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Environmental Impact Statement – Chapter 12: Matters of national environmental significance - Biodiversity

Warragamba Dam Raising

Reference No. 30012078
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On 17 July 2017, the delegate of the Commonwealth Minister for the Environment determined that the Warragamba Dam Raising Project was a controlled action requiring approval under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The advice provided to DPIE, and included as Attachment A to the Secretary's Environmental Assessment Requirements (SEARs), form the guidelines for preparing the assessment documentation relevant to the EPBC Act for assessment under the NSW Assessment Bilateral.

Attachment A to the SEARs identifies the matters of national environmental significance (MNES) protected under the EPBC Act that have been triggered for assessment, and which are referred to as 'the controlling provisions'. Proponents are only required to assess Protected Matters under the controlling provisions that have been triggered. Attachment A to the SEARs identifies the following controlling provisions:

- World Heritage properties (sections 12 and 12A)
- national heritage places (sections 15B and 15C)
- listed threatened species and communities (sections 18 and 18A).

This chapter provides an assessment of the potential impacts of the Project on MNES related to listed threatened species and communities, and to migratory species.

The SEARs relevant to MNES are identified in Table 12-1 and Table 12-2, together with where they have been addressed, either in this chapter or elsewhere in the EIS documentation.

Consideration of MNES related to World Heritage is provided in Chapter 20 (Protected and sensitive lands) and Appendix J (World Heritage assessment report), and for natural heritage places in Chapter 17 (Heritage – non-Aboriginal) and Chapter 20 (Protected and sensitive lands).

Table 12-1. 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.	Chapter 12 Appendix F5
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).	Chapters 8,9,10,11,12 Appendices F1, F2, F3, F4, F5
13 Protected and Sensitive Lands The project is designed, constructed and operated to avoid or minimise impacts on protected and sensitive lands.	13.1 The Proponent must assess the impacts of the project on the water catchment and processes (and the impact of processes on the project) including, but not limited to: (d) land or waters identified as Critical Habitat under the TSC Act, FM Act or EPBC Act;	Chapters 8,9,10,11,12 Appendices F1, F2, F3, F4, F5

1. This chapter specifically addresses SEARs requirements 1, 6, and 13 as well as SEARs Attachment A, in addition to those general requirements of the SEARs applicable to all chapters and as identified as such in Chapter 1 (Section 1.5, Table 1-1).

Table 12-2. SEARs Attachment A requirements for biodiversity-related MNES

Requirement[1]	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).	Chapter 12 Appendix F5
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).	Chapter 12 Appendix F5
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.	Chapter 12 Appendices F1, F2, F3, F4, F5
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.	Section 12.2
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.	Chapter 12 Appendices F1, F2, F3, F4 F5
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:	Appendices F1, F2, F3, F4, F5

Requirement[1]	Where addressed
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.	
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 12.13.2 Chapter 13 Appendix F6
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.	Appendices F1, F2, F3, F4, F5
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.	Appendices F1, F2, F3, F4, F5
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 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 c. description of the relevant impacts of the action having regard to the full national extent of the species or community's range d. description of the specific proposed avoidance and mitigation measures to deal with relevant impacts of the action e. identification of significant residual adverse impacts likely to occur after the proposed activities to avoid and mitigate all impacts are taken into account f. a description of any offsets proposed to address residual adverse significant impacts and how these offsets will be established	Appendices F1, F2, F3, F4, F5

Requirement[1]	Where addressed
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 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.	
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.	Appendix F6

1. This chapter specifically addresses SEARs requirements 1, 6, and 13 as well as SEARs Attachment A, in addition to those general requirements of the SEARs applicable to all chapters and as identified as such in Chapter 1 (Section 1.5, Table 1-1).

The assessment of potential impacts to biodiversity-related MNES is supported by various detailed investigations. These are documented in Appendix F1 (Biodiversity assessment report - upstream), Appendix F2 (Downstream ecological assessment), Appendix F3 (Biodiversity assessment report – construction area), Appendix F4 (Aquatic ecology assessment report) and Appendix F5 (Matters of national environmental significance – biodiversity).

The proposed management and mitigation measures in this section are collated in Chapter 29 (EIS synthesis, Project justification and conclusion).

12.1 Project and study area

12.1.1 Project description

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 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 comprise 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 flood mitigation zone (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.

Normal operation

Normal operations would apply when the reservoir level is at or lower than the full supply level (FSL), which is when the water level in the dam is at or below 116.7 mAHD.

Flood operation

Operational objectives 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.

Flood operations would apply when the water level is higher than the FSL. The raised dam would provide capacity (i.e. the FMZ) to capture temporarily around 1,000 gigalitres of water during a flood event. For larger floods the FMZ would be filled and uncontrolled discharge would occur over the central spillway and, potentially, the auxiliary spillway of the dam.

