tunnel at Copeton, NSW) was flooded by the Copeton Dam in 1976 and another one was abandoned after disturbance by macropods (Department of Environment and Energy 2018a). Thus, only two known maternity roosts remain in use. It is not known how far bats move from maternity roosts at other times of the year.

At Copeton, nursery colonies were present in the summer of two years, but not the following two years (1961 – 1966). However, guano deposits suggested the site had been used for at least 10 – 15 years. It is not clear why breeding did not occur in the final two years, but the location occupied within the cave changed between the two years and roosting bats were variously clustered, with some individuals occasionally roosting in solitary (Dwyer 1966). This may suggest that, at least while breeding, the species is very sensitive to variations in the micro-climate. Indeed, the cave examined by Pennay (2008) faced north-west and all roosting bats observed by Dwyer (1966) were in torpor. The adult sex ratio was generally strongly female biased (0 – 5 males, 8 – 13 females) as males appear to leave before the young are born. The sex ratio of juveniles varied between the years, but overall was close to 1:1 (Dwyer 1966).

At Coonabarabran in central NSW, a maternity roost was located in 2004 (Pennay 2008). Over three consecutive summer from 2001, between 14 and 40 adult females were observed to carrying twins, with births estimated as occurring in late November (Pennay 2008). The timing and other reproductive details were similar to that described by Dwyer (1966). However, this cave appeared to be used for roosting during winter, with 15 adults observed in August 2004. The difference may be due to the differences in the thermal properties of natural sandstone caves compared to the mine tunnel (Pennay 2008).

Although there are extensive cliff lines throughout the upstream study area, the requirement for fertile valleys for foraging appears to restrict high quality habitat to the upper reaches of Lake Burragorang. On the Wollondilly Arm, the most important area appears to occur south from about Nattai, becoming more extensive from near the very upper reaches of the Lake, where the valley broadens considerably. On the Coxs Arm, some more limited areas of high-quality habitat occur at the upper reaches of the Lake. However, areas of moderate quality habitat extend down both arms to the confluence of the Wollondilly and Coxs Rivers. Below this, to the dam wall, the steeply sided gorge provides marginal and highly restricted foraging habitat. Potential roost sites occur along the cliff lines surrounding the entire Lake but are more likely to be occupied in the upper reaches, closer to foraging habitat (DECC 2007). The Large-eared Pied Bat was recorded foraging at various locations in the upstream study area.

Downstream, foraging habitat occurs in remaining patches of native vegetation within suitable range of roost habitat. The Large-eared Pied Bat was recorded foraging within the study area at Yellomundee and Cattai National Parks. Roosting habitat is likely to occur outside the study area due to the absence of suitable sandstone caves on the Hawkesbury-Nepean floodplain.

Most cave roosts know to be used by the Large-eared Pied Bat are in shallow caves or near the entrances of deeper mines or caves. This exposes bats to impact that can affect these areas, including heat and smoke during fires, causing mortality. While the degree of mortality is exacerbated by more intense and/or frequent fires, it is not known exactly how the viability of populations is impacted. The recovery plan requires the establishment of fire management around roost sites to protection these critical locations (Department of Environment and Resource Management 2011). Fire may also impact on foraging habitat by altering vegetation composition and structure, enabling weed invasion and the loss of diversity of vegetation age classes (Department of Environment and Resource Management 2011).

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

As the Large-eared Pied Bat is such a poorly known species, it is difficult to estimate the size of the local population within the Project study area. While the species may occur in the lower reaches of Lake Burragorang, only marginal foraging habitat is present there. Moderate foraging habitat occurs in the middle reaches and high-quality habitat in the upper reaches (DECC 2007). While the cliff line is further from the Lake in the upper reaches, they remain sufficiently proximate to foraging habitat.

While no maternity caves are known in the Locality, the abundance of species records during foraging (DECC 2007) suggest that one or more maternity roosts are likely to be present. This is because extensive cliff lines are available, the species is thought to have relatively low mobility based on wing morphology (Department of Environment and Energy 2018a) and it appears to show fidelity to maternal roosts (Dwyer 1966). However, most of the cliff lines in the upper reaches of the Lake are outside the Project study area, but foraging habitat is present within it. It is possible that individuals associated with anywhere from one to several maternal roosts could forage in the Project study area. This suggests that 50 – 200 adults may utilise the Project study area.

The 2019/2020 bushfire event may have caused a substantial reduction in foraging habitat. Impacts to habitat not yet determined, but an estimated 4,194 hectares of potential upstream habitat for the Large-eared Pied Bat has been burnt at various intensities. The Large-eared Pied Bat is not is listed as a species requiring urgent management intervention following the 2019/2020 bushfires (Wildlife and Threatened Species Bushfire Recovery Expert Panel 2020).

The likely impact (including direct and indirect impacts) that the development will have on the habitat of the local population

The Project is not likely to affect roosting habitat. While cliff lines are present in the lower reaches of Lake Burragorang, no suitable caves were observed within the inundation area and little foraging habitat is present. In the upper reaches and downstream, roosting habitat would not be affected as all cliff lines are well above the level of inundation and are, in fact, largely outside the Project study area. However, foraging habitat (forest on fertile soils) is widely available.

The increased extent of inundation would reduce the availability of foraging habitat for the Large-eared Pied Bat. This impact would be more pronounced in the mid to upper reaches of Lake Burragorang due to the presence of higher quality foraging habitat. Foraging habitat for the Large-eared Pied Bat would be associated with moist, productive forest types (for example, Moist Blue Gum, Red Gum and Grey Gum type communities). Accordingly, there is up to an estimated 4,450 hectares of low to high quality foraging habitat within the upstream study area and up to an estimated 5,371 hectares downstream. The Project may affect up to 2,484 hectares of the potential foraging habitat available in the upstream study area and up to 625 hectares downstream.

The likely impact on the ecology of the local population

The Project is unlikely to affect roosting or breeding sites for the Large-eared Pied Bat. While foraging habitat would be reduced, suitable caves for breeding are regarded as a more significant limiting resource. This is particularly likely to be true because of the very large areas of foraging habitat available. However, the Project may still result in the loss of a small number of individuals. Despite this, the Project is unlikely to affect the reproductive cycle of the Large-eared Pied Bat.

The relationship of the local population to other populations of the species

Although the Large-eared Pied Bat has relatively limited dispersal. The extent of fairly continuous habitat through the sandstone landscape surrounding the Project study area suggests that the local population would be part of a larger population in the region (see DECC 2007).

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 lack of information about the Large-eared Pied Bat makes the assessment of threats difficult (Duncan *et al.* 1999). However, threats are known or likely to include (Department of Environment and Resource Management 2011; Department of Environment and Energy 2018b):

- Loss of foraging habitat due to agriculture and urban development
- Impacts due to forestry
- Destruction of or interference with maternity and other roosts, including threats from mining
- Mine-induced subsidence of cliff lines
- Disturbance due to recreational activities
- Habitat disturbance by introduced animals, including livestock
- Predation by introduced carnivores, such Red Foxes
- Vegetation clearing around roosts
- Fire around roosts

No major caves that would be used as roost or maternity sites were observed during investigations by boat around the perimeter of Lake Burragorang. Habitat modelling (DECC 2007) suggests that the most important foraging habitat occurs in the upper reaches of Lake Burragorang, where the cliff lines are well separated from the proposed new level of inundation, but foraging habitat is available in the valley floor. It is likely to some mine-induced subsidence of cliff lines may be already operating in the Project study area (Photo LePB1), however, this is not associated with the current or proposed operation of Warragamba Dam and is not a Project impact. Indeed, the isolated and restricted nature of the catchment provides protection of roosts from recreational activities. While the Project may result in the modification of up to an estimated 3,109 hectares of potential foraging habitat, it would have a minimal impact on population size and it would not disruption the population cycle of the species. Therefore, the Project is not likely to contribute to known threats to the Large-eared Pied Bat.

Photo LePB1: Subsidence along the Wollondilly River. Also, note the distance from the existing lake to the escarpment.

The measure/s proposed to contribute to the recovery of the species

The overall objective of the National Recovery Plan for the Large-eared Pied Bat (*Chalinolobus dwyeri*) is to ensure the persistence of viable populations across its range. As the largest known populations of the species occur in the Sydney Basin, it is important that viable populations are secured in this area. Measures associated with the Project that would contribute to the recovery of the Large-eared Pied Bat include (Department of Environment and Energy 2018b):Protection of roost and maternity sites due to the regulated access to the restricted area.

- Protection of large areas of foraging habitat.
- Enabling research into the ecology of the species to contribute to informed conservation actions.

The proposal is unlikely to affect roosting habitat and foraging habitat is protected through the regulated access to the restricted area.

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 Project is not likely to affect roosting or breeding caves used by the Large-eared Pied Bat. The amount of foraging habitat could be reduced by up to an estimated 3,109 hectares within the Project study area. Due to the specific requirements for maternity roosts, they are generally regarded as the limited factor for the Large-eared Pied Bat but given the extent of sandstone escarpment in the Locality, this may not be the case locally. The loss of foraging habitat may result in a small, but long-term, decrease of an important population of the Large-eared Pied Bat.
• **reduce the area of occupancy of an important population**
There are known records of the Large-eared Pied Bat around the Project study area. Based on these records, large areas of the Locality, with the major exception of the sandstone plateaus, are modelled habitat for the species (DECC 2007). The Project study area is surrounded by known and modelled habitat for the Large-eared Pied Bat. Therefore, the Project would not reduce the area occupancy of an important population of the species.
• **fragment an existing important population into two or more populations**
The Project would not isolate the Large-eared Pied Bat from areas of foraging habitat. The Project would extend the existing lake by maximum distances of 60–200 metres. While the Large-eared Pied Bat does not have particularly strong flight, this is not a sufficient distance to result in habitat fragmentation. Additionally, existing levels of habitat connectivity would occur in the upper reaches of Lake Burragorang as it is not as wide in this area. The Project would not fragment an existing important population into two or more populations or erect any barriers to the movement of the Large-eared Pied Bat.
• **adversely affect habitat critical to the survival of a species**
There are two components to critical habitat for the Large-eared Pied Bat: • Maternity roosts • Sandstone and volcanic cliffs and fertile, forested valleys in close proximity. Both components occur, for are likely to occur, in the Project study area. Therefore, habitat critical to the survival of the Large-eared Pied Bat occurs in the Project study area (Department of Environment and Resource Management 2011). Maternity and other roosts are unlikely to be affected by the Project. However, upstream foraging habitat proximate to cliff lines could be reduced by the Project. The Project may adversely affect habitat critical to the survival of the Large-eared Pied Bat.
• **disrupt the breeding cycle of an important population**
No potential maternity roosts would occur within the increased inundation area. Foraging habitat near potential roosting sites may be reduced, but would remain.

The Project is unlikely to adversely affect the breeding cycle of an important population of the Large-eared Pied Bat.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The project may remove up to an estimated 3,109 hectares of foraging habitat, but is unlikely to affect roosting or breeding sites. The population of Large-eared Pied Bat within the Project study area is adequately connected to additional areas of known and modelled habitat in the Locality and in the region. Additionally, the Large-eared Pied Bat has wide, if patchy distribution. Most populations of the Large-eared Pied Bat would not be affected by the Project. Although there would be some removal of potential foraging habitat, is unlikely to be to the extent that the Large-eared Pied Bat is likely to decline.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
The Red Fox (*Vulpes vulpes*) is already present in the Project study area and is a known predator of the Large-eared Pied Bat, particularly at roost sites. The Project would not cause the establishment of any new invasive species. The proposed actions are unlikely to result in an invasive species that is harmful to the Large-eared Pied Bat becoming established in its habitat.
• **introduce disease that may cause the species to decline, or**
No diseases are known to affect the Large-eared Pied Bat, or microbats more generally. The Project is unlikely to introduce disease with potential to cause the Large-eared Pied Bat to decline.
• **interfere substantially with the recovery of the species.**
A National recovery plan has been prepared for the Large-eared Pied Bat (Department of Environment and Resource Management 2011). The lack of information about the Large-eared Pied Bat makes the assessment of threats difficult (Duncan *et al.* 1999). However, threats are known or likely to include (Department of Environment and Resource Management 2011; Department of Environment and Energy 2018b): • Loss of foraging habitat due to agriculture and urban development • Impacts due to forestry • Destruction of or interference with maternity and other roosts, including threats from mining • Mine-induced subsidence of cliff lines • Disturbance due to recreational activities • Habitat disturbance by introduced animals, including livestock • Predation by introduced carnivores, such Red Foxes • Vegetation clearing around roosts • Fire around roosts The Project may result in the loss of up to an estimated 3,109 hectares of foraging habitat. However, this would have a minimal impact on population size. Roost and breeding sites would not be affected by the Project. The Project is unlikely to interfere with the recovery of the Large-eared Pied Bat.
Conclusion
The Project study area contains foraging, roosting and breeding habitat for the Large-eared Pied Bat. However, only foraging habitat would be affected by the Project. The potential modification of up to an estimated 3,109 hectares would occur in the context of thousands of hectares of known and modelled foraging habitat. The habitat areas

within the Locality are moderately to well connected to one another. The extent of Project impacts is unlikely to be of an intensity that may impact upon the viability of the local, important population of the Large-eared Pied Bat. The Project is unlikely to have a significant impact on the Large-eared Pied Bat.

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Dasyurus maculatus (Spotted-tailed Quoll)

Endangered under the EPBC Act

The Spotted-tailed Quoll is a medium-sized carnivorous marsupial. It occupies a variety of habitat types, including rainforests, wet and dry eucalypt forests, eucalypt woodlands, montane woodlands and coastal heath. It also makes use open country, such as grazing lands (Jones *et al.* 2001; Belcher 2004). It is dependent on mature and old growth forest. The loss and fragmentation of habitat has led to a range reduction of about 50%. Clearing felling forestry operations are also a threat because the logging cycles are too short to allow old growth attributes to develop (Belcher 2004). Habitat use is influenced by prey density and reveals a preference for escarpments and gullies, with avoidance of midslopes (Belcher 2004).

The Spotted-tailed Quoll is predominantly nocturnal, though some activity during the day (Körtner *et al.* 2015). Medium-sized mammals are the most important prey items, up to 80% of the diet, including brushtail possums (*Trichosurus* spp.), common ringtail possum (*Pseudocheirus peregrinus*), greater glider (*Petauroides cumin*), the long-nosed bandicoot (*Perameles nasuta*) and rabbits (*Oryctolagus cuniculus*). Other prey may include small (for example, rodents, antechinus) and large mammals (for example, macropods), birds, reptiles, invertebrates and riverine fauna (for example, waterbirds, eels, crayfish, molluscs and frogs) (Belcher 1995; Belcher *et al.* 2007; Dawson *et al.* 2007; Jarman *et al.* 2007; Pascoe *et al.* 2012). It was thought that greater gliders were being captured in their tree hollows during the day and that macropods are scavenged (Belcher *et al.* 2004)

There appears to be little difference between the diets of adult male and female Spotted-tailed Quolls, but sub-adults target smaller prey (Belcher 1995; Belcher *et al.* 2004). However, there are seasonal shifts in the relative proportions of prey due to changes in prey availability (Belcher 1995). The diet also changes after fire and an increase use of carrion may help the Spotted-tailed Quoll survive these events (Dawson *et al.* 2007). The spotted-tailed quoll exhibits a strong dietary overlap with the European Red Fox (*Vulpes cumin*) (Pascoe *et al.* 2012).

The Spotted-tailed Quoll has large home-ranges. Male home-ranges appear to range between 1000 and 3800 hectares and those of females are only about one-third of that area 250 – 870 hectares (Belcher and Darrant 2004; Claridge *et al.* 2005; Körtner *et al.* 2016). Corresponding, daily (24 hr) movement distances 1.5 – 2.7 kilometres for males and 1.0 – 1.5 kilometres for females have been reported (Belcher and Darrant 2004; Körtner *et al.* 2004; Claridge *et al.* 2005). Thus, consistent with their larger home-ranges, males tend have more extensive daily movements than females. Males also move between female territories during the breeding season (Belcher and Darrant 2004).

Spotted-tailed Quolls are solitary except when mating (Belcher and Darrant 2004). While studies have shown some variation in spatial organisation, the most typical situation appears to be exclusive home-range use between females, while male home-ranges overlap with those of both sexes (Belcher and Darrant 2004; Körtner *et al.* 2004). However, females may be philmatric (juvenile females remaining near the mother's home-range) (Firestone *et al.* 1999; Belcher and Darrant 2004). As a consequence of the large home-range and relatively low home-range overlap, population density is low (Belcher and Darrant 2004). Glen (2008) considered a population density of 0.3 per square kilometre to be high for this species.

The Spotted-tailed Quoll maintains sites of communal defecation, known as latrines. Latrines are typically found on boulders and rock outcrops in the bed of a gorge, though they may also be on bedrock. Latrines are randomly located, but some are used more than others. Latrines are used by multiple individuals of both sexes and may be used over periods of at least several years. The use of latrines facilitates social interaction and are used more frequently during the mating season (Ruibal *et al.* 2011; Kruuk and Jarman 1995).

When not active, the Spotted-tailed Quoll uses retreat sites (dens), such as fallen hollow trees, base of standing hollow trees, low hollow branches, underground burrows and rock crevices; sometimes among leaf litter, blackberry and grass tussocks. The same dens are rarely used on consecutive days (Körtner *et al.* 2004), with movements likely to facilitate the use of the large home-ranges.

It takes males three years and females two years to reach maturity (Belcher 2003). Births occur in July and August (Belcher 2003; Glen 2008). Females may breed up until four years of age, but not all females breed each year (Belcher 2003). Litter size is usually 4 – 6 (Belcher 2003; Glen 2008). Dispersal occurs at around one year (Belcher 2003) and is male-biased (Firestone *et al.* 1999). The sex ratio at birth is 1:1 (Glen 2008), but, while there is some variation in the adult sex ratio over time, males are generally captured much more frequently than females suggesting a biased adult sex ratio (Belcher 2003; Körtner *et al.* 2004; Glen 2008). Glen (2008) estimated pre-weaning mortality of 17% and an apparent adult survival rate of 28%. In comparison, Körtner *et al.* (2004) estimated annual survival to be 41%, but still considered this a high turnover and noted a high proportion of young animals in the study population. By four years, the teeth show appreciably wear and a maximum longevity of five years has been reported (Belcher 2003).

The most important threats to the Spotted-tailed Quoll appears to be habitat loss and fragmentation (Belcher 2004). While clear-felling significantly impacts on the Spotted-tailed Quoll (Belcher 2004), the impact of lower intensity selective logging does not appear to be as severe over the medium term (Belcher 2003). While Belcher (2003) reported population impacts due to 1080 baiting, Claridge and Mills (2007) did not find evidence of an impact. However, overall concern remains about 1080 baiting (Belcher 2004). Fire may cause short-term impacts on the spotted-tailed quoll until the understorey recovers (Belcher 2004). Road mortality may also affect quoll population (for example, Jones 2000). Due to the dietary overlap with the Red Fox (Pascoe *et al.* 2012), there is some concern about competition with this species (Belcher 2004).

Fire may cause short-term impacts on the Spotted-tailed Quoll until the understorey recovers (Belcher 2004; Dawson 2005). Fire has been documented to causes changes in the Spotted-tailed Quoll's diet due to shifts in prey availability mediated by habitat impacts and scavenging of carcasses (Dawson et al. 2007). Fire can also affect the availability of shelter sites, for example, by destroying hollow logs (Belcher 2004). The response of spotted-tailed quoll populations is considered to remain poorly known (Department of Environment, Land, Water and Planning 2016), possibly due to a lack of study. Dawson (2005), for example, found that a Spotted-tailed Quoll population was reduced by almost 30% in the year following fire in severely impacted habitat. However, due to immigration the population was 20% higher than pre-fire levels two years after fire. This suggests that fire impacts may be relatively short-term due to the spotted-tailed quolls ability to exploit a range of different prey species, the use of carrion and ability to use rocky areas for shelter. However, the Spotted-tailed Quoll is listed as a species requiring urgent management intervention following the fires of 2019/20 (DAWE 2020).

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

There are relatively few Spotted-tailed Quoll database records from the Project study area (the EPBC referral area), with most records being located along roads and ridge tops where there is greater access. There is a particular concentration of records in the settled areas along the Great Western Highway, most likely reflecting an increased detection rate due to a greater human presence. In contrast, the lower number of records in bushland areas reflects a combination of low survey effort due to restricted access, the difficultly in sampling the habitat away from roads due to the steep terrain and dense vegetation, the low productivity of some vegetation communities and variability density of shelter sites.

While there are some Spotted-tailed Quoll records downstream within urbanised areas, however, these records are more likely to reflect dispersing individuals rather than representing a permanent population. The first 15 kilometres downstream of the dam wall provides similar, deeply dissected terrain similar to the habitat found upstream. Beyond that, the Nepean River may provide some limited habitat, particularly where it abuts the extensive habitat within the Blue Mountains.

Spotted-tailed Quolls are capable of utilising all habitat types within the upstream, construction and downstream Project study areas, which collectively total 12,827 hectares (refer table below). Based on an intermediate male home-range area of 1,500 hectares that overlaps with an average of three females (that is, four individuals per male home-range), a total population of 14 Spotted-tailed Quolls could be supported by an area equivalent to the PMF boundary and 29 downstream (refer table below).

Area of Spotted-tailed Quoll habitat, area of habitat impacted, estimated total population in area, number (%) impacted.

Project study area	Total area (ha)	Area impacted (ha)	Estimated total population	No. Impacted
Upstream study area	5,280	1,400[1]	14	4
Construction	55	22	N/A[2]	N/A[2]
Downstream (10% AEP)	11,206	1,042	29	N/A[3]
Total	16,541	4,137	43	4

1. This is the extent of the upstream impact area; for the purpose of offsetting, the Project has assumed there would be a total loss of biodiversity values in this area.
2. N/A, not applicable – unlikely to be impacted by clearing because construction area much smaller than home-range area

3. N/A, nota applicable – unlikely to be impacted by clearing because not susceptible to the impacts

The likely impact (including direct and indirect impacts) that the development will have on the habitat of the local population

Inundation due to the Project could modify foraging habitat by removing cover, foraging resources and other substrates required by prey species of the Spotted-tailed Quoll. In contrast, the loss of vegetative cover may expose rocky habitats that may provide additional shelter sites (rock crevices) around the lake edge. The exposed edge would also be susceptible to weed invasion due to the reduction of native vegetation cover.

Habitat loss would result in a concomitant reduction in the size of the population within the assessment area. If the additional inundation first occurs after three years post-fire the population is likely to have returned to pre-fire levels. Under this scenario, the 20% AEP would affect 634 hectares (12% of the upstream study area) and the 1% AEP would affect 2,863 hectares (55% of the upstream study area). This would cause the estimated population of 14 quolls to decline to between 12 individuals (20% AEP) and six (1% AEP), respective losses of two and eight quolls. If the fire occurred within the first three years, then fire impacts are likely to still be at least partially evident. Under a fire-impacted scenario, a population of five quolls would be reduced to one (20% AEP) to three (1% AEP) individuals. Given the use of a broad range of habitats and the large movement areas of the spotted-tailed quoll, it is unlikely that the Project would result in habitat fragmentation for this species.

The construction area would also remove foraging habitat and potentially also shelters (for example, rock crevices, fallen logs, tree hollows). Noise and vibration are indirect impacts that may extend for several hundred metres around the construction area. Erosion and sedimentation, weed invasion, and vehicle movements in and out of the construction area also pose a risk of mortality due to vehicle strike. However, as the construction area is small relative to the home-range area of the Spotted-tailed Quoll, it is unlikely that habitat loss and indirect impacts would affect it in this area.

The Spotted-tailed Quoll is likely to be rare to uncommon along the Nepean River. While there are some records within urbanised areas, these are likely to be dispersing individuals rather than residents. Therefore, urban areas to not contribute to estimates of population size. However, large areas of habitat occur to the east of the Nepean River. There is an estimated 7,517 hectares of habitat downstream. Despite this, downstream impacts are likely to be minor as the Spotted-tailed Quoll is not dependent on wetlands and flood regimes.

The likely impact on the ecology of the local population

The main potential impact on the local Spotted-tailed Quoll population will be the linear reduction in population size due to habitat loss resulting in the loss of foraging resources and the loss of shelter sites. However, the loss of shelter sites is not likely to have a significant impact on the local population as there would be numerous shelter sites on the steep, rocky slopes and escarpments outside the PMF. Moreover, as noted above, some shelter sites may become available due to the new exposure of rocky substrate within the newly extended inundation zone. While recent fires within the Project Area may have temporarily reduced to population size of the spotted-tailed quoll, this is likely to only persist a few years. Unless the initial inundation event to affect habitat occurred immediately after construction, it is likely that these fires would impact the pre-inundation population status.

The impact of habitat fragmentation would be minor as the existing lake has already fragmented a previously continuous habitat. The Project is not expected to alter life history attributes (for example, birth and mortality rates) of the remaining population. The large home-ranges and high mobility of the Spotted-tailed Quoll suggest that the population directly impacted by the Project would be continuous with the population of Quolls throughout the Blue Mountains. However, given the low population density of the Spotted-tailed Quoll and uncertainty regarding the actual distribution and abundance of the local population, it is difficult to determine the impact of the Project on its population viability.

The relationship of the local population to other populations of the species

The Project study area is surrounded by large areas of habitat within conservation reserves that have numerous Spotted-tailed Quoll records (OEH 2019). Many of these records are associated with upslope or ridgetop habitats. While this undoubtedly reflects areas that are more accessible by vehicle, it also suggested that higher elevation habitat may provide living and/or connecting habitat between sub-catchments within the Locality. This suggests that the population in the Project study area would be directly (within the same sub-population) and indirectly (to other sub-populations via dispersal) connected to other Spotted-tailed Quoll populations in the Locality. The overall size of the population within the Locality would, accordingly, be quite large compared to that in the Project Area alone.

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

Recognised threats to the Spotted-tailed Quoll are:

- Habitat loss and fragmentation
- Predation by Red Foxes (*Vulpescumin*), Dingos (*Canis lupus dingo*) and domestics Dogs (*Canis lupus familiaris*)
- Fire, particularly in the short-term due to the reduction in prey availability
- Direct killing by landowners
- Road mortality
- Poisoning by Cane Toads (*Rhinella marinus*)
- 1080 baiting: while baiting is undertaken to control Quoll predators (for example, Red Foxes and Wild Dogs), poisoning can pose a direct threat to Quolls.

Of these known threats, habitat loss and fragmentation and road mortality are likely to be direct Project impacts. Fragmentation may indirectly cause an increase in predation as predators may have greater access to the remaining habitat due to the creation of new roads and other clearing (for example, Catling and Burt 1995; Lunney *et al.* 2007).

As discussed above, habitat loss and fragmentation and road mortality are not expected to affect the viability of the local Spotted-tailed Quoll population.

The measure/s proposed to contribute to the recovery of the species

The Project impacts on the Spotted-tailed Quoll will be a direct consequence of habitat loss and fragmentation associated with a larger inundation area. While this would remove foraging resources and some shelter sites and result in a reduced size of the local population, this is not likely to impact on the population viability of this species. Therefore, no specific measures are proposed that would contribute to the recovery of the Spotted-tailed Quoll. However, general habitat offsets would benefit the Spotted-tailed Quoll by securing suitable habitat in other locations.

Given that a large area of habitat is available in the Project study area and it is continuous with further habitat in the Locality, a key source population of the Spotted-tailed Quoll for breeding and dispersal and for maintaining genetic diversity would be present in the Locality.

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
It has been estimated that 5,205 hectares of habitat supporting 43 Spotted-tailed Quolls is present in the upstream study area. The Project could potentially modify all foraging habitat upstream, affecting an estimated maximum of eight adult Quolls. However, the loss of vegetation due to inundation may also provide additional rock crevices, which may be used as shelter. The area impacted by construction is small relatively to the home-range area of the Spotted-tailed Quoll, therefore, no loss of individuals is expected. However, vehicle strike is a risk during construction due to increased traffic volumes, although most of this would be during the day while the Quoll is active at night. Downstream impacts (reduced flooding) is not expected to impact the Spotted-tailed Quoll. Thus, the Project is likely to permanently remove the habitat of eight adult Spotted-tailed Quolls. The Project could potentially permanently remove the habitat of four adult Spotted-tailed Quolls, resulting in a long-term decrease in the size of the population.
• reduce the area of occupancy of a species
The Project could result in the loss of up to eight Spotted-tailed Quolls by reducing the area of occupancy by 364 (20% AEP) to 2,863 (1% AEP) hectares. The Project could reduce the area of occupancy of the Spotted-tailed Quoll.
• fragment an existing population into two or more populations
The Project may result in an expansion of the current inundation area, though the extent would be dependent on the magnitude of the flood event. The Spotted-tailed Quoll has large spatial requirements and would be capable of dispersing tens of kilometres, including through habitats types that are not suitable for residency. The Spotted-

tailed Quoll would likely continue to move through the Project study area during the construction and operation stages of the Project. The Project would likely not fragment an existing population into two or more populations or erect any barriers to the movement of the Spotted-tailed Quoll.
• **adversely affect habitat critical to the survival of a species**
Habitat that is critical to the survival of the Spotted-tailed Quoll includes large patches of forest with adequate denning resources and relatively high densities of medium-sized mammalian prey. No critical habitat has been defined due to the variability of resources across the landscape. It is considered that the Project Area would constitute critical habitat for the Spotted-tailed Quoll as it would be used for foraging, breeding, shelter and dispersal. The Project Area and surrounding Locality are also important to the maintenance of genetic diversity and long-term evolutionary development of this species. The Project would adversely affect habitat critical to the survival of the Spotted-tailed Quoll through inundation upstream of Warragamba Dam..
• **disrupt the breeding cycle of a population**
A larger area of inundation could potentially reduce the number of breeding female Spotted-tailed Quolls in the Project study area, but would not affect the breeding cycle of the remaining upstream population. In contrast, the construction activities are not likely, due to the small area affected, result in the loss of individual Quolls. However, disturbances in this area (for example, noise, vibration) may disrupt the breeding cycle of one or two females. No downstream affects are likely. The Project would likely not adversely affect the breeding cycle of the Spotted-tailed Quoll upstream or downstream. However, breeding may be disrupted in the construction area during construction.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The area of habitat that could potentially be removed by the Project surrounds the existing inundation area. Large areas of continuous habitat would remain in the Locality. These areas are protected within large conservation reserves (for example, Kanangra-Boyd National Park). Although there could potentially be some removal of potential foraging habitat, is unlikely to be to the extent that the Spotted-tailed Quoll is likely to decline.
• **result in invasive species that are harmful to an endangered or critically endangered species becoming established in the endangered or critically endangered species' habitat**
European Red Foxes (*Vulpes vulpes*), cats (*Felis catus*) and dogs (*Canis lupus familiaris*) are invasive species recognised as threats to the Spotted-tailed Quoll. These species are already be present throughout the Project Area. The Project is unlikely to result in an invasive species that is harmful to the Spotted-tailed Quoll becoming established in its habitat.
• **introduce disease that may cause the species to decline, or**
The there are no diseases recognised as affecting the Spotted-tailed Quoll. The Project is not likely to increase the potential for introduction of diseases that may affect this species. The Project is unlikely to introduce disease with potential to cause the Spotted-tailed Quoll to decline.
• **interfere substantially with the recovery of the species.**
There is a national recovery plan for the Spotted-tailed Quoll. The over-arching strategy is to reduce the impact of threatening processes. Two of the main threats are habitat loss and fragmentation and road mortality, both the

which are potential risks associated with the Project. In particular, the assumed loss of 1,400 hectares of habitat is substantial. The Project may substantially interfere with the recovery of the Spotted-tailed Quoll.
Conclusion
The Project study area contains habitat that may be utilised the Spotted-tailed Quoll for foraging, shelter, breeding and dispersal. The effects of recent fires on the Spotted-tailed Quoll are expected to be relatively short-lived. While the Project may only affect about eight adult Quolls, this is potentially significant given the large spatial requirements and low population density of this species. In contrast, there would be large areas of habitat within the locality and region. Given the ability of the Spotted-tailed Quoll to move large distances, the Project is unlikely to isolate this species from additional habitat. However, on balance, the Project may potentially have a significant impact on the Spotted-tailed Quoll.

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Grantiella picta (Painted Honeyeater)

Vulnerable under the EPBC Act

The Painted Honeyeater is listed as vulnerable under the EPBC Act. The Painted Honeyeater is nomadic and occurs at low densities throughout its range (Barea 2008b). It is sparsely distributed from south-eastern Australia to north-western Queensland and eastern Northern Territory. The greatest concentrations and almost all records of breeding come from south of 26 degrees, on inland slopes of the Great Dividing Range between the Grampians, Victoria and Roma, Queensland (Higgins *et al.* 2001). It inhabits Boree/ Weeping Myall (*Acacia pendula*), Brigalow (*A. harpophylla*) and Box-Gum Woodlands and Box-Ironbark Forests at scattered locations throughout much of the eastern third of Australia (Higgins *et al.* 2001). In the south-east of its range it usually occurs in areas of Box-Gum Woodland or River Sheeoak (*Casuarina cunninghamiana*) dominated by Mistletoe spp. The species exhibits seasonal north-south movements governed principally by the fruiting of mistletoe. Breeding occurs from October to March and is linked to the fruiting of mistletoe (Barea and Watson 2007).

Habitat loss, degradation and fragmentation pose the chief threat to declining woodland passerines (Higgins *et al.* 2001, Higgins and Peter 2002), including the Painted Honeyeater. Much of its breeding habitat has been cleared or has been reduced to ageing, widely-spaced trees, particularly in box-ironbark and boree woodlands. Its non-breeding habitat is also still being cleared for agriculture (Barea 2008). Other threats to the Painted Honeyeater include: competition with the aggressive noisy miner (*Manorina melanocephala*), predation by invasive species, deliberate destruction of mistletoe in production forests, exacerbation of tree decline through pasture improvement activities, collision with road vehicles and nest predation by over-abundant locally bird species (DEPI 2014).

The Painted Honeyeater was not recorded during the SMEC surveys but has been recorded more recently (December 2018) in the upstream study area (R. Crates, pers comm), where suitable breeding and foraging habitat occurs. Mistletoe, a main food source for the Painted Honeyeater, is abundant in the site, as are mature trees and intact woodland habitat. The Painted Honeyeater is not is listed as a species requiring urgent management intervention following the 2019/2020 bushfires (Wildlife and Threatened Species Bushfire Recovery Expert Panel 2020). However, it remains prudent to consider the impact the recent fires have had on habitat availability. An estimated 2,561 hectares of suitable habitat for the Painted Honeyeater was burnt in the 2019-2020 bushfires. The severity of the burns ranged from mild to severe and will recover at different rates. Some suitable habitat remains in the box gum woodland vegetation in the south of the study area and in small patches in the north-west. There are no records for the construction area.

The Painted Honeyeater is a rare visitor to the downstream study area. It was very occasionally recorded in the study area prior to the 1970s but has been very rarely recorded in the region since. The sole recent record from the study area is of an individual at Pitt Town Lagoon in 2013.

No targeted Painted Honeyeater surveys were conducted in the upstream, construction and downstream study areas by SMEC. Diurnal bird surveys undertaken for the Regent Honeyeater are expected to be suitable to detect the Painted Honeyeater and have been successful in detecting the Painted Honeyeater in ongoing surveys. For this assessment, it is assumed that the Painted Honeyeater is present in any suitable habitat (as determined by the TBDC, records and other scientific literature) that occurs within its geographical range, using the same methodology outlined in the project BARs Suitable habitat includes areas that have been mapped as the following PCTs:

- 724: Broad-leaved Ironbark – Grey Box – *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain Sydney Basin Bioregion
- 725: Broad-leaved Ironbark – *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain Sydney Basin Bioregion
- 830: Forest Red Gum – Grey Box shrubby woodland on shale of the southern Cumberland Plain Sydney Basin Bioregion
- 835: Forest Red Gum – Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin Bioregion
- 849: Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain Sydney Basin Bioregion
- 850: Grey Box – Forest Red Gum grassy woodland on shale of the southern Cumberland Plain Sydney Basin Bioregion
- 1067: Parramatta Red Gum woodland on moist alluvium of the Cumberland Plain Sydney Basin Bioregion
- 1081: Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion
- 1106: River Oak riparian woodland of the NSW North Coast Bioregion and northern Sydney Basin Bioregion

- 1183: Smooth-barked Apple – Sydney Peppermint – Turpentine heathy open forest on plateaux areas of the Sydney Basin Bioregion
- 1327: Yellow Bloodwood – ironbark shrubby woodland of the dry hinterland of the Central Coast Sydney Basin Bioregion
- 1328: Yellow Bloodwood – Narrow-leaved Apple heathy woodland on hinterland plateaux of the Central Coast Sydney Basin Bioregion
- 1395: Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain Sydney Basin Bioregion
- 1504: Sydney Blue Gum – Deane's Gum – River Peppermint shrubby riparian tall forest of the lower Colo River Sydney Basin Bioregion.
- 832: Forest Red Gum – Narrow-leaved Ironbark open forest of the southern Blue Mountains gorges Sydney Basin Bioregion (BVT: HN525)
- 840: Forest Red Gum – Yellow Box woodland of dry gorge slopes southern Sydney Basin Bioregion and South Eastern Highlands Bioregion (BVT: HN527)
- 860: Grey Gum – Broad-leaved Ironbark dry open forest on gorge slopes on the Blue Mountains Sydney Basin Bioregion (BVT: HN532)
- 941: Mountain Blue Gum – Thin-leaved Stringybark open forest on river flat alluvium in the Sydney Basin Bioregion (BVT: HN553)
- 1401: Narrow-leaved Ironbark – Forest Red Gum on rocky slopes of the lower Burragorang Gorge Sydney Basin Bioregion (BVT: HN557)
- 1083: Red bloodwood – scribbly gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion (BVT: HN566)
- 1105: River Oak open forest of major streams Sydney Basin Bioregion and South East Corner Bioregion (BVT: HN574)
- 1281: Turpentine – Grey Ironbark open forest on shale in the lower Blue Mountains Sydney Basin Bioregion (BVT: HN604)

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**
No important populations of Painted Honeyeater have been identified. It is not expected that individuals that occupy the study area are part of an important population given the known distribution of the species in New South Wales. The population of Painted Honeyeater within the Upstream/construction and downstream study area is not considered to be an important population of Painted Honeyeater. As such, the Project will not need to a long-term decrease in the size of an important population of the species.
• **reduce the area of occupancy of an important population**
No important population of Painted Honeyeater has been identified to occur in the study area.
• **fragment an existing important population into two or more populations**
It is believed that the Painted Honeyeater is a nomadic species that is sparsely distributed from south-eastern Australia to north-western Queensland and eastern Northern Territory with dispersal patterns following the fruiting of mistletoe. Due to their tendency to move seasonally in response to the availability of food resources, it is not expected that the proposed actions would fragment any populations of the Painted Honeyeater.
• **adversely affect habitat critical to the survival of a species**
No habitat critical to the survival of the Painted Honeyeater has been declared. Critical habitat features for the Painted Honeyeater include an abundance of mistletoe and flowering eucalypts on fertile soils.

Upstream/construction area, changes to flood duration may result in changes to vegetation, effecting the abundance of mistletoes and flowering eucalypts in the study area. The extent of these changes is unknown.
• **disrupt the breeding cycle of an important population**
The greatest concentrations of the Painted Honeyeater and almost all breeding occurs on the inland slopes of the Great Dividing Range in NSW, Victoria and southern Queensland. It is unlikely that areas to be affected are important breeding habitat and therefore the breeding cycle of any population would not be disrupted.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
Suitable habitat for the Painted Honeyeater occurs in the upstream/construction (estimated 3,774 hectares) and downstream (estimated 3,897 hectares) study areas. The proposed works may result in the modification or removal of 1,422 hectares and up to an estimated 841 hectares of potential Painted Honeyeater habitat within the upstream/construction and downstream study areas, respectively. The Painted Honeyeater is a rare visitor to the downstream study area and there are few records in the upstream area. It is therefore unlikely that an alternation to potential Painted Honeyeater habitat would case the species to decline.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
Invasive species are already present in the upstream/construction and downstream study area. The Project is unlikely to result in the introduction of any invasive species that are harmful to the Painted Honeyeater becoming established in suitable Painted Honeyeater habitat.
• **introduce disease that may cause the species to decline, or**
The Project is unlikely to introduce disease that may cause the Painted Honeyeater to decline.
• **interfere substantially with the recovery of the species.**
No recovery plan has been prepared for the Painted Honeyeater, although it is recognised that one is required as decline of the species is continuing. Threats to the species are ongoing, particularly to its woodland habitat which continues to be cleared and degraded across its range. In NSW, management actions have been identified to assist the recovery of the species. One of these is considered relevant to the Project: • Encourage landholders to protect ground layer and midstorey vegetation by implementing sensitive grazing practices and avoiding slashing or underscrubbing, and to promote the retention of a floristically and structurally diverse and spatially variable understorey. Changes to inundation levels and duration is likely to alter the structure of vegetation communities and may result in a loss of floristic diversity of the understory.
Conclusion
The Project is unlikely to have a significant impact on the Painted Honeyeater upstream or downstream of Warragamba Dam.

