Appendix J

Groundwater Dependant Ecosystems Assessment Report

Iluka Resources Limited

GDE Assessment Report

Iluka Trim Reference: 1711352

Iluka Resources Limited

Groundwater Dependent Ecosystems Assessment Report

Iluka Trim Reference: 1711352

1 May 2015

CDM Smith Australia Pty Ltd
ABN 88 152 082 936
Level 5 (541), 121 King William Street
Adelaide
SA 5000
Tel: +61 8423 4454

Table of Contents

List of Figures

List of Tables

Appendices

Document History and Status

Revision	Date Issued	Reviewed By	Approved By	Date Approved	Revision Type
1	20/02/15	P. Howe	D. Currie	20/02/15	Draft
2	16/03/15	Iluka, EMM	D. Currie	16/03/15	Final draft
3	01/05/15	Adequacy Review	D. Currie	01/05/15	Final

Distribution of Copies

Version	Date Issued	Quantity	Electronic	Issued To
1	20/02/15		1	J. Goode
2	16/03/15		1	J. Goode
3	01/05/15		1	J. Goode

Printed:	1 May 2015
Last Saved:	1 May 2015 01:55 PM
File Name:	AWS140004-01- RPT- GDE Impact Assmt v3.docx
Author:	Dougal Currie, Amy Roach
Project Manager:	Dougal Currie
Client:	Iluka Resources Limited
Document Title:	Groundwater Dependent Ecosystems Assessment Report
Document Version:	v3
Project Number:	AWS140004.01

Executive Summary

CDM Smith Australia Pty Ltd (CDM Smith) has been engaged by Iluka Resources Limited (Iluka) to undertake a Groundwater Dependent Ecosystem (GDE) assessment, which will form part of the Water Assessment and Environmental Impact Statement (EIS) being prepared for the Balranald Mineral Sands Project. The purpose of this assessment is to identify and systematically evaluate potential impacts to GDEs that may arise from water-related project activities and, if required, to develop management and mitigation measures aimed at avoiding or minimising these potential impacts.

The assessment covers all potential GDEs that have been identified by previous investigations commissioned by Iluka, with the major potential GDE types being:

- Wetlands and vegetation associated with the Murrumbidgee, Lachlan and Murray River Floodplain environments; and

- Vegetation (primarily Black Box trees) outside the floodplain and permanent streams, in topographic depressions where the water table may be shallow enough and not too saline.

The assessment considers impacts related to both surface water and groundwater (i.e. any hydrological change caused by the project). The key water-affecting activities associated with the project have been considered (including surface water impacts) as part of this assessment as follows:

1. Groundwater abstraction leading to groundwater level drawdown.

2. Disposal of excess mine water via aquifer injection leading to groundwater level mounding.

3. Mining potentially affecting groundwater quality.

4. The capture and alteration of surface runoff leading to altered surface water flows to potential GDEs.

Of the four water-affecting activities identified above, the direct effects associated with mining (3) and the capture and alteration of surface runoff (4) were deemed to be negligible. A groundwater modelling assessment (Jacobs, 2015) has been conducted to predict groundwater level drawdown and mounding.

Conceptual models have been developed for all of the major GDE types that occur within and surrounding the Balranald Project area to ascertain whether an exposure pathway exists between the water-related effects of the project and the hydrological regime that supports the potential GDEs. A level of impact (low, moderate or high) has been assigned for each of the exposure pathways identified by the assessment based on the predicted changes by the groundwater model, the major findings being:

- No impacts have been identified for the wetlands associated with the Murrumbidgee, Lachlan and Murray River Floodplain environments (due to their distance from the project area, and the stabilising influence of regulated watercourses on the water table aquifer).

- Predicted drawdown impacts are constrained to areas of Black Box vegetation near the West Balranald mine, but the extent of drawdown is such that predicted impacts are rated as low (monitoring of these areas should, however, be part of the monitoring program).

- Predicted mounding impacts are constrained to areas of Black Box vegetation near a dedicated injection borefield. A moderate rating has been assigned to some areas of Black Box vegetation in this area. While the magnitude of the predicted mounding is not substantial and remains well below the surface, the moderate rating flags that mounding in this region should be monitored throughout the mining operation.

The potential impacts identified form the basis of a management strategy that has been developed to reduce the risks associated with potential impacts to levels defined as being acceptable. Ongoing monitoring and evaluation will be a cornerstone of the management strategy and designed to provide advanced warning of potential impacts and a better understanding of the groundwater regime and ecosystem water requirements. The management strategy is linked to a trigger response framework to provide a tiered response to the risks associated with impacts to GDEs as follows:

- Tier 1: monitoring.
- Tier 2: detailed investigations to better define significance of risk and devise most appropriate direct management actions as required.
- Tier 3: deployment of direct management options to mitigate impacts.

The GDE management strategy will be integrated into the overall water management strategy for the Balranald Project.

Section 1 Introduction

1.1 Background

Iluka Resources Limited (Iluka) is currently preparing a Water Assessment to accompany an Environmental Impact Statement (EIS) as part of the approvals process to develop a mineral sands mine in south-western New South Wales (NSW), known as the Balranald Mineral Sands Project (the Balranald Project).

Initial baseline investigations conducted for the Balranald Project identified the occurrence of potential Groundwater Dependent Ecosystems (GDEs) in the vicinity of the proposed mine site (SKM, 2011). These included wetlands and vegetation associated with the Murrumbidgee and Murray River Floodplains, and vegetation (primarily Black Box trees) inland of the river and floodplains. A subsequent technical investigation of Black Box trees has been undertaken to evaluate their sources of water (Jacobs, 2014). The study found that rainfall and episodic surface water (irregular flooding and/or pooling from heavy rainfall) likely provides the dominant water source for Black Box, but there is some potential for these trees to use groundwater to supplement their water needs.

The proposed Balranald Project will involve a number of water-affecting activities (e.g. mine dewatering and excess water disposal by aquifer injection) that will alter the local hydrological environment to some extent, and there is potential for GDEs occurring within the zone of influence to be impacted.

1.2 Study objectives and scope

CDM Smith Australia Pty Ltd (CDM Smith) has been engaged to undertake a GDE impact assessment, which will form part of the water assessment and EIS, and will be submitted to regulators and to the public as part of the approvals process for the project. The purpose of this assessment is to identify and systematically evaluate potential impacts to GDEs that may arise from water-affecting project activities; and, if required, to develop management and mitigation measures aimed at avoiding or minimising these potential impacts.

This GDE assessment report contains the following elements:

- a summary of background information and an updated spatial coverage of potential GDEs within the designated project area;
- a description of the possible sensitivity of potential GDEs to alterations of the water regime, a GDE classification system according to their possible sensitivity, and a spatial coverage of where these GDE classes occur;
- an impact rating system that defines an impact rating (low, moderate or high) according to the magnitude of change to the water regime (e.g. change in water table depth) and the GDE Class (i.e. its sensitivity);
- an outline of the predicted changes to the water regime due to mining activities based on modelling results;
- an assessment that rates the level of impact at each potential GDE site (using the impact rating system) according to the predicted changes to the water regime; and

- a management strategy (aligned with the impact rating) that seeks to avoid or mitigate any potential impacts identified.

This assessment is focussed on water-related impacts to GDEs due to changes to the groundwater, surface water and soil water environments. The term GDE is used in this assessment to refer to an ecosystem which has a potential dependence on groundwater at some time.

Section 2 Project Description

2.1 Overview

The Balranald Project includes construction, mining and rehabilitation of two linear mineral sand deposits, known as West Balranald and Nepean, located approximately 12 kilometres (km) and 66 km north-west of the town of Balranald, NSW, respectively. Figure 2-1 shows the location of the two deposits and their proposed infrastructure and disturbance footprints.

Iluka plans to open-cut mine the deposits using conventional dry mining methods (truck and shovel) and process the extracted ore onsite, to produce a heavy mineral concentrate (HMC) and ilmenite, which will be transported to Victoria for further processing. The mining operation will include overburden stripping followed sequentially by ore mining, backfilling and rehabilitation. The target ore zone is around 60-70m below the ground surface, while the water table is typically around 15m below the surface. Significant dewatering activities will be required to lower the water table to below the target ore zone to provide a dry mining environment. Hypersaline water (TDS > 35,000 mg/L) extracted from the Loxton Parilla Sands (LPS) aquifer for dewatering purposes will be returned to the same aquifer by a network of injection wells.

Iluka is seeking development consent under Part 4, Division 4.1 of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) for the Balranald Project, , broadly comprising:

- open cut mining of the West Balranald and Nepean deposits, referred to as the West Balranald and Nepean mines, including progressive rehabilitation;
- processing of extracted ore in the project area to produce heavy mineral concentrate (HMC) and ilmenite;
- road transport of HMC and ilmenite from the project area to Victoria;
- backfilling of the mine voids with overburden and tailings, including transport of by-products from the processing of HMC in Victoria back to the project area for backfilling in the mine voids;
- return of hypersaline groundwater extracted prior to mining to its original aquifer by a network of injection borefields;
- an accommodation facility for the construction and operational workforce;
- gravel extraction from local sources for construction requirements; and
- a water supply pipeline from the Murrumbidgee River to provide fresh water during operation.

Separate approvals, are being sought for:

- the construction of a transmission line to supply power to the Balranald Project; and
- project components located within Victoria.

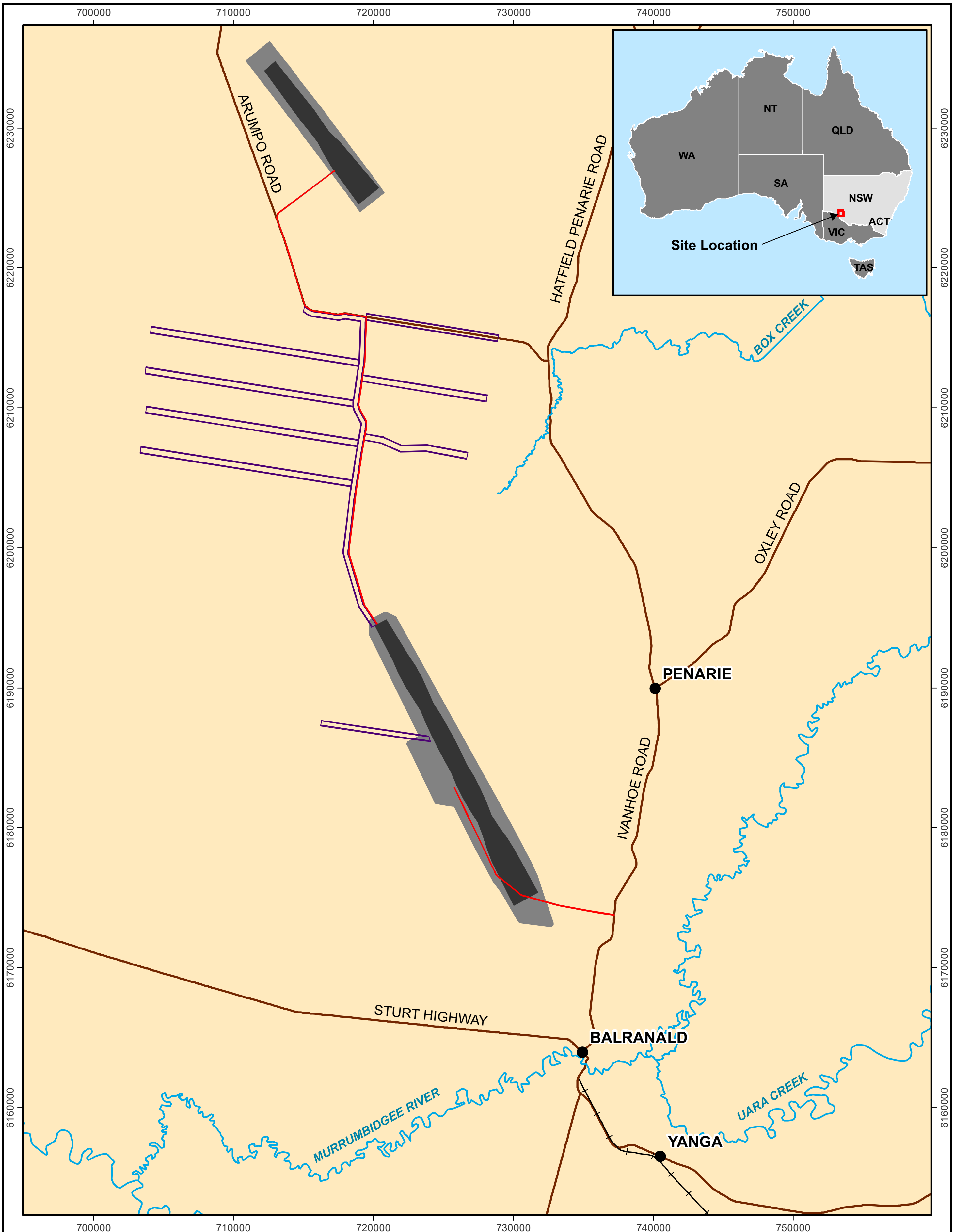


Figure 2-1 Location of project area and disturbance footprint

Key

- Town
- Road
- Railway
- Watercourse
- Off-path injection area
- Haul road
- Pit and associated disturbance areas
- Project area

0 5,000 10,000
Metres
GDA 1994 MGA Zone 54

DISCLAIMER
CDM Smith has endeavoured to ensure accuracy and completeness of the data. CDM Smith assumes no legal liability or responsibility for any decisions or actions resulting from the information contained within this map.

Data Source: Iluka Resources Limitedl
Geoscience Australia, BOM Geofab v2.1

CDM Smith
cdmsmith.com

G:\Projects\AWS140004_balnarald\mxd\final\Report\001-R1_proj_area.mxd

2.2 Approval process

The planning approval process for the Balranald Project is complex as it requires a number of approvals in NSW and Victoria, as well as approval from the Commonwealth. In NSW, the Balranald Project requires development consent under Part 4, Division 4.1 of the EP&A Act. Part 4 of the EP&A Act relates to development assessment. Division 4.1 specifically relates to the assessment of development deemed to be significant to the state, known as State Significant Development (SSD). The Balranald Project is a mineral sands mining development which meets the requirements for SSD.

Of relevance to the assessment of water impacts:

- An application for SSD must be accompanied by an EIS, prepared in accordance with the NSW Environmental Planning and Assessment Regulation 2000 (EP&A Regulation).
- An approval under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) is required for the Balranald Project (with the exception of the transmission line which will be subject to a separate EPBC Act referral process). A separate EIS will be prepared to support an application in accordance with the requirements of Part 8 of the EPBC Act.

2.3 Secretary's environmental assessment requirements

The EIS has been prepared to address specific requirements provided in the Secretary's environmental assessment requirements (SEARs) for the SSD application, issued on 2/12/14. This GDE assessment has been prepared to address specific requirements for Water and Biodiversity in the SEARs.

Table 2-1 Relevant SEARs for this assessment

Requirements	Section addressed
An assessment of the likely impacts of the development on the quantity and quality of the region's surface and groundwater resources, having regard to the EPA's and NSW Office of Water's requirements and the NSW Aquifer Interference Policy.	Sections 5, 6 and 7
An assessment of the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure, and other water users	Sections 5, 6 and 7
A detailed description of the proposed water monitoring program and other measures to mitigate surface and groundwater impacts.	Section 8
Measures taken to avoid, reduce or mitigate impacts on biodiversity.	Section 8

2.4 Project schedule

The Balranald Project will have a life of approximately 15 years, including construction, mining, backfilling of all overburden material, rehabilitation and decommissioning.

Construction of the Balranald Project will commence at the West Balranald mine, and is expected to take about 2.5 years. The construction period will overlap with the commencement of mining operations at the West Balranald mine. Operations will include mining and associated ore extraction, processing and transport activities. Construction of infrastructure at the Nepean mine will commence in approximately Year 5, with mining starting in Year 7, and being complete by approximately Year 9. Rehabilitation and decommissioning is expected to take a further two to five years.

2.5 Project area

All development for the Balranald Project that is the subject of the SSD application is within the project area. The project area is approximately 9,964 ha, and includes the following key project elements, described in subsequent sections:

- West Balranald and Nepean mines;
- West Balranald access road;
- Nepean access road;
- injection borefields;
- gravel extraction;
- water supply pipeline (from the Murrumbidgee River); and
- accommodation facility.

Within the project area, the land directly disturbed for the Balranald Project is referred to as the disturbance area. For some project elements in the project area, a larger area has been surveyed than would actually be disturbed. This enables some flexibility to account for changes that may occur during detailed design and operation. The project area and disturbance area for each project element are in Table 2-2.

Table 2-2 Balranald project area description

Project element	Project area (ha)	Disturbance area (ha)
West Balranald mine	3,059	3,059
Nepean mine	805	805
West Balranald access road	128	52 [1]
Nepean access road	173	156 [2]
Injection borefields	5,721	1214 [3]
Gravel extraction	42	42 [4]
Water supply pipeline	29	11
Accommodation facility	7	7
Total	9,964	5,346

Notes:
1. 60 m wide corridor within project area
2. 40-50 m wide corridor within project area
3. 100 m wide corridors within project area
4. 15 m wide corridor within project area

2.6 West Balranald and Nepean mines

The West Balranald and Nepean mines development includes the following infrastructure:

- Open cut mining areas (ie pit/mine void) that would be developed;
- Soil and overburden stockpiles;

- Ore stockpiles and mining unit plant (MUP) locations;
- A processing area (at the West Balranald mine), including a mineral processing plant, tailings storage facility (TSF), maintenance areas and workshops, product stockpiles, truck load-out area, administration offices and amenities;
- Groundwater management infrastructure, including dewatering, injection and monitoring bores and associated pumps and pipelines;
- Surface water management infrastructure;
- Service infrastructure (e.g. power);
- Haul roads for heavy machinery and service roads for light vehicles; and
- Other ancillary equipment and infrastructure.

The location of infrastructure at the West Balranald and Nepean mines would vary over the life of the Balranald Project according to the stage of mining.

2.7 Injection borefields

The Balranald Project requires a network of injection borefields in the project area for the return of hypersaline groundwater to the LPS aquifer. Within each borefield, infrastructure typically comprises:

- A network of pipelines with a graded windrow on either side;
- Access roads for vehicle access during construction and operation;
- Rows of injection wells, with wells spaced at 100 m intervals or greater; and
- A series of water storage dams to store water during well development.

2.8 Access roads

There are two primary access roads within the project area to provide access to the Balranald Project:

- West Balranald access road – a private access road to be constructed from the Balranald Ivanhoe Road to the West Balranald mine.
- Nepean access road – a route comprising private access roads and existing public roads. The southern portion of the road will be a private access road from the northern end of the West Balranald mine to the Burke and Wills Road. Vehicles would then use two public roads, Burke and Wills Road and Arumpo Road. A private access road would be constructed from Arumpo Road to the Nepean mine.

The West Balranald access road would be the primary access point to the project area, and would be used by heavy vehicles transporting HMC and ilmenite. The Nepean access road would primarily be used by heavy vehicles transporting ore mined at the Nepean mine to the processing area at the West Balranald mine.

2.9 Purpose of this report

CDM Smith has been commissioned to undertake a GDE Assessment for the SSD application for the Balranald Project. The GDE Assessment has been carried out in accordance with the SEARs and with reference to the following standards, guidelines and policies:

- AS/NZS 4360:2004 Risk Management (Standards Australia);
- NSW State Groundwater Dependent Ecosystem Policy (NOW);
- Risk Assessment Guidelines for Groundwater Dependent Ecosystems (NOW);
- Water Sharing Plan for the Lower Murray Darling Unregulated and Alluvial Water Sources (2011);
- National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia (ARMCANZ/ANZECC);
- NSW State Groundwater Policy Framework Document (DLWC, 1997);
- NSW State Groundwater Quality Protection Policy (DLWC, 1998);
- NSW State Groundwater Quantity Management Policy (DLWC, 1998);
- NSW Aquifer Interference Policy 2012 (NOW); and
- Water Sharing Plan for NSW Murray Darling Basin Porous Rock Groundwater Sources (2011).

Section 3 Method

The approach adopted in this assessment is based on the risk-based framework presented by Howe (2011), for assisting in assessment and management of potential local and cumulative effects of mining on groundwater resources; however it can also be meaningfully applied to surface water. The method involves a staged approach, presented in Figure 3-1.

