Hume Coal and Berrima Rail Project

Groundwater dependence assessment for cultural heritage landscapes and gardens prepared in response to recommendations R16 and R19 in the Independent Planning Commission Assessment report dated 27 May 2019

Prepared for Hume Coal Pty Ltd
April 2020

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Executive Summary

ES1 Introduction

Hume Coal Pty Limited (Hume Coal) proposes to construct and operate an underground coal mine and associated mine infrastructure in the Southern Coalfield of New South Wales (NSW) (the Hume Coal Project). The mine will produce metallurgical coal with a secondary thermal coal product. Around 50 million tonnes (Mt) of run-of-mine coal will be extracted from the Wongawilli Seam via a non-caving mining system, resulting in approximately 39 Mt of saleable coal over a project life of about 23 years, including construction and rehabilitation. The Project area is located to the west of Moss Vale, in the Wingecarribee local government area (LGA).

Hume Coal is also seeking approval in a separate development application for the construction and operation of a new rail spur and loop, known as the Berrima Rail Project. Coal produced by the Hume Coal Project will be transported to port by rail for export or to domestic markets also by rail via this new rail spur and loop. The Hume Coal Project and the Berrima Rail Project together form 'the Project'.

The development application for the Hume Coal Project was publicly exhibited between March and June 2017. Submissions were received from government agencies, organisations and the public. A response to submissions report was submitted to the Department of Planning, Industry and Environment (DPIE) in June 2018, with their Preliminary Assessment Report (PAR) provided in December 2018. The project was referred to the Independent Planning Commission (IPC), to conduct a public hearing, to assess the merits of the project, and to prepare a report outlining the Commission's findings on the projects, including any recommendations.

The IPC findings and recommendations were published in their Independent Planning Assessment Report, released in May 2019. Specific to groundwater impacts on biodiversity and historic heritage, the IPC recommended that further information should be provided to allow the assessment of drawdown on heritage items (including gardens, plantings, exotic trees, native vegetation and landscape settings) within or in the vicinity of the project area. The purpose of this groundwater impact assessment for cultural heritage landscapes and gardens is to respond directly to these recommendations (R16 and R19 in the Independent Planning Assessment Report). Technical assessment on the impacts of the project on native vegetation from a declining water table has been assessed previously and is presented in Section 13 of the RTS Main Report, Volume 1 and therefore is not assessed further in this report.

This assessment was conducted by a team comprising an ecologist, an archaeologist, a landscape planner/registered landscape architect, arboricultural specialist, a hydrogeologist and a spatial analyst, using the inputs from the Updated Statement of Heritage Impact (EMM 2020a) and Updated Water Assessment (EMM 2020c) and for the Hume Coal Project. This interdisciplinary approach provides a robust impact assessment that addresses R16 and R19.

ES2 Methods

This impact assessment is based on the results of the groundwater modelling uncertainty analysis completed in support of the RTS (EMM 2018). IPC recommendation R16 requires assessment of the potential impacts of the predicted watertable drawdown on vegetation and cultural heritage landscapes using the results of the 67th percentile (unlikely to occur) and the 90th percentile (very unlikely to occur) uncertainty analysis. The model outcomes for the 67th percentile provide a conservative prediction of the impacts caused by the Project. While these are useful when considering worst-case outcomes, results higher than the 67th percentile are considered 'unlikely', or 'not expected to occur' (Table 2.1) when considered in line with IESC guidelines (Middlemiss and Peeters 2008). The 50th percentile results were also assessed as this scenario is 'about as likely as not' to occur.

As presented in earlier submissions, the Hume Coal groundwater model has undergone numerous reviews by many leading experts in groundwater modelling in Australia, including a review by the then DPE's expert Mr Hugh

Middlemis (HydroGeoLogic Pty Ltd). Hume Coal recently engaged Dr Lloyd Townley of GW SW Pty Ltd, an expert with over 40 years of experience in groundwater modelling, to independently review the RTS groundwater model. Dr Townley's review finds that the modelling undertaken for the Project is fit for purpose, which is predicting groundwater inflows to the proposed mine and drawdown of the watertable within and near the Project area (Townley 2020). That is, the model is fit for purpose at predicting mine inflows and watertable drawdown at a regional scale.

The predicted impact of watertable drawdown has been modelled using the RTS regional model. The model predicts results for bores and areas of interest, with reference to the nearest model cell for the location of the bore and point of interest. It should be noted that while the model is accurate at the regional scale, there will be differences between model predicted depth to groundwater and reality at a local scale (ie at a bore or tree level). However, this does not mean that the groundwater model cannot be used to assess the potential effects of the changes on receptors. The groundwater model is consistent with industry standards and provides guidance on the potential watertable drawdown due to the project.

The study area for the groundwater dependence assessment presented in the EIS and RTS reports was defined as the groundwater model domain. For the purposes of this assessment, the study area (Figure 4.1) has been refined and delineated into two study areas, comprising:

- 90th percentile study area: to assess potential impacts on heritage items and private gardens. Defined as the 2-metre (m) drawdown contour for the 90th percentile; and
- cultural landscape study area: to assess potential impacts on cultural landscapes. Defined as the common boundary of:
  - the previously listed *Key Historic Unit 6 – Sutton Forest Landscape Area* on the superseded Wingecarribee LEP 1993;
  - the non-statutory landscape area *Exeter/Sutton Forest Landscape Conservation Area* recognised by the National Trust of Australia (NSW); and
  - the abovementioned predicted 2 m drawdown extent for the 90th percentile modelling results.

The assessment comprised a desktop analysis to identify heritage items, a site inspection to characterise gardens and a literature review on vegetation interactions with groundwater. Using the results of these analyses, combined with a spatial analysis conducted in ArcMap, gardens and plantings within heritage items and vegetation (non-native and grasslands) in the landscape conservation study area with access to shallow groundwater were identified. This area is defined by the common boundaries of the *Key Historic Unit 6 - Sutton Forest Landscape Area* (previously listed on the Wingecarribee LEP 1993) and the *Exeter/Sutton Forest Landscape Conservation Area* (a non-statutory listing by the National Trust of Australia (NSW)).

To assess private gardens, descriptions of historic gardens were reviewed using the *State Heritage Register* (SHR) and *Wingecarribee Local Environmental Plan 2010* (Wingecarribee LEP), where available. A review of garden species identified during the site inspection and literature review was undertaken by an arboricultural specialist. The review focused on the origin, climate, biology, typical rooting depths and response to reduced water availability of these species to assess their vulnerability to shallow watertable decline.

The level of groundwater interaction was also identified. Wooded vegetation was classified into areas with a high potential for groundwater interaction (0−3 metres below ground level (mbgl)), moderate potential for groundwater interaction (3−5 mbgl) and low potential for groundwater interaction (5−10 mbgl). Exotic grasslands only have access to groundwater to approximately 1 mbgl, and therefore all grasslands overlying groundwater 0−1 mbgl in low-lying areas and near creeks were classified as having a high potential for interaction, while areas overlying deeper groundwater had no access. Typical species within private gardens and roadside plantings sensitive to drought conditions were also identified.

ES3 Results

Shale of the Wianamatta Group geology occurs across the eastern part of the study area, while Hawkesbury Sandstone surface geology outcrops in south-west to north-west of the study area. Vegetation access to groundwater would vary across the Wianamatta Group Shale sediments with depth and permeability of the layer. Similarly, vegetation access to groundwater would vary across the Hawkesbury Sandstone surface geology and would be restricted to areas where roots could exploit cracks and fissures in the rock.

All heritage gardens occur in areas where the Wianamatta Shale outcrops at surface and therefore have a negligible risk of drawdown (see Section 4.1). The boundary between the Wianamatta Shale and Hawkesbury Sandstone intersects the property containing Mereworth House and Garden. Mereworth House and Garden, listed as having local significance under the Wingecarribee LEP lies on the Wianamatta Group Shale and therefore the listed heritage item has a negligible drawdown risk during drought conditions.

The Mereworth property also contains planted pine windbreaks to the west and south-west of the house and garden, outside the heritage curtilage. Approximately 0.1 ha of these windbreaks have a low interaction with groundwater (ie lies at 5−10 mbgl) and overlies Hawkesbury Sandstone.

Approximately 19.4 ha of vegetation, comprising non-native vegetation and exotic grasslands, has access to shallow groundwater in the landscape conservation study area. Of this 19.4 ha of vegetation, 4 ha of non-native vegetation and 3.2 ha of exotic grasslands has a high level of groundwater interaction.

The literature review and site inspection identified 60 species planted in private gardens and on roadsides in the 90th percentile study area. Of these 60 species, 26 are considered sensitive to reduced water availability where they overlie Hawkesbury Sandstone.

ES4 Impact assessment

Based on the conceptual hydrogeological understanding, in areas where the Wianamatta Group Shale is weathered and thin (in the south and west of the study area) the Shale is likely to be unsaturated (dry), with the watertable located within the Hawkesbury Sandstone underlying the Shale. Where the Shale thickens (in the east and the north), the watertable is present at varying depths depending on topography and hydrogeological properties of the Shale.

There is limited natural vertical connectivity between the Wianamatta Group Shale and the underlying Hawkesbury Sandstone aquifer, as evidenced by lower water levels in the Sandstone. At most groundwater monitoring sites (such as at the HU035A and B monitoring sites; refer to the Updated Water Assessment, Appendix B of the IPC response report (EMM 2020c)), groundwater in the Shale is perched above the regional watertable and there are areas of unsaturated Hawkesbury Sandstone underlying the saturated Shale (refer to Plate 4.1 to Plate 4.3).

In areas where hydraulic connection between these two units may occur, groundwater would leak from the Shale to the Sandstone at a low rate. Where there is no hydraulic connection between these two units (ie where the Sandstone is unsaturated below the saturated Shale, e.g. perched groundwater), downward groundwater leakage would already be occurring at a maximum rate (see Plate 4.3). Mining induced drawdown would not result in increased leakage (vertical downward movement) of groundwater from the Shale to the Sandstone, and any potential impacts to groundwater availability would be negligible. For this reason, areas of Shale overlying Sandstone will not be further assessed for potential impacts to groundwater dependent vegetation.

The regional scale RTS groundwater model was used to predict watertable drawdown in vegetated areas identified to contain plants that may access shallow groundwater and may be susceptible to water stress during periods of prolonged drought. During average and wet climate periods, vegetation in these areas will not be affected by groundwater level drawdown. During especially dry periods when the soil moisture is low and not replenished by rainfall or surface water runoff, vegetation in these areas may exhibit increased stress or die back due to reduced access to groundwater as a result of groundwater level drawdown. These areas are limited to low lying topographical areas where the watertable is shallow and near watercourses where groundwater discharges as baseflow. However, under prolonged drought conditions, without mining, the watertable would decline naturally in these areas. As such, vegetation either currently naturally adapts or is subject to water stress during these times, with replenishment when the drought breaks. In particular, exotic grasslands may die back during times of drought during water stress but would rapidly re-colonise following rain. Accordingly, the following impact assessment should be interpreted within this context.

Some planted pine windbreaks (0.1 ha) located within farm paddocks and outside of the heritage curtilage (as shown in Figure 4.2), approximately 750 m to the west and south-west of Mereworth House and Garden overlie the Hawkesbury Sandstone. The windbreaks have a low potential for groundwater interaction. In this location, the maximum predicted watertable levels (as a result of mining, under the 50th, 67th and 90th percentile results) would be >10 mbgl, and risk of the groundwater table becoming inaccessible during drought conditions is high.

Part of the southern windbreak is in an area proposed for surface mine infrastructure, in particular entry/exit to the personnel and materials drift and an access road to the explosives magazine (Figure 1.3). The northern windbreak and parts of the southern windbreak that can be avoided by mine infrastructure will be monitored for signs of water stress during prolonged drought, with remedial action taken as required (Chapter 6).

Drawdown impacts are scattered across the landscape conservation study area and are generally restricted to low-lying areas proximal to Olbury Creek, Medway Rivulet, Wells Creek and Black Bobs Creek.

Drawdown impacts using the 50th percentile (about as likely to occur as not) uncertainty analysis results in the portion of the landscape conservation study area where the Hawkesbury Sandstone outcrops at surface are shown in Table 5.2 and on Figure 5.2. The combined 50th percentile impacts across the landscape conservation study area are predicted to have:

- no risk of impact during drought conditions to 5.2 ha of non-native vegetation and 0.2 ha of grasslands;
- low risk of impact during drought conditions to 0.8 ha of non-native vegetation;
- moderate risk of impact during drought conditions to 3.5 ha of non-native vegetation; and
- high risk of impact during drought conditions to 6.8 ha of non-native vegetation and 3 ha of grasslands.

Accordingly, 9.8 ha of non-native vegetation (including exotic grasslands) has a high risk of impact during drought conditions under the 50th percentile results. This only represents 0.08% of the cultural landscape study area and 0.06% of the common boundary of the cultural landscapes.

Drawdown impacts using the 67th percentile (unlikely to occur) uncertainty analysis results in the portion of the landscape conservation study area where the Hawkesbury Sandstone outcrops at surface are shown in Table 5.2 and on Figure 5.3. The combined 67th percentile impacts across the landscape conservation study area are predicted to have:

- no risk of impact during drought conditions to 3.8 ha of non-native vegetation and 0.1 ha of grasslands;
- low risk of impact during drought conditions to 0.7 ha of non-native vegetation;
- moderate risk of impact during drought conditions to 4.5 ha of non-native vegetation; and
- high risk of impact during drought conditions to 7.2 ha of non-native vegetation and 3.1 ha of grasslands.

Accordingly, 10.3 ha of non-native vegetation (including exotic grasslands) has a high risk of impact during drought conditions under the 67th percentile results. This only represents 0.09% of the cultural landscape study area and 0.07% of the common boundary of the cultural landscapes.

Drawdown impacts using the 90th percentile (very unlikely to occur) uncertainty analysis results in the portion of the landscape conservation study area where the Hawkesbury Sandstone outcrops at surface are shown in Table 5.2 and on Figure 5.4. The combined 90th percentile impacts across the landscape conservation study area, the project is predicted to have:

- no risk of impact during drought conditions to 1.8 ha of non-native vegetation and 0.1 ha of grasslands;
- low risk of impact during drought conditions to 0.6 ha of non-native vegetation;
- moderate risk of impact during drought conditions to 5.2 ha of non-native vegetation; and
- high risk of impact during drought conditions to 8.7 ha of non-native vegetation and 3.1 ha of grasslands.

Accordingly, 11.8 ha of non-native vegetation (including exotic grasslands) has a high risk of impact during drought conditions under the 90th percentile results. This only represents 0.11% of the cultural landscape study area and 0.08% of the common boundary of the cultural landscapes.

Twenty-six plant species typically observed in private gardens are considered drought-sensitive to reduced water availability. Where these plant species overlie Hawkesbury Sandstone surface geology that contain shallow groundwater (restricted to low-lying areas and areas proximal to creeks) they may be subject to water stress during prolonged drought.

ES5 Impact mitigation strategy

Following project approval, Hume Coal will conduct additional 'post-approval' groundwater modelling and field investigations, where possible, to confirm the depth to groundwater in the areas identified as being at high risk of water stress during periods of prolonged drought.

Planted pine windbreaks on Mereworth property, that cannot be avoided by surface mine infrastructure, will be monitored for signs of water stress during prolonged drought, and supplemented with water if required.

There will be no impacts to gardens and plantings within local or state listed heritage items, and as such no mitigation measures are proposed to these areas.

The remaining non-native, exotic grassland and private gardens located within the landscape conservation study areas that are predicted to experience watertable drawdown and have been identified as being at risk of water stress during periods of prolonged drought cover a small area, are not classified as high priority GDEs and are not covered under any statutory requirement to manage or mitigate the potential and unlikely effects.

Ongoing 'post-approvals' groundwater modelling will be undertaken as and when new data become available, and at regular intervals throughout the life of the mine. It is expected the confidence level of model predictions will increase over time as the model is updated to reflect the observed effects on groundwater obtained from the monitoring program. This is consistent with International Organisation for Standardisation (ISO) continuous improvement guidelines and industry standard.

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1 Introduction

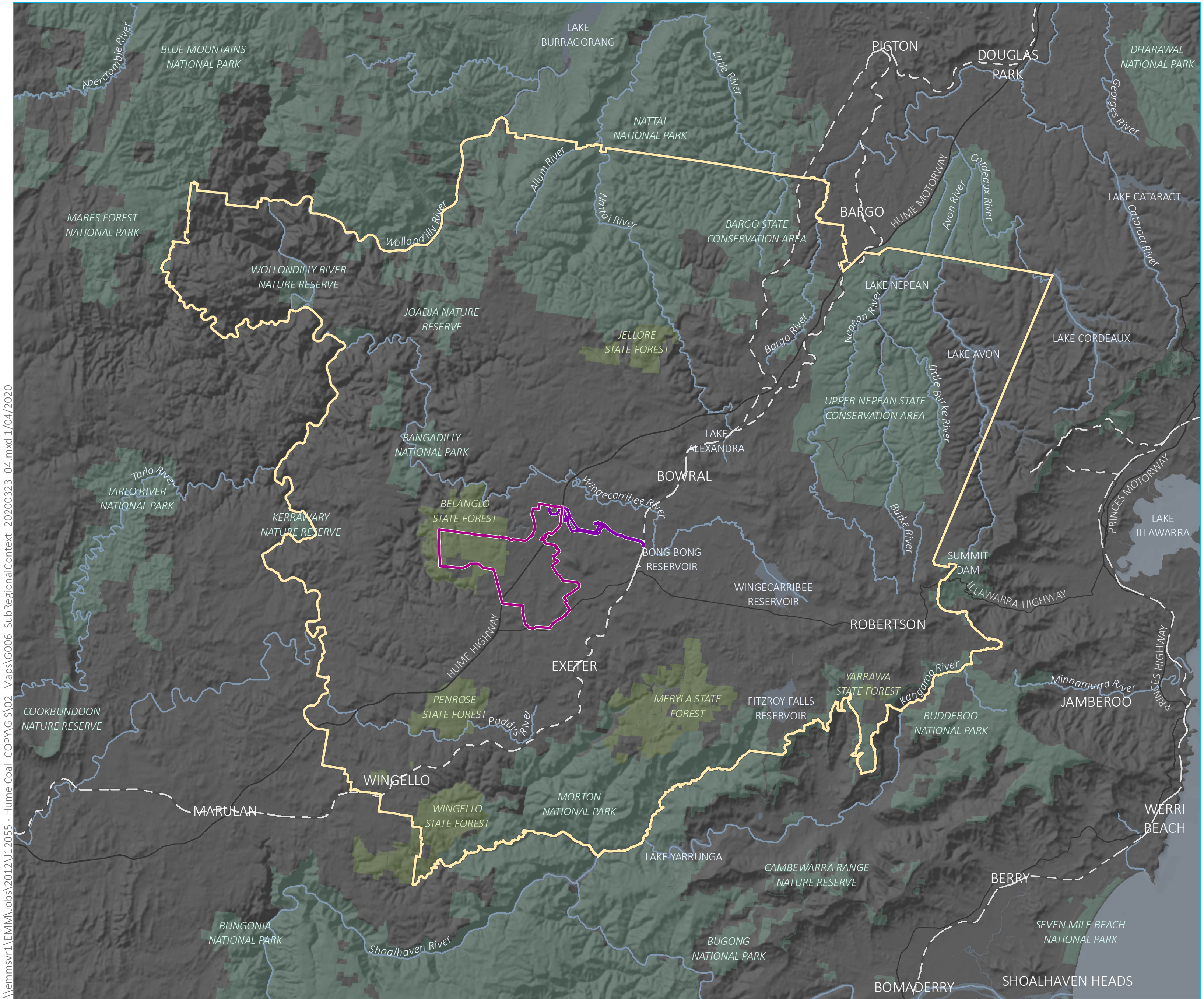
1.1 Overview of the Hume Coal Project

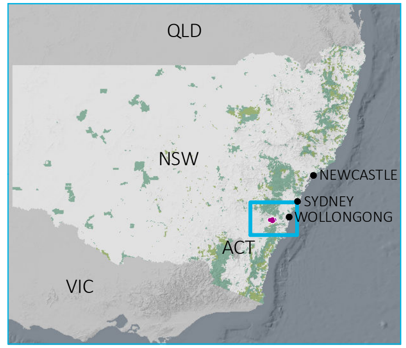
Hume Coal Pty Limited (Hume Coal) proposes to construct and operate an underground coal mine and associated mine infrastructure in the Southern Coalfield of New South Wales (NSW) (the Hume Coal Project). The mine will produce metallurgical coal with a secondary thermal coal product. Around 50 million tonnes (Mt) of run-of-mine coal will be extracted from the Wongawilli Seam via a non-caving mining system, resulting in approximately 39 Mt of saleable coal over a project life of about 23 years, including construction and rehabilitation. The Project area is located to the west of Moss Vale, in the Wingecarribee local government area (LGA). Figure 1.1 illustrates the location of the project at a regional scale.

Hume Coal is also seeking approval in a separate development application for the construction and operation of a new rail spur and loop, known as the Berrima Rail Project. Coal produced by the Hume Coal Project will be transported to port by rail for export or to domestic markets also by rail via this new rail spur and loop. The project areas for the Hume Coal Project and the Berrima Rail Project are shown on Figure 1.1. The Hume Coal Project and the Berrima Rail Project are collectively referred to as 'the project' in this report.

Indicative mine and surface infrastructure plans for the Hume Coal Project are provided in Figure 1.3. A full description of the Hume Coal Project, as assessed in this report, is provided in Chapter 2 of the main EIS report (EMM 2017a). A full description of the Berrima Rail Project is provided in Chapter 2 of the Berrima Rail Project EIS (EMM 2017b), noting the alternative option has been selected.

Approval for both the Hume Coal Project and the Berrima Rail Project is sought under Part 4 Division 4.1 (State significant development) of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act).





