BHP

Oak Dam
Underground Access Project

Retention Lease Proposal and Miscellaneous Purposes Licence Management Plans Response Document Addendum

October 2024

Executive summary

ES1 Introduction

BHP Olympic Dam Corporation Pty Ltd (BHP) is proposing to develop the Oak Dam Underground Access Project (OKDUGA Project), in the far north of South Australia.

The Oak Dam deposit is a deep iron oxide copper-gold (IOCG) mineralised system. Exploration undertaken at Oak Dam has indicated the presence of high-grade copper and associated minerals commencing at approximately 800 m below surface that may be economically viable to mine.

The OKDUGA Project has been initiated to progress the opportunity to undertake exploration drilling underground, providing accelerated resource definition and reduced drilling and development costs. Specifically, the OKDUGA Project aims to establish an underground access via twin declines, with the dual purposes of:

- providing an effective and proximal drilling platform to enable efficient mineralisation drilling to define the resource
- enabling characterisation of critical geotechnical ground conditions
- enabling hydrogeological drilling and testing.

To authorise the OKDUGA Project, BHP submitted a combined Retention Lease (RL) Proposal and Miscellaneous Purposes Licence (MPL) Management Plans (together, the Proposal) in December 2023 to the Government of South Australia's Department for Energy and Mining (DEM) under the Mining Act 1971 (SA) (Mining Act). Following agency and public consultation a Proposal Response Document (PRD) was prepared in July 2024 to consider and respond to the matters raised in the submissions made by the government agencies and the public (Municipal Council of Roxby Downs) in relation to the OKDUGA Project.

This Proposal Response Document Addendum (PRD Addendum) has been prepared in response to additional comments received from the Department for Energy and Mining – Mining Water Science (DEM) and the Department for Environment and Water – Hydrogeology (DEW) on 27 August 2024.

ES1.1 Proposal response document addendum

This PRD Addendum has been prepared to address the requirements of both the Mining Act and associated Mining Regulations 2020 (Mining Regulations), with consideration of the information needs described in:

- DEM's *Terms of Reference (TOR) Oak Dam Retention Lease Application in accordance with the Mining Act 1971,* published in The South Australian Government Gazette No. 73 dated 28 September 2023
- DEM's Determination TOR 006 Mineral mine lease/licence applications (TOR 006)
- DEM's Mineral Regulatory Guidelines MG2a Preparation of a mining application for metallic and industrial minerals (MG2a).

The purpose of this document is to consider and respond to additional groundwater matters raised by DEM and DEW in relation to the OKDUGA Project. This PRD Addendum has been prepared and should be read in conjunction with the Proposal document and PRD, which describes in full the proposed activities for which approval is sought.

ES1.2 Submissions received

This PRD Addendum addresses the following:

- DEM and DEW government agency assessment of the PRD in relation to groundwater, received on 27 August 2024.

It is noted that DEM and DEW provided additional comments for BHP's consideration as part of the Program for Environment Protection and Rehabilitation (PEPR) which will be addressed accordingly as part of the next phase of the OKDUGA Project.

ES1.3 Responses to submissions

BHP's Proposal and PRD have previously acknowledged local site-specific groundwater data gaps with the purpose and intent of the RL to provide a means to undertake further hydrogeological drilling and testing to inform a future Mining Lease Proposal (MLP) should the OKDUGA Project proceed.

Based upon available local and regional measured data, BHP has undertaken groundwater modelling and applied predictive uncertainty analysis, in line with industry best practice, to support a risk-based approach to impact assessment and water management for the OKDUGA Project.

In response to the DEM and DEW's additional groundwater comments BHP has added more regional data points to the history-matching dataset, corrected a minor boundary condition error and validated the updated model against the expanded dataset which, while providing further performance improvement, has resulted in no material change to predicted source-pathway-receptor impacts.

On this basis the outcomes and findings of this PRD Addendum do not materially change the assessment of impacts as presented in the Proposal and PRD. Based on these outcomes and findings, the proposed Environmental Outcomes for the OKDUGA Project, as presented in the Proposal, remain appropriate.

Control and management strategies for the OKDUGA Project, as described by reference to pathway and receptor in Section 8, Table 8.1 of the Proposal, are considered appropriate for managing and mitigating impacts and achieving the proposed Environmental Outcomes for construction, operations and closure.

Proposed strategies to continue to address areas of uncertainty within the impact assessment and/or control effectiveness are proposed to be addressed via an expanded PRD Addendum forward works plan which will be carried into the PEPR as a consolidated forward works plan.

Declaration of accuracy

I, Nicholas Field, the applicant, have taken the following steps to review the information in this application to ensure its accuracy:

- implementing an audit process against the terms of reference to ensure the minimum requirements have been addressed
- an internal process for review, endorsement or sign off by a suitably qualified and experienced company employee.

The information contained in this Retention Lease Proposal and Miscellaneous Purposes Licence Management Plans Response Document is, to the best of my knowledge, a true and accurate representation of the advanced exploration-related activities proposed by BHP Olympic Dam Corporation Pty Ltd for the Oak Dam Underground Access Project.

Name	Nicholas Field
Position	Manager Oak Dam Underground Access
Signature	Field, Nicholas Digitally signed by Field, Nicholas DN: cn=Field, Nicholas, o=BHP Billiton Group Operations Pty Ltd, ou=MULTI-ALLOWED Date: 2024.10.10 13:18:33 +10'30'
Date	10 October 2024

Currency

Where possible, the contents of the Retention Lease Proposal and Miscellaneous Purposes Licence Management Plans Response Document Addendum (this Document) are up to date as at 10 October 2024. This was not possible where parts of the Document were prepared from information provided by third parties (as discussed below) prior to the third-party documents being finalised.

Disclaimer

The Document has been prepared for submission to the South Australian Minister for Energy and Mining under the *Mining Act 1971* (SA), and no one other than the Minister should rely on the information contained in the Document to make, or refrain from making, any decision.

In preparing the Document, BHP have relied, in part, on information provided by specialist consultants, government agencies and other third parties. BHP have not fully verified the accuracy or completeness of that information, except where expressly acknowledged in the Document.

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Appendix C Groundwater monitoring framework updated

1. Introduction

BHP Olympic Dam Corporation Pty Ltd (BHP) is proposing to develop the Oak Dam Underground Access Project (OKDUGA Project), in the far north of South Australia (Figure 1.1).

The Oak Dam deposit is a deep iron oxide copper-gold (IOCG) mineralised system. Exploration undertaken at Oak Dam has indicated the presence of high-grade copper and associated minerals commencing at approximately 800 metres (m) below surface that may be economically viable to mine.

The OKDUGA Project has been initiated to progress the opportunity to undertake exploration drilling underground, providing accelerated resource definition and reduced drilling and development costs. Specifically, the OKDUGA Project aims to establish an underground access via twin declines, with the dual purposes of:

- providing an effective and proximal drilling platform to enable efficient mineralisation drilling to define the resource
- enabling characterisation of critical geotechnical ground conditions
- enabling hydrogeological drilling and testing.

1.1 Overview

To undertake the proposed activities, a combined Retention Lease (RL) Proposal and Miscellaneous Purposes Licence (MPL) Management Plans (together, the Proposal) was prepared under the *Mining Act 1971* (SA) (Mining Act) (BHP 2023).

The Proposal was submitted to the Government of South Australia's Department for Energy and Mining (DEM) in December 2023 to address the requirements of both the Mining Act and associated Mining Regulations 2020 (Mining Regulations), with consideration of the information needs described in:

- DEM's *Terms of Reference (TOR) Oak Dam Retention Lease Application in accordance with the Mining Act 1971*, published in The South Australian Government Gazette No. 73 dated 28 September 2023 (DEM 2023)
- DEM's Determination TOR 006 Mineral mine lease/licence applications (DEM 2021) (TOR 006)
- DEM's Mineral Regulatory Guidelines MG2a Preparation of a mining application for metallic and industrial minerals (DEM 2020) (MG2a).

Engineering and feasibility studies indicate that a twin decline is the preferred investment alternative for the underground access strategy to enable the underground drilling program. Access to the decline would be via a box cut and portal development. The surface infrastructure at the box cut includes the provision for services and constructions to support the access development and operation of the drill rigs. This includes utility facilities, diesel generation plant, refrigeration plant, administration buildings, temporary maintenance buildings, laydown area, concrete batch plant, waste rock landform (WRL), stockpiles, dams, and ponds. Outside of this area, on surface, is Oak Dam Village, borrow pit(s) area, explosives storage, access roads, transmission line and return air raise structures.

For the purpose of the Proposal (BHP 2023) the following terminology was defined:

- OKDUGA Project: the area defined by the extent of the RL Project Area, the Site Infrastructure Corridor (SIC) MPL Project Area and the Water Infrastructure Corridor (WIC) MPL Project Area (Figure 1.1).
- RL Project Area: the area defined as the extent of the proposed RL tenement (Figure 1.2).
- SIC MPL Project Area: the area defined as the extent of the proposed MPL tenement for the purposes of site access and ancillary infrastructure (Figure 1.3).
- WIC MPL Project Area: the area defined as the extent of the proposed MPL tenement for the purposes of water supply and ancillary infrastructure (Figure 1.4).
- Proposal: combined RL Proposal, SIC MPL Management Plan and WIC MPL Management Plan.

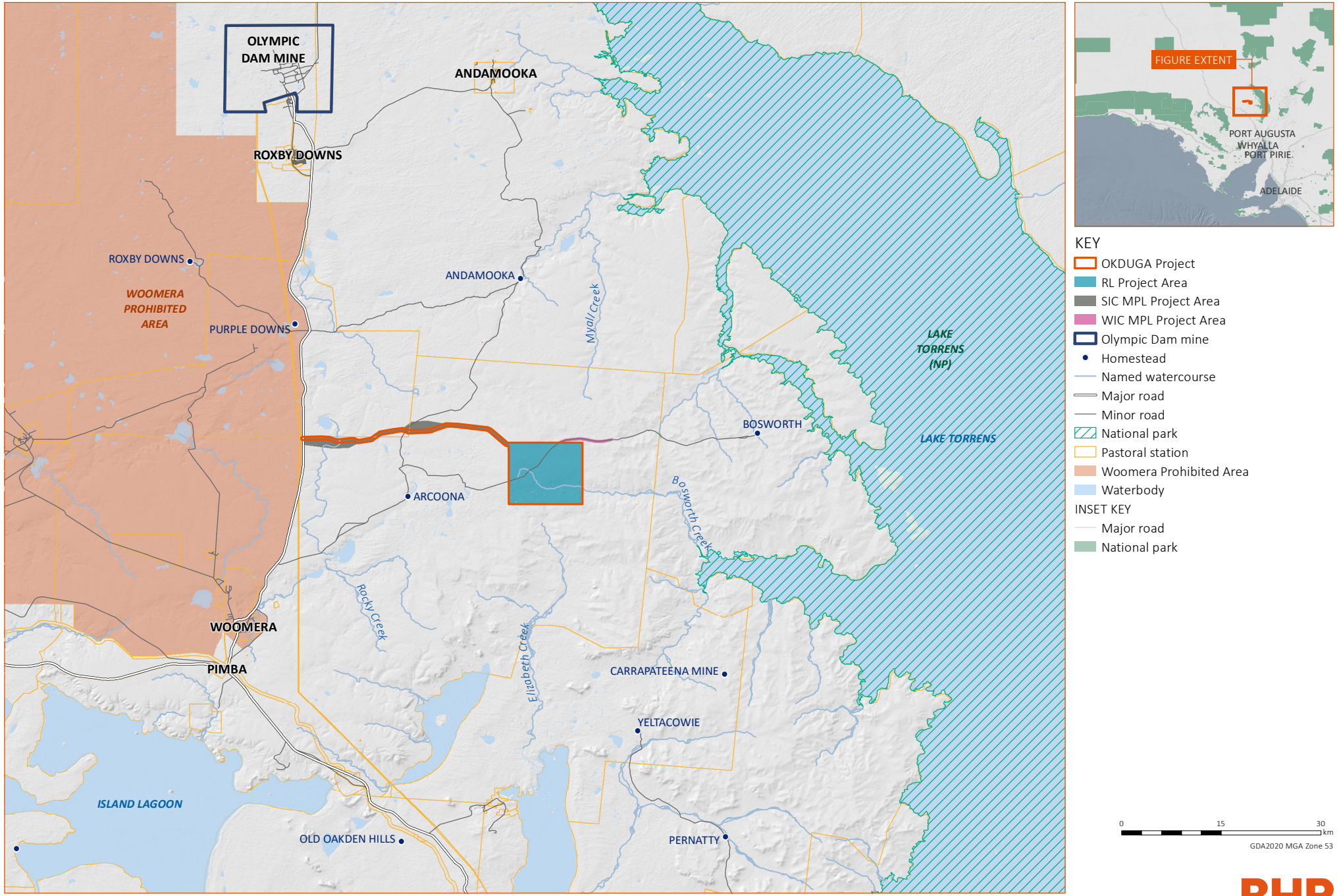


Figure 1.1 | OKDUGA Project regional locality

OKDUGA Project BHP

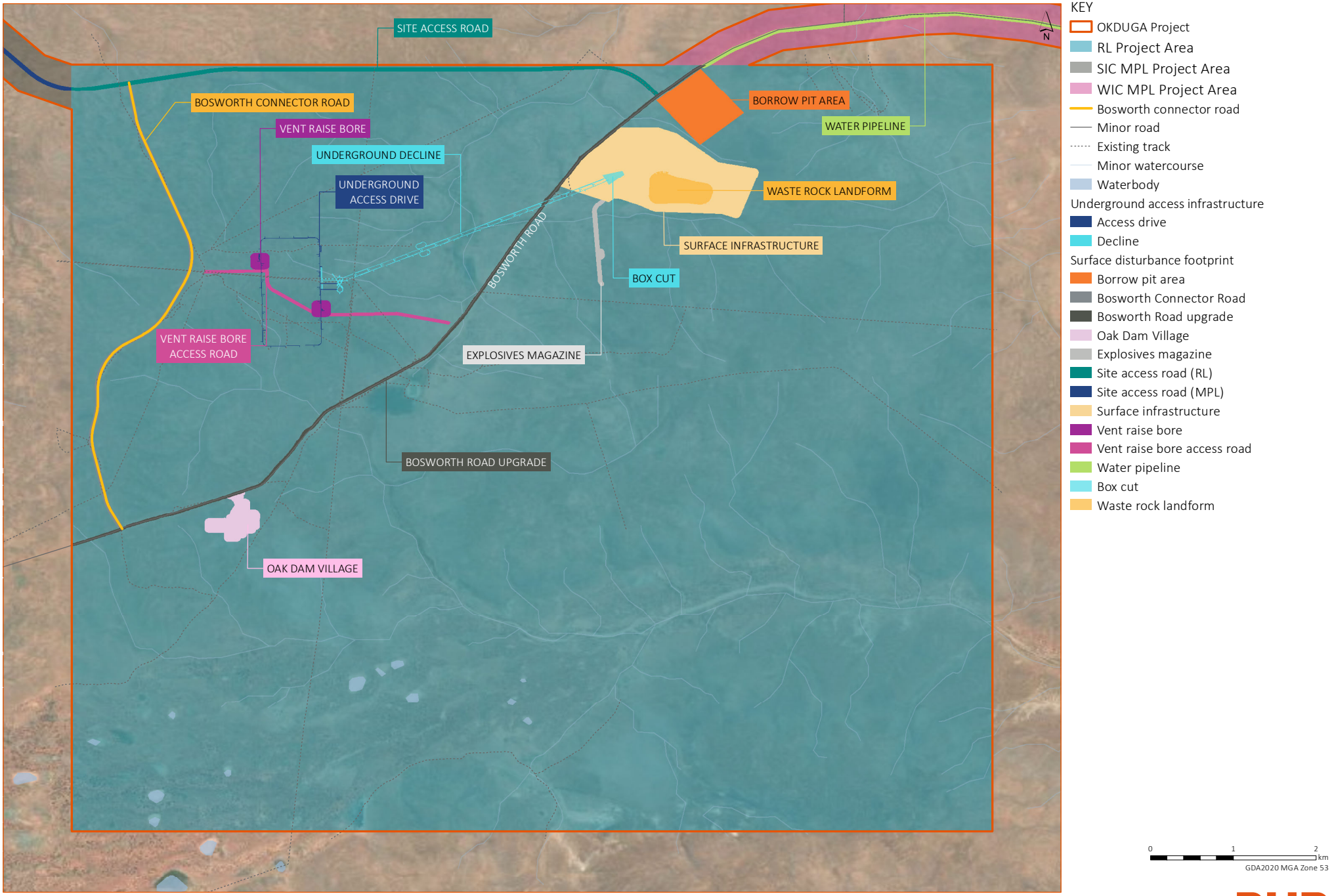


Figure 1.2 | Key infrastructure and tenements for the RL Project Area

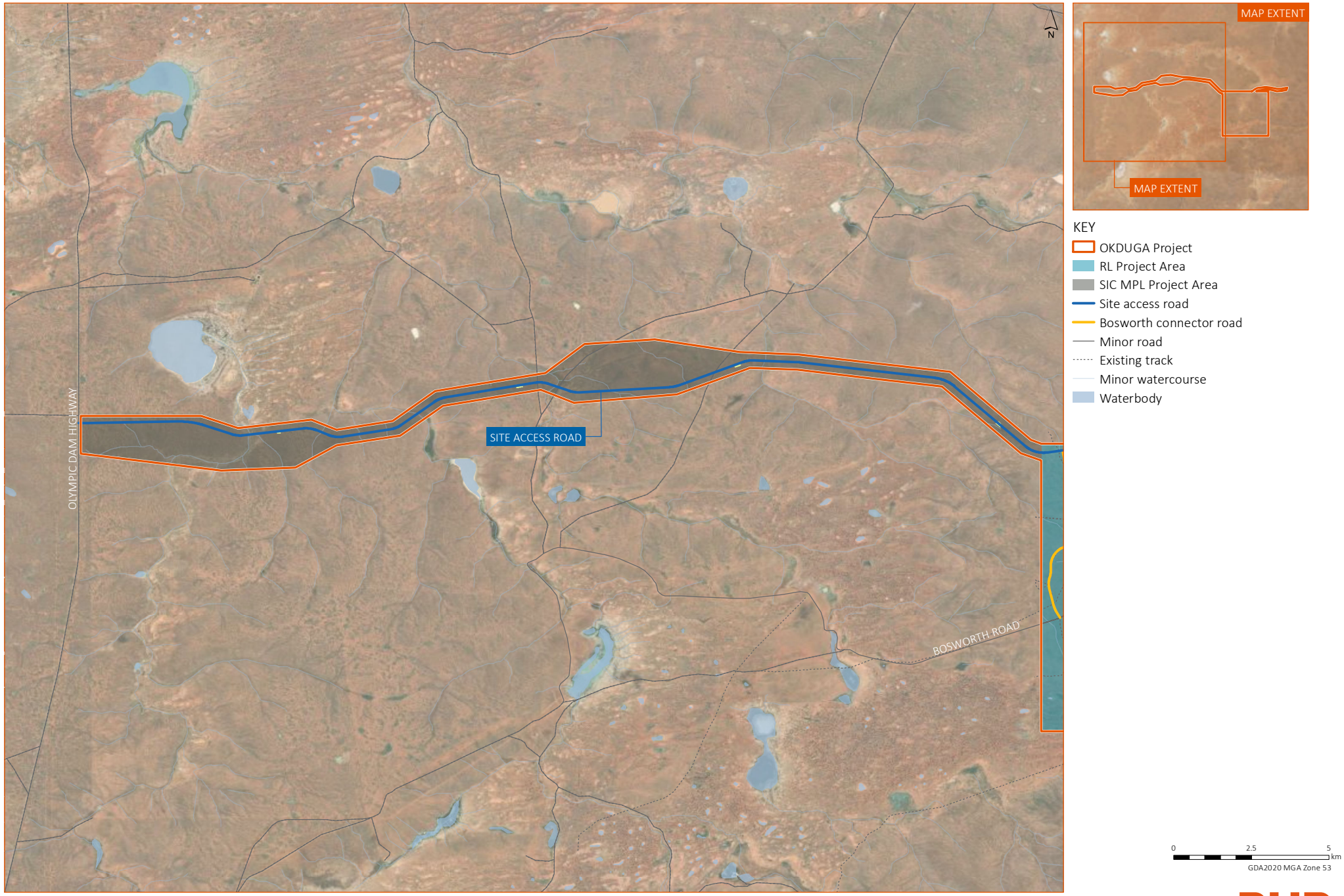


Figure 1.3 | Key infrastructure and tenements for the SIC MPL Project Area

OKDUGA Project BHP

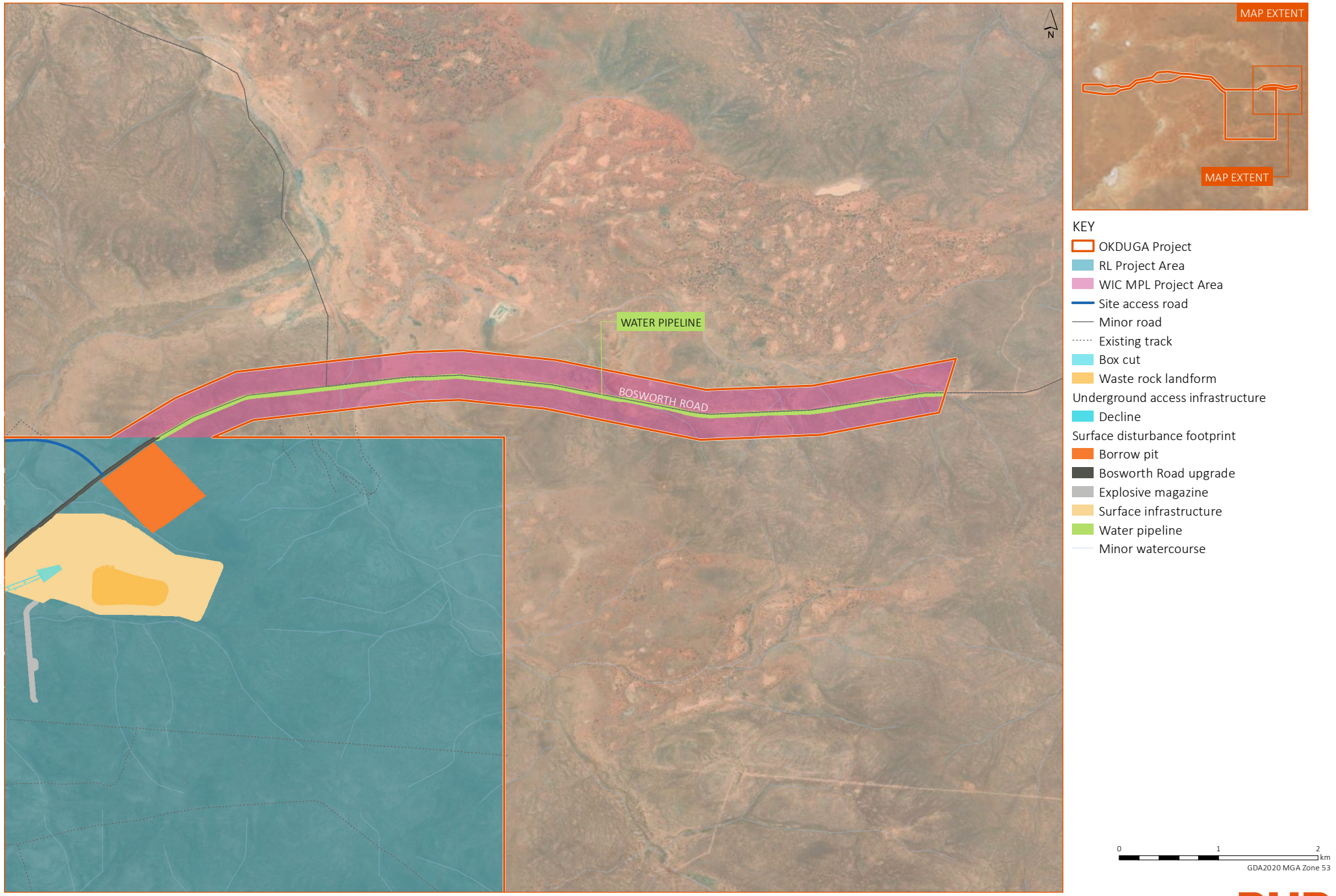


Figure 1.4 | Key infrastructure and tenements for the WIC MPL Project Area

1.2 Background

The Proposal (BHP 2023) for the OKDUGA Project was submitted to DEM on 5 December 2023 and released on public exhibition for five weeks from 28 March 2024 to 2 May 2024. A total of four submissions were received from government agencies and one submission from the public between 13 March 2024 and 30 May 2024. No submissions were received from community groups or non-government organisations.

A Proposal Response Document (PRD) was submitted to DEM on 16 July 2024 to present a detailed analysis of the five submissions received from DEM, the Department for Environment and Water (DEW), South Australian Arid Lands Landscape Board (SAAL Landscape Board), the Environment Protection Authority (EPA) and the Municipal Council of Roxby Downs.

This PRD Addendum presents detailed analysis of additional government agency comments received from DEM and DEW on 27 August 2024 in relation to the PRD.

1.2.1 Groundwater modelling and assessment approach

BHP's Proposal and PRD have previously acknowledged local site-specific groundwater data gaps with the purpose and intent of the RL to provide a means to undertake further hydrogeological drilling and testing to inform a future Mining Lease Proposal (MLP) should the OKDUGA Project proceed.

Based upon available local and regional measured data, BHP has undertaken groundwater modelling and applied predictive uncertainty analysis (PUA) to support a risk-based approach to impact assessment and water management for the OKDUGA Project as follows:

- PUA has been applied in line with industry best practice guidelines and latest software developments (PESTPP-IES) as recommended by:
    - Independent Expert Scientific Committee (IESC) Guidelines Explanatory Note – uncertainty analysis for groundwater modelling (Peeters and Middlemis 2023)
    - Australian Groundwater Modelling Guidelines (2012)
- Predictive scenarios have been modelled to support assessment of:
    - incremental (i.e. OKDUGA Project only) impacts
    - cumulative (i.e. OKDUGA Project, plus the Carrapateena mining operation, maximum Northern Wellfield groundwater abstraction and Olympic Dam mine operation) impacts
- Groundwater modelling results are presented in two formats
    - 'base realisation' being the best statistical match to measured data
    - probabilistic, percentile-based manner, which refers to the likelihood of exceeding a drawdown threshold (2 m or 0.2 m) considering all accepted model realisations including the base realisation (135 realisations)
- Likelihood statistics have been used to inform risk-based decisions associated with potential source-pathway-receptor impacts of the OKDUGA Project.

1.3 Purpose of this report

This PRD Addendum has been prepared to address the requirements of both the Mining Act and associated Mining Regulations 2020 (Mining Regulations), with consideration of the information needs described in:

- DEM's TOR Oak Dam Retention Lease Application in accordance with the Mining Act, published in The South Australian Government Gazette No. 73 dated 28 September 2023
- DEM's TOR 006
- DEM's Mineral Regulatory Guidelines MG2a.

The purpose of this document is to consider and respond to the additional groundwater matters raised by the Department for Energy and Mining – Mining Water Science (DEM) and DEW in relation to the OKDUGA Project and RL tenement grant.

It is noted that DEM and DEW provided additional comments for BHP's consideration as part of the Program for Environment Protection and Rehabilitation (PEPR) which will be addressed accordingly as part of the next phase of the OKDUGA Project.

This PRD Addendum has been prepared and should be read in conjunction with the Proposal document and PRD, which describes in full the proposed activities for which approval is sought.

1.4 Document structure

This PRD Addendum consists of the main document and supporting appendices and is structured as follows:

- Chapter 1 Introduction, which introduces the Proposal, including providing an overview of the project, project background, approval process, and the purpose and structure of this document.
- Chapter 2 Changes to the Proposal, which outlines any changes and updates to the OKDUGA Project, based on further information received or studies undertaken.
- Chapter 3 Existing environment, which describes changes to the understanding of the baseline groundwater environment since submission of the Proposal.
- Chapter 4 Responses to submissions, which provides a detailed summary of the key issues raised; and provides responses to each.
- Chapter 5 Consultation and engagement, which provides an overview of consultation with key stakeholders and government departments since the submission of the Proposal and PRD.
- Chapter 6 Management of environmental impacts, which confirms the control and management strategies developed for the Proposal and outlines the updated forward works plan for the OKDUGA Project.
- Appendices to the PRD Addendum, which support the main document:
    - Appendix A PRD additional comments from DEM and DEW
    - Appendix B Groundwater environmental assessment addendum updated
    - Appendix C Groundwater monitoring framework addendum.

2. Changes to the Proposal

This chapter outlines any changes and updates to the OKDUGA Project, based on further information received or studies undertaken.

2.1 Description of operations

For the purposes of this PRD Addendum, BHP propose no changes to the OKDUGA Project relative to the activities discussed in the Proposal (BHP 2023) and PRD (BHP 2024).

It is acknowledged that project engineering and engagement with key stakeholders is ongoing and will be used to inform the associated program for environment protection and rehabilitation (PEPR), secondary approvals, permits and licences, if required.

The key characteristics of the OKDUGA Project, as presented in the Proposal (BHP 2023), for the proposed tenements are summarised in Table 2.1.

Table 2.1 | Key project elements and characteristics

Project element	Proposal summary (Dec 2023)	Proposal Response Document (July 2024)
Proposed RL		
Underground exploration activities	Development of twin declines to access the Oak Dam deposit via traditional drill and blast development methods, with an associated box cut and portal decline access.	No change
Decline dimensions	Access decline approximately 6.0 m wide and 6.0 m high and conveyor decline approximately 6.7 m wide and 6.0 m high, with each decline approximately 6.0 km long.	No change
Extraction rate	Development is scheduled to progress at an average of approximately 270 m/month, resulting in approximately 1,200,000 t of waste rock being generated.	No change
Project life	Decline construction could take up to approximately 6 years, followed by approximately 2.5 years of underground exploration activities. Closure would nominally take approximately 2 years following the cessation of exploration activities, for a total project life of 10 years.	No change
Processing	No onsite minerals processing is proposed.	No change
Waste rock storage	Waste rock generated during decline development would be stored within a surface WRL, which would subsequently become a permanent landform at closure.	No change
Surface infrastructure	Supporting surface infrastructure includes: • offices • mechanical workshops • explosives magazines • core farm and sample storage areas (upgrade of existing infrastructure) • accommodation village (expansion of existing village) • access roads • renewables generation • borrow pit(s) • crusher • wastewater treatment plant • refrigeration plant • concrete batch plant • laydown areas.	No change
Electricity demand, supply and distribution	Up to 20 megawatts (MW) of onsite electricity generation via diesel generator sets (gensets) with the potential for onsite renewable generation via solar photovoltaic (PV). Distribution via above-ground electricity distribution lines. Total annual electricity demand would be approximately 160 gigawatt hours (GWh) per annum.	No change
Water demand, supply and distribution	A water demand of up to 740 megalitres (ML) would be required over the life of the OKDUGA Project, with daily demand peaking at approximately 0.9 megalitres per day (ML/d) during the later development stages as mine refrigeration becomes necessary. Water supply to meet external (raw and potable) demand would be met through, in whole or part, the capture of mine dewatering inflows, a dedicated water supply wellfield, the supply of water from the existing Northern Wellfield (MPL 156) and/or the import of potable water from the South Australian potable water network (subject to the completion of the Infrastructure SA (ISA) Northern Water Project (NWP)).	No change • Updated groundwater drawdown (Appendix B)
Material quarrying	Borrow material would be required for construction which may be sourced from either an onsite borrow pit(s) and/or from existing regional borrow sources. Nominal material demand would be approximately 242,000 t/month during the initial infrastructure construction phase.	No change
Workforce	Peak workforce would be up to approximately 310 people onsite at any one time. Workforce would be fly-in/fly-out (FIFO) via Olympic Dam, where a bus service would transfer personnel to site, collecting local residents on the way as required.	No change
Accommodation	Oak Dam Village – the existing accommodation would be upgraded to accommodate approximately 310 people, and would include dining halls, ablutions, laundry and recreational facilities.	No change
Exploration	Exploration activities (e.g. surface exploration, resource definition drilling, hydrogeological and geotechnical investigations) and surface infrastructure approved under EPEPR (2022-031) associated with EL 5941 Area B[1]	No change
Proposed SIC MPL		
New site access road	A new all-weather site access road would be constructed within a dedicated SIC MPL Project Area, intercepting the Olympic Dam Highway approximately 20 km north of the existing Bosworth Road intersection connecting the proposed RL to the Olympic Dam Highway.	No change

[1] It its acknowledged that BHP's EPEPR (2022-031) also refers to this area as Area 3 (BHP 2022)

Project element	Proposal summary (Dec 2023)	Proposal Response Document (July 2024)
Water supply pipeline	A water supply pipeline (lateral) may be constructed within the SIC MPL Project Area as a component of the ISA NWP. The NWP would supply water from a seawater desalination plant located on the Eyre Peninsula to site. Approval for the lateral pipeline is being managed by ISA under the Planning, Development and Infrastructure Act 2016 (SA) and is not described further in this document.	No change
Electricity transmission line and substation	Transmission line and substation may be constructed within the SIC MPL Project Area to connect to the South Australian electricity network at the Olympic Dam Highway. The transmission line design would be based on the use of steel poles of approximately 26 m height at a spacing of approximately 250 m.	No change
Proposed WIC MPL		
Water supply pipeline	A water supply pipeline may be constructed connecting the existing Northern Wellfield (MPL 156) to meet construction water demands.	No change
Water disposal pipeline	A water disposal pipeline may be constructed to allow groundwater inflows from the decline and exploration drive ring that is excess to water demands to be directed to the Northern Wellfield (MPL 156), located to the east of the OKDUGA Project.	No change

3. Existing environment

3.1 Land access

3.1.1 Pastoral stations

The RL Project Area and the WIC MPL Project Area are located entirely within the Arcoona Pastoral Station (Lease No. PE002347) held by Handbury Asset Management Pty Ltd (HAM) (Figure 1.1).

The SIC MPL Project Area is located within the following pastoral stations (Figure 1.1):

- Arcoona Pastoral Station (Lease No. PE002347) held by HAM
- Purple Downs Pastoral Station (Lease No. PE002480) held by BHP.

BHP has a Land Access and Compensation Agreement with HAM covering current exploration activities and is currently negotiating an agreement for the OKDUGA Project.

3.1.2 Native title holders

The RL Project Area, the SIC MPL Project Area and WIC MPL Project Area are located entirely within the Native Title determination boundary of the Kokatha People (Part A), tribunal file number SCD2014/004 determined in September 2014.

BHP has established a stakeholder committee with representatives of the Kokatha Aboriginal Corporation (KAC) and meets regularly to discuss the OKDUGA Project. The engagement process has been, and will continue to be, inclusive and carried out through identified representatives, procedures and decision-making structures with the ultimate objective of establishing a sustainable and mutually beneficial relationship with the Kokatha People and to reach a Native Title agreement, in the form of an Indigenous Land Use Agreement (ILUA), to satisfy the requirements of Part 9B of the Mining Act.

3.1.3 Cultural heritage

The region has a long history of occupation by Aboriginal people and many Aboriginal people maintain a strong connection with the land and water in the region.

BHP has undertaken, and will continue to undertake, cultural heritage assessments in order to satisfy the requirements of the *Aboriginal Heritage Act 1988* (SA) (Aboriginal Heritage Act). The KAC, Kuyani Yartah Association (KYA) and Barngarla Determination Aboriginal Corporation (BDAC) have been engaged throughout the past and current project phases to conduct cultural heritage surveys within and surrounding the OKDUGA Project to establish any significant cultural heritage material and document any ethnographic findings.

BHP, in consultation with KAC, KYA and BDAC, is continuing to conduct cultural heritage surveys for the OKDUGA Project to establish any significant cultural heritage material and document any ethnographic findings to inform final Project design, SIC site access road alignment and infrastructure locations. The presence of any artefacts or identified Aboriginal cultural heritage values, including landscape features, within the OKDUGA Project will be handled in accordance with legislation and the agreed procedures and protocols for heritage management with the KAC, KYA and BDAC Indigenous Groups. BHP respects the cultural rights of the Traditional Owners and will not disclose any culturally sensitive information.

3.2 Groundwater

The Groundwater Environmental Assessment (GEA) and Groundwater Modelling Report (GMR) that supported the Proposal (BHP 2023) and Groundwater Environmental Assessment Addendum (GEAA) that supported the PRD (BHP 2024) were based upon available measured groundwater data within the Groundwater Study Area at the time of preparation.

In this regard, the GEA, GMR and GEAA acknowledged the data limitations with groundwater modelling applying predictive uncertainty analysis to support a risk-based approach to impact assessment and water management. The Proposal (BHP 2023) and PRD (BHP 2024) outlined strategies for BHP to address areas of uncertainty within the impact assessment via a forward works plan.

The strategies related to groundwater have been investigated further to support this PRD Addendum and, in particular, to address key comments raised by DEM and DEW in their additional agency submissions (Appendix A) in relation to:

- shortage of local and regional data
- hydrogeological conceptualisation
- boundary conditions / regional water balance
- density corrections applied
- history-matching
- updated impact assessment to reflect the above
- forward works plan clarifications (i.e. targeted groundwater dependent ecosystem (GDE) investigations, groundwater bore census).

Based on the outcomes of further investigations, BHP have prepared Appendix B Groundwater environmental assessment addendum to further address comments and concerns raised by DEM and DEW in relation to the groundwater modelling and impact assessment. Appendix B replaces Appendix C4 of the Proposal.

The additional information presented in this PRD Addendum does not materially change the assessment of groundwater impacts. Therefore, the proposed Environmental Outcomes for the OKDUGA Project, as presented in the Proposal, remain appropriate.

3.2.1 Hydrogeological conceptualisation

The PRD (BHP 2024) updated the OKDUGA Project's hydrogeological conceptualisation, incorporating available site data obtained within the OKDUGA Project and hydrogeological understanding from the Carrapateena mine.

For the purpose of this PRD Addendum the hydrogeological conceptualisation has not changed and presents available local and regional data for the OKDUGA Project. Ongoing investigations may lead to updates to the hydrogeological conceptualisation and will form part of the PEPR.

3.2.2 Groundwater model design

A minor error was identified in a general head boundary condition assigned along part of the edge of the model domain. This has been rectified and its effect on predicted groundwater inflow to the OKDUGA underground excavations, and associated groundwater drawdown, found to be negligible. There is a relatively small effect on the modelled regional water balance but it does not affect the assessment.

Given the high and variable salinity of groundwater in the region, density corrections were applied to raw measured groundwater levels in monitoring wells, to convert them to equivalent freshwater heads. DEW requested more information on this, including a worked example. A table has been appended to the GEEA providing details on well names, locations, screen intervals, screened hydrostratigraphic unit/s, measured groundwater level and measured or assumed salinity. This is followed by a worked example outlining how the density-correction process is implemented.

The groundwater model has been validated using an expanded groundwater monitoring dataset. This totals 34 monitoring locations compared to the 20 and 30 documented in previous reports. The expanded dataset and validation process resulted in substantially improved statistical performance. The model produces an acceptable replication of measured absolute groundwater levels and dynamic trends and is considered to be fit-for-purpose with regard to predictive scenario modelling to support an RL Proposal.

3.2.3 Groundwater dependent ecosystems

EcoLogical Australia (2024) undertook remote sensing within the groundwater study area and did not report any potential aquatic GDEs in the OKDUGA Project Area, although they did conclude the lower reaches of Bosworth Creek may support potential aquatic GDEs. Accordingly, BHP's Proposal and PRD outlined the intention to undertake further GDE investigations as part of the PEPR forward works plan.

DEM and DEW have sought additional clarification on how BHP propose to address areas of uncertainty in relation to GDE, in particular the nature and scope of the targeted GDE investigations.

The purpose of the targeted GDE investigations is to determine the plant species and potential reliance on groundwater within the OKDUGA Project and at areas identified to be potentially impacted by groundwater drawdown.

The targeted GDE investigations is proposed to be undertaken as follows:

- Survey of potential GDE / vegetation species sites within the lower reaches of the Bosworth Creek.
- Sampling and comparison of stable oxygen and hydrogen isotopes of plant water and surface/groundwater samples collected.
- Analysis of the chemical composition (major cations and anions) of water samples collected.
- Assessment and reporting of GDE survey and laboratory results to determine if vegetation is using groundwater and if so, to what extent is the vegetation reliant upon groundwater:
    - a conceptual model would be developed for each site to present potential processes occurring for these for vegetation water uptake.
- Past trend assessment (i.e. monitoring) using sentinel remote sensed data paired with water sampling locations and selected control sites.

3.2.4 Groundwater bore census

BHP's Proposal and PRD forward works plan outlined undertaking a bore census prior to construction of the OKDUGA Project to confirm the status of bores, particularly at Arcoona and Bosworth pastoral leases, including usage during drought conditions.

DEM and DEW have sought additional clarification on how BHP propose to address areas of uncertainty in relation to landholder bores, in particular the nature and scope of the bore census.

The bore census is proposed to be undertaken as follows:

- Record bore details (i.e. bore owners name, pastoral station, unique identification/registered number of the bore, photograph of headworks, GPS coordinates).
- Record standing water level (SWL).
- Where a bore is equipped and/or pumping record:
    - pump details (i.e. equipment, pump depth, etc.)
    - duration of pumping and rest periods
    - maximum pumping rates.
- Record groundwater quality parameters (i.e. pH, electrical conductivity (EC), total dissolved solids (TDS)).
- Consultation with the pastoral landholder on bore water usage, including during drought conditions.

4. Responses to submissions

As outlined in Section 1, this PRD Addendum addresses the additional groundwater comments received from DEM and DEW on the PRD.

4.1 Analysis of submissions

Responses to all DEM and DEW comments received are provided in the following sections. Comments from the submissions are provided in Appendix A and are summarised, with each comment categorised under a key aspect with responses provided in the associated tables.

4.2 Response methodology

Each of the comments provided by DEM are responded to in Section 4.3. Comments provided by DEW are responded to in Section 4.4. All comments were collated and categorised into the following key aspects:

- hydrogeological conceptualisation
- GDE investigations
- groundwater modelling drawdown predictions
- groundwater modelling data
- water management/controls (groundwater)
- third-party pastoral bores.

The identification numbers (IDs) for each response in the following sections are related to the corresponding comment IDs outlined in the government agency comments document, provided by DEM dated 27 August 2024 (Appendix A). Responses were prepared for each matter by BHP, with input from technical specialists who prepared the relevant environmental assessments for the Proposal and PRD.

4.3 Department for Energy and Mining (DEM) (Hydrogeology)

DEM provided 16 additional groundwater comments in relation to the Proposal Response Document and its GEA Addendum (BHP 2024) which are outlined and responded to below in Table 4.1 to Table 4.4.