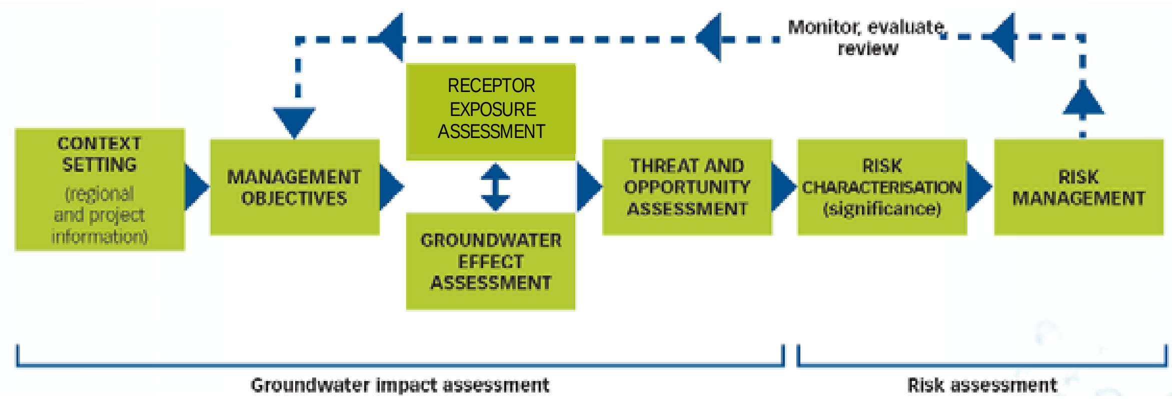


Figure 3-1 Assessment approach, adapted from Howe (2011)

To understand the significance of potential water-related impacts, it is necessary to consider how mining activities might alter the baseline water regime in such a way as to impact (either positively or negatively) receiving environments. These receiving environments, termed *receptors*, are entities within the broad region of the mining operation which have an environmental, economic and/or social/cultural value. Activities which have the potential to impact on receptors (such as dewatering, excess water and tailings disposal) are termed *water-affecting activities*. When an activity alters the water regime, *a direct effect* on the receptor may arise, which may manifest as changes to water quantity (e.g. groundwater level or stream flow), water quality (e.g. salinity), groundwater-surface water interactions, or physical disruption to the water bodies themselves (e.g. changes to water storage capacity due to removal of overburden or the interference with an aquifer by an open pit).

This study focuses specifically on GDEs as receptors, and aims to identify any potential *exposure pathways* which may cause some impact on GDEs that may be sensitive to the direct affects to the groundwater regime. The degree of impact and significance of the threat is evaluated in the risk assessment. The approach incorporates the following stages:

1. **Context setting** – a description of the baseline environment and water regime, and the identification of GDEs in the region (Section 4).

2. **Water effects assessment** - the identification of water-affecting activities and a description of the water effects assessment which is carried out using a range of scientific techniques such as groundwater modelling (Section 5).

3. **GDE Exposure assessment** - an assessment of whether or not an exposure pathway exists between the water-related effects of the mining operation and a GDE is underpinned by the conceptualisation of GDEs and the water regime that supports the functioning of these ecosystems (Section 6).

4. **GDE Assessment** - an assessment that systematically examines each GDE for which an exposure pathway exists, and characterises the significance of an impact in terms of the likelihood of it occurring (Section 7).

5. **GDE Management Strategy** - a description of management and mitigation measures to be used to manage water-related impacts to an appropriate level of risk (Section 8).

Section 4 Contextual setting

4.1 Climate

The climate of the study area is semi-arid, with Balranald experiencing a mean annual rainfall of approximately 320 mm. Rainfall decreases gradually (but not appreciably) to the north and to the west. On average, it is evenly distributed throughout the year (Figure 4-1); however it tends to be sporadic with occasional heavy summer falls (SKM, 2011). Rainfalls greater than 1 mm occur on average, between 40 and 50 days per year, while the days receiving more than 5 mm are roughly 20 per year (BoM, 2014). Annual rainfall can vary significantly; for instance 692 mm was recorded in 2010 while only 123 mm was recorded in 1967(SKM, 2011).

Temperatures are hot in summer and mild in winter. Average annual pan evaporation is roughly 2,000 mm, with the highest rates occurring in the summer months as expected. Annual areal potential evapotranspiration is 1,200 mm while the actual areal evapotranspiration is limited by the availability of water, and is on average, around 300 mm per year (BoM, 2014). Figure 4-1 illustrates that evaporative losses are greater than rainfall for all months, particularly the summer months, which limits the water availability to plants, except where groundwater might be accessible.

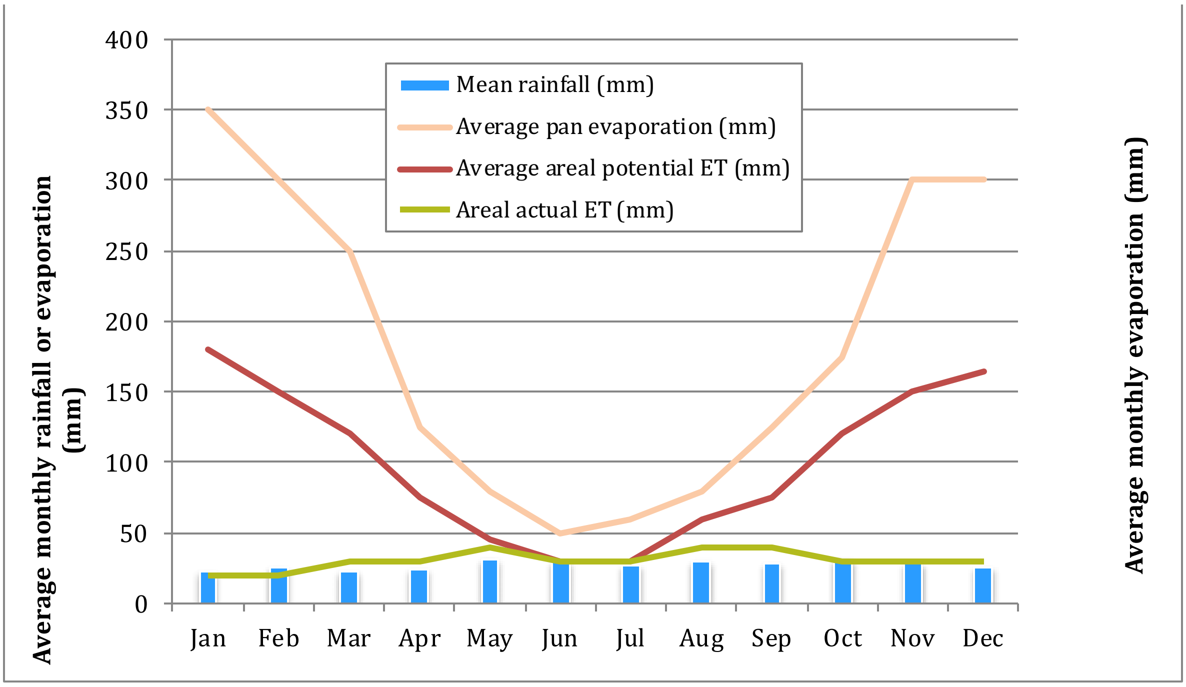


Figure 4-1 Mean monthly climate data at Balranald.

4.2 Vegetation and current land use

A summary of the region's vegetation is provided by Scott (1992), who recognised 19 main vegetation communities. The main vegetation communities occurring in the project area, as outlined by SKM (2011), are Bluebush (*Maireana spp.*) and Saltbush (*Atriplex spp.)* shrublands of the western riverine plains, Mallee shrublands (*Eucalyptus dumosa, E. socialis*) throughout the Mallee, open forests of River Red gums (*Eucalyptus camdulensis*) along the rivers and open Black Box woodland (*Eucalyptus largiflorens*) on the outer floodplains. Black Box trees also occur in isolated stands along the Box Creek corridor and in low lying areas, such as relic lakes. This assemblage has been described as Black Box Grassy Chenopod Open Woodland by flora and fauna studies conducted for the Balranald project (Niche Environment and Heritage, 2015).

Vegetation has been significantly altered by clearing and grazing since European settlement. Generally the degree of disturbance is higher to the south where there is greater access to water and better soils (SKM, 2011). Only a small portion of the region is covered by conservation reserve, including Yanga Nature Reserve, located east of Balranald, which covers 1,772 ha of Black Box woodland, and a private reserve towards the south of the West Balranald deposit, of which the majority has been mapped as Mallee shrubland (SKM, 2011).

According to the baseline GDE studies (SKM, 2011) the most significant ecological assets of the study area appear to be:

- River red gum forests of the Murrumbidgee floodplain – a particularly extensive area surrounds Redbank Weir;
- Nationally significant wetlands of the Lowbidgee floodplain between Maude and the Balranald township;
- The nationally significant Great Cumbung Swamp, located at the terminus of the Lachlan River.

No high priority GDEs are listed in the Murray-Darling Basin Porous Rock Water Sharing Plan.

Grazing is the predominant land use in the area, but there is irrigation along floodplains and in the Lowbidgee district to the east of the Balranald township and south of the Murrumbidgee River.

4.3 Geomorphology and soils

The topography is generally flat, ranging from 72 mAHD in the Nepean area to 65 mAHD in the West Balranald area. The topography includes various features that have developed through fluvial and aeolian processes, including modern channels and floodplains of the Lachlan, Murray and Murrumbidgee rivers, the broader riverine plains and depression plains, relic lakes, swamps and lunettes formed by ancient lakes, and dunefields. The geomorphology of the study area is well summarised by Scott (1992) and is outlined by SKM (2011) in the baseline assessment, from which much of this information is sourced.

The study area is within the Murray Geological Basin, which has been filled by sedimentary deposits since the Tertiary (60 million years ago). The Balranald region is part of a transitional landscape that lies between the Riverine Plains to the east (comprising continental sediments deposited by rivers) and the Mallee landscape to the west (comprising marine sediments reworked by aeolian processes) (SKM, 2011). A distinct boundary exists at the surface between the alluvial continental sediments and the aeolian marine sediments. During the Miocene (5 to 23 million years ago), the sea extended inland as far as Balranald and retreated during the Pliocene (2.5 to 5 million years ago) leaving behind the Loxton Parilla Sand beach ridges that host the target mineral sand deposits. A series of regressions and transgressions has led to the present day landforms, which in the project area are dominated by the following (SKM, 2011):

- The modern **channels and floodplains** of the Lachlan, Murray and Murrumbidgee Rivers.
- The broader **riverine plains**, which were formed by fluvial deposition but are no longer subject to inundation. These include **depression plains** (flat, riverine plains composed of heavy clays) and **scalded plains** (which are similar to depression plains, but have lost their topsoil due to wind erosion).

- **Relic lakes, swamps and lunettes** are features formed by ancient lakes. Examples include Pitarpunga and Tin Tin Lake located near the West Balranald deposit. These lakes are no longer active but were filled during the wet phase of the late Pleistocene (50,000 - 25,000 years ago) when the Willandra Lakes system flowed all the way to the Murray River to the west of Balranald (Scott, 1992). These relic lakes are smooth and elliptical with the dry lake beds composed of saline calcareous clays (gypsiferous). During the last glacial maximum 18,000 years ago, seasonal flooding and subsequent drying led to salt residues forming on the lake floor. These broke up the clay soils, which were then blown by westerly winds and deposited on the eastward margins of the lake to form crescent-shaped dunes composed of clayey sands and gypsiferous clays.
- **Sandplains** occur throughout the transitional zone where there is a thin mantle of aeolian-derived sand. These landforms are flat and there are generally no dunes.
- **Dunefields** are widespread throughout the Mallee. They consist of linear dunes with an east-west orientation that are part of the Woorinen Formation. The dunes are relic features that were stabilised by vegetation around 15,000 years ago. The difference in height between crest and swale varies between 2 to 6 m, with the swales containing heavier textured, clay loam.

4.4 Geology

A detailed overview of the region's geology and hydrogeology is provided by Kellett (1989 and 1994).

The Cainozoic sediments of the Murray Geological Basin are underlain by relatively impermeable Palaeozoic basement rock. In the Balranald region this features a concealed basement ridge complex, termed the Ivanhoe Block (Kellet, 1989).This has exerted considerable influence over the Murray Basin sediments, which are more than 400 m at the western edge of the Riverine Plain but are reduced to less than 150 m over the Ivanhoe Block complex, approximately 20 km to the west of Hatfield. The concealed ridge becomes less distinct as it trends south towards the confluence of the Murray and Murrumbidgee Rivers (SKM, 2011).

4.5 Hydrogeology

There are six major aquifer systems in the study area, both confined and unconfined. These are summarised in the baseline GDE report (SKM, 2011) with a more detailed description provided in Jacobs (2015). The Coonambidgal Formation hosts fresh groundwater of the unconfined channel sands aquifer, which is associated with the alluvium of the modern channels and floodplains of the Murrumbidgee, Lachlan and Murray Rivers. The Shepparton Formation is considered a partial aquifer, which hosts brackish to saline groundwater with isolated pockets of fresh water. The underlying LPS aquifer hosts hypersaline groundwater, and is permeable and high yielding. It can be separated into individual facies representative of depositional environments from offshore to lower shore to surf zone to foreshore. It is a confined aquifer (by the Shepparton Formation) in the region of the West Balranald deposit, but becomes unconfined over the Nepean deposit, where the Shepparton Formation is not present. The Renmark Group underlies the LPS, and contains several confined aquifers which host brackish (or stock quality) groundwater supplies. The Lower Renmark aquifer is the most productive, and in some areas is under artesian conditions. Figure 4-2 illustrates the hydrogeology in proximity to the West Balranald deposit (the Olney Formation shown is equivalent of the Upper Renmark Group). Groundwater flow is regionally from east to west, as driven by recharge in the wetter zones of the eastern riverine plains; however locally, in the area of the West Balranald deposit, groundwater flows from south to north (Figure 4-2).

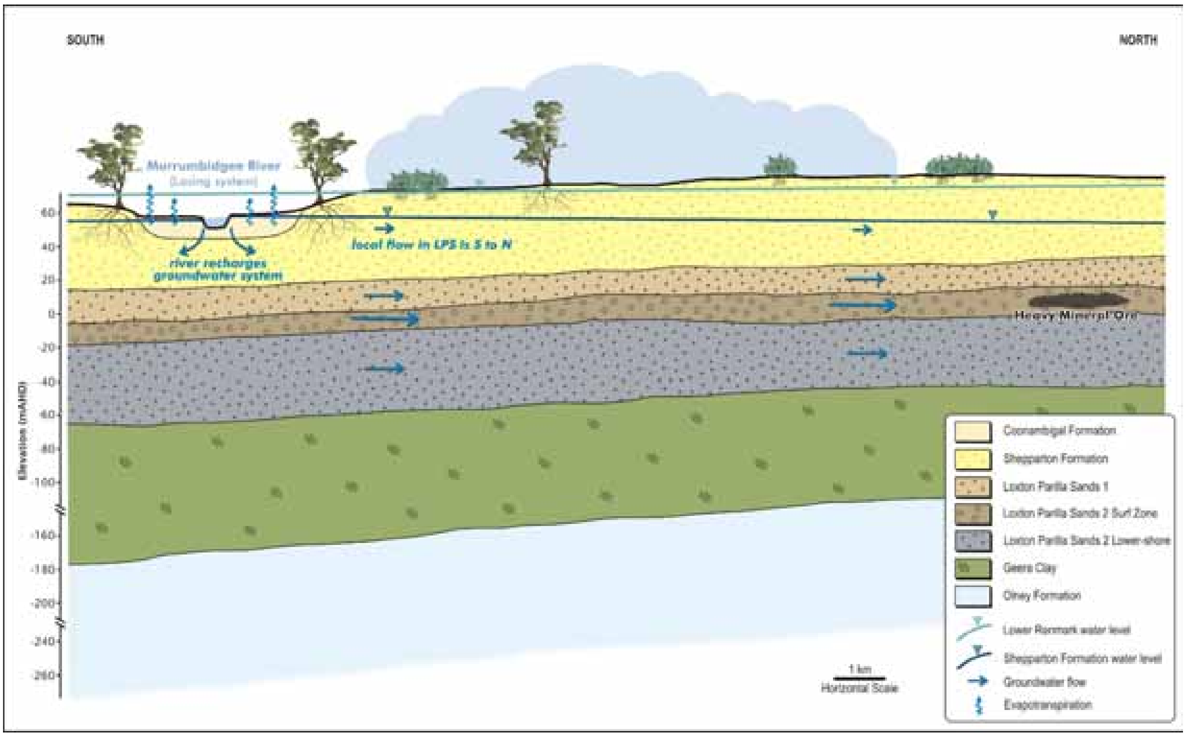


Figure 4-2 Hydrogeological cross section.

In terms of GDEs, the unconfined aquifers are the most relevant. On the eastern half of the study area and at the West Balranald deposit, the water table lies within the Shepparton Formation. On the western half of the study area and at the Nepean deposit, the water table lies within the LPS. Along the river channels and floodplains, the water table lies within the Coonambidgal Formation (SKM, 2011). Currently, the water table is typically 7-15 m below ground level (Figure 4-3). Groundwater salinities increase along the regional flowpath (east to west) and are higher at shallower depths (SKM, 2011). Figure 4-4 shows the groundwater salinity in in the water table aquifer. The salinity map is based on a basin-wide salinity coverage (MDBA, 2002), which has been refined in the immediate project area where new data has been acquired. Groundwater salinity transitions sharply from fresh at the river and floodplains, to saline in the scalded plains, sandplains and dunes in which the project area lies. Zones of hypersaline water are found in the region of the West Balranald deposit.

River regulation has resulted in additional river leakage to the adjacent aquifers compared with pre-regulated conditions (Kellett, 1994). These hydrological changes have likely influenced species composition on floodplains by elevating the water table to be consistently more accessible to plant roots (SKM, 2011).

The understanding of the baseline hydrogeological regime has been strengthened recently through Iluka's 2014 hydrogeological investigations program, including the dewatering trial drilling and pump testing program and ongoing groundwater monitoring (recently installed Shepparton monitoring wells are included in Figure 4-5). A groundwater model has also been developed based on the proposed project configuration, for operational design purposes and to investigate the impacts on the baseline groundwater regime (Jacobs, 2015).

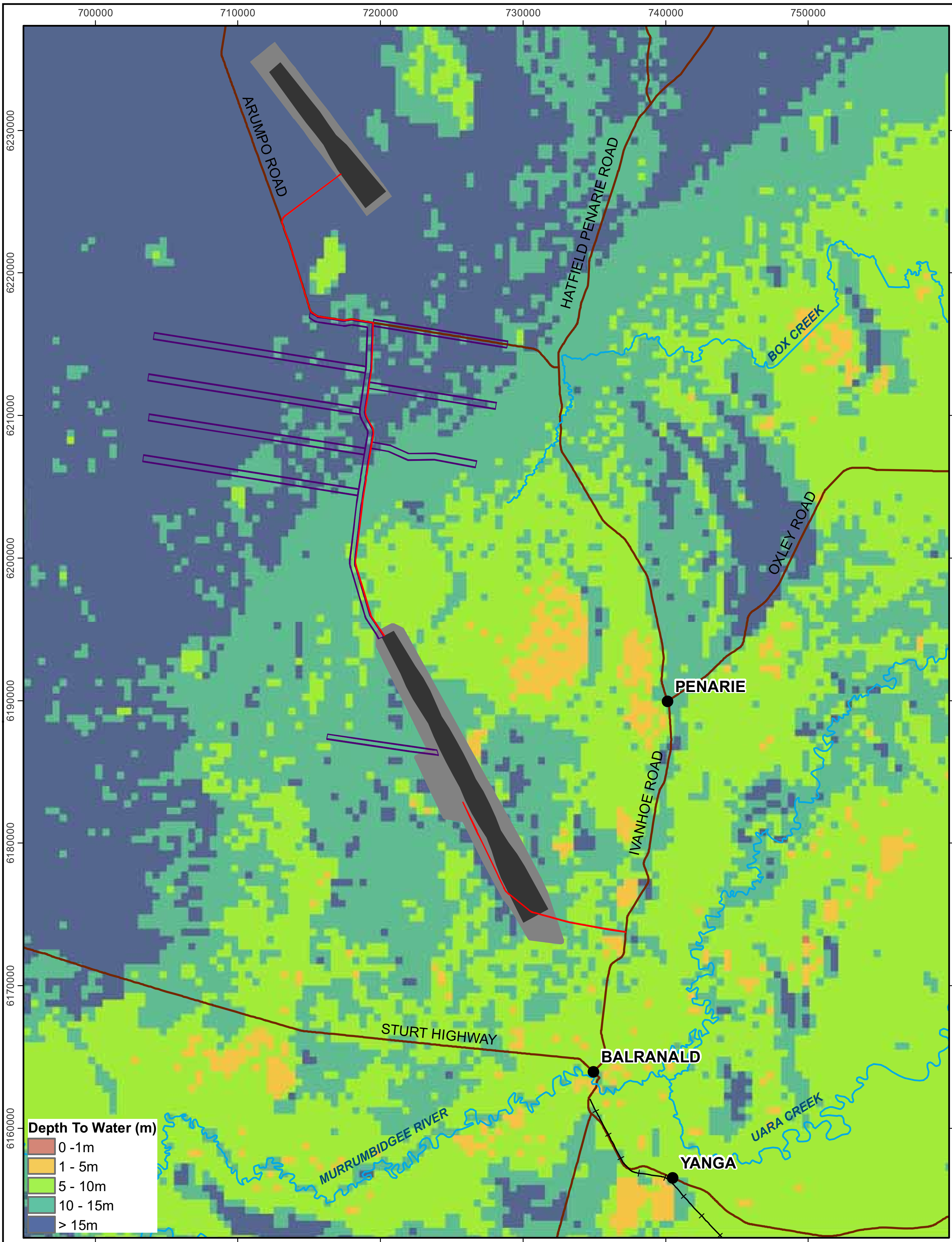


Figure 4-3: Modelled Baseline Depth To Water

Key

- Town
- Road
- Railway
- Watercourse
- Off-path injection area
- Haul road
- Pit and associated disturbance areas
- Project area

0 5,000 10,000
Metres
GDA 1994 MGA Zone 54

DISCLAIMER
CDM Smith has endeavoured to ensure accuracy and completeness of the data. CDM Smith assumes no legal liability or responsibility for any decisions or actions resulting from the information contained within this map.