KEY

- Hume Coal Project area
- Berrima Rail Project area
- Wingecarribee Shire local government area
- Rail line
- Motorways and primary roads
- River
- Named waterbody
- NPWS reserve
- State forest

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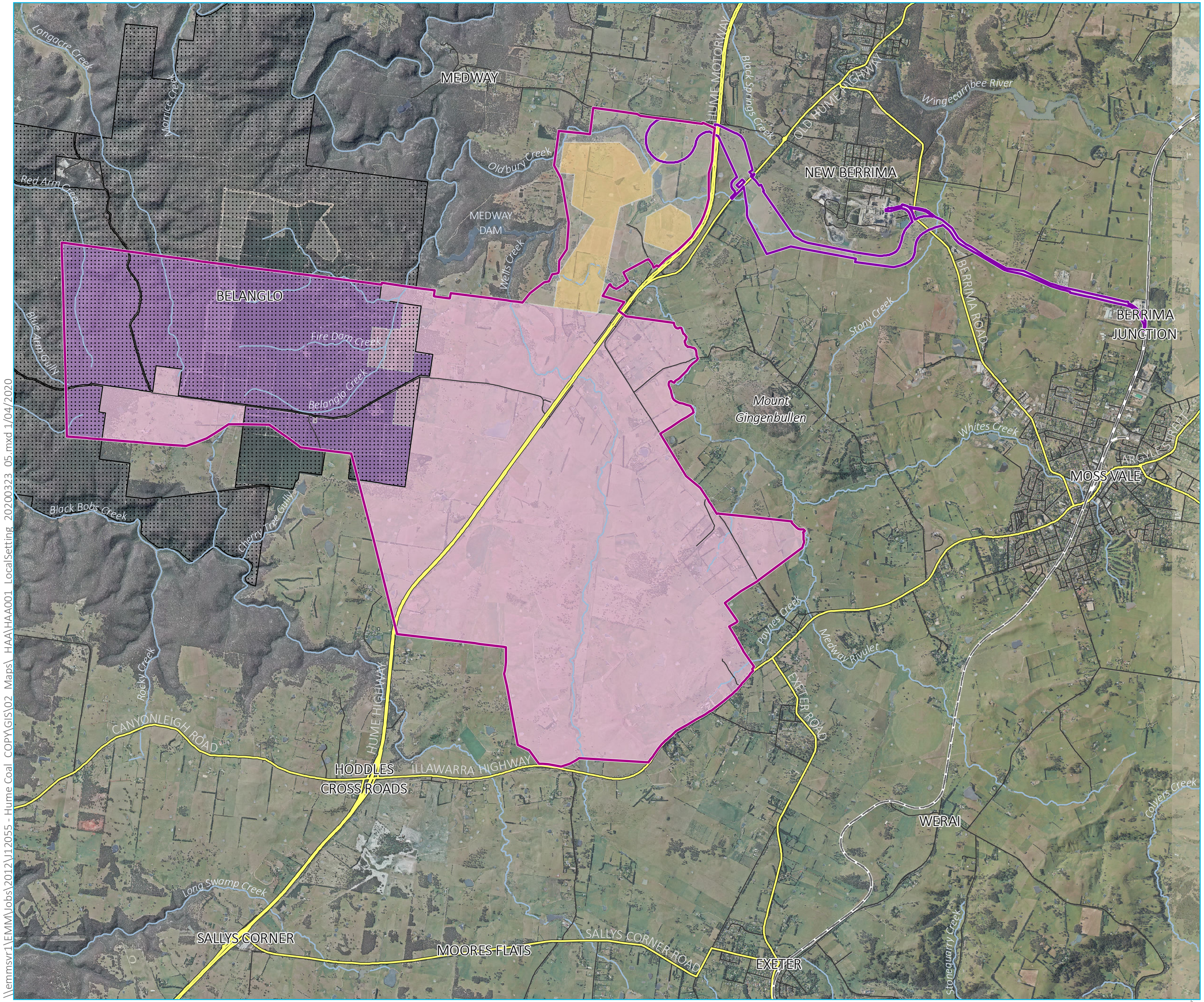
Source: EMM (2020); DFSI (2017); GA (2011); ASGC (2006)

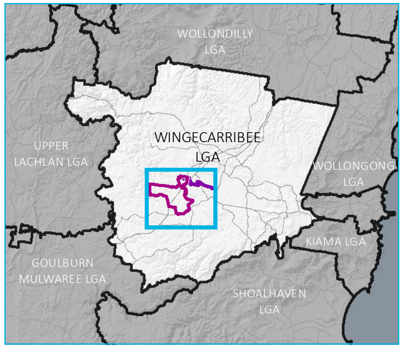
Regional setting

Hume Coal and Berrima Rail Project
Groundwater dependence assessment
for cultural heritage landscapes and gardens
Figure 1.1

HUMECOAL PROJECT

EMM creating opportunities





KEY

- Hume Coal Project area (5,051 ha, 44,740 m perimeter)
- Berrima Rail Project area (181 ha, 23,201 m perimeter)

Mining lease application area

- MLA 527
- MLA 528
- MLA 529

Existing environment

- Rail line
- Major road
- Minor road
- Named watercourse
- Waterbody
- Belanglo State Forest

Source: EMM (2020); Hume Coal (2016); DFSI (2017); DPE (2019)

0 1 2 km
GDA 1994 MGA Zone 56
N

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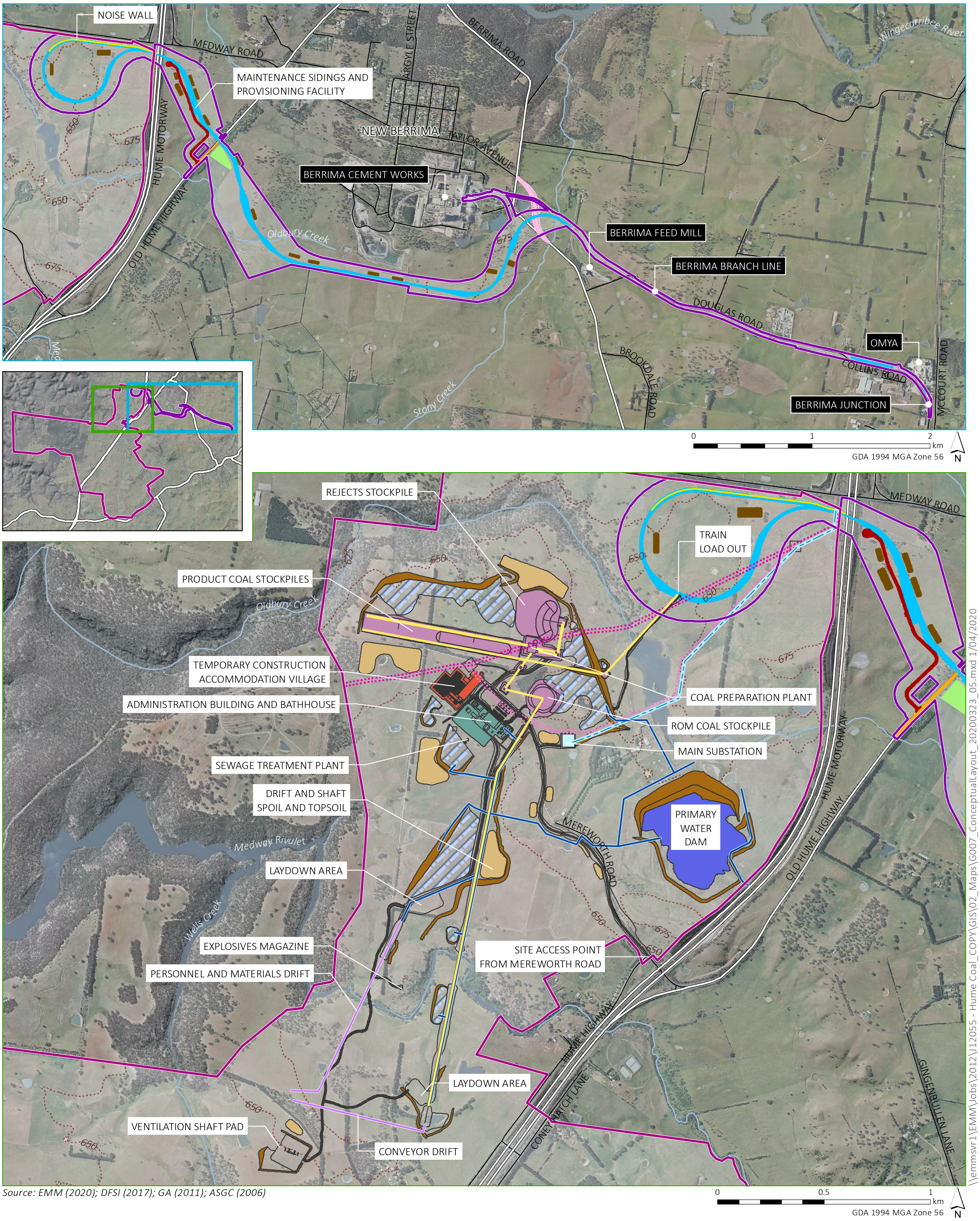
Local setting

Hume Coal and Berrima Rail Project
Groundwater dependence assessment
for cultural heritage landscapes and gardens
Figure 1.2

HUMECOAL PROJECT
EMM creating opportunities



Source: EMM (2020); DFSI (2017); GA (2011); ASGC (2006)

KEY

- Major road
- Minor road
- Contour (25 m increments)
- Named watercourse
- Waterbody
- Berrima Rail Project area

Berrima Rail Project elements

- Noise wall
- New rail line
- Rail maintenance facility access road
- Berrima Road relocation (works by Wingecarribee Shire Council)
- Topsoil stockpiles
- Rail temporary construction facility
- Turning lane/shoulder
- Hume Coal Project area

Hume Coal Project elements

- Conveyor
- Drift (underground)
- Powerline route
- Water pipeline
- Proposed powerline and pipeline easement
- Existing WSC easement
- Temporary construction accommodation village
- Administration/bathhouse/workshop
- Main substation
- Internal road
- CPP and stockpiles
- Topsoil stockpiles
- Stormwater management earthworks
- Water management area
- Top water level

Layout plan

Hume Coal and Berrima Rail Project
Groundwater dependence assessment
for cultural heritage landscapes and gardens
Figure 1.3

HUMECOAL PROJECT
EMM creating opportunities

1.2 Background and assessment process

Plate 1.1 outlines the assessment process to date.

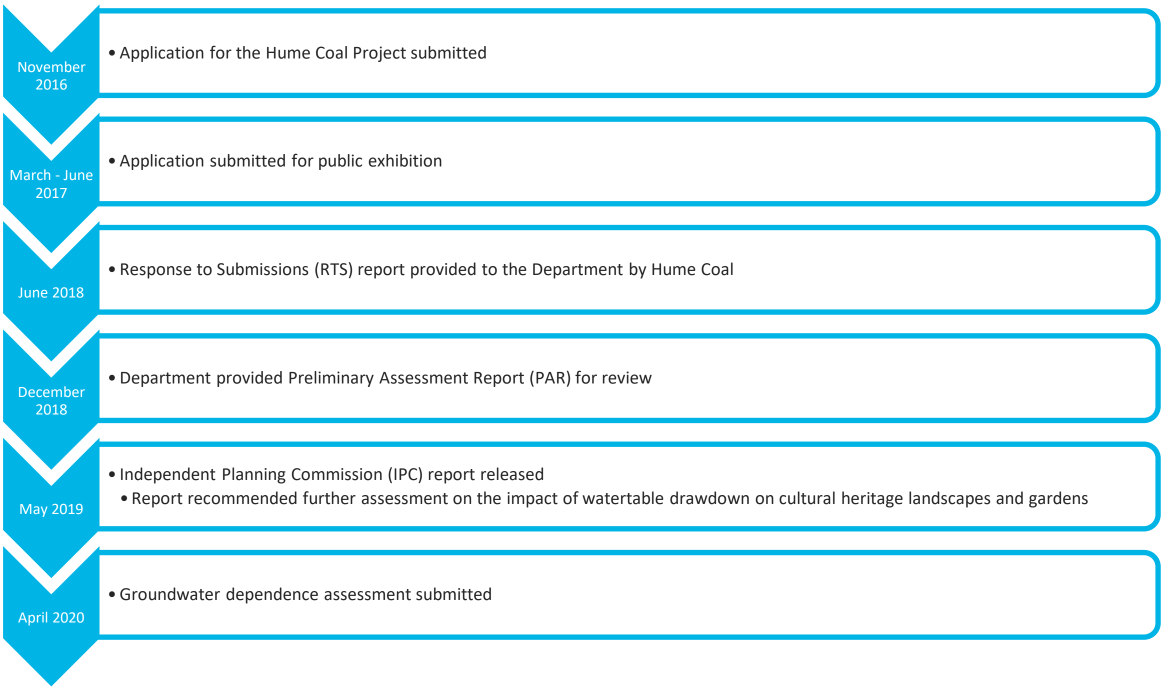


Plate 1.1 The assessment process to date

Application for the Hume Coal Project and Berrima Rail Project submitted

The development applications and accompanying environmental impact statements (EIS) for the Hume Coal Project (EMM 2017a) and the Berrima Rail Project (EMM 2017b) were submitted to the NSW Department of Planning and Environment (now the Department of Planning, Infrastructure and Environment (DPIE)) on 29 November 2016 for adequacy review. Following feedback and some modification, the two EISs were deemed adequate for exhibition, which occurred between 31 March 2017 and 30 June 2017.

A Biodiversity Assessment Report (BAR) (EMM 2017c) was prepared and submitted to the DPIE as Appendix H of the EIS for the Hume Coal Project. A Biodiversity Assessment Report (EMM 2017b) for the Berrima Rail Project was also prepared and submitted to DPIE as Appendix J to the Berrima Rail Project EIS. Both BARs were prepared in accordance with the former *Framework for Biodiversity Assessment: NSW Offsets Policy for Major Projects* (OEH 2014) and included an assessment of groundwater impacts on native vegetation, following the *Risk Assessment Guidelines for Groundwater Dependent Ecosystems* (NOW 2012).

A Statement of Heritage Impact (SoHI) was prepared and submitted to the DPIE as Appendix T of the EIS for the Hume Coal Project (EMM 2017a). A Statement of Heritage Impact for the Berrima Rail Project was also prepared and submitted to DPIE as Appendix I to the Berrima Rail Project EIS (EMM 2017b).

Response to submissions report

Following public exhibition of the EISs, Hume Coal prepared a Response to Submissions (RTS) report, responding to submissions received from government agencies, organisations and the public. A total of 12,666 submissions were received on both projects. In their submission on the project, the former Office of Environment and Heritage (OEH) concluded that there were no major issues with direct impacts on biodiversity. However, there were some minor aspects of the biodiversity assessment that required rectification. These related to re-classification of some plant community types and revision of some credit calculator inputs. The assessment was updated in the RTS report (Chapter 13 and Appendix 4), with all concerns addressed. Chapter 13 of the RTS also addressed potential impacts of water table decline on native vegetation within the project areas and surrounds.

Chapter 25 of the RTS contained an assessment of potential impacts of water table decline on four state listed heritage items: Oldbury Farm, Golden Vale, Whiteley House and Hillview House. The review concluded that these SHR properties are predominately near the edge of the zone of groundwater drawdown and for some of these areas, the predicted change (ie the magnitude of water table drawdown) is comparable to what would be experienced during natural seasonal variations and local landholder pumping.

The RTS report was submitted to the DPIE in June 2018.

Preliminary assessment report

The DPIE subsequently prepared a preliminary assessment report (PAR) for the project which was released in December 2018. In relation to biodiversity, the PAR concluded that "*The Department and OEH consider that biodiversity impacts would not be significant and could be managed through the following:*

- *Offset any impacts in accordance with the NSW Biodiversity Offsets Scheme.*
- *Prepare and implement a Biodiversity Management Plan in consultation with the OEH."*

In relation to historic heritage, the PAR concluded that "*impacts would not be significant and could be managed through the following:*

- *Include conditions requiring protection of all items.*
- *Prepare and implement management plans in consultation with OEH, Council and Heritage Council".*

Independent Planning Commission

As the number of submissions objecting to the project was greater than 25, the Minister for Planning referred the projects to the Independent Planning Commission (IPC) to conduct a public hearing, to assess the merits of the project, and to prepare a report outlining the Commission's findings on the projects, including any recommendations.

The IPC 'Independent Planning Assessment Report' (the IPC assessment report), released in May 2019, included findings and recommendations relating to Biodiversity and Historic Heritage. Table 1.1 lists IPC recommendation R16 and R19.

Table 1.1 IPC recommendations for further assessment

Submission	Category	IPC Recommendation
R16	Historic Heritage	Further information should be provided to allow the assessment of the potential impact of water table drawdown on heritage items (including gardens, plantings and landscape settings) within or in the vicinity of the Project area. The information should include confirmation of the existing level of the water table and the anticipated drawdown at both the 67th percentile and the 90th percentile.
R19	Biodiversity	The Applicant is to undertake further technical assessment on the impacts on private gardens, exotic trees and native vegetation from a declining water table.

1.3 Purpose

The purpose of this groundwater dependence assessment is to respond directly to the IPC findings and recommendations as published in the IPC assessment report released in May 2019, as they relate to IPC recommendations R16 and R19, as described in Section 1.2.

Where necessary, this study also addresses items presented in the IPC assessment report that informed the IPC findings and assessment that the applicant feels are erroneous, unsubstantiated or are otherwise worthy of response.

Table 1.2 describes where this report addresses each historic heritage item. Several items have been addressed in the *Hume Coal and Berrima Rail Projects Updated Statement of Heritage Impact* (EMM 2020a), and supplementary annexures therein.

Table 1.2 Response to IPC report on matters relating to Historic Heritage

Reference number	IPC assessment considerations	Location where addressed
283	The Commission in its assessment of merits of the Project has had regard to historic heritage impacts. The Commission has had regard to the Material before it and given consideration to the issues raised in public submissions. Relevant excerpts from the submissions included:	
	groundwater that is primarily to preserve our heritage listed gardens;	Section 4.2 Section 5.1
	the proximity of significant local and state heritage assets;	Addressed in EMM (2020a)
	Golden Vale Homestead is owned by the National Trust. The Trust is deeply concerned that the Hume Coal Project may impact on the property's water supplies;	Section 4.2
	Southern Highlands area has had a unique social and economic role and its heritage values need recognition and protection if they are to survive into the future. These values are incompatible with the development of the coal mining landscape;	Addressed in EMM (2020a)
	Berrima, located approximately two kilometres from the Project area, is one of the best-conserved towns from the colonial period of Australia. It has a significant collection of state heritage register-listed properties concentrated in a small area;	Addressed in EMM (2020a)
	there are 64 heritage items just within the village, 16 of which are on the state register;	Addressed in EMM (2020a)
	it is impossible to assert that the impact of the Project on Berrima can be mitigated;	Addressed in EMM (2020a)
	the adequacy of the SHIA, an alternate Heritage Impact Assessment (HIA) prepared on behalf of two community groups reached different conclusions, particularly in relation to the impact of the Project on the significance of Mereworth, as its heritage listing goes beyond the house and garden and includes its rural setting; and	Addressed in EMM (2020a)
	the SHIA does not address impacts, other than from the surface infrastructure works, on the heritage items in the study area and the cultural landscape. In particular, the impacts of groundwater and water table drawdown have not been adequately assessed.	Section 4.2 Section 5.1

Table 1.2 Response to IPC report on matters relating to Historic Heritage

Reference number	IPC assessment considerations	Location where addressed
284	The Commission notes that the SHIA, based on expert studies, assumes that the level of groundwater drawdown will not impact on the cultural landscape. However, there are residual questions in relation to the level of water table drawdown. The additional information provided in the Hume Coal RTS illustrated that the impact on three State Heritage Register (SHR) items outside the project area but not on the items that are within or partly within the Project area where the level of water table drawdown is greater. Furthermore, the impacts were based on the 67th percentile and not the 90th percentile and the level of water table decline is not confirmed.	Section 2.1 Section 4.2 Section 5.1
285	The Commission notes that the historic heritage impacts of the Project within the locality have been peer reviewed by the Heritage Council of NSW against the requirements of relevant Government policy frameworks. The Commission notes that the Heritage Council of NSW retained concerns which included:	Addressed in EMM (2020a)
	the adequacy of the assessment on the impacts on Mereworth House; and	Addressed in EMM (2020a) Brouwer (2020a)
	the need for a detailed assessment of the impacts of the Project on the Berrima, Sutton Forest and Exeter cultural landscape.	EMM (2020a) Brouwer (2020b) Section 4.2 Section 5.1
286	At this stage of its assessment the Commission finds that it is not satisfied with the information provided up to this point regarding historic heritage impacts. The Commission considers the magnitude of water table drawdown is not confirmed and thus there is a potential change to the aesthetic significance of the heritage items' settings (gardens, tree plantings) and cultural landscape. The SHIA relies on the VIA and further information provided with the Hume Coal RTS to assess the visual impacts of the surface infrastructure on Mereworth House, other heritage items and the cultural landscape. However, the visual impact assessment has shortcomings (that are addressed separately) and the impacts on heritage significance would need to be reassessed in accordance with an updated visual impact study.	EMM (2019) Section 4.2 Section 5.1
287	The Commission makes the following recommendations that will require further information and/or assessment:	-
R16	Further information should be provided to allow the assessment of the potential impact of water table drawdown on heritage items (including gardens, plantings and landscape settings) within or in the vicinity of the Project area. The information should include confirmation of the existing level of the water table and the anticipated drawdown at both the 67th percentile and 90th percentile.	Brouwer (2020b) Section 2.1 Section 4.2 Section 5.1
R17	The Applicant should address the recommendation of the Heritage Council of NSW's correspondence to the Department dated 17 August 2018 as referenced in paragraph 283.	Addressed in EMM (2020a)
R18	The Statement of Heritage Impact Assessment should be updated in response to recommendations R16 and R17, and the visual impact of the project on the significance of the above items and the cultural landscape in accordance with an updated visual impact assessment (see R15 in Visual Impact recommendations).	Addressed in EMM (2020a and 2020b) Brouwer (2020b)

Table 1.3 describes where this report addresses each item relevant to biodiversity. A number of items have been addressed in the *Hume Coal and Berrima Rail Project Response to Submissions Report*, Chapter 13 (EMM 2018).