4.3.1 Hydrogeological conceptualisation themes

Table 4.1 | Response to hydrogeological conceptualisation themes

ID	Document reference	Submission comment	Response/action required from BHP	BHP response	Further detail
1	Proposal Response Document	The lack of robust local hydrogeological data and inadequate conceptualisation Several aspects of conceptualisation improved but the logic and numerical values used for the new boundary conditions still need to be justified (comment 49). There are still some parameterisation issues (comments 19 and 36) and information requested on the Quaternary aquifer was not provided (comment 40). The groundwater head contours are still questionable (comments 22 and 39).	ID#19 Minor comment the lower end of hydraulic conductivity for the Quaternary Sediments is very low for an aquifer.	Noted - There are a wide range of values reported in public literature with the range of hydraulic conductivity for Quaternary Sediments derived from Olympic Dam. A notation to this effect has been added to the GEAA	GEEA, Appendix B, Section 3.6.1
			ID#22 See comments on how Figure 3.4 and Figure 3.5 were constructed at comment 39. The observation of 128.7 m AHD (now 129.13 mAHD in Figure 3.4) is still there and is placed between the 80 and 90 m AHD contours. An explanation and correction is needed.	Agreed - this is an outlier point, it is ~50 years old and was taken from WaterConnect / public database in the absence of sufficient site data. This point has been removed from Figure 3.4.	GEEA, Appendix B, Figure 3.4
			ID#34 Density correction is applied but worked numerical examples on density corrections are not provided. Also see comments on how Figure 3.4 and Figure 3.5 were constructed for comment 39.	Agreed – data and worked numerical examples on density corrections included in Appendix E to the updated GEEAGEEA	GEEA, Appendix E of Appendix B
			ID#35c Minor note: “permeability” still occurs in Section 3.2 and Table 3.1; also in Appendix B 3.6 and 3.9	Agreed - updated GEEA has removed reference to 'permeability' and replaced with ‘hydraulic conductivity’	GEEA, Appendix B, Section 3.2, Table 3.1
			ID#39 Appendix B 3.4.1 iii refers to two wells within the RL: (ADHY01M and ADHY01P), ADHY01M: 88.8 mAHD, ADHY01P:85.5 m AHD. These points could not be found in Figure 3.4 or Figure 3.5. Section 3.2 refers to these wells shown in Figure 3.1 but that figure does not have well id labels. Judging from Section 3.2, these wells should be in the PFA; i.e. Figure 3.5, the contour map for the PFA, however, does not appear to have 88.8 or 85.5 mAHD observations and, in fact, does not have a single observation within the RL. Fig.3.4 has a 129.13 mAHD in the NE corner of the RL which seems to have been excluded from the contouring (located between the 80 and 90 mAHD contours). An explanation is required on how Figure 3.4 and Figure3.5 were constructed and from what data.	The equivalent freshwater head elevations of between 85 and 89 mAHD on Figure 3.4 and Figure 3.5 compare well with density corrected regional groundwater elevation data (e.g. from Carrapateena and/or WaterConnect). However, these points have not been included on the figures, as they did not inform the contours shown.	GEEA, Appendix B, Figure 3.4, Figure 3.5
			ID#40 The discussion and model improvements are welcome but no data on the Quaternary or comparison with THA were provided.	Agreed - Additional hydrograph added to show Quaternary sediments response to rainfall (Figure 3.6). There is insufficient data to prepare a comparison between THA and Quaternary Sediments at this time.	GEEA, Appendix B, Figure 3.6
			ID#49 See comment in Section 4.3.5	See response in Section 4.3.4	N/A

4.3.2 Groundwater modelling drawdown predictions themes

Table 4.2 | Response to groundwater modelling drawdown predictions themes

ID	Document reference	Submission comment	Response/action required from BHP	BHP response	Further detail
2 & 3	Proposal Response Document	Boundary conditions and Adopted boundary values There are improvements, the boundaries have been extended and changed from constant heads to general heads, but the logic behind these still need to be justified and the numerical values used for the new boundary conditions need to be provided (comments 26, 39, 42, 43a, 43b, 47 and 50). Density corrections were applied but not documented to the extent they were requested (comments 34 and 44). There are differences along the NW boundary between Figures 3.4 and 5.3 raising uncertainty on what degree does the numerical model reflect the conceptual hydrogeology (comment 26).	ID#26, 42, 43a, 43b, 47, 50 The documentation in Sections 4 to 6 is inadequate, as it is not specified where the external reference heads for GHBs come from and what are the numerical values used to simulate GHBs. GHB (general head boundary) conditions are better than the previously used CHB. DEM understands that for a GHB, there is a fixed reference head somewhere outside the model, and the flow will be proportional to the gradient between that fixed head and the variable head at the model edge, controlled by a hydraulic conductance in between. It follows that the documentation should include the source of the reference head and the numerical values used for both the reference head and the conductance. DEM could not find an adequate description of the information above. Figure 4.4, for example shows GHBs at the model boundary not at the external location. Provide the hydraulic conductance and the external reference heads used for GHBs and the sources of those. There are also differences along the NW boundary between Figure 3.4 and Figure 5.3 raising the issue as to what degree does the numerical model reflect the conceptual hydrogeology. Figure 3.4 indicates groundwater flow along the model boundary there; Figure 5.3 suggests groundwater flow perpendicular to the boundary.	Noted - The GHBs were designed based on interpreted groundwater level contours at boundary cells, rather than a reference external head. Accordingly, a high conductance value of 100 m^2/day was assigned. This was necessary in order to induce drawdown in the THA associated with Olympic Dam mining activities. GEEA Figure 3.4 shows interpreted groundwater contours for the THA, while Figure 5.3 shows modelled groundwater contours for the THA. As shown in Section 5.5, the difference between conceptual and modelled groundwater flow direction 50 km from the OKDUGA Project area does not adversely impact history-matching performance.	GEEA, Appendix B, Figure 3.4, Figure 5.3, Section 5.5
			ID#27 The criteria do not seem to have changed and still link to model predictions. See comments on 29. Not all the details for GHBs are provided, refer to comment on comment 26. In addition, the colour shades used in Figures 4.4 to 4.6 do not allow for meaningful analysis. Resolve: Figure 4.4 title refers to GHB legend to CHB; also check if year 3040 is correct (or not in Figure 4.6). Stress periods in Table 3.2 end in 2048.	Agreed - The legend label in Figure 4.4 has been corrected and now refers to GHB. Figure 4.5 title correctly amended to 2040. Figure 4.6 has been removed to avoid confusion.	GEEA, Appendix B, Figure 4.4
			ID#28 Note that calibration on its own is not adequate, suggest to use the term “calibration and model review”.	Agreed - Proposal Response Document Addendum forward works plan has been updated to reflect DEM's request for future model calibration to include 'model review'.	PRD Addendum, Section 6.3
			ID#44 Sections 3.4.1 i and 3.4.1 iii include the methodology and application to two wells, respectively, the density correction was completed but the explanation about the potential errors this approach includes was not.	Agreed - data and worked numerical examples on density corrections included in Appendix E to the updated GEEA (aligns with ID#34).	GEEA, Appendix E of Appendix B
			ID#48 The SRMS errors in Table 5.3 are high, also in Figure 5.6 c and d.	Agreed – GEEA has been updated with a further review of history-matching target data, well screened units, and base realisation hydraulic properties, along with a dataset expanded to 34 monitoring locations. Updates to this show improved history-matching performance, with base realisation transient head SRMS of 9.1%.	GEEA, Appendix B, Section 5.5
			ID#49 See comment in Section 4.3.5.	See response in Section 4.3.5.	N/A

4.3.3 Water management/controls (groundwater) themes

Table 4.3 | Response to water management/controls (groundwater) themes

ID	Document reference	Submission comment	Response/action required from BHP	BHP response	Further detail
4	Proposal Response Document	There are important details missing on the proposed groundwater monitoring and those should be provided in accordance with the Mining Regulations and TOR 006 While most of the missing information has now been provided, the outcome measurement criteria are unchanged and still refer to model predictions. When model uncertainty is high, it is better to provide model-independent simple outcome criteria that is based on the best, but not perfect, assessment at the time. The baseline data to be used also need to be described. Comment 29.	ID#29 The what, where, and frequency are provided in Appendix C, but baseline data and achievement criteria are not. Section 6.2 refers to the proposed Outcomes as described in Section 8, Table 8.2, Table 8.4 and Table 8.5 of the Proposal (BHP 2023), respectively. Of the tables referred to, only Table 8.2 had groundwater criteria and even those are linked to model predictions. When model uncertainty is high, it is better to provide model-independent absolute outcome criteria that is based on the bets assessment at the time.	Agreed – amended Outcome, OMC and LI proposed to increase monitoring frequency for field and laboratory parameters to monthly for the first two years to establish baseline conditions. Groundwater Monitoring Framework also updated to increase monitoring frequency for field and laboratory parameters to monthly for the first two years to establish baseline conditions. In accordance with DEM's MG2b Preparation of a PEPR for metallic and industrial minerals, BHP's PEPR and associated Groundwater Management and Monitoring Plan (GMMP) will prescribe measurement criteria and leading indicator criteria (where appropriate).	PRD Addendum, Section 6.2, Table 6.1 PRD Addendum, Appendix C, Table 3.1

4.3.4 Groundwater modelling data themes

Table 4.4 | Response to groundwater modelling data themes

ID	Document reference	Submission comment	Response/action required from BHP	BHP response	Further detail
5	GEA Addendum	A better model documentation is required to support the proposal Improved but still inadequate. The logic and numerical values used for the new boundary conditions still need to be justified. Also, a better explanation of the water budget is required (comment 49) and a robust justification is required to explain the new issue. The large component of evapotranspiration in the model Figure 5.7 of appendix B indicates the "Base realisation modelled water balance over the history-matching period". Accordingly, the main inputs to the model are rainfall recharge and regional inflow, dominantly balanced by evapotranspiration (EVT). That EVT is only possible if significant parts of the model domain have shallow water table. DEM assumed this was the case near Lake Torrens "Groundwater discharges into the regionally significant Lake Torrens, where evaporative discharge occurs" (Section 3.9, conceptual hydrogeology). Comments, provided in Table 6.2 about EVT as: "this is a recirculation of water through a few boundary condition cells along the southern model boundary that are within the evapotranspiration extinction depth and does not influence model parameterisation or predictions" appear to suggest otherwise. In DEM's view, the amount of recirculated water is close to 50 ML/d (Figure 5.7), which is a very large flow; it is, in fact, the largest component of the water balance of the model in Figure 5.7. DEM was unable to find any description of this water (~50 ML/d) in the conceptual hydrogeology (Section 3.9). Conceptual hydrogeology should include all physical process that are significant enough to be represented in the model.	ID#26 See comment in Section 4.3.2.	See response in Section 4.3.2	N/A
			ID#49 Figure 5.7 of appendix B indicates the "Base realisation modelled water balance over the history-matching period". Accordingly, the main inputs to the model are rainfall recharge and regional inflow, dominantly balanced by evapotranspiration (EVT). That EVT is only possible if significant parts of the model domain have shallow water table. DEM assumed this was the case near Lake Torrens "Groundwater discharges into the regionally significant Lake Torrens, where evaporative discharge occurs" (Section 3.9, conceptual hydrogeology). Comments, provided in Table 6.2 about EVT as: "this is a recirculation of water through a few boundary condition cells along the southern model boundary that are within the evapotranspiration extinction depth and does not influence model parameterisation or predictions" appear to suggest otherwise. In DEM's view, the amount of recirculated water is close to 50 ML/d (Figure 5.7), which is a very large flow; it is, in fact, the largest component of the water balance of the model in Figure 5.7. DEM was unable to find any description of this water (~50 ML/d) in the conceptual hydrogeology (Section 3.9). Conceptual hydrogeology should include all physical process that are significant enough to be represented in the model. The numerical groundwater flow model should be the numerical representation of the conceptual hydrogeology and should not have "surprises" of this magnitude. Such a surprise cast doubt if the model is fit for the purpose of impact assessment. It is unclear if this EVT is realistic, or it is simply an artifact of the model balancing inflows with outflows. If the latter, it may be an indication of inconsistencies between the conceptual and numerical water budget, i.e. the main input, rainfall recharge may also be incorrect.	Agreed - The error as described arose from the interpolation of interpreted groundwater level contours in the THA to GHB inputs in the area of Pernatty Lagoon, where there are no bores. Interpolation between conceptual contours (see Figure 3.4) in this area led to GHB heads assigned above ground surface. This has been rectified and all models re-run (history-matching period and predictions) and results reprocessed to produce updated values, figures and table entries. Comparison of model outputs between simulations with the uncorrected and corrected/topographically constrained GHB head indicated that had no material influence on model predictions.	GEEA, Appendix B, Section 5.6

4.4 Department for Environment and Water (DEW)

DEW provided 27 comments in relation to the PRD and its GEA Addendum (BHP 2024) which are outlined and responded to below in Table 4.5 to Table 4.11.

4.4.1 Hydrogeological conceptualisation themes

Table 4.5 | Response to hydrogeological conceptualisation themes

ID	Document reference	Submission comment	Response/action required from BHP	BHP response	Further detail
6	App B Sec 3.2.1	The bores discussed in this section need to be labelled on a map.	Include locations and labels of bores on a map.	Agreed - bore IDs for ADHY01M and ADHY01P have been included in Figure 3.1 of the updated GEEA.	GEEA, Appendix B, Figure 3.1
7	App B Sec 3.4.1	It is good to see that density corrections were performed. A table showing measured and corrected head data should be included to show the effect on the data.	Include table showing original and corrected head data.	Agreed – a table providing details on well names, locations, screen intervals, screened hydrostratigraphic unit/s, measured groundwater level and measured or assumed salinity, followed by a worked example outlining how the density-correction process is implemented is included in Appendix E to the updated GEEA.	GEEA, Appendix E of Appendix B
8	App B Sec 3.4.1 iv	The data presented do not support the vertical gradients identified.	Provide additional data or modify discussion.	Agreed - additional text included in the updated GEEA. Review of the contours across the Northern Wellfield indicates the PFA elevations are higher than the THA elevations.	GEEA, Section 3.4.1 iv
9	App B Sec 3.4.2	The locations of the bores associated with these hydrographs and the production wells need to be identified on a map. Specify if these are the only hydrographs available.	Provide bore locations (and label accordingly) on a map. Identify if there are additional hydrographs available.	Agreed - additional hydrographs have been included in the history-matching hydrographs at GEEA Appendix A. Details of all bores used for history-matching, including well names, locations, screen intervals, screened hydrostratigraphic unit/s, measured groundwater level and measured or assumed salinity are provided in a table in GEEA Appendix E.	GEEA, Appendix A of Appendix B and Appendix E of Appendix B
10	App B Sec 3.6.4, Table 3.6	It is difficult to support the PFA being referred to as an aquifer with conductivity values as low as these. Refer to DEW response number 2 for further discussion.	Values as low as these for an “aquifer” need to be examined within calibration.	Noted - The PFA is a fractured rock aquifer, with variable degrees of fracturing depending on the sub-unit (GEEA, Figure 3.8). The density, connectivity, orientation and aperture of fractures all affect the effective bulk hydraulic conductivity of the fracture-matrix system represented as an equivalent porous medium. Where fracturing is less influential, the equivalent porous medium hydraulic conductivity will be far lower than where fracturing is substantial. This high variability is noted in the success rate of wells drilled as intended production wells in this unit, with only approximately one in three drilled for the Carrapateena Mine Northern Wellfield being successful. The indicative hydraulic conductivities given in Table 3.6 are suggested for regional-scale properties, and fracturing results in high variability of hydraulic conductivity (refer Table 3.4 and Table 3.5).	GEEA, Appendix B, Figure 3.8, Table 3.4, Table 3.5, Table 3.6

4.4.2 Groundwater modelling drawdown predictions themes

Table 4.6 | Response to Groundwater modelling drawdown predictions themes

ID	Document reference	Submission comment	Response/action required from BHP	BHP response	Further detail
11	App B Sec 4.3.1	The model extent must be based on where model boundaries and boundary conditions can be supported from the available data. This is not the case in question here.	Provide justification for boundary locations and associated conditions based on actual data.	Noted - The model boundary was chosen to be larger than the prior OKDUGA model, as drawdown was predicted to reach the boundary. Conversely, low spatial coverage of regional groundwater level measurements limits the data basis for inferred groundwater contours at the edges of the expanded domain. Consequently, the steady-state modelled groundwater elevations from the Carrapateena groundwater flow model were used to guide boundary condition development in the absence of measured data.	GEEA, Appendix B, Section 3.4, Figure 3.4, Figure 3.5, Section 4.5.1, Figure 4.4, Figure 4.5, Figure 4.6, Figure 4.7
12	App B Sec 4.3.2	Given the sparse amount of data that can be used to develop a supportable conceptual model, the grid is considered excessive for the numerical modelling.	The very fine grid needs to be justified based on the available data and the modelling objectives. Please provide additional discussion to this point.	Noted – The fine mesh, in targeted areas, does not detract from results of the modelling. It provides greater spatial resolution. The fine mesh is required for appropriate simulation of the Northern Wellfield, where monitoring wells are installed 10 to 20 m from production wells. Without a fine mesh in this area the stress and response could not be modelled such that they could appropriately inform history-matching. Additionally, a fine mesh around OKDUGA Project underground excavations allows resolution in this key area of the model and avoids simulation of dewatering of excessive volumes of aquifer that might result if large model cells were used.	GEEA, Appendix B, Section 4.3.2
13	App B Sec 4.3.3	The layering is considered excessive. However, it may well serve to assess the mining/dewatering process. One of the difficulties with the grid refinement in the spatial and vertical directions is with numerical accuracy/instability. This is often ignored in models with this level of refinement.	The potential for instabilities in the vertical and horizontal directions needs to be evaluated for the model results to be acceptable. Please provide discussion around this evaluation. In addition, any results from layers where no data are available for comparison make these results unsupportable.	Noted – The model did not suffer from numerical instability. The history-matching process returned an ensemble approximately half the size of the prior ensemble, but this is due to removal of realisations that achieved relatively poor history-matching performance, rather than numerical non-convergence or instability. Analysis of the base realisation water balance indicates an imbalance between modelled inflows and outflows of just 0.05%. Furthermore, the imbalance at all transient output times is less than 1%. This more than meets guidance in the Australian Groundwater Modelling Guidelines, which states "*cumulative mass balance error of not more than 1% of the total mass balance is considered acceptable*"	GEEA, Appendix B, Section 4.3, Section 5.6
14	App B Sec 4.4, Table 4.2	The provided Table 4.2 suggests that the Carrapateena well pumping started after Jan 2020. If pumping started before then, the steady state must be based on pre-production hydraulic heads.	Provide information to confirm when pumping started at Carrapateena. Furthermore, correct steady state conditions if pumping started before 2020.	Noted - The Carrapateena Northern Wellfield did not start pumping until 2020. Other Carrapateena production wells, local to the Mine and distant from the OKDUGA Project, were active prior to this, but these were not simulated, nor did they influence monitoring wells used for defining pre-development groundwater conditions. Modelled steady-state conditions were compared against measured unimpacted groundwater levels.	GEEA, Appendix B, Table 4.2, Table 4.3, Table 4.4
15	App B Sec 4.5.1	"Inferred contours of equivalent freshwater head were used to define the general head boundary conditions in the THA (layer 3), WSA (layer 5) and the PFA (layers 9–14)". Supporting information must be provided to indicate what data has been used for these statements. Figure 3.4 and Figure 3.5 do not show enough data to be used to support GHBs. Additional information is also needed to specify boundary condition values for the other vertical layers and what conductances were used.	Additional data must be provided to support the model boundary conditions.	Noted - regional groundwater data have been used noting that there are more bores in the THA than the deeper PFA. The history-matching dataset has been expanded to a total of 34 monitoring locations. In addition, predicted groundwater levels derived from BHP's Olympic Dam groundwater model (GEA - Addendum (V2) Section 4.5.1) were used to inform the head values assigned to the GHBs in this model. Layers other than those mentioned in the report are not assigned GHB boundary conditions as these are aquitards or, in the case of the basement, an aquiclude.	GEEA, Appendix B, Section 4.5.1, Figure 3.4. Figure 3.5, Figure 4.4, Figure 4.5, Figure 4.6

ID	Document reference	Submission comment	Response/action required from BHP	BHP response	Further detail
16	App B Sec 5.1, Table 5.1	There are very few monitoring wells in most layers, meaning that calibration of the model will be very difficult. This is further mentioned in Section 5.3 and has been raised in previous comments from DEW. Additional data are required. Alternatively, the proponent may wish to adopt a simpler modelling approach commensurate with the data that is currently available.	Additional data are needed to support model calibration, or the model needs to be simplified significantly.	Noted - the model makes use of data from the Northern Wellfield (MPL 156) from which data were available for several years of metered groundwater abstraction, and monitoring of aquifer responses. The model layer structure, and its representation of conceptual variability in fracture-controlled hydraulic conductivity with depth, is expected to: • produce the greatest inflows • explicitly simulate the greatest pathway for potential drawdown propagation. GEEA, Section 5.3 acknowledges how many monitoring points were used to inform history-matching of the model and has been updated to reflect the above.	GEEA, Appendix B, Section 5.3
17	App B Sec 5.2	It is necessary to compare the results from the steady state simulations with measured data using potentiometric surfaces so that the steady state model can be evaluated.	Provide comparison diagrams from steady state simulations alongside measured data for evaluation.	Agreed - new figures (Figure 5.3 and Figure 5.4) included in GEEA showing modelled (base realisation) pre-development potentiometric surfaces and measured equivalent freshwater head in the THA and Upper PFA.	GEEA, Appendix B, Figure 5.3, Figure 5.4
18	App B Sec 5.4.1	There are very few observation head data points available. Using this very large number of pilot points is excessive and suggests a well-supported calibration process. In addition, justification needs to be provided as to why Sy pilot points are included in confined aquifer investigations.	Reduce the number of pilot points to be consistent with the amount of head data available. Provide justification as to why Sy pilot points are included in confined aquifer investigations.	Noted - The use of PESTPP-IES allows for incorporation of a large number of pilot points without computational burden. Additionally, insensitive parameters (such as Sy pilot points in confined units) do not influence history-matching or predictive performance. Spatial correlation of properties is handled through prior parameter covariance matrices and IES upgrade iterations; refer Appendix C for indicative (base realisation) spatial distributions. It should be noted that some areas, local to the OKDUGA Project, may be confined prior to the Project but, as excavations and associated depressurisation of the groundwater system progress, become unconfined. In those areas Sy influences the predicted groundwater inflows to underground excavations.	GEEA, Appendix C of Appendix B
19	App B Sec 5.5.1	SRMS results for so little data are extremely poor and do not support a calibrated model. Screened intervals across multiple layers for bores NT-10OB and NT-4OB are significant; these bores should have been identified earlier and their data omitted, reducing the amount of available bore data.	Remove bores NT-100B and NT-40B and reevaluate model calibration.	Agreed – the GEEA has undertaken reviews of history-matching target data, well screened units, and base realisation hydraulic properties. Updates to this show improved history-matching performance, with base realisation transient head SRMS now reduced to 9.1%	GEEA, Appendix B, Section 5.1, Section 5.5, Table 5.1
20	App B Section 5.5.2, i, Figs 5.3 and 5.4	Measured contours need to be included on these figures for comparison. The computed results are consistent with the pre-modelling assertions; however, they would need to be based on the boundary conditions applied. In making this comment, DEW also have questions regarding the choice of boundary conditions and the data used to justify this decision.	Include measured contours on Figures 5.3 and 5.4 for comparison.	Agreed – refer response to ID#17	N/A
21	App B Section 5.5.2, ii, Figs 5.5 and 5.6 and Appendix A	DEW considers the presented results to be poor. The use of PEST++IES in this context cannot be supported. The model has not been adequately calibrated.	The model requires appropriate calibration.	Agreed – refer response to ID#17	N/A
22	App B Section 5.7, Appendices B and C	This discussion and the data presented do not provide confidence in the modelling approach. The hydrographs (Appendix A) indicate a poorly calibrated model.	The model requires appropriate calibration.	Agreed – refer response to ID#17	N/A

ID	Document reference	Submission comment	Response/action required from BHP	BHP response	Further detail
23	App B Sec 6.1	Much of the discussion in this section, and the modelling used to support it, seems to be based on Middlemis and Peeters (2018), which does not appear to have been included in the Reference list. The application of the techniques suggested in the Middlemis and Peeters (2018) report (Information Guidelines Explanatory Note: Uncertainty analysis for groundwater modelling (iesc.gov.au)) assumes a calibrated model. The OKDUGA model is not calibrated, and therefore, the same conclusions cannot be applied.	As previously stated, the model requires appropriate calibration. Include all referenced material in the reference list.	Agreed – refer response to ID#17	N/A
24	App B Section 6.2, Table 6.2 and Appendix D	There needs to be extensive discussion in the text to support the results presented in Appendix D. For example, were boundary conditions kept the same for all simulations? Some of the drawdowns appear to extend very close to the model boundaries and would bring into question the conditions applied along those boundaries. In addition, comparing the OKDUGA model with the LOM model causes confusion: the previous model had boundaries closer to the mining area and (modelled) drawdowns would have reached those boundaries. The LOM model has boundaries further out and drawdowns may affect those boundaries. Comparing the two models is not appropriate as they are different models.	Provide additional information to support the results of the groundwater model as presented in Appendix D. Alternatively, discussions in the text should be changed to appropriately reflect the conditions of the model. Reconsider comparison of OKDUGA and LOM models as they are different models.	Noted - Boundary conditions were kept the same for all simulations, with the exception of OKDUGA dewatering activities for the purposes of predicting incremental drawdown. Comparison of two different models predicting the same activities is appropriate, as it allows for differences to be identified and interrogated.	GEEA, Appendix D of Appendix B
25	App B Sec 7, Table 7.1	Without acceptable model calibration, the assessment of effects analysis table for each receptor (Table 7.1) cannot be appropriately supported.	Model calibration is required to fully support the effects analysis table.	Agreed – refer response to ID#17	N/A
26	App B Sec 8.2	As per above, the presented groundwater impact assessment cannot be accepted without appropriate model calibration.	Model calibration is required to fully support the groundwater impact assessment.	Agreed – refer response to ID#17	N/A

4.4.3 Water management/controls (groundwater) themes

Table 4.7 | Response to water management/controls (groundwater) themes

ID	PRD comment reference	Submission comment	Response/action required from BHP	BHP response	Further detail
27	72. Noted – The Proposal's Section 8.2 (Statement of proposed Environmental Outcomes) outlines BHP's proposed Outcomes and Outcome Measurement Criteria (OMC's) for the RL Project Area, SIC MPL Project Area and WIC MPL Project Area.	Not Addressed. Upon review of the provided Outcomes and Outcome Measurement Criteria, it is not clear to DEW what has changed between versions to address this concern. For example, the Proposal provided as part of this response does not appear to have a Section 8.2, or a different version of the Proposal for the one received is being referenced. Given potential ecological reliance on shallow groundwater sources, clarification is needed on management controls for potential impacts on shallow groundwater.	Provide clarification for if there are specific management controls for potential impacts on shallow groundwater, or if LI's only address groundwater in deeper aquifers.	Agreed – new Outcome, OMC and LI proposed ensure that there is no adverse change to the environmental values of the groundwater within the shallow perched aquifer as a result of chemicals or hydrocarbons from advanced explorations operations. In accordance with DEM's MG2b Preparation of a PEPR for metallic and industrial minerals, BHP's PEPR and associated Groundwater Management and Monitoring Plan (GMMP) will prescribe measurement criteria and leading indicator criteria (where appropriate).	PRD Addendum, Section 6.2, Table 6.1

4.4.4 Water management/controls (surface water)

Table 4.8 | Response to water management/controls (surface water) themes

ID	PRD comment reference	Submission comment	Response/action required from BHP	BHP response	Further detail
28	69. Agreed – The Proposal's Section 8.2 (Statement of proposed Environmental Outcomes) outlines BHP's proposed Outcomes and Outcome Measurement Criteria (OMCs) for the RL Project Area, SIC MPL Project Area and WIC MPL Project Area.	Not Addressed. Upon review of the provided Outcomes and Outcome Measurement Criteria, it is not clear to DEW what has changed between versions to address this concern. For example, the Proposal provided as part of this response does not appear to have a Section 8.2 or is a different version of the Proposal for the one received is being referenced. As similarly discussed in the tables above, the provided response appears to reference the original Proposal. Without an updated proposal, it is hard to discern if the original concern from DEW has been appropriately addressed. The objective should explicitly outline if there will be no adverse impacts.	Provide clarification on the potential for adverse impacts to occur.	Agreed – new Outcome, OMC and LI proposed ensure that there is no adverse change to the environmental values of surface water as a result of chemicals or hydrocarbons from advanced explorations operations. In accordance with DEM's MG2b Preparation of a PEPR for metallic and industrial minerals, BHP's PEPR and associated Groundwater Management and Monitoring Plan (GMMP) will prescribe measurement criteria and leading indicator criteria (where appropriate).	PRD Addendum, Section 6.2, Table 6.1

4.4.5 Site water balance themes

Table 4.9 | Response to site water balance themes

ID	PRD comment reference	Submission comment	Response/action required from BHP	BHP response	Further detail
29	68. Agreed – Water balance updated and includes dust suppression volumes during construction and operation (Appendix D).	Partially Addressed. Only the water balance for operations has been provided. Please also provide the water balance for constructions as originally requested. Additionally, the sum of inputs for the STWP still don't equal outputs, unless assuming rainfall is negligible. Please clarify and update accordingly.	Provide water balance for constructions and clarify/update the inputs for the STWP so that they are equal to the expected outputs.	Noted – the Proposal, Figure 3.1 outlined the representative water balance year 1-2 with 6 megalitres per/year (ML/yr) for dust suppression. The sum inputs for the settled water pond (STWP) assume rainfall is negligible. The annual rainfall in the South Australian Arid Lands (SAAL) natural resource management (NRM) Region has been relatively stable, recording an average of around 180 mm in both the past 30 years (1989 to 2018) and the previous 30 years (1959 to 1988) (BHP 2023).	Proposal, Figure 3.1 Proposal, Section 3.1.4.4

4.4.6 Third-party pastoral bores themes

Table 4.10 | Response to third-party pastoral bores themes

ID	PRD comment reference	Submission comment	Response/action required from BHP	BHP response	Further detail
30	78. Agreed – the forward works plan for the PEPR has been amended to include BHP undertaking a bore census to confirm the status of bores.	Partially Addressed. DEW acknowledge the plan to conduct a bore audit as part of future PEPR development. As previously specified, please refer to the correct section in the updated Proposal (Section 5 relates to Consultation and Engagement).	Provide additional draft information of Forward Works Plan for ease of assessing the PEPR.	Agreed – PRD Addendum has been updated to outline Bore Census scope of work / investigations.	PRD Addendum, Section 3.2.5

4.4.7 Groundwater Monitoring Framework themes

Table 4.11 | Response to Groundwater Monitoring Framework themes

ID	Document reference	Submission comment	Response/action required from BHP	BHP response	Further detail
31	App. C, OKDUGA Project monitoring bores, Table 2.1 and Figure 2.1	Consider implementing additional monitoring bores, especially to monitor if any impacts to potential GDEs around the lower reaches of Bosworth Creek and towards Lakes Torrens. Additional monitoring bores will also provide better spatial distribution of monitoring across the project site.	Consider implementation of additional monitoring bores for better spatial distribution across the OKDUGA RL and understanding of any impacts to potential GDEs in the lower reaches of Bosworth Creek.	Noted – GEA Addendum has been updated to outline proposed targeted GDE investigations scope of work / investigations for the lower reaches of Bosworth Creek.	PRD Addendum Section 3.2.4
32	App C, Groundwater Quality Suite, Table 3.1	Consider higher frequency of monitoring for the first two years of monitoring, to help establish a baseline. Monitoring could then be reduced to quarterly or even bi-monthly following the first two years.	Consider higher frequency of monitoring.	Agreed - Groundwater Monitoring Framework updated to increase monitoring frequency for field and laboratory parameters to monthly for the first two years to establish baseline conditions.	PRD Addendum Appendix C, Table 3.1

5. Consultation and engagement

5.1 Stakeholder engagement

BHP has actively engaged with relevant stakeholders throughout the planning and approvals process of the OKDUGA Project.

The purpose of the engagement has been to inform and obtain feedback about the OKDUGA Project. BHP's stakeholder engagement has been comprehensive to date and reflects the importance BHP places on this aspect of its business and the OKDUGA Project.

Table 5.1 describes the additional consultation undertaken with key stakeholders since the lodgement of the PRD.

Table 5.1 | Summary of stakeholder engagement and outcomes

Stakeholders	Consultation method	Potential areas of concern and opportunity
HAM (Arcoona Pastoral Station)	Meetings ongoing	Ongoing one-on-one, face-to-face meetings and pastoral station visits with Arcoona Pastoral Lessee focused on: • providing OKDUGA Project information • ongoing communication regarding aspects such as OKDUGA Project updates, ongoing discussion regarding potential issues and opportunities, operational matters including access to site, relevant exploration activities, etc • access agreements.
KAC	Meetings, heritage surveys ongoing	• Negotiation of an ILUA for the OKDUGA Project to satisfy the requirements of Part 9B of the Mining Act and section 24AA of the *Native Title Act 1993* (Cth). • KAC engaged throughout the past and current project phases to conduct cultural heritage surveys within the OKDUGA Project to establish any significant cultural heritage material and document any ethnographic findings.
KYA	Heritage surveys ongoing	• KYA engaged throughout the past and current project phases to conduct cultural heritage surveys within the OKDUGA Project to establish any significant cultural heritage material and document any ethnographic findings.
BDAC	Heritage surveys ongoing	• BDAC engaged throughout the past and current project phases to conduct cultural heritage surveys within the OKDUGA Project to establish any significant cultural heritage material and document any ethnographic findings.

5.2 Government consultation

Consultation with government agencies has been ongoing throughout the OKDUGA Project. Key government agency consultation since submission of the PRD is summarised in Table 5.2.

Table 5.2 | Summary of government agency consultation

Stakeholders	Consultation method	Potential areas of concern and opportunity
DEM	Meeting 27 September 2024	Meeting held with BHP/DEM representatives to discuss key areas of concern raised in relation to DEM/DEW additional agency submissions on the Proposal Response Document, namely in response to: • purpose of RL to enable BHP a means to obtain more hydrogeological data, which will also support refinement to groundwater model calibration and predictions to inform MLP should the project proceed • groundwater modelling/impact assessment, acknowledging shortage of local and regional data and the use of PUA to support a risk-based approach to SPR, impact assessment and water management • general aspects in relation groundwater monitoring and controls.

6. Management of environmental impacts

6.1 Control and management strategies

Control and management strategies were developed in the Proposal with consideration to significant uncertainties and assumptions regarding the likely effectiveness of proposed control measures in managing and mitigating impacts and achieving Environmental Outcomes for operations and closure.

The outcomes and findings of this PRD Addendum do not change the proposed control and management strategies for the OKDUGA Project as described by reference to pathway and receptor in Section 8, Table 8.1 of the Proposal.

6.2 Statement of proposed Environmental Outcomes

A statement of proposed Environmental Outcomes for each of the confirmed impact events (grouped) covering all stages of the OKDUGA Project – construction, operation and closure, was developed in the Proposal for each tenement based on the residual impact of the proposed activities on the receptors after the implementation of control strategies.

The proposed Environmental Outcomes are a commitment on the extent to which the OKDUGA Project would limit impact on the environment. The outcomes and findings of this PRD do not change the proposed Environmental Outcomes which are considered to be reasonable and realistically achievable, acceptable to stakeholders (as confirmed during consultation) and meet other applicable legislative requirements.

Supporting the achievement of the proposed Environmental Outcomes are OMCs, which nominate the criteria to be adopted to measure the Environmental Outcomes that are set out in this PRD Addendum and the Proposal.

In accordance with DEM's MG2b Preparation of a PEPR for metallic and industrial minerals, BHP's PEPR and associated GMMP these would be expanded in the subsequent PEPR to include details about:

- what is to be measured and the form of the measurements that are to be used
- the locations where the relevant measurements are to be taken, or how such locations are to be determined
- what is to be measured or monitored to constitute the achievement of the relevant Environmental Outcomes, with consideration being given to any inherent errors of measurement
- the frequency of any measurement or monitoring
- any background or control data that is to be used, or how any such data is to be acquired.

The proposed Outcomes, OMCs and LIs for the RL Project Area, SIC MPL Project Area and WIC MPL Project Area, are as described in Section 8, Table 8.2, Table 8.4 and Table 8.5 of the Proposal (BHP 2023), respectively and Table 6.1 below which reflects amended and new Outcomes, OMC and LI's in response to DEW additional groundwater comments.

Table 6.1 | RL Project Area – Proposed Environmental Outcome, OMC and LI

Environmental Outcome	Outcome Measurement Criteria	Leading Indicator	SPR ID
Groundwater (quality)			
Amended - The Tenement Holder must during construction, operations and closure ensure that there is no adverse change to the environmental values of water within the aquifers outside of the Tenement as a result of advanced exploration operations	Monthly ~~Quarterly~~ analysis of groundwater quality confirms no change in groundwater quality that can be attributed to advanced exploration operations	Groundwater quality monitoring at nominated monitoring bores demonstrates a trend over four consecutive monitoring periods of a change in groundwater quality, triggering an investigation with respect to the cause	GW12, GW13, GW14, GW15, GW16, GW17, GW18, GW19, GW20, GW21, GW22, GW23, GW24, GW25, GW26, GW27, GW28, GW29, GW30, GW31, GW32, GW33, GW34, GW35, GW36, GW37, GW38, GW39, GW40, GW41, GW42, GW43
New - The Tenement Holder must during construction, operation and closure ensure that there is no adverse change to the environmental values of the groundwater within the shallow perched aquifer as a result of chemicals or hydrocarbons from advanced explorations operations	Records of inspections (including photographs) undertaken during construction (monthly) and operation (annually) are made available annually at the site or as requested by DEM and demonstrate that any temporary and/or permanent hydrocarbon storage areas have been constructed and are operating as design to prevent release to the environment	Audit of surface water management infrastructure demonstrates that the surface water management infrastructure has not been constructed and/or is not operating in accordance with the approved design	GW12, GW13, GW14, GW15, GW16, GW17, GW18, GW19, GW20, GW21, GW22

6.3 Forward works plan

Proposed strategies to continue to address areas of uncertainty within the impact assessment and/or control effectiveness would be addressed via an updated PRD Addendum forward works plan for the OKDUGA Project, outlined in Table 6.2, and to be presented within the PEPR as a consolidated forward works plan.

Table 6.2 | Forward works plan update

Pathway	Uncertainty	Forward Works Plan update
PEPR		
Groundwater	Areas of mapped GDE rely on satellite imagery and have not been ground truthed	BHP will continue to undertake targeted GDE studies to determine the plant species and potential reliance on groundwater within the OKDUGA Project and at areas identified to be potentially impacted by groundwater drawdown.
	Project Area aquifer properties	BHP will conduct additional drilling and/or laboratory testing will be undertaken to further refine groundwater hydraulic properties within the OKDUGA Project.
	Hydrogeological conceptualisation	The conceptual hydrogeological understanding in the OKDUGA Project will be revised and updated to reflect additional drilling investigations.
	Water supply for new site access road	Further works may be undertaken to determine a water supply source for road construction works, including consideration of existing water supply bores, if required.
	Water quality and quantity	Water monitoring and management plan to be prepared for the OKDUGA Project.
Land	Terrestrial flora and vegetation	Ecological monitoring and management plan to be prepared for the OKDUGA Project to include (but not be limited to): • adaptive management measures for bird strikes on electrical poles • avoiding impacts to old growth trees in the OKDUGA Project to avoid impacts to nesting habitat • land disturbance procedure • feral pest management program.
	Terrestrial fauna and habitat	
	Geochemistry	Geochemical testing on representative samples to confirm geochemical characterisation (i.e. paste pH/EC, ANC, QXRD, sulfur speciation and short-term leach testing) of waste materials in terms of AMD.
	Closure and completion	Post-closure (cross section) figure to be prepared to illustrate pit slope gradient of 1V:3H.
Socio-economic	The presence of aboriginal cultural heritage and areas of cultural significance	BHP will continue to undertake cultural heritage assessments in accordance with the Aboriginal Heritage Act 1988 (SA) and the agreed procedures and protocols for heritage management with the KAC, KYA and BDAC Indigenous Groups. Identification of Aboriginal cultural heritage values will continue to be compiled through background research, predictive modelling, Aboriginal consultation, archaeological field investigations and anthropological assessments.
Construction, operations		
Groundwater	Groundwater monitoring	BHP will install and commission a groundwater monitoring network prior to commissioning to measure water quality and water levels for the OKDUGA Project.
	Landholder bores	BHP will undertake a bore census prior to construction to confirm the status of bores, particularly at Arcoona and Bosworth pastoral leases, including usage during drought conditions.
	Groundwater modelling calibration	BHP will undertake calibration and review of the OKDUGA Project groundwater model with additional drilling and operational monitoring data within two years of the decline development intersecting groundwater.
Air (radiation)	Accuracy of predictive radiation dose estimations	An environmental and occupational radiation monitoring program will be implemented prior to commissioning to address the following areas: • assess doses to the public at the sensitive receptors • assess any impacts to flora and fauna at the sensitive receptors • assess worker doses • ensure effectiveness of radiation controls, including the underground ventilation controls.
Socio-economic	Community perceptions to potential socio-economic impacts	Development and implementation of a community grievance mechanism prior to construction for the public to raise grievances and receive an appropriate response.

7. Supporting information

7.1 References

BHP (2023) *Oak Dam Underground Access Project Retention Lease Proposal and Miscellaneous Purposes Licence Management Plans.* November 2023.

DEM (Department for Energy and Mining) (2020) *Preparation of a mining application for metallic and industrial minerals*, Mineral Regulatory Guidelines MG2a. December 2020. Mineral Resources Division, DEM, Government of South Australia, Adelaide.

DEM (Department for Energy and Mining) (2021) *Determination Terms of Reference 006 Mineral mine lease/licence applications* (TOR 006). Notice under section 36 of the *Mining Act 1971*. 18 March 2021. DEM, Government of South Australia, Adelaide.

DEM (Department for Energy and Mining) (2023) *Terms of Reference for the Oak Dam Retention Lease Application in accordance with the Mining Act 1971*. Published in The South Australian Government Gazette, No. 73 p. 3374–3387. Dated 28 September 2023.

ELA (Eco Logical Australia) (2024) *Carrapateena Expansion Project Groundwater Baseline Review 2024.* 7 May 2024. Unpublished.

7.2 Abbreviated terms

7.2.1 Abbreviations and acronyms

Table 7.1 | Abbreviations and acronyms

Abbreviation	Description
ABCC	acid buffering characteristic curves
AEP	annual exceedance probability
Altair	Altair Minerals Limited
AMD	acid mine drainage
ANC	acid neutralising capacity
BDAC	Barngarla Determination Aboriginal Corporation
BHP	BHP Olympic Dam Corporation Pty Ltd
BoM	Bureau of Meteorology
CHB	constant head boundary
DEM	Department for Energy and Mining
DEW	Department for Environment and Water
EIAF	Environmental Impact Assessment Framework
EL	Exploration Licence
EPA	South Australia's Environment Protection Authority
ET	evapotranspiration
FIFO	fly-in/fly-out
FMG	FMG Resources Pty Ltd
GDE	groundwater dependent ecosystem
GEA	Groundwater Environmental Assessment (BHP 2023; Appendix C4)
GHB	general head boundary
GMR	Groundwater Modelling Report (BHP 2023; Attachment A of Appendix C4)
H	horizontal
HAM	Handbury Asset Management Pty Ltd
HSU	Hydrostratigraphic Unit
ID	identification numbers
ILUA	Indigenous Land Use Agreement
IOCG	iron oxide copper-gold
ISA	Infrastructure SA
KAC	The Kokatha Aboriginal Corporation
KYA	Kuyani Yartah Association
LI	Leading Indicators
LOM	Life of Mine
LSP	Lower Sedimentary Package
MPL	Miscellaneous Purposes Licence
NAPP	net acid producing potential

Abbreviation	Description
NORM	naturally occurring radioactive material
NVC	Native Vegetation Council
NWP	Northern Water Project
OKD	Oak Dam
OKDUGA Project	Oak Dam Underground Access Project
OMC	Outcome Measurement Criteria
OTR	Office of the Technical Regulator
OZ Minerals	OZ Minerals Limited
PAF	potentially acid-forming
PEPR	program for environment protection and rehabilitation
PFA	Pandurra Formation Aquifer
PRD	Proposal Response Document
Proposal	RL Proposal, SIC MPL Management Plan and WIC MPL Management Plan
PV	photovoltaic
RL	Retention Lease
SIC	Site Infrastructure Corridor
SEB	significant environmental benefit
SPR	source-pathway-receptor
THA	Tent Hill Aquifer
TOR	Terms of Reference
V	vertical
WAA	Water Affecting Activity
WIC	Water Infrastructure Corridor
WRL	waste rock landform
WSA	Whyalla Sandstone Aquifer

7.2.2 Units of measure

Table 7.2 | Units of measure

Unit	Description	Unit	Description
%	per cent	m	metre
µS	microsiemen	mAHD	metres Australian Height Datum
cm	centimetre	ML	megalitre
d	day	mm	millimetre
GWh	gigawatt hour	mRL	metres relative level
ha	hectare	mS	millisiemen
kg	kilogram	MW	megawatt
km	kilometre	s	second
L	litre	t	tonne
m^3	metre cubed	yr(s)	year

7.3 Glossary

7.3.1 Project extent terms

OKDUGA Project: the area defined by the extent of the **RL Project Area**, the **SIC MPL Project Area** and the **WIC MPL Project Area**.

Proposal: combined RL Proposal, SIC MPL Management Plan and WIC MPL Management Plan.

RL Project Area: the area defined as the extent of the proposed RL tenement.

SIC MPL Project Area: the area defined as the extent of the proposed MPL tenement for the purposes of site access and ancillary infrastructure.

WIC MPL Project Area: the area defined as the extent of the proposed MPL tenement for the purposes of water supply and ancillary infrastructure.

7.3.2 Impact assessment framework terms

Aspect: An element of an organisation's activities or products or services that can interact with the **environment**. Note that a significant environmental aspect has, or can have, a significant environmental **impact**.

Effect: An effect can occur on a **pathway** as a result of a **source**. It is a deviation from the baseline and can be positive and/or negative.

Environment: land, air, water, organisms and ecosystems and their constituent parts (including people and communities), includes natural, human-made or modified structures or areas; the quality, characteristics, amenity and heritage values of locations, places and areas; including the social, economic and cultural aspects.

Environmental value: the physical characteristics and qualities of the **environment**, as defined under the Mining Act, that contribute to biodiversity conservation, and the social, spiritual and economic health of individuals and society.

Impact: Any predicted and defined change to a **receptor**, whether adverse or beneficial, wholly or partially resulting from a **source**. Note, an impact is not a risk as it is predicted to occur ('planned event').

Leading indicator: Measurable standard that, when monitored, provides early warning that a control measure is failing and that an **Environmental Outcome** is potentially at risk of not being achieved. Leading indicators have been established in this document for each risk where there is a high consequence event that relies significantly on a control measure to reduce the risk.

Linkage: **Source-pathway-receptor** linkage. A linkage is confirmed where a **source** affects a **pathway** and ultimately leads to an impact on an identified **receptor**. The linkage can be broken by the application of a control strategy or inherent nature of location, e.g. distance to sensitive receptors.

Environmental Outcome: An Environmental Outcome indicate the expected impact on the **environment** caused by the proposed activity subsequent to control and management strategies being implemented. They demonstrate a commitment on the extent to which an activity would limit impact on the **environment**. Outcomes have been documented where the risk is such that specific control measures are required to minimise the risk, or there are strong public perceptions, or there is uncertainty in the risk level.

Pathway: A description of the pathway, means or route (with consideration of any natural barriers) by which an identified **receptor** can be exposed to, or may reasonably be expected to be impacted by, an identified **source**.

Receptor: A description of the **receptor** that may reasonably be expected to be impacted by the **source** via the **pathway**, taking into account the elements of the **environment**.

Risk event: An event which is not predicted to occur during planned project activities, however there is some potential (or likelihood) that they could occur in some circumstances ('unplanned event'), and should they occur, there may be a subsequent impact to a receptor.

Source: A description of the source of the potential impact event which, alone or in combination, has the potential to impact a **receptor**.

7.3.3 Technical terms

A

aquatic groundwater-dependent ecosystems (GDEs): an aquatic ecosystem which rely on the surface expression of groundwater that includes surface water ecosystems which may have a groundwater component.

aquifer: a water-bearing bed of permeable rock, sand or gravel.

artesian aquifer: an artesian aquifer is a confined aquifer. It has trapped water, surrounded by layers of impermeable rock or clay. Artesian aquifers are under pressure, so that if a well is drilled into the aquifer, the water will rise to the surface.

Australian height datum (AHD): the official applied datum for measuring altitude in Australia, which sets mean sea level as zero elevation.