Data Source: Iluka Resources Limitedl
Geoscience Australia, BOM Geofab v2.1

CDM Smith
cdmsmith.com

G:\Projects\AWS140004_balnaraId\mxd\final\Report\002-R1_dtw.mxd

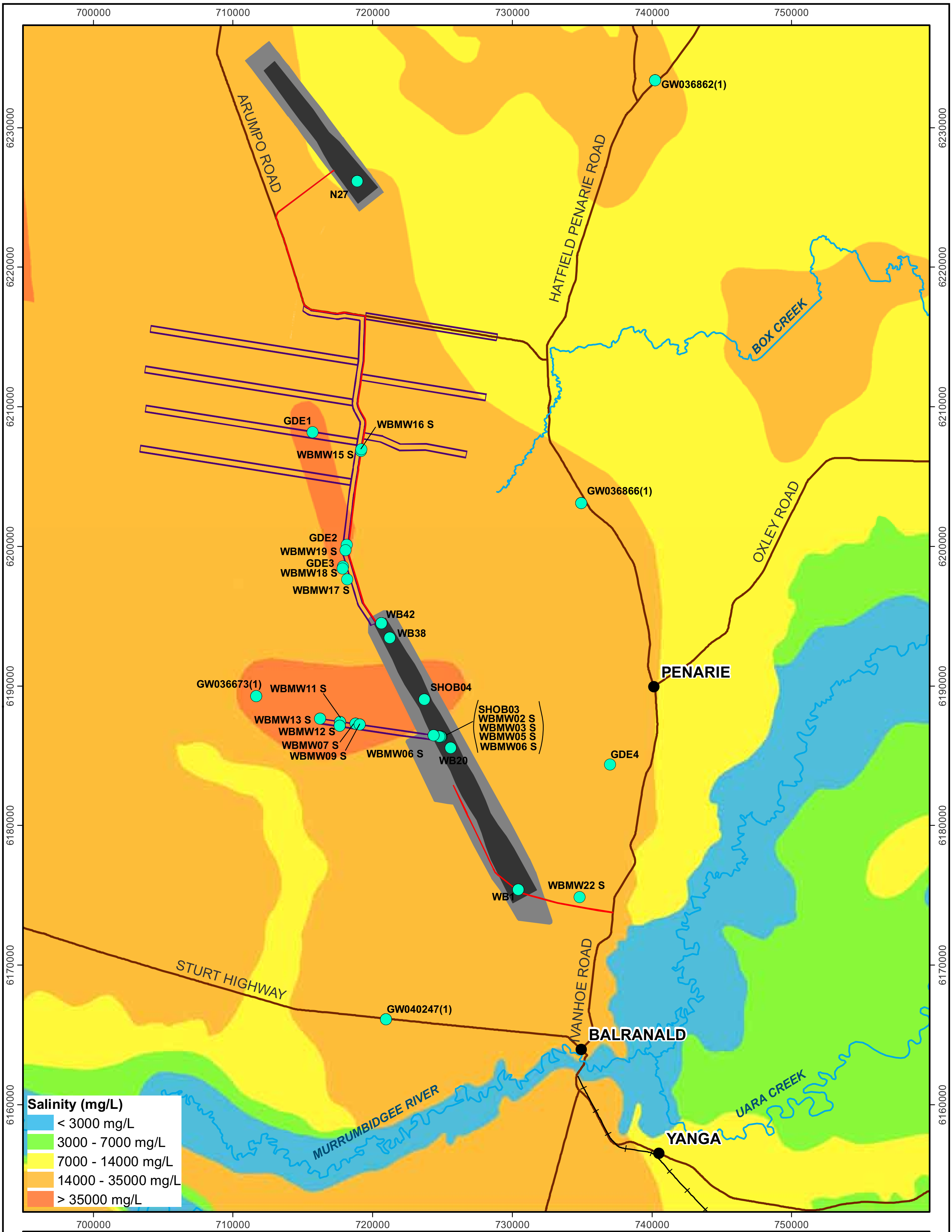


Figure 4-4: Salinity in the water table aquifer

Key

- Town
- Groundwater Monitoring Well
- Road
- Railway
- Watercourse
- Off-path injection area
- Haul road
- Pit and associated disturbance areas
- Project area

0 5,000 10,000
Metres
GDA 1994 MGA Zone 54

DISCLAIMER
CDM Smith has endeavoured to ensure accuracy and completeness of the data. CDM Smith assumes no legal liability or responsibility for any decisions or actions resulting from the information contained within this map.

Data Source: Iluka Resources Limited.
Salinity amended from Basin in Box (MDBA, 2002)
Geoscience Australia, BOM Geofab v2.1

CDM Smith
cdmsmith.com

G:\Projects\AWS140004_balnarald\mxd\final\Report\003-R2_sal.mxd

4.6 Surface water

The project area lies within the Benanee catchment, which is located in south-west NSW and borders the Lower Darling, Murray, Murrumbidgee, and Lachlan river basins. It has a catchment area of 21,390 square kilometres. The Benanee River basin is made up of a number of ill-defined ephemeral creeks, streams and lakes that contribute negligible inflows to the Murray River during typical climatic conditions.

The project area is located almost wholly within the catchment of Box Creek, an ephemeral watercourse and a distributary of the Lachlan River, which typically only flows during and immediately following heavy local rainfall and during large flood events in the Lachlan River catchment. In the vicinity of the project area, Box Creek is almost indistinguishable from the surrounding salt bush flats, and has no defined bed or banks (WRM, 2014).

The Murrumbidgee, Lachlan and Murray rivers are the major surface water features in the surrounding area. Flows within the rivers are regulated by major dams in their headwaters and by local regulating structures, including Redbank and Balranald Weirs and the Paika levee, which divert water for irrigation purposes. A number of ancient lakes that would be otherwise dry (e.g. Waldaira, Yanga and Paika Lakes) are artificially filled for irrigation water storage or environmental watering (SKM, 2011).

Due to the dry climate, flat landscape, and large areas of permeable soils, there is little locally derived runoff in the area. Extreme rainfall events are capable of filling local low permeability topographic depressions and creating flow in ancient drainage features (described by Scott, 1992), such as Box Creek, for short periods. Otherwise, surface water is confined to the major river channels and their associated backwaters and billabongs (SKM, 2011).

4.7 Previous GDE studies

The Lower Murrumbidgee Groundwater Sources Water Sharing Plan (NSW Office of Water, 2003) which covers the western Murrumbidgee floodplain to the north of the Balranald township lists potential GDEs as follows: terrestrial vegetation along the floodplains and prior streams, and the Great Cumbung Swamp, a known ecological asset, which is 50 km to the east of the West Balranald deposit. Supporting documentation for the water sharing plan speculates that the groundwater dependence of these assets is minimal, noting they are dependent mainly on surface water flows (Kumar, 2010). The prior streams are listed as GDEs of 'high priority', yet they occur to the south and west of the Murrumbidgee River, well away from the West Balranald and Nepean deposits (SKM, 2011). No high priority GDEs are listed in the Murray-Darling Basin Porous Rock Water Sharing Plan, which applies directly to the Balranald Project area.

The baseline investigations (SKM, 2011), undertaken as part of the Pre-Feasibility Study for the project, identified the occurrence of potential GDEs in the vicinity of the project area. It mapped and characterised potential GDEs into to two broad categories:

- Wetlands and vegetation associated with the Murrumbidgee, Lachlan and Murray River Floodplain environments; and
- Vegetation (primarily Black Box trees) outside the floodplain and permanent streams, in topographic depressions where the water table may be shallow enough and not too saline.

The study found that potential GDEs associated with both of these environments are likely to only partially, if at all, depend on groundwater to meet their water requirements. The potential GDEs associated with the floodplain environments include the high value River Red Gum forests and the Great Cumbung swamp. The Black Box trees away from the floodplain are less significant assets, in terms of their ecological value, but provide locally valuable shade and shelter for fauna (and stock) in a landscape sparsely populated by trees.

In 2014, a Soil-Plant-Water investigation was undertaken to establish where (in the soil profile) the Black Box vegetation is accessing water from (Jacobs, 2014). This study found that rainfall and episodic surface water (irregular flooding and/or pooling from heavy rainfall) provided the dominant water source for Black Box, but there was also found to be some potential for these trees to use groundwater opportunistically to supplement their water needs.

Previous studies have shown Black Box to be a hardy, resilient species capable of sustaining droughts and quite saline conditions. It is generally found in low-lying areas and has a preference for heavy, clay soils that are subject to periodic inundation. Studies have reported that Black Box can use saline groundwater to supplement its water needs, but if the groundwater salinity exceeds 60 mS/cm then groundwater use is negligible (Jolly and Walker, 1996 and Jolly et al., 2002).

More recently, Niche Environmental (2014) performed some mapping works to update the known spatial distribution of Black Box, within a 15 km radius of the project area. Figure 4-5 shows the spatial distribution of potential GDEs, updated from the baseline investigation to include the areas of Black Box that were recently mapped.

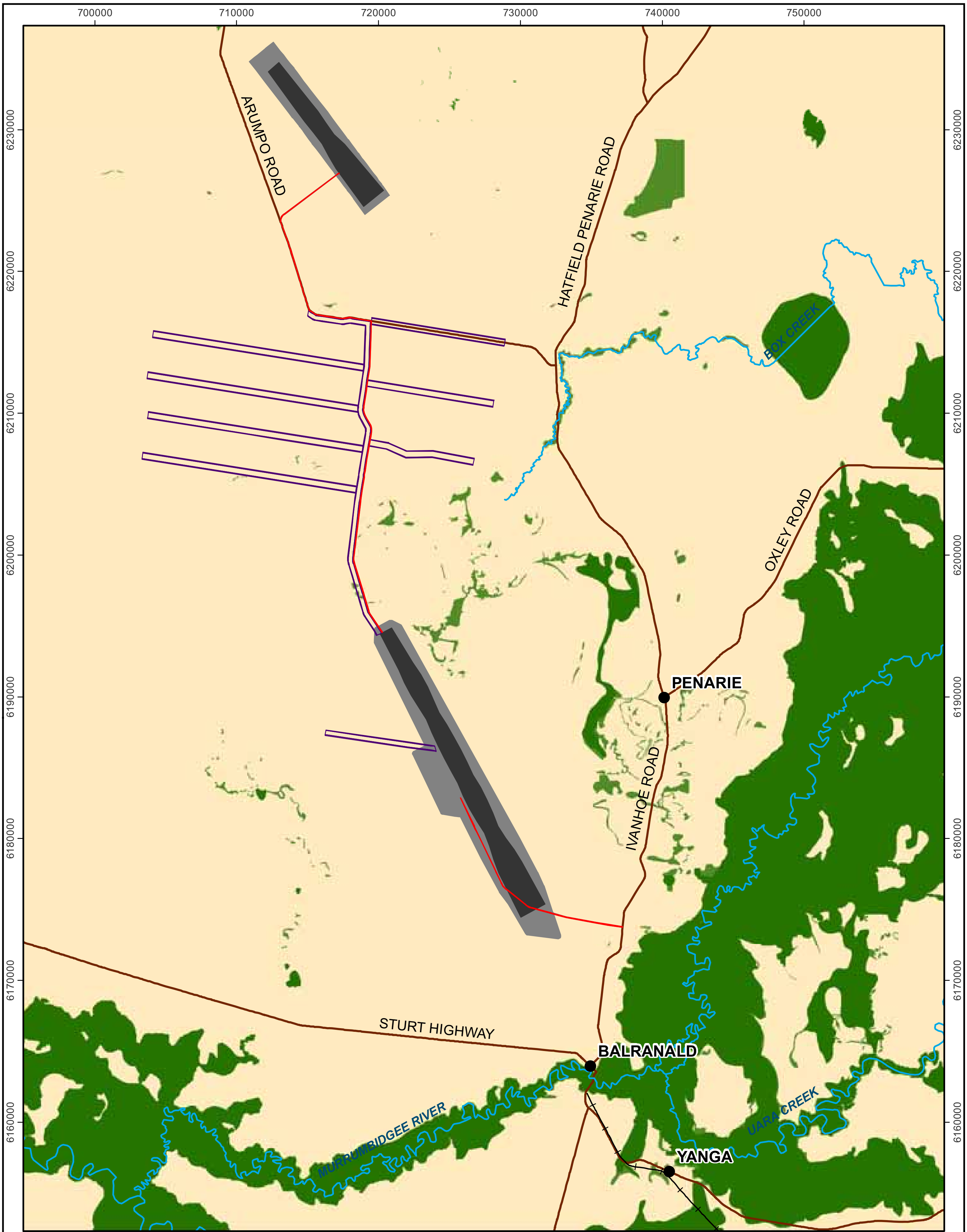


Figure 4-5 Potential GDE locations

Key

- Town
- Road
- Railway
- Watercourse
- Off-path injection area
- Haul road
- Pit and associated disturbance areas
- Project area
- Potential GDEs

0 5,000 10,000
Metres
GDA 1994 MGA Zone 54

DISCLAIMER
CDM Smith has endeavoured to ensure accuracy and completeness of the data. CDM Smith assumes no legal liability or responsibility for any decisions or actions resulting from the information contained within this map.

Data Source: Iluka Resources Limited. Geoscience Australia, BOM Geofab v2.1

CDM Smith
cdmsmith.com

G:\Projects\AWS140004_balnarald\mxd\final\Report\004-R1_gde.mxd

Section 5 Water effects assessment

5.1 Outline

The water-affecting activities that relate to potential GDEs are outlined in Table 5-1. The possible water effects identified concern both groundwater and surface water to provide a complete assessment of all possible ways in which water sources for potential GDEs could be impacted (i.e. the assessment is not restricted to groundwater-related effects).

Table 5-1 Mine activities and their effects on the water regime

Activity	Direct water effects
Groundwater abstraction for pit dewatering	▪ Groundwater level drawdown ▪ Reduced water availability to root zone
Disposal of water via injection borefield	▪ Groundwater level mounding ▪ Changes to water quality (chemistry)
Mining (removal of overburden and exposure of potentially acid forming (PAF) materials)	▪ Disturbance of unsaturated zone hydrogeology ▪ Changes to water quality (chemistry)
Capture/alteration of surface water runoff and flooding	▪ Reduced surface water runoff to streams and lakes ▪ Interference with flood flows to streams and lakes ▪ Changes to water quality (sediment load, chemistry)

5.2 Dewatering

Iluka propose to use dry mining techniques to extract the ore, which requires dewatering of the shallow aquifers (Shepparton and part of the LPS).

Groundwater will be abstracted from a series of production wells along the perimeter of the mine pit (and some in-pit wells) to lower and maintain the water table below the base of the ore. Abstraction will occur at a rate of around 700 L/s, with a peak around 1,300 L/s at the West Balranald pit. Dewatering will occur over a total of 8 years, with 6 years of mining and 2 years of backfilling the final void. Nepean will run for 18 months, at a rate of roughly 50 L/s.

Groundwater modelling has been conducted by Jacobs (2015), which outlines predicted effects to groundwater regime as a result of dewatering activities – the primary effect of relevance to potential GDEs being drawdown of the water table. Appendix B presents the predicted drawdown as a result of dewatering over the life of the mine and afterwards, as the water table recovers.

5.3 Injection

All abstracted groundwater that is surplus to mine needs will be pumped to a network of injection wells that will return the water to its original aquifer (the LPS). A dedicated injection borefield, located between the West Balranald and Nepean mines, will be used as the primary injection point, although some groundwater injection will also occur along the mine path.

The primary effect of groundwater injection that is of relevance to potential GDEs is a rise in the water table elevation (or mounding). The predicted level of mounding in the water table as a result of injection is shown in Appendix B, based on the groundwater modelling undertaken by Jacobs (2015).

5.4 Mining

Mining has the potential to alter groundwater quality as a result of Acid Mine Drainage (AMD) processes in which Potentially-Acid Forming (PAF) materials from the overburden or ore are exposed to atmospheric oxygen during mining. The potential and risk of AMD at the Balranald project has been characterised through a series of geochemical studies that are summarised in Earth Systems (2015). As an outcome of these studies, Iluka has developed a management and mitigation strategy for AMD aimed at preventing impacts to groundwater quality. As a result of the adoption of this strategy, mining (and AMD) is not considered to be water-affecting activity that will have any impact on GDEs.

5.5 Surface water runoff and flooding

Mining activities, including pit development and construction of infrastructure has the potential to alter the baseline surface water regime by interfering with natural drainage lines, causing changes in the amount and quality of runoff/flow to potential GDEs, which may also rely on surface water. These potential effects have been assessed by WRM (2015).

The maximum catchment area draining to the mine water management system is 194.3 ha, which represents less than 0.1% of the catchment area draining to Box Creek. The impact of such a loss of catchment on Box Creek flows will be insignificant, particularly considering the arid nature of the project area (WRM, 2015).

The mine water management system will be designed and operated to minimise the impacts on downstream water quality. Surface water runoff from undisturbed areas will be diverted, wherever possible, around areas disturbed by mining and released from the site, minimising the capture of clean surface runoff. Mine affected water will be collected in onsite storages and used preferentially to satisfy mine site water demands (e.g. processing, dust suppression). The mine water management system will be operated to prevent releases of mine affected or abstracted hypersaline water from the project area. Any uncontrolled releases will be contained by the construction of bunds and sumps.

The West Balranald and Nepean mine infrastructure is located outside of the predicted Box Creek and Tin Tin Lake flood extent of 1 in 100 year flow and will have no impact on flooding (WRM, 2015). However, parts of the Nepean access road and injection field are located within the flood extent of Box Creek and Tin Tin Lake. The injection field infrastructure will present an insignificant obstruction to any flood flows. The Nepean access road will be constructed at existing ground levels, and will therefore not have any impact on predicted flood levels, velocities or flow distributions.

In summary, negligible surface water effects are predicted as a result of project activities.

Section 6 Conceptualisation of GDEs

6.1 Overview

The conceptualisation of GDEs is necessary to understand whether (and how) a GDE could potentially be exposed to the water-affecting activities – i.e. does an exposure pathway exist between a direct effect, outlined in Section 5, and a potentially sensitive GDE? The process of conceptualisation is outlined in the Australian GDE Toolbox (Richardson et al., 2011). In brief, it involves describing the component flora and fauna of an ecosystem and the hydrological regime that supports the flora and fauna. If aspects of a GDEs local hydrological regime are affected by mining activities then an exposure pathway exists and the GDE could be potentially impacted.

6.2 Existing conceptual models

Preliminary conceptualisations of potential GDEs for the Balranald project were provided in SKM (2011) to characterise the hydrological regime for:

- Wetlands and vegetation associated with the Murrumbidgee, Lachlan and Murray River Floodplain environments; and
- Vegetation (primarily Black Box trees) outside the floodplain and permanent streams, in topographic depressions, that can potentially access the water table.

The conceptual model for potential GDEs within floodplain environments is shown in Figure 6-1. It depicts surface water providing the dominant water source for floodplain wetlands and vegetation, with shallow groundwater (recharged by surface water) also providing a water source.