Table 1.3 Response to IPC report on matters relating to Biodiversity

Reference number	IPC assessment considerations	Location where addressed
338	The Commission in its assessment of merits of the Project has had regard to biodiversity impacts. The Commission has had regard to the Material before it and given consideration to the issues raised in public submissions. Relevant excerpts from the submissions included:	-
	our local environment is unique with rich biodiversity, complex ecosystems, intricate waterways and a wide variety of landform, soils and living conditions;	Addressed in EMM (2018)
	biodiversity must be protected from all and every activity that would threaten it;	Addressed in EMM (2018)
	the biodiversity assessment clearly identifies that there will be negative impacts of the proposed development on an identified critically endangered ecological community and two threatened flora species;	Addressed in EMM (2018)
	the shire is considered to be a biodiversity hotspot and is one of the most biodiverse regions in Australia; and	Addressed in EMM (2018)
	impacts on both native vegetation and planted exotic gardens and trees associated with the loss of groundwater supplies.	Addressed in EMM (2018) and this report
339	The Commission notes the Applicant's attempts to best reduce surface impacts from infrastructure in the mine design and acknowledges that during its site inspection and locality tour it was apparent that the Project site has already been significantly cleared for farming purposes and that there has been significant historical investment in the establishment of exotic trees and gardens in the area.	Chapter 4
340	The Commission finds that the Applicant and Department have considered and assessed the impacts on biodiversity, and at this stage of its assessment the Commission finds that it is generally satisfied with the information provided up to this point regarding biodiversity impacts on native species, however it is not satisfied that appropriate consideration and assessment has been given to the possible impacts of water table decline on exotic trees and gardens. The Hume Coal EIS reporting is based on eucalyptus tree species and their estimated rooting depths. Nothing has been reported on the rooting depths of introduced garden plants and exotic trees.	This report
341	The Commission makes the following recommendations that will require further information and/or assessment:	-
R19	The Applicant is to undertake further technical assessment on the impacts on private gardens, exotic trees and native vegetation from a declining water table.	Section 4.3 Section 5.1 Section 5.2 Technical assessment on the impacts of the project on native vegetation from a declining water table has been assessed previously and is presented in Section 13 of the RTS Main Report, Volume 1.

2 Methods

2.1 Groundwater model uncertainty analysis

This impact assessment is based on the results of the groundwater modelling uncertainty analysis completed in support of the RTS (EMM 2018). Groundwater model uncertainty analysis gives insight into the likelihood of a project meeting or exceeding impacts predicted in the median case (based on the uncertainty inherent in the choices of model parameters). Percentile classes (Table 2.1) are used to present the results of the uncertainty analysis.

Table 2.1 Uncertainty percentile classes

Narrative descriptor	Percentile class	Description
Very likely	0-10%	Likely to occur even in extreme conditions
Likely	10-33%	Expected to occur in normal conditions
About as likely as not	33-67%	About an equal chance of occurring as not
Unlikely	67-90%	Not expected to occur in normal conditions
Very unlikely	90-100%	Not likely to occur even in extreme conditions

IPC recommendation R16 requires assessment of the potential impacts of the predicted groundwater level drawdown on vegetation and cultural heritage landscapes using the results of the 67th percentile (unlikely to occur) and the 90th percentile (very unlikely to occur) uncertainty analysis. The model outcomes for the 67th percentile provide a conservative prediction of the impacts caused by the Project. While these are useful when considering worst-case outcomes, results higher than the 67th percentile are considered 'unlikely', or 'not expected to occur' (Table 2.1) when considered in line with IESC guidelines (Middlemiss and Peeters 2008). Likewise results higher than the 90th percentile are considered 'very unlikely' or 'not likely to occur even in extreme conditions'. The model outcomes for the 50th percentile represent the median result (ie lie in the middle of the 33-67% percentile class) and are considered to have an equal chance of occurring or not occurring, and therefore is more likely than the 67th and 90th percentiles.

As presented in earlier submissions, the Hume Coal groundwater model has undergone numerous reviews by many leading experts in groundwater modelling in Australia, including a review by the then DPE's expert Mr Hugh Middlemis (HydroGeoLogic Pty Ltd). Hume Coal recently engaged Dr Lloyd Townley of GW SW Pty Ltd, an expert with over 40 years of experience in groundwater modelling, to independently review the RTS groundwater model. Dr Townley's review finds that the modelling undertaken for the Project is fit for purpose, which is predicting groundwater inflows to the proposed mine and drawdown of the watertable within and near the Project area (Townley 2020).

The predicted impact of watertable drawdown has been modelled using the RTS regional model. The model predicts results for bores and areas of interest, with reference to the nearest model cell for the location of the bore and point of interest. It should be noted that while the model is accurate at the regional scale, there will be differences between model predicted depth to groundwater and reality at a local scale (ie at a bore or tree level). However, this does not mean that the groundwater model cannot be used to assess the potential effects of the changes on receptors. The groundwater model is consistent with industry standards and provides guidance on the potential watertable drawdown due to the project.

2.2 Study area

The study area for the groundwater dependence assessment presented in the EIS and RTS reports was defined as the groundwater model domain. For the purposes of this assessment, the study area has been refined and delineated into two study areas.

To assess impacts on heritage items and private gardens, the study area is defined as the 2-metre (m) drawdown contour for the 90th percentile results shown on Figure 4.1 (the 90th percentile study area). The 90th percentile study area is 15,792 ha.

To assess impacts on cultural landscapes, the study area is defined as the common boundary of the previously listed landscape areas *Key Historic Unit 6 – Sutton Forest Landscape Area* on the superseded Wingecarribee LEP 1993, the non-statutory landscape area *Exeter/Sutton Forest Landscape Conservation Area* recognised by the National Trust of Australia (NSW) and the abovementioned predicted 2 m drawdown extent for the 90th percentile modelling results (the landscape conservation study area). The landscape conservation study area is 11,108 ha (Figure 4.1).

Parts of the common boundary of *Key Historic Unit 6 – Sutton Forest Landscape Area* and *Exeter/Sutton Forest Landscape Conservation Area* (the cultural landscapes) lie outside the landscape conservation study area (ie outside the area where drawdown predictions are greater than 2 m), to the north-east and south. The total extent of the cultural landscape is 14,636 ha.

2.3 Site inspection

A site inspection was conducted during the week of 30 September 2019 by Katie Diver (Ecologist), Pamela Kottaras (Archaeologist) and Catherine Brouwer (Landscape Planner/Registered Landscape Architect). The purpose of the inspection was to identify commonly planted trees and shrubs in the areas of interest. An inspection was completed of sites that were accessible, including Mereworth House and Garden, Boral Cement Works, the Bank of NSW and Remembrance Driveway Gardens. A brief inspection was conducted from the roadside of sites to which access was not possible. Inspections were also conducted of the cultural landscape conservation areas from prominent viewpoints. The results of the site inspection and literature review were used to inform the list of species commonly planted in private gardens.

2.4 Review of garden species response to reduced water availability

Where available, descriptions of historic gardens were reviewed using the *State Heritage Register* (SHR) and *Wingecarribee Local Environmental Plan 2010* (Wingecarribee LEP). A review of garden species identified during the site inspection and literature review was undertaken by an arboricultural specialist. The review focused on the origin, climate, biology, typical rooting depths and response to reduced water availability of these species to assess their vulnerability to shallow watertable decline.

Commonly planted species identified in the historic gardens visited during the site inspection were provided to an arboricultural specialist (Tree Survey Arboricultural Consultants). The arboricultural specialist assessed each species vulnerability to a declining watertable by examining each species:

- origin;
- typical climate;
- biology;
- typical root structure and rooting depths; and
- tolerance to reduced water availability.

The Melbourne University - Burnleigh Plant Guide Online (University of Melbourne 2016) was used to determine each species level of drought tolerance. This has been used to determine each species tolerance to reduced water availability.

2.5 Definition of potential drawdown risk areas

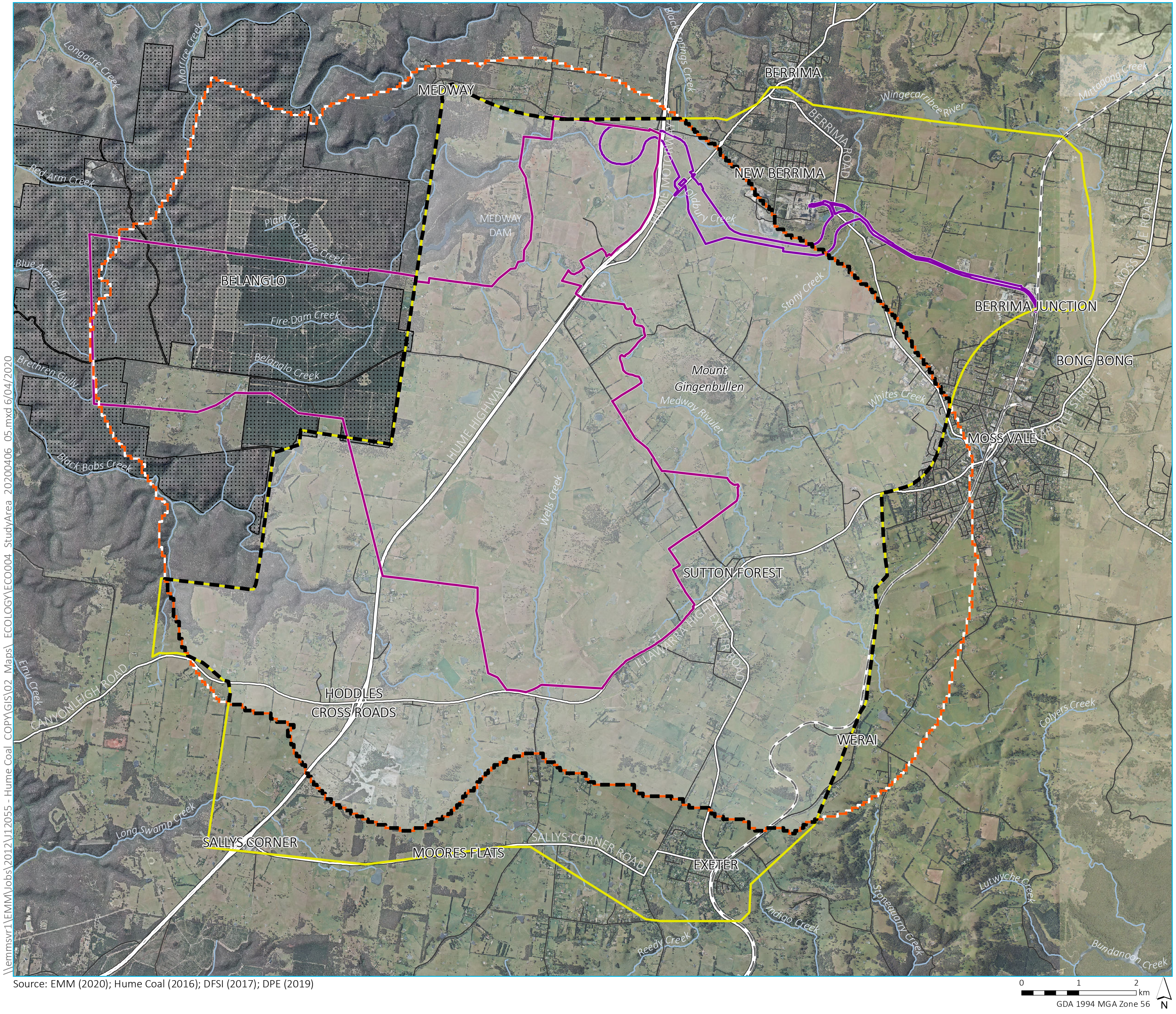
2.5.1 Data review

Spatial data and historic heritage studies were reviewed to identify heritage items that may have associated cultural landscapes, gardens and plantings within the study area:

- items listed on the SHR;
- landscape items, landscape conservation areas and general items listed on the Wingecarribee LEP;
- previously listed landscape areas *Key Historic Unit 6 – Sutton Forest Landscape Area* on the superseded Wingecarribee LEP 1993;
- non-statutory landscape area *Exeter/Sutton Forest Landscape Conservation Area* recognised by the National Trust of Australia (NSW);
- Hume Coal Project Environmental Impact Statement (EMM 2017a) and Appendices;
- Berrima Rail Project Environmental Impact Statement (EMM 2017b) and Appendices;
- Hume Coal and Berrima Rail Project Response to Submissions: Main Report (EMM 2017d);
- cultural landscapes identified in *Hume Coal and Berrima Rail Project Cultural Landscape Assessment* (Brouwer 2020b);
- Wollongong 1:250 000 Geological Sheet (Rose 1966);
- Hume Coal and Berrima Rail Project Updated Water Assessment (EMM 2020c);
- vegetation mapping in Wingecarribee Biodiversity Strategy (ELA 2003);
- LiDAR point cloud data (DFSI 2014; 2018); and
- Hume Coal Project Revised Groundwater Modelling for Response to Submissions (HydroSimulations 2018).

2.5.2 Heritage items

ArcMap was used to define areas of potential drawdown risk during drought conditions in local and state-listed heritage items within the study area. Listed heritage items were clipped to the study area, and trees and gardens occurring within these were digitised. Listed heritage items (and their associated trees and gardens) were then clipped to areas where Hawkesbury Sandstone outcrops at the surface (refer to Section 4.1).



KEY

- Hume Coal Project area
- Berrima Rail Project area
- Cultural landscape study area
- Historic landscapes
- Predicted 2 m drawdown extent (90th percentile)

Existing environment

- Rail line
- Major road
- Minor road
- Named watercourse
- Waterbody
- Belanglo State Forest

Source: EMM (2020); Hume Coal (2016); DFSI (2017); DPE (2019)

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Study area

Hume Coal and Berrima Rail Project
Groundwater dependence assessment
for cultural heritage landscapes and gardens
Figure 2.1

HUMECOAL PROJECT

EMM creating opportunities

Depth to groundwater surfaces were created for existing conditions (Digital Elevation Model (DEM) minus pre-mining watertable elevation). Resultant depth to groundwater surfaces were then reclassified into the following categories, following Serov *et al* (2012):

- high potential for groundwater interaction (depth to groundwater ranges from 0 to 3 mbgl);
- moderate potential for groundwater interaction (3 to 5 mbgl); and
- low potential for interaction (5 to 10 mbgl).

These were intersected with the height models described above to provide a modelled existing depth to groundwater for each vegetation category. All modelled assessment surfaces are of 50 m cell size.

2.5.3 Cultural landscapes

ArcMap was used to define areas of potential drawdown risk during drought conditions in non-statutory cultural landscapes (ie *Key Historic Unit 6 – Sutton Forest Landscape Area* on the superseded Wingecarribee LEP 1993 and *Exeter/Sutton Forest Landscape Conservation Area* recognised by the National Trust (NSW)) within the study area. The non-statutory cultural landscape boundaries were merged and clipped to the study area (referred to as the landscape conservation areas) and then to areas where Hawkesbury Sandstone outcrops at the surface (refer to Section 4.1).

A Digital Elevation Model (DEM) and Digital Surface Model (DSM) were generated in ArcMap from publicly-available LiDAR point cloud data (captured in 2014 and 2018). Surface features were extracted by subtracting the DEM from the DSM. The model excluded heights less than 0.5 m. This was clipped to the landscape conservation area boundary, within the study area (ie the landscape conservation study area, Figure 4.1).

Vegetation in the landscape conservation study area was classified into native vegetation, non-native vegetation (ie trees and shrubs) and exotic grasslands. As stated in Table 1.2, the impacts of the project on native vegetation from a declining watertable has been assessed previously, including areas within the landscape conservation study area, and is presented in Section 13 of the RTS Main Report, Volume 1. Accordingly, the assessment of a declining watertable in the landscape conservation areas is restricted to non-native vegetation and exotic grasslands.

The DEM was used to define all vegetation polygons in the landscape conservation study area. Native vegetation canopy polygons from the Wingecarribee Biodiversity Strategy (EcoLogical 2003) were erased from the DEM to define polygons for non-native vegetation.

Depth to groundwater surfaces were created for existing conditions relevant to non-native vegetation (DEM minus pre-mining watertable elevation). Resultant depth to groundwater surfaces were then reclassified into the following categories, following Serov *et al* (2012):

- high potential for groundwater interaction (depth to groundwater ranges from 0 to 3 mbgl);
- moderate potential for groundwater interaction (3 to 5 mbgl); and
- low potential for interaction (5 to 10 mbgl).

These were intersected with the height models described above to provide a modelled existing depth to groundwater for each groundwater interaction category. All modelled assessment surfaces are of 50 m cell size.

Depth to groundwater surfaces were also created for existing conditions relevant to exotic grasslands (DEM minus pre-mining watertable elevation). Resultant depth to groundwater surfaces were then reclassified into the following categories, informed by exotic perennial grass rooting depths (Lodge and Murphy 2006):

- high potential for groundwater interaction (depth to groundwater ranges from 0 to 1 mbgl).

The regional scale RTS groundwater model predicts watertable drawdown as a result of the simulated Hume Coal Project, including low-lying grassland areas where the watertable is shallow. Under existing pre-mining conditions, the watertable is naturally deeper in higher elevated areas and shallower in low lying topographical areas, including around watercourses where groundwater discharges as baseflow. As such, the assessment only considers shallow groundwater (less than 5 m below ground surface) areas within close proximity to or adjacent to watercourses.

2.5.4 Private gardens

ArcMap was used to define areas of potential drawdown risk during drought conditions for private gardens in the study area (Figure 4.1) in areas where Hawkesbury Sandstone outcrops at the surface (refer to Section 4.1). Depth to groundwater surfaces were created from groundwater modelling results (existing groundwater level; predicted groundwater level (existing groundwater level minus groundwater drawdown (50th, 67th, 90th percentiles)). Existing groundwater level, and each predicted groundwater level, were subtracted from the DEM to give depth to groundwater surfaces that were then categorised (0−3, 3−5, 5−10). Existing DTGW was then unioned with other predicted DTGW to compare drawdown risk for private gardens.

The following areas were removed to define the maximum extent of shallow groundwater (ie 0−10 mbgl) available to and potential drawdown risk to private gardens:

- areas of native vegetation;
- exotic grasslands; and
- pine forest in Belanglo State Forest.

It should be noted that the maximum extent of potential drawdown risk is conservative, and private gardens would only be potentially impacted during drought conditions if they contain the species identified as drought-sensitive (Table 5.3) and are not watered as normal.

2.6 Impact assessment

For heritage gardens and private gardens in the study area and non-native vegetation and exotic grasslands in the landscape conservation study area, depth to groundwater surfaces were created for the predicted maximum mining induced drawdown for the 50th, 67th and 90th percentiles (existing modelled depth to groundwater minus predicted (maximum) mining induced drawdown, with the result subtracted from the DEM). Resultant predicted (maximum) depth to groundwater surfaces were then reclassified into 0−3 mbgl, 3−5 mbgl and 5−10 mbgl categories. These were intersected with the height models described above to give predicted (maximum) depth to groundwater for each vegetation category. All modelled assessment surfaces are of 50 m cell size.

A union was performed in ArcMap with the modelled existing and predicted maximum depth to groundwater and each groundwater dependence category. Groundwater dependence categories were then compared to create categories for wooded vegetation (ie heritage gardens, non-native vegetation in the landscape conservation study area and private gardens) based on the change from the pre-mining to predicted maximum depth to groundwater categorisation and to inform the impact assessment.

A risk-matrix was developed to assess potential drawdown risk in woody vegetation during drought conditions. These categories and their associated potential drawdown risk during drought conditions are shown in Plate 2.1.

Predicted (maximum) depth to groundwater						
Existing modelled depth to groundwater (mbgl)		0 – 3 m	3 – 5 m	5 -10 m	> 10 m	Potential drawdown risk during drought conditions
	0–3 m High potential for groundwater interaction	None	Low	Moderate	Moderate	
	3–5 m Moderate potential for groundwater interaction	None	None	Moderate	High	
	5–10 m Low potential for groundwater interaction	None	None	None	High	

Plate 2.1 Potential drawdown risk categories for woody vegetation in historic gardens, non-native vegetation in the landscape conservation study area and private gardens

A risk-matrix was also developed to assess potential drawdown risk in exotic grasslands during drought conditions. These categories and their associated potential drawdown risk during drought conditions are shown in Plate 2.2.

Predicted (maximum) depth to groundwater				
Existing modelled depth to groundwater (mbgl)		0 – 1 m	> 1 m	Potential drawdown risk during drought
	0–1 m High potential for groundwater interaction	None	High	

Plate 2.2 Potential drawdown risk categories for exotic grasslands in the landscape conservation study area

3 Vegetation interactions with groundwater

3.1 Background

While no guidelines have been developed to assess groundwater impacts on cultural heritage gardens, plantings and landscapes, the Risk Assessment Guidelines for Groundwater Dependent Ecosystems (Office of Water 2012) provides a framework for the identification of vegetation interacting with groundwater and understanding their degree of groundwater dependence. Similarly, this approach can be used to assess groundwater impacts on native and non-native vegetation, including privately owned gardens.

Vegetation interactions with groundwater can be described as:

- non-dependent (ie do not access groundwater);
- facultative (have some degree of dependence on groundwater); and
- entirely dependent/obligate (ie essential to vegetation functioning).

Non-dependent vegetation does not have access to groundwater (ie groundwater is too deep to access) and the vegetation relies solely on rainfall or surface flows to fulfill its water requirements. Vegetation with a facultative dependence would rely on groundwater to partially meet its water requirements, but would also rely on rainfall, surface flows and watering. Although rainfall would contribute to water levels, entirely dependent/obligate ecosystems are nearly exclusively dependent on groundwater for functioning (ie groundwater dependent wetlands or karst/cave ecosystems).

There are seven different types of groundwater dependent ecosystems (noting that stream baseflow is both a sub-surface and surface ecosystem), comprising:

- sub-surface ecosystems:
  - karst/cave ecosystems;
  - aquifer ecosystems; and
  - stream baseflow ecosystems;
- surface ecosystems:
  - groundwater-dependent wetlands;
  - stream baseflow ecosystems;
  - estuarine and near-shore ecosystems; and
  - terrestrial vegetation.

For the purposes of this assessment, all identified vegetation types are categorised as 'terrestrial vegetation', being a surface ecosystem (and noting that other groundwater dependent ecosystems were assessed rigorously as part of the biodiversity assessments for the EIS and revised in the RTS). The interaction of terrestrial vegetation with groundwater is discussed further in Section 3.2.

3.2 Interaction of terrestrial vegetation with groundwater

For many terrestrial plants, groundwater forms only part of the overall water requirement, particularly where rainfall is seasonal and soil water (water droplets available in soil) has the potential to be regularly replenished (Howe *et al* 2007). Vegetation will draw water from sources that require the least amount of energy, meaning that vegetation will use shallow soil water first before seeking deeper soil water or groundwater (Eamus and Froend 2006). Where there is insufficient soil water to meet plant water requirements, plants that can access groundwater will become increasingly dependent on that groundwater source as soil water is depleted (Howe *et al* 2007), ie have a facultative groundwater dependence. Groundwater becomes less important as a water source to terrestrial vegetation when depths exceed 10 mbgl (Froend and Loomes 2005), as most plants do not have roots long enough to access this deeper groundwater.