B

baseline: a basic standard, level or initial known value usually regarded as a reference point for comparison (e.g. baseline environment).

biodiversity: the variety and range of plant and animal life in a particular habitat area or ecological system.

bore: a hole drilled into the ground to intersect geology or an aquifer from which water may be pumped.

C

cover sequence: the layers of soils and rock overlying the orebody.

D

decommission: a formal process of removing the mine or infrastructure from operational status.

dose: a measure of the radiation dose to tissue where an attempt has been made to allow for the different relative biological effects of different types of ionising radiation. Units are Sieverts (Sv) and millisieverts (mSv).

E

environmental offset/offset: an environmental offset involves compensating for residual adverse impacts or consequences of an action on the environment at one site, through activities at another site or alternative regulated options.

ephemeral: not permanent e.g. a stream that flows only seasonally or after rainfall; a lake that periodically dries out; or a plant that is present seasonally.

F

No terms

G

groundwater: water that exists beneath Earth's surface in the pores and spaces of rock and soil.

groundwater mound: the local rise of the water table above its natural level resulting from a localised source such as infiltration.

H

host (rock): as it pertains to mining, refers to rock or geological formation that contains (or surrounds) the ore body.

I

indigenous: Indigenous (with a capital I) refers to people of Aboriginal and Torres Strait Islander origin. Indigenous (with a lower case i) refers to a plant, species or item found naturally in, or belonging to, a particular environment.

J

No terms

K

No terms

L

leach: dissolution and removal of a soluble substance from a substrate.

leachate: the fluid in which a leached substance is dissolved or transported.

leaching: a chemical process for the extraction of valuable minerals from ore.

lithology: the description of rocks since colour, mineralogical composition, and grain size.

M

No terms

N

No terms

O

offset/environmental offset: an environmental offset involves compensating for residual adverse impacts or consequences of an action on the environment at one site, through activities at another site or alternative regulated options.

PQ

particulate: also referred to as particulate matter (PM), aerosols or fine particles. Particulates are tiny particles of solid (smoke) or liquid (aerosol) suspended in a gas. They range in size from less than 10 nanometres to more than 100 micrometres in diameter.

piezometer: an instrument for measuring the magnitude or direction of pressure.

R

resource: a concentration or occurrence of natural, solid, inorganic, or fossilised organic material in or on Earth's crust in such form, quantity and quality that its extraction is likely to have economic benefit.

risk assessment: the process of measuring risk, including both the likelihood and consequences of a risk (also known as risk analysis and risk evaluation).

risk management: the process of measuring, or assessing, risk and developing strategies to manage it. The culture, processes and structures that are directed towards effective management of potential opportunities and adverse effects.

runoff: that portion of precipitation (rain, hail, and snow) that flows from a specific area as water.

S

significant environmental benefit (SEB): The clearance of native vegetation results in the loss (even temporary) of habitat, biodiversity and environmental value. The mechanism to compensate for the loss under the *Native Vegetation Act 1991* (SA) is the allocation of an environmental **offset**, termed the significant environmental benefit.

stratigraphy: a branch of geology, it is basically the study of rock layers and layering (stratification).

T

No terms

UV

No terms

W

watercourse spring: surface water feature within a creek line that is maintained to some extent by groundwater discharging at the surface via a geological structure, such as a fault pressure within an aquifer, where during periods of low rainfall, the spring becomes physically small with highly elevated salinity.

waterhole: surface water feature that is surface water-fed, i.e. presents no indication of groundwater discharge.

XY

No terms

Appendix A
Proposal submission comments

Government of South Australia
Department for Energy and Mining

27 August 2024

Mr Andrew Woidt
Land Access and Approvals Lead (SA/NT)
BHP Olympic Dam Corporation Pty Ltd
Level 6, 10 Franklin Street
ADELAIDE SA 5000
Via email: andrew.woidt1@bhp.com

Dear Mr Woidt,

Request for further information in Response Document – Retention Lease (RL) and Miscellaneous Purpose Licence's (MPL) applications – Oak Dam Underground Access Project

I refer to BHP Olympic Dam Corporation Pty Ltd application dated 5 December 2023 and the Response Document submitted on 16 July 2024, as detailed below:

Applicant Name	**BHP Olympic Dam Corporation Pty Ltd (BHP)**
Application Type	Retention Lease (RL) and two Miscellaneous Purposes Licence (MPL)
Project Name	Oak Dam Underground Access Project

The Department for Energy and Mining (DEM) and SA Government technical experts have reviewed your responses to the issues raised during the statutory consultation stage.

The review has highlighted that further information is required in the Response Document. Please refer to the attached for details.

Next Steps		**Details**
1	Review matters raise by Government	Matters raise by Government are provided in Attachment 1 and 2.
2	Submit Revised Response Document	In accordance with section 44(2) and 49(2) of the *Mining Act 1971*, DEM requires you to provide the additional information requested in a revised Response Document within **30 days** of the date of this letter. Please submit the revised Response Document via email to: • DEM.MiningRegRehab@sa.gov.au

If you have any further queries, please contact DEM staff as below:

Sarah Pennington
Senior Assessment Officer, Mining Assessments
sarah.pennington@sa.gov.au
08 8429 2453 / 0455 075 991

Yours sincerely

Paul Thompson
MANAGER, MINING ASSESSMENTS
Signed in accordance with delegated powers and functions

Attachment:
1. DEW comments
2. DEM Hydrogeologist comments

DEW Water Science Unit – Response Document Response Date: 22 August 2024

Document:	Oak Dam Underground Access Project
Version:	2
Document date:	July 2024
Response author:	DEW Mining Water Science Referrals

Response priority:
1 – Issue to be addressed in document/response
2 – Issue to be deferred to PEPR stage (only relevant for mining lease proposals)
3 – For interest or editorial only

The following response tables assess the sufficiency of BHP's responses and the additional data provided to address previous DEW concerns. Comments have only been provided where further clarification/justification/information is needed from BHP to support their response. Any responses not mentioned in the table below are considered sufficient to have addressed previous concerns. The Groundwater Model and Groundwater Monitoring Framework have been assessed and commented on separately.

Hydrogeological conceptualisation

No	Document reference/BHP response ID	Priority	Comment	Response or actions required
1	61. Agreed – Additional discussion of the water table and groundwater in Quaternary sediments included in Appendix B.	2	**Partially Addressed.** DEW acknowledge that "perched groundwater" has been further explored, "local, perched and disconnected aquifers…" (p. 14, Appendix B), in limited discussion. Reference to previous work or supporting data that addresses the relationship between perched and other groundwater types will be required in future applications.	Provide additional discussion as previously requested and support this discussion with appropriate data and/or references.

2	91b. Agreed – Updated conceptualisation and additional datasets from Carrapateena mine, confirm the PFA is an aquifer that is the primary source of water for the Northern Wellfield.	2	**Partially Addressed.** The discussion is mostly sufficient. DEW note that the data review shows quite a difference (refer to Figure 3.8 Box and Whisker Plot, Appendix B, p. 33) between Carrapateena Mine K and Airlift yields. DEW suggests that additional justification is required in future submissions to highlight why the contradiction is unlikely to impact results and modelling output interpretation. Furthermore, PFA is observed to have low minimum conductivity (Table 3.5, Appendix B, p.30). Whilst the difference between minimum and maximum values still appears large, DEW acknowledge that a) these are not the reported values, and b) this does not necessarily talk to distribution of likelihood of occurrence. The box and whisker plot helps visualise this issue. Ideally, this visual presentation would be done for each HSU (data permitting). Further comments on the groundwater model and results are presented in the table below.	Provide additional justification to address the differences between results and interpretation of the model. Provide box and whisker plots for each HSU (data permitting).
3	98. Noted – Revised discussion around the updated hydrogeological conceptualisation and cross sections is provided in Appendix B…	3	**Addressed.** The updated discussion is useful in understanding the extents and thicknesses of HSUs, however, it would be beneficial for this data to be displayed on a figure – for ease of interpretation and better understanding of how HSU extents vary across the project area.	Display HSU extent and thickness data on a figure for ease of interpretation and understanding.

GDEs

No	Document reference/BHP response ID	Priority	Comment	Response or actions required
4	65. Noted – Wilaroo Lagoon is not located within the OKDUGA Project…	2	**Partially Addressed.** The amendments provided through Appendix B broadly address original DEW concerns. DEW acknowledge that the proponent intends to develop and implement a GDE field investigation to examine data gaps and risk, and that this is to be presented in the future PEPR. Given comments regarding model calibration (see DEW comments on Appendix B – GEA Addendum below) it would be helpful for DEW to see a more comprehensive draft/be given additional information about the nature of GDE investigations within the PRD forward works plan and how this will be reflected in the PEPR. This will help increase confidence that GDEs have been adequately identified and potential impacts addressed.	Provide additional information on the nature of proposed GDE investigations and updates to the PRD forward works plan.
5	66a. Agreed – Lake Torrens is listed as part of the Inland Saline Lakes in the Australian Directory for National Important Wetlands (DCCEEW 2024) and included as a GDE in this PRD.	2	**Partially Addressed.** DEW note that the referenced text has not been updated to reflect the provided response. The text should recognise a potential for Lake Torrens to be a potential receptor of impacts. DEW recognise the difficulty in characterising the ecological significance of Lake Torrens and therefore emphasise the importance/need for a conservative risk assessment.	Ensure that future impact assessment includes a focus on the potential for cumulative groundwater drawdown detrimentally impacting Vulnerable GDE associated with Lake Torrens.

			Consequently, DEW require that a future task of impact assessment be focussed on the potential for cumulative groundwater drawdown detrimentally impacting vulnerable GDE associated with Lake Torrens. As previously noted, DEW is aware of similar works undertaken as part of the Carrapateena PEPR (OZ Minerals 2017).	
6	66b. Agreed – see response to Comment ID 66a.	2	**Partially Addressed.** As per above.	As per above.
7	70. Agreed – The Proposal's Section 8.2 (Statement of proposed Environmental Outcomes) outlines BHP's proposed Outcomes and Outcome Measurement Criteria (OMC's) for the RL Project Area, SIC MPL Project Area and WIC MPL Project Area.	2	**Partially Addressed.** The proposed management approach seems appropriate currently (prior to additional data acquisition in future investigative works). However, given the original Proposal and its corresponding Statement of proposed Environmental Outcomes has not been updated in the most recent response from BHP, DEW considers this information still does not explicitly recognise the ecological significance of ecosystems in the project area – but does broadly characterise impacts to GDEs from groundwater affecting activities.	Provide additional information on the nature of proposed GDE investigations and updates to the PRD forward works plan.
8	71. Agreed – see response to Comment ID 66a.	2	**Partially Addressed.** As per above (DEW comment 5).	As per above. Undertake assessment of potential impacts on Lake Torrens – recognising that drawdowns associated with the project are not likely to be evenly distributed.
9	95. Agreed – This PRD (Section 3.2.2) has updated the OKDUGA Project GDE	2	**Partially Addressed**. The response mostly addresses original concerns – however, as previously suggested, additional	Provide additional information on the nature of proposed GDE investigations and forward works plan that will be detailed in the PEPR.

	baseline conditions to include additional context and Carrapateena mine investigations.		(preliminary) information is required about the proposed GDE investigations and forward works plan that will be detailed in the PEPR.	

Water management/controls (groundwater) themes

No	Document reference/BHP response ID	Priority	Comment	Response or actions required
10	72. Noted – The Proposal's Section 8.2 (Statement of proposed Environmental Outcomes) outlines BHP's proposed Outcomes and Outcome Measurement Criteria (OMC's) for the RL Project Area, SIC MPL Project Area and WIC MPL Project Area.	1	**Not Addressed.** Upon review of the provided Outcomes and Outcome Measurement Criteria, it is not clear to DEW what has changed between versions to address this concern. For example, the Proposal provided as part of this response does not appear to have a Section 8.2, or a different version of the Proposal for the one received is being referenced. Given potential ecological reliance on shallow groundwater sources, clarification is needed on management controls for potential impacts on shallow groundwater.	Provide clarification for if there are specific management controls for potential impacts on shallow groundwater, or if LI's only address groundwater in deeper aquifers.

Water management/controls (surface water)

No	Document reference/BHP response ID	Priority	Comment	Response or actions required
11	69. Agreed – The Proposal's Section 8.2 (Statement of proposed Environmental Outcomes) outlines BHP's proposed Outcomes and	1	**Not Addressed.** Upon review of the provided Outcomes and Outcome Measurement Criteria, it is not clear to DEW what has changed between versions to address this concern. For example, the Proposal provided as part of this	Provide clarification on the potential for adverse impacts to occur.

	Outcome Measurement Criteria (OMCs) for the RL Project Area, SIC MPL Project Area and WIC MPL Project Area.		response does not appear to have a Section 8.2 or is a different version of the Proposal for the one received is being referenced. As similarly discussed in the tables above, the provided response appears to reference the original Proposal. Without an updated proposal, it is hard to discern if the original concern from DEW has been appropriately addressed. The objective should explicitly outline if there will be no adverse impacts.	

Site water balance themes

No	Document reference/BHP response ID	Priority	Comment	Response or actions required
12	68. Agreed – Water balance updated and includes dust suppression volumes during construction and operation (Appendix D).	3	**Partially Addressed**. Only the water balance for operations has been provided. Please also provide the water balance for constructions as originally requested. Additionally, the sum of inputs for the STWP still don't equal outputs, unless assuming rainfall is negligible. Please clarify and update accordingly.	Provide water balance for constructions, and clarify/update the inputs for the STWP so that they are equal to the expected outputs.

Cultural amenity themes

No	Document reference/BHP response ID	Priority	Comment	Response or actions required
13	77. Noted – The Proposal's Section 6 (Consultation and engagement) and Table 6.6 outlined stakeholder engagement activities within the KAC which included meetings, workshops and a site visit for the OKDUGA Project…	2	**Partially Addressed**. The explanation in the response table provided by BHP is helpful, however, it refers to the original Proposal (DEW assumes this based on the updated response document not having a Section 8, and also Section 5 being the Consultation and Engagement section, not Section 6 as stated in the reply). Please update information accordingly.	Update the information to acknowledge cultural significance of groundwater using the correct Section references.

Third-party pastoral bores themes

No	Document reference/BHP response ID	Priority	Comment	Response or actions required
14	78. Agreed – the forward works plan for the PEPR has been amended to include BHP undertaking a bore census to confirm the status of bores …	2	**Partially Addressed**. DEW acknowledge the plan to conduct a bore audit as part of future PEPR development. As previously specified, please refer to the correct section in the updated Proposal (Section 5 relates to Consultation and Engagement).	Provide additional draft information of Forward Works Plan for ease of assessing the PEPR.

Appendix B – GEA Addendum

A new groundwater model has been provided in Appendix B – GEA Addendum. Consequently, DEW has assessed this separately to the original Response Document. All other DEW feedback on the sufficiency of BHP's responses, as tabled in the Response Document, have been assessed above.

General Comments

With respect to groundwater models used to support mining applications, DEW has the following expectations of the model:

1. It will adequately represent historic data;
2. It will be consistent with the conceptual understanding of the site; and
3. It will be appropriately designed to answer the key questions.

In addition, groundwater models and associated documentation should be as transparent as possible, defendable and robust. Further guidance on this can be found in: Anderson, Woessner and Hunt, Applied Groundwater Modelling, 2015; Middlemis, Australian Groundwater Modelling Guidelines, 2000; and the 2012 Modelling Guidelines.

DEW will review models with respect to the above principles and the comments provided are intended to make sure the model adheres to this guidance.

Specific Comments

The comments below suggest the new model requires proper calibration and additional data to support conclusions.

No	Document reference	Priority	Comment	Response or actions required
1	App B Sec 3.2.1	2	The bores discussed in this section need to be labelled on a map.	Include locations and labels of bores on a map.
2	App B Sec 3.4.1	1	It is good to see that density corrections were performed. A table showing measured and corrected head data should be included to show the effect on the data.	Include table showing original and corrected head data.

3	App B Sec 3.4.1	2	Limited data for the PFA aquifer has been included. This makes any modelling of the PFA aquifer unsupportable.	Obtain additional data for the PFA aquifer to be incorporated into the model or modify the model.
4	App B Sec 3.4.1 iv	1	The data presented do not support the vertical gradients identified.	Provide additional data or modify discussion.
5	App B Sec 3.4.2	1	The locations of the bores associated with these hydrographs and the production wells need to be identified on a map. Specify if these are the only hydrographs available.	Provide bore locations (and label accordingly) on a map. Identify if there are additional hydrographs available.
6	App B Sec 3.5	2	Clarify the accuracy of your recharge estimates using the chloride mass balance method in an area of such high groundwater chloride levels. Additionally, specify if it is assumed that recharge is only applied to the upper layer. This is unclear in the document.	Clarify and provide justification for recharge estimates, and to which layers recharge was applied.
7	App B Sec 3.6.4, Table 3.6	3	It is difficult to support the PFA being referred to as an aquifer with conductivity values as low as these. Refer to DEW response number 2 for further discussion.	Values as low as these for an “aquifer” need to be examined within calibration.
8	App B Sec 4.3.1	1	The model extent must be based on where model boundaries and boundary conditions can be supported from the available data. This is not the case in question here.	Provide justification for boundary locations and associated conditions based on actual data.
9	App B Sec 4.3.2	3	Given the sparse amount of data that can be used to develop a supportable conceptual model, the grid is considered excessive for the numerical modelling.	The very fine grid needs to be justified based on the available data and the modelling objectives. Please provide additional discussion to this point.

10	App B Sec 4.3.3	2	The layering is considered excessive. However, it may well serve to assess the mining/dewatering process. One of the difficulties with the grid refinement in the spatial and vertical directions is with numerical accuracy/instability. This is often ignored in models with this level of refinement.	The potential for instabilities in the vertical and horizontal directions needs to be evaluated for the model results to be acceptable. Please provide discussion around this evaluation. In addition, any results from layers where no data are available for comparison make these results unsupportable.
11	App B Sec 4.4, Table 4.2	1	The provided Table 4.2 suggests that the Carrapateena well pumping started after Jan 2020. If pumping started before then, the steady state must be based on pre-production hydraulic heads.	Provide information to confirm when pumping started at Carrapateena. Furthermore, correct steady state conditions if pumping started before 2020.
12	App B Sec 4.5.1	1	"Inferred contours of equivalent freshwater head were used to define the general head boundary conditions in the THA (layer 3), WSA (layer 5) and the PFA (layers 9–14)". Supporting information must be provided to indicate what data has been used for these statements. Figures 3.4 and 3.5 do not show enough data to be used to support GHBs. Additional information is also needed to specify boundary condition values for the other vertical layers and what conductances were used.	Additional data must be provided to support the model boundary conditions.
13	App B Sec 4.5.5	2	The location of the Carrapateena pumping wells needs to be included and labelled on a map.	Include labelled locations of Carrapateena pumping wells on a map.
14	App B Sec 5.1, Table 5.1	1	There are very few monitoring wells in most layers, meaning that calibration of the model will be very difficult. This is further mentioned in Sect 5.3 and has been raised in previous comments from DEW. Additional data are required.	Additional data are needed to support model calibration, or the model needs to be simplified significantly.

			Alternatively, the proponent may wish to adopt a simpler modelling approach commensurate with the data that is currently available.	
15	App B Sec 5.2	1	It is necessary to compare the results from the steady state simulations with measured data using potentiometric surfaces so that the steady state model can be evaluated.	Provide comparison diagrams from steady state simulations alongside measured data for evaluation.
16	App B Sec 5.4.1	2	There are very few observation head data points available. Using this very large number of pilot points is excessive and suggests a well-supported calibration process. In addition, justification needs to be provided as to why Sy pilot points are included in confined aquifer investigations.	Reduce the number of pilot points to be consistent with the amount of head data available. Provide justification as to why Sy pilot points are included in confined aquifer investigations.
17	App B Sec 5.5.1	1	SRMS results for so little data are extremely poor and do not support a calibrated model. Screened intervals across multiple layers for bores NT-10OB and NT-4OB are significant; these bores should have been identified earlier and their data omitted, reducing the amount of available bore data.	Remove bores NT-100B and NT-40B and reevaluate model calibration.
18	App B Section 5.5.2, i, Figs 5.3 and 5.4	2	Measured contours need to be included on these figures for comparison. The computed results are consistent with the pre-modelling assertions; however, they would need to be based on the boundary conditions applied. In making this comment, DEW also have questions regarding the choice of boundary conditions and the data used to justify this decision.	Include measured contours on Figures 5.3 and 5.4 for comparison.
19	App B Section 5.5.2, ii, Figs 5.5	1	DEW considers the presented results to be poor.	The model requires appropriate calibration.

	and 5.6 and Appendix A		The use of PEST++IES in this context cannot be supported. The model has not been adequately calibrated.	
20	App B Section 5.7, Appendices B and C	1	This discussion and the data presented do not provide confidence in the modelling approach. The hydrographs (Appendix A) indicate a poorly calibrated model.	The model requires appropriate calibration.
21	App B Sec 6.1	1	Much of the discussion in this section, and the modelling used to support it, seems to be based on Middlemis and Peeters (2018), which does not appear to have been included in the Reference list. The application of the techniques suggested in the Middlemis and Peeters (2018) report (Information Guidelines Explanatory Note: Uncertainty analysis for groundwater modelling (iesc.gov.au)) assumes a calibrated model. The OKDUGA model is not calibrated, and therefore, the same conclusions cannot be applied.	As previously stated, the model requires appropriate calibration. Include all referenced material in the reference list.
22	App B Section 6.2, Table 6.2 and Appendix D	2	There needs to be extensive discussion in the text to support the results presented in Appendix D. For example, were boundary conditions kept the same for all simulations? Some of the drawdowns appear to extend very close to the model boundaries and would bring into question the conditions applied along those boundaries. In addition, comparing the OKDUGA model with the LOM model causes confusion: the previous model had boundaries closer to the mining area and (modelled) drawdowns would have reached those boundaries. The LOM model has boundaries further out and drawdowns may affect those boundaries. Comparing the two models is not appropriate as they are different models.	Provide additional information to support the results of the groundwater model as presented in Appendix D. Alternatively, discussions in the text should be changed to appropriately reflect the conditions of the model. Reconsider comparison of OKDUGA and LOM models as they are different models.

23	App B Sec 7, Table 7.1	1	Without acceptable model calibration, the assessment of effects analysis table for each receptor (Table 7.1) cannot be appropriately supported.	Model calibration is required to fully support the effects analysis table.
24	App B Sec 8.2	1	As per above, the presented groundwater impact assessment cannot be accepted without appropriate model calibration.	Model calibration is required to fully support the groundwater impact assessment.

Appendix C - Groundwater Monitoring Framework

A new preliminary groundwater monitoring framework has been provided in Appendix C – Groundwater Monitoring Framework (acknowledging this is a framework and not a plan; subject to further development). Consequently, DEW has assessed this separately to the original Response Document. All other DEW feedback on the sufficiency of BHP's responses, as tabled in the Response Document, have been assessed above.

No	Document reference/BHP response ID	Priority	Comment	Response or actions required
1	App. C, OKDUGA Project monitoring bores, Table 2.1 and Figure 2.1		Consider implementing additional monitoring bores, especially to monitor if any impacts to potential GDEs around the lower reaches of Bosworth Creek and towards Lakes Torrens. Additional monitoring bores will also provide better spatial distribution of monitoring across the project site.	Consider implementation of additional monitoring bores for better spatial distribution across the OKDUGA RL and understanding of any impacts to potential GDEs in the lower reaches of Bosworth Creek.
2	App C, Groundwater Quality Suite, Table 3.1		Consider higher frequency of monitoring for the first two years of monitoring, to help establish a baseline. Monitoring could then be reduced to quarterly or even bi-monthly following the first two years.	Consider higher frequency of monitoring.

Hydrogeological comments: Oak Dam Underground Access Project, Retention Lease Proposal and Miscellaneous Purposes Licence Management Plans, Response Document (PRD), July 2024

Comments by Gabor Bekesi, Principal Hydrogeologist, DEM, 16/08/2024

Objective and Background

The objective is to review adequacy of groundwater aspects of the response document, i.e. the suitability of the Retention Lease Proposal and Miscellaneous Purposes Licence Management Plans for predicting the hydrogeological impacts on the environment, Groundwater Dependent Ecosystems (GDEs) and users. Specifically, this review includes, (but not limited to) the following sections of the document:

- Appendix A Proposal submission comments
- Appendix B Groundwater environmental assessment addendum
- Appendix C Groundwater monitoring framework
- Appendix D Surface water environmental assessment – site water balance addendum

BHP proposes no changes in the PRD to the OKDUGA Project relative to the activities discussed in the original Proposal in 2023 (Section 2.1). The OKDUGA Project is to establish an underground access via twin declines. A Retention Lease (RL) Proposal and Miscellaneous Purposes Licence (MPL) Management Plans (together, the Proposal) were prepared to support the proposal. The two declines are each approximately 6 to 7 m wide and 6 m high and 3 km long.

Section 3.2 describes conceptual hydrogeology and the changes BHP implemented as a response to the RFI. Section 4, Tables 4.3 to 4.7 provide a description of BHP's reaction to hydrogeological aspects of DEM's comments and 4.9 to 4.17 to those comments received from DEW (highlighted items are reviewed in this report):

DEM:
Table 4.3 Response to hydrogeological conceptualisation themes
Table 4.4 Response to GDE Investigation themes
Table 4.5 Response to groundwater modelling drawdown predictions themes
Table 4.6 Response to groundwater modelling data themes
Table 4.7 Response to water management/controls (groundwater) themes
Table 4.8 Response to geochemistry themes
DEW:
Table 4.9 Response to hydrogeological conceptualisation themes
Table 4.10 Response to GDE investigations themes
Table 4.11 Response to groundwater modelling data themes
Table 4.12 Response to water management/controls (groundwater) themes
Table 4.13 Response to water management/controls (surface water) themes

Analysis

There were six issues identified in the 29/02/2024 DEM hydrogeological report. Importantly, during the unpacking the response to a relatively minor comment related to water budget, a new issue emerged, described in detail (comment 49), relating to conceptualisation, modelling and model documentation. In DEM's view, this new issue 7, unless resolved, cast doubt about if the model is fit for purpose for impact assessment.

Issue 1. The lack of robust local hydrogeological data and inadequate conceptualisation
Several aspects of conceptualisation improved but the logic and numerical values used for the new boundary conditions still need to be justified (comment 49). There are still some parameterisation issues (comments 19 and 36) and information requested on the Quaternary aquifer was not provided (comment 40). The groundwater head contours are still questionable (comments 22 and 39).

Issues 2, boundary conditions, and 3 adopted boundary values
There are improvements, the boundaries have been extended and changed from constant heads to general heads, but the logic behind these still need to be justified and the numerical values used for the new boundary conditions need to be provided (comments 26, 39, 42, 43a, 43b, 47 and 50). Density corrections were applied but not documented to the extent they were requested (comments 34 and 44). There are differences along the NW boundary between Figures 3.4 and 5.3 raising uncertainty on what degree does the numerical model reflect the conceptual hydrogeology (comment 26).

Issue 4. Water management and proposed activities related to water management
Provided.

Issue 5. A better model documentation is required to support the proposal
Improved but still inadequate. The logic and numerical values used for the new boundary conditions still need to be justified. Also, a better explanation of the water budget is required (comment 49) and a robust justification is required to explain the new issue (refer to Issue 7 below).

Issue 6. There are important details missing on the proposed groundwater monitoring and those should be provided in accordance with the Mining Regulations and TOR 006
While most of the missing information has now been provided, the outcome measurement criteria are unchanged and still refer to model predictions. When model uncertainty is high, it is better to provide model-independent simple outcome criteria that is based on the best, but not perfect, assessment at the time**.** The baseline data to be used also need to be described. Comment 29.

Issue 7 (new). The large component of evapotranspiration in the model
Figure 5.7 of appendix B indicates the "*Base realisation modelled water balance over the history-matching period*". Accordingly, the main inputs to the model are rainfall recharge and regional inflow, dominantly balanced by evapotranspiration (EVT). That EVT is only possible if significant parts of the model domain have shallow water table. DEM assumed this was the case near Lake Torrens "*Groundwater discharges into the regionally significant Lake Torrens, where evaporative discharge occurs*" (Section 3.9, conceptual hydrogeology). Comments, provided in Table 6.2 about EVT as: "*this is a recirculation of water through a* ***few boundary condition cells along the southern model boundary*** *that are within the evapotranspiration extinction depth and does not influence model parameterisation or predictions*" appear to suggest otherwise.

In DEM's view, the amount of recirculated water is close to 50 ML/d (Figure 5.7), which is a very large flow; it is, in fact, the largest component of the water balance of the model in Figure 5.7. DEM was unable to find any description of this water (~ 50 ML/d) in the conceptual hydrogeology (Section 3.9). Conceptual hydrogeology should include all physical process that are significant enough to be represented in the model. Therefore the explanation provided in Table 6.2 came as surprise to DEM. The numerical groundwater flow model should be the numerical representation of the conceptual

hydrogeology and should not have "*surprises*" of this magnitude. Such a surprise cast doubt if the model is fit for the purpose for impact assessment. Comment 49.

1.1.1 Hydrogeological conceptualisation themes

Table Error! No text of specified style in document.**.1 | Response to hydrogeological conceptualisation themes**

Notes : link have broken during the conversion process resulting the *Error! Reference source not found.*

Red highlight indicates DEM's view that the response was not addressed.

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed y/n
17	Entire GEA document	*mRL* is not defined. Table 10.2.2 explains mRL as *metres relative level* but does not provide what the level is relative to, i.e. is there a definition for 0 mRL and what is the relationship between mRL and mAHD?	Provide a definition for what the RL is. Provide the relationship between mRL and mAHD.	Agreed – Groundwater Environmental Assessment (BHP 2023; Appendix C4) (GEA) and Groundwater Modelling Report (BHP 2023; Attachment A of Appendix C4) (GMR) present data in mAHD with Outcomes, OMCs and Leading Indicators (LIs) proposed to be presented in mAHD in the PEPR to resolve this matter.	N/A	Y

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed y/n
18	Section 3.2.1 Hydrogeology	This section should be the foundation of the conceptual hydrogeology and therefore should be clear. Because of inconsistencies between text, table and conceptual hydrogeological cross-sections, this section is ambiguous. Please also refer to Comments 19, 20 and 21. The Arcoona Quartzite is considered as an aquitard (upper section) and an aquifer (lower section) in Table 3.4. However, the Arcoona Quartzite is presented as a single unit in Figure 3.9, entitled Conceptual Hydrogeological Cross-Sections. If, as the table indicates, the upper part is an aquitard, then it would be reasonable to expect that this unit would be separated from the fractured Lower Arcoona Quartzite, that is considered an aquifer, in Figure 3.9. Further, the legend in Figure 3.9 indicates that the entire Arcoona Quartzite is part of the Tent Hill Aquifer (THA). My understanding is that is incorrect and, as Table 3.4 indicates, it is the Lower Arcoona Quartzite that is part of the THA. Please refer to comment 17 for further justification/evidence needed on the separation. The geological legend refers to the Lower Sedimentary Package while the groundwater legend refers to the PFA (Pandurra Formation Aquifer). The concepts would be easier to follow if consistent hydrogeological units were used. The conceptual cross-section in Figure 3.9 indicates the “water table” in both the THA and PFA. The water table refers to the surface where the water pressure is equal to the atmospheric pressure and therefore should not be used for deeper confined aquifers such as the PFA (or where the THA is confined). Please refer to Comment 21 for further notes on this subject.	Clarify the role of the Lower and Upper Arcoona Quartzite and ensure consistently used terms in the response document. Explain/provide further justification why the Upper and Lower Arcoona Quartzite are considered an aquitard, and aquifer, respectively. Summarise the findings of OZ Minerals (2017d) on this subject. Provide an updated version of Figure 3.9 that shows the Upper and Lower Arcoona Quartzite separated. Provide an updated version of Figure 3.9 with the corrected term for the PFA.	Agreed – The hydrogeological conceptual model cross sections have been updated using additional site data to show the PFA, Tapley Hill Formation and Whyalla Sandstone. Additional text clarifying the role of the Upper and Lower Arcoona Quartzite included in **Error! Reference source not found.**, specifically the THA comprises the lower white Arcoona Quartzite and Corraberra Sandstone.	PRD **Error! Reference source not found.**: Section 3.9, Table 3.1, Figure 3.10, Figure 3.11	Y

19	3.2.1 C4, 2.1.2	Please also refer to Comment 40. The status of the perched aquifer and the conceptualisation of it is important because some of the local landholder's reliance on shallow wells with low salinity (3.2.2.1). For perched aquifers to occur, water should accumulate over a very low hydraulic conductivity perching layer in the unsaturated zone. Under the perching layer unsaturated conditions should prevail down to where the water table aquifer occurs. *These fresher groundwater lenses are generally hydraulically disconnected from the regional saline groundwater system (OZ Minerals 2017d).* It would be beneficial to summarise the justification/evidence provided by OZ Minerals (2017d) for the disconnection of the perched and regional systems. How representative are OZ Minerals (2017d) conclusions to the OKDUGA project? The conceptual hydrogeology in 3.2.1 is not clear on the following: what is the perching layer, what evidence is there for unsaturated conditions below the perching layer and where is the water table with respect to the perched water? Figure 3.9 does not show a perched layer, it would be beneficial to indicate it. It would be important to point out that the perched water *hydraulically disconnected* is not completely independent from the underlying groundwater system as (slow) downward flow, under unsaturated conditions, could occur from the Quaternary perched water to the underlying water table.	Provide evidence/justification for the perched water concept. Clarify the position of the perched system and water table aquifer underneath. Provide maps, cross-sections and explain the relationship between perched water and the water table to ensure consistent interpretation throughout the documents.	Agreed – Revised hydrogeological conceptualisation provided in **Error! Reference source not found.**, where the Quaternary sediments occur above the low permeability Arcoona Quartzite, a localised, perched water table may occur following sufficient rainfall and/or streamflow events. However, where the Quaternary sediments directly overlie the unconfined Corraberra Sandstone and/or lower Arcoona Quartzite perched conditions are unlikely to form given the absence of low permeability or aquitard units needed to create such conditions.	PRD **Error! Reference source not found.**, Section 3.6	Y Minor comment the lower end of hydraulic conductivity for the Quaternary Sediments is very low for an aquifer.

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed y/n
20 a	Section 3.2.1 Hydrogeology Appendix A of Appendix C4, 2.4	It is appreciated that Figure 3.9 is a conceptual representation only. However, it would be important to indicate the thickness of the units correctly, at least approximately and relatively. Table 3.4 indicates the thickness of the THA as 40 m (within the OKDUGA project) and the Woomera Shale as 20 m. Figure 3.9, however, indicates the thickness of the latter Woomera Shale as larger than that of the THA. There is a significant difference between the conceptualisation of a thin aquitard between two aquifers or a thin aquifer underlain by a thick aquitard and a thick confined aquifer, in particular in understanding the hydraulic connection between the aquifers (here THA and PFA). *Under the THA, the Woomera Shale forms a competent aquitard mostly more than 100 m thick across most of the study area, except where the Pandurra Formation outcrops to the northeast of Lake Windabout, where it is absent, and directly east of the Project, where it is about 50 m thick.* The text above contradicts Table 2.4 that suggest a thickness of 20 m for the Woomera Shale.	Provide updated and corrected conceptual hydrogeological cross-sections: provide a corrected thicknesses of the HSU and updated discussion to ensure consistent information.	Agreed – Hydrostratigraphic unit thicknesses have been included in **Error! Reference source not found.**, including regional thickness and thickness within the RL Project Area, along with updated hydrogeological conceptual model cross sections.	PRD **Error! Reference source not found.**, Section 3.1, Table 3.1, Section 3.6, Figure 3.10, Figure 3.11	Y
20 b	Section 3.2.1 Hydrogeology Appendix A of Appendix C4, 2.4	It is noted that the proposal does not seem to include actual hydrogeological cross-sections. It would be beneficial to create such cross-sections, with drillholes, groundwater heads/elevations, salinity and the topography to better illustrate the linkages between hydrogeological concepts and reality.	Provide actual hydrogeological cross-sections.	Agreed – Hydrostratigraphic unit thicknesses have been included in **Error! Reference source not found.**, including regional thickness and thickness within the RL Project Area, along with updated hydrogeological conceptual model cross sections.	PRD **Error! Reference source not found.**, Section 3.9, Figure 3.10, Figure 3.11	Y

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed y/n
21	3.2.13.2.3.1 C4, 2.3, Figure xx	The conceptual cross-section in Figure 3.9 indicates the "*water table*" in both the THA and PFA. The water table refers to the surface where the water pressure is equal to the atmospheric pressure and therefore should not be used for deeper confined aquifers such as the PFA (or where the THA is confined). It would also be important to indicate the trends in groundwater elevations/heads correctly, at least approximately and relatively. In Figure 3.9 the groundwater elevations/head in the THA is consistently above that of the PFA. Figures 3.13 and 3.14, however, indicate that the two converge towards Lake Torrens. The groundwater elevations/head beneath the OKDUGA project rectangle, for example is 110-120 m AHD in the THA and 70-75 m AHD in the PFA. Just to the west of Lake Torrens, both are approximately 30-40 m AHD indicating converge towards Lake Torrens. Groundwater head/elevation is an important feature of conceptualisation and therefore it would be important to reconcile Figures 3.9, 3.13 and 3.14.	Provide updated and corrected conceptual hydrogeological cross-sections. Provide corrected thicknesses of the HSUs, terms, groundwater elevation / head curves and updated discussion to ensure consistent information.	Agreed – The hydrogeological conceptual model cross sections have been updated in **Error! Reference source not found.**, reflecting amendments to potentiometric surfaces.	PRD **Error! Reference source not found.**, Section 3.9, Table 3.1, Figure 3.10, Figure 3.11	Y

22	3.2.3.1 C4, Figure 2.10	It is unclear how Figure 2.10 in C4 (Figure 3.13 in the proposal) was constructed. There is a single datapoint marked in the north-east corner inside the RL rectangle and surrounded by a 120 m AHD groundwater elevation contour line. Figure 2.10 also indicates a groundwater high over the RL rectangle, with an approximate SW-NE orientation. It is suspected the high is the same as the groundwater divide in Figure 3-7, Appendix K1, Baseline hydrogeological assessment for the Olympic Dam expansion project. The divide in Fig. 3-7, however, is to the west of the RL rectangle. Map A of Kellett et.al., 1999 (Hydrogeological Assessment of a Region in Central Northern South Australia, J Kellett, S Veitch, I McNaught, A van der Voort. Bureau of Rural Sciences Australia. Canberra, 1999) also placed the divide west of the RL rectangle. A check of point groundwater elevation data in SARIG (refer https://minerals.sarig.sa.gov.au/Details.aspx?DRILLHOLE_NO=20755) suggest that Fig 3-7 of K1 is correct and the positioning of the high in Appendix C4, Figure 2-10 may be incorrect. The culprit appears, on a cursory check on SARIG, the single datapoint in the RL in Figure 2.10, that is probably water well 633600027. 633600027 had an erroneous groundwater elevation of 128.7 mAHD. The error is due to an incorrect transcript of the depth to groundwater, instead of 352' (107.4 m), 7.4 m was entered into SA Geodata. Further, even the 7.4 m depth to groundwater appears to be erroneous, probably representing an artificially low (perhaps the measurement was done when the water level was still recovering) groundwater. Please refer to the historical document at the end of this document. Although it is recognised that the error was in SA Geodata, the onus is on the proponent to check the quality of data used for the proposal. In this case groundwater elevation data from 633600027 should not have been used for the purpose of creating Figure 2-10. A basic check between the depth to groundwater in the database and that marked in historic documents revealed the error for DEM. As a result, depth to groundwater was changed and marked "anomalous" in by DEW colleagues on 13/2/2024). The position of the blue lines in Figure 3.13 (Figure 2.10 in C4), depicting inferred groundwater flow, appear to be inconsistent with the	Provide an updated and corrected Figure 3.1.3 (and 2.10 in C4).	Agreed – Density corrected groundwater elevations have been recreated in **Error! Reference source not found.** using additional site data and reference to existing literature.	PRD **Error! Reference source not found.**, Section 3.4.1, Figure 3.4, Figure 3.5	N See comments on how figures 3.4 and 3.5 were constructed at comment 39. The observation of 128.7 m AHD (now 129.13 mAHD in Fig.3.4) is still there and is placed between the 80 and 90 m AHD contours. An explanation and correction is needed.

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed y/n
		groundwater elevation contours, especially if the groundwater divide is where it is indicated by Fig 3-7 of Appendix K1. Unless based on information other than the contours, groundwater flow lines are assumed to be normal (perpendicular) to the contours. The blue lines, however, do not satisfy this criterion.				
30	C4, 2.1.2	*The wellfields total 16 production bores (CDM Smith 2018), and their locations as of 2018 are shown in Figure 2.1.* The position of the wellfields is important because of the proximity to OKDUGA. They are not shown in Figure 2.1. The text refers to 16 wells, Table 2.1 shows 12, Figure 2.1 shows none.	Provide an updated and corrected figure: Include the wellfield locations to ensure consistency between text, table and figure.	Agreed – MPL 156 production bores are included in **Error! Reference source not found.**, comprising location and Northern Wellfield production bore details.	PRD **Error! Reference source not found.**, Figure 3.1, Table 3.2	Y

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed y/n
31	C4, 2.1.2 C4, 2.3, Attach A	*Fracturing occurs mostly within the Pandurra Formation, only four exploration holes recorded observations of fracturing across the Tent Hill Formation.* Please refer to Comment 18. The statement above appears to contradict (or at least does not support) the fractured nature of the Lower Arcoona Quartzite in the proposal and Table 2.4 in C4.	Provide updated and corrected text to ensure consistency.	Noted – The hydrogeological conceptual model cross sections have been updated using additional site data to show the PFA, Tapley Hill Formation and Whyalla Sandstone. Additional text clarifying the role of the Upper and Lower Arcoona Quartzite added to **Error! R eference source not found.**, specifically the THA comprises the lower white Arcoona Quartzite and Corraberra Sandstone. Additional drilling investigations are proposed in the PRD forward works plan and will be further updated as part of the PEPR.	PRD **Error! R eference source not found.**, Section 3.9, Table 3.1, Figure 3.10, Figure 3.11	Y

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed y/n
32	C4, 2.1.2 C4, 2.3, Table 2.4 C4, Attach A, Table 2.3	Please refer to Comments 18 and 31. The Arcoona Quartzite is considered as an aquitard (upper section) and an aquifer (lower section) in Table 2.4. However, the Arcoona Quartzite is presented as a single unit in Figure xx entitled Conceptual Hydrogeological Cross-Sections. If, as the table indicates, the upper part is a leaky aquitard, then it would be reasonable to expect that this unit would be separated from the fractured Lower Arcoona Quartzite, considered an aquifer, in Figure xx (please also correct the figure number). Further, the legend in Figure xx indicates that the entire Arcoona Quartzite is part of the Tent Hill Aquifer (THA). My understanding is that is incorrect and as Table 2.4 indicates it is the Lower Arcoona Quartzite that is part of the THA.	Provide an updated version of Figure 3.9 that shows the Upper and Lower Arcoona Quartzite separated. Provide further explanation why the Upper and Lower Arcoona Quartzite are considered an aquitard, and aquifer, respectively. Provide justification/evidence and summarise the findings of Jacobs (2016a) on this subject.	Agreed – Additional text clarifying the role of the Upper and Lower Arcoona Quartzite included in **Error! Reference source not found.**, specifically the THA comprises the lower white Arcoona Quartzite and Corraberra Sandstone.	PRD **Error! Reference source not found.**, Section 3.9, Table 3.4, Figure 3.10, Figure 3.11	Y

33	3.2.3.1 C4, 2.2.1 C4, Attach A, Figures 2.5, and 2.6	It appears that the proponent has not acquired adequate local data for the OKDUGA project. Table 2.6 of Appendix C4 lists, under the title "*Project groundwater bore details*" 36 drillholes. On closer examination, however, it appears that there is only one active water bore (and two abandoned water wells); the rest, 33 are exploration/mineral drillholes. Thus, there appears to be only one water bore listed in Table 2.6. Closer to the OKDUGA project, the groundwater contour maps provided in the proposal have no datapoints in Figures 3.13 (THA) and 3.14 (PFA); a single datapoint in the THA (Figure 2.10 in C4) and no observation sites are marked for the PFA (Figure 2.11). In Attachment A the corresponding Figure 2.5 shows a single datapoint in the THA and Figure 2.6 none for the PFA inside the RL area (reference in full is Figures 2.5 and 2.6 in Attachment A of Appendix C4). *All drill holes with an 'AD' prefix are exploration bores only with no monitoring infrastructure installed. ADHY01 was drilled in July 2022 and has been converted into a monitoring bore targeting the PFA to support baseline studies.* No explanation is provided for what happened to the other 30+ drillholes? Judging from their depths (up to 1250 m deep), converting more of them to groundwater/monitoring wells would be a cost-effective way to generate more hydrogeological data and more certainty.	Explain why more local data were not acquired for the OKDUGA project. Provide an updated Table 2.6 with a corrected title. Reconcile text and figures so that they all show/explain correct and consistent datapoints. Explain/clarify how many groundwater monitoring wells are there within the OKDUGA project.	Noted – At the time of preparing the GEA and GMR, BHP did not have cultural heritage clearances to undertake hydrogeological drilling, nor had BHP formally acquired OZ Minerals or completed the integration process between the sites (i.e. no access to Carrapateena data). The hydrogeological conceptual model cross sections have been updated using this and additional site data to show the PFA, Tapley Hill Formation and Whyalla Sandstone. Additional drilling investigations are proposed in the PRD forward works plan and will be further updated as part of the PEPR.	PRD **Error! Reference source not found.**, Section 2.2, Table 2.1, Section 3.9	Y Appendix B Sections 2.2, 3.9 and 8.4

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed y/n
34	C4, 2.2.2 C4, Attach A, 2.4.4	*These level measurements … nor have they been density corrected for salinity.* The values adopted at CHBs [constant head boundaries] are groundwater elevations, not groundwater heads, without a density correction. No quantitative justification was provided this approach and the proponent did not quantify the magnitude of the density correction. Density correction is necessary if: 1. the groundwater elevation was calculated as the difference between the reference elevation and the depth to groundwater measured, for example by a dipper, and 2. groundwater is of a density that is significantly different from that of cold freshwater with a density of 1000 kg/m^3 (such groundwaters are typically saline, density >1000 kg/m^3 or hot with density <1000 kg/m^3). The deeper the well, the more groundwater it contains and the larger the density correction (assuming constant salinity/density in the well column). It follows that density correction may be significant for deep wells producing saline water, or for deep wells with hot groundwater. In the OKDUGA setting, the wells are deep (Table 2.6 of Attachment A of Appendix C4) and the groundwater in the PFA is saline (Section 2.4.5). Hence it is suggested that density corrected heads (sometimes referred to as equivalent freshwater heads) could significantly differ from groundwater elevations. The lack of density correction impacts not only determining boundary cell values but also groundwater head/elevation contour maps, hydraulic gradients, calibration/history matching and the interpretation of model predictions; just about every aspect of a groundwater model.	Provide worked numerical examples on density corrections. Knowing the magnitude of density corrections will enable an assessment on how important (or not) the density corrections are.	Agreed – **Error! Reference source not found.** has been updated with density corrected groundwater elevations.	PRD **Error! Reference source not found.**, Section 3.4.1(i), Figure 3.4, Figure 3.5	N Density correction is applied but worked numerical examples on density corrections are not provided. Also see comments on how figures 3.4 and 3.5 were constructed for comment 39.