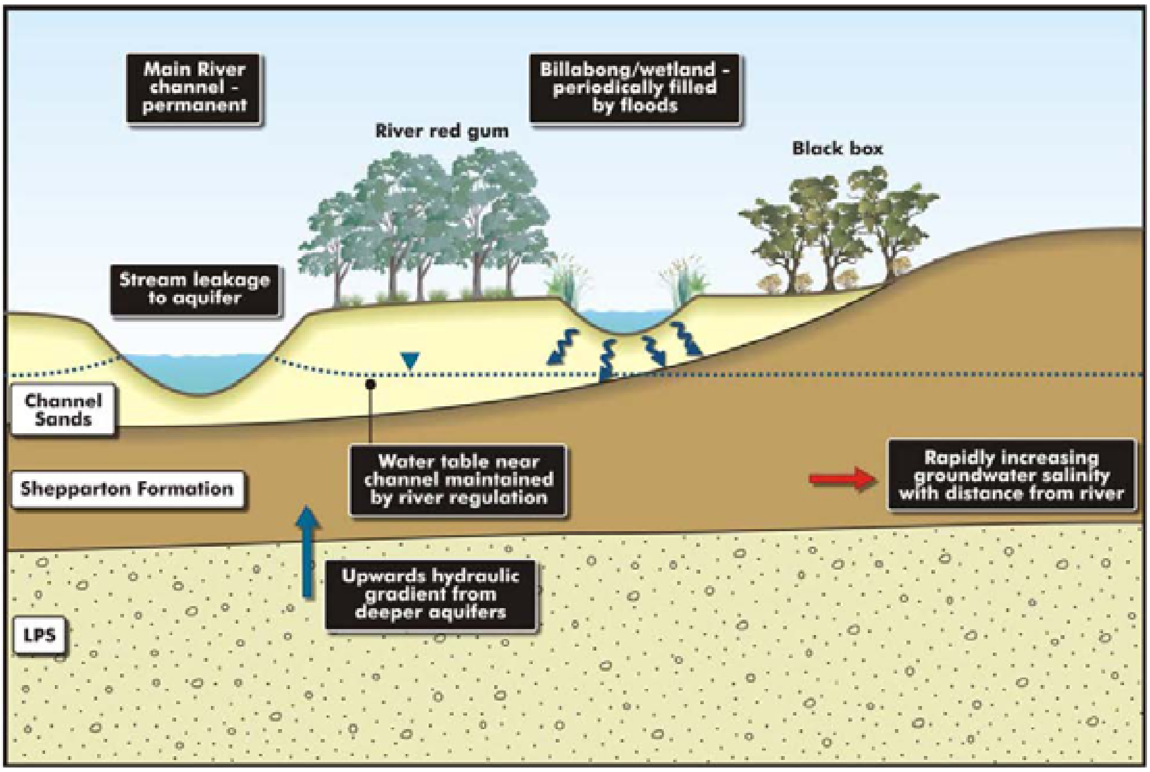


Figure 6-1 Conceptual model for potential GDEs associated with floodplain settings (SKM, 2012)

A subsequent field investigation by Jacobs (2014) provided data on the water use of Black Box trees and the factors that influence its water uptake. In alignment with studies conducted elsewhere, Black Box was found to be a hardy, resilient species requiring fresh water from rainfall and periodic inundation for the bulk of its water needs. There was some evidence of Black Box using groundwater to supplement its water needs during dry periods; however the use of groundwater is likely to be negligible in hypersaline conditions (i.e. when groundwater salinity exceeds 35,000 mg/L). A refined conceptual model was prepared for Black Box (Figure 6-2), which shows the trees being supplied predominantly by rainfall (and infrequent surface inundation), and the use of groundwater varying according to groundwater salinity and the depth to groundwater.

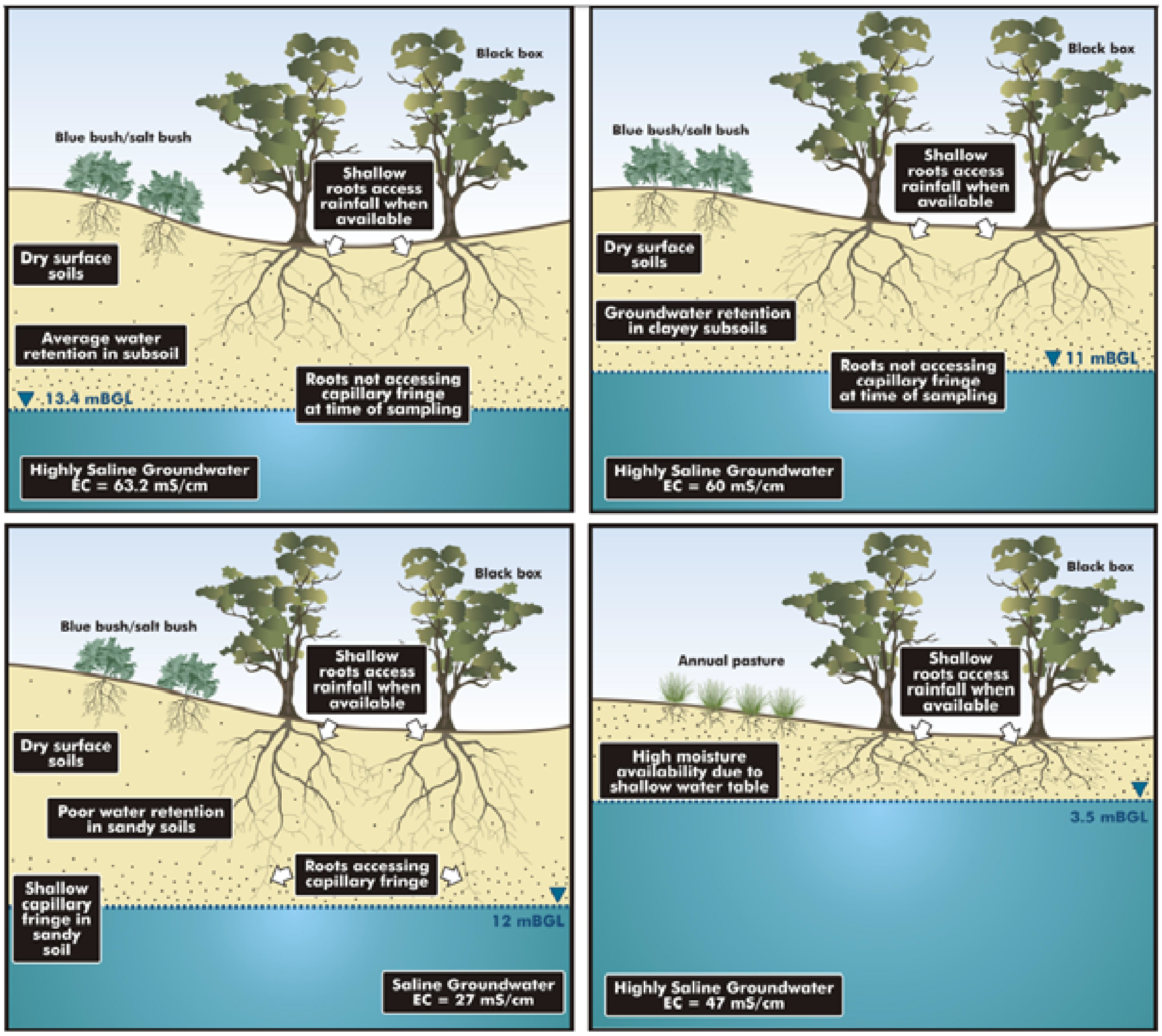


Figure 6-2 Conceptual models of Black Box water use (Jacobs, 2014)[1]

6.3 Identification of exposure pathways

The conceptualisations for floodplain environments and for Black Box in topographic depressions point to rainfall and surface inundation providing the bulk of water needs for these ecosystems, with groundwater providing a supplementary role.

[1] To convert EC (in mS/cm) to TDS (mg/L) multiply by a conversion factor (approx.) of 600.

The predicted effects to surface runoff are confined to the immediate project disturbance area (WRM, 2014), and do not affect surface runoff at the potential GDE locations shown in Figure 4-5. Therefore no exposure pathways are identified in relation to runoff and surface inundation for potential GDEs.

Exposure pathways related to groundwater may occur where the water table is predicted to be affected by drawdown or mounding. Drawdown may cause reduced water availability to vegetation that uses groundwater. Mounding may cause potential GDEs to be exposed to hypersaline groundwater and result in impacts associated with salinisation and waterlogging.

6.4 Sensitivity of potential GDEs

The extent to which GDEs may be impacted by water-affecting activities is related to the sensitivity of a GDE to a change in its hydrology. The sensitivity varies for each exposure pathway.

In terms of drawdown, the sensitivity of potential GDEs will vary according to the extent that they use groundwater. Previous studies (e.g. Jacobs, 2014) have shown that the groundwater use of vegetation in the region is influenced by two main factors: the depth of the water table and groundwater salinity. The highest level of groundwater use occurs where the water table is shallow and of a low salinity. Negligible groundwater use occurs where the water table is too deep to be accessible to roots (approximately 15 m) or is too saline (>35,000 mg/L).

A classification system for the indicative level of groundwater use has been developed based on a consideration of groundwater salinity and the depth of the water table (Figure 6-3), which extrapolates the findings of Jacobs (2014) to cover a broader range of conditions in terms of water table salinity and depth. The GDE classes derived vary in their use of groundwater from very high (Class 1) to negligible (Class 5). It follows that Class 1 GDEs will be very sensitive to groundwater level drawdown and Class 5 GDEs will be insensitive to groundwater level drawdown.

		Groundwater salinity (mg/L)				
		< 3,000	3,000 - 7,000	7,000 - 14,000	14,000 - 35,000	> 35,000
Depth of water table (mbgl)	0-1	Class 1	Class 2	Class 3	Class 4	Class 5
	1-5	Class 2	Class 2	Class 3	Class 4	Class 5
	5-10	Class 3	Class 3	Class 3	Class 4	Class 5
	10-15	Class 4	Class 4	Class 4	Class 4	Class 5
	> 15	Class 5	Class 5	Class 5	Class 5	Class 5

GDE Class	Class 1	Class 2	Class 3	Class 4	Class 5
Likely level of groundwater use	Very High	High	Moderate	Low	Negligible

Figure 6-3 Classification system used to define their indicative level of groundwater use

The position in the landscape of the different GDE classes is illustrated in Figure 6-4, which shows Class 1 and Class 2 GDEs being more likely to occur in floodplain environments where the water table is relatively shallow and less saline. Away from the river, deeper water tables and high groundwater salinities mean groundwater use will be lower.

The classification system has been applied to map the classes of potential GDEs at Balranald using the spatial coverages of groundwater depth and salinity. The resultant map of GDE Classes is shown in Figure 6-5, indicating the GDEs most sensitive to drawdown are likely those that occur in floodplain environments. The GDEs closer to the West Balranald and Nepean deposit are less sensitive to drawdown.

Figure 6-5 also shows the location of hydrograph sites in which the predicted changes to groundwater levels in the water table (i.e. drawdown and mounding) are evaluated. The hydrograph sites include a mixture of actual monitoring bores screened in the water table (installed as part of Iluka's project investigations) and 'model' monitoring sites, which are not actual monitoring bores but locations within the model that have been chosen to monitor the predicted changes in groundwater level for the purposes of this assessment (see Table 6-1). These locations have been selected to evaluate mapped potential GDEs in the vicinity of the project.

Table 6-1 Details of hydrograph sites

Hydrograph site	Comment
GDE1	Actual monitoring bore (see Jacobs, 2014)
GDE2	Actual monitoring bore (see Jacobs, 2014)
GDE3	Actual monitoring bore (see Jacobs, 2014)
GDE4	Actual monitoring bore (see Jacobs, 2014)
WBMW22	Actual monitoring bore (see Iluka, 2015)
1	Selected monitoring point within groundwater model
2	Selected monitoring point within groundwater model
3	Selected monitoring point within groundwater model
4	Selected monitoring point within groundwater model

The sensitivity of potential GDEs to mounding will depend on the species tolerance of salinity and waterlogging. Both River Red Gums and Black Box are listed as being moderately salt-tolerant and capable of tolerating soil ECe of up to 16 mS/cm (DEPI, 2014). As discussed, Black Box is capable of using saline groundwater (up to 35,000 mg/L in limited quantities) and is often found in drier and more saline environments than River Red Gum. By comparison River Red Gum is more tolerant of waterlogging.

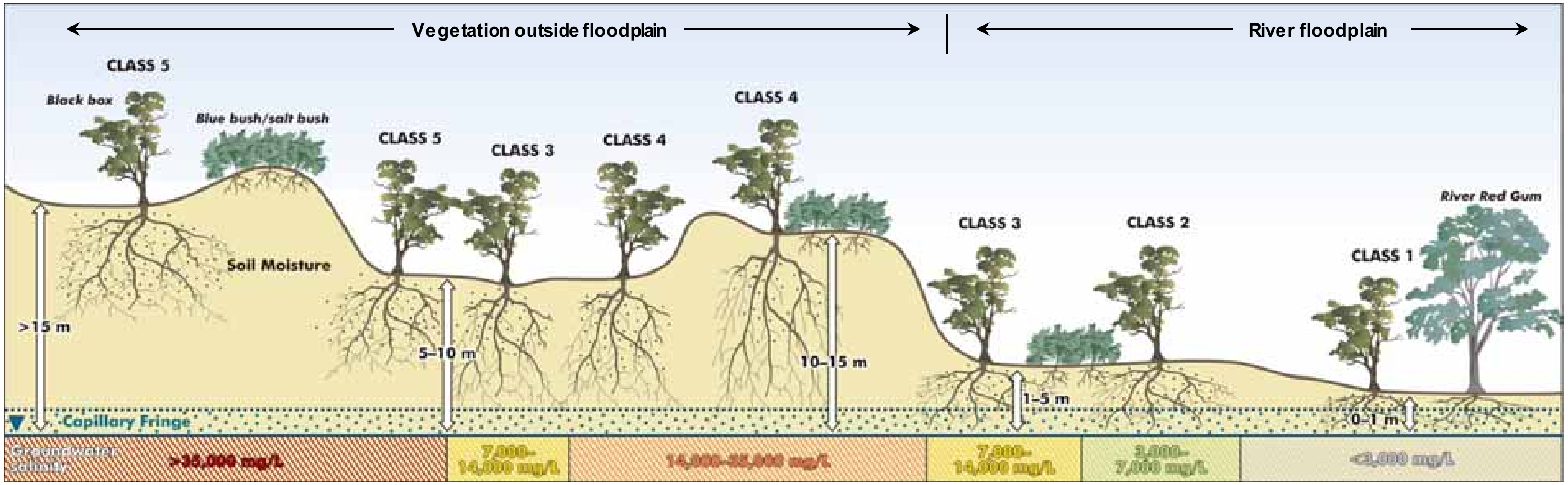


Figure 6-4 Conceptual model showing the setting of different GDE Classes in terms of groundwater conditions

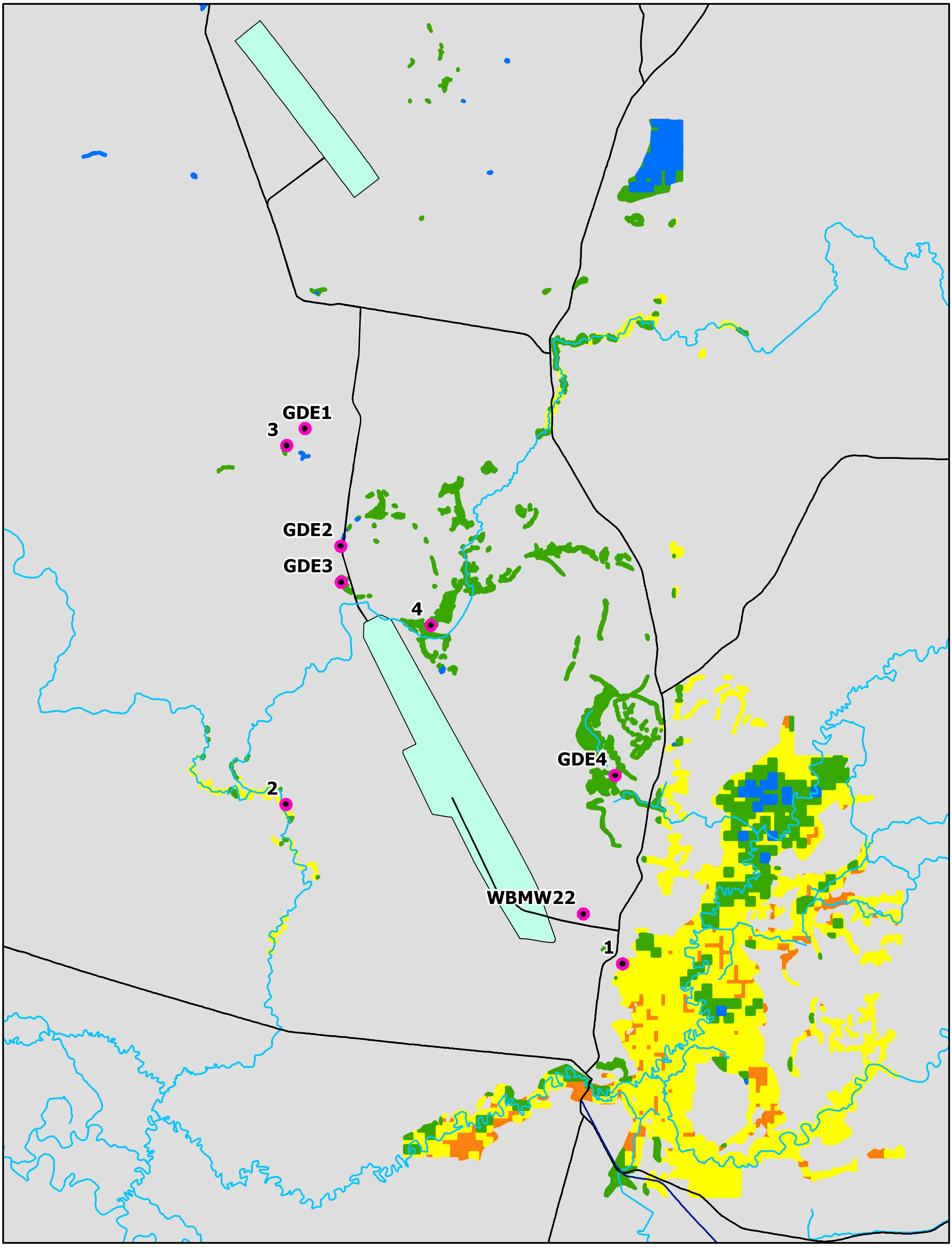


Figure 6-5: GDE Class

Key

- Hydrograph_locations
- Railway
- Major roads
- Drainage lines
- Mine Footprint

GDE_Class

- 2
- 3
- 4
- 5

0 5,000 10,000
Metres
GDA 1994 MGA Zone 54

DISCLAIMER
CDM Smith has endeavoured to ensure accuracy and completeness of the data. CDM Smith assumes no legal liability or responsibility for any decisions or actions resulting from the information contained within this map.

Data Source:

CDM Smith
cdmsmith.com

C:\Users\roacha\Documents\03_ArcGIS\Projects\Balranald\GDE Class and Hydrograph locations.mxd

Section 7 Impact assessment

7.1 Approach

The impact assessment combines the outputs of the water effects assessment (Section 5) and the identification of exposure pathways undertaken through the conceptualisation of sites (Section 6). If a water-related effect is such that it causes a change to the hydrology such that a potential GDE is exposed to a direct effect, then an impact exists. The purpose of this section is to rate these impacts (where they occur) according to the level of risk they pose to the ecosystem.

Table 7-1 presents an impact rating classification to be used in this assessment. It was developed by Froend & Loomes (2004) and assesses potential impacts on terrestrial and wetland ecosystems on a low to high ranking system. In this assessment, the two intermediate categories are combined as a moderate impact.

Table 7-1 Impact rating classification to assess potential impacts on GDEs (Froend and Loomes, 2004)

Rating	Consequence for Phreatophytic structure/distribution	Consequence for wetland structure/distribution
Low	No significant* change in distribution of terrestrial phreatophytic species.	No significant* change in distribution of species.
Low to Moderate	Some evidence of changing distribution of species, encroachment of more drought tolerant species into areas previously dominated by less drought tolerant species.	Some evidence of changing distribution of species, with disturbance and/or drying allowing establishment of exotic species.
Moderate to High	Measureable change in the demographics of some species, encroachment of more drought tolerant species into areas previously dominated by less drought tolerant species.	Signs of contraction of wetland through changing demographics of more than one species, with encroachment of exotic species into wetland areas.
High	Overstorey and understorey decline and/or loss of species from ecosystem. Greater than 50% reduction in abundance of dominant species and/or significant change in dominant populations and/or disturbance allowing establishment of exotic species.	Greater than 50% reduction in abundance of dominant species and/or significant change in dominant population (possibly complete drying out of wetland basin, reduction in period of inundation), encroachment of exotic species into wetland areas.

* Significant change is change that implies degradation.

The impact assessment draws on the predicted changes to the water table over time from the groundwater model (Jacobs, 2015). The impact ratings for drawdown are derived according to the magnitude of drawdown and the sensitivity of potential GDEs to this, as outlined in Section 6 (Figure 6-3). Figure 7-1 provides a matrix to determine the impact rating based on these factors.

For mounding, impact ratings are derived according to the extent that the water table rises (relative to the ground surface) and the salinity of groundwater, as outlined in Figure 7-2.

The rating systems developed are semi-quantitative, based on the logic outlined in Section 6 and professional judgement. The rating systems do not explicitly consider the duration of drawdown/mounding, but assume the changes in the water table occur over a sustained period (> 12 months). More complicated rating systems could be developed that include the duration of drawdown/mounding as a factor in determining impact ratings; however there is limited data to inform the development of such rating systems, and a less complicated approach is preferable for the purposes of this assessment.

GDE Class	Drawdown (m)	< 0.2	0.5 - 1	1 - 3	3 - 5	> 5
	Class 1	Low	Moderate	High	High	High
	Class 2	Low	Low	Moderate	High	High
	Class 3	Low	Low	Low	Moderate	High
	Class 4	Low	Low	Low	Low	Moderate
	Class 5	n.a.*	n.a.	n.a.	n.a.	n.a.