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SPRAT Profile Painted Honeyeater: https://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=470

OEH Profile Painted Honeyeater: https://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10357

Heleioporus australiacus (Giant Burrowing Frog)

Vulnerable under the EPBC Act

The Giant Burrowing Frog occurs along the eastern slopes of the Great Dividing Range. It is associated with the sandstone habitats of the Sydney Basin.

Breeding sites for the Giant Burrowing Frog are generally soaks or pools formed by second order streams or in small pools below hanging swamps. Individuals spend most of their time in non-breeding habitat, up to 300 metres from breeding habitat. This non-breeding habitat consists of leaf litter and loose soil where frogs burrow, sometimes repeatedly using the same burrow (Lemckert 2004). They move to breeding habitat immediately before or following heavy rain, where they stay for up to 10 days. Breeding will not be attempted by most individuals every year.

The Giant Burrowing Frog was not recorded during the surveys undertaken for this assessment. It is assumed to occur within suitable habitat present within the Project Area. Suitable habitat includes all native vegetation within 300 metres of breeding habitat, which occurs along second and third order streams on sandstone or upland swamps. An estimated 3,365 hectares of potential habitat has been identified in the combined upstream and construction study areas.

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**
Giant Burrowing Frogs are considered rare across their range, so any population of the species is likely to be considered important. Potential habitat for this species occurs within the upstream, construction and downstream areas. Giant Burrowing Frogs spend 95% of their time in non-breeding habitat, up to 300 metres from breeding habitat. They shelter underground, in leaf litter or under logs of vegetation. Breeding habitat is on first and second order streams with individuals moving to breeding habitat in response to heavy rainfall. Tadpoles are washed into more permanent pools at lower elevation to complete their development. The Project would result in the direct removal of 3.6 hectares of vegetation in the construction study area that could provide non-breeding habitat for the Giant Burrowing Frog. It could also result in changes to the duration and extent of inundation during flooding events across an estimated 1,578 hectares of the upstream study area. These events have the potential to affect the lower elevations of Giant Burrowing Frog habitats. As the majority of the life cycle of the Giant Burrowing Frog occurs beyond the reaches of the flood extents, the Project is unlikely to result in the decrease of an important population of Giant Burrowing Frog.
• **reduce the area of occupancy of an important population**
Giant Burrowing Frogs occupy habitat on first and second order streams at the upper reaches of the Hawkesbury-Nepean catchment and Sydney Basin. The Project may result in changes to the inundation levels during flood events. The Project is unlikely to reduce the area of occupancy of an important Giant Burrowing Frog population.
• **fragment an existing important population into two or more populations**
The Project may result in an expansion of the current inundation area of a major river and its tributaries. Giant Burrowing Frogs occupy habitat on first and second order streams and are capable of moving up to 300 metres into nearby vegetation for shelter outside the breeding season. The Project is unlikely to fragment any important populations of the Giant Burrowing Frog.
• **adversely affect habitat critical to the survival of a species**
No critical habitat has been declared for the Giant Burrowing Frog. The Project would not affect habitat critical to the survival of the Giant Burrowing Frog.

• **disrupt the breeding cycle of an important population**
The Giant Burrowing Frog is a long-lived species. Potential habitat for this species occurs within the upstream, construction and downstream areas. Giant Burrowing Frogs spend 95% of their time in non-breeding habitat, moving to breeding habitats in first and second order ephemeral streams in response to heavy rainfall. The Project may result in changes to the duration and extent of inundation during flooding events. These events have the potential to affect the lower elevations of Giant Burrowing Frog habitats, where tadpoles may be undergoing the final stages of development. As the majority of the life cycle of the Giant Burrowing Frog occurs beyond the reaches of the flood extent, the Project is unlikely to result in the decrease of an important population of Giant Burrowing Frog.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Giant Burrowing Frog usually breeds in ephemeral pools along first or second order streams and occupies vegetation surrounding these sites during non-breeding periods. Tadpoles complete development over periods of up to 12 months in more permanent pools that they are washed into after heavy rain. The majority of the study area does not support the lower order streams required for breeding and although there would be some modification of potential habitat, is unlikely to be to the extent that the Giant Burrowing Frog is likely to decline.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
Foxes and cats have been identified as potential threats to terrestrial amphibian species such as the Giant Burrowing Frog. These species are already present within the Project Area. Predation by the introduced Plague Minnow or Mosquito Fish *Gambusia holbrooki* is a recognised threat to the amphibians, however, habitat of the Giant Burrowing Frog does not usually support this species. The Project is unlikely to result in any additional invasive species that are harmful to the Giant Burrowing Frog becoming established in its habitat.
• **introduce disease that may cause the species to decline, or**
The chytrid fungus is a recognised threat to amphibians and has been identified as a 'moderate' threat to the Giant Burrowing Frog. A *Threat abatement plan for infection of amphibians with chytrid fungus resulting in chytridiomycosis* has been prepared (DoEE 2016). Throughout most of the study area, the Project is unlikely to introduce the chytrid fungus. Areas where construction activities are being undertaken may introduce disease to previously undisturbed habitat, which may result in the decline of the Giant Burrowing Frog through increased mortality following infection.
• **interfere substantially with the recovery of the species.**
No National recovery plan has been prepared for the Giant Burrowing Frog. One of the priority actions identified to aid in the recovery of this species is considered relevant to the Project; retain native vegetation and minimise ground disturbance where the species occurs, especially within 300 metres of known breeding sites. The Project is unlikely to substantially interfere with the recovery of the Giant Burrowing Frog.
Conclusion
The study area contains suitable non-breeding habitat for the Giant Burrowing Frog. The majority of habitat available for this species occurs on higher slopes outside the boundaries of the study area. The Project is unlikely to have a significant impact on the Giant Burrowing Frog.

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Heleioporus australiacus (giant burrowing frog) Approved Conservation Advice (2014)

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Hirundapus caudacutus (White-throated Needletail)

Vulnerable and Migratory under the EPBC Act

The White-throated Needletail is a migratory swift that breeds in north-east Asia and spends the non-breeding season (October – April) in eastern and south-eastern Australia (Higgins 1999). Whilst in Australia, the White-throated Needletail occurs most frequently in forested areas located along and east of the Great Dividing Range, where it is almost exclusively aerial (Commonwealth of Australia 2015). Large tracts of native vegetation, particularly forest, is considered a key habitat requirement (Commonwealth of Australia 2015). The White-throated Needletail also occurs over beaches, mudflats, open woodland and urban areas. A total of 10 individuals corresponds to an ecologically significant proportion of their population at the national scale, whilst a total of 100 individuals represents an internationally significant proportion of their population (Commonwealth of Australia 2015).

UPSTREAM/CONSTRUCTION

The White-throated Needletail is a relatively common summer/autumn visitor in the study area. Though there have been few observations of this species in the study area due to a lack of survey effort, this species is likely to forage above any part of the study area. No targeted White-throated Needletail surveys were conducted in the study area by SMEC.

The study area likely constitutes important White-throated Needletail habitat because the first of the following four important habitat criteria (Commonwealth of Australia 2013) is likely to be met:

- habitat utilised by a migratory species occasionally or periodically within a region that supports an ecologically significant proportion of the population of a species, and/or

  An ecologically significant proportion of their population (that is 10 individuals) is very likely to periodically use this heavily forested area each summer/autumn.

- habitat that is of critical importance to the species at particular life-cycle stages, and/or

  No critical habitat has been declared for this species.

- habitat utilised by a migratory species which is at the limit of the species' range, and/or

  The study area is not at the geographic limit of this species' distribution.

- habitat within an area where the species is declining.

  There is no evidence to suggest this species is declining in this area.

The 2019-2020 Burragorang Valley fires affected an estimated 3,423 hectares of suitable foraging and roosting habitat for the White-throated Needletail in the upstream study area. It is also likely to have affected the long-term availability of prey species through the loss of insects. The response of this species to fire is unknown. However, the White-throated Needletail is not on a list of animals requiring urgent management intervention as a result of the fires.

DOWNSTREAM

The White-throated Needletail is a common/uncommon summer/autumn visitor in the study area. This species is recorded each summer/autumn in small to large flocks across most of the study area. No targeted White-throated Needletail surveys were conducted in the study area by SMEC.

Although the study area is unlikely to support important White-throated Needletail habitat due to the lack of continuous forest, an ecologically significant proportion of their population is very likely to occasionally use the study area which meets the first of the following four important habitat criteria:

- habitat utilised by a migratory species occasionally or periodically within a region that supports an ecologically significant proportion of the population of a species, and/or

  An ecologically significant proportion of their population (that is 10 individuals) is very likely to periodically use this heavily forested area each summer/autumn.

- habitat that is of critical importance to the species at particular life-cycle stages, and/or

  No critical habitat has been declared for this species.

- habitat utilised by a migratory species which is at the limit of the species' range, and/or

The study area is not at the geographic limit of this species' distribution.

- habitat within an area where the species is declining.

  There is no evidence to suggest this species is declining in this area.

There is no National Recovery Plan or national guidelines for the White Throated Needletail. The Conservation Advice identifies broad habitat features across eastern Australia. The threats identified in the conservation advice include habitat loss, logging of breeding habitat, wind turbines and poisoning.

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 White-throated Needletail is a highly mobile, migratory species. No important populations have been declared for this species.
• **reduce the area of occupancy of an important population**
No important populations have been declared for this species.
• **fragment an existing important population into two or more populations**
No important populations have been declared for this species.
• **adversely affect habitat critical to the survival of a species**
No critical habitat has been declared for this species.
• **disrupt the breeding cycle of an important population**
No important populations have been declared for this species.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
UPSTREAM/CONSTRUCTION As an aerial species, foraging on the wing, it is assumed that all area may be appropriate habitat. An estimated 5,280 hectares of vegetation which comprises suitable aerial foraging habitat is located in the study area. It has been assumed that the Project would substantially modify or destroy about 1,400 hectares of forested habitat over which the Pacific Swift is likely to forage. However, the modification of such habitat is unlikely to translate to total loss of the suitability of this habitat for these aerial specialists but is likely to have a negative impact on prey availability (that is, habitat modification or loss of habitat for a forest dwelling bird corresponds to true or total loss, whereas for an aerial species total loss translates to a smaller overall, though still negative impact on the species) Inundation of forest and woodland in the impact area will substantially modify the structure and floristics of such habitat which is likely to have a negative impact on prey availability and hence, overall foraging habitat quality. DOWNSTREAM As an aerial species, foraging on the wing, it is assumed that all area may be appropriate habitat. An estimated 11,438 hectares habitat above which comprises suitable aerial foraging habitat is located in the study area, with an estimated 955 hectares located in the impact area. Alteration of the flow regime downstream of the Warragamba Dam is very unlikely to substantially modify (including by fragmenting, altering fire regimes, altering nutrient cycles or altering hydrological cycles), destroy or isolate an area of important White Throated Needletail habitat given that it is unlikely that the impact area supports important habitat for either of these species.

• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
UPSTREAM/CONSTRUCTION and DOWNSTREAM The Project is unlikely to result in an invasive species that is harmful to White-throated Needletail becoming established in an area of important White-throated Needletail habitat. No invasive species are known to affect the White-throated Needletail in Australia.
• **introduce disease that may cause the species to decline, or**
The Project is unlikely to introduce disease that may cause the White Throated Needletail to decline.
• **interfere substantially with the recovery of the species.**
A recovery plan has not been prepared for the White-throated Needletail and it is not recommended that one be prepared. It is considered that the Conservation Advice currently provides sufficient information to direct recovery. None of the priority actions identified in the Conservation Advice are considered relevant to the Project. UPSTREAM/CONSTRUCTION The Project is unlikely to seriously disrupt the lifecycle and therefore recovery of the White-throated Needletail's population. An ecologically significant proportion of the population of White-throated Needletail is likely to occur each year over the impact area and inundation of woodland and forest in this area is likely to reduce the availability of their key prey source (that is, insects). However, this is unlikely to seriously disrupt their foraging behaviour given: • the extent of forested habitat in the landscape surrounding the impact area. • loss of forest and woodland in the impact area will not render the airspace above such areas unsuitable for foraging swifts. DOWNSTREAM Alteration of the flow regime of the Hawkesbury-Nepean River is very unlikely to seriously disrupt the lifecycle or recovery of the White-throated Needletail's population given that minor changes to non-forested habitat is unlikely to have a significant impact on White-throated Needletail foraging overhead.
Conclusion
The Project is unlikely to have a significant impact on the White-throated Needletail.

References

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Hoplocephalus bungaroides (Broad-headed Snake)

Vulnerable under the EPBC Act

The Broad-headed Snake is a small to medium sized snake between 60 and 150 centimetres long. Snakes are black above with yellow spots that form irregular cross-bands that often link to form straight or zig-zagged stipes. The yellow cross-bands are a feature that distinguish the Broad-headed Snake from morphologically similar juvenile Diamond Pythons. The belly colour of the Broad-headed Snake is grey to greyish-black (DoEE 2014).

Broad-headed Snakes occur on exposed rocky terrain, typically sandstone outcrops and benches. The sandstone habitat is usually of Triassic or Permian origin, and from the Hawkesbury, Narrabeen and Shoalhaven groups (DoEE 2014; OEH 2017). In the summer, Broad-headed Snakes move from their sandstone habitat to shelter in tree hollows that occur within 500 metres. Snakes show preferences for large living and dead trees with multiple hollows (Webb and Shine 1997). Snakes spend up to 48 days in a single hollow (Webb and Shine 1997).

The Broad-headed Snake is endemic to eastern New South Wales. It has been recorded between Wollemi National Park to the north of its distribution, the Clyde River catchment in the south, Royal National park in the East, and Newnes Plateau to the west. The Broad-headed Snake is known to occur in the Blue Mountains National Park, Nattai National Park and Kanangra-Boyd National Park, each surrounding the upstream study area. Extensive sandstone habitat within the upstream study area occurs along the Warragamba Gorge, along the Coxs River, along the Kowmung River and in isolated occurrences along the Wollondilly and Nattai Rivers. Hollow-bearing tree habitat within 500 metres of the sandstone escarpment that surrounds Lake Burragorang is extensive throughout the upstream study area.

Vegetation associations with Broad-headed Snake habitat are variable. According to OEH's BioNet system, the Broad-headed Snake is associated with the following PCT mapped in the upstream study area:

- PCT 769 (HN517): Coachwood – Lilly Pilly warm temperate rainforest in moist sandstone gullies Sydney Basin Bioregion
- PCT 832 (HN525): Forest Red Gum – Narrow-leaved Ironbark open forest of the southern Blue Mountains gorges Sydney Basin Bioregion
- PCT 840 (HN527): Forest Red Gum – Yellow Box woodland of dry gorge slopes southern Sydney Basin Bioregion and South Eastern Highlands Bioregion
- PCT 860 (HN532): Grey Gum – Broad-leaved Ironbark dry open forest on gorge slopes on the Blue Mountains Sydney Basin Bioregion
- PCT 862 (HN533): Grey Gum – Hard-leaved Scribbly Gum woodland of the Cox River Valley
- PCT 870 (HN535): Grey Gum – Thin-leaved Stringybark grassy woodland of the southern Blue Mountains gorges Sydney Basin Bioregion.
- PCT 871 (HN536): Grey Gum shrubby open forest on gorge slopes of the Blue Mountains Sydney Basin Bioregion
- PCT 875 (HN537): Grey Myrtle – Lilly Pilly dry rainforest in dry gullies of the Sydney Basin Bioregion and South East Corner Bioregion
- PCT 941 (HN553): Mountain Blue Gum – Thin-leaved Stringybark open forest on river flat alluvium in the Sydney Basin Bioregion
- PCT 1081 (HN564): Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion
- PCT 1083 (HN566): Red Bloodwood – Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion
- PCT 1086 (HN568): Red Bloodwood – Sydney Peppermint – Blue-leaved Stringybark heathy forest of the southern Blue Mountains Sydney Basin Bioregion
- PCT 1105 (HN574): River Oak open forest of major streams Sydney Basin Bioregion and South East Corner Bioregion
- PCT 1246 (HN598): Sydney Peppermint – Grey Gum shrubby open forest of the western Blue Mountains Sydney Basin Bioregion
- PCT 1284 (HN606): Turpentine – Smooth-barked Apple moist shrubby forest of the lower Blue Mountains Sydney Basin Bioregion
- PCT 1292 (HN607): Water Gum – Coachwood riparian scrub along sandstone streams Sydney Basin Bioregion

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines an 'important population' of a Vulnerable species as being '*a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*

- *key source populations either for breeding or dispersal.*
- *populations that are necessary for maintaining genetic diversity.*
- *populations that are near the limit of the species range.*

It is difficult to estimate the size or extent of the Broad-headed Snake population. The lack of records does not mean the species is not widespread throughout the upstream study area as the remoteness of the area makes surveying difficult. Additionally, previous surveys for the species rarely located large numbers of individuals (Newell and Goldingay 2005), indicating that the species occurs at low densities. At a minimum, it is likely that the local population of the Broad-headed Snake consists of several hundred individuals due to the large area of potential and known habitat available.

Targeted surveys for the Broad-headed Snake were not undertaken throughout the upstream study area. In the absence of targeted surveys, the Broad-headed Snake has been assumed present in areas of suitable habitat – the previously listed PCTs. Using the precautionary principle, the population(s) residing within this habitat have been assessed as an important population(s) as they are key source populations for breeding and dispersal and are necessary for maintaining genetic diversity.

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 Project may impact up to an estimated 281 hectares of Broad-headed Snake habitat. Of this area, about 21 hectares would be impacted by the construction of the Project and up to an estimated 260 hectares may be impacted by the operation of the Project within the upstream study area. This may lead to a long-term decrease in the size of an important population of the Broad-headed Snake.
• **reduce the area of occupancy of an important population**
The Project may impact up to an estimated 281 hectares of potentially occupied habitat within the upstream and construction study areas. This may reduce the area of occupancy of an important population of the Broad-headed Snake.
• **fragment an existing important population into two or more populations**
The Broad-headed Snake population within the upstream and construction study areas are confined to sandstone terrain and the native vegetation within 500 metres of sandstone escarpments with hollow-bearing trees, rock crevices or flat sandstone rocks on exposed cliff edges and sandstone outcropping. This habitat occurs throughout both study areas. The original construction of Warragamba Dam and the formation of Lake Burragorang likely fragmented this population. The loss of native vegetation within these study areas would decrease the amount of habitat and increase the distances between that which remains. The Project has the potential to increase the fragmentation of the Broad-headed Snake habitat.
• **adversely affect habitat critical to the survival of a species**
According to the *Matters of National Environmental Significance Significant impact guidelines* 1.1 (DoE 2013) habitat critical to the survival of a species refers to areas that are necessary for: • activities such as foraging, breeding, roosting, or dispersal • 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 • the reintroduction of populations or recovery of the species or ecological community. The Broad-headed Snake habitat in the upstream study area has been assessed as critical habitat because it is important for foraging, breeding, the long-term maintenance of the species, and for maintaining genetic diversity.

The Project could adversely affect this habitat through the direct removal of vegetation, the flooding of sandstone terrain and the through erosion and deposition of this terrain.
• **disrupt the breeding cycle of an important population**
Broad-headed Snakes mate from Autumn to Spring with females giving birth – every second year – between April and January (Webb *et al.* 2002). Female snakes produce litters of between 4 and 12, with litters commonly including infertile oocytes or still-born offspring (Shine and Fitzgerald 1989). Compared to the size of the breeding females (50 to 70 centimetres long), offspring are exceptionally large (18-20 centimetres in length). Broad-headed Snakes grow very slowly with the time to maturity for male and female snakes, 5 and 6 years respectively (Webb *et al.* 2003). Low feeding frequencies have been postulated as a reason for slow growth-rates and long times to maturity. Juvenile snakes to not disperse long distances from their place of birth – the greatest distance a 6-month-old snake has been recorded from its place of birth is 375 metres (Webb and Shine 1997). Broad-headed Snakes in general have a high degree of site fidelity. Individual snakes have been recorded returning to the same area of woodland each year, with some individuals even being recaptured under the same rock each year (Webb and Shine 1997). The Project would likely disrupt the breeding cycle of the Broad-headed Snake population. Sandstone shelter and breeding habitat would be flooded preventing snakes from breeding, and displacing – most likely killing – both adult and juveniles. Due to snakes' high site fidelity and juveniles' tendency not to move far from their nests, the impact flooding becomes greater as snakes may not be able to adapt and move from their modified habitat. A large amount of summer tree-hollow sheltering habitat would be impacted by the Project. The disruption of this habitat would also disrupt the breeding cycle of the Broad-headed Snake.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project may impact up to an estimated 281 hectares of potentially occupied habitat within the upstream and construction study areas. Habitat would be destroyed and/or directly impacted through the clearing of native vegetation, the loss of flora and fauna habitat, and a reduction in the extent of ecological communities. Habitat would be indirectly impacted (modified, reduced in quality etc.) through fragmentation, alteration to soil conditions, edge effects, erosion and sedimentation, and thorough changes to the fire regime.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
Invasive fauna have been identified as a threat to the Broad-headed Snake in its SPRAT profile and OEH Threatened Species Profile. Specifically, foxes and cats are listed as predators of the Broad-headed Snake, and feral goats have been identified as disturbing habitat (OEH 2017; DoEE 2019). All three fauna were observed in the upstream study area however it is uncertain if the Project would promote their spread and establishment within Broad-headed Snake Habitat.
• **introduce disease that may cause the species to decline, or**
No diseases have been identified as a threat to the Broad-headed Snake.
• **interfere substantially with the recovery of the species.**
A recovery plan for the Broad-headed Snake has not been prepared. The Broad-headed Snake SPRAT profile however, does recognise the need for a national recovery plan. The Approved Conservation Advice for the Broad-headed Snake does outline both regional and local priority actions. The Project interferes with the following priority actions: *Regional Priority Actions* • Ensure there is no disturbance in areas where the Broad-headed Snake occurs, excluding necessary actions to manage the conservation of the species. • Develop and implement a suitable fire management strategy for habitat of the Broad-headed Snake. • Investigate options for linking, enhancing or establishing additional populations.

Local Priority Actions

- Undertake survey work in suitable habitat and potential habitat to locate any additional populations/occurrences/remnants.
- Restore rocky habitat to escarpments that have been disturbed.
- Retain woodland adjacent to sandstone escarpments, particularly large hollow-bearing trees.

In addition to the national recovery plan, a targeted strategy for managing the Broad-headed Snake has been developed under the NSW Government's Saving Our Species Program. Under the Saving Our Species Program, the Broad-headed Snake has been assigned to the 'site-managed species' management stream. The following 3 priority management sites have been identified for this species:

- Royal National Park in the Sutherland Shire and Wollongong LGAs.
- Woronora Plateau in the Campbelltown, Shellharbour, Sutherland Shire, Wingecarribee, Wollondilly and Wollongong LGAs.
- Morton National Park in the Shoalhaven LGA.

The Project would not impact any of the listed priority management sites.

Conclusion

The Project may impact up to an estimated 281 hectares of potentially occupied habitat within the upstream and construction study areas. This habitat may become fragmented along the edges of Lake Burragorang and the waterways that feed into it, further isolating occurrences of the Broad-headed Snake from one another. The Project may impact the breeding cycle of the Broad-headed Snake by clearing native vegetation (habitat), modifying the fire regime, modifying the hydrological environment and through erosion and deposition within habitat. These impacts may cause a decline of important population of the Broad-headed Snake. The Project has therefore been assessed as having a significant impact.

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Isoodon obesulus obesulus (Southern Brown Bandicoot)

Endangered under the EPBC Act

The Southern Brown Bandicoot is a medium-sized (averaging 850 g for males and 700 g for females) ground-dwelling marsupial. It has a very patchy distribution in south-eastern Australia (NSW, Victoria, South Australia) (Braithwaite 1995). Populations are highly disjunct and the effective female population sizes are small (Zenger *et al.* 2005). There appears to have been natural disjunctions in the species' distribution prior to European land clearing resulting from the patchy intersection of suitable habitat and suitable climate (Paull *et al.* 2013). The ecology of the Southern Brown Bandicoot is poorly described and many of the studies that have been conducted have not been published (that is, theses and departmental reports).

The Southern Brown Bandicoot occupies a variety of habitat types, including heathland, shrubland, sedgeland, heathy open forest and woodland. While they occur on a range of soil types, well-drained, infertile sandy soils are preferred (NSW DEC 2006). Vegetation structure, particularly the density of the understorey, appears to be more influential than floristics in determining Southern Brown Bandicoot abundance (Brown and Main 2010; Claridge and Barry 2000; Claridge *et al.* 1991; Lobert 1990). Preferred micro-habitats consist of dense understorey vegetation structure with 50–80% average foliage density in the 0.2–1 m height range. This may include exotic vegetation dominated by, for example, blackberry (*Rubus* spp.) (DSEWPaC 2011). Shelter and nesting sites are provided by dense vegetation, Xanthorrhoea skirts, logs, rocks and burrows (Brown and Main 2010). Preferred habitats appear to be early successional communities following fire (Braithwaite and Gullan 1978; Braithwaite 1995). It is not listed as a priority species for management intervention following the 2019/20 fires (Department of Agriculture, Water and the Environment 2020). The Southern Brown Bandicoot (eastern) is an opportunistic omnivore that forages on foods including invertebrates (mainly insects; also earthworms and other invertebrates), seeds, plant material and fungi (Stoddart and Braithwaite 1979; Lee and Cockburn 1985; Claridge *et al.* 1991). The diet shows some seasonal variation depending on food availability.

In one study (Stoddart and Braithwaite 1979), the natality rate (annual births per female) averaged 8.27 and heavier females had larger litters. Breeding was seasonally predictable and synchronous among the population. However, juvenile recruitment was low (12 – 18%). While the overall population was fairly constant, there was a high level of dispersal and transience, which may be an adaption to ephemeral habitats (Cockburn 1990). However, Li (2013) found restricted gene flow between patches indicative of poor dispersal ability, which increased in more modified environments.

Thus, populations of the Southern Brown Bandicoot appear to exhibit a high mortality rate, a high rate of dispersal and/or impermanent home-ranges. There was evidence of habitat partitioning within the population. While all age/sex classes used regenerating heathland, this was more pronounced for juveniles of both sexes, young adult females and large, old males. Middle-aged individuals expanded their movement areas to include more mature vegetation. Population density in Western Australian was estimated to be 1.24 – 1.45 per hectare, which was considered high (Pentland 1999). There appears to be no other density estimates (Department of Environment and Conservation 2006; Brown and Main 2010). Home-ranges vary from 0.5 – 9.5 hectares (Lobert 1990; Brown and Main 2010; Robinson *et al.* 2018).

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

There is one record of the Southern Brown Bandicoot within the Project Area. While occupied habitat is expected to be patchy (due to the requirement for heathy understories, dense understorey vegetation and early successional stage habitat), this is also likely to reflect a low survey effort. Similarly, however, there are few records elsewhere in the Blue Mountains. PCTs with heathy understorey within the Project Area are assumed to be potential habitat.

As the population density and variation in density of the Southern Brown Bandicoot is poorly described, it is not clear what population densities would be present in the Project Area and how this would vary with the successional stage of the local vegetation. This confounds any meaningful attempt at estimating local population sizes and, therefore, this has not been attempted. There is an estimated 4,808 hectares of potential habitat available, most of which (4,346 hectares) is upstream (refer following table). The likelihood of the species occurring in the construction footprint is low, so these areas have not been included. An estimated 2,401 hectares of potential habitat could be impacted by the Project. Thus, at least several hundred bandicoots may be affected.

Area of Southern Brown Bandicoot habitat, area of suitable habitat impacted, estimated total population in area, number (%) impacted

Project study area	Total area (ha)	Area impacted (ha)	Estimated total population	No. Impacted
Upstream	4,346	2,389	-	-
Construction	25	12[1]	-	-
Downstream	438	0	0	0
Total	4,809	2,401	-	-

1 construction area much smaller than home-range area or 2) not susceptible to the impacts.

The likely impact (including direct and indirect impacts) that the development will have on the habitat of the local population

The Project could potentially remove living habitat (foraging and shelter) within the Project study area. Inundation could potentially remove cover, foraging resources and shelter sites required by the Southern Brown Bandicoot.

The construction would remove foraging habitat. Noise and vibration are indirect impacts that may extend for several hundred metres around the construction area. Erosion and sedimentation weed invasion and chemical spills also have the potential to affect habitat quality. Vehicle movements in and out of the construction area also pose a risk of mortality due to vehicle strike.

Habitat for the Southern Brown Bandicoot is more limited in downstream area. Downstream impacts are likely to be minor as it is not dependent on wetlands and flood regimes.

The likely impact on the ecology of the local population

The main potential impact on the local Southern Brown Bandicoot population may be the linear reduction in population size due to potential habitat loss resulting in the loss of foraging resources and the loss of shelter sites. As the most productive habitat (greater food availability, greater vegetative cover) is likely to be on the lower slopes of the catchment, a high proportion of the local population could potentially be affected. Habitat loss could increase population fragmentation by increasing the distance between habitat patches. This may make some populations vulnerable to local extinction.

The relationship of the local population to other populations of the species

On one hand there is a large amount of continuous native vegetation in the locality. However, suitable habitat, including appropriate successional stages, is likely to be restricted and patchy. Thus, there may potentially be more than one local Southern Brown Bandicoot population in the Project study area. These populations are likely to be disjunction from other populations in the locality. However, at least some local populations would be connected by dispersal and one or more metapopulations may be present. There is likely to be shifts in the distribution of populations over time, with the loss of suitable habitat being offset by the availability of more preferred habitat (for example, post-fire succession).

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

Recognised threats to the Southern Brown Bandicoot are:

- Introduced predators (Red Fox, Dogs, Feral Cats)
- Habitat loss and modification (for example, grazing, inappropriate fire regimes)
- Habitat fragmentation resulting in the isolation of populations
- Inappropriate fire regimes, though the response to fire is poorly known
- Logging
- Vehicle strike causing death
- Increased risk of local extinction inherent to small populations (see Clark *et al.* 1990).

Of these known threats, habitat loss and fragmentation and road mortality are likely to be direct Project impacts. Fragmentation may indirectly cause an increase in predation as predators may have greater access to the remaining habitat due to the creation of new roads and other clearing (for example, Catling and Burt 1995; Lunney *et al.* 2007).

Given the uncertainty regarding the distribution and size of the local Southern Brown Bandicoot population(s), it is difficult to predict what impact the Project could have on this species. However, the precautionary principle suggests that a potential adverse impact should be assumed and it is, therefore, the Project could potentially lead to a decrease in the viability of the local Southern Brown Bandicoot metapopulation.

The measure/s proposed to contribute to the recovery of the species

The potential impacts of the Project on the Southern Brown Bandicoot would be linked to habitat loss and fragmentation associated with a larger inundation area. This could remove foraging resources and some shelter sites and result in a reduced size of the local population. Because the most productive habitat is likely to be on the lower slopes nearer the existing lake, the loss of habitat may have a significant impact on the population viability of this species. No specific measures within the Project study area are proposed that would contribute to the recovery of the Southern Brown Bandicoot. However, general habitat offsets would benefit the Southern Brown Bandicoot by securing suitable habitat in other locations. Offsetting would be required to compensate for Project impacts. The Project study area is not known to currently support the Southern Brown Bandicoot (Brown and Main 2010), however, there is a Bionet in the catchment. However, the dam catchment is unlikely to have been adequately surveyed and its isolation suggests that opportunistic observations (for example, road kill) are unlikely. Suitable habitat is present in the Project study area and it is likely to support a small and patchily distributed meta-population of the Southern Brown Bandicoot. Thus, the presence of the Southern Brown Bandicoot is assumed on a precautionary basis.

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**
While there is up to an estimated 4,809 hectares of habitat available in the Project study area, there is considerable uncertainty regarding the distribution and abundance of the Southern Brown Bandicoot in the Project study area due to the difficulty of accurate habitat mapping (including post-fire successional habitat) and published information on the range of possible population densities. Therefore, it is not possible to provide a meaningful population estimate for this species. However, the most productive habitat (greater food availability, greater vegetative cover) is likely to be on the lower slopes of the catchment, suggesting a significant proportion of the local population is likely to be affected by the Project upstream. The small area of habitat within the construction area is not likely to be significant. The Southern Brown Bandicoot is not dependent on wetlands and other habitats that would be sensitive to changes in hydrological regimes, therefore, downstream impacts are not expected. Given the large area of habitat potentially affected upstream, there is potential for the Project to lead to a long-term decrease in the size of the Southern Brown Bandicoot populations associated with the upstream study area.
• **reduce the area of occupancy of a species**
While the Project may result in the loss of individual Southern Brown Bandicoots, the Project study area is embedded within a landscape containing thousands of hectares of habitat. While the Southern Brown Bandicoot would be patchily distributed through this area, habitat would remain in all directions around the Project Area. The Project is not likely to reduce the area of occupancy of the Southern Brown Bandicoot.
• **fragment an existing population into two or more populations**
The Project may result in an expansion of the current inundation area. It was suggested above that a significant proportion of the Southern Brown Bandicoot population could occur along the lower slopes where productivity is higher. The removal of lower slope habitat and the loss of at least some sub-populations would increase the distances between remaining populations. If the increased distances are greater than the dispersal ability of the Southern Brown Bandicoot, then population fragmentation may occur. The Project has the potential to fragment existing populations of the Southern Brown Bandicoot into two or more populations.

• adversely affect habitat critical to the survival of a species
Habitat critical to the survival of the Southern Brown Bandicoot has not been defined (Brown and Main 2010; DEC 2006). The Project Area provides habitat that is likely to be classified as critical to the survival of the Southern Brown Bandicoot. Up to an estimated 2,401 hectares of habitat could potentially be affected by inundation effects upstream and in the construction area. Although no critical habitat has been defined for this species, the Project could potentially adversely affect habitat critical to the survival of the Southern Brown Bandicoot.
• disrupt the breeding cycle of a population
Upstream, the Project may remove Southern Brown Bandicoot habitat and reduce population size, but it is not likely to impact on the breeding of any remaining females. Downstream, no Project impacts are likely. A small area of habitat occurs within the construction area. While some removal of habitat could occur here, indirect Project impacts, such as noise and vibration, may disrupt breeding by females whose home-ranges abut the construction area. These impacts would be confined to the construction phase. The Project could potentially affect the breeding cycle of the Southern Brown Bandicoot in the construction area.
• modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline
The area of habitat that may be removed by the Project surrounds the existing inundation area. This potential loss of habitat may increase the distances between remaining habitat patches and this may be substantial enough to cause the isolation of at least some remaining populations. It is not clear how many Southern Brown Bandicoots occur in the Project study area and how many of these would be affected by upstream habitat loss. Given that the Southern Brown Bandicoot has an extensive distribution in southern Australia and that there is considerable existing population subdivision across the species' range, it is unlikely that this would cause the species to decline. However, the local extinction of some populations upstream is possible. The Project may cause the local extinction of some populations upstream, resulting in the increased isolation of some remaining populations. However, this is not expected to affect the species to the extent it is likely to decline.
• result in invasive species that are harmful to an endangered or critically endangered species becoming established in the endangered or critically endangered species' habitat
Invasive species, such as the feral cat, European Red Fox and wild dog, are known threats to the Southern Brown Bandicoot. They are already present in the study area. The Project would not cause the establishment of any new invasive species. The Project is unlikely to result in an invasive species that is harmful to the Southern Brown Bandicoot becoming established in its habitat.
• introduce disease that may cause the species to decline, or
No diseases are known to affect the Southern Brown Bandicoot. The Project is unlikely to introduce disease with potential to cause the Southern Brown Bandicoot to decline.
• interfere substantially with the recovery of the species.
The draft National Recovery Plan for the Southern Brown Bandicoot (Brown and Main 2010) describes the following recovery objectives: • Protect and manage existing populations and their habitat • Identify threats and threat abatement strategies (for example, reduce mortality) • Determine the distribution, abundance and population structure • Identify key habitat attributes, including fire succession • Build organisational support to facilitate recovery

- Manage and review recovery plan implementation
- Promote public awareness of the recovery program
- Assess need to captive populations.

The Project could remove potential Southern Brown Bandicoot habitat. However, given the uncertainty regarding the size of the local population, it is unlikely that the Project would substantially interfere with the recovery of the Southern Brown Bandicoot.

The Project is unlikely to interfere with the recovery of the Southern Brown Bandicoot.

Conclusion
The Project study area contains potential habitat for the Southern Brown Bandicoot. While the area is not currently known to support the species (Brown and Main 2010), it is conservatively assumed to be presence, though it is not possible to predict the size of the affected population and the extent to which it would be affected by upstream habitat loss. Therefore, on a precautionary basis, the Project is considered to have the potential to have a significant impact on the Southern Brown Bandicoot.

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Lathamus discolour (Swift Parrot)

Critically Endangered under the EPBC Act

The Swift Parrot is listed as critically endangered under the EPBC Act and endangered under the BC Act 2016. The Swift Parrot breeds in Tasmania each summer and overwinters in temperate woodlands and forests in south-eastern Australia, where it forages on eucalypt nectar, pollen and insects (Higgins 1999). The Swift Parrot is partly nomadic whilst wintering in NSW as it is dependent on highly spatially and temporally variable flowering resources which are distributed across a wide range of habitats (Higgins 1999). As a result, the abundance of Swift Parrot in NSW fluctuates between years and regions however a number of key sites are known to be used repeatedly each non-breeding season (Saunders and Heinsohn 2008). Key foraging tree species of the inland slopes and plains include Yellow Gum (*E. leucoxylon*), Red Ironbark (*E. tricarpa*), Mugga Ironbark (*E. sideroxylon*), Grey Box (*E. cuminate*), White Box (*E. albens*), and Yellow Box (*E. melliodora*) (Saunders and Tzaros 2011). Key foraging tree species along and east of the Great Dividing Range include Swamp Mahogany (*E. robusta*), Forest Red Gum (*E. tereticornis*), Blackbutt (*E. sieberi*) and Spotted Gum (*Corymbia cuminat*) (Saunders and Tzaros 2011). The Swift Parrot has undergone a severe decline driven primarily by loss of breeding habitat and nest predation by an introduced mammal (Stojanovic *et al.* 2014, Saunders and Tzaros 2011). The chief threat in their wintering range is the loss and degradation of wintering foraging habitat (Saunders and Tzaros 2011).

UPSTREAM/CONSTRUCTION

The Swift Parrot is likely an uncommon autumn to spring visitor in the study area. The study area supports a large area of continuous forest and woodland and the Swift Parrot may occur at any location in this area, which supports key winter flowering eucalypts. The 2019-2020 Burragorang Valley fires affected winter foraging habitat for the Swift Parrot, including an estimated 3,377 hectares of habitat in the upstream study area. Some suitable habitat in the south of the study area remains unburnt and may provide important foraging habitat as other areas regenerate. The Swift Parrot has been recorded in the Wollondilly River area, in the Nattai River area and on the south-west bank of Lake Burragorang. The abundance and distribution of Swift Parrot in the study area is poorly understood as very little survey work has been undertaken in this area.

No targeted Swift Parrot surveys were conducted in the study area by SMEC, however, it would be expected that surveys undertaken to target the Regent Honeyeater were suitable to detect this species. In all other areas of suitable habitat, occasional presence is assumed.

DOWNSTREAM

The Swift Parrot is a rare visitor in the study area. It has been recorded occasionally in the study area between Cattai and Emu Plains but is generally more commonly recorded at locations adjacent to the study area such as Scheyville National Park, Mulgoa Nature Reserve and Kurrajong.

No targeted Swift Parrot surveys were conducted in the study area by SMEC.