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed y/n
35 a	C4, 2.2.4	*Specific yield is the amount of water removed from an aquifer by the force of gravity to a bore.* Re-phrase this definition to the more wide-spread definition of yield due to a unit 1m drop in groundwater…and explain that specific yield is used for unconfined aquifers.	Provide information and statements on hydrogeological properties addressing the matters raised.	Agreed – **Error! Reference source not found.** has been updated to remove reference to specific yield, and use of hydraulic conductivity where relevant.	PRD **Error! Reference source not found.**, Section 3.6.1	Y
35 b	C4, 2.2.4	*Storativity is the **equivalent** of specific storage and aquifer thickness, representing the volume of water an aquifer releases or takes into storage.* This statement requires clarification, in particular whether this should be "*product of*" rather than *equivalent*. Also, an explanation is required that storativity refers to confined aquifers.	Provide information and statements on hydrogeological properties addressing the matters raised.	Agreed – **Error! Reference source not found.** has been updated to provide information on hydrogeological properties.	PRD **Error! Reference source not found.**, Section 3.6	Y
35c	C4, 2.2.4	Hydraulic conductivity and permeability are used in the same sections interchangeably. Section 2.2.4 would be easier to comprehend if only minimal hydrogeological terms were used corresponding to the columns in Table 2.7.	Provide information and statements on hydrogeological properties addressing the matters raised.	Agreed – **Error! Reference source not found.** has been updated to remove reference to specific yield, and use of hydraulic conductivity where relevant.	PRD **Error! Reference source not found.**, Section 3.6	Y Minor note: "permeability" still occurs in 3.2 and Table 3.1; also in appendix B 3.6 and 3.9

36	C4, 2.1, Table 2.5 C4, 2.2.4, Table 2.7 C4, Attach A, Table 2.4, Table 2.5	There are significant inconsistencies between the conceptual status of HSUs that are considered aquifers and the hydraulic conductivity values provided in Tables 2.5 and 2.7 (in Attachment A of C4, Tables 2.4 and 2.5). Either the hydraulic conductivity values are unrealistic (imported from regions not representative to local conditions) or the HSU descriptions are incorrect: • Hydraulic conductivity spans over six orders of magnitude in the **Quaternary Aquifer** according to data from Olympic Dam, covering a wide range of **aquitards** and only the high end of the range covers an aquifer. • The hydraulic conductivity range for the **Quaternary Aquifer** from the Carrapateena Mine calibrated groundwater model is more representative of an **aquitard** than an aquifer. • For the **THA, considered an aquifer**, the hydraulic conductivity range starts at 3 10^{-2} m/d (regional literature review) and 6 10^{-4} m/d (Olympic Dam, literature review and calibrated groundwater model) both indicating **aquitards**. Only the high end of the horizontal hydraulic conductivity range indicates an aquifer. • The PFA, considered an **aquifer**, has a calibrated model hydraulic conductivity from the Carrapateena Mine of 5x10^{-3} m/d and from pump tests 2.7 to 3.4 10^{-5} m/d. Such values represent **aquitards**, most probably even the lower end of aquitards. • The LSP is considered an **aquifer**, yet the various components of the LSP all have 10^{-4} to 10^{-2} m/d assumed hydraulic conductivity in Table 2.5. This range is typical to an **aquitard, not an aquifer**. • The Woomera Shale, described as a competent aquitard, is characterised by hydraulic conductivities in the range 10^{-6} to 10^{-2} m/d in Table 2.5 with a focus on 10^{-4} m/d. These values indeed represent typical aquitards; however, they are not much different from the ranges provided for the PFA/LSP that are considered aquifers.	Provide a reconciliation between the conceptual hydrogeology HSUs and their hydraulic conductivity. Provide justification and evidence for the choice of HSUs and the relevance of Olympic Dam hydrogeology to the OKDUGA project.	Agreed – Additional data is provided in **Error! Reference source not found.** regarding new hydraulic conductivity measurements. Additional drilling investigation and constant rate pump tests is proposed in the PRD forward works plan and will be further updated as part of the PEPR.	PRD **Error! Reference source not found.**, Section 3.6	Y Some comments were addressed, others may come out of the workplan proposed in Section 8.4. The workplan should be more detailed by the PEPR (if the RL/MPL is granted). Table 3.4 still has very low minimum hydraulic conductivities for the Quaternary, THA (OD and Carrapateena mine), WS (OD) and the PFA. Table 3.5 still has very low minimum hydraulic conductivities for THA (radial and northern wellfields), WS

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed y/n
						(radial wellfield) and PFA (northern wellfield).

37	C4 2.3	As described in Comment 36, there are significant inconsistencies between the conceptual status of HSUs that are considered aquifers and the hydraulic conductivity values provided in Tables 2.5 and 2.7. These inconsistencies present themselves in the hydrogeological conceptual model in Section 2.3. Comments on the first paragraph of C4 2.3: *The main study area aquifers are the sedimentary THA and PFA, located within the Stuart Shelf.* The hydraulic properties provided in Table 2.7 suggest these are aquitards, rather than aquifers. *The PFA is confined, and the THA varies from confined to unconfined depending on location.* It is unclear why and where the THA is confined if the Quaternary forms a perched aquifer. Please refer to comment 19. *Groundwater elevations are comparable (i.e. within 50 m) between the two aquifers, and there is a minor downwards vertical hydraulic gradient. Vertical hydraulic connectivity between the units is limited by the Woomera Shale, considered to be an aquitard, however, transfer of groundwater can occur via fracturing.* Please refer to Comment 21. 50 m is a very large difference in groundwater elevation/head! In Figure 3.9 (of the main proposal as well as in C4) the groundwater elevations/head in the THA is consistently above that of the PFA. Figures 3.13 and 3.14 (of the main proposal, corresponding to Figs 2.10 and 2.11 of C4), however, indicate that the heads converge towards Lake Torrens. The groundwater elevations/head beneath the OKDUGA project rectangle, for example, is 110-120 m AHD in the THA and 70-75 m AHD in the PFA. Just to the west of Lake Torrens, both are approximately 30-40 m AHD. Therefore, an approximate 40 m difference in groundwater elevation is reduced to about zero along the flow path towards Laker Torrens. In DEM's experience, near groundwater discharge areas, such as Lake Torrens, the convergence described above is typical and therefore more likely than the parallel 'water tables" indicated in Figure 3.9. Further, near discharge areas, the deeper heads (PFA)	Provide an updated and corrected text, tables and conceptual hydrogeology to ensure consistency. Clarify the status of HSUs and reconcile with the hydraulic conductivities. Consider and address these comments in the updated conceptual hydrogeology. Reconcile Figures 3.9 with 3.13 and 3.14 in the main document; Figures 3.9 with 2.10 and 2.11 in Appendix C4.	Agreed – **Error! Reference source not found.** provides an updated hydrogeological conceptualisation, with additional hydraulic conductivity data and elevation contours.	PRD **Error! Reference source not found.**, Section 3.6	Yes, but see comment above about very low hydraulic conductivities for "aquifers".

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed y/n
		tend to be higher than the shallow (THA). This may potentially occur when density correction (Comment 34) is applied.				
38	C4, Attach A, 2.4.2, 2.4.3	*regional groundwater flow from west to east, towards Lake Torrens…* *Regionally, groundwater flows into the study area from the west.* Figure 2.5 indicates, for the THA, groundwater elevations that form a high beneath the RL area and flow emanating in all directions from the high. It is unclear whether the proponent considered previous work, for example Appendix K1, Baseline hydrogeological assessment for the Olympic Dam expansion project. Please also refer to Comment 22.	Provide a corrected version of Figure 2.5 and text to ensure consistency. Explain if findings from previous studies were incorporated to the proposal.	Agreed – New site data from within the RL Project Area (including information from Olympic Dam) has been used to revise groundwater flow contours in **Error! Reference source not found.**.	PRD **Error! Reference source not found.**, Section 3.4, Figure 3.4, Figure 3.5	Y but refer to comment 39 about the way contouring was completed.

39	C4, Attach A, 2.7	*There is a minor downward gradient from the THA to the PFA local to the project.* It is unclear what is the statement above based on. Please also refer to Comment 34 about the need for knowing the magnitude of density correction and the impact correction may have on hydraulic gradients. Without density correction, a statement like above may be misleading. This is particularly important for vertical hydraulic gradients because the density (salinity) correction may be larger for the LSP/PFA than for the THA, potentially influencing (or even reversing) the inferred vertical hydraulic gradient.	Refer to Comment 34 about the need for density correction and knowing the magnitude of density correction. Provide worked numerical examples on density corrections and an explanation how they can influence vertical hydraulic gradients. Review and revise the statement based on density corrected heads.	Agreed – **Error! Reference source not found.** has been updated with density corrected groundwater elevations which shown a minor downward gradient from the THA to the PFA local to the OKDUGA Project.	PRD **Error! Reference source not found.**, Section 3.4, Figure 3.4, Figure 3.5	NS Appendix B 3.4.1 iii refers to two wells within the RL: *(ADHY01M and ADHY01P), ..* *ADHY01M: 88.8 mAHD* • *ADHY01P:85. 5 m AHD* These points could not be found in Figs. 3.4 or 3.5. Section 3.2 refers to these wells shown in Fig 3.1 but that figure does not have well id labels. Judging from Section 3.2, these wells should be in the PFA; ie. Fig 3.5, the contour map for the PFA, however, does not appear to have 88.8 or 85.5 mAHD

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed y/n
						observations and, in fact, does not have a single observation within the RL. Fig.3.4 has a 129.13 mAHD in the NE corner of the RL which seems to have been excluded from the contouring (located between the 80 and 90 mAHD contours). An explanation is required on how Figs 3.4 and 3.5 were constructed and from what data.

40	C4, Attach A, 2.4 C4, Attach A, 3.3	The status of Quaternary sediments is unclear or confusing. *The Alluvium, Quaternary sediments is described as:* *Unconfined, shallow aquifer …recharged locally by rainfall. Spatially discontinuous and often unsaturated. Shallow groundwater lenses may occur, post rainfall events.* The problem is that Section 2.4 does not provide an unambiguous description of the Quaternary sediments; rather hints that the Quaternary may form an unconfined aquifer, a perched aquifer or is unsaturated. Figure 2.8, conceptual hydrogeological cross-sections, do not even show Quaternary sediments, except beneath Lake Torrens. From the information provided, it is unclear, for instance whether the Quaternary sediments (where they exist) form a perched groundwater with the THA below being the "proper" water table aquifer. Text in 2.4.4 suggests this: *The watertable within the uppermost aquifer, the THA, …* Or, is the water table located in the Quaternary sediments (where they occur) and in the THA elsewhere. The most important aspect would be to provide groundwater heads in the Quaternary (where exists) and the THA in the same or nearby locations; the relationship between those could determine if the proposed dewatering may impact on the saturated parts of the Quaternary sediments (or not). Further, it is unclear if the Quaternary is represented in the model or not, if it is saturated or not, and if yes, where. Neither the description in the text, nor in Table 3.1 (*Arcoona Quartzite/Andamooka Limestone/surficial sediments*) provides this information. Figure 3.2 does not show Quaternary and Layer 1 starts with the Arcoona Quartzite, as part of the THA. Attachment A of C4, Section 1.6 states that: *The groundwater flow model was not designed to explicitly simulate the unsaturated zone, surface water or perched groundwater nor water quality/solute transport.* Clarification is required on whether perched is the same thing as the Quaternary.	Provide updated groundwater heads in the Quaternary (where exists) and the THA and a comparison between those at the same or nearby locations. Describe the relationship between heads in the Quaternary (where exists) and the THA. Explain and justify if dewatering may impact on the saturated parts of the Quaternary sediments (or not).	Agreed – Additional discussion of the water table and groundwater in Quaternary sediments included in **Error! Reference source not found.**. The OKDUGA Project numerical modelling has been updated with model layer 1 representing the Quaternary sediments and Andamooka Limestone.	PRD **Error! Reference source not found.**, Section 3.1, Section 4.3.3	N The discussion and model improvements are welcome but no data on the Quaternary or comparison with THA were provided.

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed y/n
		There is also a comment in 4.2.2, *Modelled steady state watertable elevation, which represents the THA*, does this suggest the water table is entirely within the THA?				

1.1.2 GDE investigation themes

Table Error! No text of specified style in document.**.2 | Response to GDE Investigation themes**

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed Y/N
23	3.5, Figure 3.30 C4, Figure 2.6	The potential GDEs are difficult to see at the scale provided, probably an inset, focusing on the OKDUGA project would help, so would increasing the transparency of the basemap. The source of the data should be stated (i.e. BOM GDE Atlas).	Provide an updated Potential GDE figure. Provide the source for the data used for this figure.	Agreed – Revised figure included in **Error! Reference source not found.**.	PRD **Error! Reference source not found.**, Figure 3.9	Y
24	3.5.5, 6.12	*Lake Torrens supports aquatic GDEs in accordance with the BoM GDE Atlas, however Lake Torrens is very often dry (i.e. it has only filled twice in the last 100 years) and is hypersaline. Therefore this classification is likely inaccurate.* This is a simplistic statement, just because the lake is often dry, that does not disqualify it from being a GDE. It is understood, for example, that endemic species may populate salt crusts. *Lake Torrens is an important feature of the South Australian Geographical Landscape and has recognised National Parks status. The importance of Lake Torrens to the people of South Australia has been considered in the OKDUGA Project design work and studies undertaken to ensure its environmental value is held for future generations.* The statements in italics from 3.5.5 and 6.12 in the same document appear to be inconsistent. The statement in 6.12 is best demonstrated by a comprehensive assessment of Lake Torrens as a GDE.	Either provide more robust justification and evidence for the claim that the classification is inaccurate, or consider Lake Torrens as a GDE.	Agreed – Lake Torrens is listed as part of the Inland Saline Lakes in the Australian Directory for Nationally Important Wetlands (DCCEEW 2024) and included as a GDE in this PRD. Revised groundwater modelling presented in **Error! Reference source not found.** predicts up to 2 m reduction in PFA groundwater levels near Lake Torrens, potentially resulting in reductions in groundwater contribution to Lake Torrens (consistent with the GEA for the Proposal). The updated groundwater modelling predicts an incremental reduction in groundwater flux to Lake Torrens of 0.02 GL/yr at the end of exploration. This equates to a reduction of 0.4% of the modelled pre-development groundwater flux to Lake Torrens from the model domain (4.2 GL/yr) and 0.02% of the estimated total flow to Lake Torrens. The impact is still considered minor as groundwater	PRD Section 3.2.3, PRD **Error! Reference source not found.**, Section 2.5, Section 7, Table 7.1	Y

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed Y/N
				contribution to Lake Torrens from the west comprises only 3% of the total water balance and groundwater is not considered to sustain the lake's water level.		

1.1.3 Groundwater modelling drawdown predictions themes

Table Error! No text of specified style in document.**.3 | Response to groundwater modelling drawdown predictions themes**

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed Y/N
25	4.10.2.2, Attachment B of Appendix C4	Options for water supply are listed in this section 4.10.2.2 without a clear statement which option constitutes the proposal. It is unclear what the status of the *Local saline wellfield* (11 wells at 2 L/s, total of **22 L/s**) is and if and how the predicted impacts from this wellfield were combined with mine dewatering and the Northern Wellfield. Attachment B of Appendix C4 reports on analytical modelling of four wells in the upper LSP (high k) layer, each at 3.75 L/s (total of **15 L/s**). Is this an alternative to 4.10.2.2 or an update? Figure B2 of Attachment B of Appendix C4 indicates significant drawdowns predicted in the LSP (high k), even intersecting (0.2m contour) the numerical model boundaries (to the SE and NW), at the end of exploration period. Figure 3.11 of Appendix C4, however, indicates predicted drawdowns (0.2m drawdown contour) in the LSP (high k) inside the model boundary of the model domain. It is understood from the text in 3.2.2 that the analytical model predictions in Figure 3.11 of Appendix C4 do include (under Cumulative Case Two) the predicted impacts from the OKDUGA wellfield: *Cumulative case two, analytical modelling of the drawdown from **OKDUGA Project** and the **Northern Wellfield** at the end of exploration, and the **OKDUGA water supply wellfield** was assessed.* It is unclear how this is possible, i.e. if the drawdown predicted from the OKDUGA water supply wells alone intersects the model boundary, how can the same	Provide an updated and corrected set of water scenarios with an explanation which scenario the predicted impacts refer to. Provide updated and corrected drawdown figures and text explanation to ensure consistency.	Agreed – The analytical modelling of four wells presented in the Proposal's Volume 3, Appendix C4 would meet construction and operational water demand (i.e. up to 15 L/s), with the abstraction volume presented Section 4.10.2.2 of the Proposal subsequently revised down. It is noted that 15 L/s is the maximum water demand for the OKDUGA Project and dedicated water supply requirements are likely to decrease after construction of the decline. The updated groundwater drawdown figures in Appendix D of the PRD **Error! Reference source not found.** present the revised groundwater modelling outputs.	PRD – **Error! Reference source not found.**	Y

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed Y/N
		predicted drawdown contour of 0.2 m in Figure 3.11 be inside the boundary from Cumulative Case Two? Note the time stamp on both figures is the same, end of exploration. Being “inside” the boundary here means less drawdown predicted from the **combined** *OKDUGA Project, the Northern Wellfield and the OKDUGA water supply wellfield* than the drawdown predicted from the latter water supply field **alone**.				

1.1.4 Groundwater modelling data themes

Table Error! No text of specified style in document.**.4 | Response to groundwater modelling data themes**

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed Y/N
26	7.3.6.2 7.4 7.5.3 7.5.7 7.5.8 7.6	The summary and groundwater impact provided is based on groundwater modelling using CHB model boundaries where, by definition, the drawdown is assumed to be zero. As per Comments 25, 42 and 50, this is an incorrect approach because the CHBs are impacted by drawdowns. Further, there is a large uncertainty in the adopted boundary values (Comments 34, 39, 43, and 44). Therefore, these sections (including what is a confirmed impact and what is not; and the uncertainties in Table 7.5), and the predicted impacts need to be revised by the latest in the PEPR (if the proposal is granted) stage.	Provide a firm commitment with a plan and associated dates, to review the model, to update and correct model boundaries. Provide an updated and corrected information relating to the assessment of potential groundwater impacts based on updated hydrogeological conceptualisation and understanding.	Agreed – Additional groundwater modelling has been undertaken, which uses GHB conditions in place of CHB model boundaries, as detailed in **Error! Reference source not found.**. In addition, BHP will undertake calibration of the OKDUGA Project's groundwater model with additional drilling and operational monitoring data within two years of commissioning.	PRD **Error! Reference source not found.**, Section 4.5, Section 5, Section 6.1, Section 6.2	N The documentation in Sections 4-6 is inadequate, as it is not specified where the external reference heads for GHBs come from and what are the numerical values used to simulate GHBs. GHB (general head boundary) conditions are better than the previously used CHB. DEM understands that for a GHB, there is a fixed reference head somewhere outside the model, and the flow will be proportional to the gradient between that fixed head and the variable head at

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed Y/N
						the model edge, controlled by a hydraulic conductance in between. It follows that the documentation should include the source of the reference head and the numerical values used for both the reference head and the conductance. DEM could not find an adequate description of the information above. Fig 4.4, for example shows GHBs at the model boundary not at the external location. Provide the hydraulic conductance and the external reference heads used for GHBs and the sources of those. There are also differences along

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed Y/N
						the NW boundary between Figures 3.4 and 5.3 raising the issue as to what degree does the numerical model reflect the conceptual hydrogeology. Fig 3.4 indicates groundwater flow along the model boundary there; Fig 5.3 suggests groundwater flow perpendicular to the boundary.
27	8	Please refer to Comment 26. The Outcome Measurement Criteria and Leading Indicators in Table 8.2, referring to the groundwater model, are unacceptable at this stage because of the significant model uncertainties.	Provide an updated and corrected groundwater model and updated Outcome Measurement Criteria and Leading Indicators or provide revised model independent outcomes and draft criteria.	Agreed – Updated groundwater drawdown figures in Appendix D of the PRD **Error! Reference s ource not found.** present revised groundwater modelling outputs to support the OMC and LIs in Table 8.2 of the Proposal.	Appendix D of PRD **Error! R eference source not found.**	N The criteria do not seem to have changed and still link to model predictions. See comments on 29. Not all the details for GHBs are provided, refer to comment on comment 26. In addition, the colour shades used in Figures 4.4 to 4.6 do not allow for

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed Y/N
						meaningful analysis. Resolve: Fig.4.4 title refers to GHB legend to CHB; also check if year 3040 is correct (or not in Fig.4.6). Stress periods in Table 3.2 end in 2048.
28	8.3	The Forward Work Plan should include a review of the groundwater model and associated date, to address the issues raised in this request for a response document.	Provide an updated and corrected Forward Work Plan that includes the review of the groundwater model (refer to comments 26 and 27).	Agreed – BHP will undertake calibration of the OKDUGA Project's groundwater model with additional drilling and operational monitoring data within two years of commissioning.	PRD Section **Error! R eference source not found.**	Y but note that calibration on its own is not adequate, suggest to use the term "calibration and model review".
41	C4, Attach A 3.5 5.2	The Northern Wellfield wells are situated close to OKDUGA and it would be beneficial to show a comparison between the OKDUGA and Carrapateena Mine models (adopted model boundaries and values, HSUs and parameters). The documentation does not appear to provide such comparison.	Provide discussions (and illustrations) using all available information of the boundary conditions used for both the Carrapateena Mine and the OKDUGA models to show consistency.	Agreed – Additional groundwater modelling has been undertaken, which has been informed by the more extensive Carrapateena mine model, as detailed in **Error! Reference s ource not found.**. A comparison between the OKDUGA Project and Carrapateena mine groundwater models will be provided as part of the PEPR.	PRD **Error! R eference source not found.**, Section 4.5, Section 5, Section 6.1, Section 6.2	Y

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed Y/N
42	C4, Attach A, 3.5.1	*As described in section 2.4.4, groundwater generally flows from west to east towards Lake Torrens. In the groundwater model, this is simulated with constant head boundary conditions in the HSUs representing the THA and LSP.* The text above disregards the local high in the THA (Comment 38). Numerical groundwater flow models aim to solve the groundwater flow equations and to do so need to make certain assumptions along the model boundaries. In the OKDUGA model, the entire model domain is surrounded by constant heads (CHB) cells. The head in CHBs are fixed regardless of the system conditions and they can provide, or remove, infinite amounts of water to maintain the heads at the constant value. CHBs need to be therefore selected carefully, otherwise CHBs can have a significant influence on the results of a simulation and may lead to unrealistic predictions if predicted drawdowns are close to the CHBs. Such (close) conditions occur for several scenarios in the OKDUGA model. This issue was raised by DEM earlier, and the proponent included, as a result, additional discussion in Section 5.3.5 (email correspondence from Kara Moore of BHP to Mike Smith of DEM, 29 November 2023) essentially flagging the issue for consideration for future groundwater modelling. This review seeks further action (as opposed to consideration) and commitment from BHP on this issue.	Provide updated and corrected CHBs or a firm commitment with a timeline, to fix the incorrect boundaries in a forward work plan.	Agreed – Refer to response to comment ID 26.	PRD **Error! Reference source not found.**, Section 4.5, Section 5, Section 6.1, Section 6.2	N refer to comment 26.
43a	C4, Attach A, 3.5.1	*… and everywhere else at the model edge they are assigned based on the inferred groundwater levels as shown in Figure 2.5. In the absence of groundwater level data for the LSP near the model boundary (see Figure 2.6), the groundwater levels for the LSP were set equal to those assigned to the THA.*	Provide a robust justification why the extrapolated and density uncorrected values used for CHBs are valid, or explore alternatives to boost data and	Agreed – Refer to response to comment ID 26.	PRD **Error! Reference source not found.**, Section 4.5, Section 5,	N Refer to comment 26.

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed Y/N
		The adopted boundary head values are based on very few datapoints (21 for the THA and 9 for the PFA), collected at different times. Figures 2.5 (THA, 21 datapoints) and 2.6 (LSP, 9 datapoints) of Appendix C4 show the datapoints and interpreted contours. The distribution of datapoints in these figures suggest that all values for CHBs were extrapolated (as opposed to interpolation, extrapolation carries more uncertainty). With the exception of the northern boundary for the THA, the distance of datapoints from the model boundaries and the data distribution suggests that all other CHB values adopted are very uncertain.	information (remeasure heads in existing wells, convert mineral drillholes to monitoring wells, include wells outside the model domain, literature review, etc).		Section 6.1, Section 6.2	
43b	C4, Attach A, 3.5.1	Boundary values for the THA and PFA The boundary values are also understood to be the same for the shallower THA and the deeper PFA aquifers; this appears to contradict the statement the intervening Woomera Shale is a competent aquitard. In DEM's experience, the groundwater heads near recharge areas tend to be higher in the shallow (here THA) aquifer. Conversely, near discharge areas such as Lake Torrens, the deeper PFA groundwater heads would be likely to be higher than those in the THA. At a minimum, groundwater heads are very unlikely to be the same for shallow and deep aquifers, separated by a competent aquitard, everywhere surrounding the model domain. Please also refer to Comment 34, about the need for density correction.	Provide evidence/justification for the use of common boundary heads for the THA and PFA HSUs or provide an updated/corrected model with boundary conditions.	Agreed – Refer to response to comment ID 26.	PRD **Error! Reference source not found.**, Section 4.5, Section 5, Section 6.1, Section 6.2	N Refer to comment 26.
44	C4, Attach A, 4.2.2	The caption of Figure 4.2 is *Scatter plot of steady state modelled versus measured hydraulic head, the x axis title is measured groundwater elevation and the y axis title is modelled groundwater elevation.* The figure, in DEM's view, shows steady state modelled **head** on the y-axis versus measured groundwater **elevation** in the x-axis.	Provide worked numerical examples on density corrections. Knowing the magnitude of density corrections will enable an assessment on how important (or not)	Agreed – Additional groundwater modelling has been undertaken, which incorporates density corrections, as detailed in **Error! Reference source not found.**.	PRD **Error! Reference source not found.**, Section 3.4.1(i)	N 3.4.1 i and 3.4.1 iii include the methodology and application to two wells, respectively, the density correction

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed Y/N
		More importantly the figure compares two different measure of groundwater and disregard the need for density correction. Models provide predictions of groundwater head while dipper/tape measurements, uncorrected to density, provide groundwater elevations. These potentially different measures are used for calibration (history matching) and this approach may or may not be appropriate to use, depending on the magnitude of the density correction. An explanation is required about the potential errors this approach includes, and the impact of such error may have on the statistics provided in the proposal. This issue is also associated with groundwater head/elevation contour maps, hydraulic gradients, model boundary condition, calibration/history matching and the interpretation of model predictions (Refer also to Comment 34).	the density corrections are. Provide an updated/corrected Figure 4.2 to ensure consistent measures of groundwater are compared.			was completed but the explanation about the potential errors this approach includes was not.
45	C4, Attach A, 4.2.2	It is unclear why there are more observation points in Figure 4.4 than in Figure 2.5. Presumably, residuals can only be calculated in Figure 4.5 if measured values exist at a location. If so, an explanation is required on where the points extra to Figure 2.5 come from. Examples include just north of the RL area there are three red points (-8.3, -9.1 and -7.9 m labelled) that do not seem to exist in Figure 2.5.	Provide an explanation on why there are more observation points in Figure 4.4 than in Figure 2.5.	Agreed – Figure 4.4 currently shows observation points within both the THA and PFA (i.e. the observation points shown on both Figure 2.5 and Figure 2.6).	N/A	N/A
46	C4, Attach A, 4.2.2	DEM does not have access to the model, only to the model documentation; hence a transparent documentation is important. The model documentation lacks details that are essential to understand, and to assess, if the model is suitable for the purpose. There is no documentation of calibrated/observed groundwater head maps for the PFA, where most of the drawdown is predicted. Histograms of parameter distributions for pilot points only are provided, without parameter distribution	Provide measured and predicted groundwater contours for the PFA and a description of these.	Agreed – Additional groundwater modelling has been undertaken, based on updated conceptualisation. Figures illustrating interpreted equivalent freshwater (i.e. density-corrected) heads are provided for both the	PRD **Error! Reference source not found.**, Figure 3.4, Figure 3.5	Y Figure 3.4 is an interpreted THA head and groundwater flow map. Figure 3.5 is an interpreted PFA head and

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed Y/N
		maps. There is no map in the proposal showing the depth to water table, where evaporation from groundwater occurs in the model, and the relationship to potential/actual GDEs. There are no actual cross sections or maps indicating the relative position of perched water in the Quaternary Sediments with respect to groundwater in the THA. There are no groundwater head contour predictions provided, similar to Figure 4.4, but for different HSUs. In particular, it would be beneficial to see the contours of Figure 2.6 overlaid with a figure providing model predicted heads for the PFA. Please also refer to Comment 34 about the need for density corrected heads.		THA and PFA detailed in **Error! Reference source not found.**.		groundwater flow map. Figures 5.3 and 5.4 provide the comparison requested.
47	C4, Attach A, 4.2.2	*Modelled groundwater flow is broadly from the west towards Lake Torrens in the east, with local variability towards the nearby ephemeral creek lines.* Figures 2.5 and 4.4 indicate otherwise. Groundwater elevations form a high beneath the RL area and flow emanating in all directions from the high. Please refer to Comment 38.	Correct the text or Figures 2.5 and 4.4 according to the matter raised.	Agreed – Refer to response to comment ID 26, as well as updated conceptualisation and modelling presented in **Error! Reference source not found.**.	PRD **Error! Reference source not found.**, Section 3.4, Figure 3.4, Figure 3.5	N Refer to comment 26.
48	C4, Attach A, 4.4	It is vital to understand the calibrated model hydraulics in order to comprehend the predicted impacts. Figure 4.5 and those in Appendix A of Attachment A of Appendix C4 do not appear to be informative on their own. These are histograms conveying the number of occurrences within a particular value range, for example for hydraulic conductivity, on the left scale for pre- and post-calibration and on the right scale for the base case scenario. The issue is that these histograms do not show the spatial distribution of parameters. It would be beneficial to see **maps** of recharge and hydraulic parameter distributions. Further, DEM consider the	Provide parameter distribution maps and consider changing the histograms to clustered columns of relative frequency.	Agreed – Figures of spatial distributions of history-matched base realisation horizontal and vertical hydraulic conductivity for the two key units, the THA and PFA, as well as recharge, are provided in **Error! Reference source not found.**. Parameter histograms are provided in a common format such	PRD **Error! Reference source not found.**, Section 5	Y The SRMS errors in Table 5.3 are high, also in Figure 5.6 c and d.

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed Y/N
		histograms would be easier to understand if a single vertical scale was used with relative frequency and the use clustered columns.		that prior and posterior distributions can be compared and the base realisation plotted on its own scale to illustrate where it lies within the broader posterior distribution.		
49	C4, Attach A, 5.3.1	It is unclear why the ET component does not change in time in Figure 5.1. Conceptually, the base case will introduce some drawdown and therefore it was expected that the ET, for the new, deeper water table (in the THA?) would decrease in time.	Explain why the ET component does not change.	Noted – Lowering of the water table only causes a reduction in modelled ET if the water table is within the extinction depth of ground surface.	N/A	No Figure 5.7 of appendix B indicates the "*Base realisation modelled water balance over the history-matching period*". Accordingly, the main inputs to the model are rainfall recharge and regional inflow, dominantly balanced by evapotranspiration (EVT). That EVT is only possible if significant parts of the model domain have shallow water table. DEM assumed this was the case near Lake Torrens "*Groundwater discharges into the regionally*

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed Y/N
						significant Lake Torrens, where evaporative discharge occurs" (Section 3.9, conceptual hydrogeology). Comments, provided in Table 6.2 about EVT as: "*this is a recirculation of water through a few boundary condition cells along the southern model boundary that are within the evapotranspiration extinction depth and does not influence model parameterisation or predictions*" appear to suggest otherwise. In DEM's view, the amount of recirculated water is close to 50 ML/d (Figure 5.7), which is a very large flow; it is, in fact, the largest component of the

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed Y/N
						water balance of the model in Figure 5.7. DEM was unable to find any description of this water (~ 50 ML/d) in the conceptual hydrogeology (Section 3.9). Conceptual hydrogeology should include all physical process that are significant enough to be represented in the model. Therefore the explanation provided in Table 6.2 came as surprise to DEM. The numerical groundwater flow model should be the numerical representation of the conceptual hydrogeology and should not have "*surprises*" of this magnitude. Such a surprise cast doubt if the model is fit for the purpose of impact assessment.

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed Y/N
						It is unclear if this EVT is realistic or it is simply an artifact of the model balancing inflows with outflows. If the latter, it may be an indication of inconsistencies between the conceptual and numerical water budget, ie the main input, rainfall recharge may also be incorrect.
50	C4, Attach A, 5.3.3	Please refer to Comment 43. Predicted incremental drawdown, due to the OKDUGA project excavations only (excluding the drawdown associated with groundwater abstraction from the Northern Wellfield) is close to the model boundaries in Figures 5.4 and 5.8 (Upper LSP high K). Further, predicted cumulative drawdown, due to both the OKDUGA and Carrapateena Northern Wellfield projects is close to the model boundaries in Figures 5.10, 5.13 and 5.14 (Upper LSP high K). It is important to note that the model *predicted* drawdown would not intersect the model boundary because the model boundary is assumed to be constant head (CHB), where drawdown, by definition, is assumed to be 0m. The model simply returns the assumption as a prediction, a type of circular logic. CHBs that are not *far* from the source of the impact are incorrect and such boundary conditions should be modified.	Provide a firm commitment, with a timeline, to correct the model boundaries.	Agreed – Additional groundwater modelling has been undertaken, which uses a wider model extent as well as GHB conditions in place of CHB model boundaries, as detailed in **Error! Reference source not found.**.	PRD **Error! Reference source not found.**, Section 4.5, Section 5, Section 6.1, Section 6.2	N Refer to comment 26.

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed Y/N
		CHBs are used to fix the head value in selected grid cells regardless of the system conditions in the surrounding grid cells, thus acting as a potentially infinite source of water entering the system, or as an infinite sink for water leaving the system. Therefore, specified head boundary conditions can have a significant influence on the results of a simulation, and may lead to unrealistic predictions, particularly when used in locations close to the area of interest (Waterloo Hydrogeologic, Conceptual Modelling Workflow > Defining Boundary Conditions > Theory (waterloohydrogeologic.com), DEM requires information on the further action and commitments proposed to address this issue.				

1.1.5 Water management/controls (groundwater) themes

Table Error! No text of specified style in document.**.5 | Response to water management/controls (groundwater) themes**

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed Y/N
29	8	The details provided on the proposed groundwater monitoring (outcome measurement criteria) are inadequate. Applicable Terms of Reference (TOR) for the Oak Dam applications requires the proponent to *as far as practical comply with the five elements set out in regulation 46(5) of the Mining Regulations 2020*. The five elements in the Mining Regulations 2020 refer to: (a) what is to be measured and the form of the measurements that are to be used; and (b) the locations where the relevant measurements are to be taken, or how such locations are to be determined; and (c) what is proposed to be taken to constitute the achievement of the relevant outcomes (with consideration being given to any inherent errors of measurement); and (d) the frequency of any measurement or monitoring; and (e) any background or control data that is to be used, or how any such data is to be acquired. Of the five elements above, the proposal only provides three (a, c and d) in Section 8. The lack of the other two aspects, in particular the number and location of monitoring wells are unacceptable at this stage of an application. A draft groundwater monitoring plan for this proposal is important because the groundwater impact assessment relies on a numerical groundwater model that is uncertain and inconsistent with the conceptual hydrogeology. In these circumstances, relying on actual and comprehensive monitoring data will be crucial for measuring the achievement of groundwater outcomes. Note that whilst this comment has been applied to the groundwater measurement criteria, DEM recommends that	Provide updated and corrected outcome measurement criteria details in accordance with applicable Terms of Reference and the Mining Regulations 2020.	Agreed – BHP have developed a groundwater monitoring framework to measure water quality and water levels for the OKDUGA Project provided in **Error! Reference s ource not found.**. A Groundwater Management and Monitoring Plan will be finalised as part of the PEPR.	PRD **Error! R eference source not found.**, Figure 2.1	N The what, where, and frequency are provided in Appendix C, but baseline data and achievement criteria are not. *Section 6.2 refers to the proposed Outcomes as described in Section 8, Table 8.2, Table 8.4 and Table 8.5 of the Proposal* *(BHP 2023), respectively.* Of the tables referred to, only 8.2 had groundwater criteria and

ID	RLP reference	Submission comment	Response/action required from BHP	BHP response	Further detail	DEM addressed Y/N
		all draft outcome measurement criteria provided in Section 8.2 of the Proposal be reviewed to ensure the requirements set out in regulation 46(5) have been appropriately addressed. Updated details should be provided wherever applicable.				even those are linked to model predictions. When model uncertainty is high, it is better to provide model-independent absolute outcome criteria that is based on the bets assessment at the time.

Appendix B
Groundwater environmental assessment addendum updated

BHP Oak Dam Underground Access Project

Groundwater Environmental Assessment Addendum

Prepared for BHP Olympic Dam Corporation Pty Ltd

October 2024

BHP Oak Dam Underground Access Project

Groundwater Environmental Assessment Addendum

BHP Olympic Dam Corporation Pty Ltd

E220745 RP24

October 2024

Approved by



Paul Gibbons
Director
11 October 2024

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Plates

Plate 3.1 Density effects 22

1 Introduction

BHP Olympic Dam Corporation Pty Ltd (BHP) is proposing to develop the Oak Dam Underground Access Project (OKDUGA Project), in the far north of South Australia (Figure 1.1).

The Oak Dam deposit is a deep iron oxide copper-gold (IOCG) mineralised system. Exploration undertaken at Oak Dam has indicated the presence of high-grade copper and associated minerals commencing at approximately 800 m below surface that may be economically viable to mine.

The OKDUGA Project has been initiated to progress the opportunity to undertake exploration drilling underground, providing accelerated resource definition and reduced drilling and development costs. Specifically, the OKDUGA Project aims to establish an underground access via twin declines, with the dual purposes of:

- providing an effective and proximal drilling platform to enable efficient mineralisation drilling to define the resource
- enabling characterisation of critical geotechnical ground conditions
- enabling hydrogeological drilling and testing.

To authorise the OKDUGA Project, a combined Retention Lease (RL) Proposal and Miscellaneous Purposes Licence (MPL) Management Plans and supporting Tenement Applications (together, the Proposal) was prepared under the *Mining Act 1971* (SA) (Mining Act).

The Proposal was submitted to the Department for Energy and Mining (DEM) in December 2023.

The key changes to this Groundwater Environmental Assessment Addendum (GEA Addendum) report iteration are in response to additional groundwater comments received from the DEM and Department for Environment and Water (DEW) on 27 August 2024 as follows:

- Shortage of local and regional data: BHP Proposal (December 2023) and GEA Addendum (June 2024) have acknowledged data gap with groundwater modelling applying predictive uncertainty analysis (in line with industry best practice guidelines) to support a risk-based approach to scenario predictions, impact assessment and water management. The groundwater modelling assumed conservative cumulative receptor impacts of up to 15 megalitres per day (ML/d) of groundwater inflows to the decline (unmitigated) and 7 ML/d abstraction from the Northern Wellfield (comprising the maximum approved abstraction).
- Hydrogeological conceptualisation: no changes with hydrogeological conceptualisation presenting available local and regional data for the OKDUGA Project. Ongoing investigations may lead to updates to the hydrogeological conceptualisation and will form part of the Program for Environment Protection and Rehabilitation (PEPR).
- Boundary conditions and regional water balance: there have been minor adjustments, but no material changes to predicted impacts.
- History-matching: additional regional data have been added to the history-matching dataset and the model performance validated against the expanded dataset with no material impacts to the scenario predictions.
- PEPR/forward work plan:
    - re-calibration and groundwater model review with additional drilling and operational monitoring data within two years of the decline development intersecting groundwater
    - groundwater dependent ecosystem (GDE) investigations intended scope of works is outlined

- bore census intended scope of works is outlined.

- Groundwater modelling report and groundwater environmental assessment: minor updates to reflect the above (this report).

Based on DEM and DEW comments received in May 2024 and August 2024, BHP has undertaken review of a number of aspects related to the groundwater modelling (e.g. boundary conditions, measured groundwater levels, density corrections) with no material change to model predictions or predicted impacts to sensitive receptors.

The OKDUGA Project and associated RL is intended to provide a means to obtain more local data, which will further inform the conceptual understanding of the groundwater system and provide a data-driven basis for updating any future modelling should the Project proceed to a future MLP. As the supporting data grow, uncertainty in predictions can be reduced through history-matching to the expanded dataset.

1.1 Background and context

In early 2023, EMM Consulting Pty Limited (EMM) undertook numerical groundwater modelling to inform the Groundwater Environmental Assessment (GEA) that supported the Proposal.

The GEA and supporting Groundwater Modelling Report (GMR) was based upon available groundwater data within the study area at the time of preparation, noting that the BHP and former OZ Minerals acquisition was not formalised until after the groundwater assessment work had been completed.

In this regard, the GEA and GMR acknowledged the data limitations and predictive uncertainty analysis that was undertaken to support a risk-based approach to impact assessment and water management.

DEM and the Department for Environment and Water (DEW) agency preliminary and final comments were received by BHP on 13 March 2024 and 30 May 2024 respectively which identified areas of groundwater concern and have requested these matters be adequately addressed as part of the Proposal Response Document and Program for Environment and Protection (PEPR).

Key concerns raised around the groundwater modelling and impact assessment included:

- lack of data
- boundary conditions and extent
- density corrections
- updated impact assessment to reflect the above.

Since the OKDUGA groundwater model was prepared, EMM has undertaken additional numerical groundwater modelling to assist BHP in their investigations to assess various potential mining strategies. A new groundwater model was developed for this purpose, referred to as the Oak Dam (OKD) Life of Mine (LOM) model.

EMM have used this existing OKD LOM model to simulate OKDUGA only and to run updated groundwater prediction scenarios to estimate potential impacts. The benefits of the LOM model are that it has been updated with additional regional and local data, density corrections and includes an expanded model domain which formed key areas of concern for both DEM and DEW.

Initial model comparisons of the original OKDUGA and OKD LOM models are summarised in Table 1.1.

Table 1.1 Initial OKDUGA and OKD LOM model comparison

	OKDUGA model	Oak Dam LOM model
Spatial extent	~35-kilometre (km) radius from RL Project Area (refer Figure 1.1).	~50 km radius from RL Project Area (refer Figure 1.1).
History-matching	Steady state only, using publicly available data from 30 bores.	Transient, using 34 wells total from: Northern wellfield observation wells, Carrapateena compliance and leading indicator wells, pastoral wells, other wells selected from WaterConnect.
Layer design	29 layers total, aligned with hydrostratigraphic unit (HSUs), noting that some were combined into a 'Lower Sedimentary Package' (LSP) unit. Refinement to model tunnels in layers 10 m thick, between layers 20 m thick.	26 layers total, aligned with HSUs (no LSP). No refinement specific to decline/exploration tunnels. Basement refined into layers of 100 m thickness within 10 km of OKD.
Temporal discretisation	Stress periods of monthly duration during excavation, one 5-year stress period during exploration.	Stress periods of 18-month duration during excavation.
Model edge boundary conditions	Constant Head (not density-corrected) in the Tent Hill Aquifer (THA) and Pandurra Formation Aquifer (PFA). Due to lack of PFA data it was set equal to THA.	General Head Boundary, with values based on density-corrected heads in the THA, Whyalla Sandstone Aquifer (WSA) and PFA – differing from layer to layer.