12.1.2 Project location and study area

The Project location and general study area are shown on Figure 12-1. Warragamba Dam is located approximately 65 kilometres west of Sydney in a narrow gorge on the lower section of the Warragamba River, 3.3 kilometres before it joins the Nepean River. The township of Warragamba is located approximately one kilometre east of the dam wall. The upstream environment includes the reservoir formed by Warragamba Dam (Lake Burragorang) and its tributaries,. The downstream environment includes a short section of the Warragamba River, the Hawkesbury-Nepean River and its floodplain, and some of the tributaries of the Hawkesbury-Nepean River (such as South Creek) that experience backwater flooding effects.

The extent of the study area for the Protected Matters relating to the MNES assessment for the Project was determined in consultation with the former Department of the Environment and Energy[1] (DoEE) and the former Office of Environment and Heritage (OEH, now part of DPIE).

- The **upstream study area** (i.e. upstream of Warragamba Dam) is defined as the area above FSL and the Probable Maximum Flood[2] (PMF) for the Project. Within this area, the agreed **survey area** comprised the area within the 1 in 100 chance in a year flood event with the Project (incorporating a nine percent climate change flood scenario).
- The **downstream study area** (i.e. downstream of Warragamba Dam) is defined as the area within the existing PMF from Warragamba Dam to the confluence of the Colo River and Hawkesbury River. Within this area, the agreed **survey area** comprised the area within the existing 1 in 10 chance in a year flood extent from

[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.

Warragamba Dam to the confluence of the Colo River and Hawkesbury River (being the area most likely to be affected by the Project).

- The **construction study area** comprises the area at and immediately around the dam where construction activities would occur.

12.1.3 Upstream impact area

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 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 MNES.

A review of the historical record identified at least one large flood above FSL would likely 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 records. This was then analysed by selecting the maximum inundation level in 20-year periods to determine the 'average' or likely inundation level. 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:

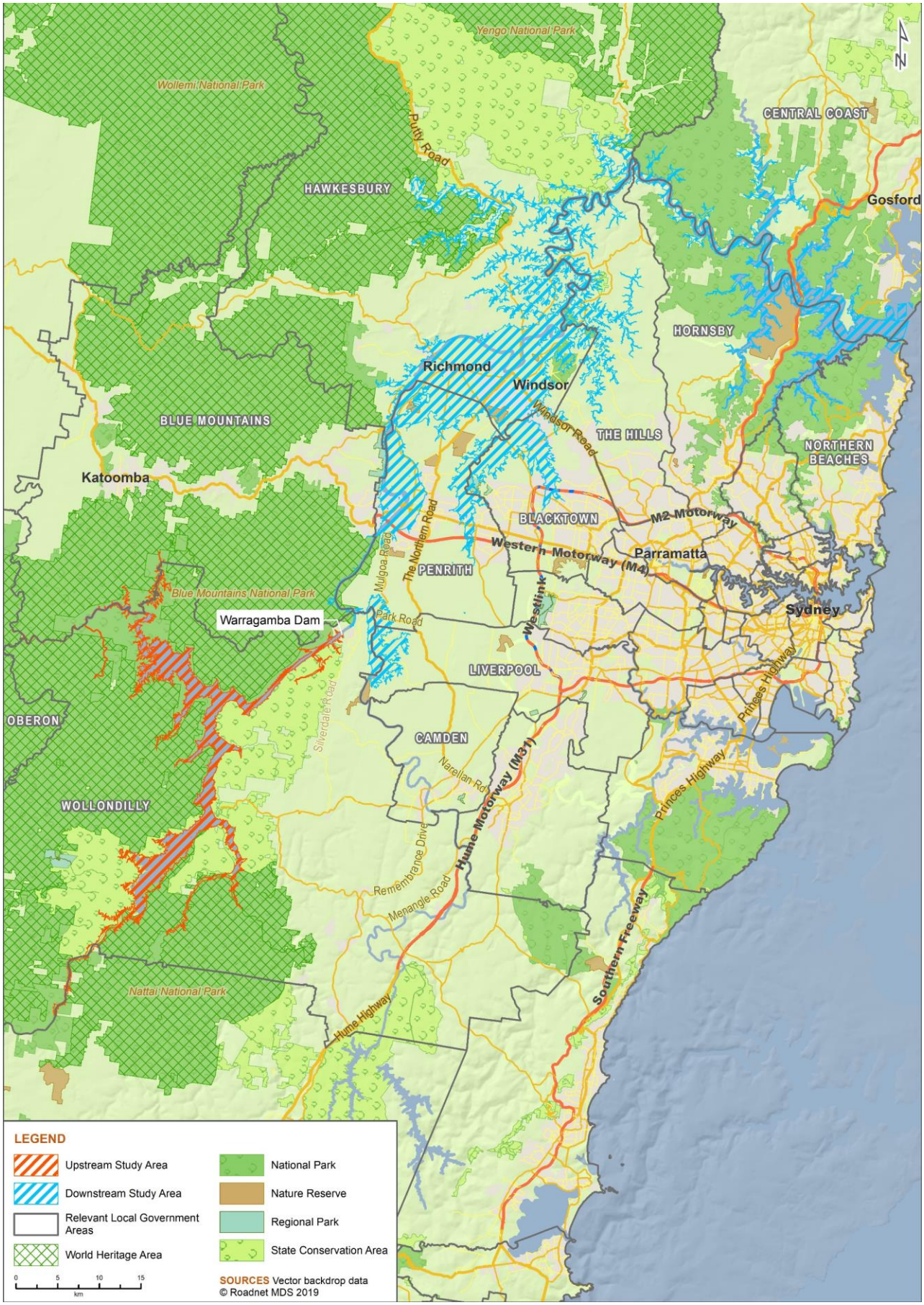
- Lower extent: 2.78 metres above FSL (119.5 mAHD)
- Upper extent: 10.25 metres above FSL (126.97 mAHD).