Terrestrial vegetation relies on the availability of groundwater below the surface but within its rooting depth. Woody terrestrial vegetation is generally characterised by a large deep tap root that extends to the watertable (where present). Water is generally accessed from the capillary fringe immediately above the saturated zone, as root growth is inhibited by saturation and low oxygen (Stygoecologia 2013).

Sown exotic perennial grasslands such as those occurring within the project area and landscape conservation study areas have been reported as ranging from 0.65 to 1 mbgl (Lodge and Murphy 2006). Given their very shallow rooting depths, exotic perennial grasslands do not have the same capability as wooded ecosystems to utilise deeper groundwater, and therefore would have a facultative-opportunistic groundwater dependence where the watertable is very shallow (ie between 0−1 mbgl).

3.3 Rooting depths, climate and surface geology

Root structure and rooting depths vary across vegetation types and range from shallow to deep, but will also vary between soil types for the same plant. Soil type and structure has a large influence on a plant's ability to access groundwater. Soils that are deep and well drained allow roots to grow to a greater depth. Deeper roots allow plants to draw groundwater from greater depths during drought and avoid hydraulic failure (Hacke *et al*. 2000). Although groundwater access is still possible, finer textured subsoil (eg clay and shale) has low permeability, restricting root growth (Xu and Li 2008). Roots are also capable of permeating into harder surface geologies like sandstone, exploiting cracks and fissures in the rock (Stygoecologia 2013).

Root systems tend to be shallower and wider in dry and hot climates, and deeper and narrower in cold and wet climates, except for trees (Schenk and Jackson 2002). The root systems of many woody trees and shrubs typically extend vertically and laterally into the soil retrieving water and nutrients from both deep and shallow soil layers. Shallow root systems are favoured over deeper root systems as the energy required for the plant to maintain shallow roots is lower (Stygoecologia 2013).

3.4 Water stress

Plants experience water stress when water availability to their roots is reduced. Measurable changes in the vigour of vegetation can include branch die-back, reduced growth and leaf shed (Serov et al 2012). Water stress reduces turgor (ie the pressure exerted by water that makes the plant rigid), which can inhibit growth and reproduction. Plants can adapt to drought and can employ strategies to survive for some time under water stress. These strategies comprise water stress tolerance and water stress avoidance (Lisar *et al* 2012). Grasslands may die back during times of drought during water stress but would rapidly re-colonise following rain.

Some plants can adapt to water stress and changes in groundwater levels by extending root networks to greater depths (Dillon *et al* 2009; Lisar *et al* 2012). However, if the groundwater depth exceeds the maximum rooting depth of a species, groundwater cannot be accessed as a water source. A watertable that declines faster than root growth will prevent groundwater access, leaving the only sources of water as rainfall and soil moisture (Dillon *et al* 2009), or watering. Minor changes to the groundwater regime may not have any adverse impacts but these ecosystems can die if the soil layer is dry and a lack of access to groundwater is prolonged (Serov et al 2012).

4 Results

4.1 Influence of water table height and geology on groundwater access

Plate 4.1 and Plate 4.2 provide conceptual diagrams of various vegetation types and the inferred groundwater access in the study area, separated to show the influence of surface geology on groundwater movement. In areas of shallow groundwater, terrestrial vegetation can have a 'facultative (opportunistic)' dependence on groundwater as it is present just below the root zone. Conversely, where the watertable is deeper, terrestrial vegetation is 'non-dependent', as plant roots cannot access groundwater.

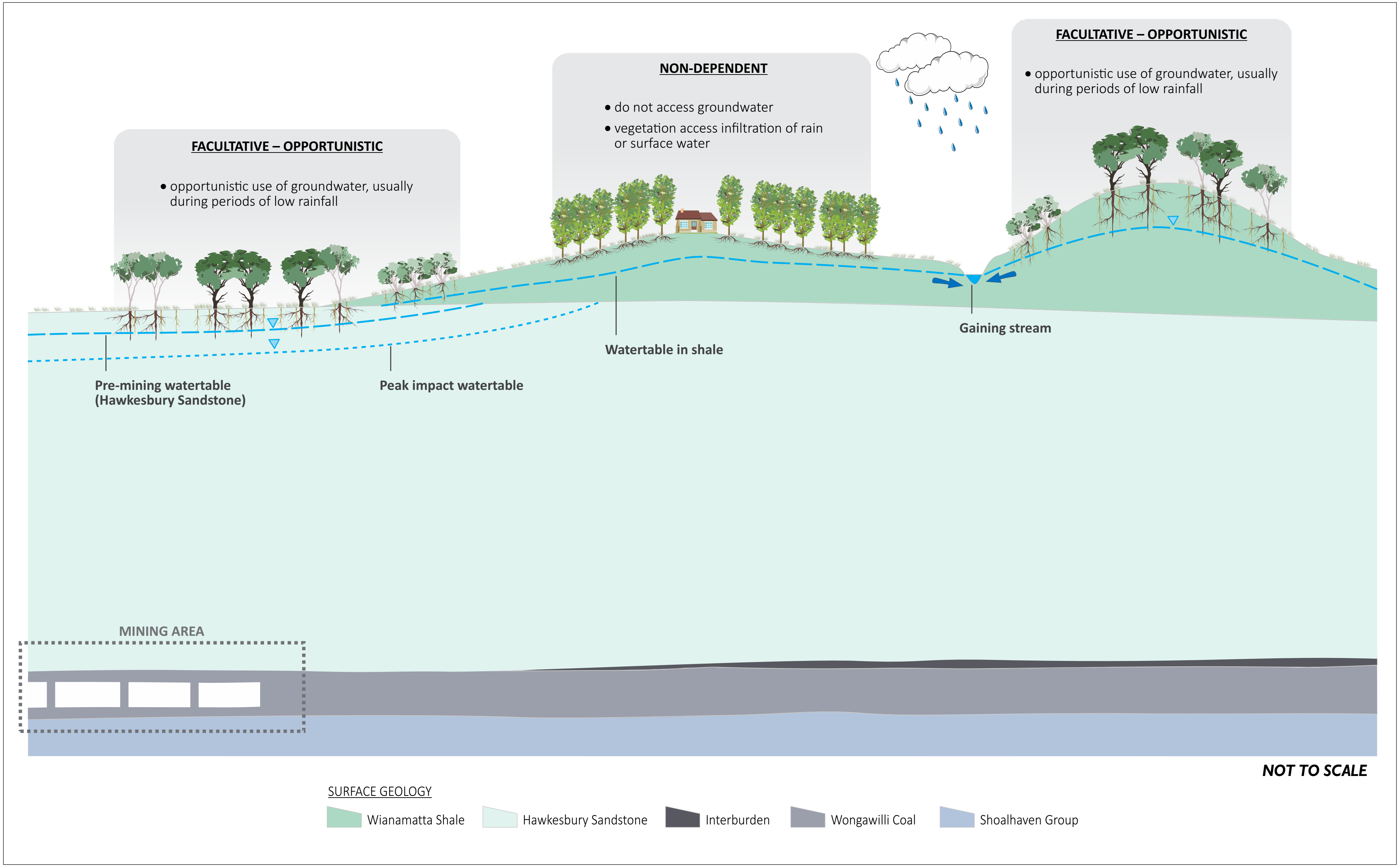
Plate 4.1 illustrates the conceptual understanding of groundwater movement in areas where the Wianamatta Group Shale is present at the surface (in the eastern part of the study area). Vegetation access to groundwater would vary in the Wianamatta Group Shale area with depth and permeability of the layer.

Plate 4.2 illustrates the conceptual hydrogeological understanding in areas where the shale is absent and the Hawkesbury Sandstone outcrops at surface (generally in the western part of the study area). Vegetation access to groundwater would vary where the Hawkesbury Sandstone is present at the surface and would be restricted to areas where roots could exploit cracks and fissures in the rock.

Based on the conceptual hydrogeological understanding, in areas where the Wianamatta Group Shale is weathered and thin (in the south and west of the study area) the Wianamatta Group Shale is likely to be unsaturated (dry), with the watertable located within the Hawkesbury Sandstone underlying the shale. Where the Wianamatta Group Shale thickens (in the east and the north), the watertable is present at varying depths depending on topography and hydrogeological properties of the Wianamatta Group Shale.

There is limited natural vertical connectivity between the Wianamatta Group Shale and the underlying Hawkesbury Sandstone aquifer, as evidenced by lower water levels in the Hawkesbury Sandstone. At most groundwater monitoring sites (such as at the HU035A and B monitoring sites; refer to the Water technical report, Appendix B of the IPC response report (EMM 2020c)), groundwater in the Wianamatta Group Shale is perched above the regional watertable and there are areas of unsaturated Hawkesbury Sandstone underlying the saturated Wianamatta Group Shale (refer to Plate 4.1 to Plate 4.3).

In areas where hydraulic connection between these two units may occur, groundwater would leak from the Wianamatta Group Shale to the Hawkesbury Sandstone at a low rate. Where there is no hydraulic connection between these two units (ie where the Hawkesbury Sandstone is unsaturated below the saturated Wianamatta Group Shale , e.g. perched groundwater), downward groundwater leakage would already be occurring at a maximum rate (see Plate 4.3). Mining induced drawdown would not result in increased leakage (vertical downward movement) of groundwater from the Wianamatta Group Shale to the Hawkesbury Sandstone, and any potential impacts to groundwater availability would be negligible. For this reason, areas of Wianamatta Group Shale overlying Hawkesbury Sandstone will not be further assessed for potential impacts to groundwater dependent vegetation.



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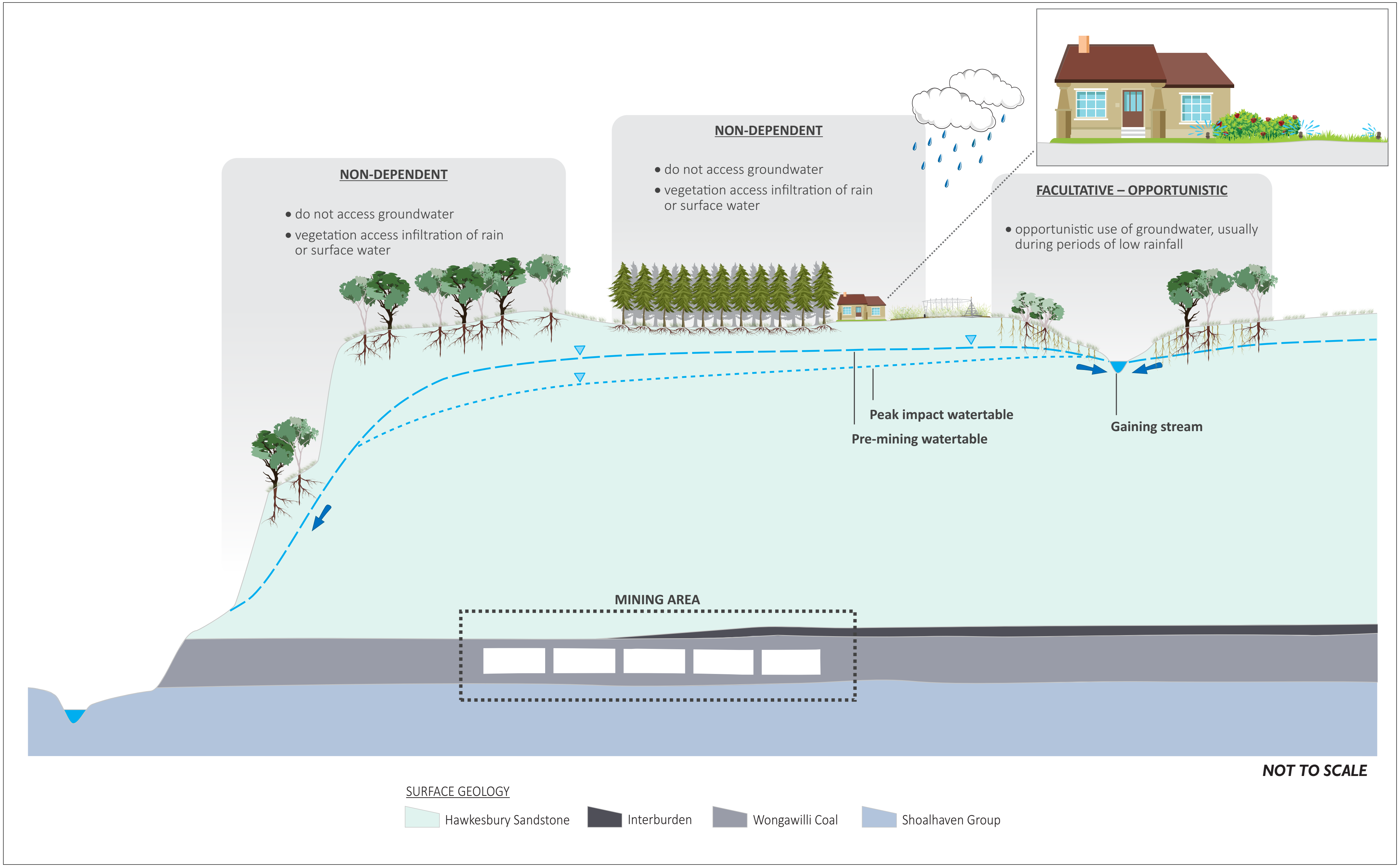
Conceptual diagram for surface vegetation interaction with groundwater – Wianamatta Group Shale outcrop areas

Hume Coal Project

Groundwater dependent ecosystem assessment for cultural landscapes and gardens

Plate 4.1

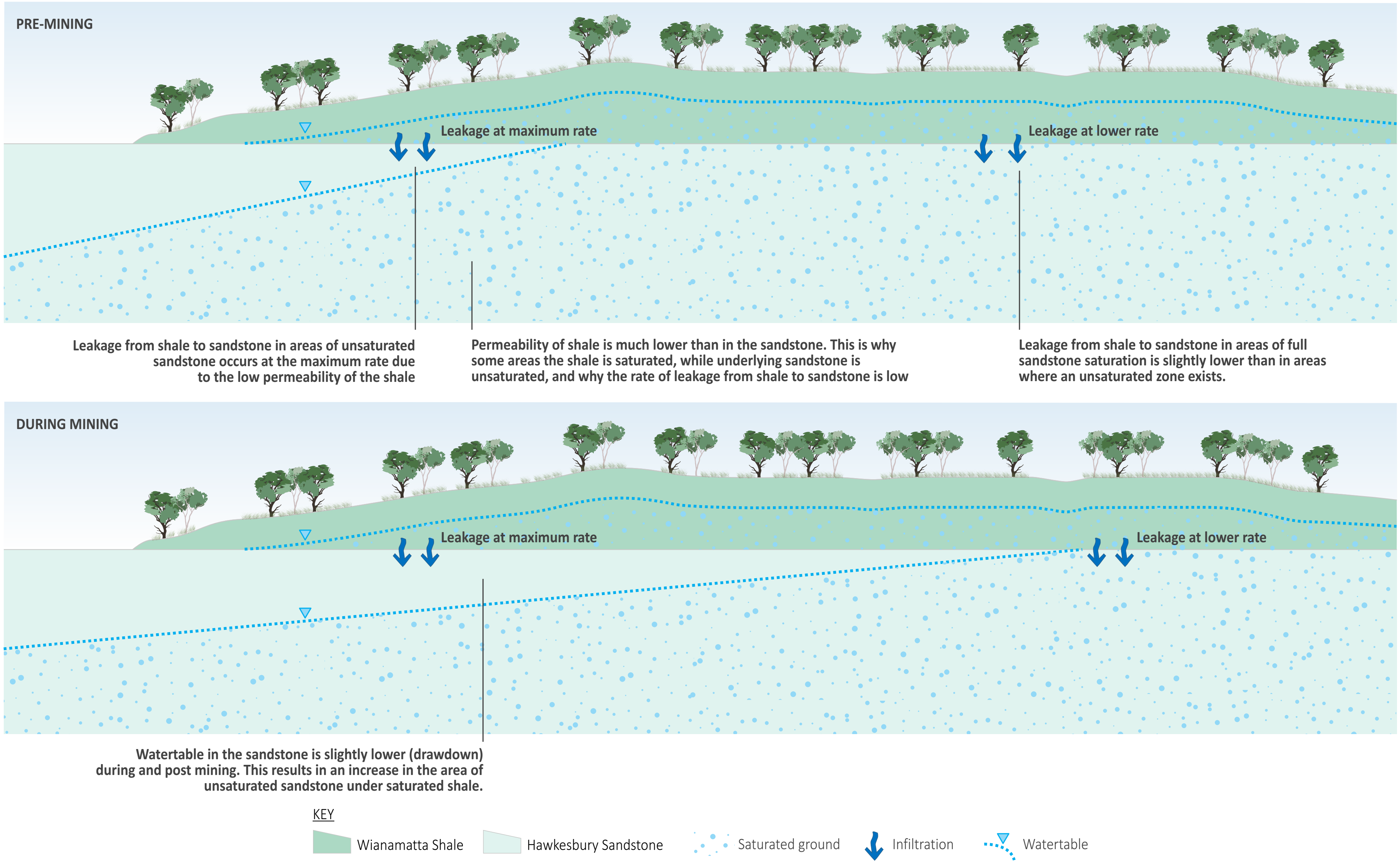


Conceptual diagram for surface vegetation interaction with groundwater – Hawkesbury Sandstone outcrop areas

Hume Coal Project

Groundwater dependent ecosystem assessment for cultural landscapes and gardens

Plate 4.2



Conceptual schematic representation of Wianamatta Group – Hawkesbury Sandstone relationship

Hume Coal Project

Groundwater dependent ecosystem assessment for cultural landscapes and gardens

Plate 4.3

EMM creating opportunities

HUMECOAL PROJECT

4.2 Cultural items in the study area

4.2.1 Overview

The study area contains 61 heritage items listed on the Wingecarribee LEP 2010 and/or the State Heritage Register. Heritage items in the study area and their conservation status are listed in Annexure A and shown on Figure 4.1. Note this excludes local and state listed heritage items that are outside the area of predicted maximum watertable drawdown when calculated at the 90th percentile.

Two landscape conservation areas, namely *Key Historic Unit 6 - Sutton Forest Landscape Area* previously listed on the Wingecarribee LEP 1993 and the non-statutory listing of the *Exeter/Sutton Forest Landscape Conservation Area*, by the National Trust of Australia (NSW), are also within the study area (referred to as the landscape conservation area). To date, the conservation values of the landscape conservation areas have not been well defined. A detailed assessment of their conservation and character is provided in Brouwer (2020b), with a summary provided below.

The landscape conservation study area is representative of the cultural landscape environment of the region and has historical, associational and aesthetic values. Its value is largely related to aesthetic appreciation of vegetation in the landscape. The vegetation types and forms with some heritage significance to the cultural landscape values, as defined by registered landscape architect Brouwer (2020b) include:

- windbreak/tree lines of pines, cypress and similar evergreen trees and roadside pine plantings (noting that these are new features that were not present until between 1997–2000);
- remnant roadside native vegetation;
- hawthorn, and similar, historical and reconstructed hedges;
- garden perimeter hedges including at road reserve edges;
- specimen trees and groups of trees -both native and exotic;
- remnant riparian corridor vegetation, including reconstruction and restoration planting; and
- historical gardens, at rural homesteads /villas, particularly as appreciated from the public realm.

Landscape character of the significant potential view zone surrounding the project area has also been characterised in the Updated Visual Impact Assessment (VIA) (see Figure 4.2, EMM 2020b) as:

- forested hills and ridges;
- plantation pine on hills;
- undulating pastoral lands;
- flat pastoral lands;
- peri-urban;
- urban; and
- Mount Gingenbullen.

For the purposes of this assessment, and to best identify potentially groundwater-dependent vegetation in the landscape conservation areas and assess impacts, the above categories were merged into:

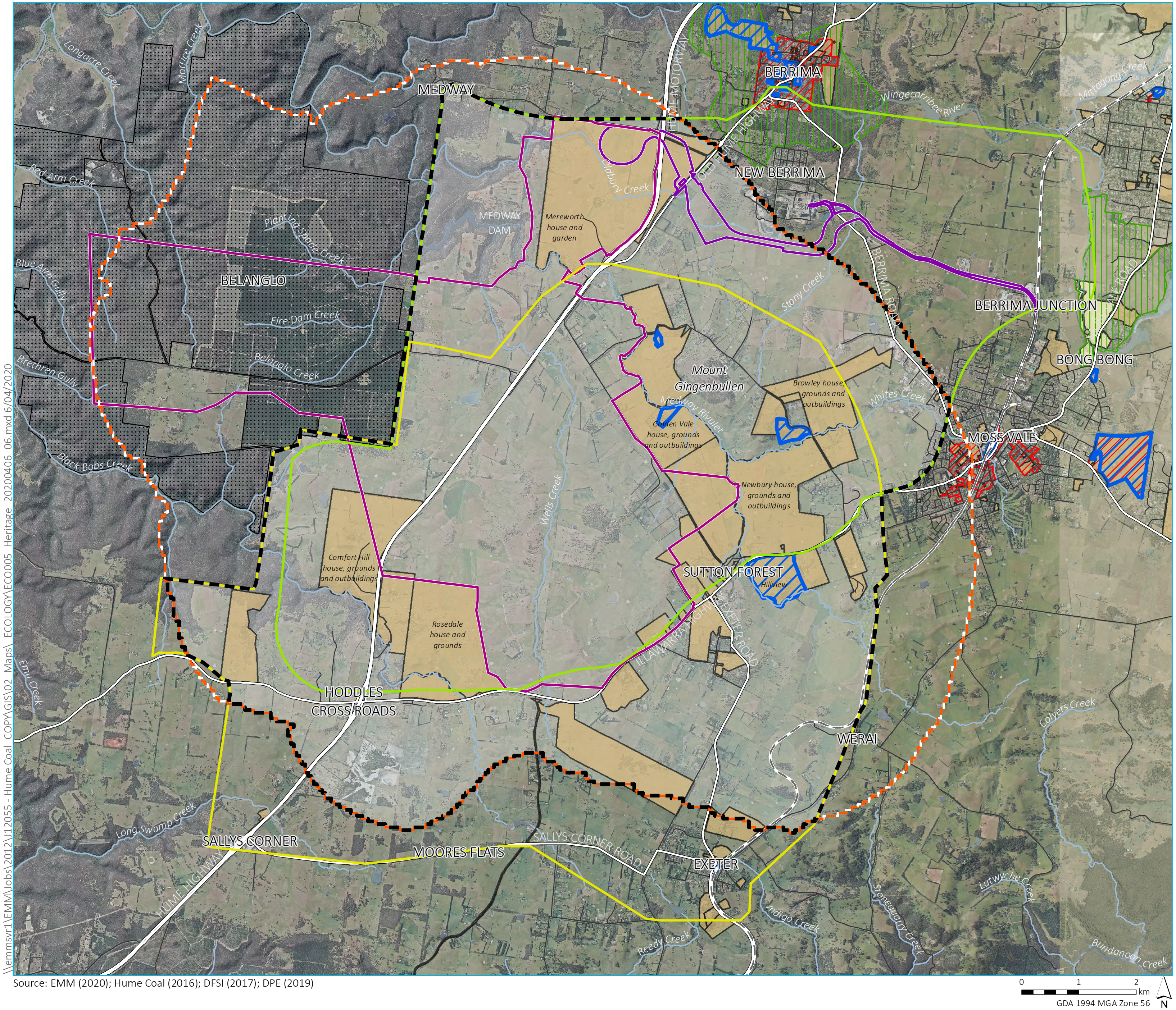
- non-native vegetation (comprising gardens, plantings, exotic trees, plantations and windrows); and
- exotic grasslands (comprising undulating and flat pastoral lands).