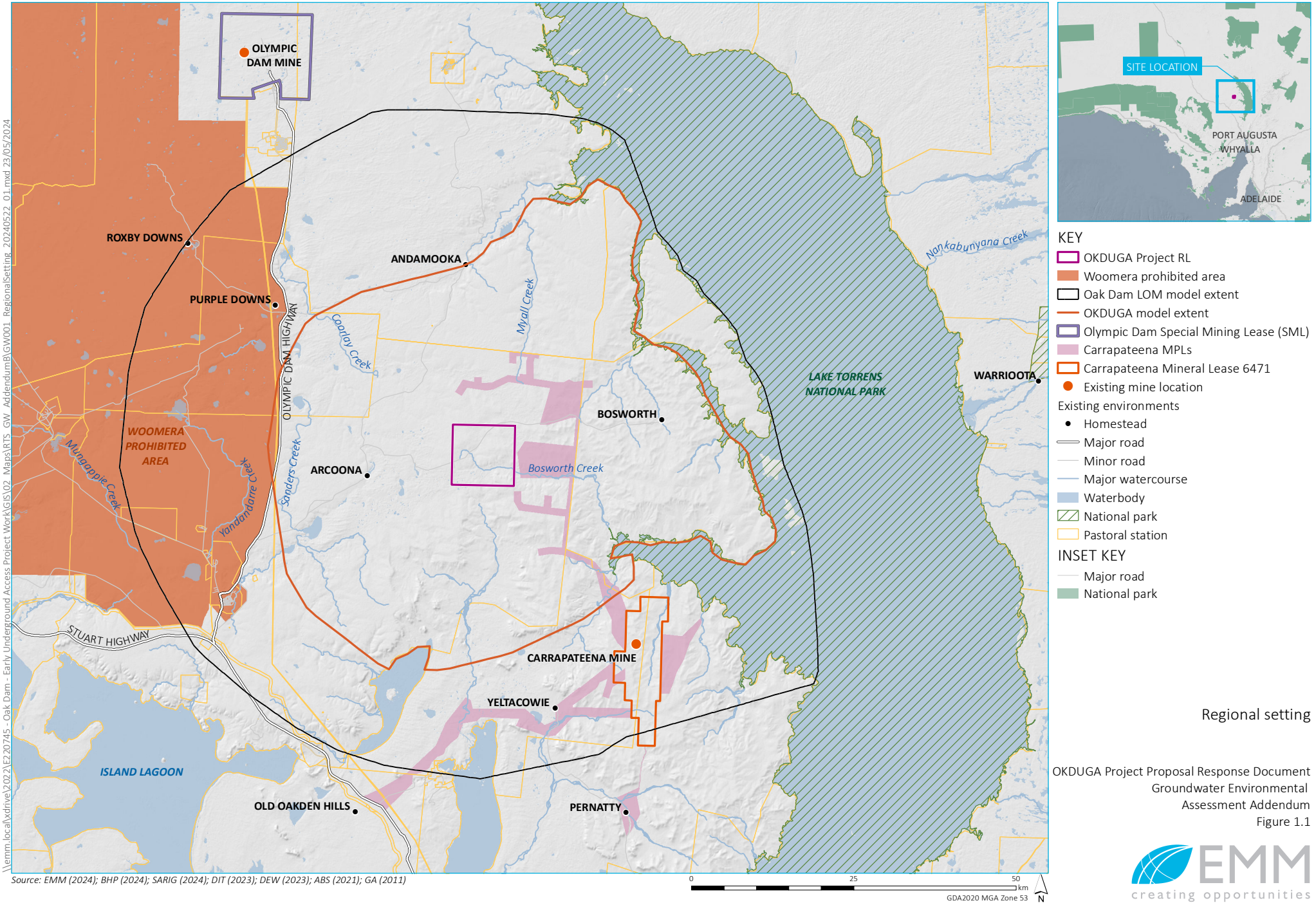
1.2 Purpose of this report

This report documents the updated OKDUGA Project hydrogeological conceptualisation and the model design aspects of the OKD LOM model, which have been utilised to simulate the OKDUGA Project. It should be noted that this report presents an interim conceptualisation, which will be updated further when additional RL Project Area hydrogeological and groundwater dependent ecosystem (GDE) RL Project Area data becomes available as part of the PEPR.

This report also details a comparative assessment of the original OKDUGA model and the OKD LOM (OKDUGA simulated only) model outputs, including discussion around the consequences for the corresponding assessment of effects and impact assessment, in accordance with the Environmental Impact Assessment Framework (EIAF) presented in the Proposal. The groundwater modelling workflow for both modelling efforts was conducted in alignment with the Australian groundwater modelling guidelines (Barnett et al. 2012) and current best practice related to predictive uncertainty analysis (Middlemis and Peeters 2018).

This report (initially dated June 2024, and updated October 2024) is proposed to supersede the GEA submitted with the Proposal (dated November 2023). For the purpose of this report the following terminology has been defined:

- OKDUGA Project: the area defined by the extent of the RL Project Area, the Site Infrastructure Corridor (SIC) MPL Project Area and the Water Infrastructure Corridor (WIC) MPL Project Area.
- RL Project Area: the area defined as the extent of the proposed RL tenement.
- Proposal: combined RL Proposal, SIC MPL Management Plan and WIC MPL Management Plan.
- Study area: the groundwater study area comprises the approximate 50 km radius from the centre of the OKDUGA Project.



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Source: EMM (2024); BHP (2024); SARIG (2024); DIT (2023); DEW (2023); ABS (2021); GA (2011)

Regional setting

OKDUGA Project Proposal Response Document
Groundwater Environmental
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Figure 1.1

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2 Environmental setting

2.1 Introduction

This section describes the environmental setting for the study area, setting the context for the hydrogeological conceptualisation. A detailed discussion on the hydrogeological information used to develop and update the hydrogeological understanding is provided in Chapter 3.

2.2 Available information

The sources of available data used to inform this assessment are summarised in Table 2.1.

Table 2.1 Overview of available information

Data type	Publicly available data	Additional BHP sourced information
Climate: rainfall, evaporation	SILO gridded database hosted by the Queensland Department of Environment and Science.	
Groundwater levels and quality	• Registered groundwater bore data sourced from the WaterConnect online groundwater database. • Groundwater investigations and assessments pertaining to the Olympic Dam and Carrapateena Mines.	• Preliminary hydrogeological reporting completed by Eco Logical Australia (2021) in support of OKDUGA Project engineering studies. • Bore logs and geological appraisal results for the OKD and Carrapateena Projects. • Groundwater level monitoring from the Carrapateena Northern Wellfield (up to January 2023).
Stratigraphy and geology	• Regional geophysical and geological data sourced from the South Australian Resources Information Gateway (SARIG) online database. • Registered groundwater bore data sourced from the WaterConnect online groundwater database. • *1:100,000 Surface geology map* (Department of Energy and Mining).	Bore logs and geological appraisal results for the OKD and Carrapateena Projects.
Groundwater users	Groundwater dependent ecosystem (GDE) data sourced from the Bureau of Meteorology (BoM) GDE Atlas.	• *Carrapateena Project, Groundwater baseline report* (OZL 2017). • *Carrapateena Project, Groundwater Baseline Assessment* (Jacobs 2016a).
Hydraulic properties		Various hydrogeological investigations: • *Olympic Dam expansion project-Supplementary Environmental Impact Statement groundwater studies* (SKM 2011). • *Carrapateena Project Groundwater Modelling and Assessment of Effects* (CDM Smith 2016). • *OZ Minerals Limited Groundwater modelling and Assessment of Effects* (CDM Smith 2018).
Topography	Digital Elevation Model (DEM) for the study area (Geoscience Australia, 1 second SRTM DEM).	
Wellfield operation		Carrapateena Northern Wellfield pumping rates.

2.3 Project location and surrounding mines

The OKDUGA Project is approximately 500 km north north-west of Adelaide in south-eastern South Australia. The study area is located on the Arcoona Plateau, an extensive tableland to the west of Lake Torrens, comprising low stony hills. The rolling terrain ranges in elevation from 135 to 188 metres Australian Height Datum (mAHD), with the highest elevation in north-western portion of the RL (Hatch 2022).

The region around the RL Project Area, SIC MPL Project Area and WIC MPL Project Area is generally part of the arid or semi-arid interior of South Australia, characterised by low rainfall, sparse vegetation, and a harsh climate. The landscape features vast expanses of gently rolling terrain, with occasional rocky outcrops and scrubby vegetation, such as saltbush, spinifex grass, and acacia trees. There are also dry creek beds, occasional waterholes, and rocky hills or ranges.

There are two major mines in the surrounding area, BHP's Olympic Dam which is 60 km north-west and BHP's Carrapateena Mine which is 40 km to the south-east of the RL Project Area (see Figure 1.1). BHP acquired the Carrapateena Mine from OZ Minerals Ltd (OZL) in April 2023. Both are copper gold mines, targeting the mineralisation of the Gawler Craton.

2.3.1 Carrapateena Mine

The Carrapateena Mine operates under the Carrapateena Mine Lease (ML) 6471 and several additional MPLs for supporting infrastructure and services. The existing Carrapateena Mine was approved by the State and Commonwealth governments in March 2018, with operations commencing in December 2019. The ancillary infrastructure at the Carrapateena Mine includes an airstrip, accommodation village, access roads, wellfields and associated infrastructure. The mine employs a sub level caving (SLC) mining method, and the current approved life of mine and wellfields operation is 30 years.

2.4 Climate

The study area is typical of northern South Australian arid climate, with hot summers and cool winters. Long term synthetic rainfall data from 2010 to 2022 were extracted from the SILO gridded database hosted by the Queensland Department of Environment and Science at station -31.00°, 137.20°. Climate statistics are summarised in Table 2.2. Evaporation is consistently an order of magnitude higher than rainfall, and peaks in the summer months (Table 2.2). Rainfall is also typically higher in the summer months and often arises from remnants of cyclonic depressions moving in from western and northern Australia and comprises intense storm events (Jacobs 2016a).

Table 2.2 Rainfall and evaporation statistics

	Rainfall (mm)	Pan evaporation (mm)
Annual average	170	2,751
Annual minimum	48	1,778
Annual maximum	305	3,128

Notes: SILO data coordinates, Latitude: -31° and Longitude: 137.20° data range: 2010–2022.

Cumulative deviation from mean (CDFM; also referred to as cumulative rainfall deviation (CRD)) rainfall is the accumulated difference between rainfall (in a day, month or year) and the long-term mean, providing an indication of the general climatic trend over time, as well as general water availability (soil water, surface water and groundwater). Correlation analysis between CDFMs and groundwater trends are commonly used to assess recharge processes and connectivity. CDFM has been calculated using the rainfall record from the SILO gridded database (Figure 2.1). The period from mid-2017 to early 2020 experienced below average rainfall conditions, with above average rainfall conditions thereafter. In Figure 2.1 downward trending slopes are interpreted to be below average rainfall while upward trending slopes are indicative of above rainfall conditions.

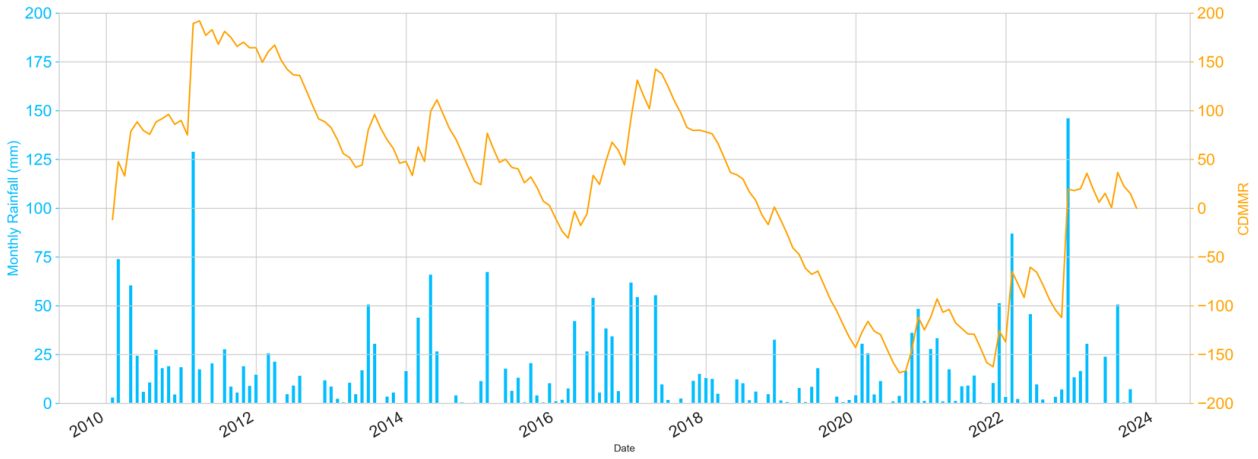


Figure 2.1 Daily rainfall and cumulative deviation from mean

2.5 Hydrology

Radiating from the Arcoona Plateau are short channels, which only receive flow following significant rainfall events. The most notable is Bosworth Creek, an ephemeral creek with its headwaters in the RL Project Area (Figure 2.2). This watercourse drains east to the Bosworth Pastoral lease, and then south, discharging into the Carrapateena Arm of Lake Torrens. Throughout the study area, ephemeral streams (such as Rocky Creek, Myall Creek, Springs Creek and Elizabeth Creek) drain to Lake Torrens, and in the south and south-west to the relatively smaller Lake Richardson, Lake Windabout and Pernatty Lagoon.

Lake Torrens is a major hydrological feature in the study area. It is a large episodic saline playa lake that is typically dry with no outflow of water (Department of Mines, South Australia 1967). The area of Lake Torrens is approximately 6,000 km² and it is the dominant regional evaporative sink for both surface water and groundwater in the region (Jacobs 2016a). OZL (2017) estimates on average, approximately 80% of water entering Lake Torrens is from direct rainfall, 10% from groundwater inflow, and 10% from catchment runoff. Based on a groundwater balance, Jacobs (2016a) estimated that the groundwater contribution to Lake Torrens from the west is approximately 3.3 gigalitres per year (GL/yr), representing approximately 3% of the total water contribution.

EMM (2023b) reports the lake has filled in 1878 and 1989, and more recently in October 2022. Any occurrence of surface water or rainfall in Lake Torrens does not recharge groundwater, as evaporation rates exceed recharge potential. The watertable is inferred to occur just below the lake surface, with evaporation sustaining an upward vertical hydraulic gradient (OZL 2017). The uppermost 60 m of groundwater below Lake Torrens is saline, while the groundwater underlying this is hypersaline (SKM 2011).



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Source: EMM (2024); DFSI (2020, 2021); ESRI (2024); GA (2011)

Surface water features

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Groundwater Environmental Assessment Addendum
Figure 2.2

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2.6 Geology

The study area is located within the Neoproterozoic age sedimentary sequences of the Stuart Shelf which overlies the Mesoproterozoic Pandurra Formation and the hard rock, crystalline Archaean Mesoproterozoic units of the Gawler Craton (Jacobs 2016b and Drexel et al. 1993). The OKDUGA Project targets mineralisation of the Gawler Craton comprising an iron oxide copper gold mineralised deposit (Porter GeoConsultancy 2021). There are two target deposits, low grade Oak Dam East and the deeper, higher grade Oak Dam West, which are approximately 4 km apart.

Figure 2.3 shows the outcropping units for the study area and an overview of the study area stratigraphy is included in Table 2.3, with the geological units present within the RL Project Area shown in bold. Publicly available drillhole logs in a 50 km radius from the centre of the RL Project Area were downloaded from WaterConnect and were manually reviewed and assigned formations based on the geological units in Table 2.3. For the OKDUGA modelling and GEA, elevation surfaces representing the top of geological units were created using the publicly available data (EMM 2023b). At the time of the OKDUGA modelling and GEA, geological and groundwater data (level, yield, hydraulic properties) were not available for use (unless the information was in the public domain) due to confidentiality agreements ahead of the merger between BHP and OZL. Due to limited data available at the time of the OKDUGA modelling, the Whyalla Sandstone, Tapley Hill Formation and Pandurra Formation were grouped together to create a “lower sedimentary package” (LSP).

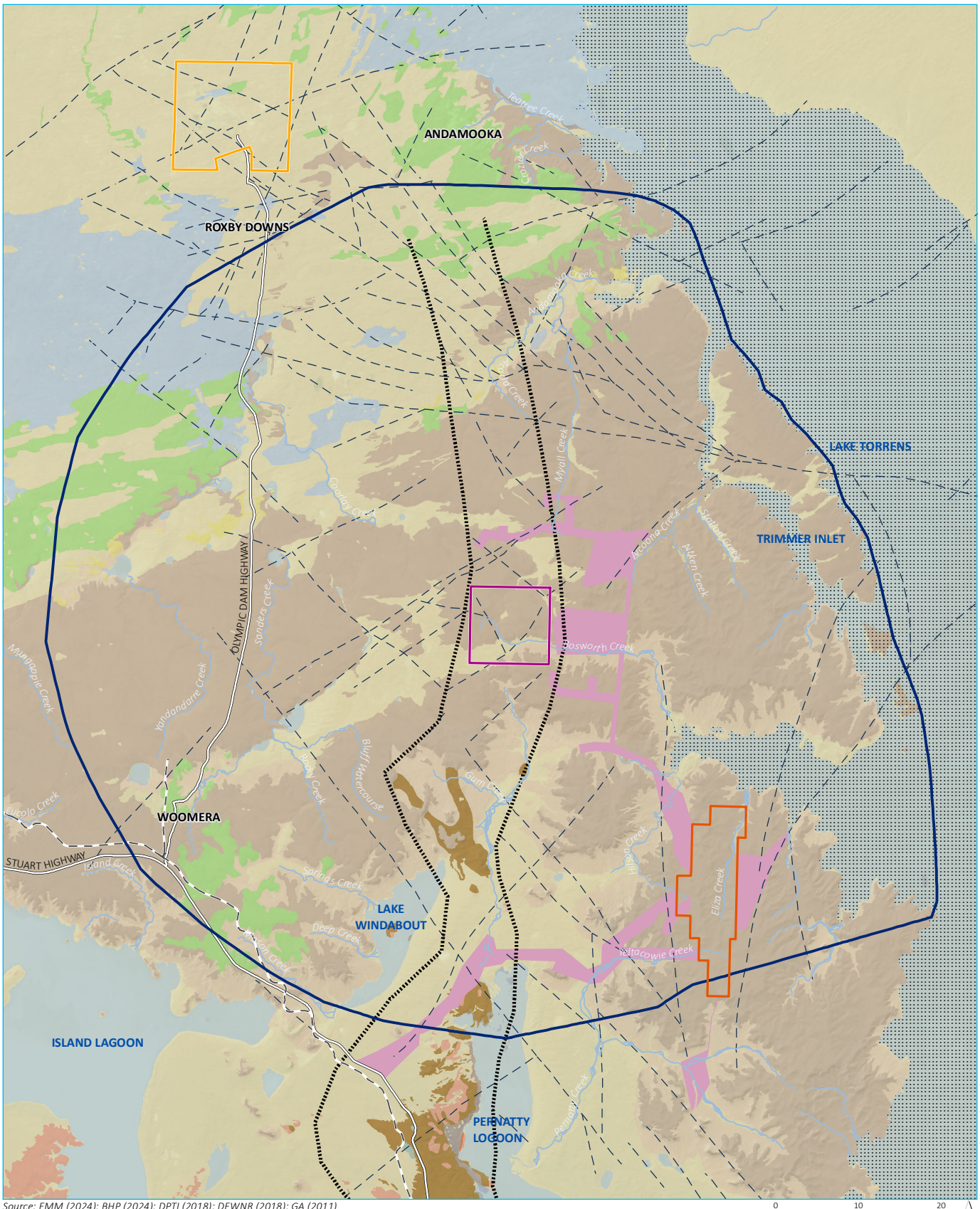
For the OKD LOM model, EMM took the HSU layers developed for the Carrapateena numerical groundwater flow model (which was developed using Carrapateena mineral drillhole data, WaterConnect data and data derived from various Carrapateena groundwater exploration programs) and replaced the area overlapping the RL Project Area and surrounding 2.5 km with HSU elevation data derived from OKD drillhole information. Linear interpolation was then undertaken within the transition zone to create a single consistent dataset that respects both datasets.

Geologic outcrop predominantly comprises Arcoona Quartzite, within some minor and localised overlying Quaternary sediments. The Corraberra Sandstone outcrops in some areas across the study area, mostly in watercourse areas or escarpments where the overlying Arcoona Quartzite has been incised. Andamooka Limestone is present at surface in the north-west, where this unit thickens, but is generally absent in the centre and south of the study area. Small areas of Bulldog Shale outcrop in the north-west and south-east. South of the RL Project Area, the Pandurra Formation outcrops, in association with the Pernatty Upwarp.

The regionally significant Tent Hill and Pandurra Formation sedimentary sequences predominantly comprise quartzites, sandstones and shales, overlying the granitic and crystalline basement at depth (Department of Mines, South Australia 1967). The sedimentary units were deposited under different environmental conditions (e.g. fluvial systems, marine environments, aeolian deposits) and thus there is variable depth and thickness, and a high degree of heterogeneity between the units related to the depositional environment. Furthermore, the geology in the study area has been influenced by post depositional faulting and possibly folding.

To the east of the Pernatty Upwarp, the Woomera/Tregolana Shale and Corraberra Sandstone dips to the east, and the Pandurra Formation thins. The Whyalla Sandstone present at the Carrapateena Mine is not present in the RL Project Area; however, it is present to the west of the Pernatty Upwarp and the RL Project Area.

Although the Stuart Shelf sediments are relatively flat lying, they conceal significant buried structures in the underlying Mesoproterozoic and Paleoproterozoic rocks. Within the RL Project Area the depth to basement fluctuates by up to 500 m and can be found between approximately 900 mAHD and 400 mAHD. The extent and highly variable thickness of the Pandurra Formation (and depth to basement) has been influenced by post depositional folding, faulting and differential erosion, such as the Pernatty Upwarp (Rollison 2016).



KEY

- OKDUGA Project RL
- Carrapateena Mineral Lease 6471
- Carrapateena MPLs
- Groundwater model extent
- SML 1 (Olympic Dam mine)
- Archaean Early Mesoproterozoic faults

Existing environment

- Rail line
- Main road
- Named watercourse
- Named waterbody
- NPWS reserve
- Pernatty Upwarp (approximate)

Surface geology 100k

Quaternary

- Quaternary
- Eyre Formation

Cretaceous

- Bulldog Shale

Cambrian

- Andamooka Limestone

Meso Proterozoic

- Pandurra Formation

Neo Proterozoic

- Corraberra Sandstone Member*
- Woocalla Dolomite Member
- Arcoona/Simmens Quartzite*
- Woomera/Tregolana Shale *
- Whyalla Sandstone
- Nuccaleena Formation*

(* members of the Tent Hill Formation)

Geological outcrop and structure

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Figure 2.3

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Table 2.3 Regional stratigraphy

Period	Formation	Member	Geological description	Thickness (m)
Quaternary		**Undifferentiated**	• Alluvium, gravels and silts of major drainage channels, outwash floodplain deposits. • Sand dunes with claypans. • Lake areas: gypsum, silts and sands. • Generally thin and/or isolated occurrences in the study area.	0–10
Tertiary		Undifferentiated/ Neuroodla Formation/ Cotabena Formation	• Lake and stream deposits comprising sand, silicified conglomerates, grits and sandstone.	0–200
Cretaceous	Bulldog Shale		• White kaolinitic siltstones with erratic rounded boulders; gravels, conglomerates. Shales and carbonaceous clays. • Occurrence is limited to the north and west of the study area, where there is some outcrop.	
Cambrian		Andamooka Limestone	• Cavernous, massive limestones and dolomitic shales. • Occurrence is limited to the north of the study area.	200+
Neo proterozoic	**Tent Hill Formation**	**Arcoona Quartzite**	• Cross-bedded flaggy, fine to coarse grained quartzite and orthoquartzite with shale and clay gall clasts. Massive and abrasive. • Equivalent to Simmens Quartzite Member and ABC Range Quartzite of the Flinders Ranges to the east. • Widespread outcrop across the study area.	20–50
		Corraberra Sandstone	• Red-brown, silty sandstone with interbedded shale and siltstone. • Regionally extensive, with some outcrop in the south.	10–100
		Woomera/Tregolana Shale	• Laminated, purple, brown and green shales partly micaceous. Locally black shale, lenticular brown weathering dolomites. • Regional extensive.	50–300
		Whyalla Sandstone	• Cross-bedded sandstone, rounded and frosted grains, coarse granule lenses and pebbles. • Generally present across the study area, including in the south and portions of the west, but absent in the north of the study area, at the Project area and Northern Well field area. Tonkin and Wallace (2021) note that Williams (1998; and earlier Curtis (1972)) thought the depositional environment was aeolian origin; however, Tonkin and Wallace (2021) describe the formation as being of shallow marine origin, with evidence of glaciomarine incursions. • The Whyalla Sandstone directly overlies the Tapley Hill Formation in the deeper parts of the basin, but through the shallower section above the Pernatty Upwarp, the Tapley Hill Formation was removed by erosion and Whyalla Sandstone lies directly on Pandurra Formation (Tonkin and Wallace 2021).	50–100

Period	Formation	Member	Geological description	Thickness (m)
	Tapley Hill Formation		• Dark grey laminated shale and siltstone, thin dolomitic bands and sandstone. • Minor presence in the study area. Not present above the Pernatty Upwarp. • It represents the first marine transgression of the Stuart Shelf, deposited below wave base.	100–500
		Woolcalla Dolomite	• Thin bedded, flaggy, oolitic dolomite. • Present in some parts of the study area; discontinuous.	50–100
	Beda Volcanics		• Amygdaloidal basalt, interbedded conglomerate that occupy a narrow north-south trending corridor extending from Whyalla to north-east of Mt Gunson. • Appears to only be present in the south-east of the study area. • The Gairdner Dolerite swarm consists of dykes which intrude the Pandurra Formation and are interpreted as feeders to the Beda Basalt (Tonkin and Wallace 2021).	0–240 (in the south-east)
Mesoroterozoic	**Pandurra Formation**		• Cross-bedded grits, red-purple quartzite, sandstone, pebbly grits. Deeply weathered near unconformity surfaces. • Present across most of the study area; not present at the Carrapateena Mine. • Fluvial deposit (braided river, alluvial fan, aeolian and lake environments), with sediments derived from erosion of the Gawler Range Volcanics and similar units on the Gawler Craton.	0–1,000
		Basement and Gawler Range Volcanics	• Crystalline basement, basic and felsic volcanics, pyroclastic rocks, granite, rhyodacite and basaltic lavas.	Unknown

Notes: Source: SARIG and Department of Mines, South Australia 1967, Rollison 2016 and Jacobs 2016b.

Bold = HSUs present in OKDUGA RL and MPL Project Area.

2.6.1 Faults and structures

Massive structural forces have resulted in regional and local faulting; the major faulting system within the region is the Torrens Fault associated with the Torrens Hinge Zone. The Torrens Hinge Zone, which underlies Lake Torrens, is a complex structure up to 2 km wide that has controlled sedimentation and deformation during the Adelaidean, early Proterozoic and Cainozoic eras (Drexel et al 1993). This is an extensive zone of south north faulting and deformation that coincides with Lake Torrens and forms the eastern boundary of the Gawler Craton (Jacobs 2016b).

A roughly north south trending series of host blocks that have been uplifted to shallower depths are associated with the Pernatty Upwarp (Jacobs 2016a, OZL 2017), which is an approximate north south complex horst structure expressed as an uplift of the Pandurra Formation (see Figure 2.4). Review of the OKDUGA bore logs indicates there is a localised low in the top of the Pandurra Formation, potentially comprising a block feature that has dropped relative to the surrounding strata within the northern half of the RL Project Area. Uplift is likely to have led to a degree of geologic deformation, predominantly faulting, within the overburden Neoproterozoic and Mesoproterozoic sedimentary sequences (Kellett et al 1999).

Along the margins of the Pernatty Upwarp structural feature, the lower strata of the Neoproterozoic sequence, including the Whyalla Sandstone, pinch out against redbeds of the Pandurra Formation (Figure 2.4). The underlying presence of the Upwarp is reflected in outcrop patterns of the upper sequence of the Stuart Shelf sediments. This reflection appears as an embayment in the southern margin of the Arcoona Plateau. This embayment directly overlies the crest of the Pernatty Upwarp, which suggests the Upwarp was responsible for faulting in the overlying sediments, resulting in accelerated erosion and removal of the sediments (Tonkin and Wallace 2021).

Faults mapped within the study area include Archaean to Early Mesoproterozoic faults and Middle Mesoproterozoic faults, and are shown in Figure 2.3. Numerous lineaments referred to as Stuart Shelf lineaments have also been mapped within the study area. Faults and lineaments typically trend in two distinct directions: north-west to south east, or north east.

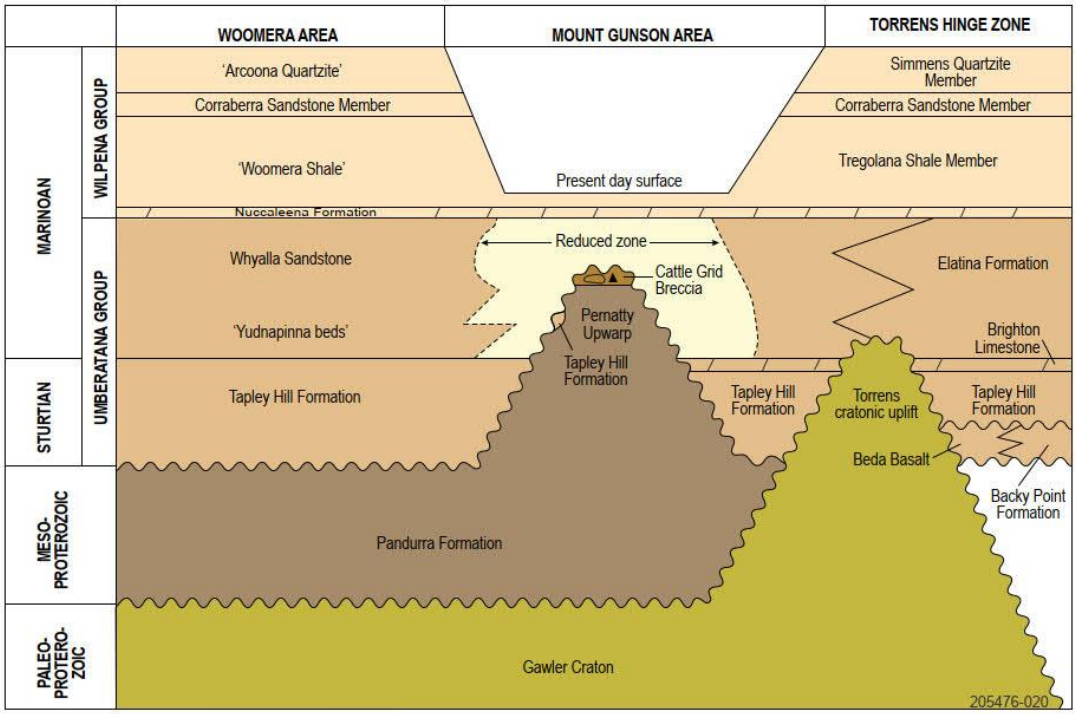


Figure 2.4 **Illustration of stratigraphic column showing the erosional gap above the buried Pernatty Upwarp (Tonking and Wallace 2021)**

3 Hydrogeology

3.1 Regional hydrostratigraphic units

The main groundwater systems within the study area are hosted by the sedimentary units of the Stuart Shelf, which overlie the hard rock lithologies of the Gawler Craton.

A summary of the regional HSUs is included in Table 3.1.

Table 3.1 Regional hydrostratigraphic units

Name	Type	Thickness within study area (m)	Salinity	Description/notes
Unconsolidated sediments	Unconfined, shallow aquifer	0–10	Brackish, owing to the relatively younger groundwater age and recharged locally by rainfall	Spatially discontinuous and often unsaturated. Shallow groundwater lenses may occur, post rainfall events.
Andamooka Limestone	Aquifer	Up to 300	Hypersaline	Present in northern part of the study area towards Olympic Dam.
Arcoona Quartzite	Aquitard	0–200	Brackish to hypersaline	The upper Arcoona Quartzite is unfractured. Forms a superficial cap and is inferred to act as a confining unit.
Tent Hill Aquifer (THA)	Aquifer	0–150	Saline to hypersaline	This HSU includes the lower white Arcoona Quartzite and Corraberra Sandstone. Can be unconfined to confined, depending on the presence of the upper Arcoona Quartzite.
Woomera/ Tregolana Shale	Leaky aquitard	Up to 350	Hypersaline	Regionally extensive.
Whyalla Sandstone Aquifer (WSA)	Aquifer and aquitard	Up to 200	Hypersaline	Not present in the RL Project Area Northern Wellfield areas, limited to the south of the Carrapateena Arm of Lake Torrens and further west of the RL Project Area. The upper Whyalla Sandstone aquifer is a fractured rock aquifer with limited primary porosity and hydraulic conductivity. Groundwater flow is predominantly via secondary porosity. The lower Whyalla Sandstone has only been observed in the Carrapateena Mine area and is observed to have higher primary porosity than the upper Whyalla Sandstone.
Tapley Hill	Aquitard	0–100	Hypersaline	Minor presence in study area.
Beda Volcanics	Aquitard (inferred)	0–240	Unknown, expected to be hypersaline	Not present in RL Project Area and Northern Wellfield areas, minor present in the south of the study area.
Pandurra Formation Aquifer (PFA)	Aquifer	0–1,000	Saline to hypersaline	Confined, regional fractured rock aquifer.
Gawler Range Volcanics	Aquitard	Unknown	Unknown, likely hypersaline	Hosts target orebody.

The main water bearing aquifers in the RL Project Area and Northern Wellfield area comprise the THA (i.e. the lower fractured portion of the Arcoona Quartzite and the Corraberra Sandstone) and the PFA. More regionally (in the study area), the WSA is also considered a productive aquifer (where fractures are encountered). The THA is separated from the WSA and PFA by the regionally extensive Woomera/Tregolana Shale leaky aquitard.

Local, perched and disconnected aquifers (in some areas) can occur in sand dune areas or in alluvial sediments adjacent to and underlying watercourses. These are also considered to be shallow perched groundwater systems. However sand dunes and/or alluvial sediments are spatially discontinuous. Groundwater in these disconnected aquifers is expected to be seasonal and highly dependent on rainfall, runoff and surface water flow events. These fresher groundwater lenses are generally hydraulically disconnected from the regional saline groundwater system due to the upper Arcoona Quartzite which forms an aquitard to the underlying THA.

3.2 Groundwater investigations

3.2.1 OKDUGA

Within the RL Project Area, 13 site exploration drillholes were drilled between 2010 and 2022, with geological formations logged. A further 21 exploration drillholes were drilled between 1976 and 2010 across the site, with some geological information available. There are two registered groundwater bores (6336 27 and 6336 28) documented on the WaterConnect database drilled in the late 1950s into the THA. These are listed as abandoned.

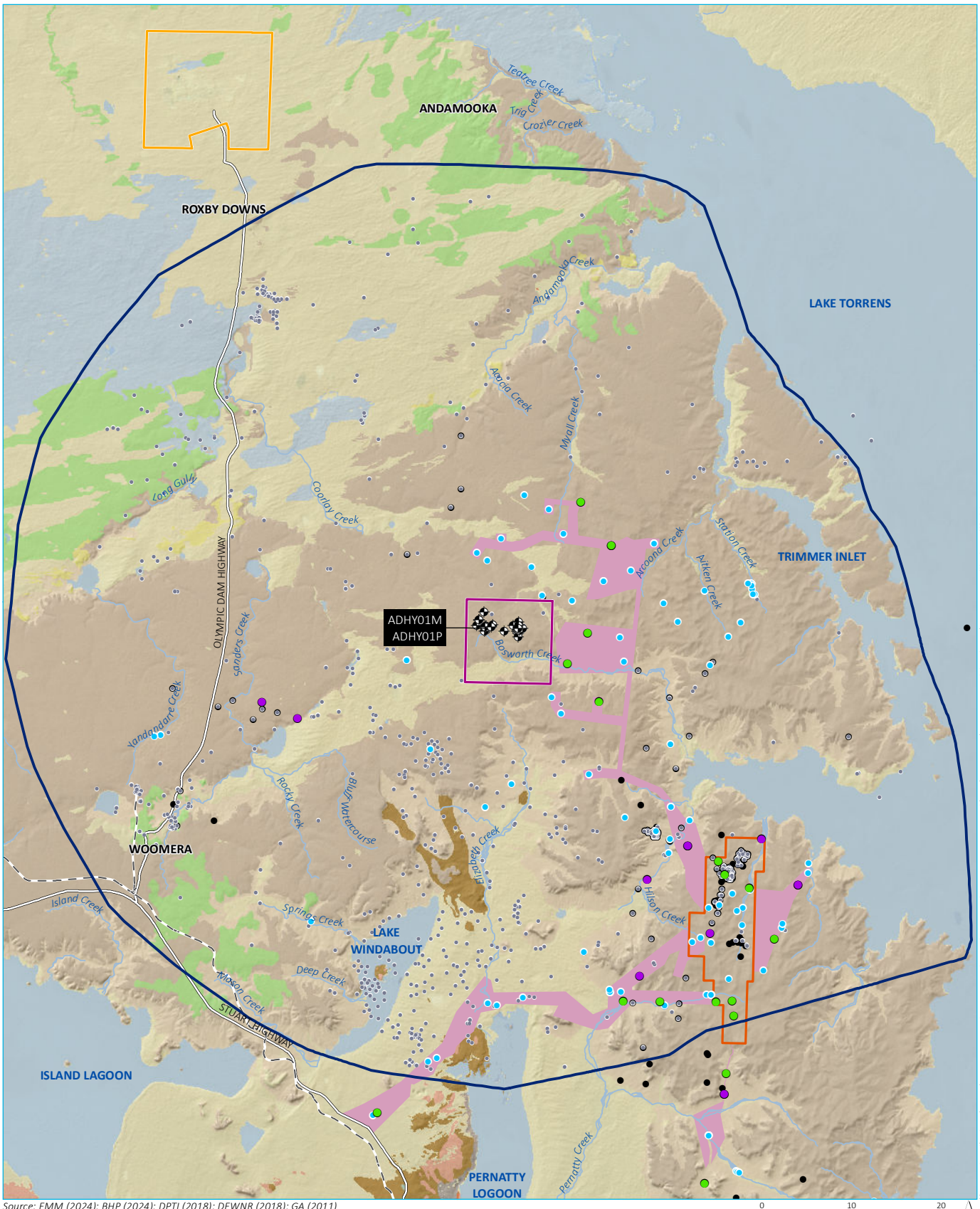
All known OKDUGA groundwater installations and mineral exploration holes are shown in Figure 3.1, along with other bores listed in WaterConnect. Drill holes with an ‘AD’ prefix are exploration holes. ADHY01 was drilled in July 2022 and has been converted into a groundwater monitoring bore, ADHY01M, targeting the PFA. An additional well, ADHY01P was subsequently drilled adjacent to ADHY01M. It also targeted the PFA.

3.2.2 Carrapateena

Since 2012, OZ Minerals Ltd (the then owner of the Carrapateena Mine) conducted numerous mineral and groundwater exploration drilling programs.

The Carrapateena Mine requires water for mineral processing, construction, dust suppression, road maintenance and accommodation purposes. Water is sourced from:

- Groundwater intercepted by underground mining operations.
- Radial Wellfield – providing the primary water supply for the mine during construction and operation, with groundwater supply being sourced from the THA and the WSA.
- Western Infrastructure Corridor (WIC) production wells – providing water to support construction and maintenance of the WIC, installed in the THA and WSA.
- Southern Access Road wells – providing water to maintain the Southern Access Road (as needed), installed in the THA and WSA.
- Northern Wellfield – acting as a supplementary water supply for the mine during operations, with groundwater supply being sourced mainly from the PFA and some wells installed in the THA.



Source: EMM (2024); BHP (2024); DPTI (2018); DEWNR (2018); GA (2011)

0 10 20 km

GDA2020 MGA Zone 53

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KEY

- OKDUGA Project RL
- Carrapateena Mineral Lease 6471
- Groundwater model extent
- Carrapateena MPLs
- SML 1 (Olympic Dam mine)
- WaterConnect drillhole/well location
- Oak Dam groundwater and geology drillhole
- Carrapateena mineral drillhole
- Carrapateena groundwater investigation hole
- Carrapateena monitoring well
- Carrapateena production well
- Rail line
- Major road
- Named watercourse
- Named waterbody

Surface geology 100k

Quaternary
- Quaternary
- Eyre Formation

Cretaceous
- Bulldog Shale

Cambrian
- Andamooka Limestone

Meso Proterozoic
- Pandurra Formation

Neo Proterozoic
- Corraberra Sandstone Member*
- Arcoona/Simmens Quartzite*
- Woomera/Tregolana Shale *
- Whyalla Sandstone
- Nuccaleena Formation*

(* members of the Tent Hill Formation)

Geological drillhole and wellfield locations

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Groundwater Environmental Assessment Addendum
Figure 3.1

EMM creating opportunities

Under the approved PEPR, BHP (then OZL) has approval to abstract up to 11 ML/d of groundwater to meet operational water demands, with up to 7 ML/d sourced from the Northern Wellfield. Permeate water is approved to be disposed of via a reverse osmosis desalination plant (RO plant) and injection wells within the Carrapateena Mine ML but does not occur at the Northern Wellfield.

The Northern Wellfield, which is of most interest to the OKDUGA Project, currently consists of six production wells within MPL 156 (with existing pilot wells drilled and identified for conversion to production wells as/when demand increases):

- NT 2P (installed in the THA)
- NT 4P THA
- NT 4P PFA
- NT 8P (installed in the PFA)
- NT 10P (installed in the PFA)
- NT 17P (installed in the PFA).

The existing Carrapateena well network (present in the study area), including monitoring and production wells, is shown on Figure 3.1.

The number of wells installed within each HSU, informing the conceptual understanding of the regional hydrogeology for the Carrapateena numerical groundwater flow model, and subsequently the repurposed OKD LOM model for the OKDUGA Project is summarised in Table 3.2.

Table 3.2 Carrapateena groundwater well network

Hydrostratigraphic unit	Well purpose	Number of wells installed
Quaternary (alluvial) sediments	Baseline monitoring	5
Arcoona Quartzite	Baseline monitoring	5
	TSF monitoring	5
Tent Hill Aquifer	Baseline monitoring	4
	Compliance	6
	Observation	15
	Planned	1
	Production/injection	14
	TSF monitoring	3
Woomera Shale	Baseline monitoring	4
	Compliance	1
Whyalla Sandstone	Compliance	4
	Observation	5
	Production	5

Hydrostratigraphic unit	Well purpose	Number of wells installed
Pandurra Formation	Baseline monitoring	3
	Observation	7
	Planned	2
	Production	5
Open across multiple HSUs (e.g. WSA and PFA)	Baseline monitoring	2
	Observation	2
Total		**98**

3.3 Groundwater quality

The groundwater in all HSUs, except for the Quaternary sediments, is saline to hypersaline. Only shallow groundwater associated with Quaternary sediments meets the beneficial use classification for stock watering purposes (when compared to SA EPA 2015/ANZG 2018, based on total dissolved solids alone). Spatial distribution of groundwater salinity data reported on WaterConnect, and data collected for the OKDUGA Project and from Carrapateena Mine are presented in Figure 3.2 for the THA and Figure 3.3 for the PFA (where multiple data measurements are available, average salinity is shown). Water sampling from ADHY01M and ADHY01P, within the RL Project Area, reports a neutral pH (averaging 7.7 pH units) and saline electrical conductivity (approximately 25 mS/cm in the THA and 75 mS/cm in the PFA (recorded during drilling at ADHY01M)). A water sample collected from ADHY01P, sent for laboratory water quality analysis, reported a salinity of 153 mS/cm (representative of the PFA).

Jacobs (2016a) documents hypersaline brines within the basin sediments and bounding rocks near Lake Torrens. The brine is inferred to have resulted from an influx of high salinity groundwater and evaporative concentration of salts from the shallow watertable in the lake sediments over time (Jacobs 2016a).

Water quality monitoring for Carrapateena has recorded salinities:

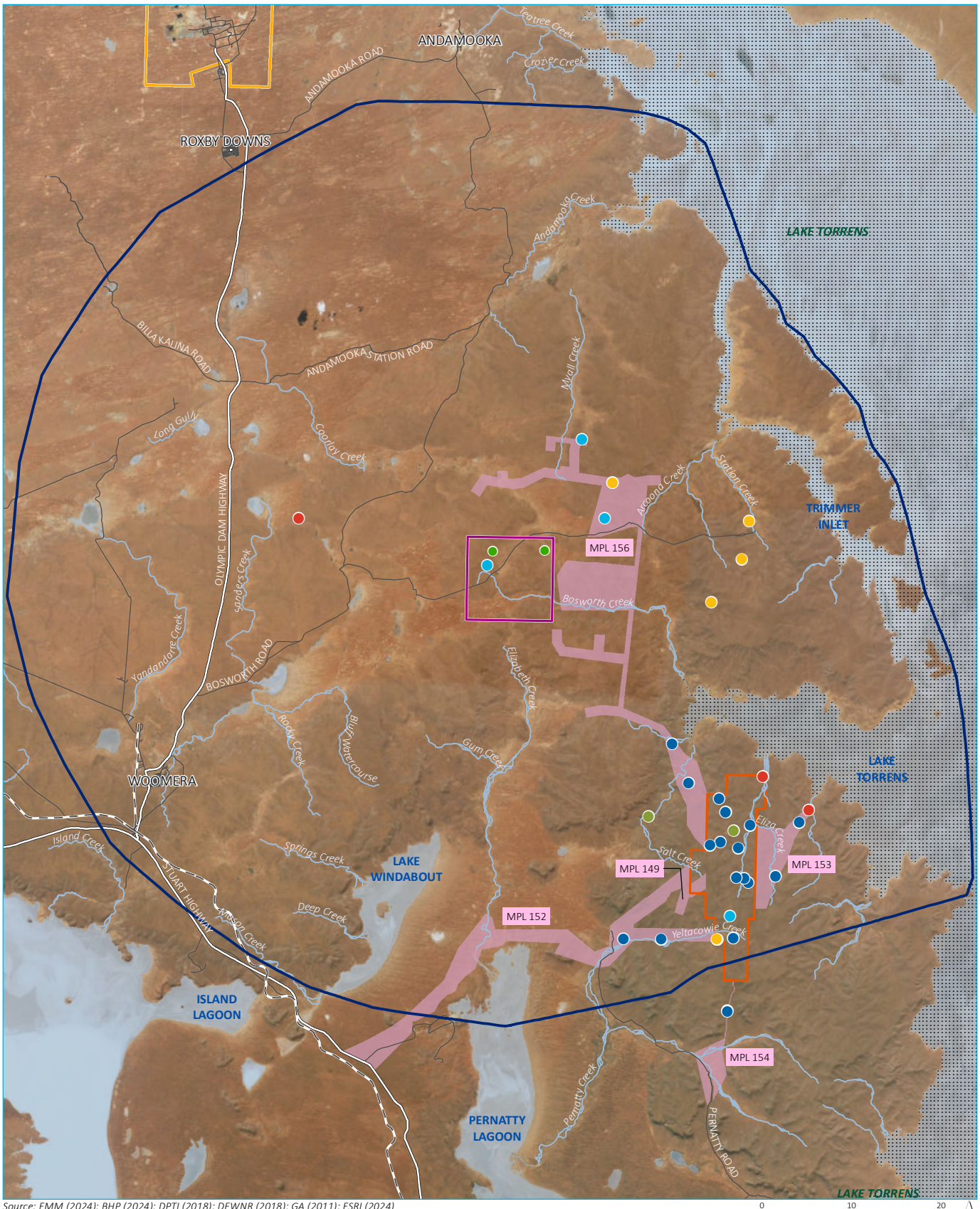
- averaging 35,000 µS/cm in the THA
- up to 200,000 µS/cm in the THA west of RL Project Area and the Northern Wellfield (at ENV N4) and around 150,000 µS/cm near Lake Torrens in the Carrapateena ML
- up to 200,000 µS/cm in the WSA (at MD3 near Lake Torrens, with salinities up to 350,000 µS/cm recorded during drilling at MD3)
- averaging 92,000 µS/cm in the PFA
- up to 195,000 µS/cm in the PFA (at NT 5P).