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.

Changes in duration of temporary inundation in the upstream impact area would be similar to Lake Burragorang, which is estimated to be 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 biodiversity 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.

Figure 12-1. Project location and study area



12.2 Legislative and policy context

12.2.1 Environment Protection and Biodiversity Conservation Act 1999

The Project is a controlled action (ref 2017/7940) because it has the potential to impact on MNES, and as such requires assessment under the 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.

12.2.2 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.

12.2.3 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 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 **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 **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.

12.2.4 Environment Protection and Biodiversity Conservation Act 1999 Environmental Offsets Policy

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 DAWE 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'* (DSEWPaC 2012, p8).

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.

12.3 Methodology

The biodiversity assessments for the upstream, construction and downstream study areas were prepared in accordance with the SEARs. 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), Appendix F4 (Aquatic ecology assessment report) and Appendix F5 (Matters

of national environmental significance – biodiversity/world heritage). 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).

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, and reviews 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 definition of the Project study area is described in Section 12.1.2.

12.4 Existing environment

12.4.1 Environmental context

12.4.1.1 Upstream catchment

The upstream catchment area comprises about 9,050 square kilometres (WaterNSW 2018b) and encompasses the five main tributaries that drain into Lake Burragorang. These are the Coxs, Kowmung, Wollondilly, Nattai, and Kedumba Rivers. 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.

Land use in the upstream catchment comprises protected areas, including the Greater Blue Mountains World Heritage Area (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.

Warragamba Dam is situated in a steep, narrow gorge. The dam reservoir, Lake Burragorang, is 52 kilometres long, has 354 kilometres of foreshore and covers a waterway area of approximately 75 square kilometres. Flooding in the upstream catchment is characterised by backwater inundation with inflows building on the upstream side of the dam wall. The water level builds until the outflow exceeds the inflow, at which time the water level recedes to the FSL.

The extent and duration of inundation is dependent upon the magnitude of the flood producing rainfall event and the dam release rate. 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 the lake. Water levels in Lake Burragorang remain elevated for a period of approximately three to five days depending on the size of the event. Although lake levels remain elevated for a period of days, the period of inundation for specific locations will vary depending on their location in the catchment.

12.4.1.2 Downstream catchment

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

The topography downstream from Warragamba Dam consists of floodplains, undulating valleys and 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.

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.

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 approximately 80 percent of the catchment at Penrith and 70 percent of the catchment at Windsor (INSW 2017). While floods can occur without contribution from the Warragamba catchment, larger floods (above the 1 in 100 chance in a year flood event) 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.

12.4.1.3 Construction area

The construction area covers an area of about 105 hectares and includes:

- native vegetation, which covers approximately 55 hectares (53 percent) of the construction area
- the existing dam wall, and the areas in and around the existing Warragamba Dam face and abutment structures
- auxiliary access roads, associated operational buildings, and landscaped areas.

Most of the existing dam infrastructure is located on the south side of the river on a relatively flat area at an elevation of around 150 metres AHD (Australian Height Datum). The land gently slopes north towards the Warragamba River embankment, where it drops steeply to the river to about 45 metres AHD. The northern side of the river is relatively undeveloped with an upper elevation of around 195 metres AHD and a gradual slope to the river embankment.

12.4.2 Database records

EPBC Act listed TECs, flora species and fauna species potentially occurring in the Project study area are listed in Table 12-3, Table 12-4 and Table 12-5 respectively.

Table 12-3. 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

Ecological community EPBC Act alignment	EPBC Act status	Potential location
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 nominated for listing as a threatened ecological community in 2017 with the proposed conservation status of 'endangered'. At the time of preparation of the EIS, this community was not listed under the EPBC Act.		