As stated in Table 1.3, the impacts of the project on native vegetation from a declining water table has been assessed previously and is presented in Section 13 of the RTS Main Report, Volume 1.

4.2.2 Heritage gardens with access to shallow groundwater

All heritage gardens occur in areas where the Wianamatta Group Shale outcrops at surface and therefore have a negligible risk of drawdown (see Section 4.1). The boundary between the Wianamatta Group Shale and Hawkesbury Sandstone intersects the property containing Mereworth House and Garden. Mereworth House and Garden, listed as having local significance under the Wingecarribee LEP lies on the Wianamatta Group Shale and therefore the listed heritage item has a negligible drawdown risk during drought conditions.

The property also contains planted pine windbreaks to the west and south-west of the house and garden, outside the heritage curtilage. Approximately 0.1 ha of these windbreaks have a low potential for interaction with groundwater (ie modelled pre-mining watertable lies at 5−10 mbgl). As the planted pine windbreaks overlie Hawkesbury Sandstone, further assessment is provided in Chapter 5.



Source: EMM (2020); Hume Coal (2016); DFSI (2017); DPE (2019)

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KEY

- Hume Coal Project area
- Berrima Rail Project area
- Cultural landscape study area
- Predicted 2 m drawdown extent (90th percentile)

Heritage Act 1977

- State Heritage Register

Heritage

- Conservation Area - General
- Conservation Area - Landscape
- Item - General
- Item - Archaeological
- Item - Landscape
- Berrima Key Historic Unit 6
- Sutton Forest/Exeter cultural landscape area

Existing environment

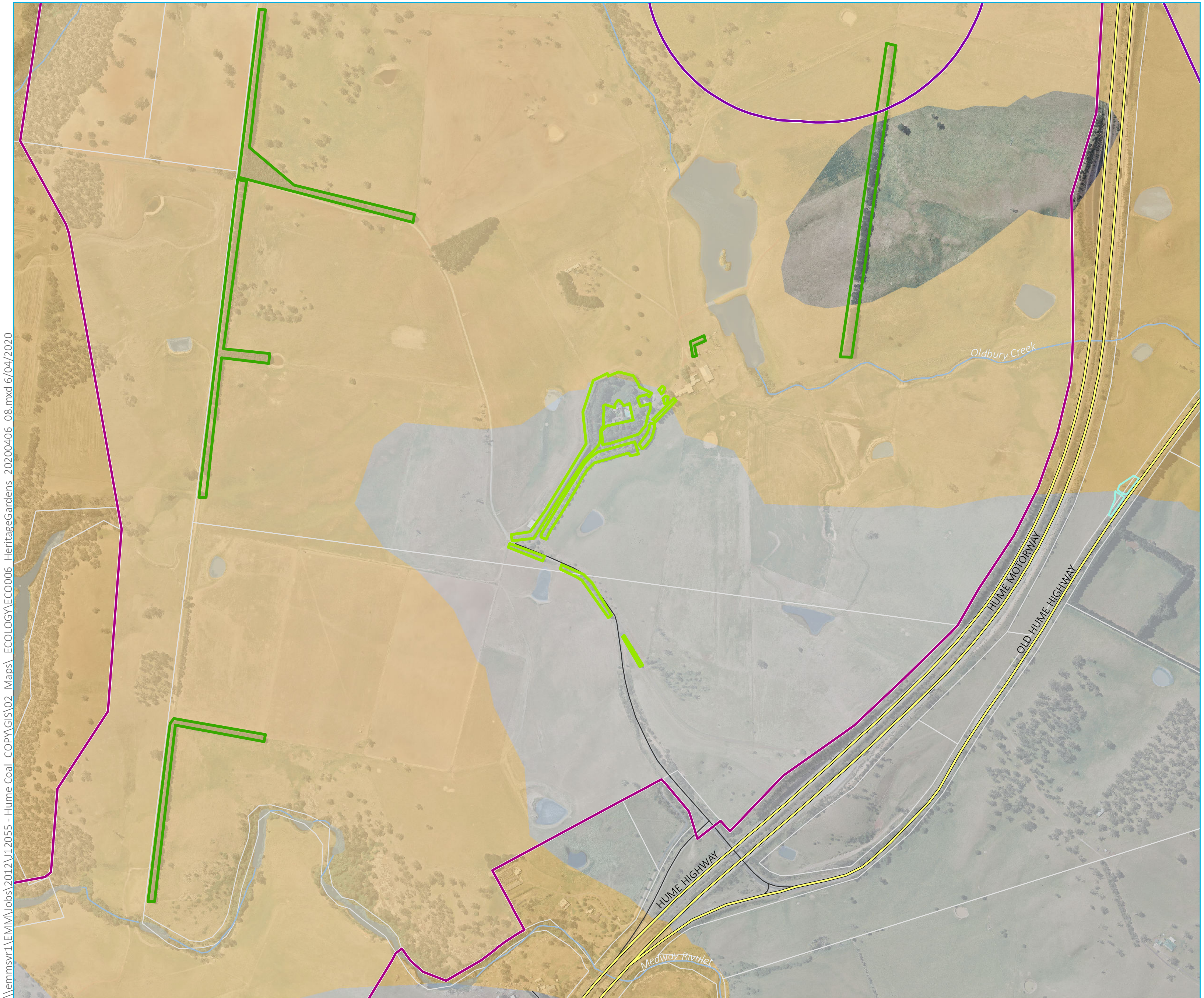
- Rail line
- Major road
- Minor road
- Named watercourse
- Waterbody
- Belanglo State Forest

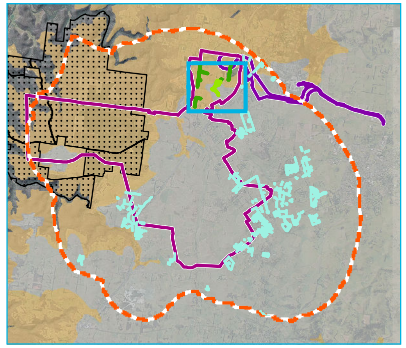
Cultural items in the project area

Hume Coal and Berrima Rail Project
Groundwater dependence assessment
for cultural heritage landscapes and gardens
Figure 4.1

HUMECOAL PROJECT

EMM creating opportunities





KEY

- Hume Coal Project area
- Berrima Rail Project area
- Predicted 2 m drawdown extent (90th percentile)

Planted gardens within listed heritage items

- Mereworth House and Garden
- Gardens and trees outside Mereworth heritage curtilage
- Other planted gardens within listed heritage items

Surface geology (250K)

- Hawkesbury Sandstone
- Wianamatta Shale

Existing environment

- Major road
- Minor road
- Named watercourse
- Waterbody
- Lot boundary
- Belanglo State Forest

Source: EMM (2020); Hume Coal (2016); DFSI (2017); DPE (2019)

0 250 500 m

GDA 1994 MGA Zone 56

N

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Heritage gardens with access to shallow groundwater

Hume Coal and Berrima Rail Project
Groundwater dependence assessment
for cultural heritage landscapes and gardens
Figure 4.2

4.2.3 Vegetation in the landscape conservation study area with access to shallow groundwater

Approximately 16.2 ha of non-native vegetation in the landscape conservation study area has access to shallow (0–10 mbgl) groundwater. Of this 16.2 ha, 4 ha has a high potential for groundwater interaction, 2.8 ha has a moderate potential for groundwater interaction and 9.4 ha has a low potential for groundwater interaction.

Approximately 3.2 ha of grasslands in the landscape conservation study area has access to shallow (0−1 mbgl) groundwater.

Table 4.1 Non-native gardens in the landscape conservation study area with access to shallow groundwater

Cultural landscape component	Depth to groundwater	Potential for groundwater interaction	Hawkesbury Sandstone surface geology
Non-native vegetation	0−3 m	High	4
	3−5 m	Moderate	2.8
	5−10 m	Low	9.4
Exotic grasslands	0-1 m	High	3.2

4.3 Private gardens

A typical root system is defined as the roots of most plants, including large trees, that typically extend 1 mbgl (Day et al 2010). However, depth is also influenced by soil type and watertable height and where suitable conditions exist, can extend to 10 mbgl.

Drought tolerance categories assigned by the Burnleigh Plant Guide (University of Melbourne 2016) have been used to determine garden species response to reduced water availability. The Guide defines drought as a shortfall of rainfall over that required by the plant, for an extended period, and is very site and location specific. The Guide states that drought tolerance mechanisms vary. For example, a plant that survives in the desert by tapping deep groundwater may perform poorly if grown in a shallow, compacted soil. In assessing drought tolerance, the soil quality of the planting site, as well as climatic extremes such as unusually extended periods without rainfall, should be considered.

The Burnleigh Plant Guide assigns four drought tolerance categories, namely 'very good', 'moderately good', 'average' and 'poor'. Various drought tolerance has been assigned where different species within the same genus, ie *Quercus sp.,* would have different drought tolerance responses. For this reason, various species have been conservatively assumed to be drought-sensitive.

These tolerance categories are based on 500−700 millimetres (mm) annual rainfall, for plants fully established in the landscape. As the study area (Moss Vale station 068045) receives a long-term average rainfall of 959.8 mm (ie. higher than the rainfall these tolerance categories was designed for), the categories are deemed suitable in determining species response to reduced water availability.

Drought tolerance categories (ie response to reduced water availability) are defined in Table 4.2.

Table 4.2 Drought tolerance categories for garden plants

Drought tolerance category	Description
Very good	Plant should perform acceptably without irrigation
Moderately good	Plant should perform acceptably without irrigation in a garden position sheltered from extreme heat, under normal rainfall patterns. Irrigation may be required during extended dry periods in the dry season.
Average	Plant will require some irrigation during the dry season to perform acceptably.
Poor	Plant requires regular irrigation during the dry season to perform acceptably.
Various	Different species within the genus (ie *Quercus sp.*) have different watering requirements.

Typical species recorded in heritage gardens, private gardens, plantings and roadsides in the landscape conservation areas are listed in Table 4.3. A description of the species biology, typical root system and rooting depths and responses to reduced water availability are also provided.

Species with a very good or moderately good tolerance to reduced water availability are unlikely to be impacted by drawdown if shallow groundwater is present in the area where they occur. Accordingly, these species are not assessed further. Conversely, species with various, poor and average tolerance to reduced water availability may be impacted by drawdown if shallow groundwater is present in the area where they occur. Potential impacts on these species are discussed further in Section 5.2.

Table 4.3 Requirements of typical species recorded in heritage gardens, private gardens, plantings and roadsides

Botanical name	Common name	Origin	Climate	Biology	Root system	Tolerance to reduced water availability	Species requirements	Ornamental features
Arbutus unedo	Strawberry Tree	Mediterranean regions, and south west Ireland	Cool, temperate	A wide-spreading and very dense-canopied evergreen small tree	Typical	Very good	Fruiting appears to be more prolific in stressed trees. Fruits are edible	Flowers: Terminal panicles of small white bell-shaped flowers in autumn and winter. Fruit: Ornamental strawberry-like fruit, yellow ripening to red.
Betula pendula	Silver Birch	Europe, northern Asia and northern Africa	Cool, temperate	Deciduous tree; upright, with ascending main branches and pendulous branchlets	Typical	Poor	Requires a cool moist site and is badly affected by drought. Ingestion can cause stomach cramps or more serious heart problems	Bark: Silvery-white peeling, with black lenticels, becoming dark grey and craggy with age.
Buxus sempervirens	Box	Western and southern Europe, western Asia and north Africa	Cool, temperate	A slow growing and very long-lived, very dense evergreen shrub, eventually becoming a gnarled tree	Typical	Moderately good	Long-lived, and very tolerant of clipping, hence its popularity for hedging; needs less attention than faster growing species. Very shade tolerant, and will tolerate full sun provided there is sufficient water available	None, does not flower.
Camellia sasanqua	Camellia	Evergreen coastal forests of Japan - southern Shikoku, Kyushu and the Ryukyu islands	Cool, temperate, subtropical	Graceful, arching evergreen shrub	Typical	Moderately good	More sun tolerant than Camellia japonica, and possibly more drought tolerant, but will not perform well in very dry sites	Flowers: Large showy flowers in single or double, smaller and more delicate than those of Camellia japonica, borne from autumn to winter. Many cultivars.

Table 4.3 Requirements of typical species recorded in heritage gardens, private gardens, plantings and roadsides

Botanical name	Common name	Origin	Climate	Biology	Root system	Tolerance to reduced water availability	Species requirements	Ornamental features
Cedrus atlantica glauca	Blue Atlas Cedar	Atlas Mountains, Morocco and Algeria	Cool, temperate	An evergreen conifer with tabular, spreading branches. Dramatic when mature	Typical	Moderately good	Very long lived, and best left to its own devices. More drought tolerant than Cedrus deodara, and slower growing	Foliage: Rich glaucous, blue-grey foliage.
Cedrus deodara	Himalayan Cedar	West Himalayas to Afghanistan	Cool, temperate	An evergreen conifer with layered, horizontal branches. The tips of the branches are down-turned	Typical	Average	Not as drought tolerant as Cedrus atlantica	Fruit: Female cones barrel shaped, 80-120 mm long, breaking up at maturity.
Cedrus sp.	Cedar	Mediterranean regions	Cool, temperate	Evergreen conifers with layered, horizontal branches	Shallow, spreading	Average	NA	None, does not flower.
Cephalothaxus harringtoniana	Japanese Yew	Japan and eastern Asia	Cool, temperate, subtropical	A dense, multi-stemmed evergreen shrub or small tree, with strongly upright branches. Dioecious	Typical	Average	Require a humid and sheltered location. Very tolerant of pruning, and suitable for hedging in shady areas. May be pruned into old wood	None, does not flower.
Chamaecyparis sp.	False Cypress	Siskiyou Mountains, Oregon and North California	Cool, temperate	The species is a tall and narrow conical evergreen conifer, but is usually grown in Australia as one of numerous cultivars	Typical	Average	Generally trouble free when young, but very sensitive to pollution, and Honey Fungus (Armillaria mellea). Cypress Canker may cause problems	None, does not flower.

Table 4.3 Requirements of typical species recorded in heritage gardens, private gardens, plantings and roadsides

Botanical name	Common name	Origin	Climate	Biology	Root system	Tolerance to reduced water availability	Species requirements	Ornamental features
Cotinus coggyria 'Purpurea'	Purple Smoke Bush	Mediterranean and south eastern Europe	Cool, temperate	A large rounded deciduous shrub; upright at first, but broadening with age	Typical	Very good	An extremely drought tolerant shrub	Foliage: Rounded leaves displaying brillant autumn foliage. Flowers: Feathery purple-pink panicles of flowers.
Cotoneaster sp.	Cotoneaster	China	Cool, temperate	An evergreen large shrub to small tree, of neat, rounded habit	Typical	Very good	A very resilient species, although plants have been observed to be very stressed in the prolonged drought of 2008–2009. Tolerant of saline soils	Flowers: Flat clusters of cream white flowers in spring. Fruit: Red pomes in numerous clusters.
Crataegus mexicana	Mexican Hawthorn	Mexico and parts of Guatemala	Cool, temperate	A deciduous, rounded, twiggy and thorny shrub to small tree	Typical	Moderately good	Due to its high pectin content, the fruit is industrially processed to extract pectin for the food, cosmetic, pharmaceutical, textile and metal industries	Flowers: White flowers in rounded corymbs in mid-spring. Fruit: Small showy golden yellow pomes.
Crataegus monogyna	Hawthorn	Europe, south-west Asia and north Africa	Cool, temperate	A deciduous, rounded, twiggy and thorny shrub to small tree. Thorns are 20–25 mm long	Typical	Moderately good	Susceptible to and a potential host of Fireblight (Erwinia amylovora), a devastating disease of pome fruits that is in 2009 not seriously established in Australia	Flowers: White flowers in rounded corymbs in mid-spring. Fruit: Small showy crimson pomes.
Crataegus oxycantha	Red Hawthorn	Northern Europe	Cool, temperate	A deciduous, rounded, twiggy and thorny shrub to small tree	Typical	Moderately good	NA	Flowers: White flowers in rounded corymbs in mid-spring. Fruit: Small showy crimson pomes.

Table 4.3 Requirements of typical species recorded in heritage gardens, private gardens, plantings and roadsides

Botanical name	Common name	Origin	Climate	Biology	Root system	Tolerance to reduced water availability	Species requirements	Ornamental features
Crataegus sp.	Hawthorn	Northern Hemisphere in Europe, Asia and North America	Cool, temperate	A deciduous, rounded, twiggy and thorny shrub to small tree	Typical	Moderately good	NA	Flowers: Prolific flowers in rounded corymbs in mid-spring. Fruit: Small pomes.
Cupressus macrocarpa	Monterrey Cypress	Cypress Point and Point Lobos, Californian coast	Temperate	Ultimately wide-spreading evergreen conifer; low branched, with massive ascending branches, although some selected forms are tighter in habit	Typical	Very good	Widely used as a hedge-windbreak plant, but will not respond if pruned back into old wood. Breaks up at about 100 years	None, does not flower.
Cupressus sempervirens	Italian Cypress	Mediterranean regions	Temperate	Tightly columnar, tall evergreen conifer, broadening with age	Typical	Very good	No special attention needed; cannot be pruned into old wood	None, does not flower.
Cupressus sp.	Cypress	Warm temperate regions in the Northern Hemisphere	Temperate	Extensive cultivation has led to a wide variety of forms, sizes and colours	Typical	Moderately good	NA	None, does not flower.
Cupressus torulosa	Cypress	Western Himalayas at high altitudes	Cool, temperate	Dense and compact evergreen conifer, with ascending branches	Typical	Moderately good	Young trees have a very distinctive spire-like tapered top and bulging base, becoming broader with age	None, does not flower.

Table 4.3 Requirements of typical species recorded in heritage gardens, private gardens, plantings and roadsides

Botanical name	Common name	Origin	Climate	Biology	Root system	Tolerance to reduced water availability	Species requirements	Ornamental features
Cuprocyparis leylandii	Lleyland Cypress	Garden origin: hybrids between Cupressus macrocarpa (cones) and Chamaecyparis nootkatensis	Cool, temperate, subtropical	A conical to columnar, very fast-growing upright evergreen conifer	Typical	Moderately good	Best suited to cool climates, but amazingly robust. Commonly used as a hedge, but will quickly grow into a large tree if left unpruned	None, does not flower.
Eucalyptus dives	Broad-leaved peppermint	South-eastern Australia	Temperate	A medium to large tree growing from an inconspicuous lignotuber	Typical	Very good	Usually grows in poor, dryish soils in open forest and woodland, usually in poor, shallow, stony soils in higher places	None, does not flower.
Eucalyptus mannifera	Brittle Gum	Inland ranges, Victoria, the ACT and New South Wales	Temperate	An open growing small to medium evergreen tree; may be erect and straight trunked, or more spreading and picturesque	Typical	Very good	Adaptable to various soils and climates providing the soils are well drained	None, does not flower.

Table 4.3 Requirements of typical species recorded in heritage gardens, private gardens, plantings and roadsides

Botanical name	Common name	Origin	Climate	Biology	Root system	Tolerance to reduced water availability	Species requirements	Ornamental features
Eucalyptus pauciflora	Snow Gum	Southern Queensland near Stanthorpe, Victoria, New South Wales, Tasmania, and a small occurrence in south-eastern South Australia; mainly in mountainous regions	Cool, temperate	A small evergreen tree with an open canopy	Typical	Moderately good	Cold tolerant. Requires well drained soils	None, does not flower.
Exocarpos cuppressiformis	Brush Cherry	Tasmania, and eastern Australia from South Australia to Queensland, in open forests	Cool, temperate, subtropical	A tree-like evergreen root parasite, resembling a rounded cypress	Typical	Very good	Plants are rarely available, as they are difficult to propagate and establish, so existing plants should be looked after where they occur. May be rejuvenated by coppicing. Fruit is a toxic green nut, supported by a red, fleshy, edible pedicel	Fruit: A toxic green nut, supported by a red, fleshy, edible pedicel.
Fagus sylvatica	European Beech	Europe	Cool, temperate	A broadly conical deciduous tree, with semi-pendulous branchlets. Graceful and very beautiful	Typical	Average	A tree for cool moist conditions; better in elevated sites. Leaves may burn on hot days in exposed sites; the purple-leaved forms are the most heat tolerant	Foliage: Vivid green in spring, bronze gold in autumn.

Table 4.3 Requirements of typical species recorded in heritage gardens, private gardens, plantings and roadsides

Botanical name	Common name	Origin	Climate	Biology	Root system	Tolerance to reduced water availability	Species requirements	Ornamental features
Fraxinus excelsio aurea pendula	Weeping Golden Ash	Garden origin	Cool, temperate	A medium deciduous tree, with a rounded to broadly pyramidal head	Typical	Average	Drought tolerance will depend on the rootstock used. No special maintenance needs	Foliage: Green turning clear yellow in autumn.
Ginkgo biloba	Maidenhair Tree	China	Cool, temperate	A primitive deciduous gymnosperm, narrow to broadly cone-shaped. Old specimens may have a weeping habit	Typical	Moderately good	Trees are dioecious; female trees bear foul smelling "fruit", and would be best avoided for street plantings	Foliage: Fan-shaped, autumn colour brilliant yellow.
Hedera sp.	Ivy	Europe, north Africa and western Asia	Cool, temperate	A woody-stemmed climber producing aerial roots along the stems. At reproductive maturity, which takes many years to reach, forms a shrub-like mound, losing its clinging habit	Typical	Moderately good	A useful and tough, extremely shade and moderately dry-tolerant self-attaching climber for covering walls, and for ground cover, also used as "topiary", trained around frames, in baskets and as cut foliage	None, does not flower.
Juniperous sp.	Juniper	Garden origin, Japan, around 1939.	Cool, temperate	Evergreen coniferous shrub	Typical	Moderately good	NA	None, does not flower.