Groundwater sampled from the THA, WSA, PFA and Woomera/Tregolana Shale for Carrapateena has a relatively consistent ionic composition comprising sodium (Na) – chloride (Cl) type. Saline and sodium chloride dominant waters are typical of arid and semi-arid areas where recharge rates are low (due to low rainfall and high evaporation), and residence times are long. Data from the Carrapateena Mine also indicate that groundwater has ‘high’ or ‘very high’ alkalinity and low levels of nitrate and nitrite, in addition to high proportions of dissolved versus total iron and manganese, which suggests that mildly reducing conditions exist in the deeper HSUs. Average groundwater chemistry comparison by HSU from Carrapateena is provided in Table 3.3.

Table 3.3 Average groundwater chemistry comparison by HSU (Carrapateena)

Analyte	Units	Arcoona Quartzite	THA	Woomera/ Tregolana Shale	WSA	PFA
No. of wells exclusively screened		**8**	**42**	**4**	**15**	**9**
Electrical conductivity	mS/cm	11.2	47.1	41.4	58.7	79.8
pH	-	7.2	6.7	7	6.7	6.5
Total alkalinity	mg/L	370	180	160	120	130
Sulphate as SO_4	mg/L	720	3,260	3,110	2,850	3,290
Chloride	mg/L	1,460	37,570	13,750	21,700	38,940
Calcium	mg/L	80	1,480	1,215	1,520	2,180
Magnesium	mg/L	40	1,120	830	1,670	1,760
Sodium	mg/L	1,290	20,600	7,500	13,400	20,100
Potassium	mg/L	7	80	60	90	190
Nitrate and Nitrite as N	mg/L	2.1	0.03	0.03	0.03	<0.01
Ammonia as N	mg/L	<0.1	0.5	1.3	1.1	1.9
Aluminium – dissolved	mg/L	<0.1	<0.1	0.02	<0.1	0.2
Iron – total	mg/L	1.5	6.1	4.4	3.7	6.0
Iron – dissolved	mg/L	0.2	4.5	3.1	3.3	3.2
Manganese – total	mg/L	0.1	1.0	0.4	2	12.3
Manganese – dissolved	mg/L	0.1	1.1	0.4	2	10
Zinc – dissolved	mg/L	0.03	1	0.15	0.4	1.9

Notes: THA = Tent Hill Aquifer; WSA = Whyalla Sandstone Aquifer; PFA = Pandurra Formation Aquifer.

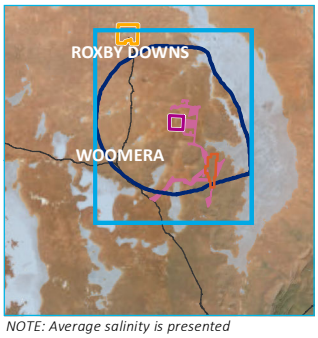


Source: EMM (2024); BHP (2024); DPTI (2018); DEWNR (2018); GA (2011); ESRI (2024)

0 10 20 km

GDA 1994 MGA Zone 53

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NOTE: Average salinity is presented

KEY

- OKDUGA Project RL
- Carrapateena Mineral Lease 6471
- Carrapateena MPLs
- SML 1 (Olympic Dam mine)
- Groundwater model extent
- Rail line
- Major road
- Minor road
- Named watercourse
- Named waterbody
- NPWS reserve

THA EC (mS/cm)

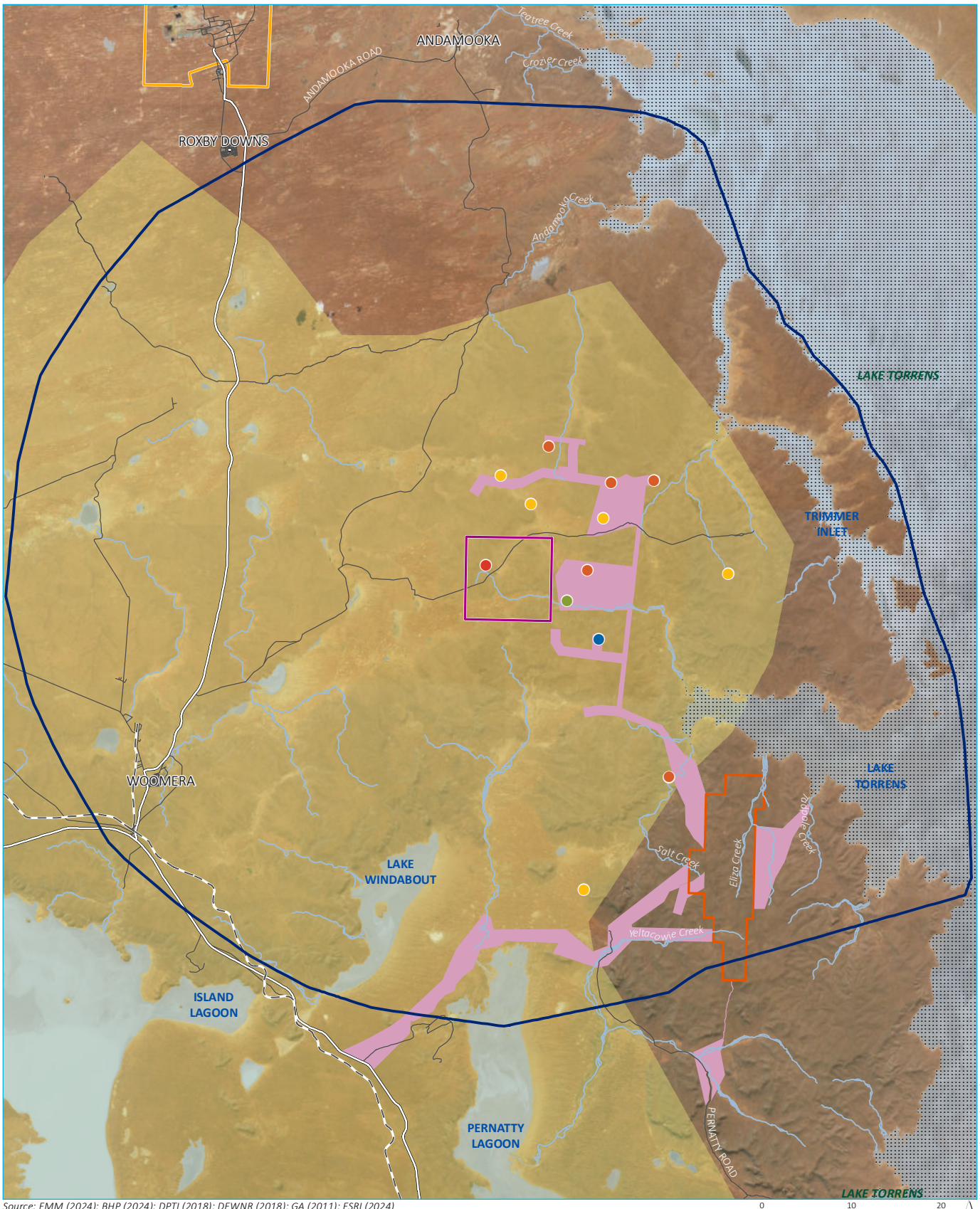
- 0 to 30
- 30 to 40
- 40 to 50
- 50 to 100
- >100

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Spatial distribution of THA groundwater salinity

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Groundwater Environmental Assessment Addendum
Figure 3.2

EMM
creating opportunities



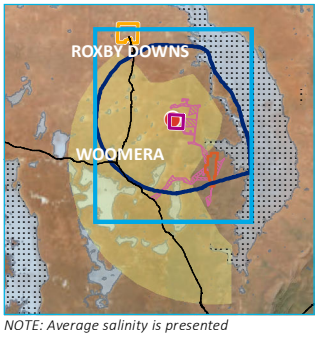
Source: EMM (2024); BHP (2024); DPTI (2018); DEWNR (2018); GA (2011): ESRI (2024)

0 10 20 km

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NOTE: Average salinity is presented

KEY

- OKDUGA Project RL
- Carrapateena Mineral Lease 6471
- Carrapateena MPLs
- SML 1 (Olympic Dam mine)
- Groundwater model extent
- Rail line
- Major road
- Minor road
- Named watercourse
- Named waterbody
- NPWS reserve
- Inferred PFA extent

PFA EC (mS/cm)

- 30 to 40
- 40 to 50
- 50 to 100
- >100

Spatial distribution of PFA groundwater salinity

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Groundwater Environmental Assessment Addendum
Figure 3.3

EMM creating opportunities

3.4 Groundwater levels and flow

Groundwater level and flow data rely on regional measurements collected at the time of well installation, reported on WaterConnect, as well as monitoring data from Carrapateena.

3.4.1 Groundwater flow direction

i Density corrections

Groundwater flows from high hydraulic head to low hydraulic head. In freshwater, the depth to groundwater level can be simply converted to a groundwater elevation using a known datum. However, groundwater salinity can affect density, and therefore groundwater pressure. Therefore, in high salinities like those measured in the study area, it is necessary to correct the measured groundwater level data for the density of the groundwater column above the measurement point.

Hydraulic head in locations of variable density can be expressed as an equivalent freshwater head, using the following equation (Post & Simmons 2022):

$$h_i = z_i + h_{p,i} = z_i + \frac{p_i}{\rho_i g}$$

Where $h_{p,I}$ represents pressure head for a piezometer at location I containing a fluid column with density ρ_i, so it is the height of the fluid column above the z_i coordinate, typically taken as the centre of the piezometer screen (Plate 3.1).

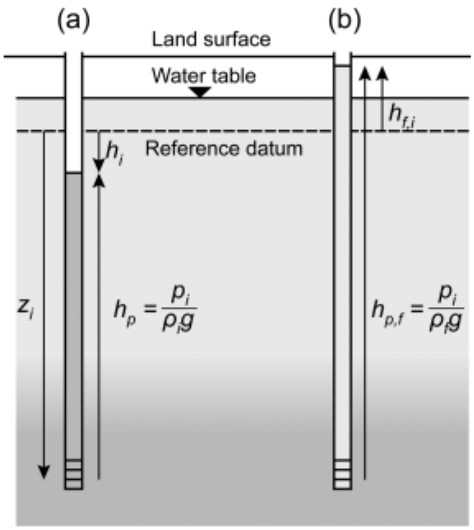


Plate 3.1 Density effects

Plate 3.1 shows a piezometer filled with (a) water of the same density as the groundwater at the well screen, indicating point-water head and (b) freshwater, indicating equivalent freshwater head (Post & Simmons 2022).

In order to convert measured groundwater level data to equivalent freshwater heads, EMM adopted the following workflow:

- For wells with multiple salinity measurements (e.g. from the Carrapateena monitoring data), the **median measured salinity** was adopted as a constant value for calculating equivalent freshwater heads over time.
- For wells with a single salinity measurement, this value was adopted for calculating equivalent freshwater head (including head over time).

- Within each HSU, the **median measured salinity across the available dataset** was adopted as the assumed salinity for wells with no salinity data (e.g. for some WaterConnect data).

- Where wells do not have screen/construction information (e.g. data from WaterConnect), the **centre elevation of the geological unit** (as described in Section 2.6) was adopted as the measurement datum for calculating freshwater head.

The data used to inform the density correction calculations for the OKDUGA Project are provided in Appendix E, along with a worked example.

ii Regional evaluation

Groundwater flow contours of equivalent freshwater head (i.e. following density correction) were prepared for the study area. Data were obtained from publicly available sources (i.e. WaterConnect) and Carrapateena groundwater monitoring data (pre-stress, i.e. prior to effects of pumping from the Northern Wellfield or the Carrapateena Mine). Within the study area, the inferred groundwater flow direction for the THA is generally towards the north-east and east towards Lake Torrens (Figure 3.4), where groundwater discharges at surface and evaporates at Lake Torrens. The influence of mining at Olympic Dam (prior to groundwater abstraction for Carrapateena) on groundwater flow in the THA is also evident. There is fewer data available for the PFA, especially west of the RL Project Area. Based on available data, groundwater flow (east of the RL Project Area) is also towards Lake Torrens to the east (Figure 3.5). Based on available literature (and groundwater flow directions observed in the WSA), groundwater flow in the PFA in the study area is inferred to be west to east; however, this should be reviewed as additional data become available.

The inferred saltwater brine wedge that occurs beneath Lake Torrens (refer to Section 3.3) complicates groundwater flow dynamics in the vicinity of the lake. Specifically, the brine wedge is inferred to cause fresher groundwater to move up and over the wedge near to the lake to discharge into shallow lake sediments (BHP Billiton 2011).

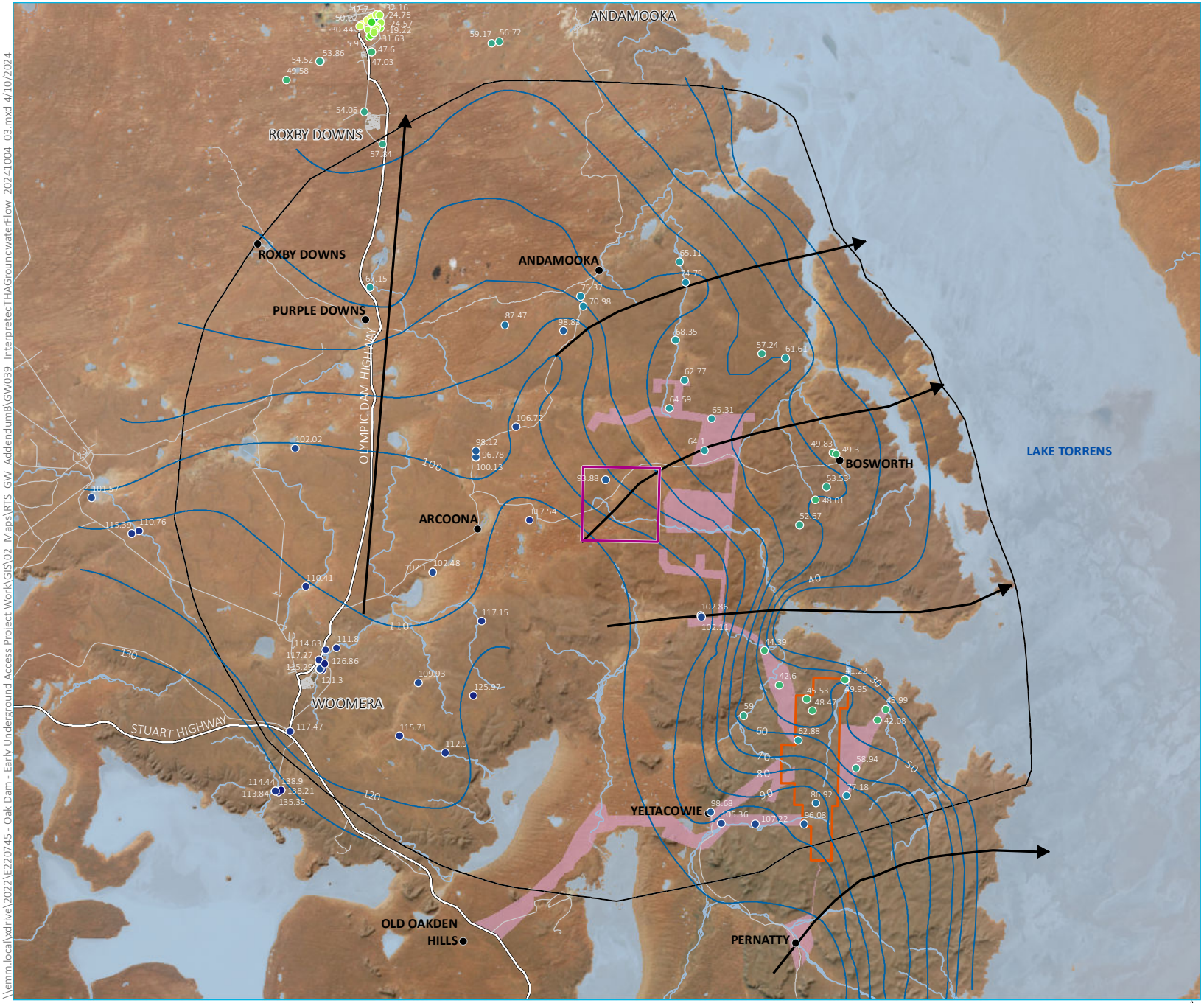
iii RL project area

The watertable within the uppermost aquifer, typically the THA, ranges from 7 to 104 metres below ground level (mbgl) within the RL Project Area. EMM reviewed the dip data from the two OKD wells (ADHY01M and ADHY01P), which had measured depths to groundwater of around 83 m and 104 m respectively (on 7 August 2023). When corrected for density (referencing a salinity of ~150,000 mg/L TDS reported on the Certificate of Analysis from a water sample collected from ADHY01P) and assuming a ground surface elevation of 160 mAHD these result in equivalent freshwater hydraulic heads of:

- ADHY01M: 88.8 mAHD

- ADHY01P: 85.5 mAHD.

Allowing for effects of the operating Northern Wellfield on the groundwater elevations at Oak Dam, these equivalent freshwater head elevations of between 85 and 89 mAHD compare fairly well with density-corrected regional groundwater elevation data (e.g. from Carrapateena and/or WaterConnect). ADHY01M and ADHY01P have been excluded from the development of the density-corrected contours in this report iteration as they were being drilled at the time the model was being developed.



KEY

- OKDUGA Project RL
- Carrapateena Mineral Lease 6471
- Carrapateena MPLs
- Groundwater level (mAHD)
- Flow direction arrow

Existing environment

- Homestead
- Major road
- Minor road
- Named watercourse
- Waterbody

Well (observation/production GWL mAHD)

- <-50.0
- -49.9 - -40.0
- -39.9 - -30.0
- -29.9 - -20.0
- -19.9 - -10.0
- -9.9 - 0.0
- 0.0 - 10.0
- 10.0 - 20.0
- 40.0 - 50.0
- 50.0 - 60.0
- 60.0 - 70.0
- 70.0 - 80.0
- 80.0 - 90.0
- 90.0 - 100.0
- 100.0 - 110.0
- 110.0 - 120.0
- 120.0 - 130.0
- 130.0 - 140.0

Interpreted THA equivalent fresh-water head and groundwater flow

Source: EMM (2024); BHP (2024); DIT (2024); DEW (2024); GA (2011); ESRI (2024)

0 10 20 km

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Groundwater Environmental Assessment Addendum
Figure 3.4

EMM creating opportunities



KEY

- OKDUGA Project RL
- Carrapateena Mineral Lease 6471
- Carrapateena MPLs
- Groundwater model extent
- Groundwater level (mAHD)
- Flow direction arrow

Existing environment

- Homestead
- Major road
- Minor road
- Named watercourse
- Waterbody

Well (observation/production GWL mAHD)

- 50.0 - 60.0
- 60.0 - 70.0
- 80.0 - 90.0
- 90.0 - 100.0
- 100.0 - 110.0

Source: EMM (2024); BHP (2024); DPTI (2018); DEWNR (2018); GA (2011); ESRI (2024)

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Interpreted PFA equivalent fresh-water head and groundwater flow

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Figure 3.5

EMM creating opportunities

iv Vertical gradients

The equivalent freshwater head contours presented in the above section indicate an upward gradient from the PFA towards the THA. Review of the contours across the Northern Wellfield indicates the PFA elevations are higher than the THA elevations. Drawdown associated with operation of the wellfield has resulted in a downward vertical hydraulic gradient near some production wells.

3.4.2 Temporal trends

Historical groundwater level monitoring undertaken for the Carrapateena Mine observed that groundwater levels in the shallow Quaternary sediments underwent rapid fluctuations by up to 1 m in response to direct rainfall recharge (Figure 3.6). Hydrographs from the THA, PFA, WSA and Woomera/Tregolana Shale HSUs show that groundwater levels are generally stable and seasonal variations are not evident. Some regional groundwater level decline is evident in association with groundwater abstraction for construction and mine water supply purposes.

Hydrographs (density corrected heads) from selected Carrapateena monitoring wells are presented in Figure 3.6, and show such trends as the following:

- NT 8Obs is the observation well adjacent to production well NT 8P installed in the PFA. Groundwater level monitoring data shows drawdown and water level fluctuations associated with production well operation.
- ENV N11 is a leading indicator monitoring well installed in the WSA west of the RL Project Area and shows an overall declining trend. This monitoring well is located approximately 17 km from the closest production well, NT 17P which abstracts water from the PFA.
- PI 8 Obs is also a leading indicator well installed in the THA and located closer to the Carrapateena Mining Lease. Groundwater levels have been relatively stable at PI 8 Obs.
- B THA is also a leading indicator well installed in the THA and located on the Bosworth pastoral lease, closer towards Lake Torrens. Groundwater levels have been relatively stable since well installation in 2019.
- B ALL is currently a leading indicator well installed in the weathered Arcoona Quartzite, near B THA and a Bosworth pastoral well (Garden Well, replaced in 2021 and renamed “New Garden Well”) and farm dam located on Bosworth Creek that fills following rainfall events. The measured groundwater level response at B-ALL is inferred to show effects from pumping from “New Garden Well” and then a rising trend due to recharge from leakage from the nearby farm dam and creek flow following large rainfall events. During those times of higher rainfall and capture of runoff in the nearby dam, it is assumed pumping from “New Garden Well” would also reduce or cease, which could be a factor contributing to the observed rising trend. The monitoring at B ALL and B THA also indicate that the weathered Arcoona Quartzite doesn’t appear to be connected with the underlying THA.

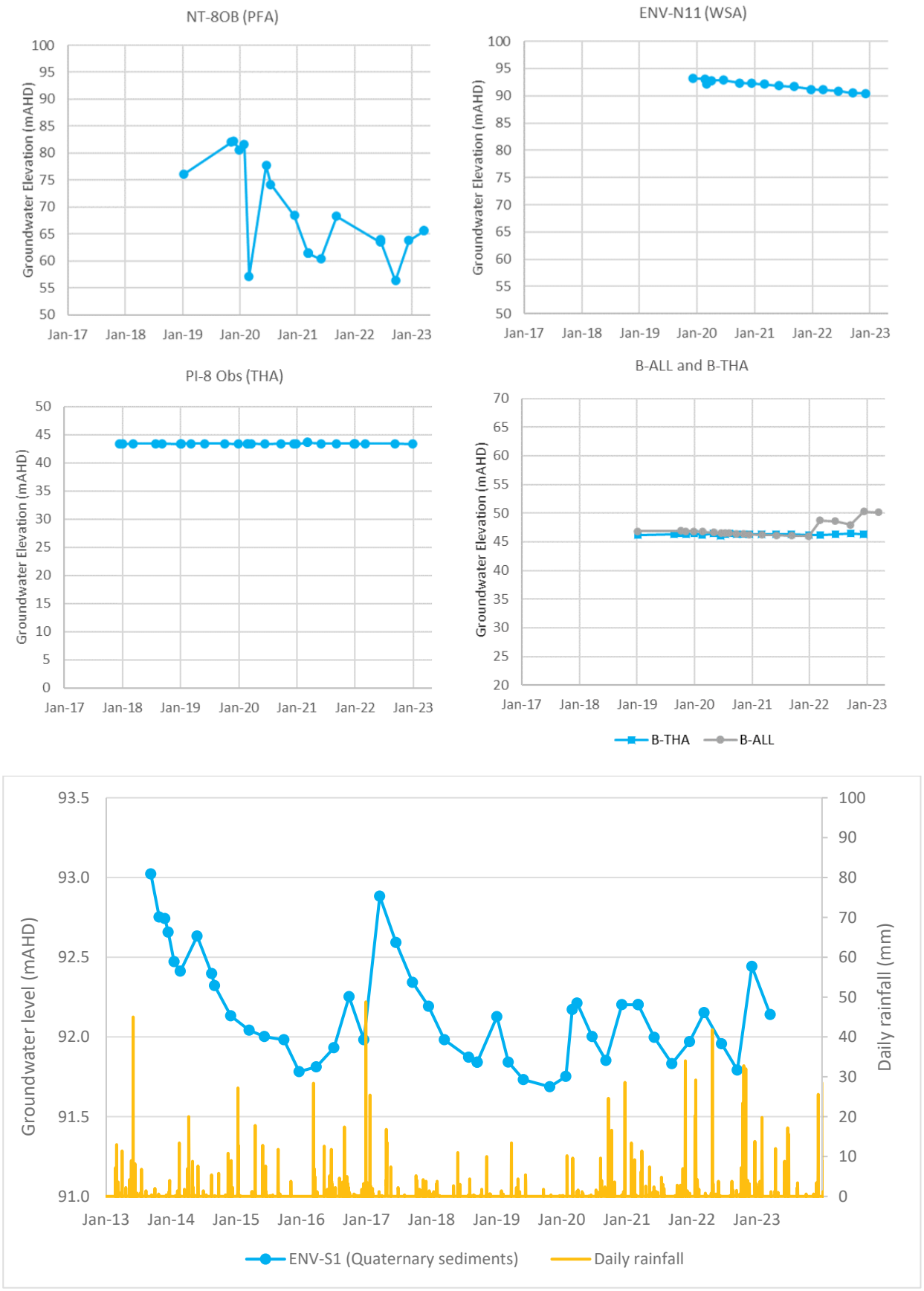


Figure 3.6 **Hydrographs from selected Carrapateena and regional monitoring locations**

3.5 Recharge and discharge mechanisms

Groundwater recharge in the Stuart Shelf area is very low due to low rainfall and high potential evaporation rates, and is expected to vary considerably across the region, with some areas capable of accumulating rainfall runoff (e.g. sand dunes and where lithologies outcrop) resulting in higher infiltration rates. Recharge to the groundwater systems in the study area is expected to occur primarily via rainfall infiltration following significant rainfall events and has historically been estimated to be around 0.1 to 0.4 mm/yr (OZL 2017, Eco Logical Australia 2021, CDM Smith 2018).

Rainfall recharge for Carrapateena was assessed using the chloride mass balance method (Scanlon et al 2002). The method assumes chloride concentrations in groundwater arise from aerosols and precipitation with negligible contributions from rock weathering and anthropogenic sources. This assumption allows the estimation of recharge based on the mass of chloride measured in groundwater. Recharge estimates were derived using the median value of chloride concentrations measured at wells from each HSU. Assuming an average rainfall rate of 185 mm/year, a rainfall chloride concentration of 7.5 mg/L, the following summarises the geometric mean of the calculated recharge rate for each HSU:

- Quaternary sediments/pastoral wells: 0.4 mm/yr
- THA: 0.07 mm/yr
- Woomera/Tregolana Shale: 0.06 mm/yr
- WSA: 0.09 mm/yr
- PFA: 0.04 mm/yr.

Where outcrop occurs, the THA receives direct rainfall recharge; however in areas where the THA does not outcrop, the surficial quartzite cap of the Arcoona Quartzite forms an aquitard, limiting groundwater recharge to underlying units where present. Furthermore, leakage from the Woomera/Tregolana Shale is inferred to act as a recharge source to the underlying PFA and/or WSA (when downward gradients are present).

Based on the groundwater flow directions (refer to Section 3.4), groundwater in the study area is inferred to discharge primarily to Lake Torrens. Ephemeral creek lines, that run towards the lakes, may act as evaporative discharge features where the watertable is near surface, particularly in their lower reaches. Minor groundwater discharge as springs is also observed within the study area (Gorge Spring and Euro Spring). Evapotranspiration is also expected to occur where the depth to the watertable is shallow (i.e. less than 2–3 m below ground surface) (Canadell et al. 1996). Smaller playa lakes, such as Lake Windabout and Pernatty Lagoon, are inferred to act generally as throughflow systems with minor groundwater discharge occurring at these features.

Groundwater abstraction associated with mine dewatering and Northern Wellfield operation is another source of outflow from the groundwater system.

3.6 Hydrogeological properties

3.6.1 Hydraulic conductivity, storativity and specific yield

Hydraulic conductivity, storativity and specific yield for the major HSUs in the study area, collated from available literature and the Carrapateena Project are presented in Table 3.4. There can be a wide range of values reported in public literature, for example the range of hydraulic conductivity for Quaternary Sediments at Olympic Dam. A summary of hydrogeological parameters estimated from Carrapateena test data is provided in Table 3.5. It is noted that field testing has typically targeted higher yielding locations, and thus may overestimate the average bulk hydraulic parameter values.

Groundwater flow in the regional, deeper groundwater systems is mainly via secondary porosity, whereby most of the flow occurs though openings formed from joints and fractures, and possibly chemical weathering. Typically, there is an order of magnitude difference in hydraulic conductivity between fractured and unfractured rock mass when tested in the THA (OZL 2017). Jacobs (2016a) inferred the basement rocks of the Gawler Range Volcanics have very little primary porosity and very few secondary permeability zones; however, this is based on limited available data.

The regionally extensive aquifer with the relative highest hydraulic conductivity is typically the THA, with reported maximum hydraulic conductivities of 2 to 30 m/d. Such a large range in hydraulic conductivity is thought to be controlled by the varied fracture density and connectivity existing in this fractured rock unit.

Furthermore, the large ranges in hydraulic properties documented may be attributed to measurements of the same HSU having been a) taken quite distant from each other (e.g. at Olympic Dam Mine versus at Carrapateena Mine versus regionally); and b) determined using different methods that sample different volumes of geological material (e.g. falling head tests versus pumping tests versus modelling). In addition to that, whilst an HSU as a whole may be considered an aquifer (e.g. the PFA), it incorporates significant heterogeneity even on a relatively localised scale due to stratification of the deposited material and introduction of secondary porosity via fracturing and faulting.

There are limited measured hydraulic conductivity data available from aquifer testing for the Woomera/Tregolana Shale in the study area (i.e. data is available for one well only). Airlift yields from drilling support the understanding that the hydraulic conductivity of the Woomera/Tregolana Shale is low. The water supply potential of the THA, PFA and WSA is structurally controlled and is dependent on adequate fracturing (and fracture connectivity), as well as large available drawdown for the PFA and WSA.

Storativity is low across all the aquifers and is mostly comparable between the HSUs as is specific yield, with the exception of the specific yield for the Quaternary sediments, which is relatively higher but within the same order of magnitude.

The hydraulic conductivity of the rock matrix in the THA, PFA and WSA can be very low, as observed in some test data and based on the long recovery time (i.e. six months) for groundwater levels to stabilise following drilling (or testing) at some wells (such as NO 1, BI 6 PAN).

3.6.2 Airlift yields

The spatial distribution of measured airlift yields from OKD and Carrapateena Mine (within 50 km of the RL Project Area) used for the OKDUGA GEA - Addendum is presented in Figure 3.7. Reported groundwater yields from wells within the study area range from <1 to 24 L/s and vary for different HSUs. The reported well yields from data sourced from the public domain may be biased by well depth, diameter, and the accuracy of the record (e.g. estimation by driller).

Review of the airlift yield data for the PFA and mapped lineaments, shown in Figure 3.7, indicates both high and low yields in the PFA occur both on and off mapped lineaments (e.g. there are yields of 24 L/s on and off lineaments, as well as yields as low as 0.5 L/s at the intersection of two lineaments). Although the Lineament Identification and Groundwater Supply Investigation, Oak Dam study (EMM 2023a) inferred that north-west to south-east trending total magnetic intensity (TMI) mapped lineaments and north east to south west trending Stuart Shelf lineaments have a greater likelihood of being associated with higher yields (irrespective of HSU) based on probability correlations.

Table 3.4 Published hydraulic conductivity values

Formation	Test type	K[1] (m/d)	Storativity (unitless)	Specific yield (%)
Quaternary sediments (aquifer)	Olympic Dam, calibrated groundwater model[2]	8.6×10^{-6} to 1.7	1×10^{-6}	7.5
	Carrapateena Mine, calibrated groundwater model[4]	1×10^{-2} (horizontal) 1×10^{-3} (vertical)	1×10^{-6}	
Andamooka Limestone (aquifer)	Regional literature review[3]	1×10^{-1} to 700	1×10^{-6} to 2×10^{-3}	Not reported
	Olympic Dam calibrated groundwater model[2]	0.9 to 22	1×10^{-4} to 5×10^{-4}	7.5
Arcoona Quartzite (aquitard)	Olympic Dam, falling head test data[6]	2×10^{-3} to 5×10^{-3}	-	-
	Olympic Dam, calibrated groundwater model and measured data[2]	8×10^{-4} to 2×10^{-1}	5×10^{-6}	1
	Carrapateena Mine, calibrated groundwater model[4]	1×10^{-3} (horizontal) 1×10^{-4} (vertical)	1×10^{-6}	-
THA (aquifer)	Regional literature review[3]	3×10^{-2} to 2	-	1
	Olympic Dam, literature review and calibrated groundwater model[2]	6×10^{-4} to 30 (horizontal) 2×10^{-2} (vertical)	1×10^{-6} to 4×10^{-4}	1 to 5
	Carrapateena Mine, calibrated groundwater model[4]	4×10^{-1} (horizontal) 4×10^{-2} (vertical)	1×10^{-6}	-
	Carrapateena Mine, pumping tests[7]	7×10^{-1} to 2×10^{1}	2×10^{-4} to 10×10^{-5}	-
Woomera/ Tregolana Shale (aquitard)	Regional literature review[3]	2×10^{-4}	-	-
	Olympic Dam, literature review and calibrated groundwater model[2, 5]	8.6×10^{-6} to 2×10^{-2}	2×10^{-4}	1
	Carrapateena Mine, calibrated groundwater model[4]	4.1×10^{-4} (horizontal) 1×10^{-5} (vertical)	1×10^{-6}	-
Whyalla Sandstone (aquifer/ aquitard)	Olympic Dam, literature review and calibrated groundwater model[2]	9×10^{-6} to 2×10^{-2}	1×10^{-6}	1
	Carrapateena Mine, calibrated groundwater model[4]	2×10^{-1} (horizontal) 2×10^{-2} (vertical)	1×10^{-6}	-
	Carrapateena Mine, pumping tests[7]	$1.3 \times 10^{0} \times 9.6 \times 10^{-2}$	-	-
	Regional literature review[3]	Unfractured: 1×10^{-3} Fractured: 1×10^{-1} to 4×10^{-1}	-	-
Tapley Hill Formation (aquitard)	Carrapateena Mine, calibrated groundwater model[4]	1×10^{-5} (horizontal and vertical)	1×10^{-6}	-

Formation	Test type	K[1] (m/d)	Storativity (unitless)	Specific yield (%)
PFA (aquifer)	Carrapateena Mine, calibrated groundwater model[4]	5×10^{-3} (horizontal and vertical)	1×10^{-6}	-
	Carrapateena Mine, pumping tests	2.7×10^{-5} to 3.4×10^{-5}	-	-
Gawler Range Volcanics (aquitard)	Olympic Dam, calibrated groundwater model[2]	8×10^{-6}	1×10^{-6}	1
	Carrapateena Mine, calibrated groundwater model[4]	1×10^{-6} (horizontal and vertical)	1×10^{-6}	-

Note:

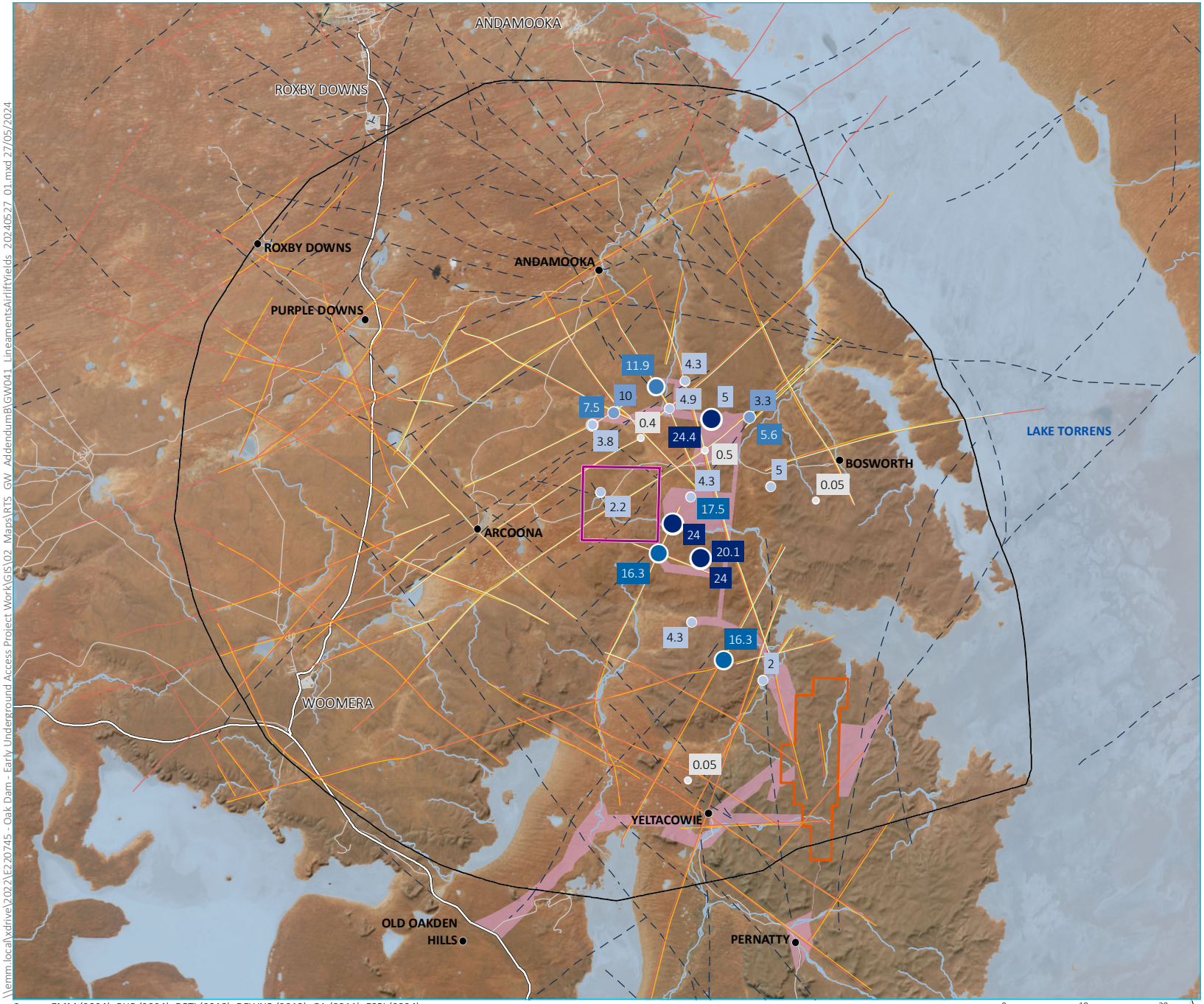
1. K = hydraulic conductivity.
2. *Olympic Dam Expansion Environmental Impact Statement* and *Supplementary Environmental Impact Statement* (BHP 2009 and 2011).
3. *Oak Dam Groundwater Exploration Project – Task 1c: Literature Review* (ELA 2021a).
4. *Carrapateena Project Groundwater Modelling and Assessment of Effects* (CDM Smith 2016).
5. *Hydrogeological Assessment of a Region in Central Northern South Australia* (Kellett et al 1999).
6. Olympic Dam expansion project, *Supplementary Environmental Impact Statement groundwater studies* (SKM 2011).

Table 3.5 Summary of measured hydrogeological properties for the Carrapateena Project

HSU	Area	Test type	Hydraulic conductivity (m/d)			Storativity (unitless)		
			Min	Max	Mean	Min	Max	Mean
Tent Hill Aquifer	Radial Wellfield and mine area	Pumping test and falling head test	1.4×10^{-7}	3.5	4×10^{-2}	8×10^{-7}	4×10^{-4}	6×10^{-5}
	Western Infrastructure Corridor	Pumping test		0.6 [a]		-	-	-
	Northern Wellfield	Pumping test	3.5×10^{-3}	2.5	5×10^{-2}	6×10^{-7}	4×10^{-5}	-
Woomera/ Tregolana Shale	Radial Wellfield	Pumping test		0.1 [a]			-	
	Southern Access Road	Pumping test		0.1 [a]			-	
Whyalla Sandstone Aquifer	Radial Wellfield and mine area	Pumping tests	2×10^{-6}	0.8	1.5×10^{-3}		4×10^{-5}	
	Southern Access Road	Pumping tests	8×10^{-2}	1	2.2×10^{-1}	1×10^{-5}	1.5×10^{-5}	-
	Western Infrastructure Corridor	Pumping test		1.4 [a]			8×10^{-4}	
	Northern Wellfield	Pumping tests	0.2	1	- [b]	-	-	-
Pandurra Formation Aquifer	Radial Wellfield	Pumping tests	3×10^{-2}	0.3	- [b]		1.5×10^{-4}	
	Northern Wellfield	Pumping tests	2×10^{-5}	1	2.3×10^{-3}	2.4×10^{-5}	1×10^{-3}	1×10^{-4}

Note:

1. Unable to present range or mean as data is available for only one well.
2. Unable to present mean as data is available for only 2 wells.



KEY

- OKDUGA Project RL
- Carrapateena Mineral Lease 6471
- Carrapateena MPLs
- Groundwater model extent
- Lineament 1
- Lineament 2
- Lineament 3
- Archaean Early Mesoproterozoic fault

Measured airlift yield during drilling (L/s)

- 0 - 1
- 1 - 5
- 5 - 10
- 10 - 15
- 15 - 20
- 20 - 25

Existing environment

- Homestead
- Major road
- Minor road
- Named watercourse
- Waterbody

Source: EMM (2024); BHP (2024); DPTI (2018); DEWNR (2018); GA (2011); ESRI (2024)

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Lineaments and airlift yields (PFA)

OKDUGA Project Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure 3.7

EMM creating opportunities

3.6.3 Data review

The RL Project Area exploration data was analysed as part of the *Lineament Identification and Groundwater Supply Investigation, Oak Dam* (EMM 2023a) with the intention of identifying potential structural offsets and fracture distribution, which may aid in the selection of prospective water supply drilling locations. As part of this work, EMM (2023a) reviewed fracture occurrence at 22 OKD exploration boreholes by searching for the presence of 'faulting' and/or 'fractured' descriptions within the exploration dataset in bore logs up to 600 m in depth. Information about hydraulic conductivity or yield was not available to support the analysis.

Fracture distribution within the RL Project Area was found to be greatest between 400–550 mbgl, with fracturing mostly occurring within the Pandurra Formation. The total fractured interval within each exploration hole varied between 4 m (AD28W3) and 320.8 m (AD38), and only four exploration holes recorded observations of fracturing across the THA. There was significant local variability in fracturing with evidence of differences in total fractured interval for exploration holes drilled on the same pad:

- Total fractured intervals for exploration holes AD34, AD34W2, AD34W4 and AD34W7, drilled on the same drill pad, varied from 25 m to 201.5 m.
- Total fractured interval for exploration holes AD38, AD38B and AD38W1, drilled on the same drill pad, varied from 25.9 m to 320.8 m.

Depths for angled holes were corrected to a vertical depth using the surveyed dip angles within the holes.

The fracture distribution analysis work (EMM 2023a) resulted in the LSP (comprising the Whyalla Sandstone, Tapley Hill Formation, Pandurra Formation) to be split into six sub-units for the initial OKDUGA modelling works (EMM 2023b). This subdivision of the LSP was undertaken based on the concept that intervals with higher fracture density correlate with relatively higher hydraulic conductivities.

For this report, further investigation into the subdivision of the PFA was undertaken using the Carrapateena data. EMM analysed the field measured water cuts, airlift yield and hydraulic conductivity data[1] from Carrapateena, and the fracture distribution data at OKD to evaluate if there was a correlation between the datasets. Airlift yield data from 101 measurements and 15 hydraulic conductivity measurements were plotted on separate axes with depth. Results of the airlift yield and hydraulic conductivity correlation analysis were presented as a series of boxplots. The plots allow visualisation and comparison between the distributions of two datasets (airlift yield and hydraulic conductivity) based on different depth bins (50 or 100 m intervals) for each HSU. The number of observations for both airlift yield and hydraulic conductivity within each depth interval bin were annotated on each plot.