Table 12-4. 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

Scientific name	Common name	EPBC Act status
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
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

Scientific name	Common name	EPBC Act status
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
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

Scientific name	Common name	EPBC Act status
Zieria murphyi	Velvet Zieria	Vulnerable

Table 12-5. 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
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

Scientific name	Common name	EPBC Act status
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

12.4.3 Native vegetation and plant communities

12.4.3.1 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 (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*, *Eucalyptus eugenioides*, *Eucalyptus 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 *Eucalyptus punctata*, *Eucalyptus tereticornis*, *Eucalyptus glaucina*, *Eucalyptus eugenioides*, *Eucalyptus fibrosa*, and *Eucalyptus crebra*
- vegetation within drainage lines consists of tall wet forest dominated by *Eucalyptus 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 *Eucalyptus melliodora*, *Eucalyptus tereticornis*, *Eucalyptus glaucina*, *Eucalyptus albens-moluccana intergrade*, and *Brachychiton populneus*. This vegetation conforms to White Box Yellow Box Blakely's Red Gum Woodland CEEC
- forested wetlands dominated by *Eucalyptus deanei*, *Eucalyptus elata*, *Eucalyptus 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 *Backhousia myrtifolia* are present along the Coxs River and Kowmung River. The dry sclerophyll forest within this area is dominated by *Eucalyptus crebra*, *Eucalyptus tereticornis*, Eucalyptus *punctata*, and various stringybark species.

Vegetation within the upstream study area is aligned with 18 PCTs. These are described and mapped in Appendix F1 (Biodiversity assessment report - upstream) and summarised in Table 12-6.

Table 12-6. PCTs within the upstream study area

PCT code/ BVT[1] code	PCT name	Area (ha)	
		Study area	Impact area
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 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).

12.4.3.2 Construction area

Native vegetation covers approximately 52 percent (55 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.

Vegetation is typical of ridgetops on skeletal soils and the area supports dry sclerophyll forest of shrubby sub-formation, as well as a smaller area of wet sclerophyll forest. Vegetation is dominated by species characteristic of ridgetop woodlands around the Sydney Basin, including *Angophora costata*, *Eucalyptus piperita*, *Eucalyptus eugenioides*, *Eucalyptus 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 *Eucalyptus pilularis*, *Syncarpia glomulifera*, *Eucalyptus punctata* and *Angophora costata*. This vegetation conforms to the Shale/Sandstone Transition Forest CEEC.

Vegetation within the construction study area is aligned with four PCTs. These are described and mapped in Appendix F3 (Biodiversity assessment report - construction) and summarised in Table 12-7.

Table 12-7. 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)

12.4.3.3 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 *Eucalyptus 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.

Flora species assessed in the downstream biodiversity assessment are presented in Appendix F2 (Biodiversity assessment report - downstream). 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.

Vegetation within the downstream study area is aligned with 24 PCTs. These are described and mapped in Appendix F2 (Biodiversity assessment report - downstream) and summarised in Table 12-8.

Table 12-8. PCTs within the downstream study area boundary and the existing 1 in 10 chance in a year flood extent

PCT code/ BVT [1]code	PCT name	Commonwealth-listed TEC and status	Area (ha)	
			1 in 10 chance in a year	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	*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 (ha)	
			1 in 10 chance in a year	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, 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

1. Biometric vegetation type

12.4.4 Fauna habitats

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 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.

12.4.4.1 Upstream

Fauna habitats recorded in the upstream study area are described in Table 12-9.

Table 12-9. 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 (*Eucalyptus 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.
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).
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. 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.
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

Fauna habitat	Description
	historical logging. This vegetation provides suitable nesting, roosting and foraging habitat for threatened woodland birds and forging habitat for microchiropteran bats.
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*).
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 broader vegetation area of approximately 200,000 hectares 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).

12.4.4.2 Construction area

Fauna habitats 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 12-10.

Table 12-10. 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.

12.4.4.3 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 12-11.

Table 12-11. 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*). ▪ 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

Fauna habitat	Description
	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 (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*).

12.4.5 Threatened species

12.4.5.1 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 and candidate species credit species recorded or assumed to occur within the upstream and construction study areas are listed in Table 12-12 and Table 12-13 respectively.

Table 12-12. Ecosystem credit species recorded or assumed to occur within the upstream and construction 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

Table 12-13. Species credit species recorded or assumed to occur within the upstream and construction 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*
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

Scientific name	Common name	EPBC Act status	Study area[1]
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
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
* Observed during field surveys for the Project.

12.4.5.2 Downstream

Threatened fauna species identified in the downstream study area are listed in Table 12-14.

Table 12-14. Threatened flora identified 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
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

Scientific name	Common name	Habitat and distribution	EPBC Act status
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, 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.	Vulnerable

Threatened fauna species identified in the downstream study area are listed in Table 12-15.

Table 12-15. Threatened fauna identified in 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

Scientific name	Common name	Location	EPBC Act status
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

12.4.5.3 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[3] noted that populations of *Posidonia australis* are found in Port Hacking, Botany Bay, 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 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.

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

Table 12-16 provides a summary of potential threatened species occurring in the study area, with descriptions provided for the species that are known or likely to occur – Macquarie Perch (*Macquaria australasica*), Australia Grayling (*Prototroctes maraena*) and Black Rockcod (*Epinephelus daemelii*).