For this assessment, it assumed that the Swift Parrot is present in any suitable habitat (as determined by the TBDC, records and other scientific literature) that occurs within its geographical range. Suitable habitat includes areas that have been mapped as the following PCTs:

- 724: Broad-leaved Ironbark – Grey Box – *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain Sydney Basin Bioregion
- 725: Broad-leaved Ironbark – *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain Sydney Basin Bioregion
- 830: Forest Red Gum – Grey Box shrubby woodland on shale of the southern Cumberland Plain Sydney Basin Bioregion
- 835: Forest Red Gum – Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain Sydney Basin Bioregion
- 849: Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain Sydney Basin Bioregion
- 850: Grey Box – Forest Red Gum grassy woodland on shale of the southern Cumberland Plain Sydney Basin Bioregion
- 877: Grey Myrtle dry rainforest of the Sydney Basin Bioregion and South East Corner Bioregion
- 883: Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain Sydney Basin Bioregion

- 958: Narrow-leaved Apple – Hard-leaved Scribbly Gum heathy woodland on sand at Agnes Banks Sydney Basin Bioregion
- 1395: Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain Sydney Basin Bioregion
- 1067: Parramatta Red Gum woodland on moist alluvium of the Cumberland Plain Sydney Basin Bioregion
- 1081: Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion
- 1557: Rough-barked Apple – Forest Oak – Grey Gum grassy woodland on sandstone ranges of the Sydney Basin
- 1385: Rough-barked Apple – Grey Gum grassy open forest of the hinterland hills of the Central Coast Sydney Basin Bioregion
- 1181: Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney Basin Bioregion
- 1183: Smooth-barked Apple – Sydney Peppermint – Turpentine heathy open forest on plateaux areas of the Sydney Basin Bioregion
- 1718: Swamp Mahogany – Flax-leaved Paperbark swamp forest on coastal lowlands of the Central Coast
- 1504: Sydney Blue Gum – Deane's Gum – River Peppermint shrubby riparian tall forest of the lower Colo River Sydney Basin Bioregion
- 1284: Turpentine – Smooth-barked Apple moist shrubby forest of the lower Blue Mountains Sydney Basin Bioregion
- 1327: Yellow Bloodwood – ironbark shrubby woodland of the dry hinterland of the Central Coast Sydney Basin Bioregion
- 1328: Yellow Bloodwood – Narrow-leaved Apple heathy woodland on hinterland plateaux of the Central Coast Sydney Basin Bioregion
- 832: Forest Red Gum – Narrow-leaved Ironbark open forest of the southern Blue Mountains gorges Sydney Basin Bioregion (BVT: HN525)
- 840: Forest Red Gum – Yellow Box woodland of dry gorge slopes southern Sydney Basin Bioregion and South Eastern Highlands Bioregion (BVT: HN527)
- 860: Grey Gum – Broad-leaved Ironbark dry open forest on gorge slopes on the Blue Mountains Sydney Basin Bioregion (BVT: HN532)
- 862: Grey Gum – Hard Leaved Scribbly Gum woodland of the Cox River Valley (BVT: HN533)
- 870: Grey Gum – Thin-leaved Stringybark grassy woodland of the southern Blue Mountain gorges Sydney Basin Bioregion (BVT: HN535)
- 871: Grey Gum shrubby open forest on gorge slopes of the Blue Mountains Sydney Basin Bioregion (BVT: HN536)
- 941: Mountain Blue Gum – Thin-leaved Stringybark open forest on river flat alluvium in the Sydney Basin Bioregion (BVT: HN553)
- 1401: Narrow-leaved Ironbark – Forest Red Gum on rocky slopes of the lower Burragorang Gorge Sydney Basin Bioregion (BVT: HN557)
- 1083: Red bloodwood – scribbly gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion (BVT: HN566)
- 1086: Red Bloodwood – Sydney Peppermint – Blue-leaved Stringybark heathy forest of the southern Blue Mountains Sydney Basin Bioregion (BVT: HN568)
- 1105: River Oak open forest of major streams Sydney Basin Bioregion and South East Corner Bioregion (BVT: HN574)
- 1281: Turpentine – Grey Ironbark open forest on shale in the lower Blue Mountains Sydney Basin Bioregion (BVT: HN604).

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 of a population**
UPSTREAM/CONSTRUCTION   An estimated 5,118 hectares of suitable or potential habitat is present in the upstream study area. It has been assumed that the Project will modify, destroy, remove or decrease the availability or quality of habitat of 1,400 hectares of suitable or potential foraging habitat. The Project is likely to significantly reduce the availability of Swift Parrot foraging habitat in the Lake Burragorang area. However, this loss of habitat is unlikely to lead to a long-term decline of Swift Parrot given that this area of habitat alone is unlikely to be critical to the survival of wintering individuals present in the region.   DOWNSTREAM   Little suitable foraging habitat is likely to be adversely impacted by the Project. An estimated 9,039 hectares of suitable or potential habitat is present in the study area. The Project will likely modify, destroy, remove or decrease the availability or quality of habitat of up to an estimated 761 hectares of suitable or potential foraging habitat. Given the nature of the predicted impact of the Project (that is, the alteration of the Nepean-Hawkesbury River flooding regime downstream of Warragamba Dam) it is unlikely that the proposed action will lead to a long-term decrease in the Swift Parrot's population size.
• **reduce the area of occupancy of the species**
UPSTREAM/CONSTRUCTION   It has been assumed that the Project will reduce the availability of 1,400 hectares of suitable or potential foraging habitat. Hence, the area of occupancy of the Swift Parrot would be reduced by about 27%.   DOWNSTREAM   The Project is unlikely to reduce the area of occupancy of the Swift Parrot significantly notwithstanding that up to an estimated 761 hectares of mapped suitable foraging habitat is likely to be lost or degraded by the alteration of the flow regime of the Hawkesbury-Nepean River.
• **fragment an existing population into two or more populations**
UPSTREAM/CONSTRUCTION   The loss and degradation of suitable and potential foraging habitat in the impact area may increase habitat fragmentation however this is unlikely to result in a loss of true habitat connectivity given the Swift Parrot's high mobility. Hence, it is unlikely that an existing population of Swift Parrots will become fragmented into two or more populations.   DOWNSTREAM   The Project is unlikely to fragment an existing Swift Parrot population into two or more populations given the high mobility of this species and the absence of any suitable habitat in the impact area.
• **adversely affect habitat critical to the survival of a species**
Habitat critical to the survival of the Swift Parrot has been identified as; 'those areas of priority habitat for which the Swift Parrot has a level of site fidelity or possess phenological characteristics likely to be of importance to the Swift Parrot or are otherwise identified by the recovery team' (Saunders and Tzaros 2011). No areas of critical habitat have been declared for this species.
• **disrupt the breeding cycle of a population**
UPSTREAM/CONSTRUCTION   The Project is unlikely to disrupt the breeding cycle of a population of Swift Parrot given that breeding habitat is restricted to Tasmania.

DOWNSTREAM The Project is unlikely to disrupt the breeding cycle of a population of Swift Parrot given that breeding habitat is restricted to Tasmania.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
UPSTREAM/CONSTRUCTION An estimated 5,118 hectares of suitable habitat is present in the study area. It has been assumed that the Project will modify, destroy, remove or decrease the availability or quality of habitat of 1,400 hectares of suitable or potential foraging habitat. Although the loss or degradation of the habitat in this area alone is unlikely to cause the species to decline this action does constitute a key threat for this species. DOWNSTREAM An estimated 9,039 hectares of suitable or potential habitat is present in the study area, of which an estimated 761 hectares is located in the impact area. However, due to the likely impact of the alteration of the flow regime of the Hawkesbury-Nepean River on forested or wooded habitat it is unlikely that the Project will modify, destroy, remove or isolate or decrease habitat availability or quality to the extent that the Swift Parrot is likely to decline.
• **result in invasive species that are harmful to an endangered or critically endangered species becoming established in the endangered or critically endangered species' habitat**
Feral cats are recognised as a threat to the Swift Parrot, and the species is acknowledged in the Threat abatement plan for predation by feral cats (DoE 2015). Feral cats are known to be present in the upstream, construction and downstream study areas. The Project is unlikely to result in invasive species that are harmful to the Swift Parrot becoming established in Swift Parrot habitat..
• **introduce disease that may cause the species to decline**
Psittacine Beak and Feather Disease (PBFD) is a common and potentially deadly disease of parrots that could affect Swift Parrots with a reduced general health from stress associated with competition for nesting and food resources (Saunders and Tzaros 2011). The Project is unlikely to introduce PBFD or any other disease that may cause the Swift Parrot to decline
• **interfere substantially with the recovery of the species**
A National Recovery Plan has been prepared for the Swift Parrot (Saunders and Tzaros 2011). One of the recovery actions is considered relevant to the proposal; manage and protect Swift Parrot habitat at the landscape scale. UPSTREAM/CONSTRUCTION Habitat loss and degradation constitutes a key threat to the Swift Parrot. Given the extensive area of habitat affected, the Project may interfere substantially with the recovery of the species. DOWNSTREAM Habitat loss and degradation is a key threat; however, no suitable habitat will be impacted by the Project

Conclusion
UPSTREAM/CONSTRUCTION The Project would cause the loss of a large area of suitable foraging habitat for the Swift Parrot. The spatial and temporal patterns of usage of the study area by the Swift Parrot are unknown. Given the large area of potential impact, the pre-cautionary principle suggests that a significant impact should be assumed in the absence of adequate information regarding actual impacts on this species. DOWNSTREAM The Project is unlikely to have a significant impact on the Swift Parrot.

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Litoria aurea (Green and Golden Bell Frog)

Vulnerable under the EPBC Act

The Green and Golden Bell Frog is an endemic Australian tree frog that is a member of the family Hylidae. Broadly, the species has been previously recorded as far as Yuraygir National Park on the North Coast of NSW to around Lakes Entrance in south-eastern Victoria (White and Pyke 2008). Breeding sites for the Green and Golden Bell Frog include a wide variety of natural waterbodies except fast flowing streams (White and Pyke 1996). It has been found they tend to prefer to breed in waterbodies that are still, shallow, ephemeral, unshaded, with aquatic plants and free of the Plague Minnow (*Gambusia holbrooki*) and other predatory fish (White and Pyke 1996). Breeding habitat also includes many human-created environments, including highly disturbed sites such as abandoned mines and quarries (Pyke *et al.* 2002) as well as artificial wetlands (Hamer *et al.* 2002; Darcovich and O'Meara 2008). Non-breeding habitat for the Green and Golden Bell Frog appears to be within 50 metres of waterbodies as the species is not found to disperse away from waterbodies into more terrestrial non-breeding habitats (100-300 metres from the breeding site) such that is the case for other Australian frog species (Lemckert 2004).

The Green and Golden Bell Frog was not recorded during the surveys undertaken for this assessment. There are historical records of the species from Longneck Lagoon and Pitt Town Nature Reserve. It is assumed the Green and Golden Bell Frog could occupy any suitable habitat within five kilometres of known records, as per the downstream BAR methodology. An estimated 7,225 hectares of potential habitat occurs in the downstream study area.

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**
Given the scarce number of known Green and Golden Bell Frog breeding sites, any population present within the Project Area would be considered important. The Green and Golden Bell Frog is considered highly dependent on its breeding sites for long term survival at the various remnant population sites (NPWS 2002). The species is known to be highly fecund (5000+ eggs/spawn mass) with tadpoles developing over an approximate three month period (depending on prevailing conditions) (NPWS 2002). Some ephemeral breeding locations are prone to drying out before tadpoles have reached metamorphosis which is considered critical for some remnant populations (NPWS 2002). Metamorphlings are highly susceptible to predation (NPWS 2002). The key impact for this species as a result of the Project is the predicted reduction of flooding extent. Should this occur in key breeding areas for Green and Golden Bell Frog it is likely that this would disrupt the life cycle. This is because the species is highly dependent on waterbodies (natural and artificial) for breeding and persisting, of which this habitat will be reduced. Within the study area, the species has historically been recorded in wetland habitats that will be subject to longer inundation and potential dry periods. It is not known how this may affect the life cycle of the Green and Golden Bell Frog specifically, but it could have negative implications for spread of *Gambusia holbrooki* and chytrid fungus – both of which are current known threats to the Green and Golden Bell Frog. As a result, the Project has the potential to lead to long-term decrease in an important population of Green and Golden Bell Frogs.
• **reduce the area of occupancy of an important population**
Suitable habitat for the Green and Golden Bell Frog occurs across the downstream study area and the species is distributed along much of the NSW coast. The area of occupancy of the species is unlikely to be reduced by the Project.
• **fragment an existing important population into two or more populations**
A reduction in peak flood extents and durations and a reduction in peak flood flows in the 10% AEP event may cause fragmentation of Green and Golden Bell Frog habitat. As the species does not tend to disperse far from its breeding or non-breeding habitat, this fragmentation may lead to isolation from other areas of Green and Golden Bell Frog habitat. While the Green and Golden Bell Frog has undergone considerable fragmentation of its once almost continuous state-wide distribution, most remaining populations are isolated by large distances and

therefore are assumed to have a restricted gene flow between them (NPWS 2002). The risk of fragmentation therefore presents a real threat the long-term survival of the species in the locality.
• **adversely affect habitat critical to the survival of a species**
No critical habitat has been declared for the Green and Golden Bell Frog. The Project is unlikely to affect habitat critical to the survival of the Green and Golden Bell Frog.
• **disrupt the breeding cycle of an important population**
Key breeding areas for Green and Golden Bell Frog could be disrupted by changes to the predicted reduction of flooding extent. This is because the species is highly dependent on waterbodies (natural and artificial) for breeding and persisting, of which this habitat may be reduced. Within the study area, the species has historically been recorded in wetland habitats that may be subject to longer inundation and potential dry periods and the effect of these changes is unknown. In addition, the breeding cycle could be disrupted by the presence of chytrid fungus and increased predation by *Gambusia holbrooki*.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
Habitat where the Green and Golden Bell Frog has been recorded is considered likely to represent 'important' habitat within the locality. This is because the species has undergone a reduction in range and population declines in recent times (Mahony 1996). A reduction in peak flood extents and durations is expected to have a high risk for wetland and floodplain vegetation communities and habitats thereby resulting in either loss or modification of these habitats. Up to an estimated 585 hectares of suitable habitat in the downstream study area is expected to be impacted by the proposal. The potential loss or modification of suitable Green and Golden Bell Frog habitat may result in a decline of the species.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
Predation by the introduced Plague Minnow or Mosquito Fish *Gambusia holbrooki* is a recognised threat to the Green and Golden Bell Frog. *G. holbrooki* is already present in the study area, however, changes to inundation periods as a result of the Project could aid the spread of this invasive species. The Project is unlikely to result in the introduction of any new invasive species that is harmful to the Green and Golden Bell Frog becoming established in the downstream study area. However, it may increase the distribution of *G. holbrooki* across the study area, resulting in the spread of the species to previously unoccupied Green and Golden Bell Frog habitat.
• **introduce disease that may cause the species to decline, or**
The chytrid fungus is a recognised threat to amphibians and has been identified as a 'lower-moderate' threat to the Green and Golden Bell Frog. A *Threat abatement plan for infection of amphibians with chytrid fungus resulting in chytridiomycosis* has been prepared (DoE 2016). The Project is unlikely to introduce the chytrid fungus to the study area, which may result in the decline of the Green and Golden Bell Frog.
• **interfere substantially with the recovery of the species.**
A draft recovery plan for NSW has been prepared for the Green and Golden Bell Frog (DEC 2005). No national recovery plan has been prepared. The NSW recovery plan supports a program that includes the implementation of the following strategies that are considered relevant to the Project: • Increases the security of key Green and Golden Bell Frog populations by way of preventing the further loss and favouring in-situ protection and management of Green and Golden Bell Frog habitat at key populations as well as secure opportunities for increasing the protection of these habitat areas

• Ensure extant Green and Golden Bell Frog populations are managed to eliminate or attenuate the operation of factors that are known or discovered to be detrimentally affecting the species. The Project may have direct and indirect impacts on the objectives of the Recovery Plan as it could impact known populations and habitat of the Green and Golden Bell Frog.
Conclusion
The Project may result in modifications to suitable habitat within the PMF representing a reduction in the availability of potential breeding habitat. It may also contribute to the spread of invasive species detrimental to the health of Green and Golden Bell Frog populations. According to Threshold 1 of the significant impacts guidelines (DEWHA 2009), there is a potential significant impacts it 'the removal or degradation of aquatic or ephemeral habitat either where the green and golden bell frog has been recorded since 1995 or habitat that has been assessed as being suitable according to these guidelines'. Since suitable habitat is considered present, the Project has the potential to result in a significant impact on the Green and Golden Bell Frog.

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Macquaria australasica (Macquarie Perch)

Endangered under the EPBC Act

The Matters of National Environmental Significance: Significant impact guidelines (DoE 2013) defines a population of an endangered species as an occurrence of the species in a particular area, this including, but not being limited to.

- a geographically distinct regional population, or collection of local populations, or
- a population, or collection of local populations, that occurs within a particular bioregion.

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 population status of Macquarie Perch in the upstream study area is not well defined, but based known habitat associations, the Macquarie Perch is likely to prefer the upstream reaches of tributaries that flow into Lake Burragorang. These areas typically have habitat characterised by rocky substrate and good water quality, attributes that Macquarie Perch prefer. Potential impacts of the Project are limited to the FMZ, and areas downstream of this. Impacts included increase in the extent of areas under temporary inundation, and potential changes to water quality. These impacts do occur currently during flood and recession of Lake Burragorang and surrounding tributaries.
• reduce the area of occupancy of the species
The Project is not expected to reduce the area of occupancy of Macquarie Perch. Temporary inundation would occur in areas that may contain Macquarie Perch; however, Macquarie Perch is mobile and would likely be more affected by flood inflows, which would occur regardless of the Project.
• fragment an existing population into two or more populations
The Project is not likely to lead to fragmentation of Macquarie Perch habitat. The upstream habitat for Macquarie Perch currently undergoes periods of inundation and recession of varying extents and over varying timeframes. While the Project would change areas of temporary inundation, flood and drought behaviour is not likely to be changed.
• adversely affect habitat critical to the survival of a species
The Project is not likely to lead to fragmentation of Macquarie Perch habitat. The upstream habitat for Macquarie Perch currently undergoes periods of inundation and recession of varying extents and over varying timeframes. While the Project would change areas of temporary inundation, flood and drought behaviour is not likely to be changed.
• disrupt the breeding cycle of a population
The Project is not likely to disrupt the breeding cycle of Macquarie Perch. Macquarie Perch spawning generally occurs during spring and early summer in shallow, fast-flowing water over gravel beds. The eggs, which are adhesive, stick to the gravel. Flood behaviour under current conditions would likely impact this to an extent however, the Project is not likely to exacerbate this.
• modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline
The Project is not likely to modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline. Macquarie Perch habitat gets inundated under existing flood conditions. This is not anticipated to change under the Project.

• **result in invasive species that are harmful to a critically endangered species becoming established in the endangered or critically endangered s species' habitat**
Invasive species harmful to the Macquarie Perch already exist in the upstream study area. The Project is not anticipated to change the distribution of these species.
• **introduce disease that may cause the species to decline, or**
The Project is not anticipated to introduce disease that may cause the species to decline.
• **interfere substantially with the recovery of the species.**
The National Recovery Plan (DoEE 2018) defines habitat critical to the survival of the Macquarie Perch as: • All areas within the species' range which are characterised by flowing runs or riffles and small complex rock piles • The current area of occupancy of the species (including historically translocated populations in Cataract Reservoir and the Mongarlowe River in New South Wales and the Yarra River in Victoria) • Any newly discovered locations within the species' natural range which hold populations that extend the area of occupancy for the species • Unoccupied habitat within the species' natural range into which the species could disperse, be stocked or be translocated. The Project is not anticipated to interfere substantially with the recovery of this species. The species is already subject to periodic flooding and recession.
Conclusion
The Project is unlikely to have a significant impact on the Macquarie Perch.

References

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Petauroides cumin (Greater Glider)

Vulnerable under the EPBC Act

The Greater Glider is an arboreal folivore that inhabits a variety of forest types, but it is more abundant in high productivity tall Eucalypt forest. The Greater Glider prefers mature mixed species forests, which provides it with tree hollows for daytime shelter and enables it to capitalise on seasonal differences in new leaf production. New leaves are favoured as these are higher in nitrogen and lower in lignocellulose. It also exhibits preferences for particular tree species, which reflects variation in foliar nutrients (Kavanagh and Lambert 1990). Larger trees are also preferred for foraging (Smith *et al.* 2007), which is probably due to foraging efficiency as only a few trees are used each night for foraging (Kavanagh and Wheeler 2004). There is some evidence that Greater Gliders prefer trees of the sub-genus Monocalyptus, with Symphomyrtus and Corymbia used to a lesser extent. This appears to be due to a lower tolerance for the anti-herbivore class of toxins known as formylated phloroglucinol compounds (FPCs) in the foliage than other folivores (for example, Koala, Common Brushtail Possum). FPCs appear to be lower in the foliage of Monocalyptus than other Eucalypts (Moore *et al.* 2004).

Home-range areas typically range from 1 to 3 hectares (Kavanagh and Wheeler 2004; Pope *et al.* 2005) but have been reported up to 11.5 hectares in low productivity habitat (Smith *et al.* 2007). Male home-ranges are larger than for females. There is a high degree of home-range overlap between the sexes but not within the sexes, particularly for males (Kavanagh and Wheeler 2004; Pope *et al.* 2005). Reported population densities range from 0.35 hectares^{-1} (Smith and Smith 2018) to 2.3 hectares^{-1} (Kehl and Borsboom 1984). Larger home-ranges are associated with lower population density (Pope *et al.* 2005).

Individual Greater Gliders tend to use multiple tree hollows, with a range of 1 – 20 den trees reported (Kavanagh and Wheeler 2004; Lindenmay *et al.* 2004; Smith *et al.* 2007). Larger trees are preferred as den sites. For example, at a site on the NSW south coast a median den tree size of 130 centimetre DBH was reported (Kavanagh and Wheeler 2004). Living trees are generally preferred for denning (Eyre 2006), but the use of dead trees has been recorded (Smith *et al.* 2007). Frequently used den trees tend to be found near the home-range core. Males appear to use more den trees than females, but many are rarely used. (Lindenmayer *et al.* 2004). This suggests the use of den trees plays a role in home-range defence. The density of hollow-bearing trees is known to influence the species richness and abundance of arboreal mammals (Kavanagh *et al.* 1995; Wormington *et al.* 2002) and there may be a lower hollow-bearing tree threshold density of around 1 hectares-1 for the Greater Glider to be present (Smith *et al.* 2007).

Greater Gliders are generally monogamous, but may be polygynous in high quality habitat (Henry 1984; Kehl and Borsboom 1984). Females give birth to a single young from March to June, but only 50-75% of females may breed in a given year (Tyndale-Biscoe and Smith 1969; Henry 1984). Sexual maturity is reached in the second year and longevity has been estimated at 15 years with an estimated annual mortality rate of 0.75 (Tyndale-Biscoe & Smith 1969b), suggesting few individuals approach the maximum reported age.

The Greater Glider moves through its habitat by gliding between trees and its habitat can, therefore, become fragmented when the inter-tree spacing exceeds gliding capacity. It shows an increasingly negative response to more intense forms of forestry primarily due to the loss of large tree hollows (Kavanagh and Bamkin 1995; Kavanagh 2000; Kavanagh and Wheeler 2004; Eyre 2006). It is also negatively affected by fires of varying severity and frequency due to mortality and low reproductive output limiting recovery, although it may persist in unburnt refuges provided they are of sufficient area (van der Ree and Lyon 2002; Lindenmayer *et al.* 2013; Berry *et al.* 2015; McLean *et al.* 2018). Persistence in refuges eventually enables Greater Gliders to recolonise burnt habitat (Andrew *et al.* 2014). The Greater Glider is listed as a species requiring urgent management intervention following the 2019/2020 bushfires (Wildlife and Threatened Species Bushfire Recovery Expert Panel 2020).

The Greater Glider forms an important part of the diet of the Powerful Owl (Bilney 2013) and heavy predation by this species can reduce the densities of local populations (Kavanagh 1988). The relatively low reproductive rate (Henry 1984) may render small isolated populations in small remnants prone to extinction (van der Ree 2004; Pope *et al.* 2005).

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

There are relatively few Greater Glider database records from the Project study area with most being located along roads. This presumably reflects a combination of low survey effort due to restricted access, the difficultly in sampling the habitat away from roads due to the steep terrain and dense vegetation, the low productivity of some vegetation communities and variability of hollow-bearing tree density. These factors may also interact. For example, flat to sloping accessible sites, while easy to survey, are also the most likely to have a history of timber extraction and, hence, a lower availability of hollow-bearing trees. Due to the steep terrain, it is frequently difficult to access sites with more abundant tree hollows.

Spotlighting is the survey method most suited to the detection of the Greater Glider (Commonwealth Threatened Species Scientific Committee 2016). Although spotlighting may not detect all individuals that are present within a habitat (Lindenmayer *et al.* 2001), the bright eyeshine and sedentary behaviour of the Greater Glider make spotlighting a suitable technique for determining presence/absence and relative abundance. During the recent impact assessment surveys, spotlighting was conducted, resulting in one detection across the Project study area. This suggests that a low density Greater Glider population is present within the Project study area.

The Greater Glider is associated with a range of vegetation communities within the Project study area. These communities vary in their productivity (for example, both wet and dry Eucalypt forest is present), history (for example, logging, fire) and extent. The first two factors would influence population density through the quality of foliage and the availability of hollow-bearing trees. The overall size of the local population effected by the Project is a product of the population density within different communities weighted by the area covered by each community.

Habitat types preferred by the Greater Glider are likely to be on the lower, particularly south-facing slopes, areas that are inaccessible (steep slopes, below escarpments, narrow gorges) as these are less likely to have been subject to forestry activities, which lowers hollow-bearing tree densities. Of all the habitats available within the Project study area, moist forest types with abundant tree hollows, such as moist Blue Gum (*Eucalyptus deanii*) and Grey Gum (*E. cuminat*) forests, are likely to support the highest densities of the Greater Glider (although, as noted above, none were recorded during the assessment surveys).

Population is expected to lower as habitat productivity and/or the availability of tree hollows decreases. Some productive vegetation communities, such as those containing Forest Red Gum (*E. tereticornis*), Narrow-leaved Red Ironbark (*E. crebra*) and Grey Box (*E. moluccana*) may provide moderate quality foraging habitat (but note that these are all Symphomyrtus species), but are often depauperate in hollow-bearing trees due to historic forestry activities. Some sandstone communities with a high proportion of Monocalyptus species, such as Sydney Peppermint (*E. piperata*) and Blue-leaved Stringybark (*E. cuminate*are likely to provide moderate quality foraging habitat. However, these communities were characterised by a low density of hollow-bearing trees. Other sandstone communities, such as Douglas Scarp Woodland, are likely to be poor quality foraging habitat due to low productivity despite moderate to high densities of hollow-bearing trees.

The preceding habitat analysis is consistent the distribution of Greater Glider records within the Project study area. Thus, different vegetation communities were assigned to two productivity/abundance classes and average glider densities were calculated for each community based on the variation in Greater Glider density reported in the literature. Two density classes used in the analysis are consistent with medium to low density estimates from published literature. Thus, an upper density of 1.4 per hectare and a minimum density of 0.35 per hectare was used (see review above). It is noted that Greater Gliders are becoming scarce in the Blue Mountains at lower elevations (Smith and Smith 2018).

The derived population size estimates are based on 0.35 per hectare in dry eucalypt forest and woodland and 1.1 per hectare in wet eucalypt forest are summarised in Table GG1. A total pre-fire Greater Glider population size of 3,812 individuals was estimated for the upstream study area occupying a total of 3,465 hectares of habitat, assuming a weighted mean density of 1.1 per hectare.

The Greater Glider is listed as a species requiring urgent management intervention following the 2019/2020 bushfire season (DAWE 2020). The recent fires within the upstream study area are likely to have caused the local population of Greater Gliders to decrease. It is estimated that 2,352 hectares (68%) of Greater Glider habitat was affected over 2019/2020 within the upstream study area, leaving 1,113 hectares. Given the sensitivity of the Greater Glider even to low intensity and/or infrequent fires it is likely that a concomitant reduction in population size has occurred. Thus, the remaining population is estimated to be 425 individuals, a loss of 2,379 gliders due to bushfire. The time to recovery for the Greater Glider is expected to be slow, i.e. decades rather than years (e.g. van der Ree and Lyon 2002; McLean *et al*. 2018).

The likely impact (including direct and indirect impacts) that the development will have on the habitat of the local population

The Greater Glider may be affected in two ways by the Project. The major potential impact is habitat loss. Habitat loss would result in a reduction in the availability of foraging resources and the number of hollow-bearing trees, which provide den sites. Habitat loss would result in a concomitant reduction in the size of the population within the Project study area. A total of 1,113 hectares of unburnt potential habitat supporting 425 gliders remains within the upstream study area. The 1% AEP (1 in 100 chance) flood extent would affect an estimated 1,803 unburnt affecting an estimated 1,984 gliders.

Some of the habitat within the upstream study area is comprised of essentially linear habitat elements within narrower gullies associated with tributaries of the lake. Higher water levels may cause areas of linear habitat to be lost as moist forest types only extend up the tributaries while the elevation gradient remains moderate. Once steeper country is reached, less productive vegetation communities are more likely to be present. If the inundation zone becomes extended beyond the preferred forest types, there is potential for habitat fragmentation if the gap across the extended water body becomes greater than the gliding distance. Gliding distance is a function of launch (tree) height and glide angle, however, the gliding performance of the Greater Glider has not been subject to a detailed assessment. Therefore, it is not clear what distance thresholds are likely for various tree heights.

It is likely that some habitat fragmentation within preferred habitat would occur due to the Project. However, given the Greater Glider can move through non-preferred habitats during dispersal (Taylor *et al*. 2007), It is not clear whether different areas of occupied habitat would become isolated from one another. Similarly, it is possible that Greater Gliders may move through burnt habitat once the canopy recovers (i.e. 2 – 3 years). So, it is not clear to what extent the fires may cause habitat fragmentation.

Greater Gliders appear to be absent or at very low density in the types of habitat that surround the construction area at the existing dam. Therefore, construction stage impacts (for example, noise, light, vibration, movement of large vehicles) are not likely to affect the Greater Glider.

The likely impact on the ecology of the local population

The main impact on the local upstream Greater Glider population will be the linear reduction in population size due to habitat loss resulting in the loss of foraging resources and the loss of hollow-bearing trees. The local population of the Greater Glider has already been reduced by an estimated 62 percent by the recent bushfires. The Project may affect up to 61 percent of the remaining habitat for the 1% AEP flood event.

While some habitat fragmentation may occur, this is likely to be relatively minor as the Greater Glider is able to move through less preferred forest types (Taylor *et al.* 2007). Thus, non-living habitat may be used as movement habitat. The Project is not expected to alter life history attributes (for example, birth and mortality rates) of the remaining population.

An estimated 216 hectares of potential habitat would be affected by the Project in the upstream study area. Assuming an average density of 1.1 per hectare (the overall weighted density estimated for the Project study area), approximately 238 individual Greater Glider could be lost due to the Project. This represents 12% of the population within the Project study area. However 1,774 Greater Gliders would remain in the Project study area. Additionally, the Project study area is connected to areas with similar habitats, suggesting that the total population size would be considerably larger. Therefore, population viability within the Project study area would be maintained.

Reducing flooding downstream is not expected to impact on the habitat occupied by the Greater Glider because the ecological process that maintain its preferred Eucalypt habitats are not dependent on flooding. The Greater Glider is unlikely to occur in the construction area.

The relationship of the local population to other populations of the species

Prior to the 2019/2020 fires, the Project study area was surrounded by large areas of habitat within conservation reserves that have numerous Greater Glider records (OEH 2018). Some of these records are associated with upslope or ridgetop habitats. Thus, higher elevation habitat may provide living and/or connecting habitat between sub-catchments within the Locality. This suggests that the population in the Project study area would have been directly (within the same sub-population) and indirectly (to other sub-populations via dispersal) connected to other Greater Glider populations in the Locality. The overall size of the population within the Locality would, accordingly, have been quite large.

The recent fires have reduced the overall population size and caused a high level of population fragmentation due to the Greater Glider's intolerance of burnt habitat. It is likely that the Greater Glider now occurs as a series of sub-populations of varying sizes and varying degrees of connectivity. Many populations are likely to be small and relatively isolated.

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

Recognised threats to the Greater Glider are:

- Habitat loss and fragmentation
- Intense and frequent fires
- Timber production
- Climate change
- Barbed-wire fencing
- Hyper-predation by owls
- Competition with Sulphur-crested Cockatoos (*Cacatua galerita*) for tree hollows
- Phytophthora root fungus.

Habitat loss and fragmentation are likely to be Project impacts and will be exacerbated by recent fires. While no particular fire regime is required by the Project, the Project would commence at a time when the local population is recovering from extensive fires during 2019/2020. Climate change may alter rainfall patterns, which in turn alters the frequency of flood events and hence the quality of habitat within the greater inundation area. The remaining factors are not relevant to the Project. Indeed, the presence of a water supply catchment excludes some of these impacts (for example, timber production ceased when the original dam was built, there is no need for internal fencing).

The measure/s proposed to contribute to the recovery of the species

The Project impacts on the Greater Glider will be a direct consequence of habitat loss and fragmentation associated with a larger inundation area. This would further reduce foraging resources and remove hollow-bearing trees. The local population is already greatly reduced by the recent fires and it is likely that several decades will be required for the population to recover to pre-fire levels. Further reduction of the population as a result of the Project is likely to impact on the population viability of the Greater Glider. The Greater Glider is not expected to be exposed to construction stage impacts. The Greater Glider is not expected to be exposed to construction stage impacts. Therefore, no specific measures are proposed that would contribute to the recovery of the Greater Glider. However, general habitat offsets would benefit the Greater Glider by securing suitable habitat in other locations.

Given that areas of unburnt habitat remain in the Project study area, these would be key source populations to enable eventual colonisation of burnt habitat. Unburnt habitat for the Greater Glider would be used for breeding and dispersal and for maintaining genetic diversity in the locality. Thus, an important population of the Greater Glider is assumed to be present in the Project study area.

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**
It was estimated that a total of 3,465 hectares of habitat supporting 3,812 Greater Gliders at a mean density of 1.1/hectare occurred in the upstream pre-fire Project study area. An estimated 68% of Greater Glider habitat was affected by the fires. This reduced the area of habitat to 1,113 hectares and a population of 425 individuals. The 1% AEP flood event would affect 1,803 hectares of habitat, potentially reducing the population by 1,984 gliders. This reduction would relate to permanent habitat loss due to the greater area of inundation resulting from the Project. Over several decades the size of the population outside the inundation areas would increase towards pre-fire levels. Because the construction area is on sandstone, similarly to the Koala (see Koala assessment), it is likely to be low quality habitat. The likelihood of Greater Gliders occurring in the construction area is low. Downstream habitat may support a low density population due to the sandstone (low nutrient) substrate and/or the low density of trees with large hollows. The vegetation communities in which the Greater Glider occurs are not likely to be affected by a reduction in flood events and, accordingly, no population impact is expected..
• **reduce the area of occupancy of an important population**
The Project would reduce the area of occupancy of an important Greater Glider population by up to an estimated 1,803 hectares under the 1% AEP flood event. The area of occupancy in the downstream study area is not likely to alter.
• **fragment an existing important population into two or more populations**
The Project would result in an expansion of the temporary inundation area. The Greater Glider is capable of dispersing at least seven kilometres and through habitats types that are not suitable for residency, such as plantations of exotic pines (Taylor *et al*. 2007). However, the recent fires have increased habitat fragmentation for the Greater Glider and caused an increase in the distances between (unburnt) habitat patches. It is possible that the interaction between increased patch distance and a greater inundation area that extends further along tributary systems would result in habitat fragmentation, at least in some parts of the Project study area..
• **adversely affect habitat critical to the survival of a species**
No critical habitat has been declared for the Greater Glider.
• **disrupt the breeding cycle of an important population**
Greater Gliders are generally monogamous but may be polygynous in high quality habitat. Females give birth to a single young glider from March to June, but only 50-75% of females may breed in a given year (Tyndale-Biscoe and Smith 1969; Henry 1984). Sexual maturity is reached in the second year. There is no suitable habitat for the Greater Glider around the dam wall, therefore, the construction phase of the Project would not disrupt the breeding cycle of the Greater Glider. A larger area of inundation would reduce the number of breeding females in the Project, but it would not affect the breeding cycle of the remaining population. It is noted, however, that in the short-term breeding success may be reduced due to the impacts of the recent fires on Greater Glider habitat. The Project is unlikely to adversely affect the breeding cycle of an important population of the Greater Glider.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The area of habitat that may be removed by the Project surrounds the existing inundation area. This habitat has recently been subject to severe bushfires and the local population is estimated to have been reduced by 88%. Further reductions in habitat availability would increase the likelihood that the project would cause the Greater Glider to decline.

• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
No invasive species are recognised as a threat to the Greater Glider. The Project is unlikely to result in an invasive species that is harmful to the Greater Glider becoming established in its habitat.
• **introduce disease that may cause the species to decline, or**
There are no diseases recognised as affecting the Greater Glider. The Project is not likely to increase the potential for introduction of diseases that may affect this species. The Project is unlikely to introduce disease with potential to cause the Greater Glider to decline.
• **interfere substantially with the recovery of the species.**
There is no recovery plan for the Greater Glider, but the development is a plan is recommended with the species' conservation listing advice. In the interim, the conservation listing advice contains the following conservation actions: • Reduce the frequency and intensity of prescribed burns • Identify appropriate levels of patch retention, habitat tree retention, and logging rotation in hardwood production • Protect and retain hollow-bearing trees, suitable habitat and habitat connectivity The Project does not require any particular fire regime, nor does it involve any logging activity. However, the protection of habitat, habitat connectivity and the retention of hollow-bearing trees are relevant to the Project. The impacts of the Project must also be considered in conjunction with the recent bushfires. The Project would interfere with recovery from the bushfires by causing a further reduction in population size. The Project is likely to interfere with the recovery of the Greater Glider.
Conclusion
The study area contains foraging habitat that may be utilised the Greater Glider. This habitat was subject to severe bushfire during the 2019/2020 season, resulting in a loss of 68% of the pre-fire habitat. While Eucalypt forests are resilient to fire events, compounding impacts resulting from the Project before the recovery of the local population has occurred will pose additional risks to the viability of the local, important Greater Glider population. Given the long post-fire recovery times report for Greater Glider populations, its population size is likely to be supressed for a considerable time. Thus, the Project is likely to have a significant impact on the population of the Greater Glider in the Project study area due to the compounding impacts of habitat loss and fragmentation in the post-fire environment.

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Petrogale pencillata (Brush-tailed Rock-wallaby)

Vulnerable under the EPBC Act

The Brush-tailed Rock-wallaby prefers rocky habitats, such as boulder piles, rocky outcrops, steep rocky slopes, cliffs, gorges and isolated rock stacks (Murray *et al.* 2008; Short 1982). Most Brush-tailed Rock-wallaby colonies are on north-facing slopes and cliff lines in areas with more ledges, caves and routes connecting the cliff top to the cliff face, which may restrict access by predators (Short 1982; Eldridge and Close 1995). However, colonies have been found at lower density on south-facing cliffs in some locations (for example, Bayne 1994). Vegetation structure and composition is also important as it provides food, shelter and some protection from predation (Bugg 1995). A range of vegetation types are associated with Brush-tailed Rock-wallaby habitat, including dense rainforest, wet sclerophyll forest, vine thicket, dry sclerophyll forest, and open forest (Murray *et al.* 2008).

During the day, the Brush-tailed Rock-wallaby shelters in rock crevices, caves and overhangs, but often basks in exposed sunny spots (Eldridge and Close 1995). Brush-tailed Rock-wallabies mainly forage at night. Their diet consists primarily of grasses, forbs and “browse” (shrubs, trees and climbers), with ferns and sedges of minor importance (Short 1989). It appears to eat Kangaroo Grass (*Themeda triandra*) more than other grasses (Jarman and Phillips 1989). Preferred habitat areas are used habitually (Joblin 1983) and these are often defended (Bayne 1994).