The Carrapateena hydraulic conductivity data did not conform with any probability distribution model i.e. normal, flat or bimodal, etc. Airlift yields from Carrapateena followed a bell curve shape and do not correlate with the limited Carrapateena hydraulic conductivity data. However, the airlift yield depth observations did correlate with the OKD fracture distribution, which also has a similar bell curve (i.e. normal distribution) shape. This correlation indicates areas with relatively high fracture counts have corresponding relatively high airlift yields, supporting the conceptual subdivision of the PFA into lower and higher hydraulic conductivity units.

The box plot data are shown in Figure 3.9 and further discussion is provided in Section 3.6.4.

[1] Noting that the hydraulic conductivity data has been estimated from pumping test analysis conducted at the completed hole/well following drilling and is not representative of a single depth interval but is representative of the whole open or screened interval.

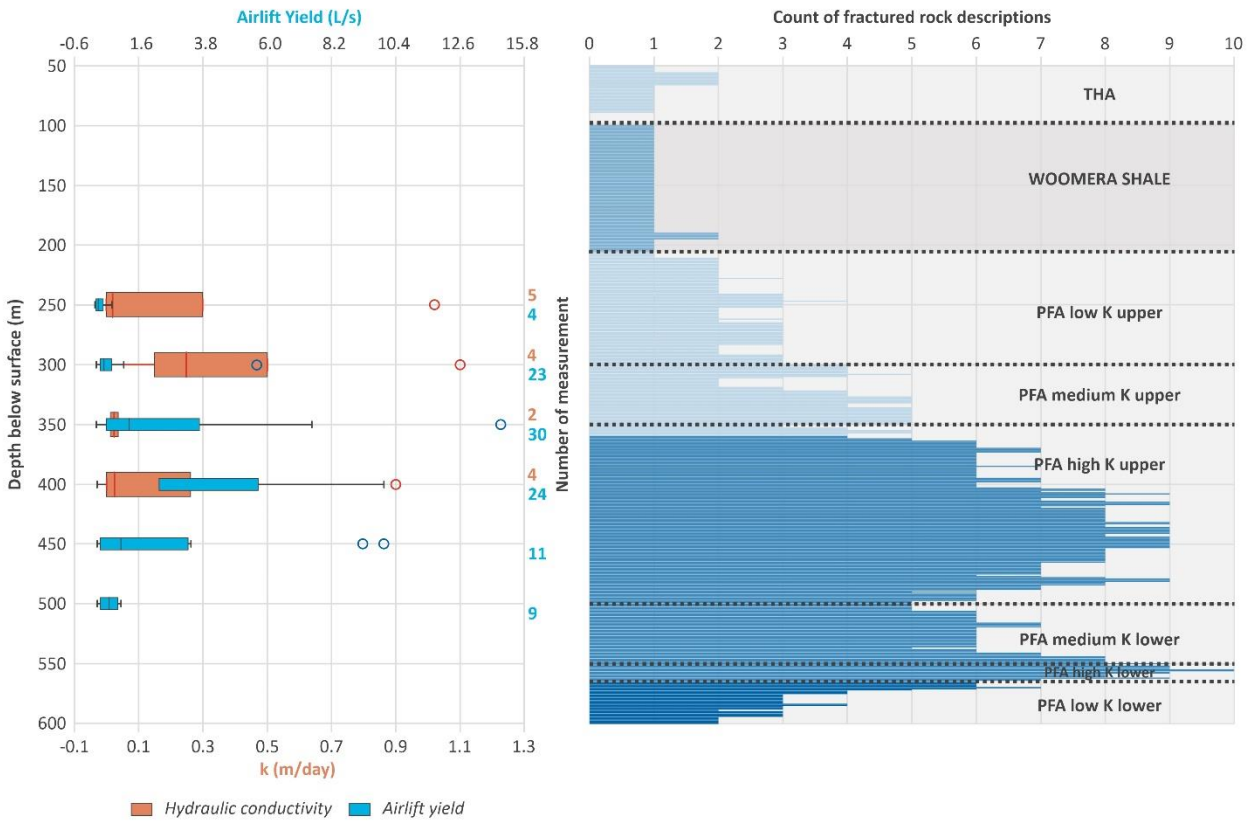


Figure 3.8 **Comparison of Carrapateena airlift and hydraulic conductivity data (left) with OKD fracture count (right)**

3.6.4 Updated hydrostratigraphy

The outcome of the hydrogeological data review works, comprising fracture count (EMM 2023a), airlift yield and hydraulic conductivity, has led to subdivision of the PFA. This is detailed in Table 3.6.

While the Pandurra Formation overall is inferred to behave as an aquifer, there are variations in lithology and primary and secondary permeability with depth that result in sub-units of inferred higher and lower hydraulic conductivity.

Works are ongoing to evaluate if this conceptualisation is representative of the Pandurra Formation across the study area. However, for simplicity, and for the purposes of the OKDUGA Project, the Pandurra Formation has been separated into the described sub-units.

Table 3.6 Subdivision of the Pandurra Formation Aquifer

HSU subdivision with depth	Indicative horizontal hydraulic conductivity (m/d)	Comment
PFA low K upper	1×10^{-4}	Top 15% of the PFA (i.e. 15% of the overall thickness).
PFA medium K upper	1×10^{-3}	10% of the PFA thickness.
PFA high K upper	1×10^{-2}	25% of the overall PFA thickness; resulting in a high transmissivity sub-unit.
PFA medium K lower	1×10^{-3}	8% thickness.
PFA high K lower	1×10^{-2}	4% thickness.
PFA low K lower	1×10^{-4}	38% of thickness and base of PFA.

3.7 Surface water-groundwater interaction

As described above, Lake Torrens acts as the dominant evaporative sink for surface water and groundwater in the region. However, the lake is predominantly dry and there are no permanent surface water bodies present in the study area, apart from two observed watercourse springs located at Salt Creek near the margin of Lake Torrens, to the south east of the RL Project Area (Figure 3.9) (Jacobs 2016a). The springs comprise mixed surface water, rainwater and groundwater.

There are two watercourse springs located on Salt Creek (Gorge Spring and Euro Spring) and geochemical analysis indicates these are partially supported by structurally controlled groundwater discharge with groundwater originating from the deeper HSUs, predominantly the WSA and PFA (OZ Minerals 2017). Geological faulting in the underlying WSA and/or PFA and basement is thought to have created weaknesses within the lithology and preferential pathways for groundwater, under pressure, to flow to the surface.

During high rainfall and surface water flow events along Salt Creek and other major creek lines, surface water is expected to flow from the watercourse into the adjacent Quaternary sediments or weathered Stuart Shelf rocks, creating groundwater lenses near the watercourses. As the water level in the watercourse drops, the hydraulic gradient between the surface water system and groundwater systems can reverse and shallow groundwater can discharge back to the watercourse, sustaining flows or pools of water in the watercourse once rainfall has ceased.

There are two waterholes along Bosworth Creek that are not likely to be supported by artesian flow from underlying aquifers. Rather, they are pools that are observed around deeply incised parts of the creek that have the ability to hold water for a period of time following rainfall and/or streamflow events. Remote sensing across the Groundwater Study Area was undertaken (ELA 2024) and did not report any potential aquatic GDEs in the OKDUGA Project, although they did conclude the lower reaches of Bosworth Creek may support potential aquatic GDEs, which is currently under further assessment by BHP.

Within the OKDUGA Project, there is a small section of terrestrial vegetation associated with Bosworth Creek which is listed as groundwater dependent on the Bureau of Meteorology's (BoM) GDE Atlas (BoM 2024). However, owing to the high salinities (average 22,651 µS/cm) and great depths to the fractured rock aquifers, terrestrial vegetation that potentially relies on groundwater likely utilises water from the shallow Quaternary sediments. Due to the high salinity of the deep fractured rock aquifers, it is unlikely deep-rooted vegetation identified within the OKDUGA Project utilise such groundwater resources. Rather, it is more likely that deep-rooted vegetation, such as eucalyptus woodlands, can potentially access shallow and freshwater sources in perched Quaternary sediments such as surficial lenses or bank storage where recharge water sits within the soil profile that is not part of a typical groundwater system.

Field investigative works were conducted by OZ Minerals (2017) to conceptualise the likelihood and type of groundwater dependence of vegetation located within and immediately adjacent to ephemeral creek lines for Carrapateena. Data interpretation relied on groundwater levels, soil-water potentials, leaf-water potentials and stable isotope analysis (soil water, plant xylem water and groundwater). Similar investigation techniques are being undertaken by BHP along Bosworth Creek as part of the Proposal's forward works plan to support the PEPR.

Following large rainfall events, salt lakes and playa lakes in the region are inundated and fill with fresh water. Based on the GDE Atlas, Lake Torrens supports aquatic GDEs; however Lake Torrens is typically dry (i.e. it has filled twice in the last 150 years, in 1878 and 1989) and is hypersaline. Lake Torrens is however listed as an Inland Saline Lake in the Nationally Important Wetlands by the Australian Government (DCCEEW 2024). The other playa lakes in the Groundwater Study Area, including Lake Richardson, Lake Windabout and Pernatty Lagoon, which are also considered potential groundwater discharge zones filling only when surface water runoff is high and sustained.

3.8 Groundwater users

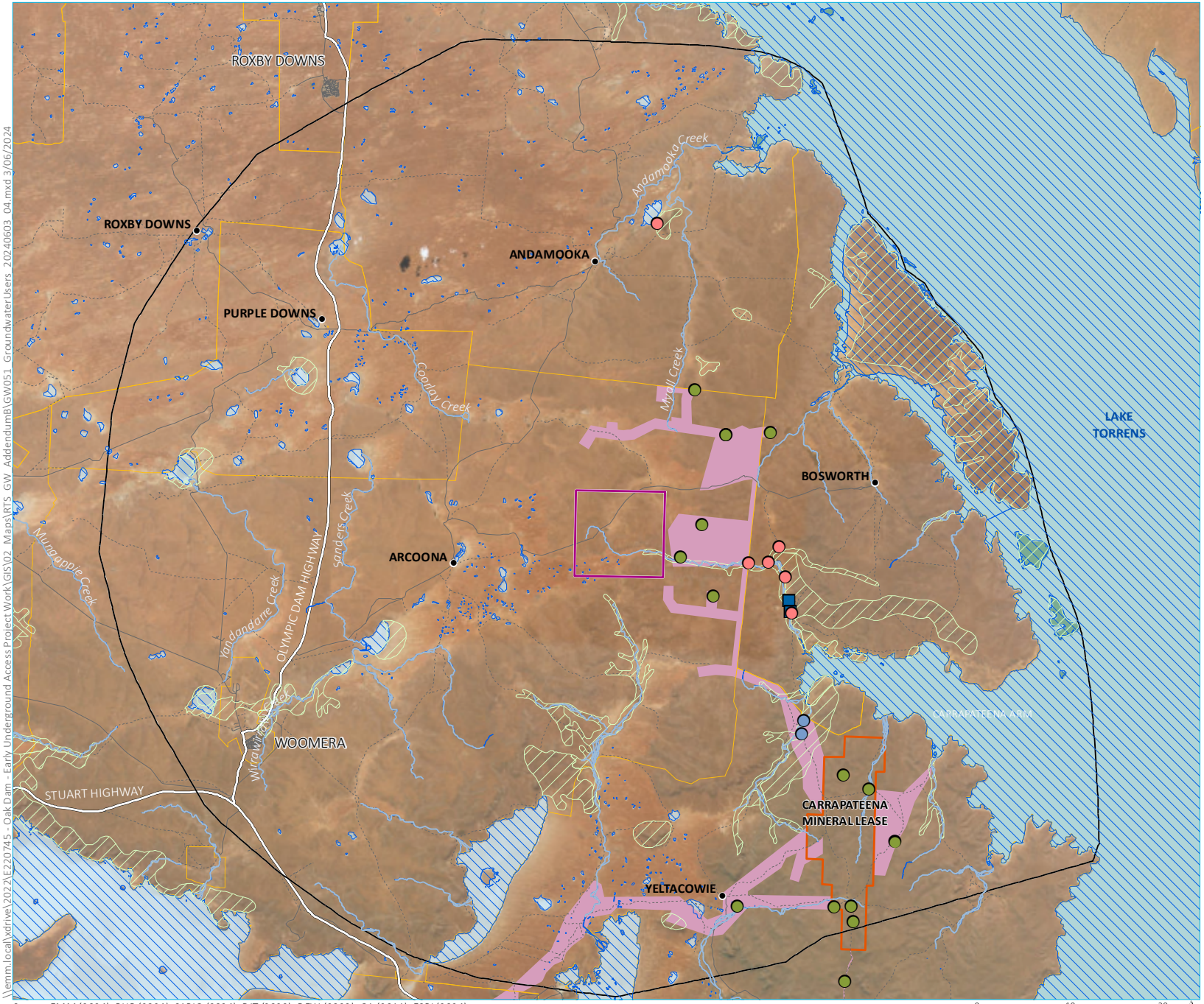
Groundwater users in the study area include potential groundwater dependent ecosystems (GDEs; including Euro Spring and Gorge Spring) and third-party users (including wells used for pastoral purposes). There are no towns within the groundwater study area that rely on groundwater for water supply. Native Title groups also have a strong connection within the South Australian Arid Lands, and the resources located within it. The OKDUGA Project Area is located within the Native Title determination boundary of the Kokatha People (Part A), tribunal file number SCD2014/004 determined in September 2014. The following pastoral leases: Arcoona, Bosworth, Oakden Hills, Pernatty and South Gap have some reliance on shallow wells and use groundwater for stock and domestic purposes. Wells are inferred to access shallow groundwater within Quaternary sediments or weathered Arcoona Quartzite, to depths of generally less than 30 m.

Within the RL Project Area, there is a small section of terrestrial vegetation associated with Bosworth Creek which is listed as groundwater dependent on the BoM GDE Atlas. Within the broader study area, terrestrial vegetation associated with major creek lines is also mapped as groundwater dependent on the BoM GDE Atlas. Terrestrial vegetation potentially relying on groundwater likely utilises shallow groundwater from the Quaternary sediments (rather than the deeper fractured rock aquifer owing to the high salinities and greater depths to water cuts), as well as surface water recharge to the soil profile from rainfall and creek flow events. Ecological field surveys undertaken for Carrapateena interpreted that terrestrial vegetation relies on rainfall runoff, creek flows and shallow groundwater, and this vegetation is mostly associated with creek lines and springs (EBS Ecology 2018).

Following large rainfall events, numerous salt lakes and playa lakes in the area are inundated and fill with fresh water. Based on the GDE Atlas, Lake Torrens supports aquatic GDEs[2]; however the Lake is typically dry (i.e. it has only filled twice in the last 100 years) and is hypersaline, and therefore this BoM classification is likely inaccurate. Lake Torrens is however listed as part of the Inland Saline Lakes in the Australian Directory for Important Wetlands (DEE 2017). The other playa lakes in the study area, including Lake Richardson, Lake Windabout and Pernatty Lagoon, are also considered potential groundwater discharge zones filling only when surface water runoff is high and sustained.

Eco Logical Australia (2024b) undertook remote sensing within the study area and did not report any potential aquatic GDEs in the OKDUGA Project Area, although they did conclude the lower reaches of Bosworth Creek may support potential aquatic GDEs. BHP is also undertaking further GDE investigations as part of the PEPR forward works plan (Figure 3.9, Section 8.4).

[2] Aquatic ecosystems rely on the surface expression of groundwater which includes surface water ecosystems which may have a groundwater component.



KEY

- OKDUGA Project RL
- Carrapateena Mineral Lease 6471
- Carrapateena MPLs
- Groundwater model extent
- Carrapateena production well
- GDE investigation area
- Watercourse springs
- Waterhole
- Pastoral station

Potential Groundwater Dependent Ecosystem (GDE)

- Aquatic
- Terrestrial

Existing environment

- Homestead
- Major road
- Minor road
- Vehicular track
- Major watercourse
- Waterbody
- National park

Source: EMM (2024); BHP (2024); SARIG (2024); DIT (2023); DEW (2023); GA (2011); ESRI (2024)

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Groundwater users

OKDUGA Project Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure 3.9

EMM creating opportunities

3.9 Hydrogeological conceptual model

All available data have been used to inform the hydrogeological conceptualisation, and there have been no changes to the previous hydrogeological conceptualisation. Figure 3.10 and Figure 3.11 present an illustration of the conceptual hydrogeological understanding in the OKDUGA Project area and further afield towards the Carrapateena Northern Wellfield and Carrapateena Mine.

Key elements of the hydrogeological conceptualisation discussed through earlier sections are summarised below.

- The main study area aquifers are the deeper sedimentary THA, WSA and PFA. Geologic structural controls influence groundwater, and within the RL Project Area there is a localised low in the top of the Pandurra Formation, potentially comprising a block feature that has dropped relative to the surrounding strata.

- The uppermost Quaternary sediments are spatially discontinuous hosting shallow and often perched groundwater lenses which are generally low yielding (<0.25 L/s) and not considered a long-term viable water supply option, although there is some use by pastoral stations.

- The PFA is confined over the majority of the study area, except where it outcrops at surface. Prior to commissioning of the Northern Wellfield, the vertical hydraulic gradient is inferred to have been largely upward from the PFA towards the THA. Drawdown associated with operating of the wellfield has resulted in a downward vertical hydraulic gradient near some production wells (e.g. NT 10P). Vertical hydraulic connectivity between the units is limited by the Woomera/Tregolana Shale, considered to be a leaky aquitard, however, transfer of groundwater can occur via fracturing where present. Within the RL Project Area the PFA has a large available drawdown, i.e. approximately 200 to 800 m.

- The groundwater flow direction in the THA and WSA is from west to east, towards Lake Torrens, and hydraulic gradients can differ closer to Lake Torrens. East of the RL Project Area, the groundwater flow direction in the PFA is also from west to east. The groundwater flow direction west of the RL Project Area is uncertain due to data paucity; however available literature suggests groundwater flow is in a west to east direction. Groundwater flow is mainly through secondary porosity via fracture flow, with high yields (i.e. greater than 5 L/s) thought to be dependent on the intersection of fractures. There is very little primary porosity. Geological structural controls, i.e. faults and the regionally extensive Pernatty Upwarp, can promote fracturing.

- Groundwater recharge in the Stuart Shelf area is very low due to low rainfall and high potential evaporation rates, and ranges between 0.07 and 0.04 mm/yr for the deeper HSUs. Groundwater discharges into the regionally significant Lake Torrens, where evaporative discharge occurs. This playa lake acts as a groundwater sink and termini for surface drainage. Groundwater residence times likely range between 10,000 and 20,000 years (Kellett et al. 1999).

- There is no permanent surface water present in the study area, apart from a few small waterholes and watercourse springs in Bosworth and Salt Creeks respectively. Creeks, drainage lines and playa lakes in the study area are usually dry, acting as evaporative discharge features where the watertable is shallow.

- Groundwater supported springs are located on lower margins of Salt Creek near the margins of Lake Torrens. Waterholes along Bosworth Creek are not likely to be supported by artesian flow from underlying aquifers. Rather, they are pools that are observed around deeply incised parts of the creek that have the ability to hold water for a period of time, following a rainfall event of sufficient magnitude. Where they occur, GDEs can support terrestrial vegetation in creek lines, which may opportunistically access groundwater. However, given the groundwater salinity, these communities are more likely to access soil moisture or bank storage, post rainfall and/or flood events. BHP is undertaking further GDE investigations along Bosworth Creek as part of the PEPR forward works plan (Figure 3.9, Section 8.4).

- Groundwater in the deeper HSUs is saline to hypersaline, and typically precludes use without prior treatment. Very low recharge rates and low hydraulic conductivity or flow rates contribute to long groundwater residence times and high groundwater salinity. The exception is groundwater in the uppermost Quaternary sediments systems, which are localised and rely on rainfall recharge and overbank flows, although salinity is still brackish to saline.

- Regionally, groundwater is not heavily utilised. The exceptions are minor utilisation of perched Quaternary sediments for stock watering and groundwater abstraction associated with the Carrapateena Mine. Noting that a portion of this water undergoes reverse osmosis treatment to lower salinity prior to potable use.

The conceptual hydrogeological understanding in the OKDUGA Project Area will be updated to reflect additional drilling investigations as part of the PEPR forward works plan (Section 8.4).

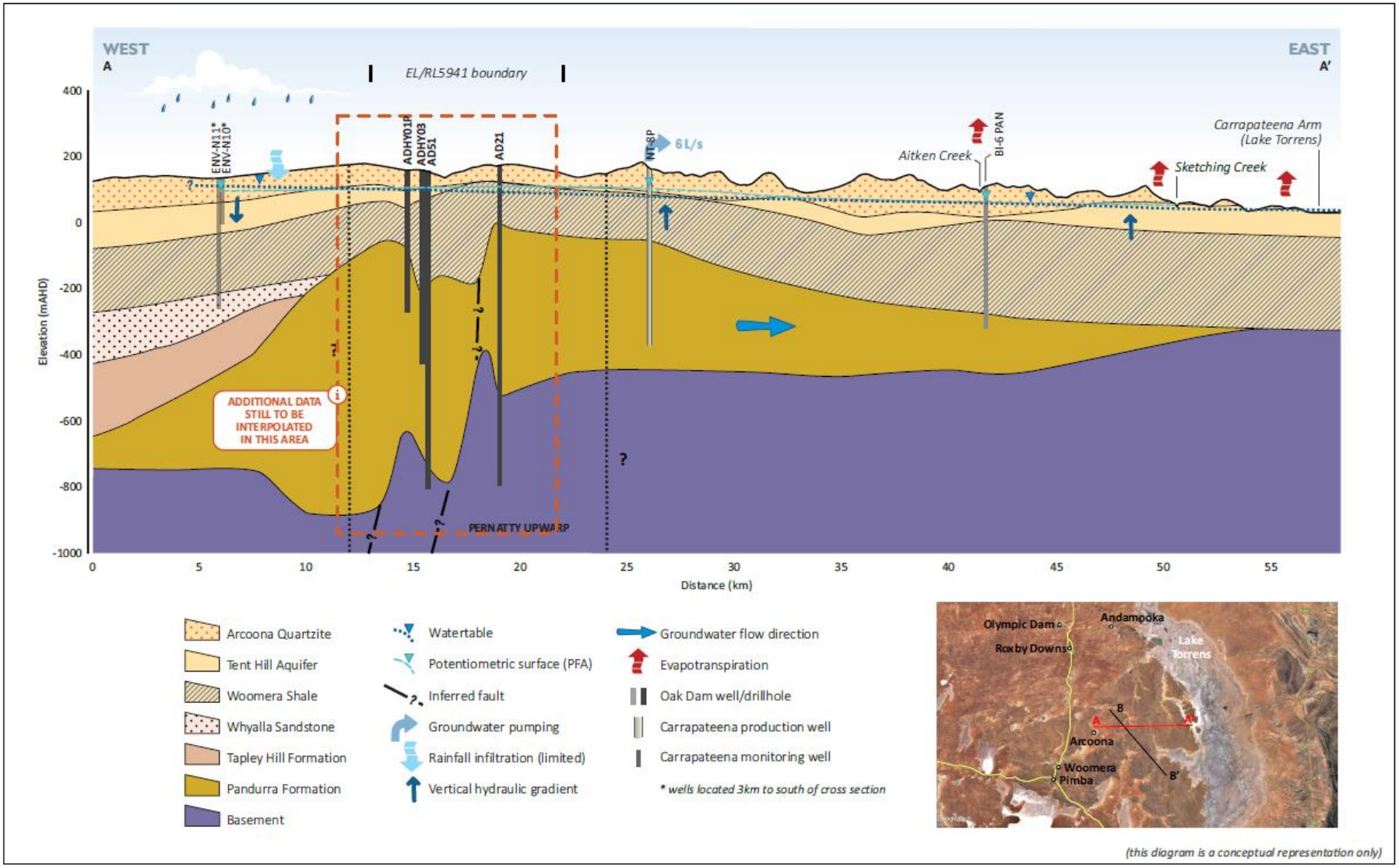


Figure 3.10 Updated hydrogeological conceptual west-east cross section

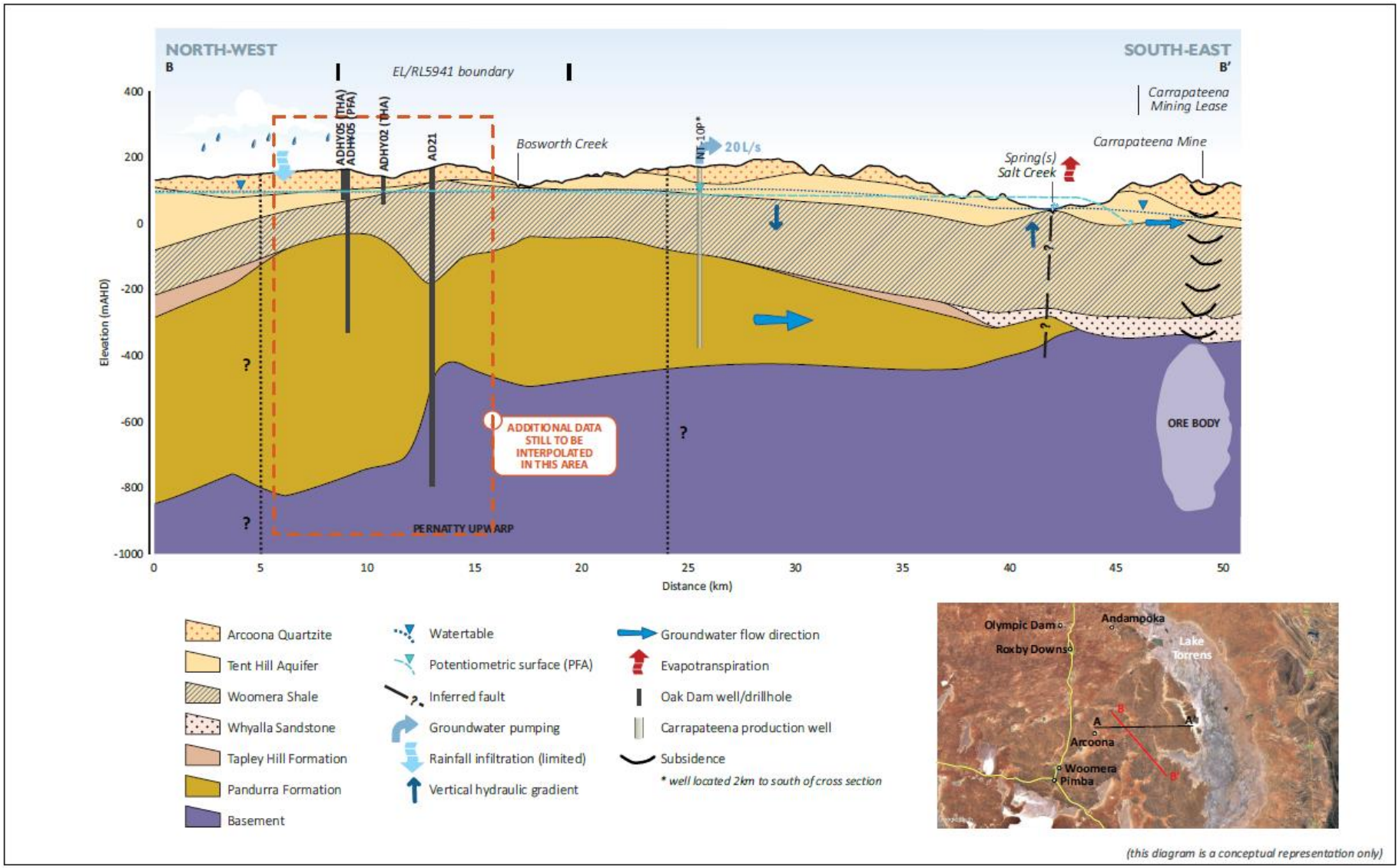


Figure 3.11 Updated hydrogeological conceptual north-west to south-east cross section

4 Model design

4.1 Equivalent porous medium approach

Given the scale and complexity of the model and the modelling objectives, the numerical groundwater flow model was designed using an equivalent porous medium (EPM) approach, although it is acknowledged that fractures can play a significant role in the groundwater system. This approach is commonly used in larger scale groundwater models of fractured rock environments. The EPM method assigns bulk hydraulic properties for an HSU and treats the rock matrix and any associated networks as if they were a single porosity medium, such as a granular aquifer (Anderson and Woessner 1991). This approach was adopted for the following reasons:

- It is environmentally conservative to assume that the intermediate fractured rock groundwater system is permeable and interconnected at the site wide scale. This assumption allows for drawdown/mounding to propagate radially outwards from the OKDUGA Project components and, therefore, assessment of impacts to receptors is skewed towards over emphasising potential impacts.

- From an OKDUGA Project water balance perspective, assuming interconnected and permeable fractured rock conditions is also conservative in that it may tend to over predict groundwater inflow rates during construction and mining, which will reduce the risk of under estimating groundwater licensing requirements.

- Dual porosity and discrete fracture network models require significant detail on fracture/joint orientations, spacings, lengths and apertures, which were not available for the geology in the model domain.

It is noted that the EPM approach is appropriate for a larger scale groundwater model, though one of the limitations is that small scale accuracy is reduced by not capturing the detail in local fracture network properties. The adopted approach to overcome that limitation was to explore predictive uncertainty through probabilistic uncertainty analysis.

4.2 Software

The model was developed using the MODFLOW-USG code (Panday et al. 2017) through the Groundwater Vistas V8 Pro graphical user interface (Rumbaugh and Rumbaugh, 2020). MODFLOW-USG represents a major revision of the standard MODFLOW code, in that it uses a different underlying numerical scheme: control volume finite difference (CVFD), rather than the previous MODFLOW finite difference (FD) scheme. ‘USG’ is an acronym for Un Structured Grid, meaning that MODFLOW-USG supports a variety of structured and unstructured model grids, including those based on cell shapes (Panday et al. 2017). The CVFD method also allows a model cell to be connected to an arbitrary number of adjacent cells, which is not the case with a standard FD scheme.

In contrast with structured rectangular finite difference grids, flexible meshes have several advantages. Firstly, they allow finer mesh resolution to be focused solely in areas of a model that require it (e.g. along ventilation shafts, around production wells and within excavated features), as opposed to refinement over the entire mesh. This significantly decreases cell count and consequently, model run times and file sizes. Secondly, spatial areas not required in the model may be omitted rather than deactivating cells or retaining ‘dummy’ layers (i.e. pinching out of layers). Thirdly, flexible meshes allow cell boundaries to follow important geographical or geological features, such as watercourses or outcrop traces, more accurately modelling the geometry of the physical system. Finally, the orientation of the flow interfaces between cells may vary, allowing preferential flow directions to be modelled with higher accuracy.

Additionally, MODFLOW-USG can simulate variably saturated flow and can handle desaturation and re saturation of multiple hydrogeological layers without the 'dry cell' problems of traditional MODFLOW. This is pertinent where simulating the depressurisation and desaturation that occurs due to excavation of underground features. Traditional versions of MODFLOW can handle depressurisation and desaturation to some extent, but model cells that are dewatered (reduced below atmospheric pressure) are replaced by 'dry' cells, which can interfere with the simulation of various flow processes and cause model instability.

4.3 Domain and spatial discretisation

4.3.1 Model extent

The model domain extends in an approximate 50 km radius from the RL Project Area, following groundwater flow features where reasonable. The eastern edge of the model domain aligns with the approximate western edge of Lake Torrens. The northern, western and southern edges of the model domain were extended sufficiently far to capture the effects of the operating Northern Wellfield, the Carrapateena Mine and predicted change in groundwater level at watercourse springs along Salt Creek.

The model domain covers an area that is approximately 8,302 km^2. The extent of the model domain from the RL Project Area was informed by an estimate of the cone of depression based on the Marinelli and Niccoli (2000) analytical solution, with the aim to:

- encompass the main identified groundwater receptors
- include the main hydrogeological boundary conditions influencing groundwater flow
- encompass changes to the groundwater system related to mining, wellfield operation and effects of other mining operations (such as Carrapateena and Olympic Dam)
- prevent undue influence of boundary conditions on model predictions.

4.3.2 Mesh

A Voronoi polygon mesh (Amenta and Bern 1998) was created to spatially discretise the model domain. This has the advantage of being not only irregular but maintaining the property that a line connecting adjacent cell centres is perpendicular to the shared cell boundary. The mesh contains 31,428 cells per layer. The Voronoi mesh was generated using AlgoMesh 2.0 (HydroAlgorithmics 2020), which provides significant control over the mesh generation process.

The following general approach was taken when creating the mesh:

- Points along the alignment of the various decline options and proposed excavation schedules of each mining method were sampled every 7 m to define the excavated areas.
- Several buffers around the areas of mining activity were used to give more model detail near the mining areas.
- Polylines along the mapped ephemeral creeks were point sampled at regular 100 m intervals to conform the mesh to mapped drainage networks, and to enforce spatial detail along the creeks to allow for accurate simulation of evapotranspiration in those areas.
- Additional discretisation was applied at 300 m intervals along the margins of Lake Torrens, and at two playa lakes in the south of the domain: Pernatty Lagoon and Lake Windabout. Additional discretisation was also applied at the location of the Carrapateena Mine.

- Additional discretisation was applied around the locations of paired production and monitoring wells of the Carrapateena Northern Wellfield.
- Monitoring well locations were included in the mesh generation process to centralise them within model cells and minimise interpolation errors.

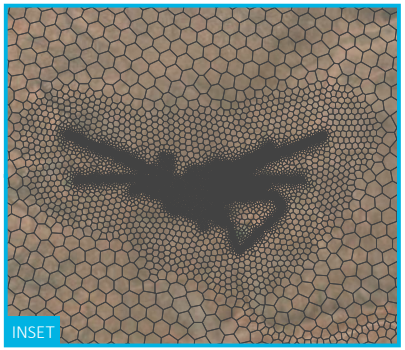
In the Voronoi mesh, the maximum 'cell size' in an area, defined as the distance between the centroids of two adjacent cells, was used as a constraint in the creation process. The adopted maximum cell sizes in key areas of interest are as follows:

- 2 m at Carrapateena Northern Wellfield paired production and monitoring well locations.
- 5 m at ventilation shaft locations (for the mining methods).
- 20 m at other mining excavation features.
- 100 m at ephemeral creek lines.
- 200 m within one kilometre of mining excavations.
- 500 m within five kilometres of mining excavations.
- 100 m at monitoring well locations that are not adjacent a Northern Wellfield production well.
- 500 m cell representing the Carrapateena Mine.
- 2,500 m maximum over the remainder of the model domain.

Cells progressively expand in size moving away from areas of defined refinement.

Figure 4.1 illustrates the model domain and Voronoi mesh with the inset showing a zoomed in view in the vicinity of the OKDUGA Project.





KEY

- OKDUGA Project RL
- Carrapateena Mineral Lease 6471
- Carrapateena MPLs
- Model mesh

Existing environment

- Homestead
- Major road
- Minor road
- Major watercourse
- Waterbody

Source: EMM (2024); SARIG (2023); DIT (2023); DEW (2023); ESRI (2024)

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Model domain and Voronoi mesh

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Figure 4.1

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4.3.3 Layers

As described in Sections 3.6.3 and 3.6.4, with the acquisition of OZL by BHP in May 2023, the Carrapateena numerical model and the more extensive dataset used to construct it became available for BHP to use in the OKD LOM modelling. The availability of the Carrapateena data, combined with the expanded domain of the OKD LOM model, led to use of the Carrapateena model layers as a base for the OKD model layers for the OKDUGA Project.

A total of 26 model layers were used to both represent the conceptual hydrogeological understanding and the complex geometry of the OKDUGA Project excavations. The ten regional HSUs and additional sub division of the PFA defined in Section 3.6.4 combine to a total of fifteen HSUs that have been used to develop layers for the groundwater model (refer Table 4.2).

Model layers 15 through 26 represent the regionally extensive basement. To represent mining progression with depth the basement was divided into twelve sub layers of 100 m thickness within 10 km of the OKDUGA Project excavations. At distances greater than 10 km from the OKDUGA Project, the basement was represented as one model layer with a maximum thickness of 2,030 m. The base of the model was set at a uniform elevation of 2,100 mAHD.

The model uses a feature of MODFLOW-USG which allows cells to be “pinched out” where not needed. In this case, in areas where an HSU is less than 1 m thick, cells were pinched out and deactivated such that they were removed from all calculations. With a mesh of 31,428 cells per layer, and 26 model layers, the model contains a total of 817,128 total cells. However, approximately 56% were pinched out resulting in a total of 459,850 active cells.

All model layers were set to layer type 4 (variably confined/unconfined upstream watertable). This allows each layer to simulate confined or unconfined conditions, depending on the simulated elevation of the watertable at each point in time.

A cross section through the model layers and a 3-D view of model layers and outcropping HSUs are presented in Figure 4.2 and Figure 4.3, respectively.

Table 4.1 Model layers

Layer/s	HSU
1	Quaternary sediments/Andamooka Limestone
2	Arcoona Quartzite
3	Tent Hill Aquifer
4	Woomera/Tregolana Shale
5	Whyalla Sandstone Aquifer (upper)
6	Whyalla Sandstone Aquifer (lower)
7	Tapley Hill Formation
8	Beda Volcanics
9	Pandurra Formation Aquifer subunit: low K upper
10	Pandurra Formation Aquifer subunit: medium K upper
11	Pandurra Formation Aquifer subunit: high K upper
12	Pandurra Formation Aquifer subunit: medium K lower
13	Pandurra Formation Aquifer subunit: high K lower

Layer/s	HSU
14	Pandurra Formation Aquifer subunit: low K lower
15–26	Gawler Range Volcanics and Breccia Complex (Basement)

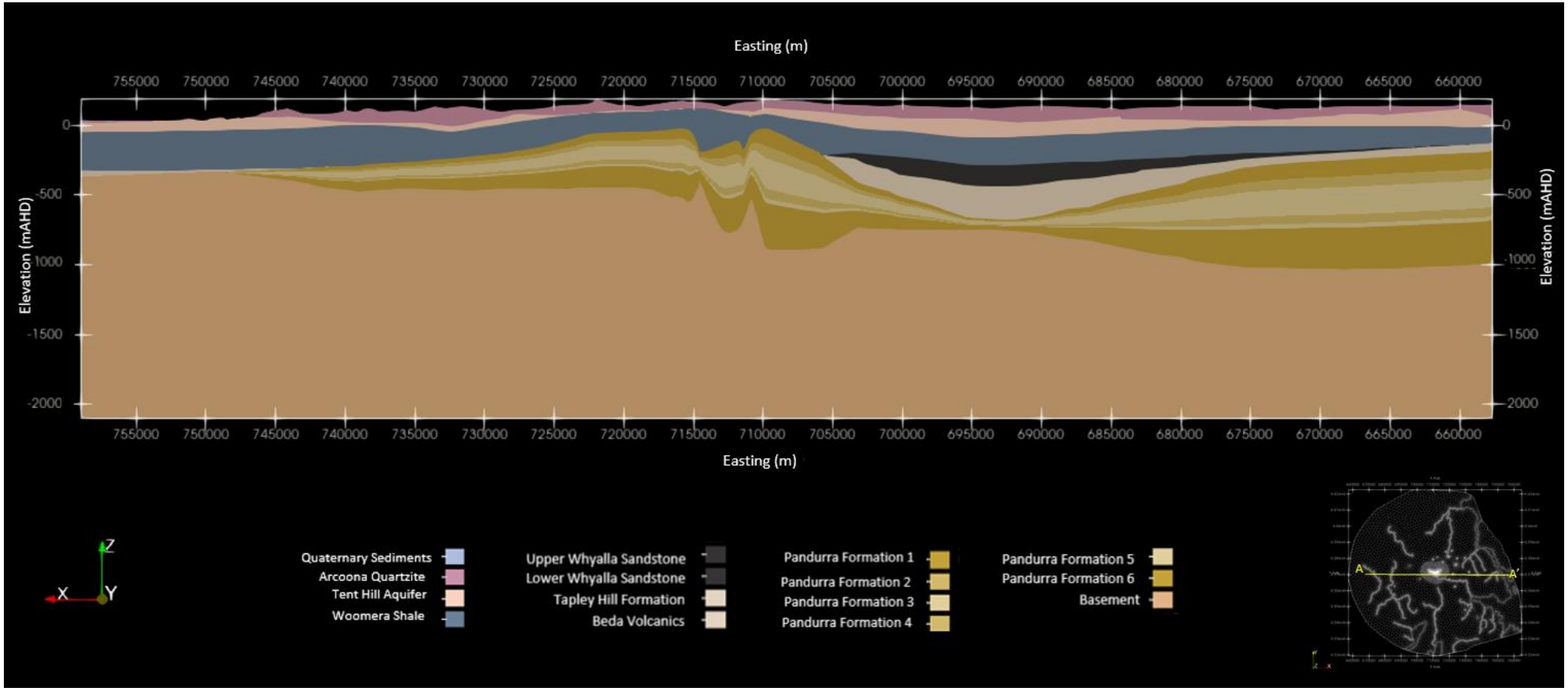


Figure 4.2 **E-W cross section through model layers at 6571020°mN**

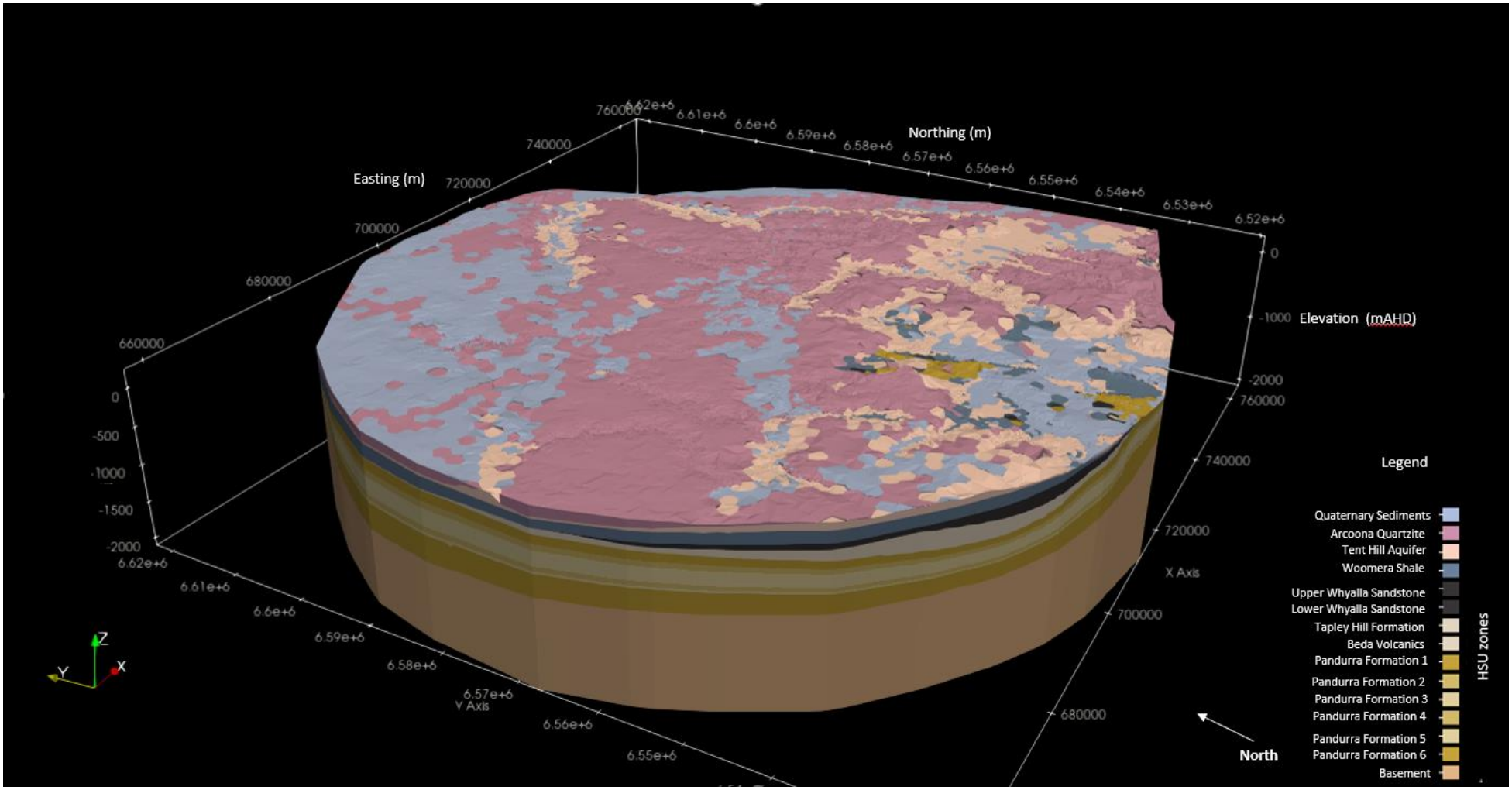


Figure 4.3 **3-D view of model layers and outcropping HSUs**

4.4 Temporal discretisation and numerical solution

The stress periods implemented in the model are summarised in Table 4.2.

The history matching period employs two predevelopment stress periods; one transient stress period run to pseudo steady state for numerical stability, and a subsequent true steady state stress period to establish stable long term groundwater conditions. Following the steady state stress period, 35 monthly stress periods were employed for the history matching period from January 2020 (representing the commissioning of the Northern Wellfield) to January 2023.

The Carrapateena Northern Wellfield is simulated as starting in January 2020 and finishing at the end of 2047. Sixty-five monthly stress periods are used to simulate Project excavation. After excavation, all workings are kept dewatered for five years of exploration, then the site is left to recover naturally for 100 years.

Table 4.2 Stress periods

Stress period	Stress period duration	Start date	Description
1	120 years	N/A	Pseudo steady state stress period run in transient mode to aid numerical stability when varying parameter values during history-matching.
2	Steady state	N/A	Simulates pre-development steady state conditions in response to modelled hydraulic properties and boundary conditions.
3 to 38	Monthly	January 2020	History-matching period. Pumping stresses from the Carrapateena Northern Wellfield.
39	3 years	January 2023	Carrapateena Northern Wellfield pumping – constant abstraction.
40 to 105	Monthly	May 2026	Excavation over 5.5 years.
106	5 years	November 2031	5 years of exploration with all excavations kept dewatered.
107	11 years	November 2036	Start of 100 years recovery from project. Carrapateena Northern Wellfield pumping finishes at the end of this period.
108	89 years	January 2048	Remainder of 100 years recovery from project.