*not applicable due to no exposure pathway (Class 5 have negligible groundwater dependence)

Figure 7-1 Impact rating system for drawdown

GW Salinity (mg/L)	Mounding (mbgl)	< 2	2 - 5	5 - 10	> 10
	< 3,000	Moderate	Low	Low	Low
	3,000 - 7,000	High	Moderate	Low	Low
	7,000 - 14,000	High	Moderate	Low	Low
	14,000 - 35,000	High	Moderate	Moderate	Low
	> 35,000	High	High	Moderate	Low

Figure 7-2 Impact rating system for mounding

7.2 Impact assessment

The impact assessment was conducted separately for drawdown and mounding. In both cases, a spatial GIS analysis using groundwater modelling outputs was used to derive impact ratings for the potential GDEs shown in Figure 4-5.

The process for calculating drawdown impact ratings was as follows:

1) Gridded surfaces of predicted water table elevations were obtained from the groundwater model at selected times throughout the model run (see Table 7-2).

2) The surfaces were overlain to produce a surface that maps the maximum drawdown at any point in time over the model run.

3) The integrated drawdown surface was overlain with the distribution of potential GDEs, and impact ratings were calculated for each GDE polygon according to GDE Class and the magnitude of drawdown using Figure 7-1.

The process for calculating mounding impact ratings was as follows:

1) Gridded surfaces of predicted water table elevations were obtained from the groundwater model at selected times throughout the model run (see Table 7-2).

2) The surfaces were overlain to produce an integrated surface that maps the maximum mounding at any point in time over the model run.

3) The integrated mounding surface was overlain with the map of potential GDEs and the salinity of the water table, and impact ratings were calculated for each GDE polygon according to the extent to which the water table rises (relative to the land surface) and the salinity of the groundwater using the rating system outlined in Figure 7-2.

Table 7-2 Times of outputs obtained from groundwater model (Jacobs, 2015)

	Mining Year	Start date	End date	Stress period length	Project water-affecting activities
1	n/a	1-Jan-1914	1-Jan-2014	100 yr	None (equilibration)
2	-3.0 to -1.5	1-Jan-2014	1-Jul-2015	1.5 yr	Water supply: borefield 3
3	-1.5 to -0.5	1-Jul-2015	1-Jul-2016	1 yr	Water supply: borefield 7 and plant well
4	-0.5 to 0.0	1-Jul-2016	1-Jan-2017	0.5 yr	Water supply: plant well
5	0.0 to 0.25	1-Jan-2017	1-Apr-2017	0.25 yr	West Balranald mining above watertable
6-141	0.25 to 5.9	1-Apr-2017	1-Dec-2022	14 d	West Balranald (mining) dewatering and injection
142	5.9 to 6.0	1-Dec-2022	1-Jan-2023	30 d	West Balranald (backfilling) dewatering and Nepean (mining) dewatering
143-146	6.0 to 6.3	1-Jan-2023	1-May-2023	30 d	West Balranald (backfilling) dewatering, West Balranald make-up water supply (56 L/s) and Nepean (mining) dewatering
147-154	6.3 to 7.0	1-May-2023	1-Jan-2024	30 d	West Balranald (backfilling) dewatering, West Balranald make-up water supply (12 L/s) and Nepean (mining) dewatering
155-159	7.0 to 7.5	1-Jan-2024	1-Jul-2024	30 d	West Balranald (backfilling) dewatering and Nepean (mining) dewatering
160-166	7.5 to 8.0	1-Jul-2024	1-Jan-2025	30 d	West Balranald (backfilling) dewatering
167	n/a	1-Jan-2025	1-Jan-2125	100 yr	None (recovery)

Drawdown impact ratings are shown in Figure 7-3 and groundwater level hydrographs for selected locations are shown in Appendix C. Based on the numerical model predictions, none of the potential GDEs have an impact rating greater than low and many of the potential GDEs have no defined impact, being located outside of the extent of drawdown. Most of the potential GDEs within the zone of drawdown are not likely to be particularly sensitive to drawdown (Class 4) and therefore the likelihood of drawdown impacts eventuating have been rated as low.

Mounding impact ratings are shown in Figure 7-4 and groundwater level hydrographs for selected locations are shown in Appendix C. The area where mounding impacts are noted surrounds the dedicated injection borefield that is located between the West Balranald and Nepean deposits. The potential GDEs within this area have been assigned impact ratings of either low or moderate. While the moderate ratings flag that some impact is possible, the predicted magnitude of mounding evident in the hydrographs (e.g. see sites GDE1, GDE2 and GDE3 in Appendix C) is such that the water table remains well below the surface. Nevertheless, these results indicate that some focus should be directed towards potential mounding impacts in a GDE management strategy (Section 8).

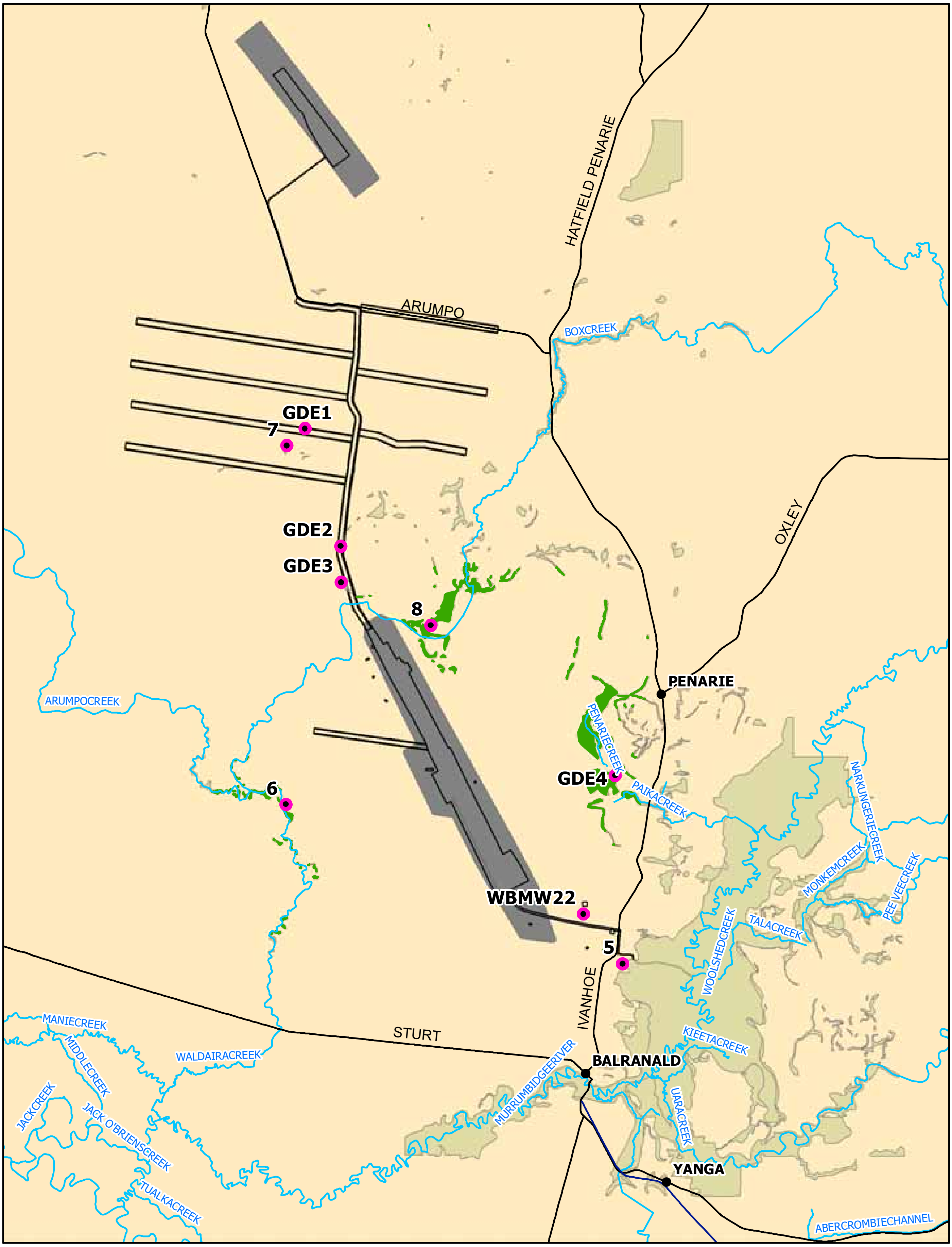


Figure 7-3: Drawdown impact

Key

- Town
- Hydrograph locations
- Railway
- Major roads
- Drainage lines
- Project area
- Pit and associated disturbance areas
- Mapped GDEs

Predicted Impact

- L

0 5,000 10,000
Metres
GDA 1994 MGA Zone 54

DISCLAIMER
CDM Smith has endeavoured to ensure accuracy and completeness of the data. CDM Smith assumes no legal liability or responsibility for any decisions or actions resulting from the information contained within this map.

CDM Smith
cdmsmith.com

Data Source:

C:\Users\roacha\Documents\03_ArcGIS\Projects\Balranald\Drawdown Impact.mxd

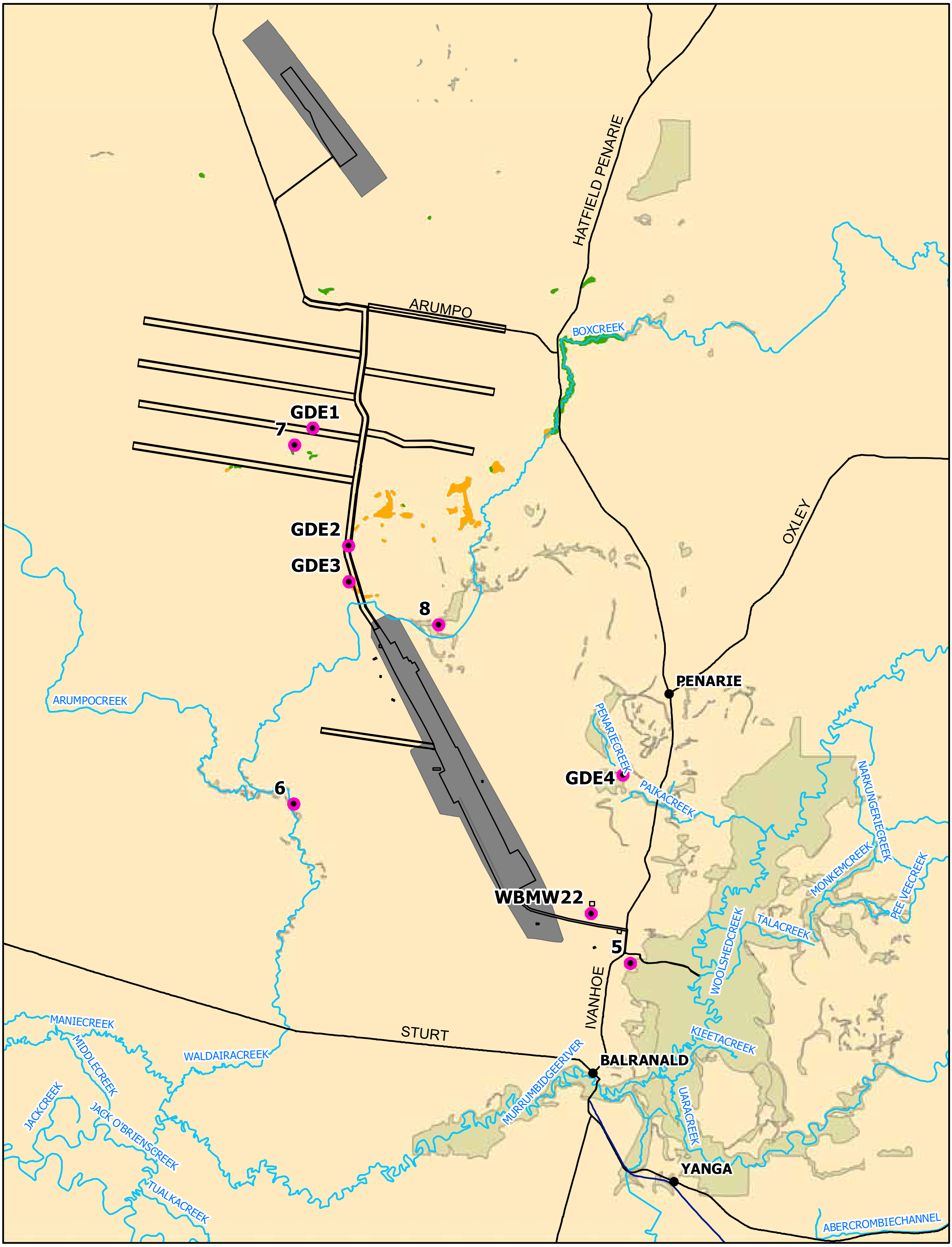


Figure 7-4: Mounding impact

Key

- Town
- Hydrograph locations
- Railway
- Major roads
- Drainage lines
- Project area
- Pit and associated disturbance areas
- Mapped GDEs

Predicted Impact

- L
- M

0 5,000 10,000
Metres
GDA 1994 MGA Zone 54

N W E S

DISCLAIMER
CDM Smith has endeavoured to ensure accuracy and completeness of the data. CDM Smith assumes no legal liability or responsibility for any decisions or actions resulting from the information contained within this map.

Data Source:

CDM Smith
cdmsmith.com

C:\Users\roacha\Documents\03_ArcGIS\Projects\Balranald\Mounding Impact.mxd

Section 8 GDE management strategy

8.1 Philosophy

The following approach (depicted in Figure 8-1) has been taken to guide the development of the GDE management strategy:

- GDEs should be managed to meet the ecosystem objectives and predicted outcomes as specified in the EIS.
- Ongoing monitoring and evaluation will be a cornerstone of the management strategy and designed to provide advanced warning of potential impacts as well as a better understanding of the groundwater regime and ecosystem water requirements.
- A trigger response framework will be established which outlines a tiered response to the risks associated with impacts to GDEs as follows:
  - Tier 1: monitoring, analysis and evaluation.
  - Tier 2: detailed investigations to better define significance of risk and devise most appropriate direct management actions as required.
  - Tier 3: deployment of direct management options to mitigate impacts, or the implementation of contingency plans.

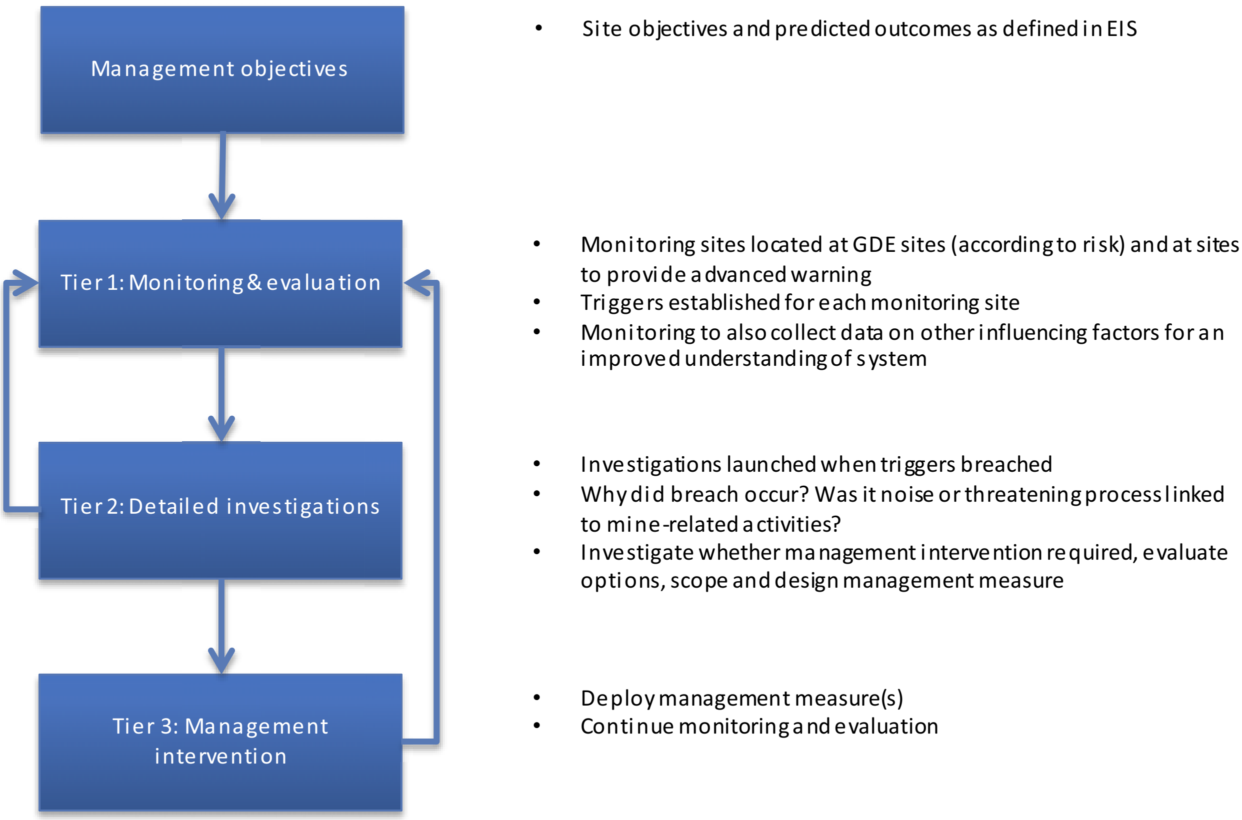


Figure 8-1 GDE management strategy

The GDE management strategy will be integrated into the overall water management strategy for the Balranald Project.

8.2 Tier 1: Ongoing monitoring, analysis and evaluation

The general elements of the monitoring plan for potential GDEs are as follows:

- Designated monitoring sites to be established at sites of high conservation value, those that are deemed to be at risk according to the impact assessment, advance warning (sentinel) sites, and the establishment of control sites to make allowances for background trends and influences associated with climatic variability and/or cumulative impacts.
- The monitoring regime will include sites designed to monitor groundwater conditions (level and quality), and vegetation condition/stress.
- Each site will have monitoring triggers defined. The triggers will be designed to indicate substantial deviation from expected or predicted impacts or to provide an early warning of an impact that has not been predicted.
- Data will also be collected around the performance and hydrogeological conditions encountered during the operation of the water abstraction and disposal regime.
- Over time, the refined understanding of hydrogeological regime will be used to refine the groundwater model and re-evaluate predicted impacts.
- Continual analysis, evaluation and reporting, which includes an ongoing review and refinement of conceptual models and triggers as appropriate.

Specifically, in relation to the impacts identified in Section 7, the following monitoring activities should be a focus of the monitoring program for GDEs:

- Monitoring of the water table aquifer (level and salinity) in areas of groundwater level drawdown and mounding.
- Monitoring of Black Box vegetation using photographic survey techniques, selecting sites within the areas of predicted mounding and drawdown, and at control sites, away from project activities. The methodology outlined in Souter et al. (2009) could be adapted for local conditions and a protocol developed to carry out these surveys at regular intervals (e.g. quarterly).

8.3 Tier 2: Detailed investigations

If monitoring triggers are breached, the immediate response is to conduct a more detailed investigation into factors contributing to the breach, and to more closely evaluate the risk of the potential impact. If the risk is deemed significant, then the next facet of these investigations is to devise an appropriate management response to reduce the risks to an acceptable level. If the risk is not deemed to be significant, a revision of the trigger may be required.

8.4 Tier 3: Options for direct management intervention

If deemed necessary by Tier 2 investigations, direct management intervention may be required to reduce the risk of unacceptable impacts occurring. These responses will vary according to site-specific considerations and the nature of the impact. Options, in the event of unacceptable groundwater mounding, include:

- Revegetation of impacted area;
- Selective watering of high value sites with a fresh water source (the risk posed by mounding is primarily associated with salinity which causes, in effect, a reduction in plant water availability); and
- Reconfiguration/optimisation of groundwater injection, noting that the scope to alter the injection process is limited by the volumes of water that require reinjection and the location of injection wells.

Section 9 Summary and key findings

This GDE assessment has been completed to systematically evaluate the potential for water-related impacts to GDEs as a result of the Balranald Project. The primary objectives of the impact assessment are to quantify the significance of the potential impacts to GDEs and to develop a management strategy.

The assessment covers all potential GDEs that have been identified by previous investigations commissioned by Iluka, with the major potential GDE types being:

- Wetlands and vegetation associated with the Murrumbidgee, Lachlan and Murray River Floodplain environments; and
- Vegetation (primarily Black Box trees) outside the floodplain and permanent streams, in topographic depressions where the water table may be shallow enough and not too saline.

The key water-affecting activities associated with the project have been considered (including surface water impacts) as part of this assessment as follows:

1. Groundwater abstraction leading to groundwater level drawdown.
2. Disposal of excess mine water via aquifer injection leading to groundwater level mounding.
3. Mining potentially affecting groundwater quality through AMD processes.
4. The capture and alteration of surface runoff leading to altered surface water flows to potential GDEs.