Considerable variation in the home-range area has been reported. Smaller home-ranges of 2 – 3 hectares from south-eastern Queensland (Laws and Goldizen 2003) and 0.5 – 5 hectares from the New England region of NSW (Joblin 1983) have been reported, but these appear to have been nocturnal ranges only. Larger home-range areas of 26 hectares (with a core area of 2.5 hectares) were reported from Victoria (Molyneux *et al.* 2011). In central NSW, home-ranges varied from 6 – 30 hectares, with a mean of 15 hectares. These home-ranges extended 400 – 900 metres along the cliffs (mean 700 metres) (Short 1980). Larger male home-ranges overlap the smaller home-ranges of females (Bayne 1994). Rock-wallabies often demonstrate high site fidelity (Bayne 1994). There appears to be little movement between site as colonies appear to be genetically distinct and only a small number of individuals (~5%) are immigrants into a population (Piggott *et al.* 2006). Some of the variation in home-range size may be related to the relative predation risk at different sites (Menkhorst and Hynes 2011).

They appear to live in small groups of 2 to 11 individuals, including adults and sub-adults (young-at-foot) (Short 1980; Joblin 1983; Dovey *et al.* 1997; Vernes *et al.* 2011). Brush-tailed Rock-wallabies are polygamous and a dominant male will be found with up to four adult females. Females give birth to a single pouch young after a gestation period of approximately 30 days. Births can occur throughout the year, but usually peak in autumn. The young remain in the pouch for six months. Weaning is believed to occur 86 days after leaving the pouch, when the joey is nine months old. Sexual maturation of females occurs at 18 months and males at 20–24 months (Joblin 1983; Lee and Ward 1989).

There is considerable uncertainty regarding the response of the Brush-tailed Rock-wallaby to fire. However, given its requirements for patches of dense vegetative cover and the dispersed distribution of colonies (requiring movement between them) suggests that fire would have deleterious effects on this species (Menkhorst and Hynes 2011). It is not known how long it takes suitable habitat to recover, and this would vary according to fire intensity. Given the dispersed nature of suitable habitat and the presence of patches of different fire intensities, it is expected that complete movement paths at least would take many years to fully recover. High fire frequency is listed as a KTP affecting the Brush-tailed Rock-wallaby under the BC Act and the EPBC Act and it is included on a list of animals requiring urgent management intervention as a result of the 2019-2020 fires (Wildlife and Threatened Species Bushfire Recovery Expert Panel 2020).

The size of the local population potentially directly and indirectly impacted by the Project

Population size was determined by assessing the length of north-facing steep, rocky slopes in the study area and dividing this value by the mean length (700 metres) of the home-range (Short 1980). These areas were identified with the assistance of aerial imagery and topographic maps. The resulting value was then multiplied by the mean group size to provide a population estimate. A total of 36 kilometres of north-facing slope was determined in the upstream study area, with individual cliff lines ranging from 385 metres (but note, this area of slope extended outside the study area and was, therefore, longer in total extent) to 4.6 kilometres. It is likely that some smaller areas of occupied habitat were overlooked due to the size of the study area and the resulting mapping scales required. It is unlikely any suitable habitat for the Brush-tailed Rock-wallaby occurs in the downstream study area.

The analysis suggested that prior to the 2019-2020 bushfire event, a total of 51 groups may occur in the study area. These are mostly clustered into two areas: the lower reaches of Lake Burragorang and the upper Coxs River. Using a typical group size of approximately nine individuals (adults and sub-adults), this suggests a total population of 468.

However, it is acknowledged that there is a high level of uncertainty associated with this estimate as the proportion of potential habitat actually occupied is unknown. A population of 468 is high compared to the size estimates from populations subject to detailed study (e.g Short 1980; Joblin 1983; Vernes *et al.* 2011), but these studies did not necessarily account for all groups over large areas of land.

There is no current estimate provided for the amount of habitat affected by fire due to the unknown response of the Brush-tailed Rock-wallaby to fire.

The potential impact (including direct and indirect impacts) that the development could have on the habitat of the local population

The Project may impact on the Brush-tailed Rock-wallaby in several ways. Firstly, habitat loss within the inundation area may result in a direct reduction in the availability of foraging resources and shelter sites. This could lead to a reduction in the number of rock-wallaby groups within the study area and possibly also a reduction in the mean group size. Both factors may result in an overall reduction in population size.

Habitat fragmentation is unlikely, but may further reduce the already low level of exchange between groups of Brush-tailed Rock-wallabies. This would introduce indirect Project impacts. Lower movement rates would reduce genetic exchange, possibility leading to inbreeding (for example, Eldridge *et al.* 2004) and lessen the chances of recolonising areas of suitable habitat if they became vacant (for example, after fire). The loss of safe movement and foraging areas may expose the Brush-tailed Rock-wallaby to higher levels of predation as it may become forced to use riskier areas for foraging and movement (for example, Eldridge *et al.* 2004).

All three factors may operate together to lower the viability of populations within the study area as population size, migration and mortality rates are all important drivers of population viability (for example, Goldingay and Sharpe 2004).

The potential impact on the ecology of the local population

The Project could potentially affect shelter, foraging and movement habitat and may also alter the rate of predation. As noted above, these factors could reduce population size, disrupt movement patterns and increase the rate of mortality. The disruption of ecological processes may affect the viability of the local populations and this may be sufficient to result in the loss of some groups.

The relationship of the local population to other populations of the species

While there may be many populations of the Brush-tailed Rock-wallaby throughout the Blue Mountains area, genetic data suggests that there is only likely to be a low level of connectivity via migration between various local populations.

The extent to which the proposed development could potentially 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

Threats to the Brush-tailed Rock-wallaby include (Dovery *et al.* 1997; NSW Department of Environment and Conservation 2005; Menkhorst and Hynes 2011):

- Habitat degradation
- Small population size
- Low migration rates
- Bioclimatic factors
- Drought
- Fire, at least until the vegetation structure recovers
- Historic hunting
- Disease
- Predation of adult and/or juvenile Rock-wallabies by cats (*Felis catus*), Wedge-tailed Eagles (*Aquila audax*), Red foxes (*Vulpes vulpes*), Lace Monitors (*Varanus varius)* and wild dogs (*Canis lupus*)
- Competition with feral goats (*Capra hircus*) and rabbits (*Oryctolagus cuniculus*).

Of these, habitat loss and degradation due to inundation may further reduce population size and further lower migration rates by fragmenting movement habitat. These factors may force Brush-tailed Rock-wallabies into less secure habitat, where they may be more vulnerable to predation by native and introduced predators. Following fire, it would be more difficult for any occupied habitat that becomes temporarily unsuitable to be recolonised once the vegetation structure recovers. Given that Brush-tailed Rock-wallaby populations are already small and fairly isolated from one-another, the Project may impact upon the viability of the local population by reducing population size, genetic exchange and increasing the mortality rate due to predation, thus disrupting meta-population processes.

The measure/s proposed to contribute to the recovery of the species

Menkhort and Hynes (2011) describe the following recovery actions for the Brush-tailed Rock-wallaby:

1. Determine and manage threats to the Brush-tailed Rock-wallaby and its habitat.
2. Determine distribution, abundance, population trends and viability for the Brush-tailed Rock-wallaby.
3. Establish and maintain separate, viable captive populations derived from the Southern and Central ESUs.
4. Undertake translocations to improve the genetic and demographic robustness of populations and to establish new colonies of Brush-tailed Rock-wallabies.
5. Investigate key aspects of Brush-tailed Rock-wallaby biology and ecology for conservation management.
6. Increase community awareness and support for Brush-tailed Rock-wallaby conservation.

Several of these may be relevant to the Project:

Point 1. Threats to the Brush-tailed Rock-wallaby were listed above and those that relate to the Project were identified. In summary, habitat loss and fragmentation are direct Project impacts that would reduce population size. Reduced migration and increased predation are indirect Project impacts. The Project would interact with fire by making the re-colonisation of empty patches more difficult once suitable post-fire habitat becomes available.

Point 2. There is a large degree of uncertainty associated with the population estimates in the study area and with the extent to which the population would be reduced by the Project. However, there is no indication of population trends in the affected populations and, therefore, an uncomplete understanding of the impact of the Project on population viability.

Points 4, 5 and 6. To mitigate Project impacts, contributions could be made to assist with management interventions, such as translocation, and to funding research into the Brush-tailed Rock-wallaby. Funding could also be made available to increase community awareness and support for Brush-tailed Rock-wallaby conservation.

Menkhorst and Hynes (2011) describe the Nattai National Park population, which is to the south-east of the Project study area, as an important population of the Brush-tailed Rock-wallaby. This is because the loss of this population may result in a large range gap between the Shoalhaven population and populations further north. The Project study area provides an important link between the Nattai population and locations of the Brush-tailed Rock-wallaby in the Blue Mountains to the north of the Project study area. Thus, an important population of the Brush-tailed Rock-wallaby occurs in the Project study area.

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**
A total of 36 kilometres of north-facing steep, rocky slopes was estimated for the Project study area. Based on the mean home-range length of 700 metres, there could be up to an estimated 51 Brush-tailed Rock-wallaby groups and a total population of 468 individuals present. The Project has the potential to cause changes to vegetation structure through changes to inundation levels, resulting in potential permanent loss of foraging habitat adjacent to rocky areas that provide shelter for the rock-wallaby population. The Project may reduce the amount of Brush-tailed Rock-wallaby habitat in the Project study area. Thus, the Project may result in the long-term loss of individual Brush-tailed Rock-wallabies in the Project study area from an important population.

• reduce the area of occupancy of an important population
Brush-tailed Rock-wallabies are restricted to steeper, rocky slopes, indicating they would be patchily distributed in the Project study area. The Brush-tailed Rock-wallaby population in the Project study area is adjacent to the important Nattai population and, therefore, would have to highest level of connectivity compared to populations elsewhere in the Blue Mountains. The potential loss of habitat associated with the Project could reduce the area of occupancy of an important Brush-tailed Rock-wallaby population.
• fragment an existing important population into two or more populations
Brush-tailed Rock-wallaby populations are already fragmented due to low numbers and existing Lake Burragorang. The inundation of Brush-tailed Rock-wallaby habitat within the Project study area may cause some groups to be displaced to an insufficient area of remaining predator-safe habitat to support them. Movement between Brush-tailed Rock-wallaby groups is estimated to be only 5%, however, they are capable of moving through higher elevation areas to disperse Temporary inundation may restrict movement to lower slopes. The Project is unlikely to fragment the Brush-tailed Rock-wallaby population in the Project study area into two or more populations and to erect permanent barriers to the movement of individuals.
• adversely affect habitat critical to the survival of a species
Habitat critical to survival of the Brush-tailed Rock-wallaby includes rocky refuge habitat, foraging habitat and commuting routes between the two. This has not yet been precisely mapped for the species. Proposed recovery actions include determining habitat that is critical to survival of the Brush-tailed Rock-wallaby (Menkhorst and Hynes 2011). Thus, although the requirements for critical habitat is known, no actual critical habitat has been determined. As no critical habitat has been defined, the Project is unlikely to adversely affect habitat critical to the survival of the Brush-tailed Rock-wallaby.
• disrupt the breeding cycle of an important population
Females give birth to a single pouch young after a gestation period of approximately 30 days. Births can occur throughout the year, but usually peak in autumn. The young remain in the pouch for six months. Weaning is believed to occur 86 days after leaving the pouch, when the joey is nine months old. Sexual maturation of females occurs at 18 months and males at 20–24 months. It is unlikely that the Brush-tailed Rock-wallaby persists in habitat near the existing dam wall due to the proximity of human habitation and the presence of threats, such as dogs and Red Foxes. Therefore, the construction phase of the Project would be unlikely to disrupt the breeding cycle of the Brush-tailed Rock-wallaby. A larger area of inundation could reduce the number of breeding females in the Project study area, but would likely not affect the breeding cycle of the remaining population. The Project is not likely to affect the breeding cycle of the Brush-tailed Rock-wallaby.
• modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline
The area of habitat that could potentially be removed by the Project surrounds the existing inundation area. The modification of potential habitat may reduce the size of the local population, remove refuge sites resulting in a greater exposure to predation and reduce the rate of movement of individuals between Brush-tailed Rock-wallaby groups.
• result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat
A number of invasive species are known to threaten the Brush-tailed Rock-wallaby and are known or are highly likely to already exist in the Project study area. For example, a Red Fox was observed sheltering in a cave at the edge of the existing lake, indicating they are capable of penetrating deep into the Project study area and occupy

potential Brush-tailed Rock-wallaby habitat. Wild dogs and cats are also likely to be present. Feral goats and rabbits are known to compete with the Brush-tailed Rock-wallaby. Rabbits were also observed in the Project study area and there are a number of goat records in the Locality. The Project would not cause the establishment of any new invasive species that are harmful to the Brush-tailed Rock-wallaby.

Although several invasive species that are harmful to the Brush-tailed Rock-wallaby have known or likely to already occur in the Project study area, the Project is not likely to result in the introduction of any further harmful species.

- **introduce disease that may cause the species to decline, or**

Diseases that affect other macropod species are thought to affect the Brush-tailed Rock-wallaby. While the exact impact of disease is not known, it is a recognised threat to the species. Diseases appear to arise due to close contact with livestock (for example, hydatid cysts), toxoplasmosis carried by cats and lumpy jaw from contact with humans and processed food (NSW Department of Environment and Conservation 2005). However, there is no reason to suggest that the Project would be responsible for introducing disease into the Project study area.

The Project is unlikely to introduce disease with potential to cause the Brush-tailed Rock-wallaby to decline.

- **interfere substantially with the recovery of the species.**

Commonwealth and State recovery plans have been prepared for the Brush-tailed Rock-wallaby. Threats to the Brush-tailed Rock-wallaby include (Dovey *et al.* 1997; NSW Department of Environment and Conservation 2005; Menkhorst and Hynes 2011):

- Habitat degradation
- Small population size
- Low migration rates
- Bioclimatic factors
- Drought
- Fire, at least until the vegetation structure recovers
- Historic hunting
- Disease
- Predation of adult and/or juvenile Rock-wallabies by cats (*Felis catus*), Wedge-tailed Eagles (*Aquila audax*), Red foxes (*Vulpes vulpes*), Lace Monitors (*Varanus varius*) and wild dogs (*Canis lupus*)
- Competition with feral goats (*Capra hircus*) and rabbits (*Oryctolagus cuniculus*).

The Project may increase the current operation of threats in the Project study area, namely habitat degradation, further reduction of population size, reduce already low migration rates and increase predation rate via the loss of shelter sites and alteration to vegetative structure.

The Project has the potential to substantially interfere with the recovery of the Brush-tailed Rock-wallaby.

Conclusion

The Project study area supports part of the important Nattai Brush-tailed Rock-wallaby population. The Project may reduce population size and interfere with the recovery of the species. The response of Brush-tailed Rock-wallaby populations to the Project is unknown, therefore, according to the precautionary approach, the Project is likely to have a significant impact on the Brush-tailed Rock-wallaby.

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Phascolarctos cinereus (Koala)

Vulnerable under the EPBC Act

The Koala is an arboreal folivore that inhabits a variety of forest types throughout eastern Australia. However, their presence and density is influenced by the presence of preferred tree species (Phillips *et al.* 2000; McAlpine *et al.* 2006), which differ throughout the species range (Moore and Foley 2000). Almost all significant food trees are within the genus Eucalyptus and can be divided into species of primary or secondary importance. The importance of trees with heavy, shaded crowns to provide shelter from heat is also recognised (Crowther *et al.* 2014). The highest Koala densities are achieved in habitats with a high density of primary food species, while the population density is lower if primary food trees are at a low density or where only secondary food trees are available (McAlpine *et al.* 2006).

Eucalypt foliage is generally low in nutrients, high in fibre and contains anti-herbivore toxins (Moore and Foley 2000 2005). Koalas select food trees with a comparatively high nutrient status and relatively low concentrations of toxins. The Koala has a suite of physiological and behavioural adaptions that enable it to persist on a diet of Eucalypt foliage, such as selecting larger individual trees with a comparatively high nutrient status and relatively low concentrations of toxins, a low metabolic rate and a low reproductive output, (Cork *et al.* 1983; Cork and Sanson 1990; Phillips and Callaghan 2000; Logan and Sanson 2003; Krockenberger 2003; Moore *et al.* 2004; Marsh *et al.* 2007). Koalas move between trees daily (Ellis *et al.* 2002 2009) and there is a low incidence of repeat visits to individual trees (Matthews *et al.* 2007; Lollback *et al.* 2018).

Home-range areas are generally in the range of 5-25 hectares and are larger for males (White 1999; Kavanagh *et al.* 2007; Lassau *et al.* 2008; de Oliveira *et al.* 2014). Home-ranges are based on the distribution of key food trees and the variation in home-range area is a function of their distribution and density (Mitchell 1990) and in some areas may greatly exceed 100 hectares (for example, Ellis *et al.* 2002). Home-ranges overlap between individual Koalas but only about 1-5% of trees used by more than one Koala (Mitchell 1990; Kavanagh *et al.* 2007; Matthews *et al.* 2007; Ellis *et al.* 2009). Koalas are able to persist in fragmented habitat, including in urban areas, with home-ranges extending to and straddling habitat edges (Lassau *et al.* 2008; de Oliveira *et al.* 2014). Koala densities are a function of home-range area and the extent of overlap and may range between 0.2 hectares-1 to 3.0 hectares-1 (Martin 1985; Ellis *et al.* 2013).

While the home-ranges of male and female Koalas overlap, residency may not result in higher male reproductive success (Ellis *et al.* 2002b). Reproductive maturity is reach at about 24 months, but it may take up to four years for males to be competitive with other males (Martin and Handasyde 1990). A single young per female is born per year, but not all females breed each year (Martin and Handasyde 1995). Most births occur between December and March. Dispersal is male biased, occurring between July and December when Koalas are 20 – 36 months of age (Dique *et al.* 2003a).

Recognised threats to the Koala are habitat loss, drought, disease, climate change, vehicle strike and dog attack (Reed and Lunney 1990; Dique *et al.* 2003b; Lunney *et al.* 2004; NSW Department of Environment and Climate Change 2008; Tarlinton *et al.* 2008; Adams-Hosking *et al.* 2011; Seabrook *et al.* 2011). Death rates are highest in spring during dispersal and the onset of breeding as Koalas are more mobile at this time (Dique *et al.* 2003a).

Fires are known to cause the decline of Koala populations, with the extent of impact relating to fire intensity. Fires can cause direct mortality during the fire and indirect impacts, including starvation and predation, following a fire (Melzer *et al*. 2000; Lunney *et al*. 2004, 2007). The recovery of Koala populations following fire will depend on the intensity and extent of the fire, the extent of habitat fragmentation that results, the availability of source populations for recolonization and the extent of other threats (e.g. dog predation) (Department of Environment and Climate Change 2008). Following a fire, surviving Eucalypts respond by rapidly producing epicormic growth (Burrows 2013). Koala have been recorded foraging on epicormic growth within three months following fire (Matthews *et al*. 2007).

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

Preferred Koala food trees present within the Project Area include the primary food species, Forest Red Gum (*Eucalyptus tereticornis*) and the secondary species Grey Gum (*E. punctata*), Grey Box (*E. moluccana*), Blue-leaved Stringybark (*E. agglomerata*), Thin-leaved Stringybark (*E. eugenioides*), Yellow Box (*E. melliodora*) and White Box (*E. albens*). However, Grey Gum and Blue-leaved Stringybark may only be preferred when growing on shale rather than sandstone (Phillips and Callaghan 2000). Thus, the Koala would be limited to habitats, and sometimes specific geologies, containing preferred species. The Koala may move through other vegetation communities to reach preferred feeding areas.

The presence of the Koala in the Project Area was assessed by direct observation during spotlighting (Wilmott *et al.* 2018) and by the Koala SPOT assessment technique (KSAT). The KSAT is an indirect survey methods based on the detection of faecal pellets (Phillips and Callaghan 2011). Direct detection methods work well at higher population densities, but indirect methods, such as the KSAT, may be superior at detecting Koalas at low population densities (Mossaz 2010). However, the detectability of Koala pellets is influenced by the density of groundcover vegetation and their decay (or alternatively, persistence) rate is influenced by rain, moisture and insect activity. Thus, caution must be exercised when comparing absolute or relative population densities/activity levels in different habitats and at different times (Rhodes *et al.* 2011; Cristescu *et al.* 2012).

The paucity of Koala records from the surveys of the Project Area suggest that a small population is present. There are few Bionet records from the Project Area, but it is unclear how strongly this relates to survey effort. Based on the genetic diversity (allelic richness and heterozygosity) of the Blue Mountains Koala population is comparable to the highest diversity found in any Koala population investigated (Lee *et al.* 2010). This suggests that the Koalas within the Project Area are likely to be part of a much larger population and that the population is larger than suggested by surveys records, which are limited by accessibility in the rugged terrain.

Based on assessments of suitable habitat within the study area and the absence of records from surveys, it is estimated that any Koala population in the Project study area would occur at close to the known minimum density of 0.2 animals per hectare. An estimated Koala population size of 1,056 individuals was estimated for the upstream study area occupying a total of 5,280 hectares of habitat. The assessment has assumed a total loss of biodiversity values for an area of 1,400 hectares, this equating to an estimated 280 individuals.

Downstream there is an estimated 9,905 hectares of potential Koala habitat in the Project study area. Due to high levels of disturbance, isolation and threats of vehicle strike and dogs, it is estimated that only a small proportion of this habitat could be occupied by Koalas. While the Koala habitat generally occurs on soils with a high moisture content, this does not mean it is dependent on flooding to achieve this. Thus, the Project is unlikely to result in a decrease in Koala population size downstream.

The Koala is listed as a species requiring urgent management intervention following the 2019/2020 bushfire season (DAWE 2020). The recent fires within the study area are likely to have caused the local population of the Koala to decrease. It is estimated that 691 hectares of Koala habitat was affected over 2019/2020 bushfire event within the upstream study area. Given the overall severity of the fires, it is likely that a concomitant reduction in population size has occurred. Thus, the remaining population is estimated to be about 918 individuals, a loss of an estimated 138 Koalas due to bushfire. The time to recovery for the Koala is dependent of the development of epicormic growth and is often relatively rapid, i.e. months rather than years (e.g. Curtin et al. 2001; Matthews et al. 2007).

The likely impact (including direct and indirect impacts) that the development will have on the habitat of the local population

Habitat loss within the upstream impact area would be the major impact on the Koala due to the reduction in the availability of foraging resources. As site quality has a major influence on Koala distribution and abundance, the inundation would affect a fairly high proportion of its habitat in the Project Area resulting in a reduction in the size of the local population. An assumed 1,400 hectares (the upstream impact area) of potential habitat would be affected by the Project. Assuming the density of 0.2 hectares^{-1}, an estimated 280 individual Koalas would be lost due to the Project. This represents about 27% of the estimated population within the upstream study area. The ability of the Koala to move through low quality habitat suggests that the Project would not result in any significant habitat fragmentation.

Koalas appear would be absent or at very low density in the types of habitat that surround the construction area at the existing dam. Therefore, construction stage impacts (for example, noise, light, vibration, movement of large vehicles) are not likely to affect the Koala.

The likely impact on the ecology of the local population

The main impact on the local Koala population will be the linear reduction in population size due to habitat loss resulting in the loss of foraging resources. Habitat fragmentation is not expected to be a significant factor. The Project is not expected to alter life history attributes (for example, birth and mortality rates) of the remaining population.

An assumed 1,400 hectares (the upstream impact area) of potential habitat would be affected by the Project. Assuming the density of 0.2 hectares^{-1}, an estimated 280 individual Koalas would be lost due to the Project. This represents about 27% of the estimated population within the upstream study area. However an estimated 776 Koalas would remain in the upstream study area. Additionally, the upstream study area is connected to areas with similar habitats, suggesting that the total population size would be considerably larger (see below). Therefore, population viability within the upstream study area would be maintained.

A description of the extent to which the local population will become fragmented and isolated as a result of the proposed development

Koalas are capable of dispersing over 10-16 kilometres (White 1999; Dique *et al.* 2003a) and on lands with various types of cover ranging from rural and urban areas to forest communities of varying density. This suggests that the Koalas within the Project Area are not likely to become fragmented and isolated as a result of the Project due to the presence of large tracts of open Eucalypt forest.

The relationship of the local population to other populations of the species

The genetic diversity (allelic richness and heterozygosity) of the Blue Mountains Koala population is comparable to the highest diversity found in any Koala population investigated (Lee *et al.* 2010). As Koalas are capable of dispersing over many kilometres. These factors suggest that the Koalas within the Project Area are likely part of a much larger population.

The extent to which the Project 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

Recognised threats to the Koala are:

- Habitat loss and fragmentation
- Drought
- Disease
- Climate change
- Vehicle strike
- Dog attack.

Of these, only habitat loss is expected to be a Project impact. The remaining factors are not relevant to the Project. Indeed, the presence of a water supply catchment excludes some of these impacts (for example, vehicle strike).

As discussed above, habitat loss is not expected to affect the viability of the local Koala population.

The measure/s proposed to contribute to the recovery of the species

The Project impacts on the Koala will be a direct consequence of habitat loss associated with a larger inundation area. While this would remove foraging resources and result in a reduced size of the local population, this is not likely to impact on the population viability of the Koala. The Koala is not expected to be exposed to construction stage impacts. Therefore, no specific measures are proposed that would contribute to the recovery of the Koala. However, general habitat offsets would benefit the Koala by securing suitable habitat in other locations.

The Project Area occurs within the geographic range of the Koala. Therefore, the Project must be assessed under the EPBC Act. The Koala habitat assessment criteria for a coastal population (defined by average annual rainfall >800 mm) is applied to the Project in the following table. While the rainfall is variable over such a large area, parts of the catchment have an average annual rainfall that exceeds 800 millimetres (Bureau of Meteorology 2018). The Sydney Basin is also mapped as coastal habitat in Map 2 of the Draft EPBC Act Referral Guidelines for the Koala (Department of Environment 2014) (the Guidelines). The Guidelines provide the "Koala habitat assessment tool" (Table 3 of the Guidelines). This tool enables recognition of habitat critical to the survival of the Koala, defined as a score of 5 or more derived from the habitat assessment tool.

Koala habitat assessment

Attribute	Score	Inland	Evaluation	Score
Koala occurrence	+2 (high)	Evidence of one or more koalas within the last 2 years.	No evidence of the Koala was recorded in the Project Area during the recent field surveys. The most recent records in the Project Area are from 2004, but it is likely	1
	+1 (medium)	Evidence of one or more koalas within 2 kilometres of the edge of		

Attribute	Score	Inland	Evaluation	Score
		the impact area within the last 5 years.	that the area has been poorly surveyed due to accessibility. The Bionet Atlas provides one record of the Koala within 2 kilometres of the Project Area in the last five years.	
	0 (low)	None of the above.		
Vegetation composition	+2 (high)	Has forest or woodland with 2 or more known koala food tree species, or 1 food tree species that alone accounts for >50% of the vegetation in the relevant strata.	One primary (Forest Red Gum, *Eucalyptus tereticornis*), three secondary (Slaty Red Gum *E. glaucina*, Grey Box *E. moluccana,* Grey Gum *E. punctata*) and two stringybark (Blue-leaved Stringybark *E. agglomerata*, Thin-leaved Stringybark *E. eugenioides*) tree species known to be used by the Koala in the Sydney Basin are present in the Project Area.	2
	+1 (medium)	Has forest or woodland with only 1 species of known koala food tree present.		
	0 (low)	None of the above.		
Habitat connectivity	+2 (high)	Area is part of a contiguous landscape ≥ 500 ha.	The contiguous habitat area greatly exceeds 500 ha	2
	+1 (medium)	Area is part of a contiguous landscape < 500 ha, but ≥ 300 ha.		
	0 (low)	None of the above		
Key existing threats	+2 (low)	Little or no evidence of koala mortality from vehicle strike or dog attack at present in areas that score 1 or 2 for koala occurrence. Areas which score 0 for koala occurrence and have no dog or vehicle threat present.	While there is no evidence of Koala mortality in the Project, this may be largely due to its remote location that makes the detection of mortality events very unlikely. Clearly, vehicle strike is very unlikely (though possibly >0). However, some predation by wild dogs is likely, particularly as there are roads through much of the Project Area, which would allow access.	2
	+1 (medium)	Evidence of infrequent or irregular koala mortality from vehicle strike or dog attack at present in areas that score 1 or 2 for koala occurrence, or areas which score 0 for koala occurrence and are likely to have some degree dog or vehicle threat present.		
	0 (high)	Evidence of frequent or regular koala mortality from vehicle strike or dog attack in the study area at present, or areas which score 0 for koala occurrence and have a significant dog or vehicle threat present.		
Recovery value	+2 (high)	Habitat is likely to be important for achieving the interim recovery objectives for the relevant context, as outlined in Table 1.	The interim recovery objectives in coastal areas are to “Protect and conserve large, connected areas of koala habitat, particularly large, connected areas that support koalas that are: Of sufficient size to be genetically robust / operate as a viable sub-population or free of disease or have a very low incidence of disease or breeding. Maintain corridors and connective habitat that allow movement of koalas between large areas of habitat.	2
	+1 (medium)	Uncertain whether the habitat is important for achieving the interim recovery objectives for the relevant context, as outlined in Table 1.		
	0 (low)	Habitat is unlikely to be important for achieving the interim recovery objectives for the relevant context, as outlined in Table 1.		

Attribute	Score	Inland	Evaluation	Score
			On one hand there is a paucity of Koala records in the Project Area. However, large areas of potential habitat are available and the elevation of much of the Project Area may provide some refuge from future climate change. Therefore, the Project Area is likely to be important for achieving the interim recovery objectives for the Koala.	
Total Score				9

A habitat assessment score of nine was achieved, indicating that habitat critical to the survival of the Koala is present in the Project Area. The referral guidelines do not provide specific guidance on the definition of an important population (Commonwealth of Australia 2014). Therefore, the definition given above will be used.

Given that a large amount of habitat is available in the Project Area and it is part of the continuous habitat in the Locality, a key source population for breeding and dispersal and for maintaining genetic diversity (see Lee *et al.* 2010) would be present. Thus, an important population of the Koala is present in the Project Area.

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**
An important population of the Koala is considered to be present in the upstream study area. The upstream study area may support an estimated 1,056 Koalas in 5,280 hectares of habitat at an average density of 0.2 hectares^{-1}. This is a reasonably low Koala density, which is consistent with the paucity of Koalas records, although the remote and inaccessible location of the Project Area may limit the collection of location records. The construction area habitats include preferred Koala food trees, such as Grey Gum (*E. cuminat*) and Blue-leaved Stringybark (*E. cuminate*) (Phillips and Callaghan 2000). However, these species are only preferred when growing on shale. In contrast, the construction area is on sandstone. The Koala is unlikely to occur in the construction area at a detectable level, but it might occasionally move through the area during dispersal. Downstream there is an estimated 9,905 hectares of potential Koala habitat in the Project Study Area, with an estimated 965 hectares within the changed 10% AEP flood extent. While the Koala habitat generally occurs on soils with a high moisture content, this does not mean they are dependent on flooding to achieve this. Thus, the Project is unlikely to result in a decrease in Koala population size downstream. An assumed 1,400 hectares (the upstream impact area) of potential habitat would be affected by the Project in the upstream study area. Assuming the density of 0.2 hectares^{-1}, an estimated 280 individual Koalas would be lost due to the Project. This represents about 27% of the estimated population within the upstream study area. Downstream and construction area impacts are unlikely to affect population size.
• **reduce the area of occupancy of an important population**
While the Project may result in the loss of individual Koalas, the Project Area is embedded within a landscape containing thousands of hectares. There are Koala records in all directions around the Project Area, particularly to the south-east. These peripheral areas would be connected to the Project Area by migration and, therefore, are part of the same population. The Project is unlikely to reduce the area of occupancy of an important Koala population.
• **fragment an existing important population into two or more populations**
The Project may result in an expansion of the current inundation area. The Koala is capable of dispersing at least 10-16 kilometres (White 1999; Dique *et al.* 2003a) and through a variety of habitats types, including areas with

scattered trees. The Koala would continue to move through the Project Area during the construction and operation stages of the Project, although it would avoid the immediate area of construction. The Project would not fragment an existing population into two or more populations or erect any barriers to the movement of the Koala.
• **adversely affect habitat critical to the survival of a species**
Habitat critical to the survival of the Koala was identified in the Project Area and 49% of the upstream habitat in the Project Study Area would be removed by the Project. The Project would adversely affect habitat critical to the survival of the Koala.
• **disrupt the breeding cycle of an important population**
Breeding occurs between December and March. A single young per female is born per year (Martin and Handasyde 1995). Dispersal is male biased, occurring between July and December when Koalas are 20 – 36 months of age (Dique *et al.* 2003a). There is no suitable habitat for the Koala around the dam wall, therefore, the construction phase of the Project would not disrupt the breeding cycle of the Koala. A larger area of inundation would reduce the number of breeding females in the Project Area, but it would not affect the breeding cycle of the remaining population. The Project is not likely to affect the breeding cycle of the Koala.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The area of habitat that would be removed by the Project surrounds the existing inundation area. Large areas of continuous habitat would remain in the Locality. These areas are protected within large conservation reserves (for example, Kanangra-Boyd National Park). Although there would be some removal of potential foraging habitat, it is unlikely to be to the extent that the Koala is likely to decline.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
Invasive species, such as the European Rabbit, European Red Fox and Wild Dogs are already present in the Project Study Area. The former two are not likely to affect the Koala. Dogs are known predators of the Koala. The Project would not cause the establishment of any new invasive species. The proposed actions are unlikely to result in an invasive species that is harmful to the Koala becoming established in its habitat.
• **introduce disease that may cause the species to decline, or**
Koalas are affected by Chlamydia and Koala Retrovirus. Chlamydia reduces female fertility, which may contribution to the loss of small, isolated Koala populations. Koala Retrovirus causes a range of conditions, including leukaemia and immunodeficiency syndrome. Both diseases are likely to currently exist in the local Koala population. The Project is not likely to introduce any other diseases associated with the Koala. The Project is unlikely to introduce disease with potential to cause the Koala to decline.
• **interfere substantially with the recovery of the species.**
The EPBC Act referral guidelines for the Vulnerable Koala state that the interim recovery objectives for the Koala in coastal areas are to "Protect and conserve large, connected areas of koala habitat, particularly large, connected areas that support koalas that are: • Of sufficient size to be genetically robust / operate as a viable sub-population or free of disease or have a very low incidence of disease or breeding • Maintain corridors and connective habitat that allow movement of koalas between large areas of habitat.

The Project Area is large, likely to have a low incidence of disease due to its remoteness and would contain breeding females. Thus, the Project Area is capable of supporting a viable Koala population. Although the Project may impact upon the Koala and reduce its upstream population size by 49%, it is not likely to impact upon the viability of the local population because large and connected areas of habitat would persist in the Locality, including large areas of habitat within conservation reserves. The Project is unlikely to interfere with the recovery of the Koala.
Conclusion
The Project Study Area contains foraging habitat that may be utilised the Koala. The Referral Guidelines for the Vulnerable Koala suggest that the removal of greater than 20 hectares of habitat almost certainly constitutes a significant impact on the Koala. The Project would affect an estimated 2,365 hectares (1,400 hectares upstream and 965 hectares downstream) of Koala habitat. Therefore, the Project is likely to have a significant impact on the Koala.

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Polytelis swainsonii (Superb Parrot)

Vulnerable under the EPBC Act

The Superb Parrot is listed as vulnerable under the EPBC Act and vulnerable under the BC Act 2016. The core range of the superb parrot is west of the Great Dividing Range in New South Wales (NSW) from Canberra (Australian Capital Territory, ACT), Goulburn and as far west as Nyngan and Swan Hill. In Victoria, the species is now largely confined to Barmah forest area with sightings south to Shepparton and east to Wangaratta and Corryong along the Murray River. There are three main breeding areas: an area of the south-west slopes bounded by Molong, Rye Park, Yass, Coolac, Cootamundra and Young (NSW); along the Murrumbidgee River, between Wagga Wagga and Toganmain Station, and farther north at Goolgowi (NSW); and along the Murray and Edward Rivers, from east of Barmah and Millewa State Forest to south of Taylors Bridge (NSW and Victoria) (Baker-Gabb 2011). Local abundance outside the breeding season has a strong positive relationship with plant productivity, but this can vary from year to year. Therefore, a general winter movement into northern NSW is not necessarily a regular migration (Manning *et al.* 2007).

The Superb Parrot uses a number of habitats for different activities. Superb Parrots breed in either River Red Gum forests and woodlands or box woodlands (Webster 1998). In the Riverina Region of NSW and adjacent areas of Victoria, the Superb Parrot usually breeds in forests dominated by large mature River Red Gums, typically close to watercourses, though nests are also occasionally located in Blakely's Red Gum (*E. blakelyi*), Grey Box (*E. 437cuminate437*), Red Box (*E. polyanthemos*) and Inland Red Box (*E. intertexta*) (Webster 1988). In the South-west Slope Region of NSW, Superb Parrots breed in box-gum forests and woodlands dominated by River Red Gum (*E. camaldulensis*), Blakely's Red Gum (*E. blakelyi*), Apple Box (*E. bridgesiana*), Grey Box (*E. mircocarpa*), White Box (*E. albens*) and Red Box (*E polyanthemos*) (Webster 1998).

Most nest sites are within 10 kilometres of box-gum woodland and are sometimes within it (Manning *et al.* 2004). The same nest hollows are used in successive years, although it is not known if it is always by the same pair (Webster & Ahern 1992; Davey 1997; Manning *et al.* 2004). After breeding, superb parrots use a variety of woodland types and other habitat types (Webster 1988), including artificial habitats such as crops and recreation reserves. They mostly feed on the ground, where they take a variety of native and introduced seeds, but also in shrubs and trees on seeds and blossom (Webster 1988). A generation time of 7.5 years (BirdLife International 2020) is derived from an age at first breeding of one year and a maximum longevity in the wild of 14 years (Baker-Gabb 2011). The population is estimated to contain 10,000+ birds and cover 95,300 square kilometres (BirdLife International 2020).

Upstream/Construction

The Superb Parrot is unlikely to inhabit the study area but may visit rarely. The study area falls outside of, but is adjacent to, known and predicted distribution. The majority of the vegetation within the study area is not their preferred habitat of box gum woodlands, although some of this community does occur.

No targeted Superb Parrot surveys were conducted in the study area by SMEC, however, it would be expected that surveys undertaken to target the Regent Honeyeater were suitable to detect this species. In all other areas of suitable habitat, occasional presence is assumed.

Downstream

The Superb Parrot is likely a rare visitor in the study area. The study area is located about 50 kilometres away from the edge of known Superb Parrot distribution. This species has been recorded few times in the study area near Richmond but most records are noted as being likely escapees from captivity.

No targeted Superb Parrot surveys were conducted in the study area by SMEC due to the low likelihood of it being detected during survey given the location is outside the known distribution of the species.

For this assessment, it assumed that the Superb Parrot may visit any suitable habitat (as determined by the TBDC, records and other scientific literature). Suitable habitat includes areas that have been mapped as the following PCTs:

- 1401: Narrow-leaved Ironbark – Forest Red Gum on rocky slopes of the lower Burragorang Gorge Sydney Basin Bioregion (BVT: HN557) – 957 ha within the downstream study area
- 840: Forest Red Gum – Yellow Box woodland of dry gorge slopes southern Sydney Basin Bioregion and South Eastern Highlands Bioregion (BVT: HN527) – 490 ha within the downstream study area.

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**

No important populations of Superb Parrot have been declared.

The Study Area is unlikely to support any permanent or important populations of Superb Parrot as the Study Area falls outside of known and predicted Superb Parrot distribution. Although some individuals may pass through the 957 hectares of PCT 1401 or 490 hectares of PCT 840 within the PMF. Both of these areas will be impacted by the development.

The Project would not lead to a long-term decrease in the size of an important population of a species.

- **reduce the area of occupancy of an important population**

No important populations of Superb Parrot have been declared.

Due to their high mobility capability, the Project is unlikely to result in the loss of foraging individual Superb Parrots. The Project study area is outside of known or predicted habitat but embedded within a large contiguous forested landscape which Superb Parrots could use to disperse through. All breeding habitat is known to be located more than 100 kilometres away.

The Project would not reduce the area of occupancy of an important Superb Parrot population.

- **fragment an existing population into two or more populations**

No important populations of Superb Parrot have been declared.