Table 12-16. Threatened fish species known or possibly occurring in the Hawkesbury-Nepean catchment

Species name	Common name	EPBC Act status[1]	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 metres above sea level, mostly commonly at 100-175 metres 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)
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).

1 E: Endangered, V: Vulnerable.

12.4.6 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.

12.4.6.1 Upstream

EPBC Act listed TECs associated with PCTs identified in the upstream study area, including a summary of the key diagnostic characteristics that were relied upon as justification for the TEC's presence, are detailed in Table 12-17. Detailed analysis and maps are provided in Appendix F1 (Biodiversity assessment report – upstream).

Table 12-17. 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	PCT 840 HN527 PCT 1401	142.16	1,447.73	▪ Grassy woodland dominated by *Eucalyptus albens – moluccana intergrade* and *E. melliodora*

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	
Native Grassland (Critically Endangered)	HN557			▪ 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 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.

12.4.6.2 Construction area

EPBC Act listed TECs associated with PCTs identified in the construction study area, including a summary of the key diagnostic characteristics that were relied upon as justification for the TEC's presence, are detailed in Table 12-18. Detailed analysis and maps are provided in Appendix F1 (Biodiversity assessment report – construction).

Table 12-18. 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

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
				▪ 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.

12.4.6.3 Downstream

EPBC Act listed TECs associated with PCTs identified in the downstream study area, including a summary of the key diagnostic characteristics that were relied upon as justification for the TEC's presence, are detailed in Table 12-19. Detailed analysis and maps are provided in Appendix F1 (Biodiversity assessment report – downstream).

Table 12-19. EPBC Act listed TECs associated with PCTs - downstream study area

Federally listed TEC and status	PCT	Existing 1 in 10 chance in a year (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 ▪ 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

Federally listed TEC and status	PCT	Existing 1 in 10 chance in a year (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.
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 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

Federally listed TEC and status	PCT	Existing 1 in 10 chance in a year (ha)	Study area (ha)	Summary of the key diagnostic characteristics present in vegetation in the study area
				▪ 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 ▪ Occurrences 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 ▪ 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.

12.4.7 Groundwater dependent ecosystems

12.4.7.1 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 (Biodiversity assessment report - upstream) and summarised in Table 12-20.

Table 12-20. 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[1]	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

Vegetation type	GDE classification summary
Megalong-Tonalli Sandstone Forest	High GDE for most areas
Riparian Acacia Shrub/Grass/Herb Forest: *Casuarina cunninghamiana*	High GDE for all areas
Riverbank Forest[1]	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[1]	Low to Moderate GDE

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

12.4.7.2 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 12-21.

Table 12-21. Groundwater dependent ecosystems – construction area

Vegetation type	GDE classification summary
Coastal Sandstone Ridgetop Woodland	Low to moderate potential GDE
Cumberland River Flat Forest[1]	High potential GDE
Hinterland Sandstone Gully Forest	High potential GDE
Sydney Hinterland Transition Woodland	High potential GDE

1 Components of this GDE may meet the listing advice for EPBC Act TECs

12.4.7.3 Downstream

Two of the thirteen groundwater management areas (GWMAs) identified in the State of the Catchments 2010 report for the Hawkesbury-Nepean region[4] 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*

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

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 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.

12.4.8 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 including the Protected Matters Search Tool (DoEE 2015). This section summarises the number of migratory species identified as potentially occurring within the upstream, construction and downstream study areas.

12.4.8.1 Upstream

The EPBC Protected Matters Search Tool (DoEE 2015) 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.

12.4.8.2 Construction area

The EPBC Protected Matters Search Tool (DoEE 2015) 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.

12.4.8.3 Downstream

The EPBC Protected Matters Search Tool (DoEE 2015) 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).

12.5 Likelihood of occurrence

12.5.1 Introduction

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 12-22 provides definitions of likelihood of occurrence for the TECs listed in Table 12-23, threatened species listed in Table 12-24 and migratory species listed in Table 12-25.

Table 12-22. 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.

12.5.2 Threatened ecological communities

Protected Matters searches for TECs in the upstream, downstream and construction study areas are summarised in Table 12-23, which also identifies the conservation status of each TEC (vulnerable, V; endangered, E; critically endangered, CE).

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 12-23. 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

Common name	EPBC Act status	Likelihood of occurrence		
		Upstream	Downstream	Construction
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

12.5.3 Threatened species

Protected Matters searches for threatened species in the upstream, downstream and construction study areas are summarised in Table 12-24, which also identifies the conservation status of each species (vulnerable, V; endangered, E; critically endangered, CE). The likelihood of occurrence and related descriptors are as described in Appendix F5 (MNES, Appendix A).

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.

12.5.4 Migratory species

Protected Matters searches for migratory species in the upstream, downstream and construction study areas are summarised in Table 12-25, which also identifies the conservation status of each species (vulnerable, V; endangered, E). The likelihood of occurrence and related descriptors are as described in Appendix F5 (MNES, Appendix A).