Table 4.3 Requirements of typical species recorded in heritage gardens, private gardens, plantings and roadsides

Botanical name	Common name	Origin	Climate	Biology	Root system	Tolerance to reduced water availability	Species requirements	Ornamental features
Larix sp.	Larch	Europe	Cool, temperate	A conical deciduous conifer, with branches drooping, but upturned at the tips. Becomes wider with age. Growth rate is variable, depending on growing conditions	Typical	Poor	NA	Fruit: Small upright cones, retained for several years.
Liquidambar styraciflua	Liquid Amber	Eastern North America	Cool, temperate, subtropical	A broadly-pyramidal medium to large deciduous tree. Becomes rounded with age	Shallow, spreading	Average	Roots are large and vigorous and many are close to the surface, making it difficult to grow other plants beneath. Often implicated in blockage of drains and lifting of pavements. Brittle wooded, and subject to wind damage	Foliage: Glossy green above, lighter green beneath. Autumn colour yellow to deep crimson.
Magnolia sp.	Magnolia	South-eastern North America	Cool, temperate, subtropical	Group of small trees with fragrant flowers	Typical	Average	NA	Flowers: Ornamental, often fragrant flowers.
Malus sp.	Crab Apple	Said to be Japan, although perhaps an old Japanese garden hybrid	Cool, temperate	A widespreading, rounded deciduous small tree	Typical	Average	Generally trouble free. Susceptible to, and a potential host of, Fireblight (Erwinia amylovora), a devastating disease of pome fruits that in 2009 is not seriously established in Australia. Susceptible to Armillaria mellea (Honey Fungus)	Flowers: Prolific flowers.

Table 4.3 Requirements of typical species recorded in heritage gardens, private gardens, plantings and roadsides

Botanical name	Common name	Origin	Climate	Biology	Root system	Tolerance to reduced water availability	Species requirements	Ornamental features
Olea europaea. Subsp. Europaea	Olive	Mediterranean to India	Temperate	An evergreen large shrub to small tree. Old specimens are often multi-trunked, and very handsome, with glossy, billowing grey foliage	Typical	Very good	No special attention needed. May be clipped as a robust hedge. Susceptible to damage by heavy frosts	None, does not flower.
Olea sp.	Olive	Mediterranean to India, Africa and Asia	Temperate	A long-lived, vigorous, dense and spreading evergreen tree	Typical	Very good	NA	None, does not flower.
Paeonia suffruticosa	Paeonie	Bhutan, Tibet and China	Cool, temperate	A rounded, deciduous shrub with fleshy roots	Typical	Average	Peonies are cool to cold climate plants, and can be tricky in Australia in all but the coolest areas, although they can be surprisingly resilient, and will tolerate some drought once established	Flowers: Large delicate flowers with crepe-like petals. Cultivars may be red, pink, mauve, purple, white or occasionally pale yellow, and are often very double.
Picea sp.	Spruce	Western North America	Cool, temperate	A very stiff and regularly conical evergreen conifer	Typical	Average	Drought-stressed specimens become very unattractive	Fruit: Pendulous oblong female cones are borne towards the top of the tree.
Pinus radiata	Radiata Pine	Monterey County, California	Temperate	A fast-growing, large and statuesque evergreen conifer, with a very dark canopy	Typical	Very good	Extensively planted throughout southern Australia for timber, and as a shelter-belt tree on farms	None, does not flower.

Table 4.3 Requirements of typical species recorded in heritage gardens, private gardens, plantings and roadsides

Botanical name	Common name	Origin	Climate	Biology	Root system	Tolerance to reduced water availability	Species requirements	Ornamental features
Pinus sp.	Pine Tree	Northern hemisphere	Various	Various	Typical	Various	NA	None, does not flower.
Pinus sylvestris	Scots Pine	Northern Eurasia, from Scotland to Scandinavia, and the Baltic to far eastern Russia	Cool, temperate	An evergreen conifer, of variable height and form depending on provenance and density of the stand	Typical	Poor	Less suited to Australian conditions than some species. Occasionally encountered as a park tree. Slow growing	None, does not flower.
Platanus x acerifolia	Plane Tree	Garden origin (reputed to be a hybrid between Platanus occidentalis and Platanus orientalis)	Cool, temperate	Deciduous rounded to pyramidal tree	Typical	Moderately good	Well-suited to conditions in streets and grows well in southern Australia	Foliage: Alternate, maple-like leaves. Autumn colour yellow-brown.
Platanus x hybrida	Plane Tree hybrid	Garden origin (reputed to be a hybrid between Platanus occidentalis and Platanus orientalis)	Cool, temperate	Deciduous rounded to pyramidal tree	Typical	Moderately good	Well-suited to conditions in streets and grows well in southern Australia	Foliage: Alternate, maple-like leaves. Autumn colour yellow-brown.

Table 4.3 Requirements of typical species recorded in heritage gardens, private gardens, plantings and roadsides

Botanical name	Common name	Origin	Climate	Biology	Root system	Tolerance to reduced water availability	Species requirements	Ornamental features
Poplus sp.	Poplar	Northern hemisphere	Cool, temperate	Group deciduous trees	Shallow, spreading	Average	A very tough tree, but defoliates when very drought stressed. No special maintenance needs: the main issues with this tree will be control of suckers and invasive roots	None, does not flower.
Prunus laurocerasis	Cherry Laurel	From the Balkans to southern Russia	Cool, temperate	A rounded, dense and solid large evergreen shrub	Typical	Moderately good	Cold and shade tolerant	Flowers: Small, white single five-petalled flowers, in stiff, ascending racemes.
Prunus serrulata	Japanese Flowering Cherry	Garden origin - Japan	Cool, temperate	Deciduous small trees; habit varies with cultivar, from flat-topped and very wide-spreading to upright (some cultivars are identified by their form)	Typical	Average	At its best in cool moist climates, and in sheltered sites; performs well in good garden conditions, but tends to scorch on hot days in Australian summers	Flowers: Prolific flowers.
Prunus sp.	Cherry	China and Japan	Cool, temperate	Deciduous small trees; habit varies with cultivar, from flat-topped and very wide-spreading to upright (some cultivars are identified by their form)	Typical	Average	At its best in cool moist climates, and in sheltered sites; performs well in good garden conditions, but tends to scorch on hot days in Australian summers	Flowers: Prolific flowers.

Table 4.3 Requirements of typical species recorded in heritage gardens, private gardens, plantings and roadsides

Botanical name	Common name	Origin	Climate	Biology	Root system	Tolerance to reduced water availability	Species requirements	Ornamental features
Pseudotsuga menziesii	Douglas Fir Tree	Western North America, from British Columbia to California, in mountains, often on gravelly slopes	Cool, temperate	A large conical evergreen conifer. Lower branches droop, upper ones are horizontal	Typical	Average	Does well in more elevated sites. No special maintenance needs. Sometimes seen in suburban gardens much too small for its ultimate size	Fruit: Long, pendulous cones with soft scales, and conspicuous three-pronged bracts. Cones are shed, but do not break up.
Pyrus salicifolia 'Pendula'	Willow-leaved Pear	Garden origin for this cultivar; the species is from south east Europe to the Caucasus	Cool, temperate	A pendulous, small deciduous tree, forming a dense weeping mound	Typical	Moderately good	Plants need to be trained up to give them some height. Best in full sun. Moderately dry-tolerant when established. Once established need no special attention	Foliage: Grey-tomentose when young, becoming less so as the season advances.
Pyrus sp.	Pear	China	Cool, temperate	Deciduous broadly pyramidal tree	Typical	Moderately good	NA	None, does not flower.
Quercus palustris	Pink Oak	East and central North America	Cool, temperate	A large deciduous tree, tabular and conical when young, becoming more rounded with age	Typical	Average	Generally trouble free. Leaf Miners are occasionally seen, but the species seems freer from these than many other oaks commonly grown in south-eastern Australia. Prone to chlorosis in alkaline	Foliage: Vibrant autumn colours.

Table 4.3 Requirements of typical species recorded in heritage gardens, private gardens, plantings and roadsides

Botanical name	Common name	Origin	Climate	Biology	Root system	Tolerance to reduced water availability	Species requirements	Ornamental features
Quercus sp.	Oak Tree	Northern hemisphere	Cool, temperate	Comprises both deciduous and evergreen trees	Typical	Various	NA	Foliage: Vibrant autumn colours.
Rhododendron sp.	Rhododendron	Northern hemisphere	Cool, temperate	A rounded and dense evergreen shrub	Typical	Average	A plant for good garden or landscape conditions, best with some protection, shade, and adequate water, in acid soils. More vigorous cultivars may become open, and benefit from pruning. Can be hard pruned to rejuvenate	Flowers: Prolific flowers.
Rosmarinus officinalis	Rosemary	Southern Europe and north Africa	Cool, temperate	Erect to spreading or nearly prostrate evergreen shrubs, varying in habit according to cultivar	Typical	Very good	A very tough plant. Can be trimmed after flowering to keep bushy, and clips well as a low hedge. Tolerates moderate pruning, but not into old wood with no green growth apparent	Flowers: Small, pale to dark or bright blue flowers in clusters forming short racemes. Flowering is mostly in spring, but also sporadic throughout the year.
Sequoiadendron giganteum	Giant Sequoia	Western slopes of the Sierra Nevadas, California	Cool, temperate	An evergreen conifer with massive trunk and conical crown	Typical	Average	Trees in southern Australia have been affected in recent years by a fungal disease that causes die-back of patches of foliage. There is no known treatment	None, does not flower.

Table 4.3 Requirements of typical species recorded in heritage gardens, private gardens, plantings and roadsides

Botanical name	Common name	Origin	Climate	Biology	Root system	Tolerance to reduced water availability	Species requirements	Ornamental features
Taxodium distichum	Swamp Cypress	South-eastern North America, famously in swamps, but also in drier sites	Cool, temperate, subtropical	A large deciduous conifer, conical when young, although can be multi-stemmed and spreading with age. Trunks of mature trees are often buttressed at the base	Shallow	Average	In wet conditions produces upward-growing protuberances from the roots, (commonly known as "cypress knees"). Slow when young	Foliage: Long deciduous small branchlets which are arranged on the stems in spirals. Autumn colour rich russet brown.
Ulmus glabra	Golden Elm	Garden origin; a form of Ulmus glabra, the Wych Elm	Cool, temperate	A wide-spreading deciduous tree with a rounded crown	Typical	Moderately good	As for all elms, must be monitored for Elm Leaf Beetle, and other disease problems. Ulmus glabra and its cultivars are non-suckering	Foliage: Oblong and rough textured, pale green at first, becoming clear golden-yellow.
Ulmus glabra pendula	Weeping Wych Elm	Garden origin; a form of Ulmus glabra, the Wych Elm	Cool, temperate	A wide-spreading deciduous tree with a rounded crown	Typical	Moderately good	As for all elms, must be monitored for Elm Leaf Beetle, and other disease problems. Ulmus glabra and its cultivars are non-suckering	Foliage: Pendulous, pale green at first, becoming clear golden-yellow.
Ulmus procera 'Vanhouttei'	English Elm	Western and southern Europe	Cool, temperate	A medium to large deciduous tree, with a straight trunk and broad columnar canopy	Typical	Average	Requires considerable attention since the arrival of Elm Leaf Beetle in Australia. Old trees are prone to branch drop and decay, and require regular monitoring to ensure safety	None, does not flower.

Table 4.3 Requirements of typical species recorded in heritage gardens, private gardens, plantings and roadsides

Botanical name	Common name	Origin	Climate	Biology	Root system	Tolerance to reduced water availability	Species requirements	Ornamental features
Ulmus sp.	Elm	Western and southern Europe	Cool, temperate	A wide-spreading deciduous tree with a rounded crown	Typical	Average	NA	None, does not flower.
Vitus sp.	Grape	NA	NA	NA	Typical	NA	NA	None, does not flower.

Notes: A 'typical' root system is defined as the roots of most plants, including large trees, that grow primarily in the top meter of soil (Harris et al 2010)

5 Impact assessment

5.1 Cultural items

5.1.1 Overview

The regional scale RTS groundwater model was used to predict watertable drawdown in vegetated areas identified to contain plants that may access shallow groundwater and may be susceptible to water stress during periods of prolonged drought. During average and wet climate periods, vegetation in these areas will not be affected by groundwater level drawdown.

During especially dry periods when the soil moisture is low and not replenished by rainfall or surface water runoff, vegetation in these areas may exhibit increased stress or die back due to reduced access to groundwater as a result of groundwater level drawdown. These areas are limited to low lying topographical areas where the watertable is shallow and near watercourses where groundwater discharges as baseflow. However, under prolonged drought conditions, without mining, the watertable would decline naturally in these areas.

As such, vegetation either currently naturally adapts or is subject to water stress during these times, with replenishment when the drought breaks. In particular, exotic grasslands may die back during times of drought and water stress but would rapidly re-colonise following rain. Accordingly, the impact assessment presented in Section 5.1.2 to 5.2 below should be interpreted within this context.

5.1.2 Heritage gardens located in sandstone outcrop areas

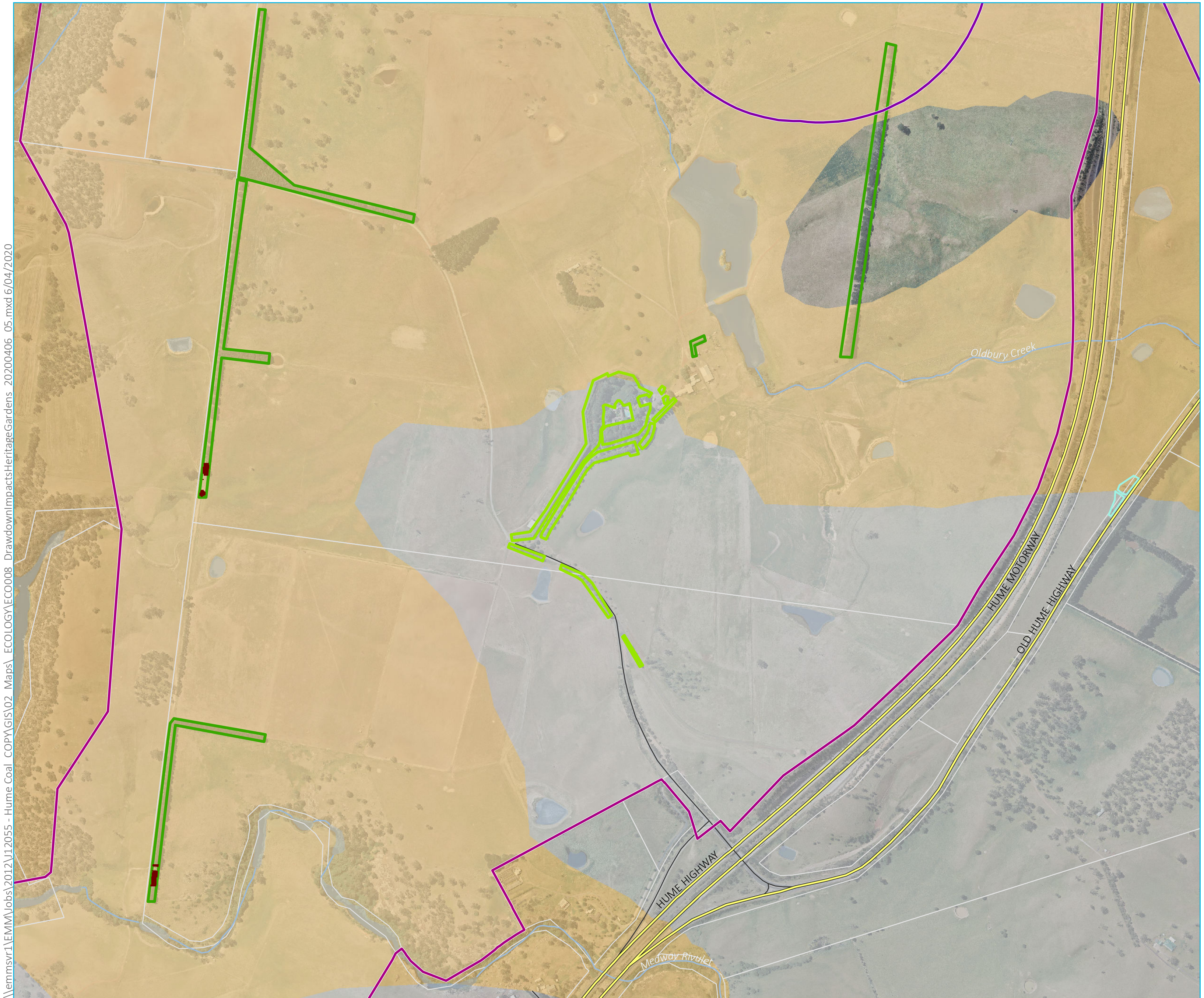
The planted pine windbreaks on the Mereworth property (0.1 ha) have a low potential for groundwater interaction, with a pre-mining inferred depth to groundwater of 5−10 mbgl. Although located on the same property, these planted pine windbreaks are outside the heritage curtilage of Mereworth House and Garden (listed as having local significance under the Wingecarribee LEP).

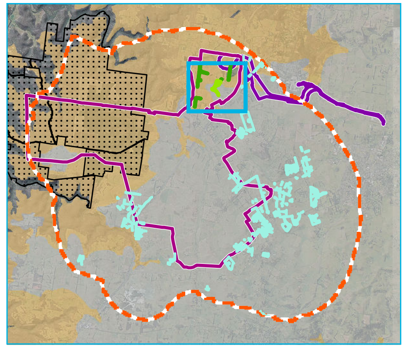
In this location, the maximum predicted water table level (as a result of mining, under the 50th, 67th and 90th percentile results) would be >10 mbgl. Based on the risk matrix presented in Table 5.1, the risk of the groundwater table becoming inaccessible drought conditions is high.

Part of the southern windbreak is in an area proposed for surface mine infrastructure, in particular entry/exit to the personnel and materials drift and an access road to the explosives magazine (Figure 1.3). Parts of the windbreak that can be avoided by mine infrastructure will be monitored for signs of water stress during prolonged drought, with remedial action taken as required (Chapter 6).

Table 5.1 Potential drawdown impacts on pine windbreaks on the Mereworth property in areas of Hawkesbury Sandstone outcrop (outside the heritage curtilage of Mereworth House and Garden)

Impact category		Groundwater interaction category	50th percentile results (ha)	67th percentile results (ha)	90th percentile results (ha)	Risk of impact during drought conditions
Pre-mining inferred depth to groundwater	Predicted (maximum) depth to groundwater					
5−10 m	>10 m	Low	0.1	0.1	0.1	High





KEY

- Hume Coal Project area
- Berrima Rail Project area
- Predicted 2 m drawdown extent (90th percentile)

Planted gardens within listed heritage items

- Mereworth House and Garden
- Gardens and trees outside Mereworth heritage curtilage
- Other planted gardens within listed heritage items

Drawdown risk categories for cultural plantings on Hawkesbury Sandstone*

- 5 - 10 m (no groundwater access)

Surface geology (250K)

- Hawkesbury Sandstone
- Wianamatta Shale

Existing environment

- Major road
- Minor road
- Named watercourse
- Waterbody
- Lot boundary
- Belanglo State Forest

Source: EMM (2020); Hume Coal (2016); DFSI (2017); DPE (2019)

0 250 500 m

GDA 1994 MGA Zone 56

N

Potential drawdown impacts on gardens and trees outside Mereworth heritage curtilage – 50th, 67th and 90th percentiles

Hume Coal and Berrima Rail Project
Groundwater dependence assessment for cultural heritage landscapes and gardens
Figure 5.1

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5.1.3 Cultural landscapes on sandstone

Drawdown impacts using the 50th uncertainty percentile class represents the median results, and is described as 'about as likely to occur as not' (Table 2.1). Based on this assessment, potential impacts on vegetated areas within the landscape conservation study area where the Hawkesbury Sandstone outcrops at surface are shown in Table 5.2 and on Figure 5.2. Drawdown impacts are scattered across the landscape conservation study area and are generally restricted to low-lying areas proximal to Olbury Creek, Medway Rivulet, Wells Creek and Black Bobs Creek. Based on the risk matrices in Plate 2.1 and Plate 2.2, the project is predicted to result in:

- no risk of impact during drought conditions to 5.2 ha of non-native vegetation and 0.2 ha of grasslands;
- low risk of impact during drought conditions to 0.8 ha of non-native vegetation;
- moderate risk of impact during drought conditions to 3.5 ha of non-native vegetation; and
- high risk of impact during drought conditions to 6.8 ha of non-native vegetation and 3 ha of grasslands.

Accordingly, 9.8 ha of non-native vegetation (including exotic grasslands) has a high risk of impact during drought conditions under the 50th percentile results. This only represents 0.08% of the cultural landscape study area and 0.06% of the common boundary of the broader cultural landscapes.

Drawdown impacts using the 67th uncertainty percentile class are described as 'unlikely to occur' (Table 2.1). Based on this assessment, potential impacts on vegetated areas within the landscape conservation study area where the Hawkesbury Sandstone outcrops at surface are shown in Table 5.2 and Figure 5.3. Based on the risk matrices in Plate 2.1 and Plate 2.2, the project is predicted to result in:

- no risk of impact during drought conditions to 3.8 ha of non-native vegetation and 0.1 ha of grasslands;
- low risk of impact during drought conditions to 0.7 ha of non-native vegetation;
- moderate risk of impact during drought conditions to 4.5 ha of non-native vegetation; and
- high risk of impact during drought conditions to 7.2 ha of non-native vegetation and 3.1 ha of grasslands.

Accordingly, 10.3 ha of non-native vegetation (including exotic grasslands) has a high risk of impact during drought conditions under the 67th percentile results. This only represents 0.09% of the cultural landscape study area and 0.07% of the common boundary of the cultural landscapes.