The loss and degradation of suitable and potential foraging habitat in the impact area may increase habitat fragmentation however this is unlikely to result in a loss of true habitat connectivity given the Superb Parrot's high mobility. Hence, it is unlikely that any existing or transient populations of Superb Parrots will become fragmented into two or more populations.

The Project would not fragment an existing population into two or more populations or erect any barriers to the movement of the Superb Parrot.

- **adversely affect habitat critical to the survival of a species**

All declared critical habitat for the Superb Parrot falls outside of the Study Area.

The Project would not affect habitat critical to the survival of the Superb Parrot.

- **disrupt the breeding cycle of an important population**

No important populations of Superb Parrot have been declared.

Due to their high mobility capability, the Project is unlikely to result in the loss of foraging individual Superb Parrots. The Project study area is outside of known or predicted habitat but embedded within a large contiguous forested landscape which Superb Parrots could use to disperse through. All breeding habitat is known to be located more than 100 kilometres away.

The Project would not reduce the area of occupancy of an important Superb Parrot population.

- **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**

No important populations of Superb Parrot have been declared.

The loss and degradation of suitable and potential foraging habitat in the impact area may increase habitat fragmentation however this is unlikely to result in a loss of true habitat connectivity given the Superb Parrot's high mobility. Hence, it is unlikely that any existing or transient populations of Superb Parrots will become fragmented into two or more populations.

The Project would not fragment an existing population into two or more populations or erect any barriers to the movement of the Superb Parrot.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
The Project is unlikely to result in an invasive species that is harmful to the Superb Parrot becoming established in its habitat.
• **introduce disease that may cause the species to decline, or**
There are no diseases recognised as affecting the Superb Parrot. The Project is not likely to increase the potential for introduction of diseases that may affect this species.
• **interfere substantially with the recovery of the species**
The national recovery plan for the Superb Parrot lists the following conservation objectives: • Determine population trends in the Superb Parrot. • Increase the level of knowledge of the Superb Parrot's ecological requirements. • Develop and implement threat abatement strategies. • Increase community involvement in and awareness of the Superb Parrot recovery program. Several threats listed under conservation objective 3 include may be exacerbated by the Project: • Loss and degradation of habitat • Irrigation and regulated flows • Disturbance The high dispensability capabilities of the species and low likelihood of occurrence in the area indicate the Project is unlikely to interfere with the recovery of the Superb Parrot.
Conclusion
The study area contains foraging habitat that may be utilised Superb Parrots intermittently. The Project is unlikely to have a significant impact on the Superb Parrot.

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Pommerhelix duralensis (Dural Land Snail)

Endangered under the EPBC Act

The Dural Land Snail occurs on shale-influenced habitats along the western and north-western fringes of the Cumberland IBRA subregion. There is currently a degree of uncertainty about the distribution and identity of the snails in this and related species. *P. duralensis* in the strict sense is found in an area of north-western Sydney between Rouse Hill – Cattai and Wiseman's Ferry, west from Berowra Creek.

The species has a strong affinity for communities in the interface region between shale-derived and sandstone-derived soils, with forested habitats that have good native cover and woody debris. The Dural Land Snail favours sheltering under rocks or inside curled-up bark. It does not burrow nor climb. The species has also been observed resting in exposed areas, such as on exposed rock or leaf litter, however it will also shelter beneath leaves, rocks and light woody debris.

Migration and dispersal are limited, with overnight straight-line distances of under one metre identified in the literature and studies. The species is active from approximately one hour after dusk until dawn and no confirmed diurnal activity is reported. It exhibits no roost-site behaviour.

No targeted searches for the Dural Land Snail were undertaken by SMEC. It assumed the Dural Land Snail could occupy any suitable habitat that occurs within its geographical range. For this assessment, suitable habitat includes areas that have been mapped as the following PCTs in the downstream study area:

- 724: Broad-leaved Ironbark – Grey Box – *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain Sydney Basin Bioregion
- 725: Broad-leaved Ironbark – *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain Sydney Basin Bioregion
- 830: Forest Red Gum – Grey Box shrubby woodland on shale of the southern Cumberland Plain Sydney Basin Bioregion
- 849: Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain Sydney Basin Bioregion
- 850: Grey Box – Forest Red Gum grassy woodland on shale of the southern Cumberland Plain Sydney Basin Bioregion
- 1081: Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain Sydney Basin Bioregion
- 1181: Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney Basin Bioregion
- 1183: Smooth-barked Apple – Sydney Peppermint – Turpentine heathy open forest on plateaux areas of the Sydney Basin Bioregion
- 1281: Turpentine – Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion
- 1284: Turpentine – Smooth-barked Apple moist shrubby forest of the lower Blue Mountains Sydney Basin Bioregion
- 1395: Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain Sydney Basin Bioregion.

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 size of the total population of Dural Land Snails is unknown due to insufficient data but is likely to be highly fragmented into smaller sub-populations that are isolated by fragmentation (DoEE 2015). Although an estimated 921 hectares of suitable habitat for this species occur within the study, it is only likely to occupy areas of intact vegetation in the north of the study area. The Dural Land Snail relies on ground covers, rocks and bark to provide shelter. The effect of changes to floristic composition of native vegetation and its subsequent effect on the Dural Land Snail as a result of altering the flow and flood levels of the Hawkesbury-Nepean River are unknown.

• **reduce the area of occupancy of a species**
The Dural Land Snail occurs on the shale-influenced habitats along the western and north-western fringes of the Cumberland IBRA subregion. Its estimated maximum global distribution based on records is 240,000 hectares. The Project would not result in the direct removal of any vegetation that provides potential habitat for the Dural Land Snail, therefore, it is unlikely to reduce the area of occupancy of the species.
• **fragment an existing population into two or more populations**
Migration and dispersal of the Dural Land Snail is limited, with movements less than one metre generally recorded. Habitat for the Dural Land Snail is already severely fragmented due to vegetation clearing for various land uses across western Sydney. Several populations are now isolated into remnants under five hectares in size, which may be resulting in genetic isolation and inbreeding depression (Ridgeway *et al.* 2014). The Project would not require any direct clearing of vegetation suitable for the Dural Land snails so is therefore not likely to result in further fragmentation of Dural Land Snail populations.
• **adversely affect habitat critical to the survival of a species**
No critical habitat has been listed for the Dural Land Snail. The Dural land snail has a strong preference for shale-influenced vegetation types and has not been confirmed outside such habitats, although it remains possible that the species may be found outside these habitats. Shale-influenced habitats along the northwest fringes of the Cumberland Plain are considered important to the species survival (DoEE 2015). The Project will not impact on habitat critical for the survival of the Dural Land Snail. Parts of the study area provide important habitat for the Dural Land Snail. Areas in which the Dural Land Snail would be predicted to occur are unlikely to undergo significant changes as a result of the Project.
• **disrupt the breeding cycle of a population**
A recovery plan under the EPBC Act has not been prepared for the Dural Land Snail, nor has it been listed as a species covered within the Cumberland Plain Recovery Plan. No critical breeding habitat has been declared for this species. It is likely that *Pommerhelix duralensis* relies on the occurrence of rain rather than a specified habitat to reproduce, as in related species (Ridgeway *et al.* 2014). The breeding cycle of the Dural Land Snail is unlikely to be impacted by the 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 Project may result in the potential modification of an estimated 197 hectares of suitable habitat for the Dural Land Snail. No suitable habitat would be removed. The Project will lead to major reductions in maximum discharge rates during 1 in 5 chance in a year 1 in 10 chance in a year and 1 in 20 chance in a year flood events. This may result in relatively drier habitat conditions on the edges on the flood zone. This may modify less than 5% of the *Pommerhelix duralensis*'s known habitat. Drier conditions may result in this area may result in changes of vegetation structure. As a terrestrial species, reduced flood area may increase appropriate habitat area. The Project is unlikely to modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline.
• **result in invasive species that are harmful to an endangered or critically endangered species becoming established in the endangered or critically endangered species' habitat**
Predation by the introduced Common Blackbird (*Turdus merula*) is recognised as a potential threat to the Dural Land Snail (DoEE 2015). The Project is unlikely to increase the range of Common Blackbirds into the habitat of this species. Competition with introduced garden snail (*Cornu aspersum*) is also listed as a threat to the Dural Land Snail but the Project is unlikely to influence spread of this introduced species. There are no other invasive species known to threaten the Dural Land Snail.

• **introduce disease that may cause the species to decline**
Current information does not identify any diseases that effect this species. The Project is unlikely to introduce disease that may cause the Dural Land Snail to decline.
• **interfere substantially with the recovery of the species**
No recovery plan has been prepared for the Dural Land Snail. The conservation advice for this species identifies that a recovery plan is not recommended as the approved conservation advice provides sufficient direction to implement priority actions and mitigate against key threats (DoEE 2015). The conservation advice identifies habitat clearing, development and fragmentation as the dominant threats to the recovery of this species. The Project is unlikely to exacerbate these known impacts within *Pommerhelix duralensis*'s known area of distribution.
Conclusion
The Project is unlikely to lead to a long-term decrease, reduce the area of occupancy, disrupt the breeding cycle of a population, adversely affect habitat critical to the survival of the species or substantially interfere with the recovery of *Pommerhelix duralensis*. The Project is unlikely to have a significant impact on the Dural Land Snail.

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Potorous tridactylus tridactylus (Long-nosed Potoroo)

Vulnerable under the EPBC Act

The Long-nosed Potoroo (south-eastern mainland sub-species) occurs in sclerophyll forest and coastal heath with a dense understory for diurnal shelter and predator protection and occasional open areas for foraging (Bennett 1993; Claridge and Barry 2000; Norton *et al*. 2010). Habitats in mid-slope and gully positions are preferred (Claridge *et al*. 1993a). Preferred soil types are friable to enable digging and low in nutrients (Claridge and Barry 2000).

The Long-nosed Potoroo is mainly nocturnal, sheltering in dense vegetation during the day and foraging by digging at night. Its diet consists mainly of the sporocarps (fruiting bodies) of hypogeal (underground) fungi, but arthropods, seeds, tubers and fleshy fruits are also consumed (Bennett and Baxter 1989; Claridge et al. 1993b) Home ranges are usually between 2-5 hectares (Long 2001). There is strong home-range overlap between males and females, with lower rates of intra-sex overlap (Long 2001; Norton et al. 2011). Sex ratio approximately 1:1 (Norton et al. 2011). Population densities of 0.20 to 0.40 per hectare have been reported (Kitchener 1973; Mason 1997).

The Red Fox is a major predator and the Long-nosed Potoroo responds positively to its control (Dexter and Murray 2009). Fire also causes a reduction in the population size of the Long-nosed Potoroo and preferred habitat may take more than 20 years to recover (Claridge and Barry 2000).

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

The Long-nosed Potoroo was not detected during recent surveys and is not known to occur in the study area, however, the species is often difficult to detect. Due to the lack of records, the Long-nosed Potoroo was not a target species for survey but would be possible to detect during surveys for the Southern Brown Bandicoot. It has therefore been assumed that the species may occur in suitable habitat within its known distribution. An estimated 4,443 hectares of potential habitat for the Long-nosed Potoroo occurs in the upstream study area based on known PCT associations. The majority of the study area does not provide suitable habitat for the species due to the absence of required vegetation structure and sandy soils. Only the upstream study area is likely to provide suitable habitat.

An estimated 4,442 hectares of potential Long-nosed Potoroo was available in the upstream study area prior to the bushfires. Assuming an intermediate population density (see above) of 0.3 per hectare, this would equate to a population size of 1,333 individuals.

The Long-nosed Potoroo is listed as a species requiring urgent management intervention following the 2019/2020 bushfire season (DAWE 2020). The recent fires within the study area are likely to have caused the local population of the Long-nosed Potoroo to decrease. It is estimated that 3,007 hectares (68%) of Long-nosed Potoroo habitat was affected over 2019/2020 within the upstream study area, leaving 1,435 hectares. Given the sensitivity of the Long-nosed Potoroo to fire it is likely that a concomitant reduction in population size has occurred. Thus, the remaining population is estimated to be 431 individuals, a loss of 902 Long-nosed Potoroos due to bushfire. The time to recovery for the Long-nosed Potoroo is expected to be slow, i.e. up to two decades rather than years (e.g. Claridge and Barry 2000).

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 Long-nosed Potoroo was not detected in recent surveys and there are no records of the species occurring in the study area. Known populations occur in the north and south of the Sydney Basin, near Gosford and the Southern Highlands. It is possible that parts of the population south of Sydney extend into the upstream study area, but the species has not been detected there. Long-nosed Potoroos require a dense vegetation structure on sandy loam soils with occasionally open grassy areas for foraging. This type of habitat does not occur throughout most of the study area. The absence of records and suitable habitat indicate that an important population of the Long-nosed Potoroo is unlikely to be present in the study area. Therefore, the proposed actions would be unlikely to lead to a long-term decrease in the size of an important population of Long-nosed Potoroos.

• **reduce the area of occupancy of an important population**
An assumed 1,400 hectares (the upstream impact area) of potential habitat would be affected by the Project. Assuming the density of 0.3 hectares^{-1}, an estimated 420 individuals could be lost due to the Project. This represents about 32% of the estimated population within the upstream study area. However, as previously noted, it is considered unlikely that there is an important population in the upstream study area. As such, the Project would not reduce the area of occupancy of an important population of Long-nosed Potoroos.
• **fragment an existing important population into two or more populations**
The Project will result in an expansion of the current upstream temporary inundation area. The modification of potential Long-nosed Potoroo habitat around the existing Lake Burragorang would not result in the fragmentation of habitat. The Project is unlikely to fragment any important population of Long-nosed Potoroos.
• **adversely affect habitat critical to the survival of a species**
Habitat critical to survival of the Long-nosed Potoroo is not defined. Critical habitat for the Long-nosed Potoroo would include habitat to support all stages of its life-cycle. As no critical habitat has been defined, the Project would not adversely affect habitat critical to the survival of the Long-nosed Potoroo.
• **disrupt the breeding cycle of an important population**
The Project may result in the modification of vegetation that could provide suitable habitat for the Long-nosed Potoroo. An important population of the Long-nosed Potoroo is unlikely to be present in the Project Area.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project may result in the temporary inundation and therefore modification of vegetation that may provide suitable habitat for the Long-nosed Potoroo. This habitat is unlikely to be isolated from other areas of more suitable habitat where Long-nosed Potoroos are known to occur. No potential habitat would be directly removed. The Project would not result in any changes to potential habitat that may result in the decline of the Long-nosed Potoroo.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
Invasive species, such as feral cats, foxes and wild dogs, are known threats to the Long-nosed Potoroo. These species are already present in the study area and it is unlikely the Project may result in the establishment of any new invasive species that are a threat to the Long-nosed Potoroo.. The proposed actions are unlikely to result in an invasive species that are harmful to the Long-nosed Potoroo becoming established in its habitat.
• **introduce disease that may cause the species to decline, or**
No diseases are known to affect the Long-nosed Potoroo. The Project is unlikely to introduce disease with potential to cause the Long-nosed Potoroo to decline.
• **interfere substantially with the recovery of the species.**
No recovery plan is available for the Long-nosed Potoroo. However, recognised threats to the Long-nosed Potoroo are: • Habitat loss and fragmentation from land clearing for development

- Inappropriate fire regimes (fire regimes determine the distribution and size of habitat patches of different successional stages) - Predation from foxes, dogs and cats. The Project may result in the modification of vegetation that is potential habitat for the Long-nosed Potoroo. It is unlikely that this would interfere with the recovery of the species.
Conclusion
The Project study area is unlikely to support an important Long-nosed Potoroo population and the vegetation to be modified is unlikely to result in a decline of the species or interfere with any attempts to recover the species. The Project is unlikely to have a significant impact on the Long-nosed Potoroo.

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Pseudomys novaehollandiae (New Holland Mouse)

Vulnerable under the EPBC Act

The New Holland Mouse occupies drier heath and heathy woodland Haering and Fox 1997; Wilson and Laidlaw 2013; Lazenby *et al*. 2018). While fire can be a threat to New Holland Mouse populations, it prefers early to mid-serial stage regeneration that typically occurs after fire (Pye 1991; Wilson 1991; Fox *et al*. 2003; Wilson *et al*. 2018), but also following disturbances such as sand mining (Fox and Fox 1978). Fire causes changes in vegetative structure. The New Holland Mouse is highly competitive in vegetation 1 – 6 years old; its density then declines in older vegetation as other species, such as the Swamp Rat (*Rattus lutreolus*) and Bush Rat (*Rattus fuscipes*), become more competitive (Fox 1982; Fox and Pople 1984; Norton 1987; Fox *et al*. 2003; Braithwaite and Gullan 2006). Populations tend to be small, localised and prone to extinction. Drought has a negative impact on populations, while high rainfall can facilitate rapid population increases (Lock and Wilson 2017; Wilson et al. 2018).

The New Holland Mouse prefers friable soils (coastal sands and sandstone derived soils) due to its burrowing habit (Pye 1991; Wilson and Laidlaw 2003; Murphy 2005). A high diversity of heath plants, including perennial legumes, and vegetative cover between 0.5 and one metre is favoured (Fox and Fox 1978; Hocking 1980; Wilson 1991). Males and females have a similar diet, which shows seasonal variation depending on the availability of foods such as dicotyledon leaf, fungi, invertebrates and seeds (Norton 1987; Haering and Fox 1997; Wilson and Bradtke 1999).

Population density may range up to 19 hectares^{-1} (Fox 1978; Kemper 1980), but densities of 0.5 – 3 hectares^{-1} appear more typical (Braithwaite and Gullan 1987; Wilson 1991). Breeding occurs November to March (Pye 1991; Wilson 1991). First year females produce one litter per year, while second year females may produce 3 – 5 litters per year. Litter size range between two and six, with a mean of 4.6. Up to 20 offspring can be produced per female per year. Sexual maturity may be reached in the first year (males 33%, females 13 – 88%). Females reach sexual maturity earlier when population density is low (Kemper 1980).

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

There is one Bionet record of the New Holland Mouse within the Project Area, which was obtained from a cat scat. While occupied habitat is expected to be patchy (due to the requirement for heathy understories and a preference for early successional stage habitat), this is also likely to reflect a low survey effort. Similarly, however, there are few records elsewhere in the Blue Mountains. PCTs with heathy understorey within the Project Area are assumed to be potential habitat. The New Holland Mouse is not likely to occur in the construction or downstream study areas.

The population density and variation in density of the New Holland Mouse is known from previous studies. The post-fire population size is the sum of the population within unburnt habitat and within burnt habitat. For this study, a pre-fire/unburnt density of 1.5 per hectare and a post-fire density of 5 per hectare is assumed. The net result is an increase in population sizes post-fire due to the higher population density in now burnt habitat.

There is an estimated 166 hectares of potential suitable habitat available within the upstream study area, providing an estimated population size of 249 individuals prior to the bushfire event. Fire affected an estimated 79 hectares within the upstream study area, leaving 87 hectares unburnt. This gives an estimated post-fire population of 525, a gain of 276 individuals relative to the pre-fire numbers. The species is known to exhibit a positive short term response to fire leading to increased population sizes.

The likely impact (including direct and indirect impacts) that the development will have on the habitat of the local population

While the recent fires would likely have increased the population size within the upstream study area, this would be relatively short-lived and a reduction in density in the burnt areas would occur after five or six years and the population would return to baseline levels. Temporary inundation in the upstream study area may remove cover, foraging resources and shelter sites required by the New Holland Mouse. Assuming the current post-fire density, there would be 525 New Holland Mice within the upstream study area. The Project may remove 48 individuals with regard to the 20% AEP (1 in 5 chance in a year) event and 265 individuals with regard to the 1% AEP (1 in 100 chance in a year) event. The loss of 265 individuals would leave a population size of 259 mice, similar to the pre-fire population estimate of 248. However, population impacts once density had returned to baseline levels in pre-burnt habitat would be more significant. In that case, the upstream study area would support 249 individuals. The 20% AEP event would affect 29 individuals and the 1% AEP 133 individuals. The loss of 133 New Holland Mice would leave an upstream population of 115 based on densities in unburnt habitat.

The construction area would also remove foraging habitat. Noise and vibration are indirect impacts that may extend for several hundred metres around the construction area. Erosion and sedimentation, weed invasion, import of disease (for example, Phytophthora) and chemical spills also have the potential to affect habitat quality. Vehicle movements in and out of the construction area also pose a risk of mortality due to vehicle strike.

Habitat for the New Holland Mouse is more extensive in the downstream area, but still only estimated to be 347 hectares and there is a low likelihood of the species occurring.

The likely impact on the ecology of the local population

The main impact on the local New Holland Mouse population will be the linear reduction in population size due to habitat loss resulting in the loss of foraging resources. This would occur irrespective of the prevailing population size at the time habitat loss occurs in relation to a fire event. The impact of loss would have a lower immediate impact on population viability if it occurred following a fire event when population density (and therefore population size) is higher. However, as burnt habitats recovered and population density lowered the extent of impact would return to the pre-fire level. The loss of suitable habitat may also cause the distances between remaining populations to increase, resulting in population fragmentation, including the inability to disperse into suitable habitat after fire.

The relationship of the local population to other populations of the species

On one hand there is a large amount of continuous native vegetation in the locality. However, suitable habitat, including appropriate successional stages, is likely to be restricted and patchy. Thus, there may be more than one local New Holland Mouse population in the Project study area. These populations are likely to be disjunction from some other populations in the locality. However, at least some local populations would be connected by dispersal and one or more metapopulations may be present. There is likely to be shifts in the distribution of populations over time, with the loss of suitable habitat being offset by the availability of more preferred habitat (for example, post-fire succession).

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

Recognised threats to the New Holland Mouse are:

- Habitat loss and modification (including weed invasion and dieback caused by root fungus Phytophthora
- Inappropriate fire regimes (fire regimes determine the distribution and size of habitat patches of different successional stages)
- Predation from the European Red Fox (*Vulpes vulpes*), dog and cat
- Possible competition from the introduced House Mouse (*Mus musculus*)
- Climate change effects on habitat distribution and quality

Of these known threats, habitat loss and modification are likely to be the most important direct Project impacts. Construction vehicles may also transport weeds and Phytophthora into the Project study area. Areas of more open habitat may enable to ingress of introduced predators (for example, Catling and Burt 1995; Lunney *et al.* 2007). The loss of habitat due to the Project and changes in habitat distribution mediated by climate change may act together to increase the isolation of remaining populations.

The measure/s proposed to contribute to the recovery of the species

The Bionet database provides no records of the New Holland Mouse within the Project study area, but there is a record of the species upstream of the existing lake in the extreme north of the Coxs River catchment. However, given the large size of the Warragamba Dam catchment survey information is likely to be limited. Suitable habitat is present in the Project study area and it is likely to support a small and patchily-distributed meta-population of the New Holland Mouse. Thus, the presence of the New Holland Mouse is assumed on a precautionary basis.

The potential impacts on the New Holland Mouse will relate to potential habitat loss and fragmentation associated with a larger inundation area. This may remove foraging resources and shelter sites and result in a reduced size of the local population. It is uncertain whether this will have a significant impact on the population viability of this species. Fire management would be an important aspect of New Holland Mouse management. However, to protect water quality, habitat management with fire is not proposed as part of the Project. No other specific measures are proposed that would contribute to the recovery of the New Holland Mouse. General habitat offsets would benefit the New Holland Mouse by securing suitable habitat in other locations. Offsetting would be required to compensate for Project impacts.

The 2019-2020 fires in the Burragorang Valley are estimated to have affected 79 hectares of potential New Holland Mouse habitat. In areas subject to low intensity fires, the species would be expected to respond in a positive manner, given their preference to occupy regenerating vegetation. In areas where the fire was of a high intensity, small sub-populations may have been lost, but these areas could be occupied over a longer time frame as the vegetation regenerates. Before regeneration, the species is at increased risk of predation by introduced carnivores. The species is also included on a list of animals requiring urgent management intervention as a result of these fires due to the extent of habitat loss and extinction risk.

Given the lack of New Holland Mouse records and the relatively small estimated area of habitat available (166 hectares) it is likely that total population sizes are relatively small. The individual Project areas are separate from each other and it is further likely that habitat is patchy within each area. It is uncertain whether an important population of the New Holland Mouse is present in the Project study area. Accordingly, adopting a precautionary position, it is assumed that an important population may be present.

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**
There is an estimated 166 hectares of suitable habitat for the New Holland Mouse in the upstream study area. However, there is uncertainty regarding the distribution and abundance of the New Holland Mouse due to the difficulty of accurate habitat mapping, particularly mapping post-fire successional habitat. The Project may result in the and remove 108 hectares of habitat upstream. An additional 19 hectares would be affected by construction impacts, including habitat loss, noise and vibration. The Project is not expected to affect habitat downstream as the New Holland Mouse prefers drier habitats. An important population of the New Holland Mouse may be present in the Project Area. Habitat loss and fragmentation could lead to a long-term reduction in population upstream due to the greater temporary inundation area.
• **reduce the area of occupancy of an important population**
The Project study area is embedded within a landscape containing thousands of hectares. While the New Holland Mouse would be patchily distributed through this area, habitat would remain in all directions around the Project study area. The Project may decrease the area of occupancy of the New Holland Mouse population in the upstream study area by up to an estimated 88 hectares.
• **fragment an existing important population into two or more populations**
The Project would result in an expansion of the current temporary inundation area upstream of Warragamba Dam. The potential removal of habitat and the possible loss of at least some sub-populations would increase the distances between remaining populations. If the increased distances are greater than the dispersal ability of the New Holland Mouse, then population fragmentation may occur. The Project has the potential to fragment existing populations of the New Holland Mouse into two or more populations.
• **adversely affect habitat critical to the survival of a species**
Habitat critical to survival of the New Holland Mouse is not defined. It is known to prefer early successional heath and heathy woodland on sandy soils with a high floristic diversity, particularly leguminous perennials. The Project may affect up to 88 hectares upstream. As no critical habitat has been defined, the Project would not adversely affect habitat critical to the survival of the New Holland Mouse.

• disrupt the breeding cycle of an important population
Upstream, the Project may remove New Holland Mouse habitat and could reduce population size, but it is not likely to impact on the breeding of any remaining females. Downstream, no Project impacts are likely. A small area of habitat occurs within the construction area. While some removal of habitat would occur here, indirect Project impacts, such as noise and vibration, may disrupt breeding by females whose home-ranges abut the construction area. These impacts would be confined to the construction phase.
• modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline
The area of habitat that may be removed by the Project surrounds the existing upstream inundation area. This potential loss of habitat may increase the distances between remaining habitat patches and may be substantial enough to cause the isolation of at least some remaining populations. It is not clear how many New Holland Mice occur in the Project study area as the population density estimates are subject to a high degree of uncertainty. Given that the New Holland Mouse population within the Project study area is likely to be relatively small, it is unlikely that this would cause the species to decline. However, the local extinction of some populations upstream is possible. It is uncertain whether the Project would modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the New Holland Mouse is likely to decline.
• result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat
Invasive species, such as the European Red Fox, feral cat and wild dog, are known threats to the New Holland Mouse. They are already present in the study area. The Project would not cause the establishment of any new invasive species. The proposed actions are unlikely to result in an invasive species that are harmful to the New Holland Mouse becoming established in its habitat.
• introduce disease that may cause the species to decline, or
No diseases are known to affect the New Holland Mouse. The Project is unlikely to introduce disease with potential to cause the New Holland Mouse to decline.
• interfere substantially with the recovery of the species.
No recovery plan has been prepared for the New Holland Mouse. However, recognised threats to the New Holland Mouse are: • Habitat loss and modification (including weed invasion and dieback caused by root fungus Phytophthora • Inappropriate fire regimes (fire regimes determine the distribution and size of habitat patches of different successional stages) • Predation from the European Red Fox, dog and cat • Possible competition from the introduced House Mouse (*Mus musculus*) • Climate change effects on habitat distribution and quality The Project Area may remove potential New Holland Mouse habitat. Given the uncertainty regarding the New Holland Mouse distribution and abundance across its range, it is possible that habitat loss due to the Project may interfere with the recovery of this species.
Conclusion
The Project Area may support an important New Holland Mouse population. The Project may remove or indirectly affect 166 hectares of potential habitat, which may substantially interfere with the recovery of the species. Thus, the Project may have a significant impact on the New Holland Mouse.

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Pteropus poliocephalus (Grey-headed Flying-fox)

Vulnerable under the EPBC Act

The Grey-headed Flying-fox utilises a wide range of vegetation communities, including rainforest, Eucalypt forest and woodland, swamp forest and Banskia heath. Its numbers were greatly reduced by the late 1920s due to on-going habitat clearing, shooting and drought (Ratcliffe 1932) and by 30% since 1989, primarily due to on-going habitat loss and modification (reviewed by Department of Environment, Climate Change and Water NSW 2009). The current distribution is from Rockhampton, Qld, south to Melbourne, Victoria. It mostly occurs in coastal areas, but is sometimes recorded west of the Great Dividing Range (Department of Environment, Climate Change and Water NSW 2009).

The Grey-headed Flying-fox is a highly mobile species (Eby 1991; Tidemann and Nelson 2004; Roberts at al. 2012) that relies on food sources with irregular spatio-temporal patterns of production (Eby and Law 2008). Consequently, patterns of occurrence and relative abundance within its distribution vary widely between seasons and between years. At a local scale, the species is generally present intermittently and irregularly because the phenology of food plants supports regular annual cycles of migration at regional scales (Parry-Jones and Augree 1992; Eby and Law 2008). However, some areas have permanent habitation by some individuals (Eby 1991; Fleming and Eby 2003; Roberts *et al.* 2012). For example, resident populations now occur in urban areas due to the continuity of food provided by a diversity of native and exotic plants provides a stable food supply (Parry-Jones and Augee 2001) and changes to the local climate (warmer temperatures, supplementary watering) (Parris and Hazell 2005). A single population occurs throughout the species' range (Eby 1991). The most recent population estimate is 674,000 individuals from 2005 (Department of the Environment and Energy 2018).

The diet of the Grey-headed Flying-fox is dominated by nectar and fruit (Eby 1991 1998; Parry-Jones and Augee 1991). Across its distribution range, a wide variety of tree and shrub species are used (see Tables 4.1 and 4.3 in Eby and Law 2008). Most valuable nectar-producing species are in the Families Myrtaceae and Proteceae. A wide variety of plant families provide fruit, by the Myrtaceae and Moraceae easily contain the most species. While exotic fruits may be consumed, this usually only occurs when native foods are limiting (Parry-Jones and Augee 1991).

At the habitat scale, the species richness and density of significant food plants are important. Significant food species used by the Grey-headed Flying-fox are highly productive, reliable and are available over long periods of 1 - >3 months (Eby and Law 2008). There can be geographic variation due to latitude and elevation in the temporal availability of nectar within a species. Food is generally least available in winter and spring, during which time the population becomes concentrated on the NSW north coast and south-east Queensland where high concentrations of nectar-producing species are found (Eby and Law 2008). Grey-headed Flying-foxes are important pollinators and seed dispersers of their food plants, particularly as they can transfer plant genes over longer distances than birds or insects (Eby 1991; Southerton *et al.* 2004).

Fire is a recognised threat to the Grey-headed Flying-fox because it reduces the availability of nectar and fruit (DECCW 2009). The Grey-headed Flying-fox is provisionally listed as a high priority species while more information is gathered following 2019/20 fires (Department of Agriculture, Water and the Environment 2020). Given that these fires were so extensive at a landscape scale and occurred during severe drought, it is likely that the Grey-headed Flying-fox has experienced a population decline across its range. However, it is difficult to quantify the population impacts of fire on this species at a local scale due to its high mobility. The re-establishment of fleshy fruit is likely to take some time due to the general sensitivity of mesic flora to fire. However, nectar volumes may return to baseline levels within 1-3 years after fire (Law *et al*. 2000). Thus, local impacts of fire are likely to be relatively short-lived in eucalypt forests where nectar is the primary foraging resource.

Grey-headed Flying-foxes roost in aggregations called camps. Camps are usually located in forests with a thick canopy (for example, rainforest, swamp forest, riparian vegetation and mangroves), usually near water (Department of Environment, Climate Change and Water NSW 2009). Individuals roost in the exposed branches of canopy trees (Eby 1991; Parry-Jones and Augee 1992). The locations of camps are generally stable through time and they may be used permanently, intermittently or seasonally. (Eby 1991; Lunney and Moon 1997). Camps provide resting habitat, sites of social interactions and refuge for animals during significant phases of their annual cycle, such as birth, lactation and conception (Parry-Jones and Augee 1992). Camps with annual patterns of occupation are usually located in coastal areas north from Batemans Bay, NSW (Department of Environment, Climate Change and Water NSW 2009). Camps may be located up to 50 kilometres from foraging habitat; their use and size is influenced food availability. The size of camps can range from several hundred up to 200,000 individuals and contain adults, sub-adults and juveniles (Eby 1991).

Grey-headed flying foxes breed seasonally. Mating occurs in April to May, with females giving birth October-December (Martin and McIlwee 2002). Typically, a single young is born, indicating that the species has low reproductive output, which is balanced by a moderate average life expectancy of about 7 years. Lactation continues until March/April. Females spontaneously abort if exposed to physiological stress late in the pregnancy, and lactation can be interrupted during food shortages (Martin *et al.* 1996). Thus, elevated energy demands associated with reproduction last from late winter through autumn.

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

Three Grey-headed Flying-fox camps are known from the Project study area (Department of the Environment 2018; SMEC observations); Emu Plains, Yarramundi and Wallacia. The nearest known camps within the 50-kilometre foraging range of the species but outside the Project study area are reviewed in the following table.

Locations of known Grey-headed Flying-fox camps and their distance to the Project study area (Source: Department of the Environment 2018). Semi-regular = 50 – 70% of years, regular = 71-95% of years, Permanent 96-100% of years.

Location	Number	Frequency	Distance (km)
Picton	500-10,000	Regular	16
Camden	<500-10,000	Semi-regular	16
Emu Plains	500-10,000, rarely to <50,000	Semi-regular	Downstream
Ropes Creek	500-10,000	Regular	19
Macquarie Fields	500-10,000	Permanent	26
Wetherill Park	500-2,500	Occasional	31
Cabramatta	2,500-10,000, rarely to 16,000	Semi-regular	32
Parramatta Park	2,500-50,000	Permanent	38
Yarramundi	500-2,500	Semi-regular	Downstream

Eby and Law (2008, Tables 4.1 and 4.3) have reviewed the use of various tree species by the Grey-headed Flying-fox and their seasonal availability, reliability and productivity. This enables valuable foraging habitats within the Project study area to be identified and their relative importance estimated. Some areas of rainforest occur within the Project study area, and these may provide seasonal fruit. Foraging habitat includes both nectar and fruit resources.

Of the tree species listed by Eby and Law (2008) 12 occur in the Project study area and six are regarded as important species because they are both productive and reliable. The six important species are Smooth-barked Apple (*Angophora costata*), Red Bloodwood (*Corymbia gummifera*), Spotted Gum (*C. maculata*), Mountain Blue Gum (*Eucalyptus deanei*), Grey Box (*E. moluccana*), Forest Red Gum (*E. tereticornis*) and Turpentine (*Syncarpia glomulifera*). Broad-leaved Ironbark (*Eucalyptus fibrosa*) and Grey Gum (*E. punctata*) also rank highly. Of the species known to the Project study area, Spotted Gum and Gympie Messmate (*E. cloeziana*) were only found in an old forestry growth plot. The other species occur naturally and are widespread. The other six species would also be used by the Grey-headed Flying-fox but would have a more restricted availability or would only be extensively used when more productive species are not available in the region.

Narrow-leaved Ironbark (*Eucalyptus crebra*) is common in the Project study area, but Eby and Lay (2008) were not able to comment on its use but expected it would be used. This is odd given how widespread this species north of the Project study area in NSW and Queensland, where it may occur in coastal and inland communities. Based on this, if Narrow-leaved Ironbark was important, it would be recognised. Narrow-leaved Ironbark has small flowers, suggesting it may be insect pollinated and not of particular value to nectivorous mammals. However, Narrow-leaved Ironbark is often present with other Eucalypts used by the Grey-headed Flying-fox (for example, Forest Red Gum, Grey Gum). Therefore, habitats containing Narrow-leaved Ironbark were captured by the habitat analysis irrespective of its value to the Grey-headed Flying-fox.

Several rainforest communities occur in the Project study area and contain fleshy-fruited trees within the Myrtaceae. However, rainforest communities only occupy a small percentage of the Project study area. Flesh-fruited trees may also occur in the understorey of moist Eucalypt communities (for example, Mountain Blue Gum communities). Overall, fleshy fruits would only provide a small foraging resource to the Grey-headed Flying-fox compared to the availability of nectar.

Due to large fluctuations in the numbers of Grey-headed Flying-foxes using the Project study area due to the spatio-temporal availability of food resources, it is difficult to provide precise population size estimates. There is an estimated 16,666 hectares of native vegetation in the Project study area, all of which could potentially be used by the Grey-headed Flying-fox. However, as food resources are seasonally available, the entire Project study area would not be used at any one time.

The likely impact (including direct and indirect impacts) that the development will have on the habitat of the local population

Pre-fire, there was an estimated 5,205 hectares of foraging habitat for the Grey-headed Flying-fox in the upstream study area. While recent fire has reduced this by 66 percent to 1,782 hectares, it is expected that this will recover (i.e. provide nectar volumes similar to pre-fire levels during flowering events) within three years (e.g. Law *et al*. 2000). Assuming on a rapid return to pre-fire nectar availability, the Project would affect 634 hectares (20% AEP) to 2,863 hectares (1% AEP), respective reductions of 12 percent and 55 percent.

The likely impact on the ecology of the local population

The Project would reduce seasonal food availability, resulting in a reduction in the number of Grey-headed Flying-fox capable of using the Project study area. The reduction of food availability during lactation (spring and summer) may reduce the breeding success within nearby camps.

The relationship of the local population to other populations of the species

Due to the high mobility of the Grey-headed Flying-fox, its use of seasonal food resources and asynchrony in the regional availability of food, individuals are part of one large population. Thus, impacts on the species within the Project study area would have regional and state-wide effects. The large are of habitat within the Project study area suggests that this area is important in the context of the region and the species' range.

The extent to which the Project 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. Overall, habitat loss and fragmentation are the greatest threats. Habitat loss associated with the Project is likely to lead to a reduction in the state-wide Grey-headed Flying-fox. However, due to the complex seasonal use of food resources over large areas, it is difficult to determine the exact impact of the habitat loss on population viability.

No targeted Grey-headed Flying-fox surveys were conducted in the study area by SMEC. For this assessment, it assumed that the Grey-headed Flying-fox could occur in any suitable habitat that occurs within the study area. Suitable habitat includes all vegetation types that have been mapped within the study area.