Table 12-24. 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
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

Scientific name	Common name	EPBC Act status	Likelihood of occurrence		
			Upstream	Downstream	Construction
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
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

Scientific name	Common name	EPBC Act status	Likelihood of occurrence		
			Upstream	Downstream	Construction
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
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

Scientific name	Common name	EPBC Act status	Likelihood of occurrence		
			Upstream	Downstream	Construction
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
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

Scientific name	Common name	EPBC Act status	Likelihood of occurrence		
			Upstream	Downstream	Construction
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
*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
Thesium australe	Austral Toadflax**	V	Moderate	Low	Low

Scientific name	Common name	EPBC Act status	Likelihood of occurrence		
			Upstream	Downstream	Construction
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

Table 12-25. 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
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

Scientific name	Common name	EPBC Act status	Likelihood of occurrence		
			Upstream	Downstream	Construction
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
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

12.6 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. In response, DAWE released initial advice relating to 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 from 1 August 2019 to 13 January 2020. Regular updates are progressively being provided through the Department's website[5]. Of this list, 58 species either recorded during field surveys carried out for the Project, or predicted to occur based on habitat preferences. These species include:

- Regent Honeyeater *(Anthochaera phrygia)*
- Black-faced Monarch *(Monarcha melanopsis)*
- Gang-gang Cockatoo *(Callocephalon fimbriatum)*
- Rockwarbler *(Origma solitaria)*
- Pilotbird *(Pycnoptilus floccosus)*
- Superb Lyrebird *(Menura novaehollandiae)*
- Red-browed Treecreeper *(Climacteris erythrops)*
- Koala *(Phascolarctos cinereus)*

[5] https://www.environment.gov.au/biodiversity/bushfire-recovery

- Yellow-bellied Glider *(Petaurus australis)*
- Greater Glider *(Petauroides volans)*
- Brush-tailed Rock-wallaby *(Petrogale penicillate)*
- Long-nosed Potoroo *(Potorous tridactylus tridactylus)*
- Spot-tailed Quoll *(Dasyurus maculatus)*
- New Holland Mouse *(Pseudomys novaehollandiae)*
- Grey-headed Flying-fox *(Pteropus poliocephalus)*
- Golden-tipped Bat *(Phoniscus papuensis)*
- Platypus *(Ornithorhynchus anatinus)*
- Broad-headed Snake *(Hoplocephalus bungaroides)*
- Southern Water-skink (*Eulamprus tympanum*)
- Broad-tailed Gecko (*Phyllurus platurus*)
- Giant Burrowing Frog (*Heleioporus australiacus*).

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. These are documented in Appendix F5 (Section 1.6, 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 descriptions of these criteria are provided in Appendix F5 (MNES, Section 1.6, Table 1-1).

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 Appendix F5 (MNES, Section 1.6, Table 1-4). This includes both threatened species (listed under the EPBC Act or BC Act), and species not listed as threatened under either Act. This 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.

12.7 World Heritage

Biodiversity values associated with the Outstanding Universal Value of the GBMWHA have been assessed separately in Appendix J (World Heritage assessment report). However, given the overlap with MNES related to biodiversity, relevant discussion from that report has been included in this chapter to cover matters that have not necessarily been addressed in other biodiversity reports (Appendices F1, F2, F3 and 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 12-2.