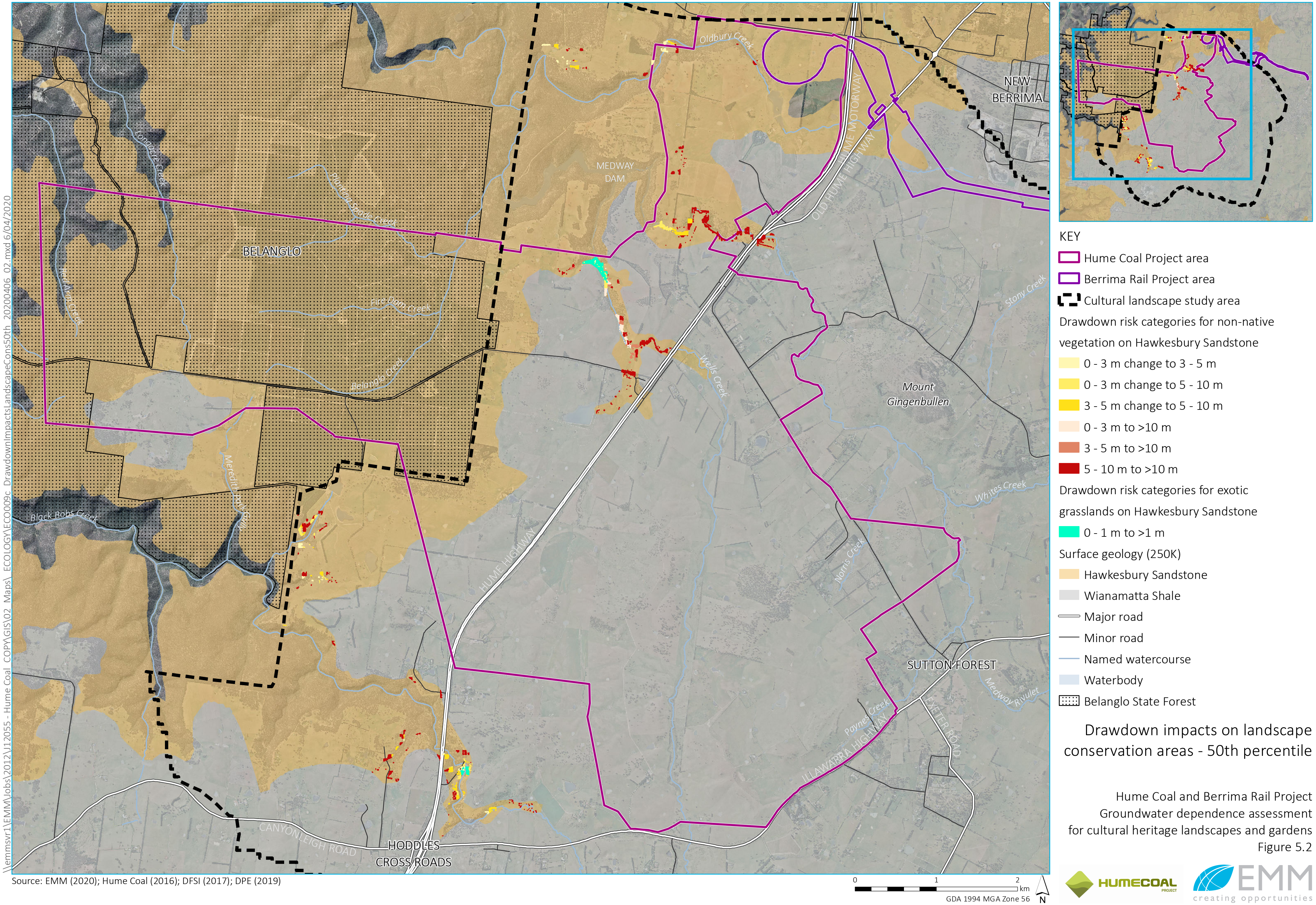
Drawdown impacts using the 90th uncertainty percentile class are described as 'very unlikely to occur' (Table 2.1). Based on this assessment, potential impacts on vegetated areas within the landscape conservation study area where the Hawkesbury Sandstone outcrops at surface are shown in Table 5.2 and on Figure 5.4. Based on the risk matrices in Plate 2.1 and Plate 2.2, the project is predicted to result in:

- no risk of impact during drought conditions to 1.8 ha of non-native vegetation and 0.1 ha of grasslands;
- low risk of impact during drought conditions to 0.6 ha of non-native vegetation;
- moderate risk of impact during drought conditions to 5.2 ha of non-native vegetation; and
- high risk of impact during drought conditions to 8.7 ha of non-native vegetation and 3.1 ha of grasslands.

Accordingly, 11.8 ha of non-native vegetation (including exotic grasslands) has a high risk of impact during drought conditions under the 90th percentile results. This only represents 0.11% of the cultural landscape study area and 0.08% of the common boundary of the cultural landscapes.

Table 5.2 Potential drawdown impacts in the landscape conservation study area in areas of Hawkesbury Sandstone outcropping –50th, 67th and 90th percentile uncertainty analysis model results

Impact category		50th percentile results (ha)	67th percentile results (ha)	90th percentile results (ha)	Risk of impact during drought conditions
Pre-mining inferred depth to groundwater	**Predicted (maximum) depth to groundwater**				
		Non-native vegetation			
0–3 m	0–3 m	1.6	1.5	1.1	None
3–5 m	3–5 m	0.5	0.6	1.0	None
5–10 m	5–10 m	0.8	0.7	0.6	None
0–3 m	3–5 m	1.1	1.2	1.4	Low
0–3 m	5–10 m	0.3	0.1	0.0	Moderate
3–5 m	5–10 m	0.6	1.1	1.4	Moderate
0–3 m	>10 m	1.8	1.6	1.4	Moderate
3–5 m	>10 m	3.3	2.2	0.7	Moderate
5–10 m	>10 m	6.1	7.2	8.7	High
Sub-total non-native vegetation	-	**16.3**	**16.3**	**16.3**	-
		Grasslands			
0-1 m	0–1 m	0.3	0.1	0.1	None
0-1 m	>1 m	3.0	3.1	3.1	High
Sub-total grasslands	-	**3.2**	**3.2**	**3.2**	-



Source: EMM (2020); Hume Coal (2016); DFSI (2017); DPE (2019)

Drawdown impacts on landscape conservation areas - 50th percentile

Hume Coal and Berrima Rail Project
Groundwater dependence assessment for cultural heritage landscapes and gardens
Figure 5.2

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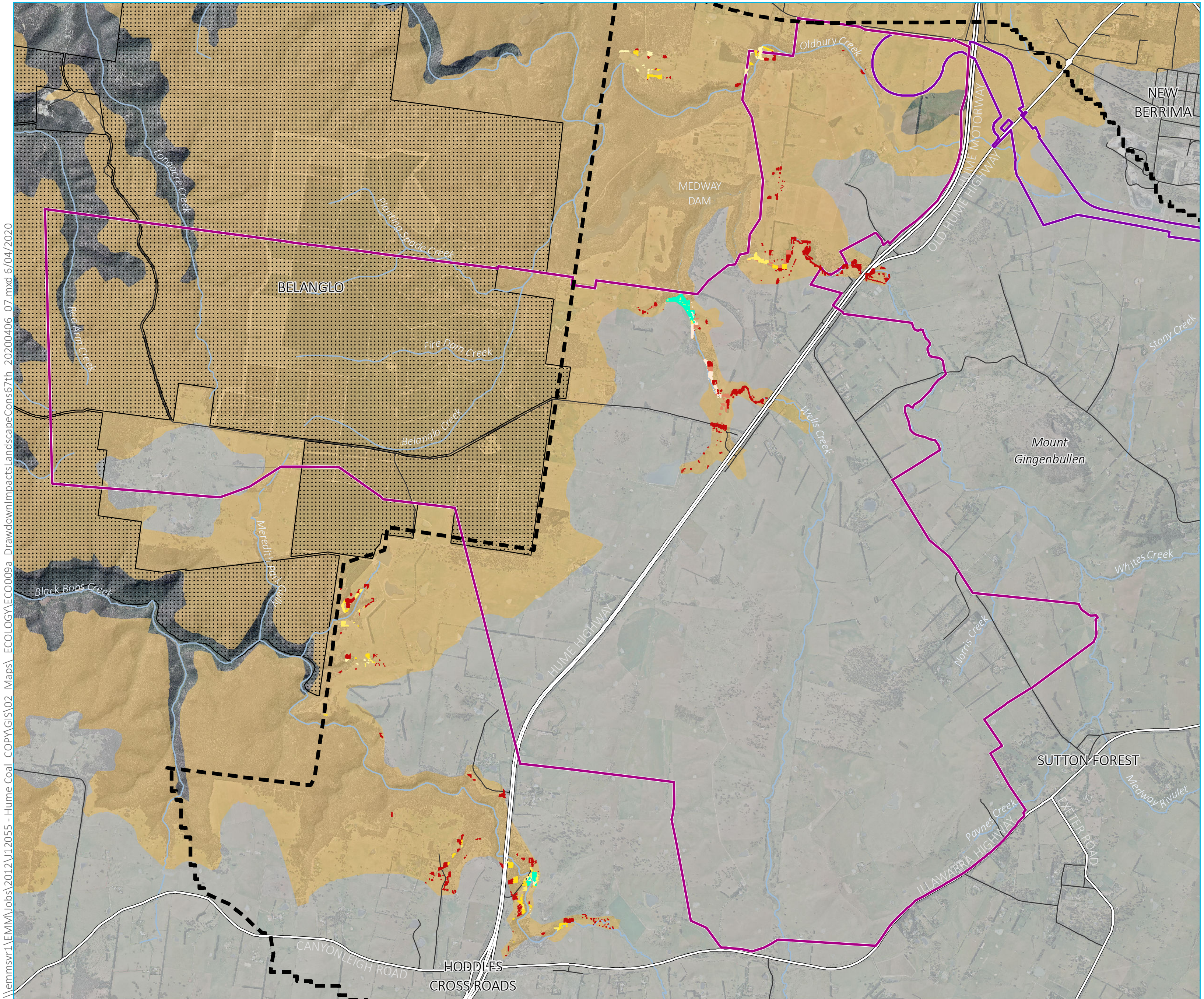

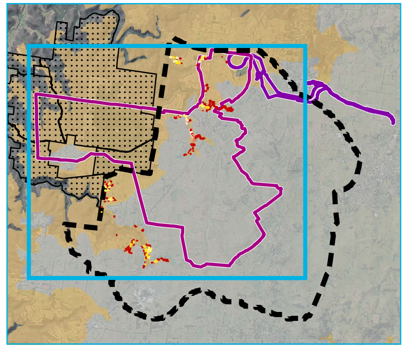

KEY

- Hume Coal Project area
- Berrima Rail Project area
- Cultural landscape study area

Drawdown risk categories for non-native vegetation on Hawkesbury Sandstone

- 0 - 3 m change to 3 - 5 m
- 0 - 3 m change to 5 - 10 m
- 3 - 5 m change to 5 - 10 m
- 0 - 3 m to >10 m
- 3 - 5 m to >10 m
- 5 - 10 m to >10 m

Drawdown risk categories for exotic grasslands on Hawkesbury Sandstone

- 0 - 1 m to >1 m

Surface geology (250K)

- Hawkesbury Sandstone
- Wianamatta Shale
- Major road
- Minor road
- Named watercourse
- Waterbody
- Belanglo State Forest

Drawdown impacts on landscape conservation areas - 67th percentile

Hume Coal and Berrima Rail Project
Groundwater dependence assessment
for cultural heritage landscapes and gardens
Figure 5.3

Source: EMM (2020); Hume Coal (2016); DFSI (2017); DPE (2019)

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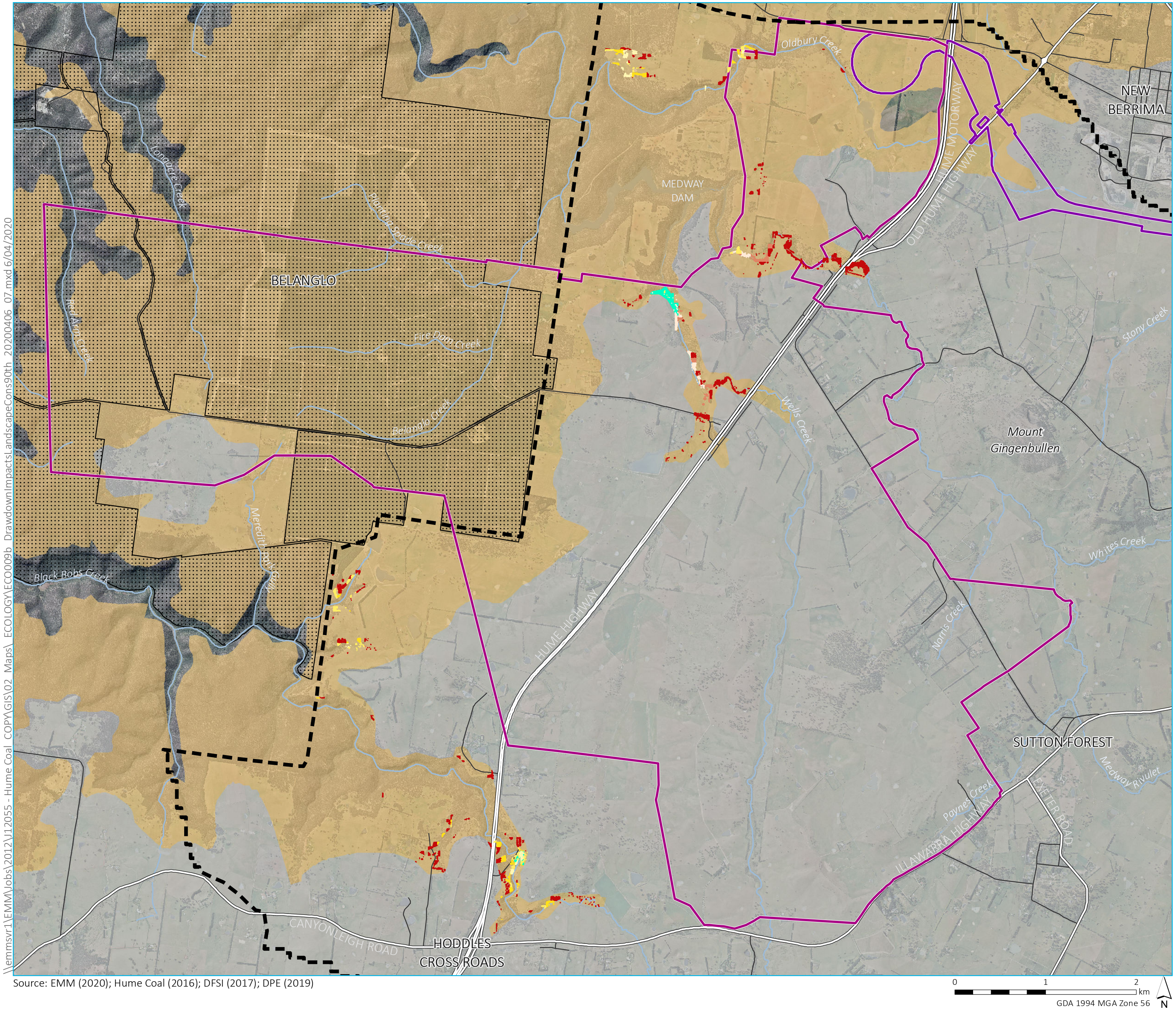

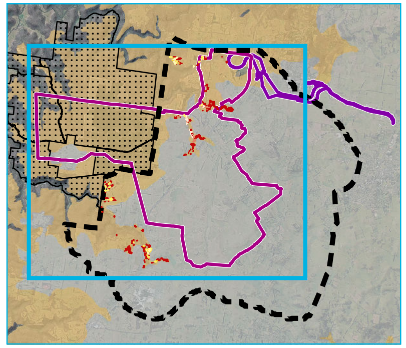

KEY

- Hume Coal Project area
- Berrima Rail Project area
- Cultural landscape study area

Drawdown risk categories for non-native vegetation on Hawkesbury Sandstone

- 0 - 3 m change to 3 - 5 m
- 0 - 3 m change to 5 - 10 m
- 3 - 5 m change to 5 - 10 m
- 0 - 3 m to >10 m
- 3 - 5 m to >10 m
- 5 - 10 m to >10 m

Drawdown risk categories for exotic grasslands on Hawkesbury Sandstone

- 0 - 1 m to >1 m

Surface geology (250K)

- Hawkesbury Sandstone
- Wianamatta Shale
- Major road
- Minor road
- Named watercourse
- Waterbody
- Belanglo State Forest

Drawdown impacts on landscape conservation areas - 90th percentile

Hume Coal and Berrima Rail Project
Groundwater dependence assessment
for cultural heritage landscapes and gardens
Figure 5.4

Source: EMM (2020); Hume Coal (2016); DFSI (2017); DPE (2019)

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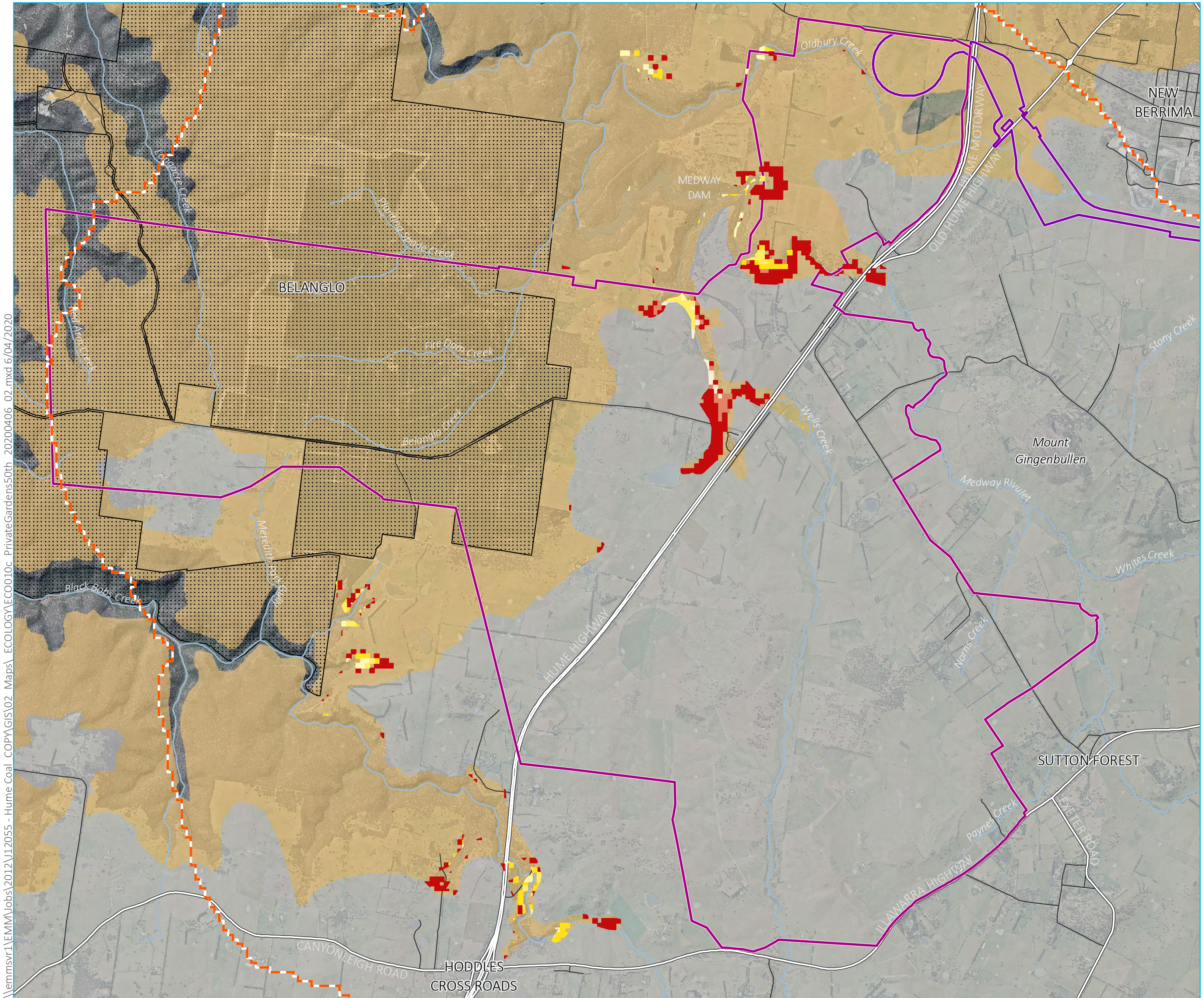
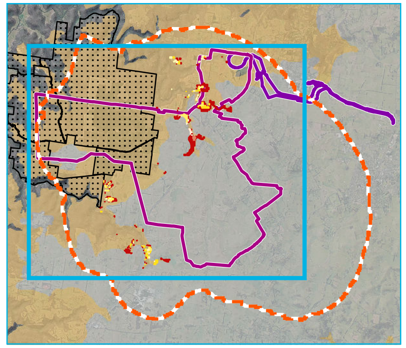
5.2 Private gardens

Twenty-six plant species observed in private gardens are considered sensitive to reduced water availability (Table 5.3). Where private gardens containing these plant species overlie areas of shallow groundwater within the Hawkesbury Sandstone (see Figure 5.5 to Figure 5.7), these plants may be subject to water stress during periods of prolonged drought. It should be noted that the maximum extent of potential drawdown risk is conservative, and private gardens would only be potentially impacted during drought conditions if they contain the species identified as drought-sensitive.