Of the four water-affecting activities identified above, the direct effects associated with mining (3) and the capture and alteration of surface runoff (4) were deemed to be negligible. A groundwater modelling assessment (Jacobs, 2015) has been conducted to predict groundwater level drawdown and mounding.

Conceptual models have been developed for all of the major GDE types that occur in the study area to ascertain whether an exposure pathway exists between the water-related effects of the project and the hydrological regime that supports the potential GDEs. A level of impact (low, moderate or high) has been assigned for each of the exposure pathways identified by the assessment based on the predicted changes by the groundwater model, the major findings being:

- No impacts have been identified for the wetlands associated with the Murrumbidgee, Lachlan and Murray River Floodplain environments (due to their distance from the project area, and the stabilising influence of regulated watercourses on the water table aquifer).
- Predicted drawdown impacts are constrained to areas of Black Box vegetation near the West Balranald mine, but the extent of drawdown is such that predicted impacts are rated as low (monitoring of these areas should, however, be part of the monitoring program).
- Predicted mounding impacts are constrained to areas of Black Box vegetation near the dedicated injection borefield. A moderate rating has been assigned to some areas of Black Box vegetation in this area. While the magnitude of the predicted mounding is not substantial and remains well below the surface, the moderate rating flags that mounding in this region should be monitored throughout the mining operation.

The potential impacts identified form the basis of a management strategy that has been developed to reduce the risks associated with potential impacts to levels defined as being acceptable. Ongoing monitoring and evaluation will be a cornerstone of the management strategy and designed to provide advanced warning of potential impacts and a better understanding of the groundwater regime and ecosystem water requirements. The monitoring and evaluation program is linked to a trigger response framework to provide a tiered response to the risks associated with impacts to GDEs as follows:

- Tier 1: monitoring.
- Tier 2: detailed investigations to better define significance of risk and devise most appropriate direct management actions as required.
- Tier 3: deployment of direct management options to mitigate impacts.

The GDE management strategy will be integrated into the overall water management strategy for the Balranald Project.

Section 10 References

Legislation, standards, guidelines and policies

- AS/NZS 4360:2004 Risk Management (Standards Australia)
- Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)
- National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia (ARMCANZ/ANZECC)
- NSW Aquifer Interference Policy 2012 (NOW)
- NSW *Environmental Planning and Assessment Act 1979* (EP&A Act)
- NSW Environmental Planning and Assessment Regulation 2000 (EP&A Regulation)
- NSW State Groundwater Dependent Ecosystem Policy (NOW)
- NSW State Groundwater Policy Framework Document (DLWC, 1997)
- NSW State Groundwater Quality Protection Policy (DLWC, 1998)
- NSW State Groundwater Quantity Management Policy (DLWC, 1998)
- Risk Assessment Guidelines for Groundwater Dependent Ecosystems (NOW)
- Water Sharing Plan for NSW Murray Darling Basin Porous Rock Groundwater Sources (2011)
- Water Sharing Plan for the Lower Murray Darling Unregulated and Alluvial Water Sources (2011)

General references

- Bureau of Meteorology (BoM) (2014) Climate Data Online, http://www.bom.gov.au/climate/data/ accessed on 15 December, 2014.
- Department of Environment and Primary Industries, DEPI (2014) Black Box. Victoria. Resources Online, Statewide. http://vro.depi.vic.gov.au/dpi/vro/vrosite.nsf/pages/water_sss_black_box accessed on 10 December, 2014.
- Earth Systems Pty Ltd (2015) Balranald Mineral Sands Project Geochemistry Assessment. Prepared by Earth Systems Pty Ltd on behalf of Iluka Resources Pty Ltd.
- Froend, R. and Loomes, R. (2004) Approach to determination of ecological water requirements for groundwater dependant ecosystems in Western Australia - a report to the Department of Environment, Edith Cowan University, Perth, Western Australia.
- Howe, P. (2011) Framework for assessing potential local and cumulative effects of mining on groundwater – project summary report, Waterlines report, National Water Commission, Canberra.

- Jacobs (2014) Balranald Project soil-water-plant investigations. VE23830 v2. Report to Iluka Resources Ltd 19 September 2014.
- Jacobs (2015) Balranald Project DFS1 groundwater modelling. Impact assessment modelling. Report to Iluka Resources Ltd 19 January 2015.
- Jolly, I.D. and Walker, G.R. (1996). Is the field water use of Eucalyptus largiflorens F. Muell. Affected by short term flooding? Australian Journal of Ecology 21, 173-83.
- Jolly, I.D., McEwan, K., Cox, J., Walker, G. and Holland, K (2002) Managing groundwater and surface water for native terrestrial vegetation health in saline areas. CSIRO Land and Water Technical Report 23/02, September 2002.
- Kellett J.R. (1989) The Ivanhoe Block – its structure, hydrogeology and effect on groundwaters of the Riverine Plain of New South Wales. BMR Journal of Australian Geology and Geophysics 11:333-353.
- Kellett J.R. (1994) Balranald Hydrogeological Map (1:250,000 scale). Australian Geological Survey Organisation, Canberra.
- Kumar, P.B., (2010), Lower Murrumbidgee Groundwater Sources – Resource condition assessment report – 2010, NSW Office of Water, Sydney.
- Niche Environment and Heritage (2015) Balranald Mineral Sands Project, Terrestrial ecology assessment for the Environmental Impact Assessment. Report to Iluka Resources Limited.
- Murray-Darling Basin Authority, MDBA (2002) Basin in a Box dataset. Murray-Darling Basin Authority, Canberra.
- Richardson et al. (2011) Australian groundwater-dependent ecosystem toolbox part 1: assessment framework, Waterlines report, National Water Commission, Canberra
- Scott, J.A. (1992) The natural vegetation of the Balranald – Swan Hill area. Cunninghamia 2(4): 597-652.
- SKM (2011) Balranald PFS baseline environmental investigations: Groundwater Dependent Ecosystems. Phase 1 Report: Data review and identification of Groundwater Dependent Ecosystems. Report to Iluka Resources Ltd. 23 December 2011.
- Souter, N.J., Watts, R.A., White, M.G., George, A.K., McNicol, K.J (2009) Method Manual For The Visual Assessment Of Lower River Murray Floodplain Trees. River Red Gum (Eucalyptus camaldulensis), DWLBC Report 2009/25, Government of South Australia, through Department of Water, Land and Biodiversity Conservation, Adelaide.
- WRM Water and Environment (2014) Balranald Mineral Sands Project Surface Water Management Report. 1083-01-C_DRAFT. Report to Iluka Resources Ltd. 27 November 2014.

Appendix A - Disclaimer and Limitations

This report has been prepared by CDM Smith Australia Pty Ltd (CDM Smith) for the sole benefit of Iluka Resources Limited for the sole purpose of the Groundwater Dependent Ecosystem (GDE) assessment for the Balranald Project.

This report should not be used or relied upon for any other purpose without CDM Smith's prior written consent. CDM Smith, nor any officer or employee of CDM Smith, accepts no responsibility or liability in any way whatsoever for the use or reliance of this report for any purpose other than that for which it has been prepared.

CDM Smith, nor any officer or employee of CDM Smith, accepts no liability or responsibility whatsoever for or in respect of any use or reliance upon this report by any third party.

The information on which this report is based has been provided by Iluka Resources Limited and third parties. CDM Smith (including its officer and employee):

(a) has relied upon and presumed the accuracy of this information;

(b) has not verified the accuracy or reliability of this information (other than as expressly stated in this report);

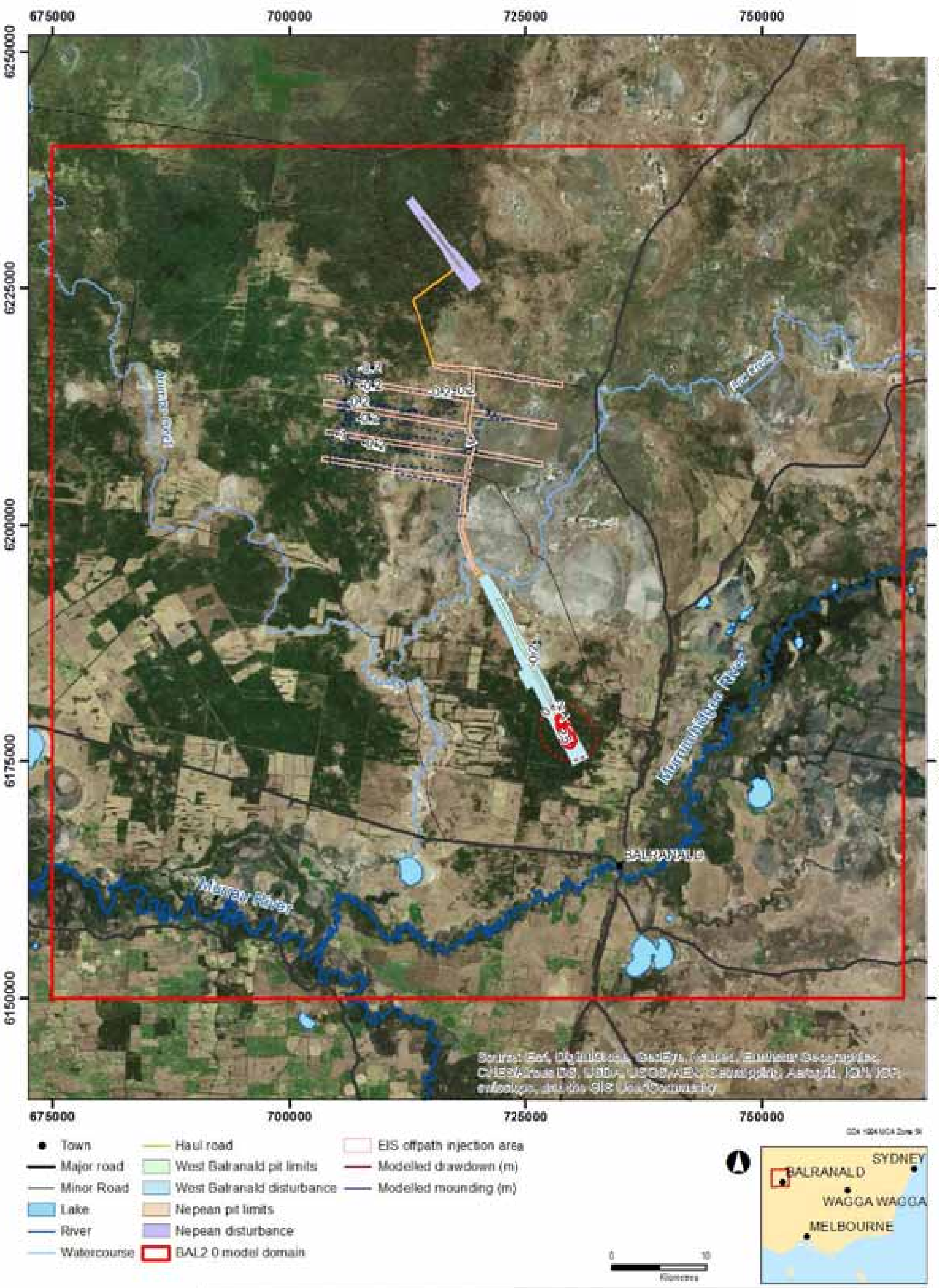
(c) has not made any independent investigations or enquiries in respect of those matters of which it has no actual knowledge at the time of giving this report to Iluka Resources Limited; and

(d) makes no warranty or guarantee, expressed or implied, as to the accuracy or reliability of this information.

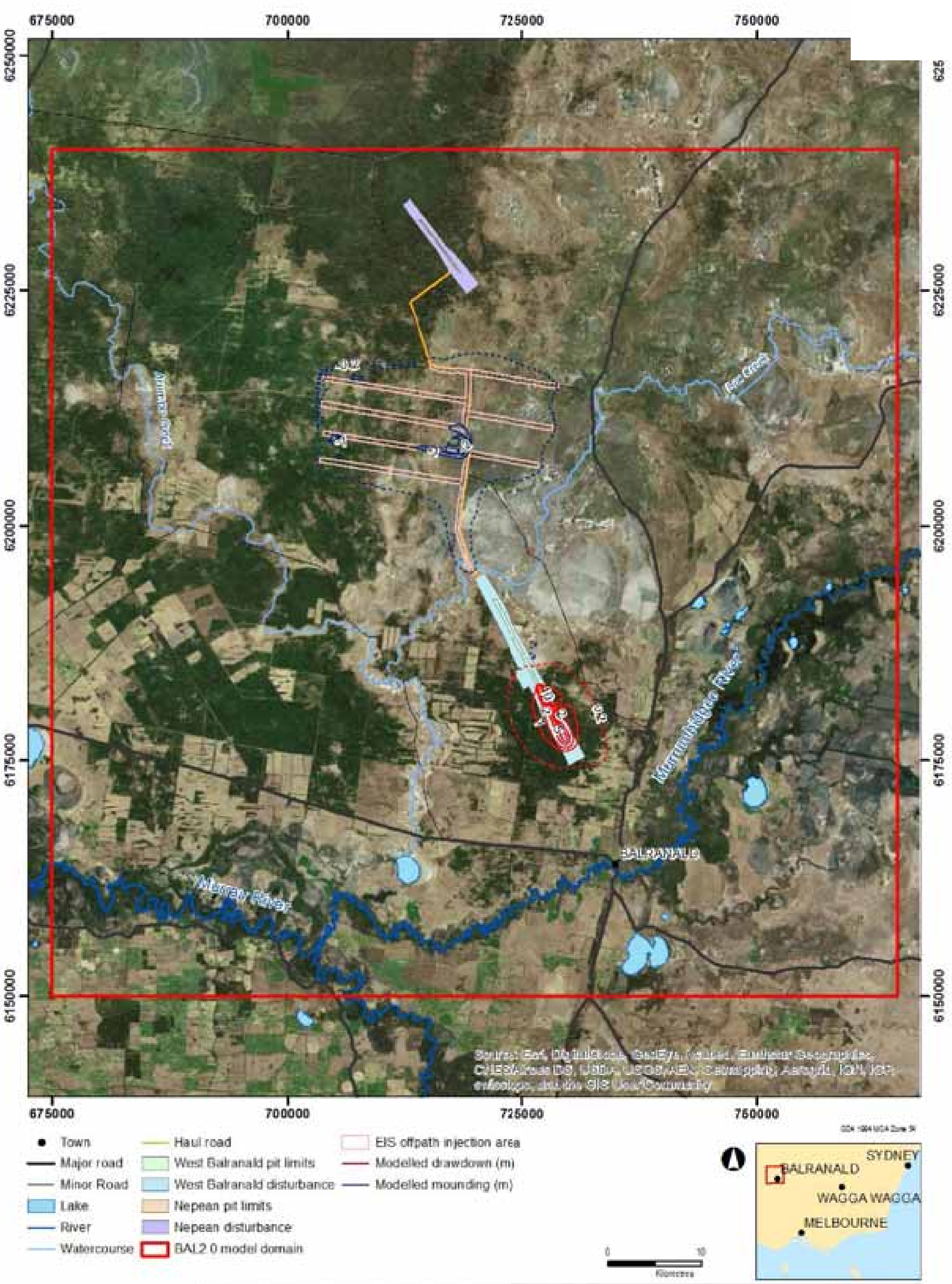
In recognition of the limited use to be made by Iluka Resources Limited of this report, Iluka Resources Limited agrees that, to the maximum extent permitted by law, CDM Smith (including its officer and employee) shall not be liable for any losses, claims, costs, expenses, damages (whether in statute, in contract or tort for negligence or otherwise) suffered or incurred by Iluka Resources Limited or any third party as a result of or in connection with the information, findings, opinions, estimates, recommendations and conclusions provided in the course of this report.

If further information becomes available, or additional assumptions need to be made, CDM Smith reserves its right to amend this report.