12.7.1 Impacts on plant communities

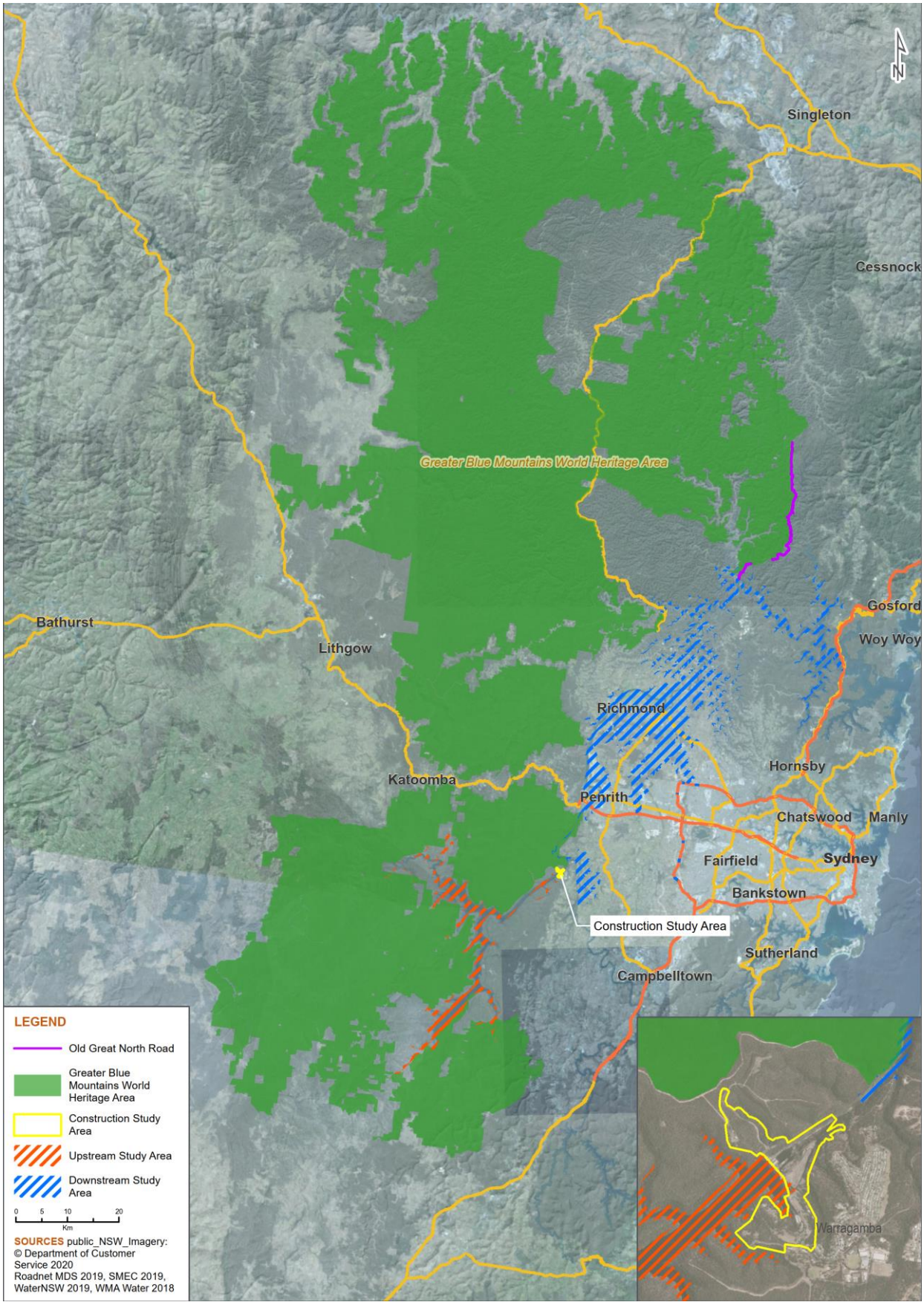
The primary values for inscription of the GBMWHA on the World Heritage list relate to biodiversity. The principal potential impact of the Project with regard to plant communities relates to temporary inundation when the FMZ is in operation. Depending on the magnitude of the inflow event and the depth 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.

Figure 12-2. Project study area relative to the GBMWHA and to the Old Great North Road World Heritage Area



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 12-26. The areas of the same plant communities within the broader upstream study area (5,280 hectares) are also provided for context.

Table 12-26. 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

BVT Code	PCT Name	Area within upstream study area (ha)	Area within upstream impact area (ha)
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

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.

12.7.1.1 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.

12.7.1.2 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.

12.7.1.3 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). 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.

12.7.1.4 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.

12.7.2 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. In summary, it is not possible to make a precise statement of the potential 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.

12.7.3 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.

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

12.7.4.1 *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[6].

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 (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

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

(*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 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.

12.7.4.2 *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[7]. Individuals and clusters of *Eucalyptus 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.

12.7.4.3 *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 (*Acacia baueri* subsp. *aspera*; Bynoes Wattle, *Acacia bynoeana*; Flockton's Wattle, *Acacia flocktoniae*; Gordon's Wattle, *Acacia gordonii*, and Downy Wattle, *Acacia 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.

12.7.5 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). 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.

12.7.6 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.*

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

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 Platypus and the Short-beaked Echidna are not listed as threatened but are known to occur in the Project area, and are discussed as follows.

12.7.6.1 Platypus

The Platypus (*Ornithorhynchus anatinus*) 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.

12.7.6.2 Short-beaked Echidna

The Short-beaked Echidna (*Tachyglossus aculeatus*) is not listed as threatened under any current Commonwealth or NSW 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 its 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.

12.7.6.3 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. 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.

12.7.6.4 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.

12.7.6.5 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 their being unlikely to occur in the study area.

12.7.7 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.

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.

12.8 Assessments of significant impact

Significant impact assessments were prepared in accordance with the *Matters of National Environmental Significance Significant impact guidelines 1.1* (refer Section 12.2.3). These assessments are provided in Appendix F5 (MNES, Appendix A) for TECs and species with potential moderate or high likelihood, or known/recorded occurrence within the upstream (U), construction (C), and downstream (D) study areas. Summaries are given in Table 12-27 (ecological communities), Table 12-28 (threatened species) and Table 12-29 (Migratory species). TECs/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.

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 temporary inundation, and the associated tolerance of vegetation to inundation. 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 guidelines address when a significant impact is likely. To be 'likely', it is not necessary for a significant impact to have a greater than 50 percent 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.

Table 12-27. 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 12-28. 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.
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.