Table 5.3 Garden species sensitive to reduced water availability

Botanical name	Common name	Tolerance to reduced water availability
Cedrus deodara	Himalayan Cedar	Average
Cedrus sp.	Cedar	Average
Cephalothaxus harringtoniana	Japanese Yew	Average
Chamaecyparis sp.	False Cypress	Average
Fagus sylvatica	European Beech	Average
Fraxinus excelsio aurea pendula	Weeping Golden Ash	Average
Liquidambar styraciflua	Liquid Amber	Average
Magnolia sp.	Magnolia	Average
Malus sp.	Crab Apple	Average
Paeonia suffriticosa	Paeonie	Average
Picea sp.	Spruce	Average
Poplus sp.	Poplar	Average
Prunus serrulata	Japanese Flowering Cherry	Average
Prunus sp.	Cherry	Average
Pseudotsuga menziesii	Douglas Fir Tree	Average
Quercus palustris	Pink Oak	Average
Rhododendron sp.	Rhododendron	Average
Sequoiadendron giganteum	Giant Sequoia	Average
Taxodium distichum	Swamp Cypress	Average
Ulmus procera 'Vanhouttei'	English Elm	Average
Ulmus sp.	Elm	Average
Betula pendula	Silver Birch	Poor
Larix sp.	Larch	Poor
Pinus sylvestris	Scots Pine	Poor
Pinus sp.	Pine Tree	Various
Quercus sp.	Oak Tree	Various





KEY

- Hume Coal Project area
- Berrima Rail Project area
- Predicted 2 m drawdown extent (90th percentile)

Drawdown risk categories for private gardens on Hawkesbury Sandstone - 50th percentile

- 0 - 3 m change to 3 - 5 m
- 0 - 3 m change to 5 - 10 m
- 3 - 5 m change to 5 - 10 m
- 0 - 3 m to >10 m
- 3 - 5 m to >10 m
- 5 - 10 m to >10 m

Surface geology (250K)

- Hawkesbury Sandstone
- Wianamatta Shale
- Major road
- Minor road
- Named watercourse
- Waterbody
- Belanglo State Forest

Area of potential impacts on private gardens - 50th percentile

Hume Coal Project
Groundwater dependence assessment for cultural heritage landscapes and gardens
Figure 5.5

Source: EMM (2020); Hume Coal (2016); DFSI (2017); DPE (2019)

0 1 2 km
GDA 1994 MGA Zone 56
N

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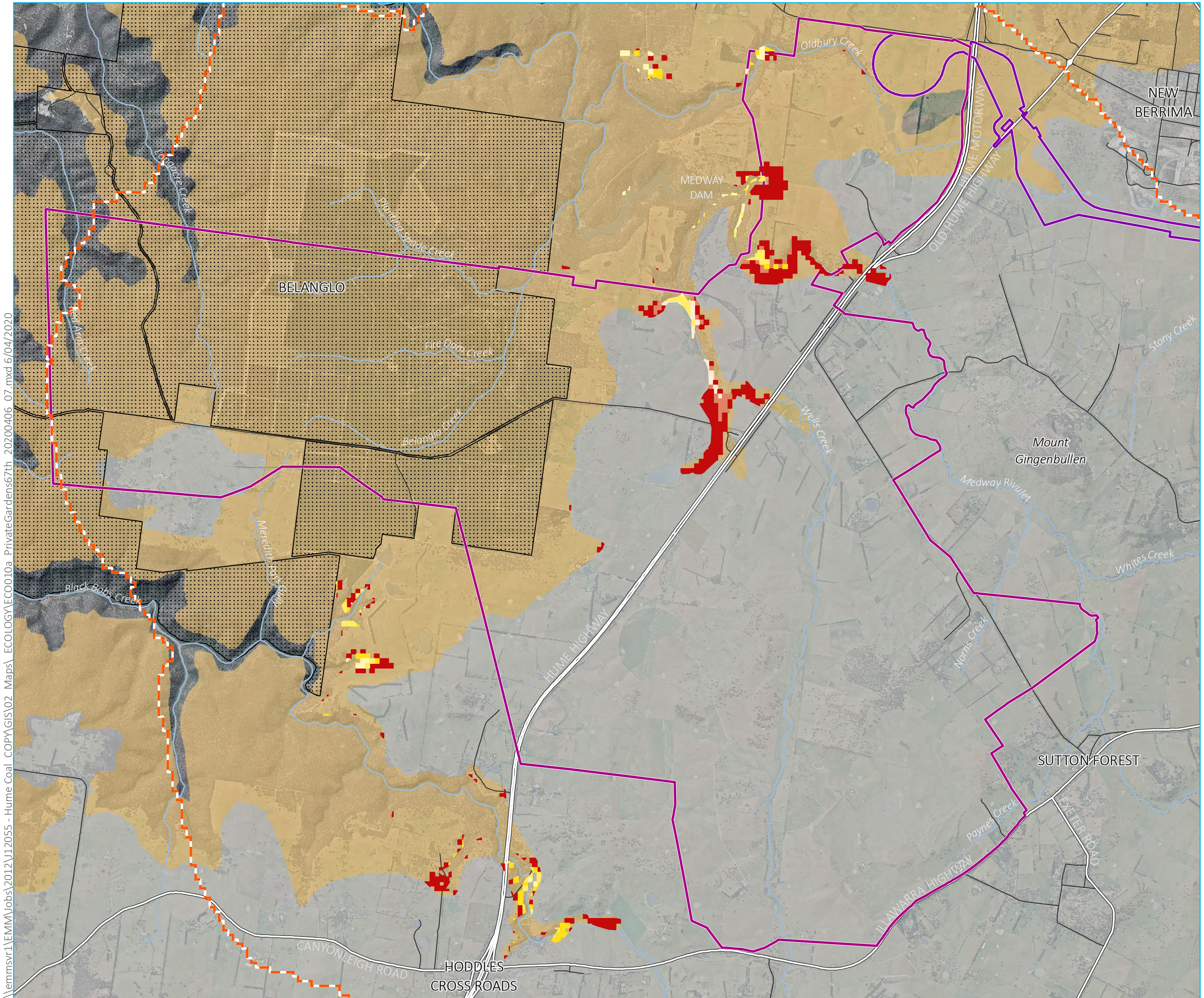

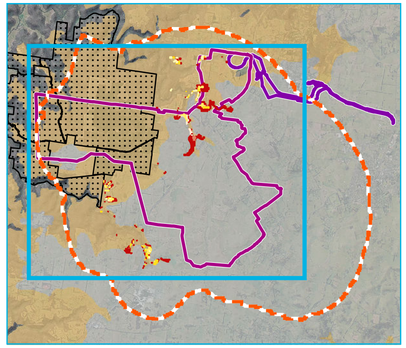

KEY

- Hume Coal Project area
- Berrima Rail Project area
- Predicted 2 m drawdown extent (90th percentile)

Drawdown risk categories for private gardens on Hawkesbury Sandstone - 67th percentile

- 0 - 3 m change to 3 - 5 m
- 0 - 3 m change to 5 - 10 m
- 3 - 5 m change to 5 - 10 m
- 0 - 3 m to >10 m
- 3 - 5 m to >10 m
- 5 - 10 m to >10 m

Surface geology (250K)

- Hawkesbury Sandstone
- Wianamatta Shale
- Major road
- Minor road
- Named watercourse
- Waterbody
- Belanglo State Forest

Area of potential impacts on private gardens - 67th percentile

Hume Coal Project
Groundwater dependence assessment for cultural heritage landscapes and gardens
Figure 5.6

Source: EMM (2020); Hume Coal (2016); DFSI (2017); DPE (2019)

0 1 2 km
GDA 1994 MGA Zone 56
N

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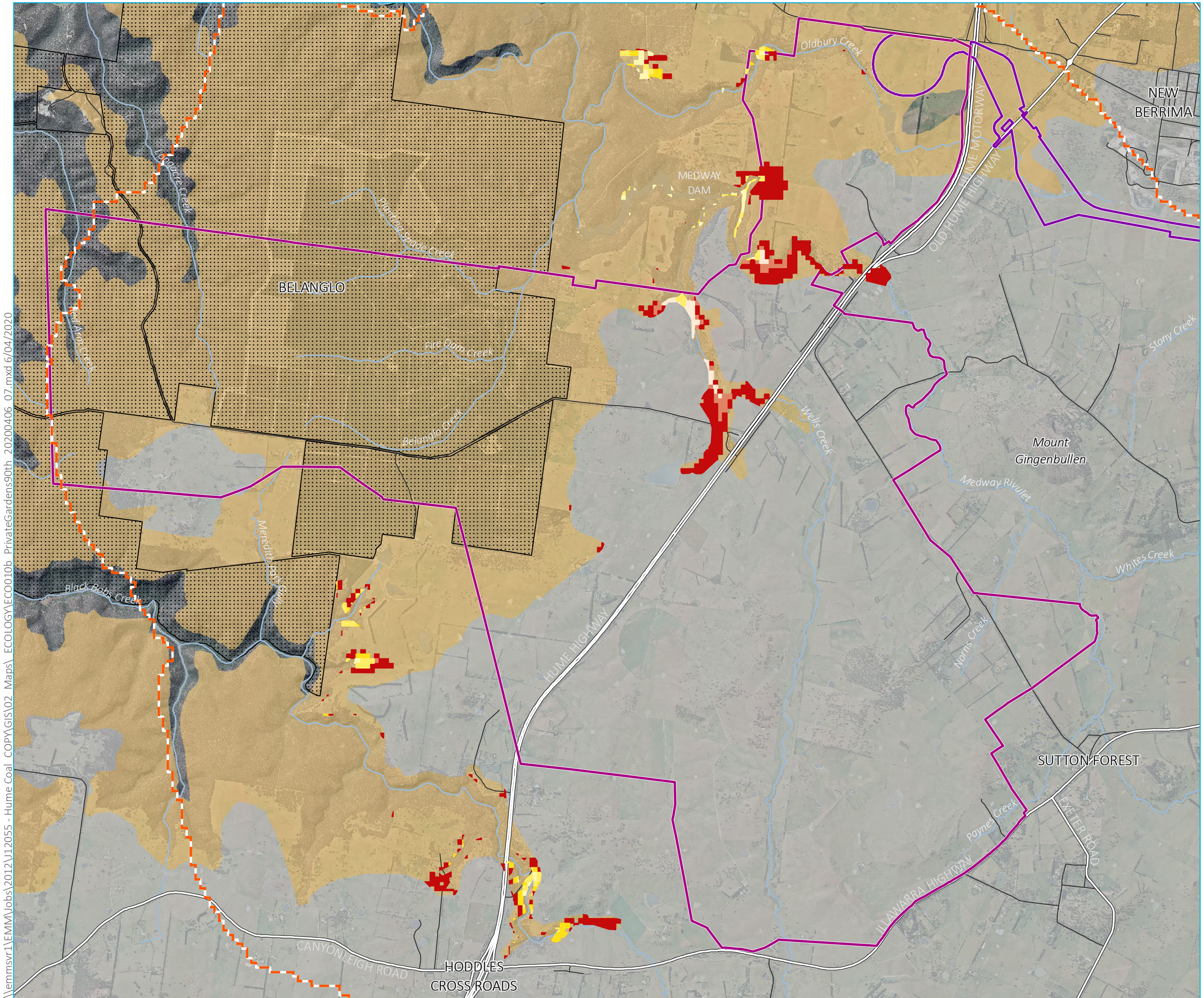

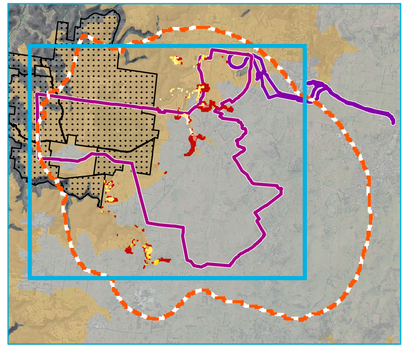

Source: EMM (2020); Hume Coal (2016); DFSI (2017); DPE (2019)

0 1 2 km

GDA 1994 MGA Zone 56

N

KEY

- Hume Coal Project area
- Berrima Rail Project area
- Predicted 2 m drawdown extent (90th percentile)

Drawdown risk categories for private gardens on Hawkesbury Sandstone - 90th percentile

- 0 - 3 m change to 3 - 5 m
- 0 - 3 m change to 5 - 10 m
- 3 - 5 m change to 5 - 10 m
- 0 - 3 m to >10 m
- 3 - 5 m to >10 m
- 5 - 10 m to >10 m

Surface geology (250K)

- Hawkesbury Sandstone
- Wianamatta Shale
- Major road
- Minor road
- Named watercourse
- Waterbody
- Belanglo State Forest

Area of potential impacts on private gardens - 90th percentile

Hume Coal Project
Groundwater dependence assessment for cultural heritage landscapes and gardens
Figure 5.7

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6 Monitoring, management and mitigation

The regional scale RTS groundwater model was used to predict watertable drawdown in vegetated areas identified to contain plants that may access shallow groundwater and may be susceptible to water stress during periods of prolonged drought.

During average and wet climate periods, vegetation in these areas will not be affected by groundwater level drawdown. During especially dry periods when the soil moisture is low and not replenished by rainfall or surface water runoff, vegetation in these areas that may access groundwater may exhibit increased stress or die back due to reduced access to groundwater as a result of groundwater level drawdown. However, these areas are limited to low lying topographical areas where the watertable is shallow and near watercourses where groundwater discharges as baseflow. However, under prolonged drought conditions, without mining, the watertable would decline naturally in these areas. As such, vegetation either naturally adapts or is subject to water stress during these times, with replenishment when the drought breaks.

Following project approval, Hume Coal will conduct additional 'post-approval' groundwater modelling and field investigations, where possible, to confirm the depth to groundwater in the areas identified as being at high risk of water stress during periods of prolonged drought.

Planted pine windbreaks on Mereworth, that cannot be avoided by surface mine infrastructure, will be monitored for signs of water stress during prolonged drought, and supplemented with water if required.

There will be no impacts to gardens and plantings within local or state listed heritage items, and as such no mitigation measures are proposed to these areas.

The remaining non-native, exotic grassland and private gardens located within the landscape conservation study areas that are predicted to experience watertable drawdown and have been identified as being at risk of water stress during periods of prolonged drought cover a small area, are not classified as high priority GDEs and are not covered under any statutory requirement to manage or mitigate the potential and unlikely effects.

Ongoing 'post-approvals' groundwater modelling will be undertaken as and when new data become available, and at regular intervals throughout the life of the mine. It is expected the confidence level of model predictions will increase over time as the model is updated to reflect the observed effects on groundwater obtained from the monitoring program. This is consistent with International Organisation for Standardisation (ISO) continuous improvement guidelines and industry standard.

7 Conclusion

This assessment has been prepared to respond directly to the IPC findings and recommendations, as published in the IPC assessment report released in May 2019. Gardens within heritage items, vegetation within landscape conservation areas and species typically planted in private gardens have been identified. The potential impacts of the predicted change in groundwater depth as result of the project on the identified at-risk vegetation has been assessed, using the groundwater model, spatial analysis and a risk-based approach.

All listed heritage gardens accessing shallow groundwater and part of the vegetation in the landscape conservation areas are situated above the Wianamatta Group shale. As this is a perched groundwater system with limited hydraulic connection to the underlying Hawkesbury Sandstone (where groundwater drawdown is predicted to occur), no impacts are predicted in these areas. Should private gardens, non-native vegetation or exotic grasslands occur in areas where the Wianamatta Group Shale outcrops at surface, there will also be no impacts due to the perched groundwater system.

The regional scale RTS groundwater model was used to predict watertable drawdown in vegetated areas identified to contain plants that may access shallow groundwater and may be susceptible to water stress during periods of prolonged drought. During average and wet climate periods, vegetation in these areas will not be affected by groundwater level drawdown. During especially dry periods when the soil moisture is low and not replenished by rainfall or surface water runoff, vegetation in these areas may exhibit increased stress or die back due to reduced access to groundwater as a result of groundwater level drawdown. These areas are limited to low lying topographical areas where the watertable is shallow and near watercourses where groundwater discharges as baseflow. However, under prolonged drought conditions, without mining, the watertable would decline naturally in these areas. As such, vegetation either currently naturally adapts or is subject to water stress during these times, with replenishment when the drought breaks.

During drought conditions, approximately 0.1 ha of planted pine windbreaks at the Mereworth property (outside the heritage curtilage of Mereworth House and Garden) has a high risk of impact during drought conditions. Part of the southern windbreak is in an area proposed for surface mine infrastructure, in particular entry/exit to the personnel and materials drift and an access road to the explosives magazine. Parts of the windbreak that can be avoided by mine infrastructure will be monitored for signs of water stress during prolonged drought, with remedial action taken as required.

Within the landscape conservation study area, the 50th percentile results (about as likely as not) where Hawkesbury Sandstone outcrops at the surface predicts:

- no risk of impact during drought conditions to 5.2 ha of non-native vegetation and 0.2 ha of grasslands;
- low risk of impact during drought conditions to 0.8 ha of non-native vegetation;
- moderate risk of impact during drought conditions to 3.5 ha of non-native vegetation; and
- high risk of impact during drought conditions to 6.8 ha of non-native vegetation and 3 ha of grasslands.

Accordingly, 9.8 ha of non-native vegetation (including exotic grasslands) has a high risk of impact during drought conditions under the 50th percentile results. This only represents 0.08% of the cultural landscape study area and 0.06% of the common boundary of the cultural landscapes.

Within the landscape conservation study area, the 67th percentile results (unlikely) where Hawkesbury Sandstone outcrops at the surface predicts:

- no risk of impact during drought conditions to 3.8 ha of non-native vegetation and 0.1 ha of grasslands;

- low risk of impact during drought conditions to 0.7 ha of non-native vegetation;
- moderate risk of impact during drought conditions to 4.5 ha of non-native vegetation; and
- high risk of impact during drought conditions to 7.2 ha of non-native vegetation and 3.1 ha of grasslands.

Accordingly, 10.3 ha of non-native vegetation (including exotic grasslands) has a high risk of impact during drought conditions under the 67th percentile results. This only represents 0.09% of the cultural landscape study area and 0.07% of the common boundary of the cultural landscapes.

Within the landscape conservation study area, the 90th percentile results (very unlikely) where Hawkesbury Sandstone outcrops at the surface predicts:

- no risk of impact during drought conditions to 1.8 ha of non-native vegetation and 0.1 ha of grasslands;
- low risk of impact during drought conditions to 0.6 ha of non-native vegetation;
- moderate risk of impact during drought conditions to 5.2 ha of non-native vegetation; and
- high risk of impact during drought conditions to 8.7 ha of non-native vegetation and 3.1 ha of grasslands.

Accordingly, 11.8 ha of non-native vegetation (including exotic grasslands) has a high risk of impact during drought conditions under the 90th percentile results. This only represents 0.11% of the cultural landscape study area and 0.08% of the common boundary of the cultural landscapes.

Private properties with gardens containing the species listed in Table 5.3 located within the predicted area of groundwater drawdown and overlying the Hawkesbury Sandstone may be subject to increased water stress during prolonged drought as a result of the project.

Following project approval, Hume Coal will conduct additional 'post-approval' groundwater modelling and field investigations, where possible, to confirm the depth to groundwater in the areas identified as being at high risk of water stress during periods of prolonged drought.

Planted pine windbreaks on Mereworth, that cannot be avoided by surface mine infrastructure, will be monitored for signs of water stress during prolonged drought, and supplemented with water if required.

There will be no impacts to gardens and plantings within local or state listed heritage items.

The remaining non-native, exotic grassland and private gardens located within the landscape conservation study areas that are predicted to experience watertable drawdown and have been identified as being at risk of water stress during periods of prolonged drought cover a small area, are not classified as high priority GDEs and are not covered under any statutory requirement to manage or mitigate the potential and unlikely effects.

Ongoing 'post-approvals' groundwater modelling will be undertaken as and when new data become available, and at regular intervals throughout the life of the mine. It is expected the confidence level of model predictions will increase over time as the model is updated to reflect the observed effects on groundwater obtained from the monitoring program. This is consistent with International Organisation for Standardisation (ISO) continuous improvement guidelines and industry standard.

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Annexure A

Heritage items in the study area

Table A.1 Heritage items in the 90th percentile study area

Heritage item	Heritage Act 1977 No 136	Wingecarribee Local Environmental Plan 2010	
	State significance	Local significance	State significance
"Cottesbrooke" house		1	
All Saints Anglican Church hall and cemetery			1
Argyle/Browley St Conservation Area		1	
Black Bob's Bridge			1
Bonheur house, grounds and outbuildings		1	
Boscobel house, grounds and outbuildings		1	
Browley house, grounds and outbuildings		1	
Bunya Hill house, grounds and outbuildings		1	
Cardrona, (former Eagleroo) grounds		1	
Charlie Grey's Cottage		1	
Clover Hill house, grounds and outbuildings		1	
Coach House Antiques, Argyle Galleries		1	
Comfort Hill house, grounds and outbuildings			1
Cottage		1	
East St Conservation Area		1	
Eccleston Park house and outbuildings		1	
Eling Forest Winery house, grounds and outbuilding			1
Everything Store, former Butcher Shop		1	

Table A.1 Heritage items in the 90th percentile study area

Heritage item	Heritage Act 1977 No 136	Wingecarribee Local Environmental Plan 2010	
	State significance	Local significance	State significance
Former Post Office		1	
Former St John's Anglican Rectory		1	
Glendalough		1	
Golden Vale	1		
Golden Vale house, grounds and outbuildings			1
Highfield house, grounds and outbuildings			1
Hillview	1		
Hillview house, grounds and outbuildings			1
Interwar bungalow		1	
Interwar transitional bungalow		1	
Jemmy Moss Inn		1	
Kalaurgan		1	
Lynton		1	
Mereworth house and garden		1	
Montrose house and grounds		1	
Moss Vale Public School		1	
Newbury house, grounds and outbuildings		1	
Oldbury Farm	1		

Table A.1 Heritage items in the 90th percentile study area

Heritage item	Heritage Act 1977 No 136	Wingecarribee Local Environmental Plan 2010	
	State significance	Local significance	State significance
Oldbury house, grounds and outbuildings			1
Peppers, (former Mt Broughton) house, grounds			1
Railway station gatehouse		1	
Remembrance Driveway Plantings		1	
Remembrance Driveway Trees		1	
Road Reservation		1	
Rosedale house and grounds			1
Rotherwood house, grounds and outbuildings			1
Royal Hotel (Sutton Forest Inn)		1	
Semi-detached houses		1	
Spring Grove Farm house, grounds and outbuildings		1	
St Andrew's Presbyterian Church		1	
St John's Anglican Church		1	
St Patrick's Roman Catholic Church and cemetery			1
St Paul's International College (former Dominican			1
Summerlees house and grounds		1	
Sutton Farm house, grounds and outbuildings (forme		1	
Sutton Forest Public School— 1879 classroom and toilets and 1912 classroom		1	

Table A.1 Heritage items in the 90th percentile study area

Heritage item	Heritage Act 1977 No 136	Wingecarribee Local Environmental Plan 2010	
	State significance	Local significance	State significance
The Harp (former Bindagundra) house, grounds		1	
The Pines slab cottage		1	
Victorian shop, painted wall signs and house		1	
Vine Lodge house, grounds and outbuildings			1
Whitley house, grounds and outbuildings			1
Whitley, outbuildings, entry gate, garden	1		
Willow Grange house and grounds		1	
Grand Total	4	42	15