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**
Due to its high mobility and use of seasonal foraging at a landscape scape, all Grey-headed Flying-fox are part of one population. This is, clearly, an important population and it makes use of the Project study area. All vegetation within the Project Area could potentially be used as foraging habitat by the Grey-headed Flying-fox when suitable species are in flower or fruit. The Project may result in the loss or modification of up to an estimated 3,827 hectares of Grey-headed Flying-fox foraging habitat. This includes habitat in which winter/spring flowering Forest Red Gum is an indicator species. This may introduce seasonal reductions in regional food supply, including during winter/spring when food shortages occur across most of the distribution range. As all Grey-headed Flying-fox belong to one population, the Project would lead to a long-term reduction in the size of this population. No Grey-headed Flying-fox camps are known from the upstream Project study area (Department of the Environment 2018). Therefore, the upstream Project study area only supports foraging habitat. Three Grey-headed Flying-fox camps are known from the downstream Project study area; Emu Plains, Yarramundi and Wallacia. Other camps are located between 16 and 38 kilometres away at Picton, Camden, Ropes Creek, Macquarie Fields, Wetherill Park, Cabramatta and Parramatta Park. The Project would require the removal of critical foraging habitat for the Grey-headed Flying-fox. This may result in a long-term decrease of the size of an important population of the Grey-headed Flying-fox. It is difficult to estimate

the number of individuals that would be lost because of the Project due to the complex interaction of patch-based phenological events (flowering and fruiting) and regional food availability.
• **reduce the area of occupancy of an important population**
While the Project may result in the loss of individual Grey-headed Flying-foxes, the Project study area is embedded within a landscape containing thousands of hectares. There is Grey-headed Flying-fox foraging habitat in all directions around the Project study area. The Project would not reduce the area of occupancy of an important Grey-headed Flying-fox population.
• **fragment an existing important population into two or more populations**
The Project may result in an expansion of the current inundation area. The Grey-headed Flying-fox is a highly mobile species (Eby 1991; Tidemann and Nelson 2004; Roberts *et al*. 2012) that relies on food sources with irregular spatiotemporal patterns of production. The Project may result in an expansion of the current inundation area. The Grey-headed Flying-fox is a highly mobile species that can fly long distances (up to 50 kilometres) to reach seasonal foraging resources. The increase in temporary flooding extent would not pose a barrier to movement for the Grey-headed Flying-fox. The Project would not fragment and important population of the Grey-headed Flying-fox into two or more populations.
• **adversely affect habitat critical to the survival of a species**
Critical habitat for the Grey-headed Flying-fox may be distinguished in two ways, foraging and roosting habitat. Natural foraging habitat that meets one or more of the following criteria is considered habitat critical to survival, or essential habitat, for the Grey-headed Flying-fox: • productive during winter and spring, when food bottlenecks have been identified (Parry-Jones and Augee 1991, Eby *et al.* 1999) • known to support populations of > 30,000 individuals within an area of 50 kilometres radius (the maximum foraging distance of an adult) • productive during the final weeks of gestation, and during the weeks of birth, lactation and conception (September to May) • productive during the final stages of fruit development and ripening in commercial crops affected by Grey-headed Flying-foxes (months vary between regions) • known to support a continuously occupied camp. The Project study area supports a number of important nectar-producing tree species. This includes Forest Red Gum, which flowers winter and spring when seasonal food availability across the species' range is low. Additional species are available within the reproductive period of this species. Large areas of continuous habitat are available in the Locality, including habitat within conservation reserves. Therefore, the area within 50 kilometres of the Project study area is capable of seasonally supporting >30,000 individual foraging Grey-headed Flying-foxes. Foraging habitat critical to the survival of the Grey-headed Flying-fox occurs within the Project study area. Three Grey-headed Flying-fox camps occur in the downstream Project study area and none occur in the upstream or construction area. None of the camps are identified as Nationally Important camps. There are a number of other Grey-headed Flying-fox camps to the east of the Project study area in western Sydney, within 50 kilometres. Individuals occupying these camps would be able to forage in the Project study area. Foraging habitat critical to the survival of the Grey-headed Flying-fox occurs in the Project study area (see above). The Project may remove or modify an estimated 3,827 hectares of this habitat. The Project could adversely affect habitat critical to the survival of the Grey-headed Flying-fox.

• **disrupt the breeding cycle of an important population**
Three Grey-headed Flying-fox camps occur in the downstream Project study area and none occur in the upstream or construction area. None of the camps are identified as Nationally Important camps. By removing or modifying some seasonal foraging resources, the Project may affect the breeding success of some females, but it would not disrupt breeding by most females within the important population. The Project would not adversely affect the breeding cycle of an important population of the Grey-headed Flying-fox.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
The Project may result in the loss of an estimated 3,639 hectares of Grey-headed Flying-fox foraging habitat. Large areas of foraging habitat would remain in the Locality and in the region. The Grey-headed Flying-fox is a highly mobile species that can fly long distances to reach seasonal foraging resources, indicating that these areas would remain available to the Grey-headed Flying-fox. The Project would reduce the local and regional availability of Grey-headed Flying-fox foraging habitat, resulting in the loss of individuals. Although it is difficult to determine how many individuals would be lost, it is to be of sufficient magnitude that the species may decline.
• **result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat**
Invasive species, such as the European Rabbit and European Red Fox are already present in the Project study area but are not likely to affect the Grey-headed Flying-fox. The Project would not cause the establishment of any new invasive species. The proposed actions are unlikely to result in an invasive species that is harmful to the Grey-headed Flying-fox becoming established in the Project study area.
• **introduce disease that may cause the species to decline, or**
Grey-headed Flying-fox are known to carry a number of diseases (for example, Australian bat Lyssavirus (ABL), Equine Paramyxovirus (Hendra virus) and Menangle Pig virus) that are widespread within the population at a moderate to low level. ABL generally only affects <1% of individuals, but the incidence may increase during periods of stress (for example, due to food shortages). ABL would already be present within individual Grey-headed Flying-fox using the Project study area. The other two viruses are not known to cause clinical disease in the species. The Project is unlikely to introduce disease with potential to cause the Grey-headed Flying-fox to decline.
• **interfere substantially with the recovery of the species.**
A draft recovery plan has been prepared for the Grey-headed Flying-fox (DoEE 2017). Actions identified in the recovery plan aim to: • Improve the national population trend • Identify, manage and secure key foraging and roosting habitat • Improve the community's capacity to coexist with flying-foxes • Increase awareness about flying-foxes, the threats they face and the important ecosystem services they provide as seed dispersers and pollinators. Recognised key and other important threats to the Grey-headed Flying-fox are: • Habitat loss • Camp disturbance • Mortality in commercial fruit crops • Heat stress • Entanglement in backyard netting

- Electrocution on power lines. Foraging habitat critical to the survival of the Grey-headed Flying-fox is present throughout the Project study area, but the presence of critical roosting habitat is unlikely. The Project may result in the removal of modification of up to an estimated 3,827 hectares of critical foraging habitat, increasing the operation of this threat. Although the Project would remove critical foraging habitat, this would not be sufficient to substantially interfere with the recovery of the Grey-headed Flying-fox because: i) critical foraging habitat would remain in the Project study area (77%) and in the Locality, ii) the Grey-headed Flying-fox is highly mobile and individuals utilise foraging habitat elsewhere within its range and iii) the Project does not preclude the re-establishment of foraging habitat within the movement range of individual Grey-headed Flying-fox.
Conclusion
The Project study area contains critical foraging habitat for the Grey-headed Flying-fox that provides seasonal nectar and fleshy fruits. Three roosting camps occur within the downstream Project study area. While the Project would entail habitat loss, there would remain significant areas of foraging habitat at the local and regional scale. The Project would not result in habitat fragmentation or interfere with the regional movements of the species. The Project is unlikely to interfere with the breeding cycle of the Grey-headed Flying-fox or substantially increase recognised threats. The Project is unlikely to have a significant impact on the Grey-headed Flying-fox.

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Rostratula australis (Australian Painted Snipe)

Endangered under the EPBC Act

The Australian Painted Snipe is listed as endangered under the EPBC Act and endangered under the BC Act. Australian Painted Snipe inhabit shallow terrestrial freshwater (occasionally brackish) wetlands, including temporary and permanent lakes, swamps and claypans at scattered locations in eastern and northern Australia (Marchant and Higgins 1993). They also inhabit inundated or waterlogged grassland or saltmarsh, dams, rice crops, sewage farms and bore drains. Typical foraging sites include those with rank emergent tussocks of grass, sedges, rushes or reeds, or samphire; often with scattered clumps of lignum Muehlenbeckia or cane grass or sometimes tea-tree (Melaleuca). The Australian Painted Snipe has declined substantially in eastern Australia since the mid-20th century as a result of the loss and alteration of wetland habitat due to wetland drainage and the diversion of water to reservoirs and for agricultural purposes (Garnet and Crowley 2000). Total population estimates range from a few hundred individuals to 5000 breeding adults (Garnett & Crowley 2000; Lane & Rogers 2000; Oring *et al.* 2004; Watkins 1993).

The Australian Painted Snipe is a rare/occasional visitor to the Hawkesbury-Nepean River floodplain which is usually recorded in pairs or singly. The Australian Painted Snipe has been recorded at Pitt Town Lagoon (2017 2018), Pitt Town Bottoms Rd Wetland (2011), McGrath Hill STP (1959 1982), Little Wheeney Lagoon (2007) Pitt Town Bottoms (2011), Bushells Lagoon (1985), Penrith Lakes (1980) and on the Richmond Lowlands (2009 2011). A record of four Australian Painted Snipe including dependent young in 1959 is the sole breeding record of this secretive species in the study area.

Little suitable habitat is in the study area upstream or downstream of the Richmond/Windsor/Pitt Town area barring Penrith Lakes and the minor wetlands on the Colo River.

Assessing the potential impact of the Project on the Australian Painted Snipe and the estimated 317hectares of suitable habitat located in the impact area is difficult given:

- The Australian Painted Snipe is known to be threatened by the damming of rivers, diversion of water and drainage of wetlands though the sensitivity of this species to past anthropogenic changes to the flow regime of the Hawkesbury-Nepean River has not been studied and is therefore, poorly understood and largely unknown. Negative impacts associated with reduced flow area are likely (Garnet and Crowley 2000) however the degree to which the habitat condition of key sites such as Pitt Town Lagoon depends on upstream flows (as opposed to purely local rainfall) is poorly understood and requires detailed examination.
- The magnitude, frequency and duration of potential environmental flow releases post-development is unknown.

No targeted Australian Painted Snipe surveys were conducted in the study area by SMEC. For this assessment, it assumed that the Australian Painted Snipe could occur in any suitable habitat that occurs within the study area. Suitable habitat includes areas that have been mapped as the following PCTs:

- 781: Coastal freshwater lagoons of the Sydney Basin Bioregion and South East Corner Bioregion
- 1106: River Oak riparian woodland of the NSW North Coast Bioregion and northern Sydney Basin Bioregion.

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**
An estimated six hectares of suitable or potential habitat may be impacted by the Project; this is unlikely to lead to a long-term decrease of a population of Australian Painted Snipe given that only very low numbers of Australian Painted Snipe occasionally visit the study area and, • No known important breeding sites are located in the study area • Suitable habitat at the highest quality foraging sites in the study area such as Pitt Town Lagoon and Bakers Lagoon is unlikely to become degraded as a result of the Project to the point that such sites become unsuitable for Australian Painted Snipe. The rationale behind this conclusion is discussed further in response to criterion ‘modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline’.

• **reduce the area of occupancy of the species**
The Project is unlikely to reduce the area of occupancy of the Australian Painted Snipe although the distribution of suitable shallow habitat at the local scale (that is, the Hawkesbury-Nepean River floodplain in the vicinity of Richmond/Pitt Town) may be reduced for longer than normal periods of time as a result of the Project. Key sites such as Pitt Town Lagoon are unlikely to become degraded to the point that such sites will no longer provide suitable habitat for Australian Painted Snipe.
• **fragment an existing population into two or more populations**
The Project is unlikely to fragment an existing Australian Painted Snipe population into two or more populations given the high mobility of this species.
• **adversely affect habitat critical to the survival of a species**
No critical habitat has been declared for this species.
• **disrupt the breeding cycle of a population**
There has been one breeding record in the study area (1959) and given that the Australian Painted Snipe is a particularly secretive species undetected breeding events may have occurred in the area since. Hence, it is possible that the study area may support very rarely utilised breeding habitat. Due to the likely low frequency of use for breeding and the nature of the impacts of the alteration of the flow regime of the Hawkesbury-Nepean River it is unlikely that the Project will disrupt the breeding cycle of a population of Australian Painted Snipe.
• **modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline**
Up to an estimated 317 hectares of suitable or potential habitat is within the study area of which about 77 hectares is within the downstream impact area. The Project may modify, destroy, remove or isolate or decrease habitat availability or quality of an estimated six hectares of Australian Painted Snipe habitat but is unlikely to do so to the extent that the Australian Painted Snipe is likely to decline. Habitat quality at preferred sites such as Pitt Town Lagoon is not likely to be reduced to the point that such sites become unsuitable for Australian Painted Snipe. Changes to the frequency of wetland inundation could lead to temporary and/or prolonged improvements and/or reductions in habitat quality given that the Australian Painted Snipe forages in areas of shallow water and exposed or vegetated edges of wetlands. The degree to which local rain influences the condition suitable Australian Painted Snipe habitat at key sites such as Pitt Town Lagoon in the long-term is likely to partly determine the extent of suitable habitat retained, degraded or lost. It is possible that certain areas of wetland on the edge of the floodplain that are only occasionally inundated under the current flood regime but are likely to receive flows far less frequently as a result of the Project will be significantly impacted. Such areas may dry more frequently which could the lead to the temporary or permanent loss of important wetland components such as aquatic vegetation however such potential impacts are unlikely to cause the species to decline.
• **result in invasive species that are harmful to an endangered or critically endangered species becoming established in the endangered or critically endangered species' habitat**
The Project is unlikely to result in invasive species that are harmful to the Australian Painted Snipe becoming established in Australian Painted Snipe habitat. Introduced predators which may pose a risk to Australian Painted Snipe such as Red Fox (*Vulpes vulpes*) and feral cat (*Felis catus*) are currently present in the study area.
• **introduce disease that may cause the species to decline**
The Project is unlikely to introduce disease that may cause the Australian Painted Snipe to decline.
• **interfere substantially with the recovery of the species**
The Project may result in the loss and degradation of wetland habitat, a key threat to this species, though this is not expected to interfere substantially with the recovery of the Australian Painted Snipe as it is an occasional visitor to the study area in low numbers.

Conclusion
Although suitable habitat is likely to be impacted by the alteration of the Hawkesbury-Nepean River flow regime, the Project is unlikely to have a significant adverse impact on the Australian Painted Snipe.

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Threatened ecological communities

Castlereagh Scribbly Gum and Agnes Banks Woodlands of the Sydney Basin Bioregion

Endangered Ecological Community under the EPBC Act

The Castlereagh Scribbly Gum and Agnes Banks Woodlands ecological community is located within the Sydney Basin Bioregion. It occurs primarily in the Castlereagh area in the north-west of the Cumberland Plain with other known occurrences near Holsworthy, Kemps Creek and Longneck Lagoon (Tozer *et al.* 2010; NSW Scientific Committee 2013). The ecological community occurs mostly in the Cumberland, with small occurrences just outside the Cumberland sub-region in the Sydney Cataract, Wollemi and Burragorang sub-regions.

The ecological community occurs primarily on Tertiary sands and gravels of the Hawkesbury-Nepean river system. These ancient alluvial soils were deposited by the rivers in sites that can be quite distant from the present-day flood zones (James 1997; Keith 2004). In Agnes Banks the ecological community primarily occurs on aeolian (wind-blown) sands overlying Tertiary alluvium. The soils of the Castlereagh Scribbly Gum and Agnes Banks Woodlands are typically low in nutrients, unlike more recent alluvial deposits (Keith 2004). The sediments on which the ecological community occurs may be almost pure sand. The sand deposits often transition to, and include, areas of gravel and clay.

The canopy is composed of trees with a mature height of 10 metres to around 20 metres. The canopy contains, and is often dominated by, one or more of the following species: *Angophora bakeri* (narrow leaved apple), *Eucalyptus racemosa* (scribbly gum, narrow leaved scribbly gum) and *E. parramattensis* subsp. *parramattensis* (Parramatta red gum) (Keith 2004; CHAH 2006; Tozer *et al.* 2010). *Melaleuca* species including *M. decora* (paperbark) may also be prominent in the canopy (and/or mid layer) of the ecological community. *Eucalyptus fibrosa* (red ironbark) is also occasionally prominent in the canopy (Keith 2004; Tozer *et al.* 2010).

A shrub layer (average height approximately 2 metres) is present and is sometimes dominated by either *Banksia* or *Melaleuca* species. Mid layer species often include*: Banksia aemula* (wallum) and *Conospermum taxifolium* (variable smoke bush) (particularly in Agnes Banks Woodland)*, B. serrata* (old man banksia), *B. oblongifolia* (fern-leaved banksia), *B. spinulosa* (hairpin banksia), *Melaleuca decora* (paperbark), *Leptospermum trinervium* (flaky-barked tea-tree), *Dillwynia sericea* (showy parrot-pea), *Monotoca scoparia* (broom heath), *Platysace ericoides*, *Persoonia nutans* (nodding geebung)

The ground layer consists of a diverse range of graminoids and forbs including *Themeda australis* (kangaroo grass), *Entolasia stricta* (wiry panic), *Cyathochaeta diandra, Dianella revoluta* subsp*. revoluta* (blue flax-lily), *Lepidosperma urophorum* (at Agnes Banks), *Stylidium graminifolium* (grass triggerplant), *Lepyrodia scariosa, Mitrasacme polymorpha, Trachymene incisa* subsp*. incisa, Laxmannia gracilis* (slender wire lily), *Lomandra spp.* and *Aristida warburgii* (Keith 2004; Tozer *et al.* 2010; NSW Scientific Committee 2000 2010).

This TEC occupies an area of 986.76 hectares in the downstream study area. This is about 31 percent of the global occurrence of this TEC (3,190 hectares) (DoE 2015).

In the downstream study area, none of the TEC was mapped as burnt by the FESM mapping. The community has not been mapped as occurring in the construction or upstream study areas.

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**
As stated above, the Castlereagh Scribbly Gum and Agnes Bank Woodland TEC occurs solely within the downstream study area. The Project could result in reductions in flood extent and frequency across: • 0.3 hectares of TEC within the 10% AEP event changed flood extent • 50.05 hectares of the TEC within the 1% AEP event changed flood extent This equates to about 0.03 percent and about five percent respectively of the local population of this TEC within the study area. The TEC does not occur in the FMZ discharge area. It is noted that a 1% AEP flood event has not occurred since Warragamba Dam was constructed in 1960 so impacts to this TEC related to this flood event are considered unlikely. Given the small area (0.3 hectares) of this TEC within the 10% AEP event changed flood extent, it is considered unlikely there is a real chance or possibility that the Project will reduce the extent of this TEC.

• **fragment or increase fragmentation of an ecological community, for example by clearing vegetation for roads or transmission lines**
Not allowing for any variable impacts to extent of Castlereagh Scribbly Gum and Agnes Banks Woodlands within the study area, the parts of the local extent that occur outside the study area have the potential to be fragmented and isolated by impacts within the study area. The area of these fragments is equivalent to about 987 hectares across at least five separate patches. These areas would seem to have high edge effects and are variable in shape, width and pattern. The areas of the TEC within the changed flood extent areas are already isolated and generally surrounded by agricultural land or urban development. It is unlikely that the changed flooding regime would increase this fragmentation.
• **adversely affect habitat critical to the survival of an ecological community**
Areas that meet the minimum (moderate class) condition thresholds are considered critical to the survival of this TEC. Additional areas such as adjoining native vegetation and areas that meet the description of the ecological community but not the condition thresholds are also considered important to the survival of the ecological community, for example, as buffers for higher condition areas, and should be considered in the surrounding environment and landscape context. The estimated area of extent of this TEC is mapped as 3,190 hectares. Noting that there are limitations to the accuracy of the current extent of the TEC within the study area, local extent and global extent, the current estimate for the purposes of this assessment of impacted TEC within the local occurrence is about 31% of that estimate of global extent of this TEC. The Project would result in reductions in flood extent and frequency across: • 0.3 hectares of TEC within the 10% AEP event changed flood extent • 50.05 hectares of the TEC within the 1% AEP event changed flood extent This equates to about 0.03 percent and about five percent respectively of the local population of this TEC within the study area. The TEC does not occur in the FMZ discharge area. It is noted that a 1% AEP flood event has not occurred since Warragamba Dam was constructed in 1960 so impacts to this TEC related to this flood event are considered unlikely. This TEC is included within the Cumberland Plain Recovery Plan which has identified Priority Conservation Lands (PCLs). PCLs are considered to contain habitat critical to the survival of threatened entities on the Cumberland Plain. The area of this TEC potentially impacted by the Project occurs within mapped PCLs. Given the small area (0.3 hectares) of this TEC within the 10% AEP event changed flood extent, it is considered unlikely there is a real chance or possibility that the Project will adversely affect habitat critical to the survival of this TEC.
• **modify or destroy abiotic (non-living) factors (such as water, nutrients, or soil) necessary for an ecological community's survival, including reduction of groundwater levels, or substantial alteration of surface water drainage patterns**
The Project could alter abiotic factors that may be critical to the long-term survival of the TEC. Abiotic factors include (but are not limited to) changes to soil properties (such as the chemistry, structure etc.), hydrological processes (including surface water patterns) and nutrient cycling. This TEC is a high-potential Groundwater Dependant Ecosystem (BoM 2019). However, flooding comprises a relatively minor contribution to groundwater recharge. The dominant mechanism for groundwater recharge in the geological Sydney Basin is likely to be infiltration of rainfall and runoff through alluvial deposits in valleys ((Parsons Brinckerhoff 2011, cited in Herron *et al* 2018). Given the small area (0.3 hectares) of this TEC within the 10% AEP event changed flood extent, it is considered unlikely that the Project would result in significant modifications to or destruction of abiotic factors.
• **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**
This TEC includes many characteristic species adapted to and/or requiring seasonal waterlogging, and the community is mapped in its limited location as a high-potential Groundwater Dependant Ecosystem (BoM 2019).

However, as noted previously, flooding would comprise a relatively minor contribution to groundwater recharge. Given the small area (0.3 hectares) of this TEC within the 10% AEP event changed flood extent, it is considered unlikely that the Project would cause a substantial change in the species composition of this TEC.

- **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 Project may constitute, and/or be part of, and/or may result in the operation of, and/or increases the impact of several threatening processes that may cause substantial reduction in the quality or integrity of an occurrence (DoE 2015):

- alteration to the natural flow regimes of rivers, streams, floodplains and wetlands
- Aggressive exclusion of birds from woodland and forest habitat by abundant Noisy Miners (*Manorina melanocephala*)
- Ecological consequences of high frequency fires
- Land clearance
- Competition from feral honey bees, *Apis mellifera* L.
- Forest eucalypt dieback associated with over-abundant psyllids and Bell Miners
- Invasion of native plant communities by exotic perennial grasses
- Invasion and establishment of exotic vines and scramblers
- Invasion of native plant communities by Bitou Bush (*Chrysanthemoides monilifera*)
- Invasion of native plant communities by African Olive (*Olea europaea* subsp. *cuspidata* Wall. Ex G. Don)
- Invasion and establishment of Scotch Broom (*Cytisus scoparius*)
- Invasion establishment and spread of Lantana (*Lantana camara* L. *sens.* Lat)
- Infection of native plants by *Phytophthora cinnamomi*
- Introduction and establishment of Exotic Rust Fungi of the order Pucciniales pathogenic on plants of the family Myrtaceae
- Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants
- Loss of Hollow-bearing Trees
- Removal of dead wood and dead trees

Given the small area (0.3 hectares) of the TEC within the 10% AEP event changed flood extent, it is considered unlikely that the Project would cause a substantial reduction in the quality or integrity of an occurrence of this TEC.

- **interfere with the recovery of an ecological community.**

There is no adopted or drafted Commonwealth Recovery Plan for Castlereagh Scribbly Gum and Agnes Banks Woodlands. The NSW Cumberland Plain Recovery Plan (DECCW 2010) includes provisions for both Agnes Banks Woodland in the Sydney Basin Bioregion (listed as Critically Endangered under the BC Act) and Castlereagh Scribbly Gum Woodland in the Sydney Basin Bioregion (listed as Vulnerable under the BC Act). These NSW listed TECs are components of the EPBC listed Castlereagh Scribbly Gum and Agnes Banks Woodlands.

The approved Conservation Advice for Castlereagh Scribbly Gum and Agnes Banks Woodlands (DoE 2015), lists the following High Priority Conservation Actions for the TEC:

- Protect and conserve remnants that meet the condition thresholds for this ecological community to avoid further clearance and fragmentation
- Identify high conservation value sites for conservation management (formal reserve and off-reserve protection), on private and public lands

- Promote formal conservation arrangements, management agreements and covenants on private land. For crown and private land, promote inclusion in reserve tenure
- Avoid disturbances to native vegetation (e.g. under-scrubbing, slashing, mowing, grazing or burning), particularly during peak flowering and fruiting seasons of the ecological community
- Protect the soil seedbank and support the regeneration of the ecological community
- Undertake weed control and restoration activities
- Control introduced pest animals, including limiting access by domestic pets and feral animals, to allow natural regeneration and to manage other impacts (e.g. to threatened species)
- Undertake appropriate fire management practices that vary in frequency, intensity and seasonality, in order to maximise biodiversity outcomes
- Control storm-water and other urban run-off to prevent the further alteration of hydrological regimes in the ecological community
- Minimise edge effects
- Prevent the spread of *Phytophthora cinnamomi*

The Project is not consistent with actions which would support the recovery of the TEC, however, given the small area (0.3 hectares) of this TEC within the 10% AEP event changed flood extent, it is considered unlikely that the Project would interfere with the recovery of this TEC.

Conclusion

The Project would result in reductions in flood extent and frequency across:

- 0.3 hectares of TEC within the 10% AEP event changed flood extent
- 50.05 hectares of the TEC within the 1% AEP event changed flood extent

This equates to about 0.03 percent and about five percent respectively of the local population of this TEC within the study area. The TEC does not occur in the FMZ discharge area. It should also be noted that a 1% AEP flood event has not occurred since Warragamba Dam was constructed in 1960.

Given the small area (0.3 hectares) of this TEC within the 10% AEP event changed flood extent, it is considered unlikely that the Project would have a significant impact on the Castlereagh Scribbly Gum and Agnes Banks Woodlands TEC.

References

Department of the Environment (2015). Approved Conservation Advice (including listing advice) for Castlereagh Scribbly Gum and Agnes Banks Woodlands of the Sydney Basin Bioregion. Canberra: Department of the Environment. Available from: http://www.environment.gov.au/biodiversity/threatened/communities/pubs/119-conservation-advice.pdf. In effect under the EPBC Act from 17-Mar-2015.

Department of Environment, Climate Change and Water (NSW) (2010) Cumberland Plain Recovery Plan, Department of Environment, Climate Change and Water (NSW), Sydney.

Herron NF, McVicar TR, Rohead-O'Brien H, Rojas R, Rachakonda PK, Zhang YQ, Dawes WR, Macfarlane C, Pritchard J, Doody T, Marvanek SP and Li LT (2018) Context statement for the Sydney Basin bioregion. Product 1.1 from the Sydney Basin Bioregional Assessment. Department of the Environment and Energy, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia. http://data.bioregionalassessments.gov.au/product/SSB/SSB/1.1.

Cooks River/Castlereagh Ironbark Forest of the Sydney Basin Bioregion

Critically Endangered Ecological Community under the EPBC Act

Cooks River/Castlereagh Ironbark Forest of the Sydney Basin ecological community (CRCIF) is endemic to the Cumberland subregion of the Sydney Basin Bioregion. Cooks River/Castlereagh Ironbark Forest is an open-forest or low woodland, usually dominated by *Eucalyptus fibrosa* (broad-leaved ironbark) and *Melaleuca decora*. The shrub-layer is comparatively variable and can include *Melaleuca nodosa* and *Lissanthe strigosa*. It also includes a range of smaller 'pea' flower shrubs, including *Dillwynia tenuifolia*, *Pultenaea villosa* and *Daviesia ulicifolia* (DoE 2015).

Cooks River/Castlereagh Ironbark Forest occurs on either clay soils on Tertiary alluvium, or on shale soils on Wianamatta Shale. This CEEC occurs below 100 m above sea level with mean annual rainfall of 800 -1000 mm (Tozer *et al.* 2010).

This CEEC was recorded in the downstream study area as PCT 725: Broad-leaved Ironbark – *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain Sydney Basin Bioregion. It was assessed with a low likelihood of occurrence in the upstream study area and as not occurring in the construction study area, and is therefore not subject to further assessment in these areas.

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**
Cooks River/Castlereagh Ironbark Forest CEEC occurs on clay-rich soils derived from Tertiary alluvium and on Wianamatta Shale derived soils found next to Tertiary alluvium, with the majority of the TEC located in the Castlereagh area between Penrith and Richmond. Since European settlement, the Cooks River/Castlereagh Ironbark Forest has undergone a significant reduction in extent, having been cleared or substantially modified by urban and rural/residential development. It is estimated that 1,011 hectares, or eight percent, of the original extent of the CEEC remains. Based on the predicted extent of PCT 725 in the study area, up to 412.23 hectares of the CEEC may occur within the study area. This equates to about 41 percent of the estimated extent of the CEEC. The Project would result in a reduction in flood extent and frequency across portions of the EEC. Cooks River/Castlereagh Ironbark Forest does not occur within the FMZ discharge area, and therefore would not be subject to an increase in flood duration and frequency as a result of discharges from the FMZ. The Project would result in a reduction in flood extent and frequency across: • 0.12 hectares of CEEC within the 10% AEP event changed flood extent • 18.30 hectares of the CEEC within the 1% AEP event changed flood extent. This equates to about 0.03 percent and about four percent respectively of the local population of the Cooks River/Castlereagh Ironbark Forest within the study area. It is noted that a 1% AEP flood event has not occurred since Warragamba Dam was constructed in 1960. Cooks River/Castlereagh Ironbark Forest generally occurs below 100 metres in elevation, with a mean annual rainfall between 800-1000 millimetres. Due to its distribution within the Hawkesbury-Nepean floodplain, the community is a moderate potential Groundwater Dependent Ecosystem with a strong correlation in the extent, both historical and present, of this community within areas of groundwater influence in the locality. The dominant mechanism for groundwater recharge in the geological Sydney Basin is likely to be infiltration of rainfall and runoff through alluvial deposits in valleys ((Parsons Brinckerhoff 2011, cited in Herron *et al* 2018). Accordingly, flooding (overbank flows) would comprise a relatively minor contribution to groundwater recharge. While the Project would modify downstream hydrology, and noting that this would also continue to be influenced by contributions from catchments below Warragamba Dam, it is not considered this would result in a real chance or possibility that it will reduce the extent of this CEEC.

• **fragment or increase fragmentation of an ecological community, for example by clearing vegetation for roads or transmission lines**
The vegetation of the Hawkesbury-Nepean catchment floodplain is currently subject to high fragmentation because of prior land use (agriculture and suburban development) and vegetation clearance. The area of the CEEC in the downstream study area is already fragmented by past and current land use practices. While the Project may reduce the extent of patches of CEEC, it is unlikely that the changed flooding regime would substantially increase this level of fragmentation across the study area.
• **adversely affect habitat critical to the survival of an ecological community**
According to the Matters of National Environmental Significance impact guideline (DoE 2013), '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' (DoE 2013). Cooks River/Castlereagh Ironbark Forest has been identified in the Cumberland Plain Recovery Plan (NSW Department of Environment, Climate Change and Water 2010). In view of this, habitat within the downstream study area is regarded as critical to the survival of the CEEC as defined in the MNES significant impact guidelines. The Project could potentially adversely impact the 0.12 hectares of CEEC within the 10% AEP event changed flood extent. A potential adverse impact on the 18.30 hectares of the CEEC within the 1% AEP event changed flood extent is considered unlikely in view of the rarity of this flood event..
• **modify or destroy abiotic (non-living) factors (such as water, nutrients, or soil) necessary for an ecological community's survival, including reduction of groundwater levels, or substantial alteration of surface water drainage patterns**
In addition to potential impacts resulting from changes to hydrological processes (modification of vegetation composition and floristics), the Project could alter abiotic factors that may be critical to the long-term survival of the CEEC. Abiotic factors include (but are not limited to) changes to soil properties (such as the chemistry, structure etc.), hydrological processes (including surface water patterns) and nutrient cycling. Cooks River/Castlereagh Ironbark Forest is a moderate potential Groundwater Dependent Ecosystem with a strong correlation in the extent, both historical and present, of this community within areas of groundwater influence in the locality. However, as noted previously, flooding would comprise a relatively minor contribution to groundwater recharge. The predicted reduction of flooding extent across the study area event could result in adverse impacts or modifications to the CEEC. However, there is little information available to accurately characterise the extent of changes to abiotic factors required to have a detrimental effect on the long-term survival of the CEEC. Given the small area (0.12 hectares) of this CEEC within the 10% AEP event changed flood extent, it is considered unlikely that the Project would result in significant modifications to or destruction of abiotic factors.
• **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**
Cooks River/Castlereagh Ironbark Forest is a moderate potential Groundwater Dependent Ecosystem with a strong correlation in the extent, both historical and present, of this community within areas of groundwater influence in the locality. However, as noted previously, flooding would comprise a relatively minor contribution to groundwater recharge. Given the small area (0.12 hectares) of this CEEC within the 10% AEP event changed flood extent, it is considered unlikely that the Project would cause a substantial change in the species composition of this CEEC.

- **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**

Structural and floristic modifications which could occur across the extent of the CEEC associated with the Project have the potential to reduce the quality and integrity of the CEEC within the study area. Changes to vegetation composition have the potential to reduce the resilience of the CEEC, making it more susceptible to detrimental processes such as:

- invasive species, such as weeds, that may establish and colonise within the CEEC
- infection by pathogens and disease
- aggressive exclusion of woodland birds by overabundant Noisy Miners
- Bell Miner associated die-back

Given the small area (0.12 hectares) of the CEEC within the 10% AEP event changed flood extent, it is considered unlikely that the Project would cause a substantial reduction in the quality or integrity of an occurrence of this CEEC.

- **interfere with the recovery of an ecological community.**

There is no adopted or draft Commonwealth Recovery Plan for Cooks River/Castlereagh Ironbark Forest. The NSW Cumberland Plain Recovery Plan (DECCW 2010) includes provisions for Cooks River/Castlereagh Ironbark Forest in the Sydney Basin Bioregion (listed as Endangered under the BC Act). This NSW listed TEC is commensurate with the EPBC listed Cooks River/Castlereagh Ironbark Forest.

The approved Conservation Advice Cooks River/Castlereagh Ironbark Forest (DEWHA 2009), lists the following High Priority Conservation Actions for the TEC:

- Protect and conserve patches of the CEEC, through the identification of high values conservation sites both on public and private land
- Avoid disturbances to native vegetation (e.g. under-scrubbing, slashing, mowing, grazing or burning), particularly during peak flowering and fruiting seasons of the ecological community
- Protect the soil seedbank and support the regeneration
- Undertake weed control and restoration activities consistent with the three phases of weed control outlined in the Best Practice Guidelines: Cooks River/Castlereagh Ironbark Forest
- Avoid planting potential weeds in roadworks, landscaping and other development near the ecological community
- Control introduced pest animals, including limiting access by domestic pets and feral animals, to allow natural regeneration and to manage other impacts (e.g. to threatened species)
- Undertake appropriate fire management practices that vary in frequency, intensity and seasonality, in order to maximise biodiversity outcomes.
- Control storm-water and other urban run-off to prevent further alteration of hydrological regimes in the ecological community
- Stream-bank restoration and other actions to mitigate stream-bank erosion should also be undertaken within remnants of the ecological community
- Minimise edge effects
- Manage tree dieback, including preventing the spread of *Phytophthora cinnamomi*

The Project has the potential to interfere with the recovery of the CEEC given that it is not consistent with actions which would support the recovery of this CEEC. However given the small area (0.12 hectares) of this CEEC within the 10% AEP event changed flood extent, it is considered unlikely that the Project would interfere with the recovery of this CEEC.

Conclusion
The Project would result in reductions in flood extent and frequency across: • 0.12 hectares of CEEC within the 10% AEP event changed flood extent • 18.30 hectares of the CEEC within the 1% AEP event changed flood extent. This equates to about 0.03 percent and about four percent respectively of the local population of the Cooks River/Castlereagh Ironbark Forest within the study area. It should be noted that a 1% AEP flood event has not occurred since Warragamba Dam was constructed in 1960. Given the small area (0.12 hectares) of this CEEC within the 10% AEP event changed flood extent, it is considered unlikely that the Project would have a significant impact on the Cooks River/Castlereagh Ironbark Forest CEEC.

References

Department of Environment, Climate Change and Water (NSW) (2010) Cumberland Plain Recovery Plan, Department of Environment, Climate Change and Water (NSW), Sydney.

Department of the Environment (2015). Approved Conservation Advice (including listing advice) for Cooks River/Castlereagh Ironbark Forest of the Sydney Basin Bioregion. Canberra: Department of the Environment. Available from: http://www.environment.gov.au/biodiversity/threatened/communities/pubs/129-conservation-advice.pdf. In effect under the EPBC Act from 17-Mar-2015.

Herron NF, McVicar TR, Rohead-O'Brien H, Rojas R, Rachakonda PK, Zhang YQ, Dawes WR, Macfarlane C, Pritchard J, Doody T, Marvanek SP and Li LT (2018) Context statement for the Sydney Basin bioregion. Product 1.1 from the Sydney Basin Bioregional Assessment. Department of the Environment and Energy, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia. http://data.bioregionalassessments.gov.au/product/SSB/SSB/1.1.

Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest

Critically Endangered Ecological Community under the EPBC Act

Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest represents certain occurrences of the coastal plain grassy eucalypt woodlands that are endemic to the shale hills and plains of the Sydney Basin Bioregion in NSW and which occur primarily in, but not limited to, the Cumberland Sub-region. The ecological community incorporates the grassy eucalypt shale hills and plains woodlands and the shale-gravel transition forests of this region.

The ecological community ranges from grassy woodland to forest, with the understorey (that is, the ground plus shrub layers) varying from predominately grassy to predominately shrubby. Some stands are much denser than the typical woodland form, particularly in the shale-gravel transition forest variant. The ecological community may have an upper tree layer, lower tree layer, shrub layer and a ground layer though in any given patch one or more layers may be absent or depauperate. For the purposes of listing under the EPBC Act, the ecological community always has upper tree layer species present and either a shrub or ground layer present.

The tree canopy is typically dominated by *Eucalyptus moluccana* (Coastal Grey Box), *E. tereticornis* (Forest Red Gum) and/or *E. fibrosa* (Red Ironbark). Other canopy species may occur in association with typical dominants and may be locally dominant at some sites. A sparse smaller tree stratum, typically with young eucalypts and Acacia species, may also be present. The understorey typically is dominated by the ground layer and comprises a variety of perennial native grasses, grass-like plants and other non-woody plants. A shrub layer may also be present, to variable extent, and is usually dominated by Bursaria spinosa (Blackthorn).

Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest ecological community is limited to the Sydney Basin Bioregion with most occurrences in the Cumberland Sub-region. This covers a geographic area commonly known as the Cumberland Plain, a rain shadow coastal valley to the immediate west of Sydney. This ecological community occurs within the Sydney Metro and Hawkesbury-Nepean Natural Resource Management Regions.

Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest typically occurs on flat to undulating or hilly terrain, at elevations up to approximately 350 metres above sea level. Some occurrences may extend onto locally steep sites at slightly higher elevations. Most occurrences are on clay soils derived from Wianamatta Group geology, with limited to rare occurrences on other soil types. In 2009, the ecological community occupied a maximum area of 12,300 hectares (hectares) but is highly fragmented into generally small remnants, mostly under 10 hectares in size (Tozer 2003).

In the downstream study area, none of the TEC was mapped as burnt by the FESM mapping. The community has not been mapped as occurring in the construction or upstream study areas.

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**
Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest CEEC occurs on soils derived from Wianamatta Shale, and throughout the driest part of the Sydney Basin. Tozer (2003) estimated the total extent of woody vegetation referred to as The Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest CEEC was 11,054 hectares. Based on the predicted extent of PCTs 724, 849 and 850 in the study area, up to 3,574.30 hectares of Cumberland Plain Woodland CEEC is expected to occur within the downstream study area. About 29 percent of the CEEC total occurrence is within the study area. As stated above, the Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest occurs solely within the downstream study area. Consequently, the Project would result in a reduction in flood extent and frequency across portions of the EEC. Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest also occurs within the FMZ discharge area, and therefore would not be subject to an increase in flood duration and frequency as a result of discharges from the FMZ. Consequently, the Project could result in reductions in flood extent and frequency across: • 203.36 hectares of CEEC within the 10% AEP event changed flood extent • 662.93 hectares of the CEEC within the 1% AEP event changed flood extent.

This is about 18 percent of the local population of the Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest in the Project study area. Should the area of TEC associated with larger flood events be considered, the proportion of the local population subject to reductions in flood extent could be higher.

In addition, increased inundation is expected to occur across 24.95 hectares in the FMZ discharge area, which may result in temporary damage to fringing vegetation.

The mean annual rainfall for areas containing the CEEC is typically in the range of 700-900 millimetres and is generally lower than that received on more elevated terrain that partially surrounds the plain. Due to its distribution within the Hawkesbury-Nepean floodplain, the community may be dependent on flooding events within a certain frequency range. The predicted reduction of flooding extent across the study area event could result in adverse impacts or modifications to the CEEC. Increased inundation could occur across 26.18 hectares in the FMZ discharge area, which may result in temporary damage to fringing vegetation. The area subject to increased inundation is relatively small and represents about one percent of the predicted extent of the community in the downstream study area.

As a result, the reduction in flooding extent and across the study area, and increase in flood frequency within the FMZ discharge area has the potential to have an adverse effect on the extent of the ecological community.