Scientific name	Common name	Likelihood of occurrence	Assessment of significance	Comment
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.
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.

Scientific name	Common name	Likelihood of occurrence	Assessment of significance	Comment
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 would reduce an important population in the upstream study area. It 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.
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.

Scientific name	Common name	Likelihood of occurrence	Assessment of significance	Comment
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.
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.

Scientific name	Common name	Likelihood of occurrence	Assessment of significance	Comment
*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.
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.

Scientific name	Common name	Likelihood of occurrence	Assessment of significance	Comment
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.
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.
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.

Scientific name	Common name	Likelihood of occurrence	Assessment of significance	Comment
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.
*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.

Scientific name	Common name	Likelihood of occurrence	Assessment of significance	Comment
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.
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.

Scientific name	Common name	Likelihood of occurrence	Assessment of significance	Comment
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.
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.

Scientific name	Common name	Likelihood of occurrence	Assessment of significance	Comment
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 12-29. 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 unlikely to have a significant impact on this

Scientific name	Common name	Agreement[1]			Likelihood of occurrence	Assessment of significance	Comment
		C	J	K			
							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)

12.9 Matters relevant to biodiversity in the EPBC Act and Regulations

12.10 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. Table 12-30 provides an assessment for each of these matters.

Table 12-30. 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 12.13).
(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 12.13).
(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[8].

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[9].

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

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

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

12.11 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 12-31 provides an assessment for each of these matters.

Table 12-31. 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 12-29 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 12-29). 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 12-29). 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.

12.12 Summary of potential impacts

12.12.1 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 Project. 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.

Further detail is provided in Appendix F3 (Biodiversity assessment report – construction area).

12.12.2 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 greatest increase in the duration of upstream inundation would be up to 10.4 days. The increase in temporary inundation impacts would decrease with distance upstream from Warragamba Dam, Lake Burragorang and further up 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.

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.

12.12.2.1Threatened 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. These species and their conservation status (vulnerable, V; endangered, E; or critically endangered CE) are listed in Table 12-32. 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 12-32. Threatened flora likely to be significantly impacted

Scientific name (Common name)	EPBC Act status	Area (ha)			
		DS FMZ	DS 10% AEP difference	DS PMF difference	Construction dev footprint
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

Scientific name (Common name)	EPBC Act status	Area (ha)			
		DS FMZ	DS 10% AEP difference	DS PMF difference	Construction dev footprint
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
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	-	-	-	-

12.12.2.2 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. These species and their conservation status (vulnerable, V; endangered, E; or critically endangered CE) are listed in Table 12-33. 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 12-33. Threatened fauna likely to be significantly impacted

Scientific name (Common name)	EPBC Act status	Area (ha)			
		DS FMZ	DS 10% AEP difference	DS PMF difference	Construction dev footprint
Anthochaera phrygia (Regent Honeyeater)	CE	-	-	-	NA – see AoS
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	-
Pseudomys novaehollandiae (New Holland Mouse)	V	-	-	-	-

12.12.2.3 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.

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 12-34 summarises the extent of inundation on these TECs for the upstream impact area. Detailed discussion of impacts is provided in Appendix F1 (Biodiversity assessment report – upstream, section 7.3.3).

Table 12-34. Extent of temporary inundation on affected TECs for the upstream impact area

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

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 12-35 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 Appendix F3 (Biodiversity Assessment Report – Construction Area, Section 7.2.2).

Table 12-35. 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.

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 12-36 shows the extent of each TEC depending on a change in flood event for the FMZ, a 1 in 10 chance in a year flood event, a 1 in 20 chance in a year flood event, a 1 in 100 chance in a year flood event, and the PMF together with a broad summary of associated impacts. Detailed discussion of the impacts to these TECs are provided in Appendix F2 (Downstream Ecological Assessment, Section 6.4.1).

Table 12-36. 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.
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.

12.12.3 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.

12.12.4 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.

12.12.4.1 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.

12.12.4.2 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. Generally, controlled discharges from the FMZ would be about 100 gigalitres per day and could occur for up to around two weeks, depending on the size of the flood event.

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.

12.12.4.3 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.

12.13 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).

12.13.1 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.

Proposed actions to avoid impacts to biodiversity values where practicable are addressed in Table 12-37. Site selection considerations are addressed in Table 12-38.

Table 12-37. 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 12-38. 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.

12.13.2 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 BOS would be delivered through the Warragamba Offset Program as described in Section 6 of the BOS (Appendix F6 to the EIS). A key element of the program will be 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.

12.14 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.

12.15 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 Environmental Offsets Policy.

12.16 Risk assessment

An environmental risk analysis was carried out in accordance with the SEARs. The risk analysis includes assessing residual risk of potential impacts both before and after the implementation of mitigation measures. Risk assessments related to biodiversity are presented in Chapter 8 (Biodiversity upstream), Chapter 9 (Downstream ecological assessment), Chapter 10 (Biodiversity construction area), and Chapter 11 (Aquatic ecology).

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