Appendix B - Model Results



BAL2.0 TS2 opt29 modelled drawdown in Shepparton Formation at mining year 1



BAL2.0 TS2 opt29 modelled drawdown in Shepparton Formation at mining year 2

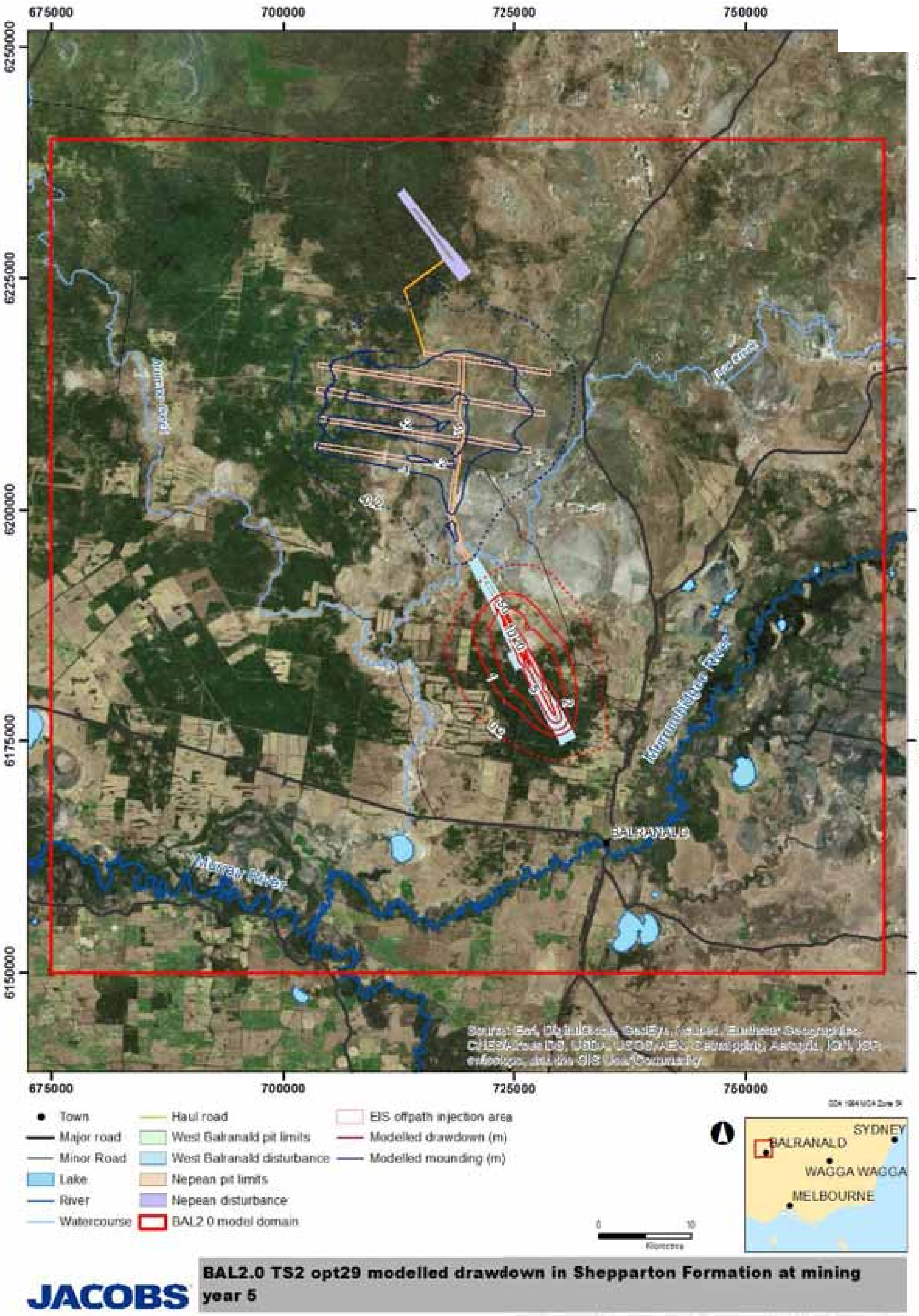
JACOBS

BAL2.0 TS2 opt29 modelled drawdown in Shepparton Formation at mining year 3

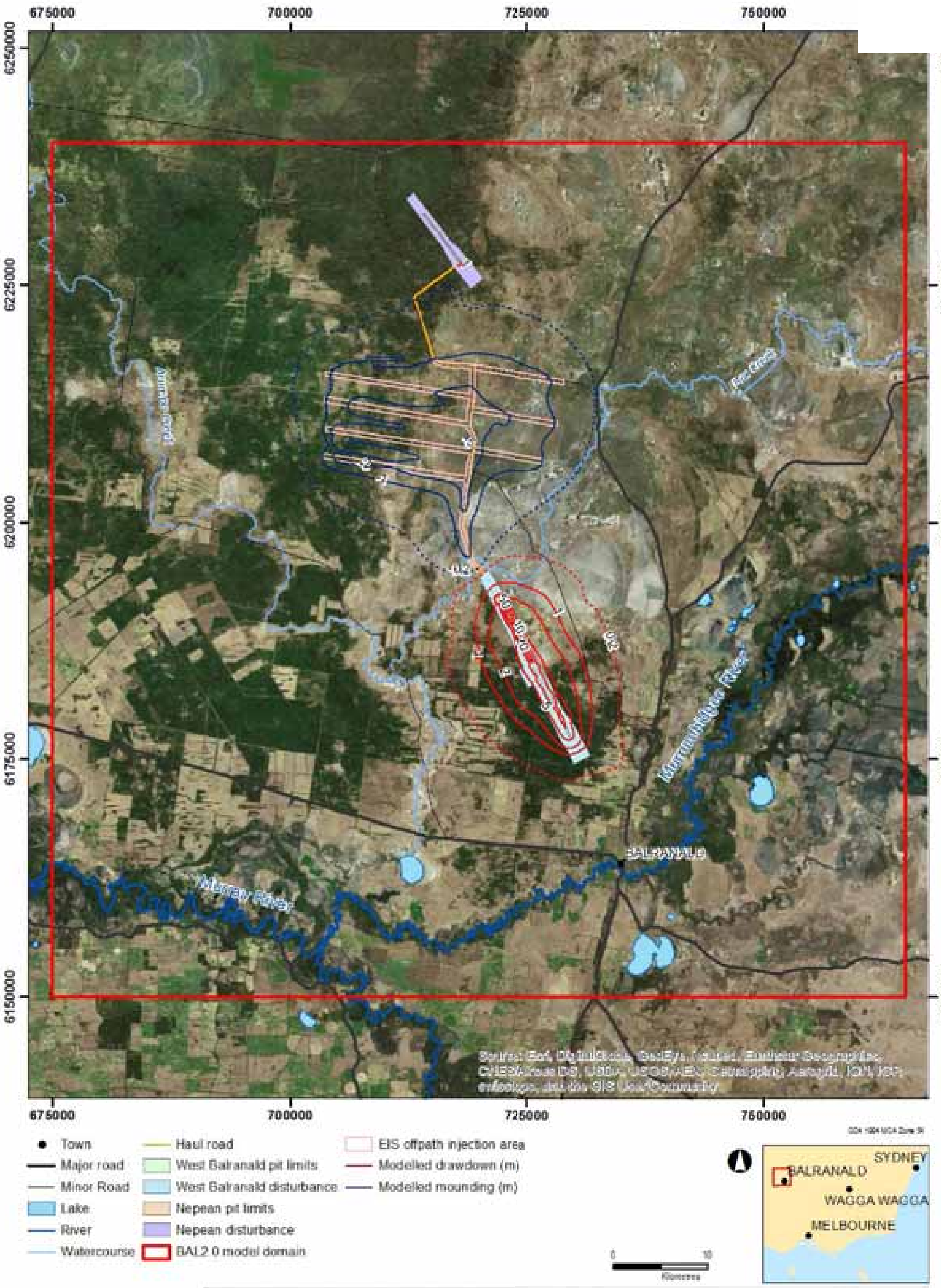
JACOBS

JACOBS

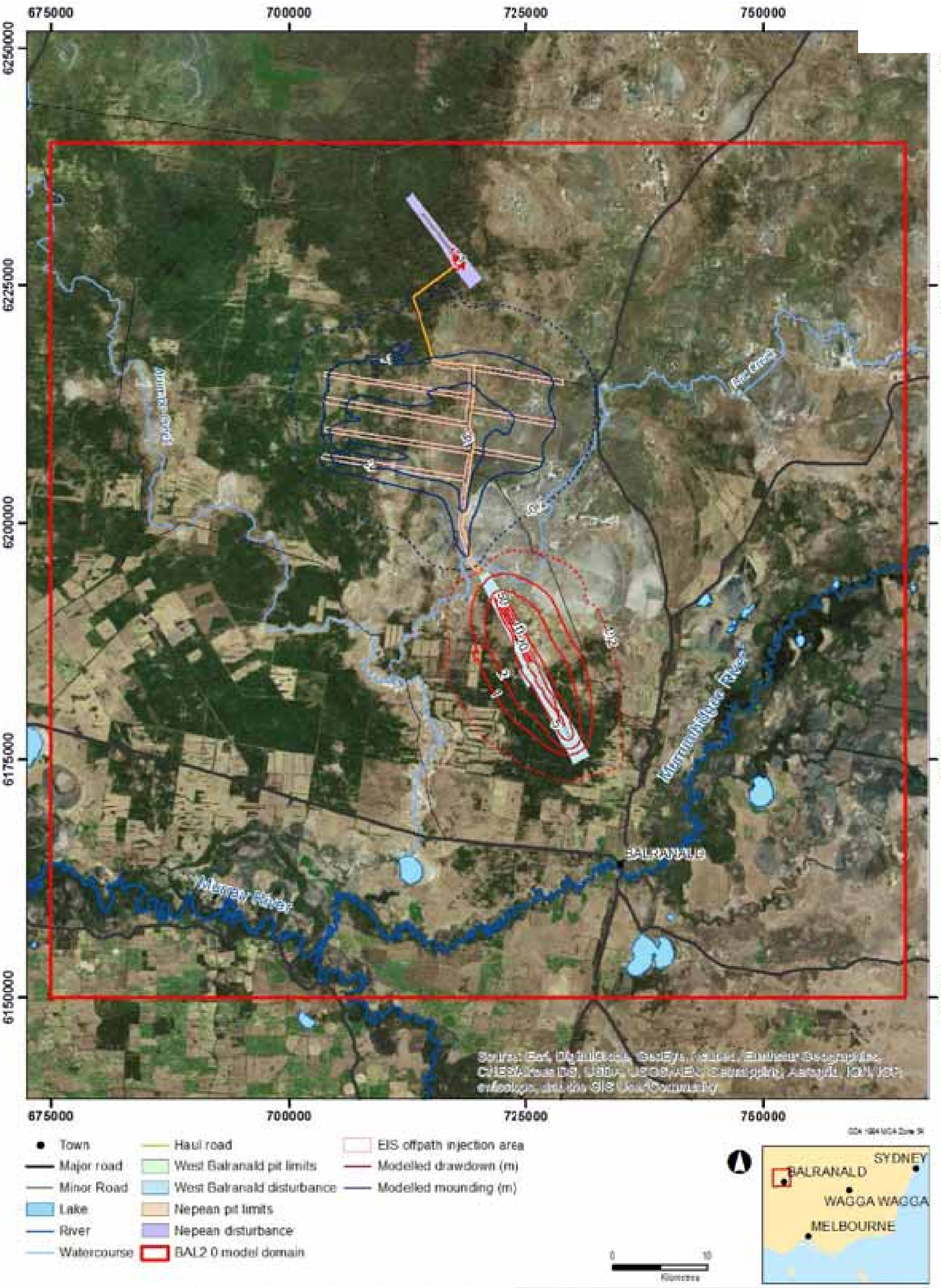
BAL2.0 TS2 opt29 modelled drawdown in Shepparton Formation at mining year 4



BAL2.0 TS2 opt29 modelled drawdown in Shepparton Formation at mining year 5

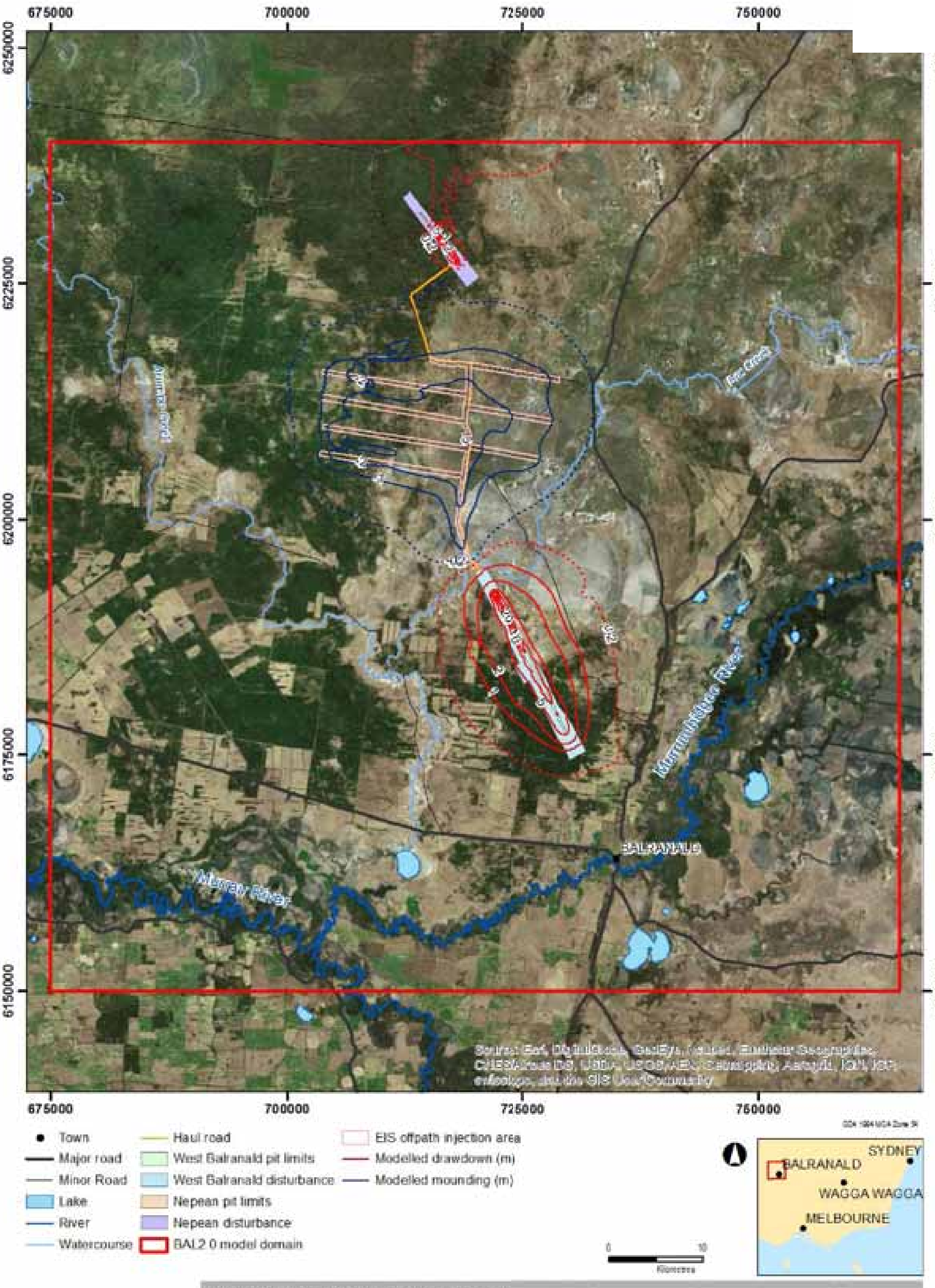


BAL2.0 TS2 opt29 modelled drawdown in Shepparton Formation at mining year 6

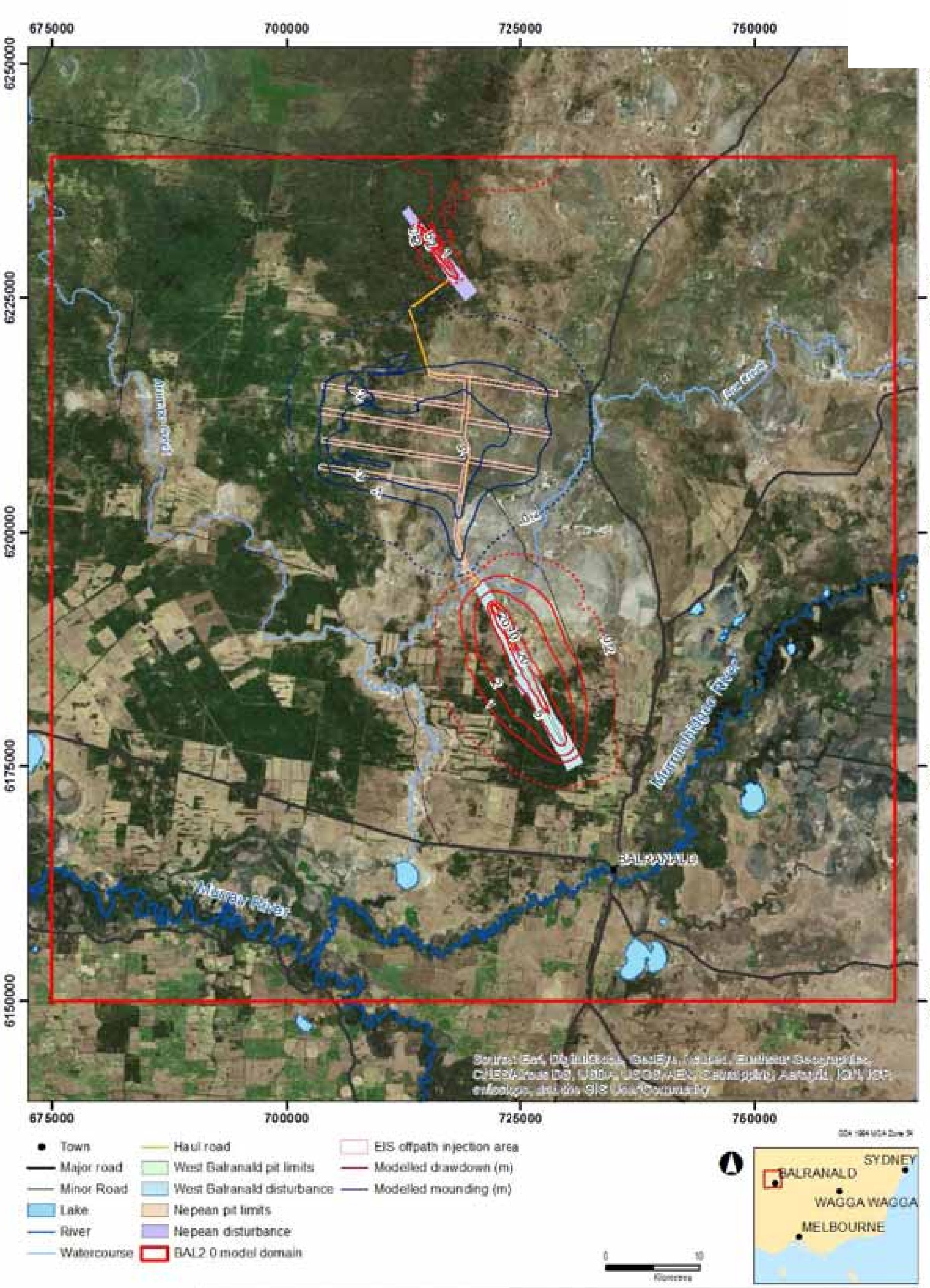


JACOBS

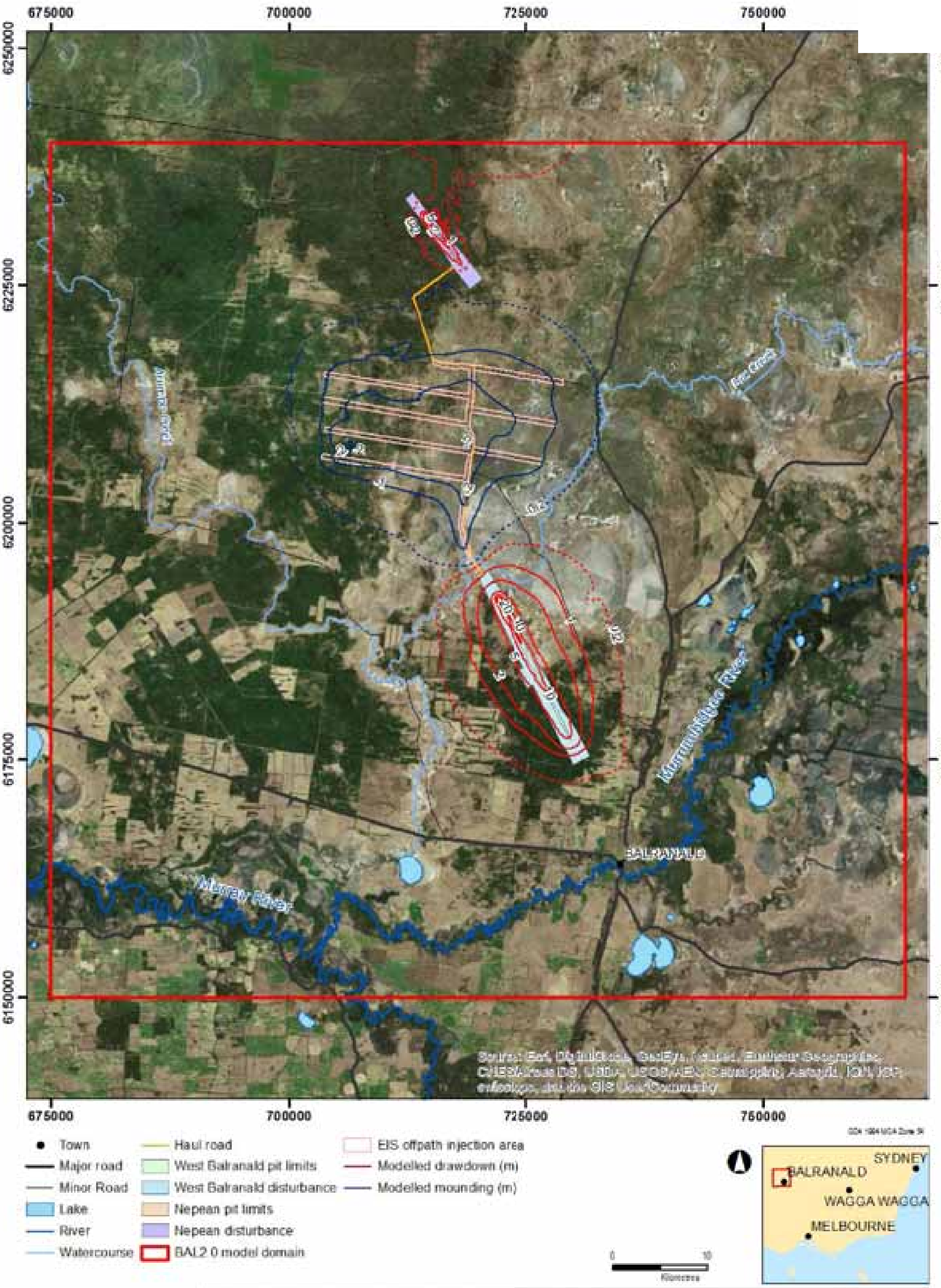
BAL2.0 TS2 opt29 modelled drawdown in Shepparton Formation at mining year 6.3 (end of 56 L/s water supply)



BAL2.0 TS2 opt29 modelled drawdown in Shepparton Formation at mining year 7

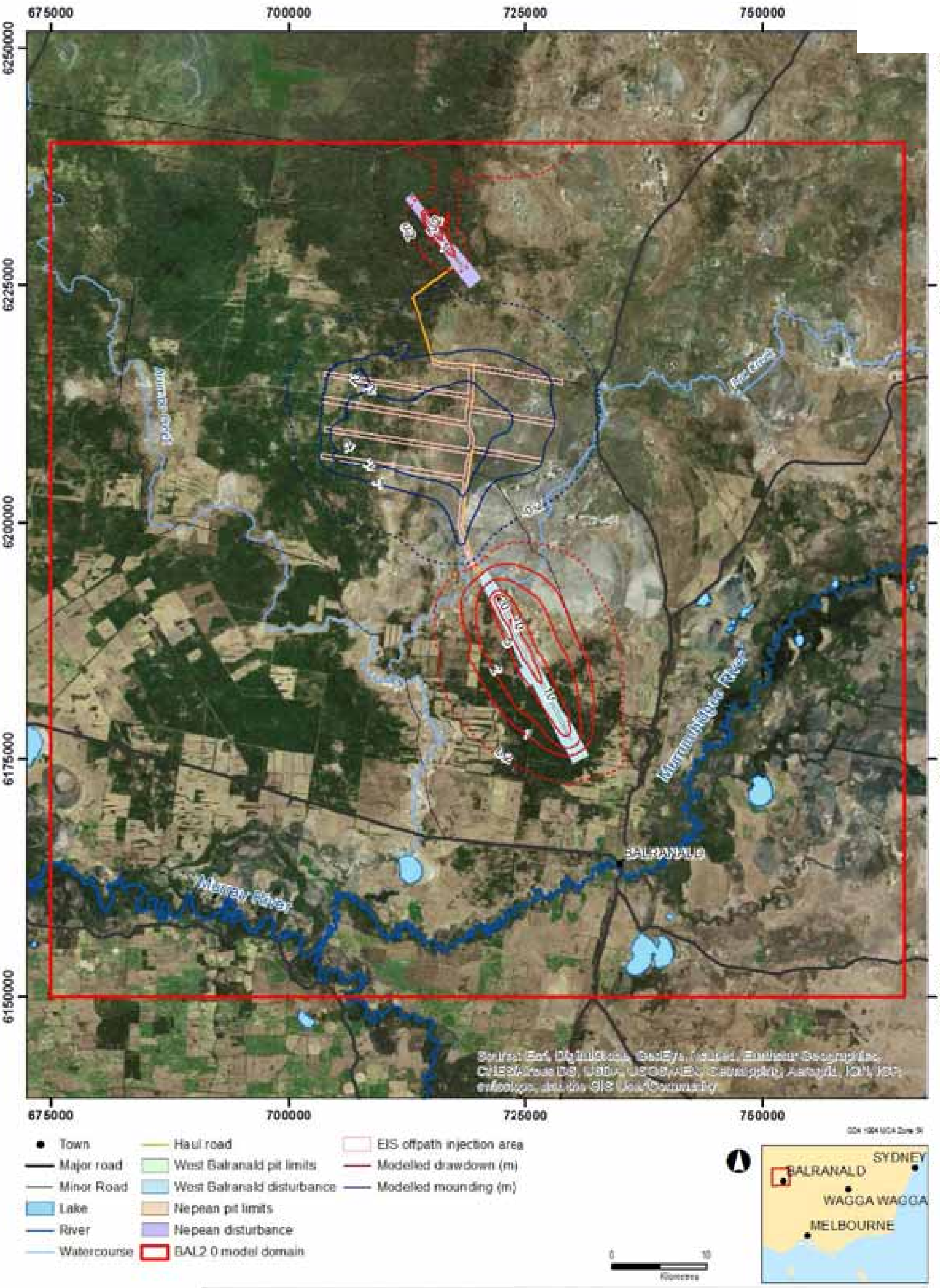


BAL2.0 TS2 opt29 modelled drawdown in Shepparton Formation at mining year 7.4 (maximum West Balranald dewatering rate)