While gradual alterations to the structure of the community may occur over the long-term, the extent of this change is unlikely to result in a complete loss of the CEEC. The longer period of inundation in the FMZ discharge area could result in damage to fringing vegetation, however this is not expected to have a permanent adverse effect on this community.

- **fragment or increase fragmentation of an ecological community, for example by clearing vegetation for roads or transmission lines**

The vegetation of the floodplain in the Hawkesbury-Nepean catchment is highly fragmented due to past land use and vegetation clearance due to agriculture and suburban development. The area of the CEEC in the downstream study area is already fragmented by past and current land use practices. While the Project may reduce the extent of patches of CEEC, it is unlikely that the changed flooding regime would substantially increase this level fragmentation across the study area.

- **adversely affect habitat critical to the survival of an ecological community**

According to the Matters of National Environmental Significance impact guideline (DoE 2013), ‘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’ (DoE 2013).

Cumberland Plain Woodland and Shale Gravel Transition Forest CEEC has been identified in the Cumberland Plain Recovery Plan (NSW Department of Environment, Climate Change and Water 2010). This makes the habitat within the downstream study area critical to the survival of the CEEC as defined in the MNES significant impact guidelines. The Project could adversely impact the following areas of this critical habitat:

- 203.36 hectares of TEC within the 10% AEP event changed flood extent
- 662.93 hectares of the TEC within the 1% AEP event changed flood extent
- 24.95 hectares within the FMZ discharge area.

• **modify or destroy abiotic (non-living) factors (such as water, nutrients, or soil) necessary for an ecological community's survival, including reduction of groundwater levels, or substantial alteration of surface water drainage patterns**
In addition to impacts associated with clearing or modification of vegetation, the Project could alter abiotic factors that may be critical to the long-term survival of the CEEC. Such abiotic factors include (but not limited to) changes to soil properties (such as the chemistry, structure, etc.), hydrological processes (including surface water patterns) and nutrient cycling. However, there is little information available to understand the extent of changes to abiotic factors that would be required to consequently have a detrimental effect on the long-term survival of the CEEC. Applying the precautionary principle, it has been assumed that any change to abiotic factors could detrimentally affect the quality and integrity of the CEEC within the study area.
• **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**
While gradual alterations to the structure of the community may occur over an extended dry period, the extent of this change is unlikely to result in a complete loss of the CEEC. The longer period of time for inundation in the FMZ discharge area could result in damage to fringing vegetation, however this is not expected to have a permanent adverse effect on this community. However, there may be a loss of functionally important species as a result of modification to vegetation structure and composition over the long term.
• **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 structural and floristic modifications which could occur across the extent of the CEEC as a result of the Project have the potential to reduce the quality and integrity of the CEEC within the study area. Specifically, the changes to vegetation composition have the potential to reduce the resilience of the CEEC, potentially making it more susceptible to detrimental processes such as: • invasive species, such as weeds, to establish and colonise within the CEEC • infection by pathogens and disease, such as Myrtle Rust • aggressive exclusion of woodland birds by overabundant Noisy Miners • Bell Miner associated die-back
• **interfere with the recovery of an ecological community.**
There is no adopted or drafted Commonwealth Recovery Plan for Cumberland Plain Woodland and Shale Gravel Transition Forest. The NSW Cumberland Plain Recovery Plan (DECCW 2010) includes provisions for both Cumberland Plain Woodland in the Sydney Basin Bioregion (listed as Critically Endangered under the BC Act) and Shale Gravel Transition Forest in the Sydney Basin Bioregion (listed as Endangered under the BC Act). These NSW listed TECs are components of the EPBC listed Cumberland Plain Woodland and Shale Gravel Transition Forest. The approved Conservation Advice for Cumberland Plain Woodland and Shale Gravel Transition Forest (DEWHA 2009), lists the following Regional Priority Actions for the CEEC: • monitor, identify, and mitigate threats associated with habitat loss, disturbance, and modification. This includes identifying sites of high conservation priority • manage changes to hydrology which may result in changes to water table levels • manage and treat invasive exotic species in line with best practice guidelines • minimise trampling or grazing • mitigate against inappropriate fire regimes with adequate planning and consultation • promote conservation information • Enable the recovery through identifying options to maintain and improve connectivity.

The Project has the potential to interfere with the recovery of the CEEC given that it is not consistent with actions which would support the recovery of the CEEC, including: • it may result in a reduction in the extent of the CEEC • it may adversely affect the habitat critical to the survival of the CEEC • it has the potential to modify the abiotic factors important to the survival of the CEEC • it may cause a reduction in the quality and integrity of the CEEC.
Conclusion
The Project would result in reductions in flood extent and frequency across: • 203.36 hectares of CEEC within the 10% AEP event changed flood extent • 662.93 hectares of the CEEC within the 1% AEP event changed flood extent. This is about 18 percent of the local population of the Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest in the Project study area. Should impacts associated with larger flood events be considered, the proportion of the local population impacted could be higher. In addition, increased inundation is expected to occur across 24.95 hectares in FMZ discharge area, which may result in temporary damage to fringing vegetation. As a result, the Project has the potential to: • alternate the structure and composition of the CEEC such that the extent of the TEC is reduced • adversely affect habitat critical to the survival of the CEEC • modify or destroy abiotic factors necessary for the CEECs survival • substantially and adversely modifying the composition of the ecological community • interfere objectives or actions of a recovery plan or threat abatement plan • constitute and contribute to key threatening processes which may affect the CEEC The Project is likely to have a significant impact on the Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest CEEC.

References

Department of Environment, Climate Change and Water (NSW) (2010) Cumberland Plain Recovery Plan, Department of Environment, Climate Change and Water (NSW), Sydney.

Department of the Environment, Water, Heritage and the Arts (2009). Approved Conservation Advice for Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest ecological community. Canberra, ACT: Department of the Environment, Water, Heritage and the Arts. Available from: http://www.environment.gov.au/biodiversity/threatened/communities/pubs/112-conservation-advice.pdf. In effect under the EPBC Act from 09-Dec-2009.

River-flat eucalypt forest on coastal floodplains of southern New South Wales and eastern Victoria

Critically Endangered Ecological Community under the EPBC Act

The extents of this community in the upstream and downstream study areas are summarised as follows. This community does not occur in the construction study area.

Upstream:

- PCT 941 (HN553) Mountain Blue Gum - Thin-leaved Stringybark open forest on river flat alluvium in the Sydney Basin Bioregion

This PCT occupies an area of about 378 hectares in the upstream study area and about 105 hectares in the upstream impact area.

Downstream:

This TEC is represented by the following PCTs in the downstream study area:

- PCT 835 - Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain Sydney Basin Bioregion
- PCT 1106 - River Oak riparian woodland of the NSW North Coast Bioregion and northern Sydney Basin Bioregion
- PCT 1504 - Sydney Blue Gum - Deane's Gum - River Peppermint shrubby riparian tall forest of the lower Colo River Sydney Basin Bioregion

About 3,429 hectares of this TEC occurs across the downstream Project study area based on equivalent PCTs mapped in *Remnant Vegetation of the western Cumberland subregion VIS_ID 4207* (OEH 2015). A breakdown by PCT is provided in the following table.

Component PCTS in downstream study area

PCTs	Total area (ha)			
	In study area	In survey area	In changed 10% AEP flood extent	In FMZ discharge area
PCT 835 - Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin Bioregion	3,209.28	1,903.59	437.73	777.83
PCT 1106 - River Oak riparian woodland of the NSW North Coast Bioregion and northern Sydney Basin Bioregion	158.51	151.28	22.66	65.88
PCT 1504 - Sydney Blue Gum - Deane's Gum - River Peppermint shrubby riparian tall forest of the lower Colo River, Sydney Basin Bioregion	60.94	59.93	0.39	8.97
Total	**3,428.73**	**2,114.8**	**460.780**	**852.68**

The Conservation Advice for the *River-flat eucalypt forest on coastal floodplains of southern New South Wales and eastern Victoria* (DAWE 2020) notes that the ecological community occurs on alluvial landforms related to coastal river floodplains and associated sites where transient water accumulates, including floodplains, river-banks, riparian zones, lake foreshores, creek lines (including the floors of tributary gullies), floodplain pockets, depressions, alluvial flats, fans, terraces, and localised colluvial fans. Floodplains may be occasionally or more often saturated, water-logged or inundated. The ecological community is typically found below 50 metres above sea level (mASL), although it can occur up to 250 mASL (e.g. on floodplain pockets and plateaus above nick points).

DAWE (2020) identifies that hydrological change, including from flood mitigation, detrimentally impacts the CEEC from such works. Changes in the extent of small and medium-sized floods in particular is identified as having adverse impacts on this vegetation type from downstream flood mitigation.

DAWE (2020) also notes that alteration of the natural flow regimes of rivers, streams and wetlands is recognised as a major factor contributing to loss of biological diversity and ecological function in aquatic ecosystems and their associated floodplains, as per the NSW Scientific Committee (2002). The effect of both increases and decreases in frequency, extent, depth and duration of flow regimes has potential impacts that include:

- Increased habitat for invasive species
- Loss or disruption of ecological function
- Reduction of habitat due to change in area, frequency and duration of flooding of floodplains
- Riparian zone degradation through altered flow patterns
- Increased flows causing more permanent flooding.

As such, changes to flow and flooding within the upstream and downstream study areas are identified as the principal potential impacts to this CEEC.

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**
Upstream, this community occupies about 378 hectares in the upstream study area and about 105 hectares in the upstream impact area. For the purpose of the assessment, it has been assumed that there would be a total loss of biodiversity values in the upstream impact area. Downstream this community occur throughout the Project 10% AEP event area, particularly associated with the alluvial areas associated with floodplains, rivers, creeks, lagoons and tributaries. It is the most widespread TEC in the downstream 10% AEP event and Project study areas, with about 461 hectares occurring in the changed 10% AEP flood event area and 853 hectares within the FMZ discharge area. About 3,429 hectares of the River-flat Eucalypt Forest on Coastal Floodplains of Southern New South Wales and Eastern Victoria CEEC may occur in the downstream study area based on the predicted extent of PCTs 835, 1106 and 1504. The key downstream impacts for this community as a result of the Project is the predicted reduction of flooding extent and the increased duration of inundation in the FMZ discharge area. About 461 hectares of the TEC within the 10% AEP event area is likely to experience a reduction in flooding during minor flood events; areas which are currently inundated every 10 years on average are predicted to be inundated every 20 years on average with the Project. It is acknowledged that this community is associated with habitats where flooding is periodic and flood mitigation is a key threat for the persistence of this community. In addition, 853 hectares of this community would be subject to increased inundation within the FMZ discharge area. The reduced flooding frequency across 461hectares in the Hawkesbury-Nepean catchment represents about 13 percent of the predicted extent of the community in the Project study area. Long-term changes in relation to species composition and structure could occur during prolonged dry periods. While the longer period of time for inundation in the FMZ discharge area may result in temporary damage to fringing vegetation and water quality reduction due to sedimentation and turbidity, this is not expected to have a permanent adverse effect on this community. Gradual alterations to the structure of the community may occur over an extended dry period, modifying the existing characteristics including important component species. The TEC includes characteristic species adapted to and/or requiring existing regimes of seasonal inundation and/or waterlogging, the spatial extent of component flora and fauna species that make up the local occurrence would be determined by these existing hydrological ecological regimes. Given the assumed total loss in the upstream impact area and the reduction in the 10% AEP event flood extent and frequency in the downstream study area, it is considered that there is a real chance or possibility that the Project will reduce the extent of this ecological community.
• **fragment or increase fragmentation of an ecological community, for example by clearing vegetation for roads or transmission lines**
The downstream extent of this CEEC in the floodplain of the Hawkesbury-Nepean catchment shows some fragmentation due to land use, weed competition and vegetation clearance as a result of agriculture and suburban

development. Despite this, the CEEC shows some significant extents of linear connectivity along its narrow distribution along waterways and floodplains, typically low down in the landscape. This linear pattern of occurrence makes this CEEC highly susceptible to edge effects, further driving fragmentation. DAWE (2020) notes an association between vulnerability of fragmentation and flooding. It is likely that the Project would increase fragmentation of the CEEC.

- **adversely affect habitat critical to the survival of an ecological community**

DAWE (2020) notes that habitat or areas critical to the survival of the ecological community are those patches that are in the best condition. However, this does not mean that areas that otherwise meet the minimum condition thresholds are unimportant for the survival of the ecological community. Many of these patches occur in locations or landscape positions that are particularly important for biodiversity or function and/or may contain suites of species or habitat features that are important in a regional or local context. DAWE (2020) notes that these areas can still be critical to the survival of the ecological community.

The extent of patches in moderate to good condition that meet thresholds to automatically be considered critical habitat, and patches in poorer condition but part of the same local occurrence and drainage catchment, generally means that at least most and potentially all extents of this CEEC would be considered critical habitat. This large extent of critical habitat could be adversely affected.

- **modify or destroy abiotic (non-living) factors (such as water, nutrients, or soil) necessary for an ecological community's survival, including reduction of groundwater levels, or substantial alteration of surface water drainage patterns**

The Project would alter the pattern of flooding downstream of Warragamba Dam broadly through a reduction in flood extent for all flood events, a reduction in the frequency of all flood events, and through an increase in the duration of elevated water levels (generally contained within the river channel) while the FMZ was in operation. This could alter abiotic factors relevant to this CEEC affecting its long term survival. Relevant abiotic factors include (but are not limited to) changes to soil properties such as the chemistry and structure including nutrient and carbon cycling, movement of organic matter, and sedimentation and erosion patterns.

- **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**

DAWE (2020) notes that the range and condition of plant species varies in different locations due to numerous ecological patterns such as disturbance or natural variation, historical biogeography and local environmental gradients that influence soils, water and flood regimes. Additionally, surrounding vegetation has a significant influence on the species composition.

Changes to the flood regime within the downstream study area could affect the species composition within patches of the CEEC, and considering existing fragmentation, variable condition and ecosystem functionality, edge effects, patch size, and broader floodplain changes associated to other communities and species within the study area, a decline or loss of the species composition of an occurrence of the CEEC is likely.

- **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 structural and floristic modifications which could occur across the extent of the CEEC as a result of the Project have the potential to reduce the quality and integrity of the CEEC within the study area. Specifically, the changes to vegetation composition have the potential to reduce the resilience of the CEEC, potentially making it more susceptible to detrimental processes such as:

- invasive species, such as weeds, to establish and colonise within the CEEC
- infection by pathogens and disease, such as Myrtle Rust
- aggressive exclusion of woodland birds by overabundant Noisy Miners

- Bell Miner associated die-back
- **interfere with the recovery of an ecological community.**
There is no adopted or drafted Commonwealth Recovery Plan for River-flat eucalypt forest on coastal floodplains of southern New South Wales and eastern Victoria. The River-Flat Eucalypt Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions TEC (listed under the BC Act) is included in the approved recovery plan for the Cumberland Plain. The proposed recovery objectives as outlined in the Cumberland Plain Recovery Plan (Department of Environment, Climate Change and Water 2010) are as follows: • 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 primary management objectives are compatible with biodiversity conservation. • To develop an 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. • 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 NSW government's Saving our Species program aims to secure as many threatened species and ecological communities as possible. As part of this, a conservation strategy for the CEEC aims to secure the ecological community in the long term. The strategy was developed by experts who identified the priority management areas and conservation actions required to manage critical threats to conserve the ecological community. A key threat identified in the Saving our Species program for this CEEC is '*Altered hydrology particularly from narrowing of corridors and the installation of infrastructure for flood mitigation and drainage causing a lack of periodic flooding, water entering more quickly and in larger volumes, water not standing long enough or being inundated for too long leading to changes in floristics.*' The Project would not directly assist or facilitate any of the priority objectives (or their actions) and actively involves a key threat over a significant area identified against the recovery of the CEEC.
Conclusion
The Project has assumed a total loss of about 105 hectares of this community in the upstream impact area. In the downstream study area, the Project has the potential to affect about 461 hectares in the changed 10% AEP flood event area and 853 hectares within the FMZ discharge area. As a result, the Project is considered to have the potential to: • alternate the structure and composition of the CEEC such that the extent of the TEC is reduced • adversely affect habitat critical to the survival of the CEEC • modify or destroy abiotic factors necessary for the CEECs survival • substantially and adversely modifying the composition of the ecological community • interfere with recovery of the CEEC • constitute and contribute to key threatening processes which may affect the CEEC The Project is likely to have a significant impact on River-flat eucalypt forest on coastal floodplains of southern New South Wales and eastern Victoria.

Reference

Department of Agriculture, Water and the Environment (2020) *Conservation Advice for the River-flat eucalypt forest on coastal floodplains of southern New South Wales and eastern Victoria*, Canberra, ACT.

Shale Sandstone Transition Forest of the Sydney Basin Bioregion

Critically Endangered Ecological Community under the EPBC Act

This threatened ecological community is known to occur within the downstream and construction study areas as PCT 1395 (HN556): Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain Sydney Basin Bioregion and PCT 1281 (HN604): Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains Sydney Basin Bioregion, respectively. It was assessed with a low likelihood of occurrence in the upstream study area and is therefore not subject to further assessment in this area.

In the downstream study area, none of the TEC was mapped as burnt by the FESM mapping. All of the 4.88 hectares of the TEC was mapped by FESM mapping as burnt.

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**
Before European settlement, Shale Sandstone Transition Forest CEEC was extensive around the edges of the Cumberland lowlands throughout western Sydney, most particularly in the southern half. It is estimated that 9,950 hectares remains intact. The Project could impact 686.43 hectares of moderate to good condition Shale Sandstone Transition Forest CEEC. This corresponds to the occurrence of 684.79 hectares potentially impacted within the downstream study area and 1.64 hectares directly impacted in the construction footprint. It should be noted that there is potential for impacts to the CEEC to be minimised during detailed design phase of the Project. The key impacts to this community as a result of the Project is the predicted reduction of flooding extent (684.79 hectares) in the study area, increased inundation within the FMZ discharge area (73.76 hectares) and the direct clearing of 1.64 hectares within the construction footprint. With regard to the latter, the Project would reduce the extent of the CEEC by at least 1.64 hectares and with potential for further reductions.
• **fragment or increase fragmentation of an ecological community, for example by clearing vegetation for roads or transmission lines**
The vegetation of the Hawkesbury-Nepean floodplain is highly fragmented due to past land use (agriculture and suburban development) and vegetation clearance. This CEEC however, is rather well connected by its distribution along waterways in the northern areas of the study area, and by its connectivity to the Blue Mountains National Park in the Construction Footprint. It is therefore unlikely that the Project may substantially increase the fragmentation of this CEEC in either the downstream or construction study areas.
• **adversely affect habitat critical to the survival of an ecological community**
According to the Matters of National Environmental Significance impact guideline (DoE 2013), '*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'* (DoE 2013). Shale Sandstone Transition Forest has been identified in the Cumberland Plain Recovery Plan (NSW Department of Environment, Climate Change and Water 2010). This makes the habitat within the study area critical to the survival of the CEEC as defined in the Matters of National Significance impact guidelines. The occurrence of the CEEC within the construction study area occurs at the edge of its known range. It also contains species considered to be atypical of this CEEC's broader distribution which supports the view that the community in the study area is occurring on the margin of its distribution (NSW Scientific Committee's Final Determination). Areas of this CEEC near or at the limit of its range are also considered important as a result of its compositional rarity and potential genetic significance.

Accordingly, the Project could adversely impact this critical habitat.
• **modify or destroy abiotic (non-living) factors (such as water, nutrients, or soil) necessary for an ecological community's survival, including reduction of groundwater levels, or substantial alteration of surface water drainage patterns**
In addition to direct impacts, the Project could alter abiotic factors that may be critical to the long-term survival of the CEEC. These abiotic factors include (but are not limited to) changes to soil properties (such as the chemistry, structure, etc.), hydrological processes (including surface water patterns) and nutrient cycling. However, there is little information available to understand the extent of changes to abiotic factors that would be required to consequently have a detrimental effect on the long-term survival of the CEEC. Applying the precautionary principle it has been assumed that any change to abiotic factors could detrimentally affect the quality and integrity of the CEEC within the study area.
• **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 clearing of 1.64 hectares of this CEEC in the construction footprint would remove all the native species characteristic of the TEC. In the downstream study area, while gradual alterations to the structure of the community may occur over an extended dry period, the extent of this change is unlikely to result in complete loss of the CEEC, rather a potential long-term modification of the existing floristic and structural characteristics. The CEEC is not known to depend on flooding regimes or seasonal inundation and/or waterlogging. Any modification to the floristic composition of the local occurrence of the CEEC is expected to be minimal and long-term and is unlikely to result in the loss of the CEEC in the locality.
• **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 structural and floristic modifications which could occur across the extent of the CEEC as a result of the Project have the potential to reduce the quality and integrity of the CEEC within the study area. Specifically, the changes to vegetation composition have the potential to reduce the resilience of the CEEC, and therefore making it more susceptible to detrimental processes such as: • invasive species, such as weeds, to establish and colonise within the CEEC • infection by pathogens and disease, such as Myrtle Rust • aggressive exclusion of woodland birds by overabundant Noisy Miners • Bell Miner associated die-back
• **interfere with the recovery of an ecological community.**
The Project has the potential to interfere with the recovery of the CEEC given that: • it may result in a reduction in the extent of the CEEC • it could adversely affect the habitat critical to the survival of the CEEC • it has the potential to modify the abiotic factors important to the survival of the CEEC • it may cause a reduction in the quality and integrity of the CEEC.

Conclusion
The Project would reduce the extent of Shale Sandstone Transition Forest in the construction study area and could reduce its extent in the downstream study area where the Project may result in minor modifications to up to 91 hectares of this TEC in the 10% AEP event. Areas which are currently inundated every 10 years on average are predicted to be inundated every 20 years on average with the Project. The known distribution of the TEC across the Sydney Basin suggests that the community is not dependent on frequent flood events to persist. 91 hectares of the TEC represents about 0.9 percent of the estimated remaining extent of the community. Impacts in relation to increased inundation in the FMZ Discharge area are expected to be temporary. The Project is unlikely to result in a significant impact on the Shale Sandstone Transition Forest in the Sydney Basin Bioregion TEC within the 10% AEP event changed flood extent.

Turpentine-Ironbark Forest of the Sydney Basin Bioregion

Critically Endangered Ecological Community under the EPBC Act

Turpentine–Ironbark Forest in the Sydney Basin Bioregion (TIF) is an open forest community endemic to the Sydney Basin bioregion, NSW. The tree canopy of the TIF is typically dominated or co-dominated by *Syncarpia glomulifera* (turpentine). Ironbark species are common (especially on the Cumberland Plain), including species such as *Eucalyptus paniculata*, *E. crebra* and/or *E. fibrosa*. On the plateaux shale caps, *E. paniculata* and *E. notabilis* may become common in association with *S. glomulifera*. A layer of small trees can occur, including *Pittosporum undulatum, Trema aspera* and *Acacia parramattensis*. A shrub layer may include – when present - *Polyscias sambucifolia, Notelaea longifolia, Leucopogon juniperinus, Pittosporum revolutum, Breynia oblongifolia*, and *Ozothamnus diosmifolius*. Where not disturbed, the ground layer may include *Oplismenus aemulus, Pseuderanthemum variabile, Echinopogon ovatus, Microlaena stipoides*, and *Themeda triandra* (DoE 2014).

Turpentine Ironbark Forest is a transitional community occurring between the Cumberland Plain Shale Woodlands and Shale Gravel Transition Forest that occurs on the drier parts of the Cumberland Plain, and Blue Gum High Forest which occurs on the wetter ridges. As such, TIF occurs in areas subject to between 800 and 1,100 millimetres of rainfall a year and occurs from less than 320 metres above sea level to 750 metres. This TEC is supported by fertile clay soils derived from the Wianamatta Shale or clay lenses within Hawkesbury sandstone.

This threatened ecological community is known to occur within the downstream study area as two PCTs: PCT 1284 (HN606): Turpentine - Smooth-barked Apple moist shrubby forest of the lower Blue Mountains Sydney Basin Bioregion and PCT 1183 (HN587): Smooth-barked Apple - Sydney Peppermint - Turpentine heathy open forest on plateaux areas of the Sydney Basin Bioregion. It was assessed with a low likelihood of occurrence in the upstream and construction study areas and was therefore not subject to further assessment in these areas.

In the downstream study area, none of the TEC was mapped as burnt by the FESM mapping. The community has not been mapped as occurring in the construction or upstream study areas.

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**
An estimated 113.19 hectares of this TEC occurs within the 10% AEP Project flood extent and 49.53 hectares within the PMF extent. As this community appears to be dependent on sustained moisture for plant growth, less frequent flooding may result in some modification to the vegetation structure and composition in the long term. However, noting that the community is also associated with areas subject to moderate rainfall events, this could mitigate this limitation. Taking a precautionary [position, the Project has been assessed as having the potential to reduce the extent of this TEC.
• **fragment or increase fragmentation of an ecological community, for example by clearing vegetation for roads or transmission lines**
The vegetation of the Hawkesbury-Nepean catchment floodplain (which the PMF occurs within) is currently subject to high fragmentation because of prior land use (agriculture and suburban development) and vegetation clearance. The area of the TEC in the 10% AEP flood extent and PMF extent is contiguous with the native vegetation around Wollemi National Park and Parr State Conservation Area. It is unlikely that the changed flooding regime would increase fragmentation for this community.
• **adversely affect habitat critical to the survival of an ecological community**
No habitat critical for the survival of TIF declared within recovery plan or critical habitat determination.
• **modify or destroy abiotic (non-living) factors (such as water, nutrients, or soil) necessary for an ecological community's survival, including reduction of groundwater levels, or substantial alteration of surface water drainage patterns**
In addition to a potential reduction in extent due to impacts from inundation, the Project could alter abiotic factors that may be critical to the long-tern survival of the TEC. These abiotic factors include (but are not limited to) changes to soil properties (such as the chemistry, structure etc.), hydrological processes (including surface water patterns) and nutrient cycling. However, there is little information available to understand the extent of changes to

abiotic factors that would be required to have a detrimental effect on the long-term survival of the TEC. Applying the precautionary principle it has been assumed that any change to abiotic factors may detrimentally affect the quality and integrity of the EEC within the study area.
• **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**
While gradual alterations to the structure of the community may occur over an extended dry period, the extent of this change is unlikely to result in complete loss of the TEC. The Project is therefore unlikely to have an adverse effect on the composition of the ecological community.
• **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 Project has the potential to facilitate the further spread and establishment of invasive species within the 10% AEP flood extent. • It is unknown whether the Project could mobilise fertilisers, herbicides and other chemicals throughout the 10% AEP flood extent.
• **interfere with the recovery of an ecological community.**
The Project is unlikely to interfere with the recovery of the TEC.
Conclusion
Turpentine Ironbark Forest has been recorded within the PMF boundary. The Project has been assessed as potentially reducing the extent of this TEC within the PMF extent and to modify the composition of its species. The Project is unlikely to reduce the extent of this TEC or modify its species composition to the extent that it would likely cause a local extinction. The Project is unlikely to have a significant impact on Turpentine Ironbark Forest.

Western Sydney Dry Rainforest and Moist Woodland on Shale

Critically Endangered Ecological Community under the EPBC Act

The Western Sydney Dry Rainforest and Moist Woodland on Shale ecological community is a type of dry rainforest that grades into moist woodland. It is found in gullies and slopes around western Sydney and its vegetation occurs in several forms, depending on the landscape position, climate or land use history. The ecological community generally occurs in higher rainfall areas (relative to surrounding areas on the western Sydney plains) at elevations up to 300m above sea level. It is often found in steeper, more rugged terrain. The dry rainforest form typically occupies gully bottoms and lower slopes. The moist woodland form typically occurs upslope from gullies, with some patches extending onto gentler, undulating terrain. From there, it may intergrade with the critically endangered Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest ecological community. Moist woodland may also develop where partial clearance or fire has disturbed the dry rainforest vegetation. This CEEC Typically occurs on clay soils derived from Wianamatta Group shale geology.

The dry rainforest form is a low, closed forest dominated by non-eucalypts—notably prickly-leaved paperbark (*Melaleuca styphelioides*), hickory wattle (*Acacia implexa*) and native quince (*Alectryon subcinereus*), while white euodia (*Melicope micrococca*) may also be common. The moist woodland form has a more open canopy dominated by eucalypts, notably forest red gum (*Eucalyptus tereticornis*) and coastal grey box (*E. moluccan*a). The vegetation underneath the canopy includes a variable presence of shrubs, and a generally sparse cover of grasses, ferns and other herbs. Vines and scramblers are typically present, though are most common in the dry rainforest form. The ecological community is characterised by a good representation of moisture-dependent species, such as broad-leaved shrubs and ferns. Some plants that often occur in other types of rainforest/moist woodland in New South Wales are usually absent or uncommon in this ecological community. For instance, palms, figs, vascular epiphytes, mosses and grey myrtle (*Backhousia myrtifolia*) are not a common feature of this ecological community.

This ecological community is known to occur in the downstream study area in PCT877: Western Sydney Dry Rainforest in the Sydney Basin Bioregion and PCT830: Moist Shale Woodland in the Sydney Basin Bioregion.

In the downstream study area, none of the TEC was mapped as burnt by the FESM mapping. The community has not been mapped as occurring in the construction or upstream study areas.

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 Western Sydney Dry Rainforest and Moist Woodland ecological community has a highly restricted distribution. The ecological community occurs in the Sydney Basin bioregion in New South Wales where it is confined to sheltered slopes and gullies on steeply sloping, rugged topography on the edges of the Cumberland Plain sub-region distribution (Tozer 2003; Tozer *et al.* 2010). (Some patches may occur on more gentle, undulating terrain and/or in the centre of the Cumberland Plain). There are only 950 hectares of this community left, about 29 percent of its original extent. About 24.85 hectares has been mapped in the downstream study area representing 2.6 percent of its remaining distribution. This TEC is typically associated with sheltered lower slopes and in gullies on clay soils derived from Wianamatta shale. It is likely that in areas with less habitat dependence on aspect (south facing slope, narrow or deep gullies), that flooding extent within and/or proximity to low inflammability floodplain mesic vegetation are key drivers for this community's extent. The former habitat values may be driving factors within the FMZ discharge area and the lower flood contours such as the 10% AEP. The key impacts for this community as a result of the Project is the predicted reduction of flooding extent in wetland and floodplain vegetation communities and habitats and increased inundation within the FMZ discharge area. Associated potential impacts to these would be the increased potential for the spread of disease and pathogens, and exotic species resulting in competition. Current extents of this CEEC within the PMF (24.85 hectares) are considered to have the potential to see increased associated spread and weed species such as Lantana, African Olive and Bridal Creeper. Additionally, a localised increase in shade competition, humidity and periods of time with plants underwater would assist the spread and impact of Myrtle Rust on this locally dominated *Backhousia myrtifolia* which is known be susceptible to the disease. Within the 10% AEP flood extent, up to 7.23 hectares of the EEC may see a decrease in flood inputs to soil moisture, potentially resulting in changes to inflammability of this fire sensitive EEC, both within mesic buffering vegetation and within the existing dry rainforest. This could lead to a reduction of lower slope fire refuge values. The lower

slope extents of the EEC are likely strongly driven by the obligate input in most lower areas of soil moisture inputs such as proximity to and frequency of riparian and floodplain processes. Disruption of this lower slope fire refuge values could have implications to fire behaviour across the broader study area, particularly with contiguous relevant vegetation to lower slope dry rainforest with increased inflammability. The Project has the potential to reduce the extent of the ecological community within the downstream study area.
• **fragment or increase fragmentation of an ecological community, for example by clearing vegetation for roads or transmission lines**
This CEEC is highly fragmented across its distribution across the Cumberland Plain. The generally naturally linear distribution of this CEEC renders it highly susceptible to fragmentation and isolation. The Project may increase the fragmentation within the 10% AEP flood extent as changes to habitat may result in the loss of certain extents of this community. The nature of the impacts would develop over time and may be ongoing. Variable spatial impacts may occur over time, meaning that fragmentation could occur as the impacts accrue. The increase in physical distance and decrease in abundance of component species may cause isolation between stands of this community by genetically isolating these component species. If certain populations of component species become genetically isolated, inbreeding may occur, potentially reducing the population's fitness. If an event was to occur (such as a flood, drought or prolonged warming event) that placed a component species under environmental stress, the affected population may no longer contain the genetic robustness (required alleles) to withstand this event.
• **adversely affect habitat critical to the survival of an ecological community**
The two PCTS that make up this CEEC are included within the Cumberland Plain Recovery Plan which has identified Priority Conservation Lands (PCLs). PCLs are considered to contain habitat critical to the survival of threatened entities on the Cumberland Plain. The area of this CEEC impacted by the Project occurs within mapped PCLs. As such, the Project may impact upon extents of the CEEC and could impact habitat considered to be critical for the survival of the EEC.
• **modify or destroy abiotic (non-living) factors (such as water, nutrients, or soil) necessary for an ecological community's survival, including reduction of groundwater levels, or substantial alteration of surface water drainage patterns**
In addition to a potential reduction in extent due to impacts from inundation, the Project could alter abiotic factors that may be critical to the long-tern survival of the EEC. These abiotic factors include (but are not limited to) changes to soil properties (such as the chemistry, structure, etc.), hydrological processes (including surface water patterns) and nutrient cycling. However, there is little information available to understand the extent of changes to abiotic factors that would be required to consequently have a detrimental effect on the long-term survival of the EEC. Applying the precautionary principle it has been assumed that any change to abiotic factors could detrimentally affect the quality and integrity of the EEC within the study area.
• **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 local extents of this EEC are dominated by *Backhousia myrtifolia*. This relatively simple and homogenous floristic dominance across the study area, and the shared impacts of reduced flooding extent over the study area, could see broadly shared, albeit spatially variable, impacts from the Project. However, the dynamics of these impacts across the study area are likely variable and not linearly correlated to flood levels in those locations. The nature of the broad impact pathways identified above mean that changes to flood extents may alter the composition of the EEC across the study area. The reduction in the 10% AEP flood extent has the potential to have an adverse effect on the composition of the ecological community such that its local occurrence within the Study Area could be significantly affected.

- **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 structural and floristic modifications which could occur across the extent of the CEEC as a result of the Project have the potential to reduce the quality and integrity of the CEEC within the study area. Changes to vegetation composition have the potential to reduce the resilience of the CEEC, making it more susceptible to detrimental processes such as:

- invasive species, such as weeds, to establish and colonise within the CEEC
- infection by pathogens and disease, such as Myrtle Rust
- aggressive exclusion of woodland birds by overabundant Noisy Miners
- Bell Miner associated die-back

- **interfere with the recovery of an ecological community.**

Unoccupied habitat may occur over a larger area in the study area and local occurrence than this CEEC currently occupies due to clearing and disturbance of this vegetation and habitat. Impacts associated with urban and agricultural land use have removed or modified the CEEC in those habitat areas such that it does not currently occur as the assemblage of species. There are likely also areas that support the community or its habitat that have not been previously mapped as such.

It is assumed that there are some areas of habitat within the study area that could recover naturally if current anthropogenic inputs such as mowing/slashing and grazing were ceased, or if assisted natural regeneration such as bush regeneration and weed removal, was facilitated. Large extents of occupied and unoccupied habitat within the PMF extent could be impacted through changes in hydrology and associated ecological changes.

This CEEC is included in the approved recovery plan for the Cumberland Plain. The proposed recovery objectives as outlined in the Cumberland Plain Recovery Plan (NSW Department of Environment, Climate Change and Water 2010) are as follows:

- 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 primary management objectives are compatible with biodiversity conservation.
- To develop an 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.
- 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 Project would not directly assist or facilitate any of the priority objectives (or their actions). It could result in impacts not consistent with the objectives and actions of the Cumberland Plain recovery plan. The Project would not likely facilitate the recovery of the CEEC.

Conclusion

Potential impacts associated with the Project that may affect the species composition of this community include (but are not limited to):

- Deposition of soil and debris on lower strata species. Flood events may deposit soils and debris on lower strata species inhibiting their ability to grow and function.
- Competition with non-locally native species. A changed disturbance regime may facilitate the spread of non-locally native species (invasive species).
- Adversely impact the extent and composition
- Substantially and adversely modify the composition of the ecological community

- Remove, modify, fragment or isolate habitat important to be to the long-term survival of ecological community in the locality
- Directly conflicts with the objectives or actions of a recovery plan or threat abatement plan.

The Project may impact up to about 25 hectares of the Western Sydney Dry Rainforest and Moist Woodland on Shale ecological community (about 2.6 percent of its total extent). This community only occurs in the Sydney Basin Bioregion and is already highly fragmented, making any existing extent important to its survival. The potential impacts of the Project could lead to an extinction of the local occurrence of the community.

The Project is likely to have a significant impact on the Western Sydney Dry Rainforest and Moist Woodland on Shale CEEC.

White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland

Critically Endangered Ecological Community under the EPBC Act

The White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Grasslands CEEC is characterised by a species-rich understorey of native tussock grasses, herbs and scattered shrubs, and the dominance, or prior dominance, of White Box, Yellow Box or Blakely's Red Gum trees. In the Nandewar Bioregion, Grey Box (*Eucalyptus microcarpa or E. moluccana*) may also be dominant or codominant. The tree-cover is generally discontinuous and consists of widely-spaced trees of medium height in which the canopies are clearly separated (Yates & Hobbs 1997).

In its pre-1750 state, this ecological community was characterised by:

- a ground layer dominated by tussock grasses;
- an overstorey dominated or co-dominated by White Box, Yellow Box or Blakely's Red Gum, or Grey Box in the Nandewar bioregion; and,
- a sparse or patchy shrub layer.

Associated, and occasionally co-dominant, trees include, but are not restricted to: Grey Box (*Eucalyptus microcarpa*), Fuzzy Box (*E. conica*), Apple Box (*E. bridgesiana*), Red Box (*E. polyanthemos*), Red Stringybark (*E. macrorhyncha*), White Cypress Pine (*Callitris glaucophylla*), Black Cypress Pine (*C. enderlicheri*), Long-leaved Box (*E. gonicalyx*), New England Stringybark (*E. calignosa*), Brittle Gum (E. mannifera), Candlebark (*E. rubida*), Argyle Apple (*E. cinerea*), Kurrajong (*Brachychiton populneus*) and Drooping She-oak (*Allocasuarina verticillata*) (Austin *et al.* 2002; Beadle 1981; Fischer *et al.* 2004; NSW National Parks & Wildlife Service 2002; Prober & Thiele in press).

Thiele and Prober (2000) estimated that less than 0.1 percent of Grassy White Box Woodlands (a component of the White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Grasslands CEEC) remains in a near-intact condition. Much of the original extent of this CEEC has been cleared for agriculture. In most of the areas that remain, grazing and pasture-improvement have effectively removed the characteristic understorey, leaving only the overstorey trees with an understorey dominated by exotic species (McIntyre *et al.* 2002; Prober & Thiele in press). In these areas, grazing has also largely prevented the regeneration of the overstorey species (Sivertsen 1993). Due to the high levels of clearing that have taken place, and continued grazing, large areas of healthy, regenerating overstorey are rare. Areas containing a number of mature trees or regenerating trees are important as they provide current and future breeding and foraging habitat for woodland animals, such as Regent Honeyeaters (*Anthochaera phrygia),* Squirrel Gliders *(Petaurus norfolcensis*) and Superb Parrots (*Polytelis swainsonii*) (NSW Scientific Committee 2002).

The White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Grasslands CEEC occurs in an arc along the western slopes and tablelands of the Great Dividing Range from Southern Queensland through NSW to central Victoria (Beadle 1981). It occurs in the Brigalow Belt South, Nandewar, New England Tableland, South Eastern Queensland, Sydney Basin, NSW North Coast, South Eastern Highlands, South East Corner, NSW South Western Slopes, Victorian Midlands and Riverina Bioregions (Environment Australia 2000).

The White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Grasslands CEEC only occurs in the upstream study area of the Project. The ecological community conforms to:

- HN527: Forest Red Gum - Yellow Box woodland of dry gorge slopes southern Sydney Basin Bioregion and South Eastern Highlands Bioregion
- HN557: Narrow-leaved Ironbark - Forest Red Gum on rocky slopes of the lower Burragorang Gorge Sydney Basin Bioregion

The FESM mapping noted that of the 1447.72 hectares of the CEEC in the study area, that 1034.15 hectares is mapped as burnt by the 2019-2020 bushfires, or 71 percent of the total mapped extent of the CEEC in the study area. Further:

- 608.62 hectares of the 854.66 hectares in the 1% AEP has been mapped as burnt; this is 71.21% of the CEEC in the 20% AEP.
- 132.38 hectares of the 188.33 hectares in the 20% AEP has been mapped as burnt; this is 70.29 % of the CEEC in the 1% AEP.
- 308.49hectares of the 430.56 hectares in the Agreed Upstream Impact Area has been mapped as burnt. This is 71.65% of the CEEC in the Agreed Upstream Impact Area.

While these areas in the order of 70% burnt would be at risk from any cumulative and interactive effects of potential inundation as part of the Project, the balance of this CEEC, in the order of 30%, that hasn't been burnt, would be an important genetic refuge for the CEEC and its component species in the broader locality and if impacted by the Project would likely be impacting these regional important refugial values. It was noted that spatially this area of unburnt CEEC is found as a relatively cohesive extent along the Wollondilly River in the Joorilands and Murphy's Crossing locality.

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 Project would reduce the extent of, or impact up to about 431 hectares of White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Grasslands CEEC within the upstream impact area. This represents about 30% of the extent of this community within the upstream study area. For the purpose of offsetting the upstream biodiversity impacts of the Project, it has been assumed that there would be a total loss of biodiversity values in this area. Accordingly, there is a real chance or possibility that the Project will reduce the extent of this CEEC.
• **fragment or increase fragmentation of an ecological community, for example by clearing vegetation for roads or transmission lines**
The areas of the CEEC that occur within the study area are contiguous with larger tracts of the CEEC within the locality. The Project may cause fragmentation within and potential isolation from some of these contiguous stands.
• **adversely affect habitat critical to the survival of an ecological community**
The area of this TEC within the upstream study area is an important area of the TEC as defined by the FBA (OEH 2014). An important area comprises an area of the TEC that is necessary for the entities' long-term persistence and recovery. This may include areas identified in recovery plans, and/or an area large in comparison to other stands of the CEEC or EEC or occurrences of the CEEC or EEC at the limit of the community's range. The National Recovery Plan for White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland identifies habitat critical for the survival of the CEEC, and states that given the highly degraded state of the ecological community, all areas of White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland which meet the minimum condition requirements under the EPBC Act should be considered critical for the survival of the CEEC. Both HN527 and HN557 conform to the Final Determination of the CEEC under the EPBC Act due to their high level of species richness, they include a high number of important species, and meet the condition thresholds. The area of this CEEC within the upstream wider study area occurs within lands reserved as part of National Parks and Wildlife Estate as well as within Kanangra-Boyd and Nattai Declared Wilderness areas. The areas that occur within the study area are contiguous with larger tracts of the CEEC within the locality. The Project has the potential to adversely affect habitat critical to the survival of this ecological community.
• **modify or destroy abiotic (non-living) factors (such as water, nutrients, or soil) necessary for an ecological community's survival, including reduction of groundwater levels, or substantial alteration of surface water drainage patterns**
The Project could alter abiotic factors that may be critical to the long-term survival of the CEEC. Such abiotic factors include (but not limited to) changes to soil properties (such as the chemistry, structure etc.), hydrological processes (including surface water patterns) and nutrient cycling. However, there is little information available to understand the extent of changes to abiotic factors that would be required to consequently have a detrimental effect on the long-term survival of the CEEC. Applying the precautionary principle it has been assumed that any change to abiotic factors could detrimentally affect the quality and integrity of the CEEC within the upstream study area.
• **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 Project may impact up to about 431 hectares of moderate to good condition HN527 and HN557 conforming to White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland CEEC within the upstream impact area. The CEEC within the upstream study area possesses over 32 functionally important species such as *Cheilanthes distans, Themeda triandra, and Arthropodium milleflorum.* Areas of the TEC that occur proximal

(however external) to the study area have the potential to be affected through edge effects, weed invasion, altered hydrological processes and loss of structural and floristic complexity though inappropriate fire regimes over the long term. This may also lead to a loss of characteristic and functionally important species associated with the CEEC in these areas.

- **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**

White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland CEEC could be impacted via various pathways following inundation events. Impacts such as edge effects, changes to hydrology, weed invasion and encroachment, introduction or spread of diseases and pathogens, erosion and sedimentation and changes to natural fire regimes could contribute to further impacts on composition, structure and function of other extents of the CEEC occurring proximal (however external) to the study area. These impacts may further fragment the extent of the CEEC and reduce their quality and integrity.

The CEEC within the study area is considered to be of a high quality due to having high species diversity, structural intactness and a demonstrated resilience to past agricultural land use practices. However, the Project could reduce the quality and integrity of remaining stands of the CEEC within the study area to some degree.

- **interfere with the recovery of an ecological community.**

The Recovery Plan for this CEEC (DECC/WaterNSW 2010) lists the following specific objectives:

- achieving no net loss in extent and condition of the ecological community throughout its geographic distribution;
- increasing protection of sites with high recovery potential;
- increasing landscape functionality of the ecological community through management and restoration of degraded sites;
- increasing transitional areas around remnants and linkages between remnants; and
- bringing about enduring changes in participating land manager attitudes and behaviours towards environmental protection and sustainable land management practices to increase extent, integrity and function of Box-Gum Grassy Woodland.

Given the assumed total loss of biodiversity values within the upstream impact area, the Project would not be consistent with all these objectives and would interfere with the recovery of this CEEC.

Conclusion

The Project is likely to have a significant impact on the White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland CEEC.

References

Department of Environment, Climate Change and Water NSW (2010) *National Recovery Plan for White Box - Yellow Box - Blakely's Red Gum Grassy Woodland and Derived Native Grassland*. Department of Environment, Climate Change and Water NSW, Sydney.

Migratory species

Apus pacificus (Pacific Swift/Fork-Tailed Swift)

Migratory under the EPBC Act

The Pacific Swift is a widespread, almost exclusively aerial migratory species which is distributed throughout much of north-east, east and south-east Asia and Australia (Higgins 1999). The nominate race migrates to Australia during the non-breeding season (October-April) over a broad range of different habitat types. Pacific Swift mostly occur over dry or open habitats on inland plains but are known to occur over ocean, beaches, islands, and mountainous and/or heavily forested areas. A total of 100 individuals corresponds to an ecologically significant proportion of their population at the national scale, whilst a total of 1000 individuals corresponds to an internationally significant proportion of their population (Commonwealth of Australia 2015).

Upstream/Construction

The Pacific Swift is an uncommon summer/autumn visitor in the study area. Though there have been few observations of this species in the study area due to a lack of survey effort, this species is likely to forage above any part of the study area. No targeted Pacific Swift surveys were conducted in the study area by SMEC.

The study area is unlikely to support important Pacific Swift habitat, as none of the following four important habitat criteria (Commonwealth of Australia 2013) are likely to be met:

a) habitat utilised by a migratory species occasionally or periodically within a region that supports an ecologically significant proportion of the population of a species, and/or

   An ecologically significant proportion of their population is unlikely to periodically use the study area.

b) habitat that is of critical importance to the species at particular life-cycle stages, and/or

   No habitat of critical importance to this species at particular life-cycle stages is likely to be present in the impact area.

c) habitat utilised by a migratory species which is at the limit of the species' range, and/or

   The study area is not at the geographic limit of this species' distribution.

d) habitat within an area where the species is declining.

   There is no evidence to suggest that this species is already declining in the area.

Downstream

The Pacific Swift is an uncommon summer/autumn visitor in the study area. This species may forage over any part of the study area, though the majority of records in the study area are from the Richmond/Windsor area where flocks of up to 45 individuals have been recorded in the past five years. No targeted Pacific Swift surveys were conducted in the study area by SMEC.

The study area is unlikely to support important Pacific Swift habitat, as none of the following four important habitat requirements are likely to be met:

a) habitat utilised by a migratory species occasionally or periodically within a region that supports an ecologically significant proportion of the population of a species, and/or

   An ecologically significant proportion of their population is unlikely to periodically use the study area.

b) habitat that is of critical importance to the species at particular life-cycle stages, and/or

   No habitat of critical importance to this species at particular life-cycle stages is likely to be present in the impact area.

c) habitat utilised by a migratory species which is at the limit of the species' range, and/or

   The study area is not at the geographic limit of this species' distribution.

d) habitat within an area where the species is declining

   There is no evidence to suggest that this species is already declining in the area.

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**
Upstream/Construction As an aerial species, foraging on the wing, it is assumed that all area may be appropriate habitat. Approximately 6,289 hectares habitat above which comprises suitable aerial foraging habitat is located in the study area. The Project is likely to substantially modify or destroy approximately 3,090 hectares of forested habitat over which the Pacific Swift is likely to forage. However, the modification of such habitat is unlikely to translate to total loss of the suitability of this habitat for these aerial specialists but is likely to have a negative impact on prey availability (that is, habitat modification or loss of habitat for a forest dwelling bird corresponds to true or total loss, whereas for an aerial species total loss translates to a smaller overall, though still negative impact on the species) Inundation of forest and woodland in the impact area will substantially modify the structure and floristics of such habitat which is likely to have a negative impact on prey availability and hence, overall foraging habitat quality. Downstream As an aerial species, foraging on the wing, it is assumed that all area may be appropriate habitat. Approximately 11,207 hectares habitat above which comprises suitable aerial foraging habitat is located in the study area 1,042 hectares of which is located in the impact area. Alteration of the flow regime downstream of the Warragamba Dam is very unlikely to substantially modify (including by fragmenting, altering fire regimes, altering nutrient cycles or altering hydrological cycles), destroy or isolate an area of important Pacific Swift habitat given that it is unlikely that the impact area supports important habitat for either of these species.
• **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**
Upstream/Construction and Downstream The Project is unlikely to result in an invasive species that is harmful to Pacific Swift becoming established in an area of important Pacific Swift habitat. No invasive species are known to affect the Pacific Swift in Australia.
• **seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.**
Upstream/Construction The Project is unlikely to seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the Pacific Swift's population. Inundation of woodland and forest in the impact area is likely to reduce the availability of their key prey source (that is, insects). However, this is unlikely to seriously disrupt their foraging behaviour given: a) the extent of forested habitat in the landscape surrounding the impact area. b) loss of forest and woodland in the impact area will not render the airspace above such areas unsuitable for foraging swifts. Downstream Alteration of the flow regime of the Hawkesbury-Nepean River is very unlikely to seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the Pacific Swift's population given that minor changes to non-forested habitat is unlikely to have a significant impact on foraging overhead.

Conclusion
Upstream/Construction The Project is unlikely to have a significant impact on the Pacific Swift. **Downstream** The Project is unlikely to have a significant impact on the Pacific Swift.

Calidris melanotos (Pectoral Sandpiper) and *Calidris acuminata* (Sharp-tailed Sandpiper)

Migratory under the EPBC Act

Both the Pectoral Sandpiper (*Calidris melanotos*) and the Sharp-tailed Sandpiper (*Calidris acuminata*) have been assessed with a moderate or higher likelihood of occurring only in the downstream study area. As such this assessment is only applicable to the downstream study area.

Pectoral Sandpiper

The Pectoral Sandpiper occurs at coastal lagoons, estuaries, bays, swamps, lakes, inundated grasslands, saltmarshes, river pools, creeks, floodplains and artificial wetlands (Higgins and Davies 1996). The Pectoral Sandpiper prefers water bodies that have open fringing mudflats and low, emergent or fringing vegetation, such as grass or samphire. It is usually found in coastal or near coastal habitat but is occasionally found further inland. The Pectoral Sandpiper's EAAF population is estimated to comprise 1,220,000 – 1,930,000 individuals (Hansen *et al.* 2016). The Pectoral Sandpiper is an occasional/rare visitor (October – April) in the study area which has been most regularly recorded at Pitt Town Lagoon but is also infrequently observed at nearby sites such as McGrath's Hill STP (1981 1982 1986 1991 1997), Bushells Lagoon (2013) and Bakers Lagoon (2002 2013). Notable observations include records of seven and four individuals at Pitt Town Lagoon in 1997 and 2015 respectively.

Sharp-tailed Sandpiper

The Sharp-tailed Sandpiper primarily utilises shallow fresh or brackish wetlands, with inundated or emergent sedges, grass, saltmarsh or other low vegetation (Higgins and Davies 1996). This includes intertidal mudflats, lagoons, swamps, lakes and pools near the coast, and dams, waterholes, soaks, bore drains and bore swamps, saltpans and sewage farms. The Sharp-tailed Sandpiper's EAAF population is estimated to comprise 85,000 individuals (Hansen *et al.* 2016). The Sharp-tailed Sandpiper is a common visitor (September – April) in the study area which is regularly recorded at Pitt Town Lagoon and Bushells Lagoon but has also been recorded at Little Wheeney Lagoon (2009), Fernleigh's Lagoon (2002 2003 2004), Bakers Lagoon (1948 1985- 1987 1991 2002 2013), Longneck Lagoon (2003), Pugh's Lagoon (2002 2013), Penrith Lakes (2002 2012) and McGraths Hill STP (1979-1981 1984-1986 1991 2002 2003 2009 2013). Notable observations include several records of between 100 – 400 individuals at Pitt Town Lagoon in late 2002 and a flock of 200 at this location in 2006, 300 at Pitt Town Bottoms in 1948 200 at Bakers Lagoon in 1991. The timing of the occurrence of the largest observed flocks at Pitt Town Lagoon has appeared to coincide with severe droughts in NSW.

Important shorebird habitat and ecologically significant proportions of shorebird populations

The number of individual birds that corresponds to an ecologically significant proportion (0.1%) of the total population in accordance with the latest population estimates (Hansen *et al.* 2016) is as follows:

- Pectoral Sandpiper = 1,220
- Sharp-tailed Sandpiper = 85

Shorebird habitat for migratory shorebirds listed under the EPBC Act 1999 is considered internationally important according to the EPBC Act Policy Statement 3.21 (Commonwealth of Australia 2017) if it regularly supports:

- 1 percent of the individuals in a population of one species or subspecies of waterbird or

  Available data suggest that the study area does not regularly support 1% of either the Pectoral Sandpiper or Sharp-tailed Sandpiper populations.

- a total abundance of at least 20,000 waterbirds.

  Available data suggest that the study area does not regularly support at least 20,000 waterbirds.

Shorebird habitat for migratory shorebirds listed under the EPBC Act 1999 is considered nationally important according to the EPBC Act Policy Statement 3.21 (Commonwealth of Australia 2017) if it regularly supports:

- 0.1 percent of the flyway population of a single species of migratory shorebird or

  Existing records of these species in the study area suggests that neither the Pectoral Sandpiper nor the Sharp-tailed Sandpiper is likely to occur in nationally significant numbers in the study area.

- 2,000 migratory shorebirds or

  Available data suggest that the study area does not regularly support 2000 migratory shorebirds.

- 14 migratory shorebird species

Available data suggest that the study area does not regularly support 14 migratory shorebird species.

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**
Approximately 3,000 hectares of known suitable or potential habitat is located in the downstream study area of which approximately 50 hectares is located in the 1% AEP. There is likely more appropriate habitat that may be impacted in the Downstream study area, but these areas are difficult to calculate as its entire extent has not been ground-truthed. The alteration of components of the current Hawkesbury-Nepean River flow regime such as the magnitude, frequency and duration of flood events is likely to impact known wetland foraging habitat. It is possible that given their preference for shallow wetlands a reduction in flows in the Hawkesbury-Nepean River may enhance the habitat quality of certain wetlands in the impact area whilst potentially negatively impacting suitable foraging habitat at others (Pressey 1979). The Project is unlikely to substantially modify, destroy or isolate any areas of important Pectoral Sandpiper or Sharp-tailed Sandpiper habitat given that no such habitat areas are present in the Downstream study area.
• **result in an invasive species that is harmful to the migratory species becoming established in an area of important habitat for the migratory species**
The Project is unlikely to result in an invasive species that is harmful to the Pectoral Sandpiper and/or Sharp-tailed Sandpiper becoming established in an area of important habitat. Introduced predators which may pose a risk to these wetland birds such as the Red Fox and Feral Cat are currently present in the study area.
• **seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species**
The Project is unlikely to seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the populations of the Pectoral Sandpiper and/or Sharp-tailed Sandpiper given: The impacts associated with the Project are unlikely to degrade the habitat present in the PMF to the point that it seriously disrupts the foraging or resting behaviour of the Pectoral Sandpiper and/or Sharp-tailed Sandpiper.
Conclusion
The Project may have a negative impact on the Pectoral Sandpiper and Sharp-tailed Sandpiper though this is unlikely to correspond to a significant adverse impact. The Project is unlikely to have a significant impact on the Pectoral Sandpiper and Sharp-tailed Sandpiper.

Monarcha melanopsis (Black-faced Monarch), *Myiagra cyanoleuca* (Satin Flycatcher), *Rhipidura rufifrons* (Rufous Fantail), *Symposiachrus trivirgatus* (Spectacled Monarch)

Migratory under the EPBC Act

The Black-faced Monarch (*Monarcha melanopsis*) is a small insectivorous migrant which breeds in eastern coastal Australia during summer and migrates to spend the non-breeding winter period in New Guinea. A portion of the population overwinters in northern Australia rather than making the full migration to New Guinea. The Black-faced Monarch is a wet forest specialist which primarily occurs in riparian vegetation and tropical, sub-tropical and temperate rainforest in eastern Australia (Higgins *et al.* 2006). In wet sclerophyll forest, the species mostly frequents sheltered gullies and slopes with a dense understorey of ferns and/or shrubs. They forage mainly gleaning from foliage or branches of trees and shrubs or by taking insect prey from the air (sallying).

The Satin Flycatcher (*Myiagra cyanoleuca*) occurs along the Great Dividing Range on the eastern and south-eastern seaboard of Australia from Cape York to Tasmania and south-eastern South Australia. The Satin Flycatcher undergoes a north-south migration throughout this range. It is a breeding summer migrant to the south-east and Tasmania. After breeding, Satin Flycatchers leave southern Australia in February – April. It winters in northern Queensland, New Guinea and the Bismarck Archipelago. The Satin Flycatcher inhabits wet and dry sclerophyll forests and tall woodlands in eastern Australia, particularly heavily vegetated gullies (Higgins *et al.* 2006). During migration, the Satin Flycatcher occurs across a wide range of wooded habitats including coastal forests, woodlands and mangroves.

The Rufous Fantail (*Rhipidura rufifrons*) nominate subspecies *R. r. rufifrons* occurs in south-eastern mainland Australia, from approximately Brisbane, through NSW and Victoria and across to the eastern side of the Adelaide Hills. This sub-species primarily breeds in forests within 300 kilometres of the coast and migrates northwards during non-breeding periods. The first birds arrive in Victoria in the third week of October and the last ones depart in the first week of April. Subspecies *R. r. intermedia* occurs along the north-eastern seaboard of Australia, from northern NSW to the Cape York Peninsula. It undertakes local movements and altitudinal migration as well as regular longer distance migration to the Trans Fly region of New Guinea. The Rufous Fantail occurs in moist, dense habitats, including mangroves, rainforest, riparian forests and thickets, and wet eucalypt forests with a dense shrubby understory in eastern Australia (Higgins *et al.* 2006). Rufous Fantail often inhabit often 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*). They also occur in subtropical and temperate rainforests.

The Spectacled Monarch (*Symposiachrus trivirgatus*) is an insectivore, taking insects across a range of forest strata. They are observed in dense vegetation, wet gullies, dense waterside vegetation, mainly in rainforest but also in moist forest or wet sclerophyll and occasionally in other dense vegetation such as mangroves, drier forest and woodlands. The nest is usually built in a vertical fork of a tree, sapling or shrub, and an association with water courses has been noted. The global population size has not been quantified, but the species is reported to be generally common. In Australia this species is considered secure across its range. Distribution is mainly limited to coastal eastern Australia. In NSW they are associated with coast and eastern slopes of Great Dividing Range to northern Hunter Region. Occasional records further south at sites around Newcastle, Central Coast and Sydney.

Upstream/Construction

The Black-faced Monarch is a common visitor in the study area. Despite supporting extensive areas of suitable habitat there are few records of this species in the Lake Burragorang area due to a lack of survey effort. There are 50 + records in similar habitat in the central Blue Mountains area where survey effort is greater. This species is likely to occur in most of the wetter forested areas in the impact area, particularly adjacent to the northern and south-eastern sections of Lake Burragorang.

The Satin Flycatcher is an uncommon visitor in the study area. Despite supporting extensive areas of suitable habitat there are few records of this species in the Lake Burragorang area due to a lack of survey effort. The Satin Flycatcher has only been recorded twice in the Warragamba Special Area (near the Burragorang Lookout in 2003 and near Silverdale in 1978) however there are numerous records in equivalent habitat in adjacent, more accessible parts of the Blue Mountains which have been subject to far greater survey effort. This species is likely to occur in most of the wetter forested areas in the impact area and may occur in any wooded area during migration.

The Rufous Fantail is a common visitor in the study area. Despite supporting extensive areas of suitable habitat there are relatively few records of this species across large portions of the Lake Burragorang area due to a lack of survey effort. There are 100 + records in similar habitat in the central Blue Mountains area where survey effort is far greater.

This species is likely to occur in most of the wetter forested areas in the impact area and may occur in any wooded area during migration.

The Spectacled Monarch is an uncommon visitor to the study area. There is some marginal habitat that may accommodate this species in the study area but as distribution is mainly limited to coastal habitats and occasionally further inland, north of the study area around Newcastle, there are no records on site. This species may occur in the wetter forested areas in the impact area and may occur in any wooded area during migration.

No targeted Black-faced Monarch, Satin Flycatcher, Rufous Fantail, Spectacled Monarch or surveys were conducted in the study area by SMEC.

The impact/study area may support important Black-faced Monarch, Satin Flycatcher, Rufous Fantail, or Spectacled Monarch habitat as the first of the following four important habitat criteria (Commonwealth of Australia 2013) may, or is likely to be met:

a) habitat utilised by a migratory species occasionally or periodically within a region that supports an ecologically significant proportion of the population of a species, and/or

   It is likely that the habitat in the impact area is occasionally or periodically utilised by the Black-faced Monarch, Satin Flycatcher, Rufous Fantail, and Spectacled Monarch. A total of 460 1700, 4800, and 650, individuals correspond to an ecologically significant proportion of the Black-faced Monarch's, Satin Flycatcher's, Rufous Fantail's, and Spectacled Monarch's population respectively at the national scale (Commonwealth of Australia 2015). It is likely that the region supports an ecologically significant proportion of the population of Black-faced Monarch, Satin Flycatcher, Rufous Fantail, and Spectacled Monarch considering the study area's position in an extensive forested landscape which is situated in a key northward-southwards migratory corridor.

b) habitat that is of critical importance to the species at particular life-cycle stages, and/or

   No habitat of critical importance to these species at particular life-cycle stages is likely to be present in the impact area.

c) habitat utilised by a migratory species which is at the limit of the species' range

   The study area is not at the geographic limit of any of these species' distributions.

d) habitat within an area where the species is declining.

   There is currently insufficient evidence to conclude whether these species are declining, stable or increasing in NSW. Similarly, their population trends at the national scale are also unknown.

Downstream

The Black-faced Monarch is an uncommon visitor in the study area. It has been recorded adjacent to the Hawkesbury-Nepean River near Wisemans Ferry, Pitt Town, Richmond Lowlands and Wallacia and may occur anywhere in suitable habitat in the study area particularly during migration.

The Satin Flycatcher is an uncommon/rare visitor in the study area. It has been recorded at very few locations in the study area during the past two decades but may occur in suitable habitat anywhere along the Hawkesbury-Nepean River particularly during migration.

The Rufous Fantail is an uncommon visitor in the study area. It has been occasionally recorded in the study area along the Hawkesbury-Nepean River between Warragamba Dam and Wisemans Ferry. It may occur anywhere in suitable habitat in the study area particularly during migration.

The Spectacled Monarch is an uncommon visitor to the study area. There is some habitat that may accommodate this species, although southerly distribution is mainly limited to north of the study area around Newcastle and occasionally south towards Sydney. There are no records on site, and one ~20 kilometres away, near Mount Tomah. This species may occur in the wetter forested areas and may occur in any wooded area during migration.

No targeted Black-faced Monarch, Satin Flycatcher, Rufous Fantail, Spectacled Monarch or Yellow Wagtail surveys were conducted in the study area by SMEC.

The site is unlikely to support important Black-faced Monarch, Satin Flycatcher, Rufous Fantail or Spectacled Monarch habitat as none of the following four important habitat criteria are likely to be met:

a) habitat utilised by a migratory species occasionally or periodically within a region that supports an ecologically significant proportion of the population of a species, and/or

A total of 460 1700 and 4800, and 650 individuals correspond to an ecologically significant proportion of the Black-faced Monarch's, Satin Flycatcher's, Rufous Fantail's, and Spectacled Monarch's population respectively at the national scale (Commonwealth of Australia 2015). It is unlikely that the study area supports enough habitat to be occasionally or periodically utilised by these species in a region supports an ecologically significant proportion of the population of Black-faced Monarch, Satin Flycatcher, Rufous Fantail, and Spectacled Monarchs considering the habitat type and extent in this region. It is possible or probable that an ecologically significant proportion of the population of each of these species migrate through the region but due to the extent and type of habitat it is unlikely that habitat in this area supports ecologically significant proportions of the population of each of these species.

b) habitat that is of critical importance to the species at particular life-cycle stages, and/or

No habitat of critical importance to these species at particular life-cycle stages is present in the impact area.

c) habitat utilised by a migratory species which is at the limit of the species' range

The study area is not at the geographic limit of any of these species' distributions.

d) habitat within an area where the species is declining

There is currently insufficient evidence to conclude whether these species are declining, stable or increasing in NSW. Similarly, their population trends at the national scale are also unknown.

Assessment of significance: Black-faced Monarch (Monarcha melanopsis), Satin Flycatcher (Myiagra cyanoleuca), Rufous Fantail (Rhipidura rufifrons), and Spectacled Monarch (Symposiachrus trivirgatus)

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**

Upstream/Construction

The Project is likely to substantially modify or destroy approximate areas of suitable or potential habitat listed in the table below. As discussed above these areas may or are likely to constitute important habitat.

According to the draft referral guidelines for 14 birds listed migratory under the EPBC Act (Commonwealth of Australia 2015) 'actions which constitute substantial loss or modification of important habitat and therefore a likely significant impact are those actions that are likely to meet or exceed the upper thresholds (1%)' identified in table below. Extent of habitat loss because of the inundation of the impact area is unlikely to reach or exceed the upper thresholds for any of these migratory species. However, the important habitat area thresholds for the assessed species which are considered nationally significant are likely to be breached as a result of the inundation of the impact area.

The size of areas of important habitat likely to result in a significant impact if affected (Commonwealth of Australia 2015). The following habitat area thresholds apply with the upper figure (1%) representing areas of international significance, the lower figures (0.1%) national significance.

Species	Area thresholds (ha)[1]		Area impacted (ha)[1]
	1%	**0.1%**	
Black-faced Monarch	2,600	260	1,637
Satin Flycatcher	4,400	440	5,671
Rufous Fantail (southern)	2,600	260	1,637
Spectacled Monarch	2,100	210	5,671

* No threshold area can be determined at this time or has identified given lack of knowledge or rarity.

The Project is likely to substantially modify and destroy an area of important habitat in accordance with the assessment criteria followed throughout this document (that is, the significant impact criteria outlined in the significance impact guidelines 1.1 – matters of national environmental significance (Commonwealth of Australia 2013)) but not in accordance with the criteria presented in the draft referral guidelines for 14 birds listed migratory under the EPBC Act (Commonwealth of Australia 2015).

Downstream

The Project is likely to substantially modify or destroy approximate areas of suitable or potential habitat listed in the table below. Given the nature of the predicted impact of the Project (that is, the alteration of the Nepean-Hawkesbury River flow regime downstream of Warragamba Dam) it is unlikely that the proposed action will substantially modify (including by fragmenting, altering fire regimes, altering nutrient cycles or altering hydrological cycles), destroy or isolate an area of important habitat. No important habitat is likely to be present in the study area given none of the four important habitat criteria are likely to be met.

The size of areas of important habitat likely to result in a significant impact if affected (Commonwealth of Australia 2015). The following habitat area thresholds apply with the upper figure (1%) representing areas of international significance, the lower figures (0.1%) national significance

Species	Area thresholds (ha)[1]		Area impacted (ha)[1]
	1%	**0.1%**	
Black-faced Monarch	2,600	260	3,548
Satin Flycatcher	4,400	440	11,207
Rufous Fantail	7,500	750	3,548
Spectacled Monarch	2,100	210	11,207

* No threshold area can be determined at this time or has identified given lack of knowledge or rarity.

- **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**

Upstream/Construction

The Project is unlikely to introduce an invasive species that is harmful to Black-faced Monarch, Satin Flycatcher, Rufous Fantail or Spectacled Monarch (that is, Black rat (*Rattus rattus*) and invasive vines (Commonwealth of Australia 2015)) becoming established in an area of important Black-faced Monarch, Satin Flycatcher, Rufous Fantail and Spectacled Monarch habitat.

Downstream

The Project is unlikely to introduce an invasive species that is harmful to Black-faced Monarch, Satin Flycatcher, Rufous Fantail or Spectacled Monarch (that is, Black rat (*Rattus rattus*) and invasive vines (Commonwealth of Australia 2015)) becoming established in an area of important Black-faced Monarch, Satin Flycatcher, Rufous Fantail or Spectacled Monarch habitat.

- **seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.**

Upstream/Construction

The Project is unlikely to, but may seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the Black-faced Monarch, Satin Flycatcher, Rufous Fantail's, and Spectacled Monarch population given that:

a) an ecologically significant proportion of each species' population may be negatively impacted by loss of important habitat though this may not translate to a serious disruption to the breeding, feeding, migration or resting behaviour of an ecologically significant proportion of each species population.

Downstream

The Project is unlikely to disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the Black-faced Monarch, Satin Flycatcher, Rufous Fantail's or Spectacled Monarch's or population given that:

a) an ecologically significant proportion of each species' population is unlikely to utilise the impact area
b) due to the nature of the likely impact of the Project, it is unlikely that any suitable habitat present in the impact area will be degraded or lost.

Conclusion
Upstream/Construction The Project is unlikely to be have a significant impact on the Black-faced Monarch, Satin Flycatcher, Rufous Fantail, or Spectacled Monarch. **Downstream** The Project is unlikely to have a significant impact on the Black-faced Monarch, Satin Flycatcher, Rufous Fantail, or Spectacled Monarch.

Tringa nebularia (Common Greenshank), *Gallinago hardwickii* (Latham's Snipe)

Migratory under the EPBC Act

The two wetland bird species assessed below are listed as migratory under the EPBC Act 1999 and have large non-breeding area distributions which encompass large parts of coastal, near-coastal and/or inland Australia. These shorebird species have been recorded either regularly, occasionally or rarely in the vicinity of lagoons and wetlands on the Hawkesbury-Nepean River floodplain in the Richmond/Windsor/Pitt Town/Wilberforce area. Bushells Lagoon, Bakers Lagoon and Pitt Town Lagoon provide the highest quality foraging habitat for these species in the study area and the broader north-west Sydney region.

These two wetland bird species face threats in their breeding range in the Northern Hemisphere, along their migration pathway, the East Asian-Australasian Flyway (EAAF), which spans 23 countries, and in their foraging habitat and roosting sites in Australia. Threats to these wetland birds include habitat loss and degradation at staging areas in East Asia through land reclamation and other factors (Murray *et al.* 2014, Piersma *et al.* 2016), hunting in East Asia, disturbance and habitat degradation in their non-breeding habitat (that is, from recreational activities such as fishing, boating, walking dogs, night lighting) (Priest *et al.* 2002, Glover *et al.* 2011), and global warming (Wauchope *et al.* 2016).

'Coastal freshwater lagoons of the Sydney Basin Bioregion and South East Corner Bioregion' (PCT781) is the only associated habitat mapped in the study area. 1,107 hectares of this PCT is mapped downstream, 50 hectares of which will be impacted by the Project. There is likely significantly more appropriate habitat within the study area, but impacted area is difficult to calculate in this circumstance as not all area within a 'forested wetland' is appropriate wetland habitat.

Assessing the impact of the Project on these wetland bird species and the 1350+ hectares, of suitable habitat located in the impact area is difficult given:

- The sensitivity of each species to a reduction in flows in the Hawkesbury-Nepean River is largely unknown. This is partly because the degree to which habitat condition at key sites (for example, Pitt Town Lagoon, Bakers Lagoon, Bushells Lagoon) relies on upstream flows (as opposed to local rainfall) during flood events to is not well understood. However, it is likely that given their preference for shallow water and exposed mudbanks these wetland birds may be less vulnerable to reductions in flows to key lagoons than other waterbirds. Indeed, a reduction in flows in the Hawkesbury-Nepean River may enhance the habitat quality of certain wetlands in the impact area such as Pitt Town Lagoon (Pressey 1979) whilst potentially reducing the quality of others depending on the physical nature (that is, factors such as depth, shape, extent, proximity to the Hawkesbury-Nepean River) of individual wetlands.
- The magnitude, frequency and duration of potential environmental flow releases post-development is unknown.

Common Greenshank

The Common Greenshank occurs in a wide variety of inland wetlands and sheltered coastal habitats of varying salinity. In sheltered coastal habitats, they typically forage at sites containing mudflats, saltmarsh, mangroves or seagrass (Higgins and Davies 1996). Inland habitat types utilised include permanent and ephemeral terrestrial wetlands, including swamps, lakes, dams, rivers, creeks, billabongs, waterholes, inundated floodplains and claypans. The Common Greenshank's EAAF population is estimated to comprise 110,000 individuals. This species is an occasional visitor (September – February) in the study area which is irregularly recorded at the major wetlands and lagoons in the study area such as Pitt Town Lagoon, Bushells Lagoon and Bakers Lagoon. Notable observations of Common Greenshank include a flock of 10 at Pitt Town Lagoon in 1958.

This species was assessed as having a moderate likelihood of occurrence in the upstream study area.

Latham's Snipe

The Latham's Snipe occurs in permanent and ephemeral wetlands up to 2,000 m above sea-level. It prefers open, freshwater wetlands with low, dense vegetation (for example, swamps, flooded grasslands or heathlands, around bogs and other water bodies) but also occasionally inhabit saline or brackish water, in modified or artificial habitats (Higgins and Davies 1996). The Latham's Snipe's EAAF population is estimated to comprise 35,000 individuals (Hansen *et al.* 2016). The Latham's Snipe is a regular though uncommon visitor (September – March) to the lagoons and wetlands of the Hawkesbury-Nepean River floodplain between Sackville and Penrith Lakes. Pitt Town Lagoon is the key site for Latham's Snipe in the study area where it is regularly recorded each non-breeding season. The Latham's

Snipe has also been recorded at Little Wheeny Lagoon (2005-2010 2012-2015), Wheeny Lagoon (2002 2004 2005), Fernleigh's Lagoon (2003 2004), Penrith Lakes (2012 2014), Richmond Lowlands (2017), Sackville (2015 2017 2018), Longneck Lagoon (1949 1977 1980 1982 1983 1998 1999 2003 2011), Yaramundi Lagoon (2002-2004), Pugh's Lagoon (1998 2013 2017), McGrath's Hill STP (1983 1984 1986 1998-2003 2015), Bakers Lagoon (1980 1982 1987 1988), Bushells Lagoon (2013 2017 2018) and Wilberforce Lagoon (2013). Notable observations in the study area include aggregations of 40 individuals at Pitt Town Lagoon in 2004, 30 at Longneck Lagoon in 1980 29 at Pitt Town Lagoon in 1982 and 20 at Pitt Town Lagoon in 2006.

This species was assessed as having a high likelihood of occurrence in the upstream and downstream study areas.

Important wetland bird habitat and ecologically significant proportions of wetland bird populations

The number of individual birds that corresponds to an ecologically significant proportion (0.1%) of the total population of each of the four shorebirds included in this assessment in accordance with the latest population estimates (Hansen *et al.* 2016) is as follows:

- Common Greenshank: 110
- Latham's Snipe: 18 (Hansen *et al.* 2016).

Existing records of these species in the study area suggest that only the Latham's Snipe is likely to occur in nationally significant numbers in the study area.

Habitat for migratory wetland birds listed under the EPBC Act 1999 is considered internationally important according to the EPBC Act Policy Statement 3.21 (Commonwealth of Australia 2017) if it regularly supports:

- one percent of the individuals in a population of one species or subspecies of waterbird or

  Available data suggest that the study area does not regularly support 1% of any of the four shorebirds' populations.

- a total abundance of at least 20 000 waterbirds.

  Available data suggest that the study area does not regularly support at least 20,000 waterbirds.

Habitat for migratory wetland birds listed under the EPBC Act 1999 is considered nationally important according to the EPBC Act Policy Statement 3.21 (Commonwealth of Australia 2017) if it regularly supports:

- 0.1 percent of the flyway population of a single species of migratory wetland bird, barring Latham's Snipe, for which it is 0.05% or

  Available data suggest that at times the study area supports an ecologically significant proportion of the Latham's Snipe's (18 individuals). The highest count of Latham's Snipe at a particular location at any given time in the study area (40 individuals) corresponds to more than double the significant proportion of a population threshold at the national scale. It is likely that Pitt Town Lagoon or other similar wetlands in the study area occasionally support more than 18 individuals. Furthermore, it is likely that at certain times small groups of Latham's Snipe are simultaneously foraging or roosting at several locations in the study area.

  It is known that an ecologically significant proportion of the population Latham's Snipe do occur in the study area but whether this corresponds to regular use depends on one's definition of 'regularly'. In the case of this assessment, it is assumed that these species do regularly occur in the study area in significant numbers given the lack of systematic survey data and in light of the flock sizes of these species that have been recorded at specific wetland sites within the study area (which encompasses multiple wetlands).

- 2,000 migratory wetland birds:

  Available data suggest that the study area does not regularly support 2,000 migratory wetland birds.

- 14 migratory wetland bird species

  Available data suggest that the study area does not regularly support 14 migratory wetland bird species.

Assessment of significance assessed against the migratory species significant impact criteria for Common Greenshank (Tringa nebularia)

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**
About 1,110 hectares of known suitable or potential habitat is located in the upstream study area. The Project is unlikely to substantially modify (including by fragmenting, altering fire regimes, altering nutrient cycles or altering hydrological cycles), destroy or isolate an area of important Common Greenshank habitat.
• **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**
The Project is unlikely to result in an invasive species that is harmful to the Common Greenshank, or becoming established in an area of important Common Greenshank. Introduced predators which may pose a risk to these wetland birds such as Red Fox and Feral Cat are currently present in the upstream study area.
• **seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.**
The Project is unlikely to disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of Common Greenshank as the upstream study area does not support an ecologically significant proportion of any of these species.
Conclusion
The Project is unlikely to have a significant impact on the Common Greenshank.

Assessment of significance assessed against the migratory species significant impact criteria: Latham's Snipe (Gallinago hardwickii)

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**
About 1,110 hectares of known suitable or potential habitat occurs in the Project study area of which about 50 hectares is located in the impact area. There is likely significantly more appropriate habitat within the study area, but impacted area is difficult to calculate in this circumstance as not all area within a 'forested wetland' is appropriate wetland habitat. An ecologically significant proportion of the population of Latham's Snipe is known to utilise the study area. hence habitat in this area constitutes important habitat.   Given its preference for shallow wetlands, the Latham's Snipe may be less vulnerable to reductions in flows to key lagoons than other waterbirds. Indeed, a reduction in flows in the Hawkesbury-Nepean River may enhance the habitat quality of certain wetlands in the impact area such as Pitt Town Lagoon (Pressey 1979) whilst potentially reducing the quality of others depending on the physical nature (that is, factors such as depth, shape, extent, proximity to the Hawkesbury-Nepean River) of individual wetlands.   Nevertheless, the Project could substantially modify an area of important Latham's Snipe.

• 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
The Project is considered unlikely to result in an invasive species that would be harmful to Latham's Snipe becoming established in an area of important Latham's Snipe habitat. Introduced predators which may pose a risk to these shorebirds such as Red Fox and Feral Cat are currently present in the Project study area.
• seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.
The Project is considered unlikely to seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of Latham's Snipe given the impacts associated with the Project are unlikely to degrade the habitat to the point that it could seriously disrupt the foraging or resting behaviour of Latham's Snipe.
Conclusion
The Project could have a negative impact on Latham's Snipe, however, this is considered unlikely to correspond to a significant adverse impact. The Project is unlikely to have a significant impact on Latham's Snipe.

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