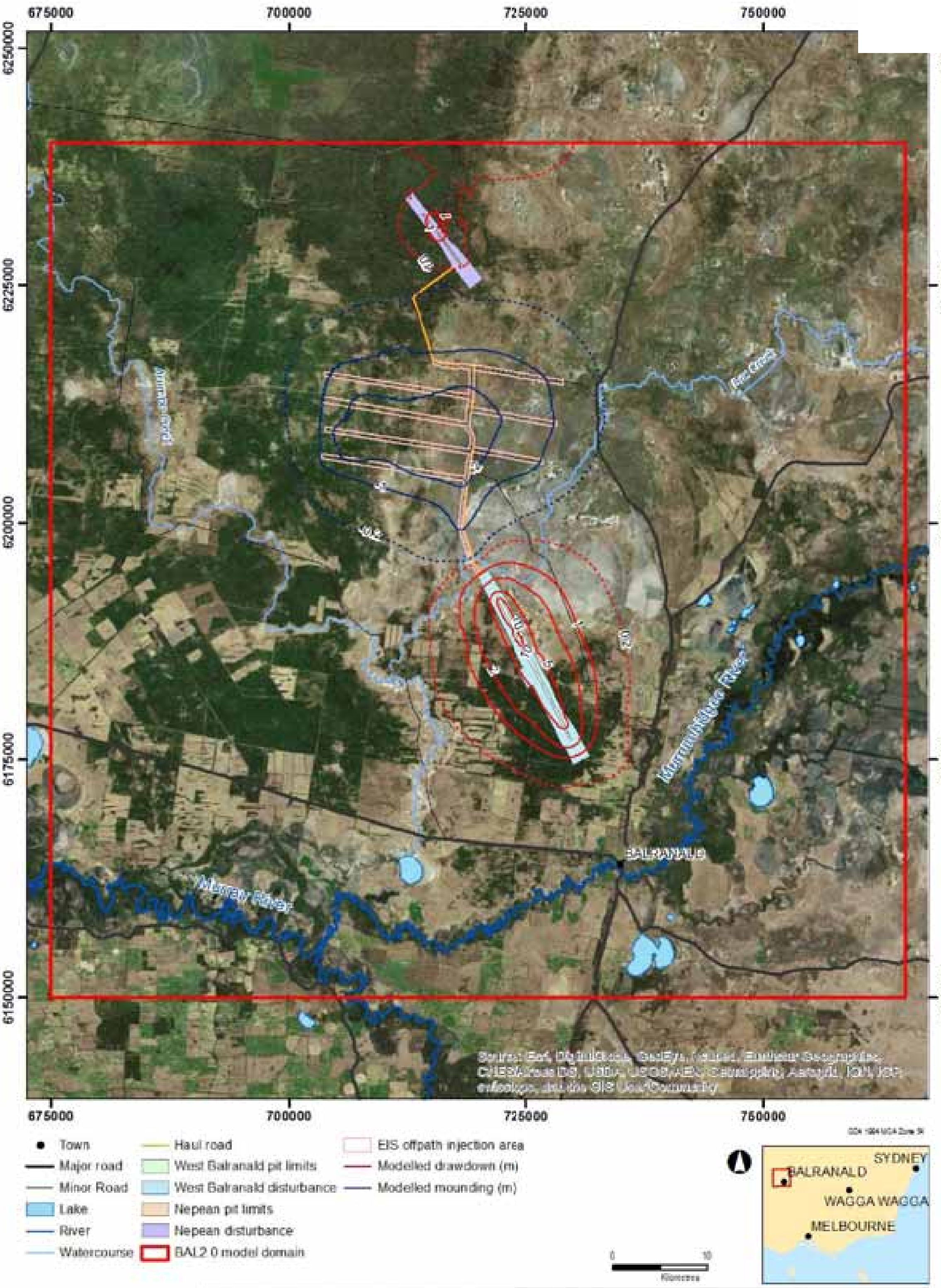
JACOBS

BAL2.0 TS2 opt29 modelled drawdown in Shepparton Formation at mining year 8



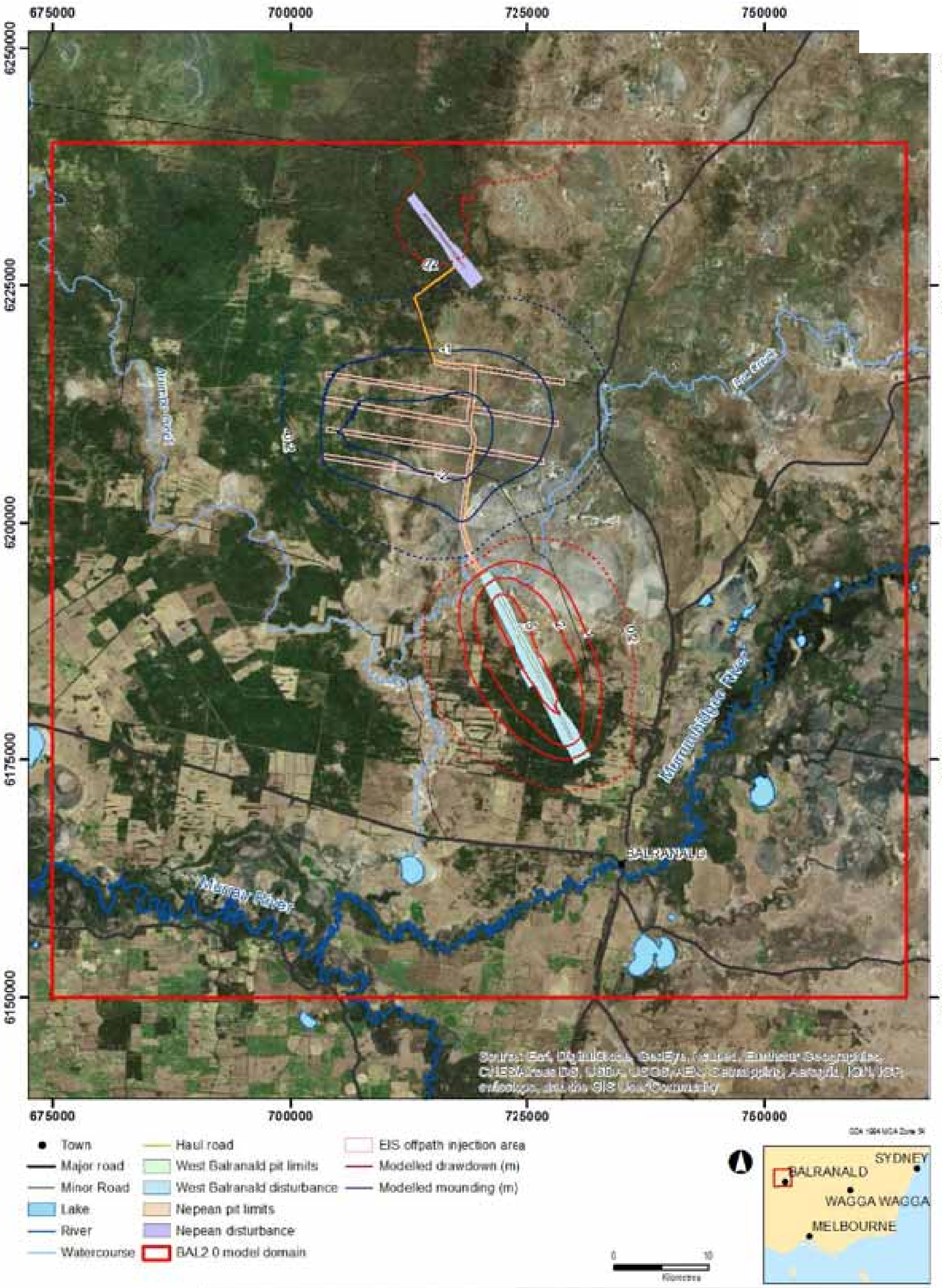
JACOBS

BAL2.0 TS2 opt29 modelled drawdown in Shepparton Formation 1 year post-mining



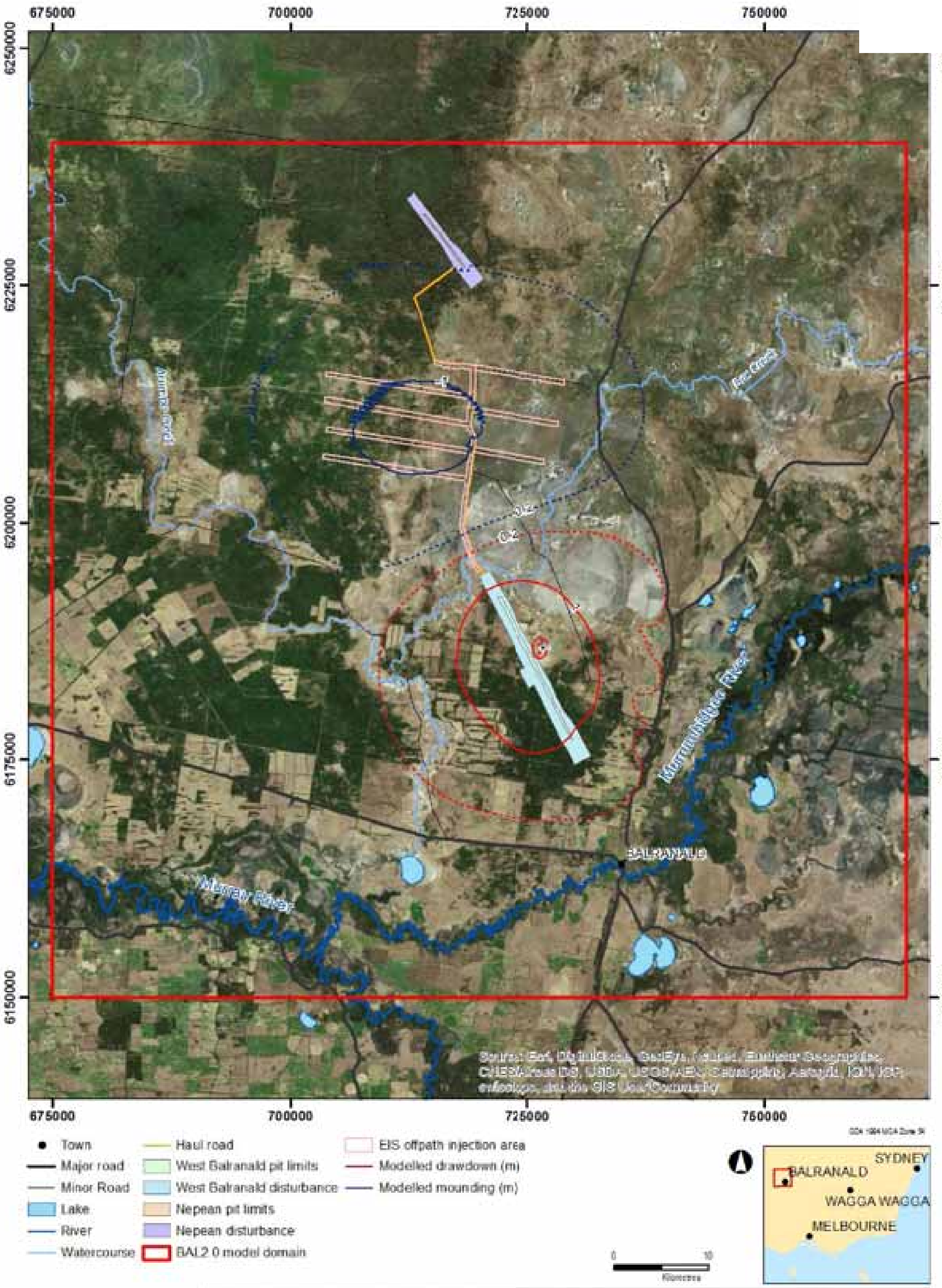
JACOBS

BAL2.0 TS2 opt29 modelled drawdown in Shepparton Formation 5 years post-mining



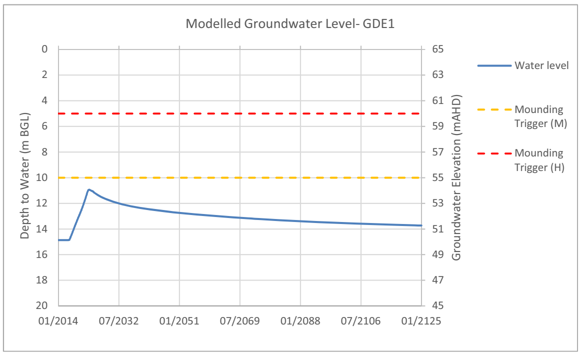
BAL2.0 TS2 opt29 modelled drawdown in Shepparton Formation 10 years post-mining

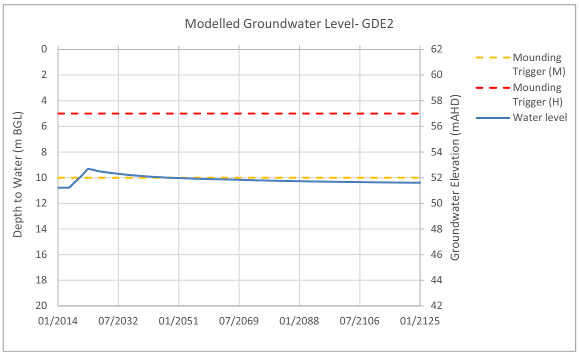
BAL2.0 TS2 opt29 modelled drawdown in Shepparton Formation 30 years post-mining

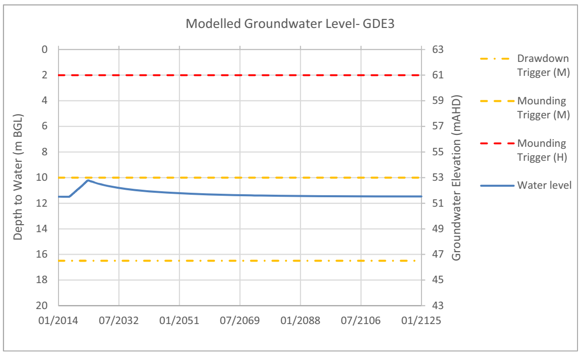


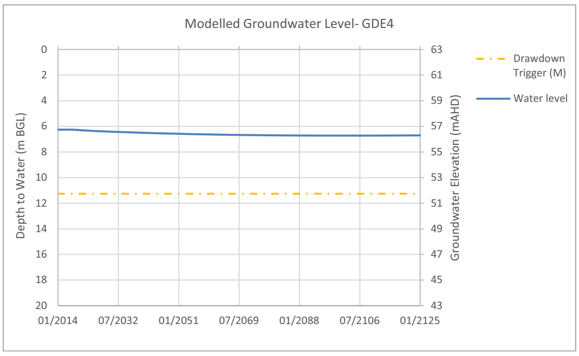
BAL2.0 TS2 opt29 modelled drawdown in Shepparton Formation 100 years post-mining

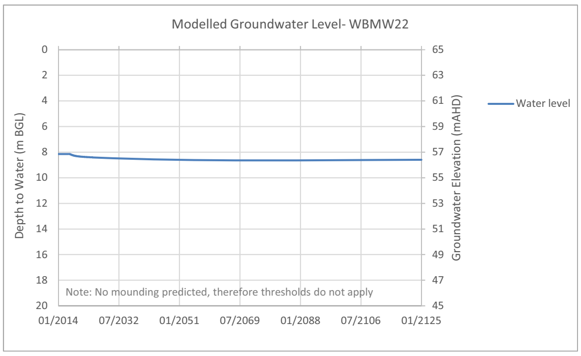
Appendix C - Model hydrographs

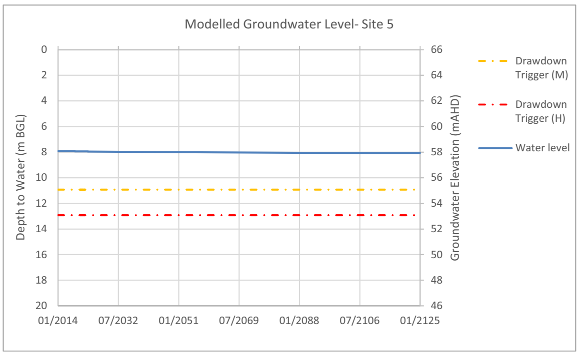


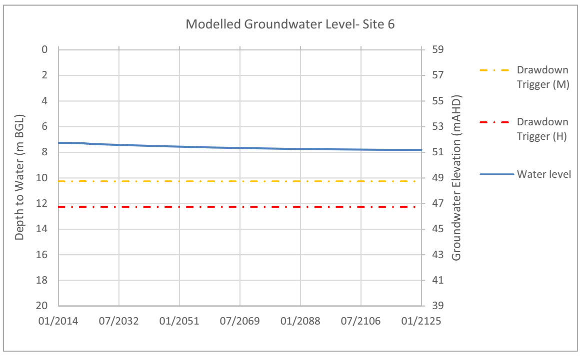


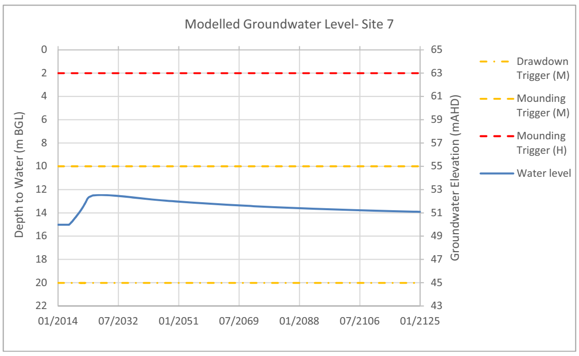


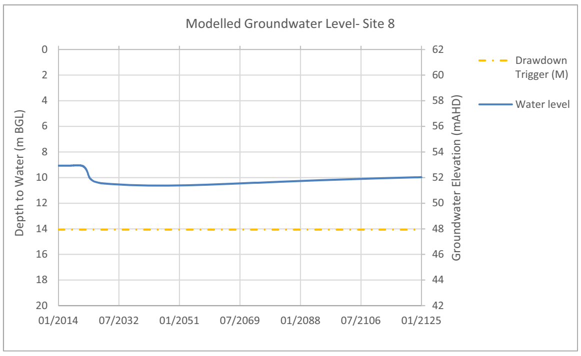












Predicted Impacts						
	Drawdown			Mounding		
Site	DD (m)	GDE Class	Impact	MND (mbgl)	Salinity Class	Impact
GDE1	n/a	n/a	n/a	5-10	>35000	M
GDE2	n/a	5	n/a	5-10	>35000	M
GDE3	n/a	4	n/a	5-10	14000-35000	M
GDE4	0.2-1	4	L	n/a	14000-35000	n/a
WBMW22	0.2-1	n/a	L	n/a	14000-35000	n/a
5	n/a	3	n/a	n/a	<3000	n/a
6	0.2-1	3	L	n/a	7000-14000	n/a
7	n/a	4	n/a	>10	14000-35000	L
8	1-3	4	L	n/a	14000-35000	n/a

EMM
EMGA Mitchell McLennan

www.emgamm.com

SYDNEY
Ground Floor, Suite 1, 20 Chandos Street
St Leonards NSW 2065
T 02 9493 9500 F 02 9493 9599

NEWCASTLE
Level 5, 21 Bolton Street
Newcastle NSW 2300
T 02 4927 0506 F 02 4926 1312

BRISBANE
Suite 1, Level 4, 87 Wickham Terrace
Spring Hill Queensland 4000
T 07 3839 1800 F 07 3839 1866