The adaptive time stepping feature of MODFLOW-USG was used to efficiently discretise stress periods into timesteps such that a numerically stable solution was obtained. The Sparse Matrix Solver (SMS package) was employed to solve the differential equations with a head closure criterion (HCLOSE) of 0.001 m.

4.5 Boundary conditions

4.5.1 Regional groundwater flow

As described in Section 3.4, groundwater generally flows from west to east towards Lake Torrens. General head boundary conditions (GHB package) were applied at the model boundaries in the three primary aquifers (refer Figure 4.4 to Figure 4.7) to represent groundwater flow to and from the broader groundwater system.

Inferred contours of equivalent freshwater head were used to define the general head boundary conditions in the THA (layer 3), WSA (layer 5) and the PFA (layers 9–14) as shown in Figure 3.4 and Figure 3.5. The hydraulic head assigned to the general head boundary condition was set at the estimated elevation of equivalent freshwater head in each of the three layers. As presented in Section 3.4, there is limited groundwater elevation data available in the west and south-west of the model domain for the deeper HSUs. As such, the steady state groundwater elevations from the Carrapateena numerical model were used to define boundary conditions along the model domain where needed and where consistent with the conceptual understanding. At the dry lakebeds of Lake Torrens and Lake Windabout, groundwater levels were set at three metres below ground level in the THA. As shown on Figure 4.6 and Figure 4.7, the WSA and PFA are predominantly absent along the margin of Lake Torrens.

The general head boundary condition in the north of the model domain near Olympic Dam was adjusted throughout simulations in line with the predicted drawdown in the THA as reported in the supplementary EIS (BHP 2011). Predicted drawdown contours are available at current day, 2050, 2150 and 2550 (BHP 2011). These were interrogated to estimate magnitude and extent of drawdown as a function of time, which was then interpolated to provide inputs to the model for each stress period. As the THA aquifer is the most laterally extensive of the three main aquifers, and the only aquifer currently conceptualised to be present in the Northern domain where the drawdown influence of Olympic Dam extends, time varying boundary conditions were only applied to model layer 3 representing the THA. The PFA and WSA general head boundaries did not vary with time.

Figure 4.4 and Figure 4.5 show the change in hydraulic head assigned to general boundary conditions in the THA during the predictive modelling period. Where model edge cells were not assigned general head boundary conditions, they were simulated as no flow boundaries.

4.5.2 Recharge

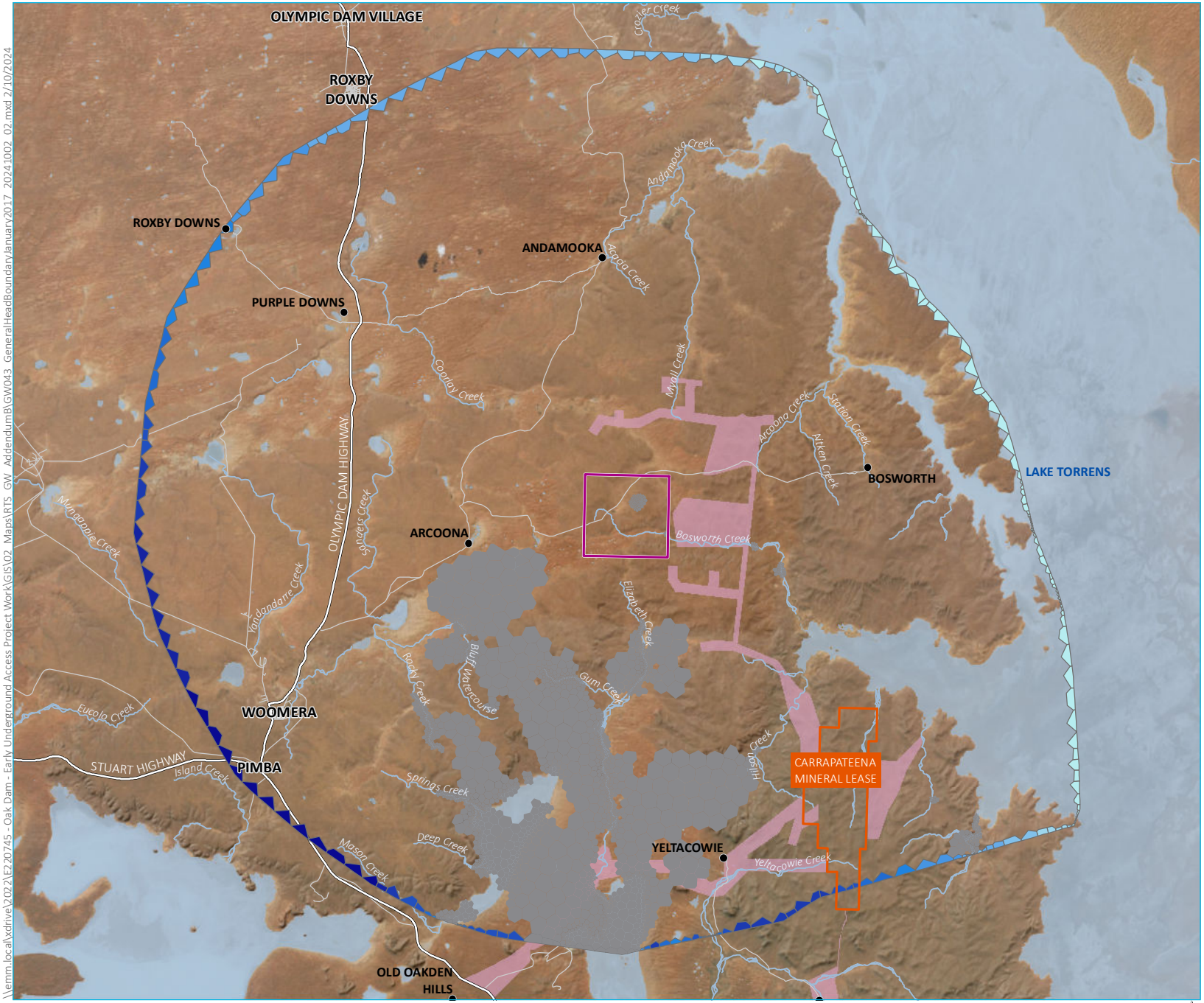
The MODFLOW Recharge (RCH) package was used to simulate diffuse rainfall recharge. Rainfall recharge was modelled at a constant rate over time and was calibrated via PESTPP-IES in a range from 0.04 to 4 mm/yr with an initial estimate of 0.44 mm/yr based on modelling completed for the Carrapateena Mine. Recharge was applied directly to the watertable, irrespective of model layer.

4.5.3 Evapotranspiration

The MODFLOW evapotranspiration (EVT) package is employed to represent evapotranspiration from groundwater. The maximum potential evapotranspiration rate is set at the annual average of 2,300 mm/yr reported by the Bureau of Meteorology (BoM 2023). Based on the sparse vegetation in the study area, and review of aerial photography, an extinction depth of three metres was applied across the model domain.

4.5.4 Surface water

Apart from two watercourse springs (Euro Spring and Gorge Spring), there is no significant permanent surface water in the model domain. As described in Section 3.5, where the watertable is sufficiently shallow (particularly in lower reaches), groundwater evaporative discharge may occur. Therefore, the mesh is refined along the ephemeral creeks and the topographic elevation of the cells along them is set to the lowest point in the cell instead of the average as used in all other cells. This methodology allows shallow groundwater along those creeks to be removed via the evapotranspiration boundary condition.



KEY

- OKDUGA Project RL
- Carrapateena Mineral Lease 6471
- Carrapateena MPLs
- THA absent

Existing environment

- Homestead
- Major road
- Minor road
- Named watercourse
- Waterbody

General head boundary condition (mAHD)

- 20 - 30
- 30 - 40
- 40 - 50
- 50 - 60
- 60 - 70
- 70 - 80
- 80 - 90
- 90 - 100
- 100 - 110
- 110 - 120
- 120 - 130

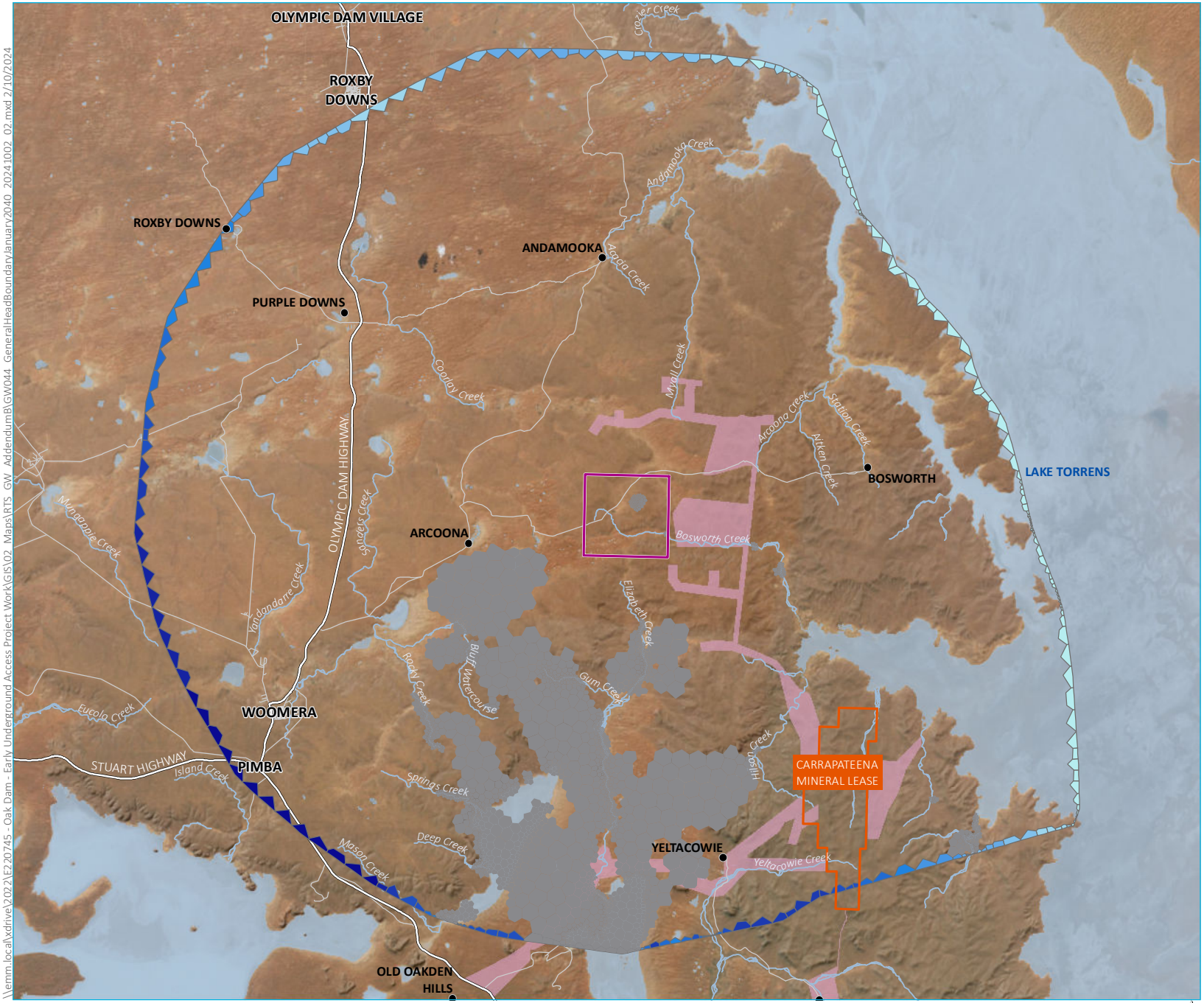
Source: EMM (2024); SARIG (2024); DIT (2024); DEW (2024); ESRI (2024)

General head boundary in January 2017 in THA (model layer 3)

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Figure 4.4

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KEY

- OKDUGA Project RL
- Carrapateena Mineral Lease 6471
- Carrapateena MPLs
- THA absent

Existing environment

- Homestead
- Major road
- Minor road
- Named watercourse
- Waterbody

General head boundary condition (mAHD)

- 20 - 30
- 30 - 40
- 40 - 50
- 50 - 60
- 60 - 70
- 70 - 80
- 80 - 90
- 90 - 100
- 100 - 110
- 110 - 120
- 120 - 130

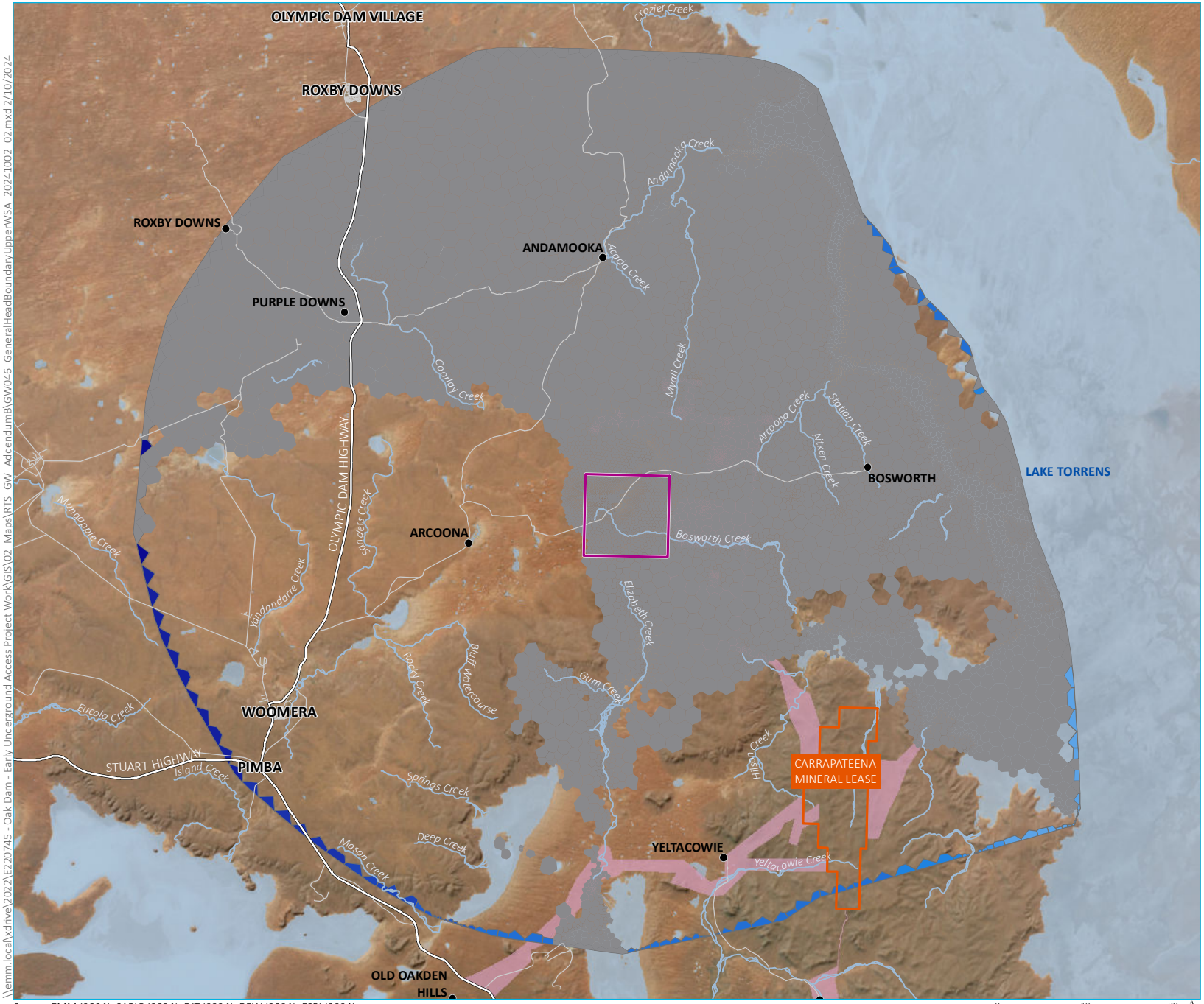
Source: EMM (2024); SARIG (2024); DIT (2024); DEW (2024); ESRI (2024)

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General head boundary in January 2040 in THA (model layer 3)

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Figure 4.5

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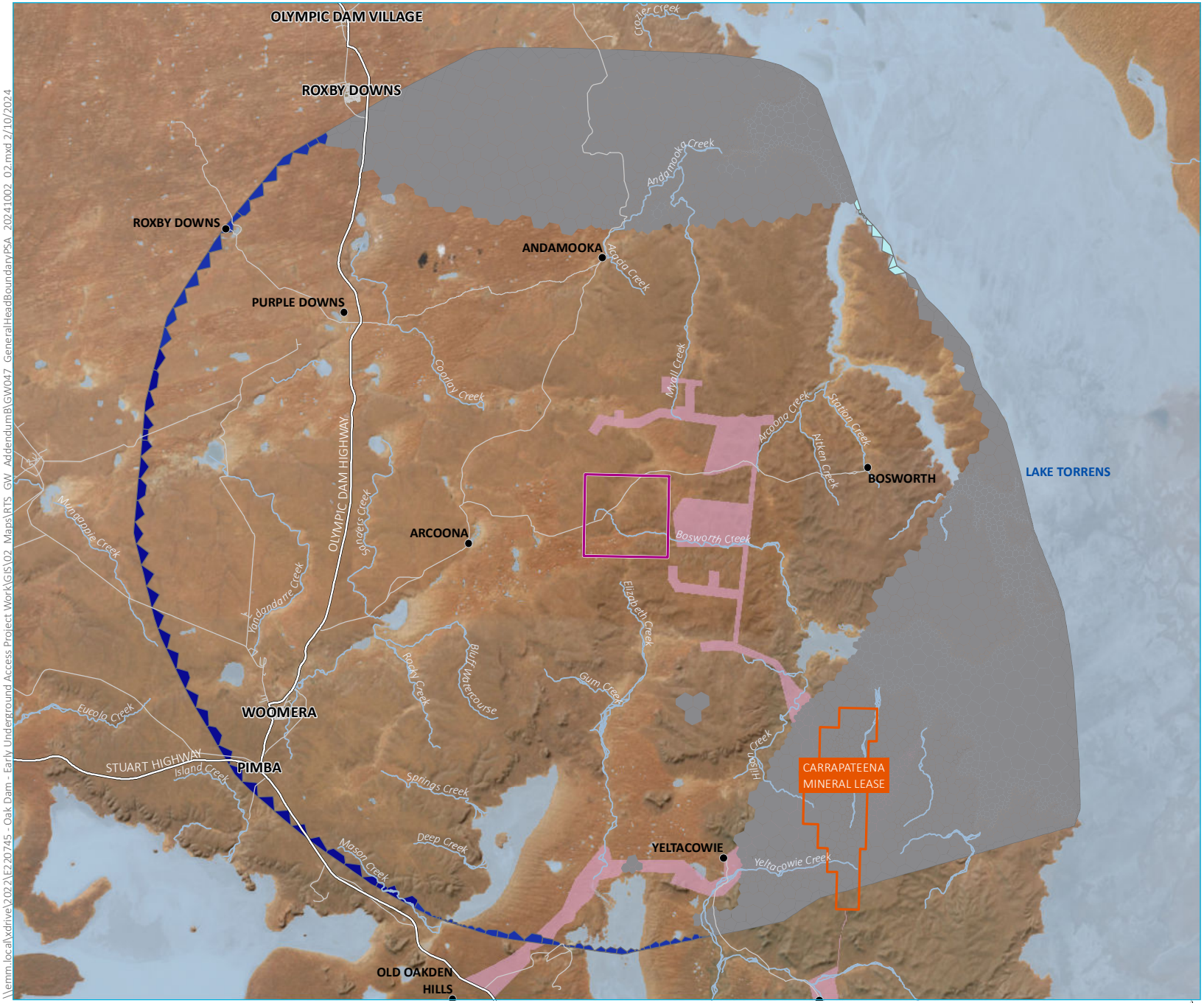
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Source: EMM (2024); SARIG (2024); DIT (2024); DEW (2024); ESRI (2024)

General head boundary in Upper WSA (model layer 5)

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Figure 4.6

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KEY

- OKDUGA Project RL
- Carrapateena Mineral Lease 6471
- Carrapateena MPLs
- PFA absent

Existing environment

- Homestead
- Major road
- Minor road
- Named watercourse
- Waterbody

General head boundary condition (mAHD)

- 40 - 50
- 50 - 60
- 60 - 70
- 70 - 80
- 80 - 90
- 90 - 100
- 100 - 110

Source: EMM (2024); SARIG (2024); DIT (2024); DEW (2024); ESRI (2024)

0 10 20 km

GDA2020 MGA Zone 53

N

General head boundary in PFA (model layer 9)

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Figure 4.7

EMM creating opportunities

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4.5.5 Other groundwater users

As described earlier, the Carrapateena Northern Wellfield is permitted to abstract up to 7 ML/d and currently comprises seven production wells. Groundwater abstraction rates from the Northern Wellfield were obtained for the period from January 2020 to January 2023 and used for history-matching.

There are differences in how the Carrapateena Northern Wellfield were implemented in the original OKDUGA model and the OKD LOM model, as detailed in Table 4.3 and Table 4.4, respectively. Pumping rates used in the updated predictive simulations were based on the average of metered pumping volumes over the last 12 months, equating to 2.75 ML/d. This rate was held constant over the predictive period until the end of 2047 when the Carrapateena Northern Wellfield ceases to operate.

Groundwater abstraction from pastoral wells is assumed to be minor and is not simulated.

Table 4.3 OKDUGA model – Carrapateena Northern Wellfield representation

Well ID	Pumping rate (L/s)	Screened HSU	Model layer	Easting	Northing
C_6336-120	9.95	Pandurra high K upper	25 (equivalent to 11 in OKD LOM model)	729606	6580280
C_6336-119	9.95	Pandurra high K upper	25 (equivalent to 11 in OKD LOM model)	722214	6570255
C_6335-569	9.95	Pandurra high K upper	25 (equivalent to 11 in OKD LOM model)	723452	6562574
C_6335-568	9.95	Pandurra high K upper	25 (equivalent to 11 in OKD LOM model)	723452	6562574
C_6336-101	9.95	Pandurra high K upper	25 (equivalent to 11 in OKD LOM model)	729606	6580271
C_6336-99	9.95	Pandurra high K upper	25 (equivalent to 11 in OKD LOM model)	722205	6570253
C_6336-98	9.95	Pandurra high K upper	25 (equivalent to 11 in OKD LOM model)	725788	6569811
C_6335-555	9.95	Pandurra high K upper	25 (equivalent to 11 in OKD LOM model)	723440	6562569
C_6336-81	9.95	Pandurra high K upper	25 (equivalent to 11 in OKD LOM model)	712519	6580813
C_6336-80	9.95	Pandurra high K upper	25 (equivalent to 11 in OKD LOM model)	723973	6576081
C_6336-79	9.95	Pandurra high K upper	25 (equivalent to 11 in OKD LOM model)	723974	6576070
C_6336-100	9.95	Pandurra high K upper	25 (equivalent to 11 in OKD LOM model)	730747	6573527

Table 4.4 OKD LOM model – Carrapateena Northern Wellfield representation

Well ID	Pumping rate (L/s)	Screened HSU	Model layer	Easting	Northing
NT-10P	6.47	Pandurra (med-high upper)	10–11	723452	6562572
NT-17P	7.47	Pandurra (med-high upper)	10–11	719925	6566854
NT2P	3.01	Arcoona, Tent Hill, Woomera	2–4	721446	6584856
NT-4P_P	5.43	Woomera, Whyalla U+L, Tapley, Beda, Pandurra (low-high upper)	4–11	724809	6580022
NT-4P_T	2.99	Arcoona, Tent Hill, Woomera	2–4	724809	6580029
NT-5P	3.04	Pandurra (med-high upper, lower, low lower)	10–14	729606	6580266

Well ID	Pumping rate (L/s)	Screened HSU	Model layer	Easting	Northing
NT-8P	3.05	Pandurra (med-high upper, lower, low lower)	10–14	722201	6570258

4.5.6 GDEs

The potential GDEs shown in Figure 3.9 and discussed in Section 3.8 (including the watercourse springs) are not explicitly simulated but evaporative discharge from creeks is modelled via the EVT package combined with mesh refinement and selective sampling of topography to represent topographic lows along the creek lines.

4.5.7 Project groundwater-affecting activities

Project excavations are simulated with drain (DRN package) boundary conditions. These are assigned for the boxcut, along approximately 3 km of twin decline tunnels, figure eight decline sections, about 4 km of additional tunnels for the exploration loop and other miscellaneous rooms.

To aid model numerical stability, the two ventilation shafts are simulated with well (WEL package) boundary conditions, extracting water at a very high flow rate (assigned at 10 ML/d per model cell intercepted by a ventilation shaft). This rate adaptively reduces, where/when it cannot be supplied by the surrounding HSUs, to a rate that can be supplied. Thereby it produces the same effect as drain boundary conditions.

5 History-matching

5.1 Data

History matching was undertaken for the period between January 2020 and January 2023 using transient hydraulic head data at 34 wells, which were predominantly within the Northern Wellfield. The hydraulic head history matching dataset includes measurements from:

- Northern Wellfield observation wells
- Carrapateena compliance and leading indicator wells
- pastoral wells
- other wells selected from the WaterConnect database.

The full list of monitoring wells used in the history-matching process is given in Table 5.1.

Table 5.1 Monitoring wells used for history-matching

Well ID	Easting[1]	Northing[1]	Screened HSU	Model layer	Data availability
6335-338	694895.7475	6545231.52	Arcoona Quartzite	2	Steady state
6336-22	706226.7075	6591109.26	Tent Hill Aquifer	3	Steady state
6336-24	731108.8775	6588223.28	Tent Hill Aquifer	3	Steady state
6336-27	717277.6375	6572486.22	Tent Hill Aquifer	3	Steady state
6336-31	703220.7075	6579213.17	Arcoona Quartzite	2	Steady state
BI-15	739246	6571493	Tent Hill Aquifer	3	Transient
BI-16	735857	6566722	Tent Hill Aquifer	3	Transient
BI-6_THA	737900	6569846	Tent Hill Aquifer	3	Transient
BLUFF_WELL	695951.5775	6554583.06	Arcoona Quartzite	2	Steady state
B-THA	740069	6575779	Tent Hill Aquifer	3	Transient
Centenary_well	720839.9975	6599756	Tent Hill Aquifer	3	Steady state
Elizabeth_Well	707448.8375	6548549.07	Pandurra Formation	10	Steady state
ENV-N10	702000	6567263	Tent Hill Aquifer	3	Transient
ENV-N11	702041	6567269	Upper WSA	5	Transient
ENV-N4	689809	6560753	Tent Hill Aquifer	3	Transient
ENV-N7	715919	6577645	Pandurra Formation	11	Transient
ENV-N8	685847	6562541	Upper WSA	5	Transient
GILES_WELL	695186.7075	6575179.51	Tent Hill Aquifer	3	Steady state
NICK_OF_TIME	720303.9975	6589909	Tent Hill Aquifer	3	Steady state
NO-1	712518	6580811	Pandurra Formation	12	Transient
NO-3	723973	6576068	Pandurra Formation	11	Transient

Well ID	Easting[1]	Northing[1]	Screened HSU	Model layer	Data availability
NT-10OB	723458	6562571	Pandurra Formation	14	Transient
NT-17OB	719924	6566867	Pandurra Formation	9	Transient
NT-2OB	721439	6584865	Tent Hill Aquifer	3	Transient
NT-4 OB (THA)	724822	6580028	Tent Hill Aquifer	3	Transient
NT-4 OB (PFA)	724822	6580028	Pandurra Formation	12	Transient
NT-5OB	729605	6580278	Pandurra Formation	10	Transient
NT-8OB	722234	6570251	Pandurra Formation	11	Transient
OLD_WHIP_WELL	700265	6579046	Tent Hill Aquifer	3	Steady state
PI-8-Obs	731480	6550904	Tent Hill Aquifer	3	Steady state
ROCKY_WELL	687969	6546849	Woomera Shale	4	Steady state
Tod_ridge_well_6	708680	6594213	Tent Hill Aquifer	3	Steady state
Welcome Well	695647	6536876	Tent Hill Aquifer	3	Steady state
WHIM_WELL	698871	6591855	Tent Hill Aquifer	3	Steady state

Notes: 1. MGA 94 Zone 53.

5.2 Approach

Apart from the PFA sub-unit layers, the initial model parameter values, ranges and standard deviations were assigned based on values from the yet to be reported 2023 Carrapateena history matching process carried out by EMM, adopting bounds consistent with the conceptual understanding and estimated parameters from aquifer testing. A combined steady state and transient history matching process was conducted, whereby the computed steady state heads provided the starting heads for the following transient period of history matching.

An automated (using PESTPP-IES version 5.2.9) approach to history-matching was employed. This method innately connects history-matching and predictive uncertainty analysis by developing an ensemble of history-matched realisations (250 in this case) that each produce different predictions. From these, conceptualisation and data constrained likelihoods of predictions of interest can be calculated.

5.3 Targets

First head measurements and subsequent drawdown (head-change) at the 34 well locations were used during history-matching, generating a total of 315 calibration targets. Of the history-matching targets, nineteen were screened in the THA, nine within in the PFA, two within the upper WSA, three within the Arcoona Quartzite and one within the Woomera Shale (refer Table 5.1).

5.4 Parameterisation

To overcome limitations associated with the EPM approach, data availability, conceptual uncertainty, parameter uncertainty and to allow for spatial variability in hydraulic properties, a highly parameterised approach to modelling was implemented via the use of pilot points. This approach is consistent with best practice guidance and provides a numerically sound basis for representing site wide scale heterogeneities (Barnett et al. 2012). Prior distributions of adjustable model parameters are presented in Table 5.2.

5.4.1 Pilot point locations

As PESTPP-IES allows use of a large number of parameters (in this case via pilot points) with a minimal impact on computational burden, a Delaunay triangulation algorithm was employed to place pilot points between history-matching target locations. Additional pilot points were placed at approximately 4 km spacings within a 10 km radius of the excavated area and at approximately 10 km spacings across the remainder of the model domain. This resulted in 145 pilot point locations (shown on

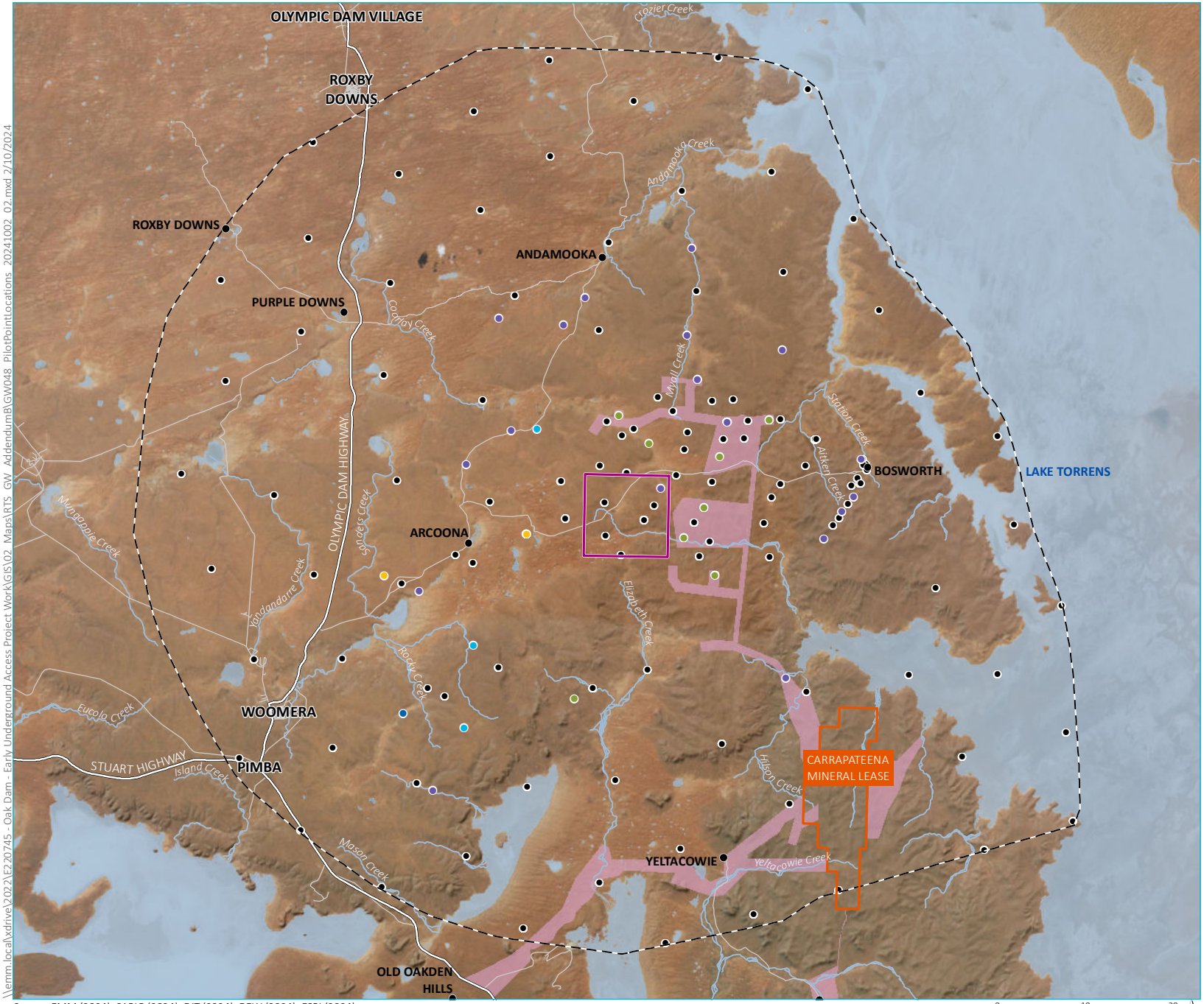
Figure 5.1) to allow for spatial variability in hydraulic properties across the model domain. At each of these 145 locations, hydraulic properties were progressively adjusted to allow initial parameterisations to shift towards values that produce a better match to the target dataset. Parameters allowed to vary included recharge, and the following four hydraulic properties for each of the 15 modelled HSUs:

- horizontal hydraulic conductivity
- vertical hydraulic conductivity
- specific storage
- specific yield.

The total number of pilot point parameters used during history-matching was 8,701.

Table 5.2 Prior parameter distributions for adjustable parameters

Layer	Horizontal hydraulic conductivity (Kh, m/d)			Kh/Kz ratio (-)			Specific storage (Ss, 1/m)			Specific yield (Sy, -)		
	Expected	Minimum	Maximum	Expected	Minimum	Maximum	Expected	Minimum	Maximum	Expected	Minimum	Maximum
1	0.01	8.6×10^{-6}	1.7	10	1	100	1.0×10^{-6}	2.3×10^{-7}	1.3×10^{-5}	0.075	1.0×10^{-3}	0.15
2	0.001	1.0×10^{-5}	0.2	10	1	100	1.0×10^{-6}	2.3×10^{-7}	1.3×10^{-5}	0.005	1.0×10^{-3}	0.075
3	0.1	1.4×10^{-7}	3.5	10	1	100	1.0×10^{-6}	2.3×10^{-7}	1.3×10^{-5}	0.005	1.0×10^{-3}	0.05
4	0.00041	8.6×10^{-6}	0.3	10	1	100	1.0×10^{-6}	2.3×10^{-7}	1.3×10^{-5}	0.01	1.0×10^{-3}	0.05
5	0.001	2.3×10^{-6}	1.4	10	1	100	1.0×10^{-6}	2.3×10^{-7}	1.3×10^{-5}	0.02	1.0×10^{-3}	0.05
6	0.005	2.3×10^{-6}	1.4	10	1	100	1.0×10^{-6}	2.3×10^{-7}	1.3×10^{-5}	0.02	1.0×10^{-3}	0.05
7	0.0004	4.0×10^{-5}	0.004	10	1	100	1.0×10^{-6}	2.3×10^{-7}	1.3×10^{-5}	0.005	1.0×10^{-3}	0.05
8	0.001	1.0×10^{-4}	0.01	10	1	100	1.0×10^{-6}	2.3×10^{-7}	1.3×10^{-5}	0.005	1.0×10^{-3}	0.05
9	0.0005	5.0×10^{-5}	0.005	10	1	100	1.0×10^{-6}	2.3×10^{-7}	1.3×10^{-5}	0.01	1.0×10^{-3}	0.075
10	0.005	5.0×10^{-4}	0.05	10	1	100	1.0×10^{-6}	2.3×10^{-7}	1.3×10^{-5}	0.01	1.0×10^{-3}	0.075
11	0.05	5.0×10^{-3}	0.1	10	1	100	1.0×10^{-6}	2.3×10^{-7}	1.3×10^{-5}	0.01	1.0×10^{-3}	0.075
12	0.005	5.0×10^{-4}	0.05	10	1	100	1.0×10^{-6}	2.3×10^{-7}	1.3×10^{-5}	0.01	1.0×10^{-3}	0.075
13	0.05	5.0×10^{-3}	0.1	10	1	100	1.0×10^{-6}	2.3×10^{-7}	1.3×10^{-5}	0.01	1.0×10^{-3}	0.075
14	0.0005	5.0×10^{-6}	0.005	10	1	100	1.0×10^{-6}	2.3×10^{-7}	1.3×10^{-5}	0.01	1.0×10^{-3}	0.075
26	0.00001	1.0×10^{-6}	0.0005	10	1	100	1.0×10^{-6}	2.3×10^{-7}	1.3×10^{-5}	0.005	1.0×10^{-3}	0.02



KEY

- OKDUGA Project RL
- Carrapateena Mineral Lease 6471
- Carrapateena MPLs
- Groundwater model extent
- Pilot point

History-matching target wells

- Arcoona Quartzite
- Pandurra Formation
- Tent Hill Aquifer
- Whyalla Sandstone
- Woomera Shale

Existing environment

- Homestead
- Major road
- Minor road
- Named watercourse
- Waterbody

Source: EMM (2024); SARIG (2024); DIT (2024); DEW (2024); ESRI (2024)

0 10 20 km

GDA2020 MGA Zone 53

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Pilot point locations

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Figure 5.1

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5.5 Performance

Of the 250 realisations initiated, 135 successfully converged and performance statistics for the suite are presented below. The 'base realisation' refers to the realisation with the best statistical match. For the ensemble, percentile-based statistics are used with nomenclature of 'P10' meaning the 10th percentile out of all 135 or 'P90' meaning the 90th percentile. This parameter ensemble provides a basis for undertaking measurement-constrained predictive uncertainty analysis; exploring parameter uncertainty within the hydrogeological conceptualisation and constrained by model performance against measured data, in line with best practice guidance (Peeters & Middlemis 2023).

5.5.1 Statistical performance

History matching performance was evaluated using several metrics. Statistical quantification was undertaken using scaled root mean square (SRMS) error of hydraulic head, given as a percentage:

$$SRMS = \frac{100}{\Delta H}\sqrt{\frac{1}{n}\sum_{i=1}^{n}[W_i(z_{hi} - h_i)]^2}$$

Where:

- ΔH is the range of measured hydraulic heads across the model domain
- n is the number of measurements used in the history match dataset
- W_i is the statistical weighting (between 0 and 1) applied to measurement i
- z_{hi} is the modelled hydraulic head at location/time i
- h_i is the measured hydraulic head at location/time i.

The statistical performance of the calibrated model suite to the hydraulic head calibration targets (transient head and initial heads) is presented in Table 5.3.The base realisation calculated SRMS error for the transient head statistics was 9.1%, and for initial hydraulic head was 11.5%. These statistics show acceptable history-matching performance for both the base realisation and ensemble, suggesting the parameter ensemble is appropriate for undertaking predictive uncertainty analysis.

Table 5.3 History-matching performance summary

Transient head targets			
	Base realisation	**P10**	**P90**
SRMS	9.1%	10.4%	13.2%
Mean residual (m)	-2.6	-6.8	-3.8
Mean absolute residual (m)	5.9	6.8	8.8
First head targets			
	Base realisation	**P10**	**P90**
SRMS	11.5%	11.1%	14.5%
Mean residual (m)	2.6	0.7	3.3
Mean absolute residual (m)	7.0	7.0	8.6

5.5.2 Hydraulic head

i Steady state/first head

A scatter plot of modelled versus measured first head targets is presented in Figure 5.2. The data show minimal bias, are correlated well across the dataset, and are generally clustered close to a 1:1 line of perfect fit. Five of the targets have base realisation residuals exceeding 15 m, only one of which (NT-4Ob(PFA)) is a BHP well. However, the overall fit to measured data indicates a generally good match to regional groundwater levels and flow directions across multiple HSUs.

Figure 5.3 presents the modelled (base realisation) pre-development potentiometric surface in the THA with measured equivalent freshwater heads used for history-matching. Figure 5.4 shows the equivalent for the PFA, with modelled groundwater contours from the high hydraulic conductivity upper sub-unit (model layer 11). Measured point data align with modelled contours, demonstrating consistency with inferred regional groundwater conditions.

Figure 5.5 presents the modelled (base realisation) pre-development groundwater elevations in the THA with residuals shown scaled by value. The modelled groundwater levels capture the trends and elevations observed in the pre-development inferred groundwater levels (Figure 3.4). Inferred groundwater flow direction in the THA is north easterly and easterly towards Lake Torrens, with groundwater elevations of approximately 120 m across the region of the excavated area. These trends and levels are replicated well by the numerical model.

Figure 5.6 presents the modelled (base realisation) pre-development groundwater levels in the PFA high hydraulic conductivity upper sub-unit with residuals shown scaled by value. The modelled groundwater elevations generally capture the flow directions and elevation of inferred freshwater head at the data locations and are consistent with the hydrogeological conceptualisation described in Section 3.4.

For both the THA and the PFA, the majority of residuals are less than 5 m. Residuals are generally uniformly scattered and there are no evident trends or bias to the residuals.

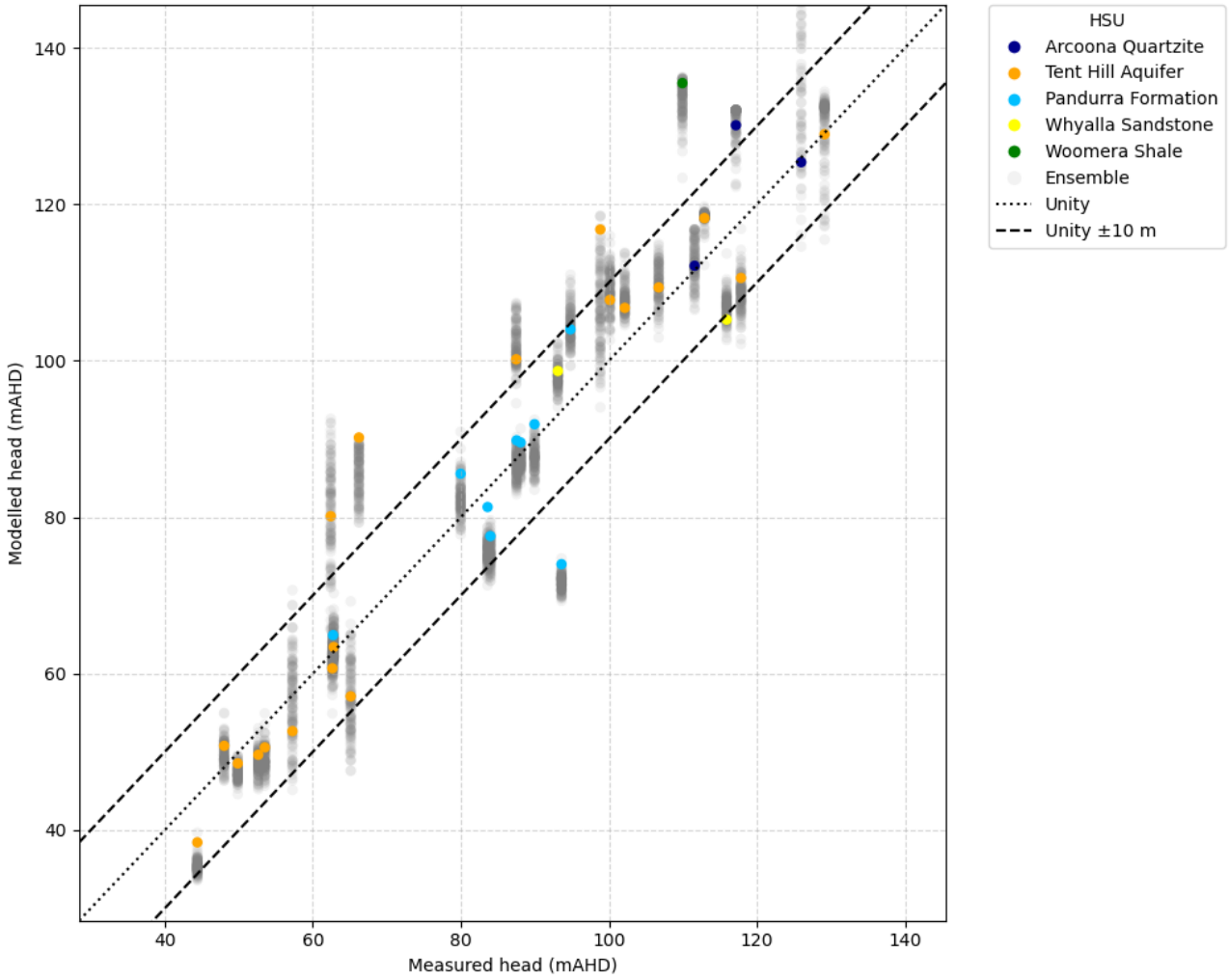


Figure 5.2 **Scatter plot of modelled versus measured first heads illustrating base realisation and ensemble, categorised by HSU**



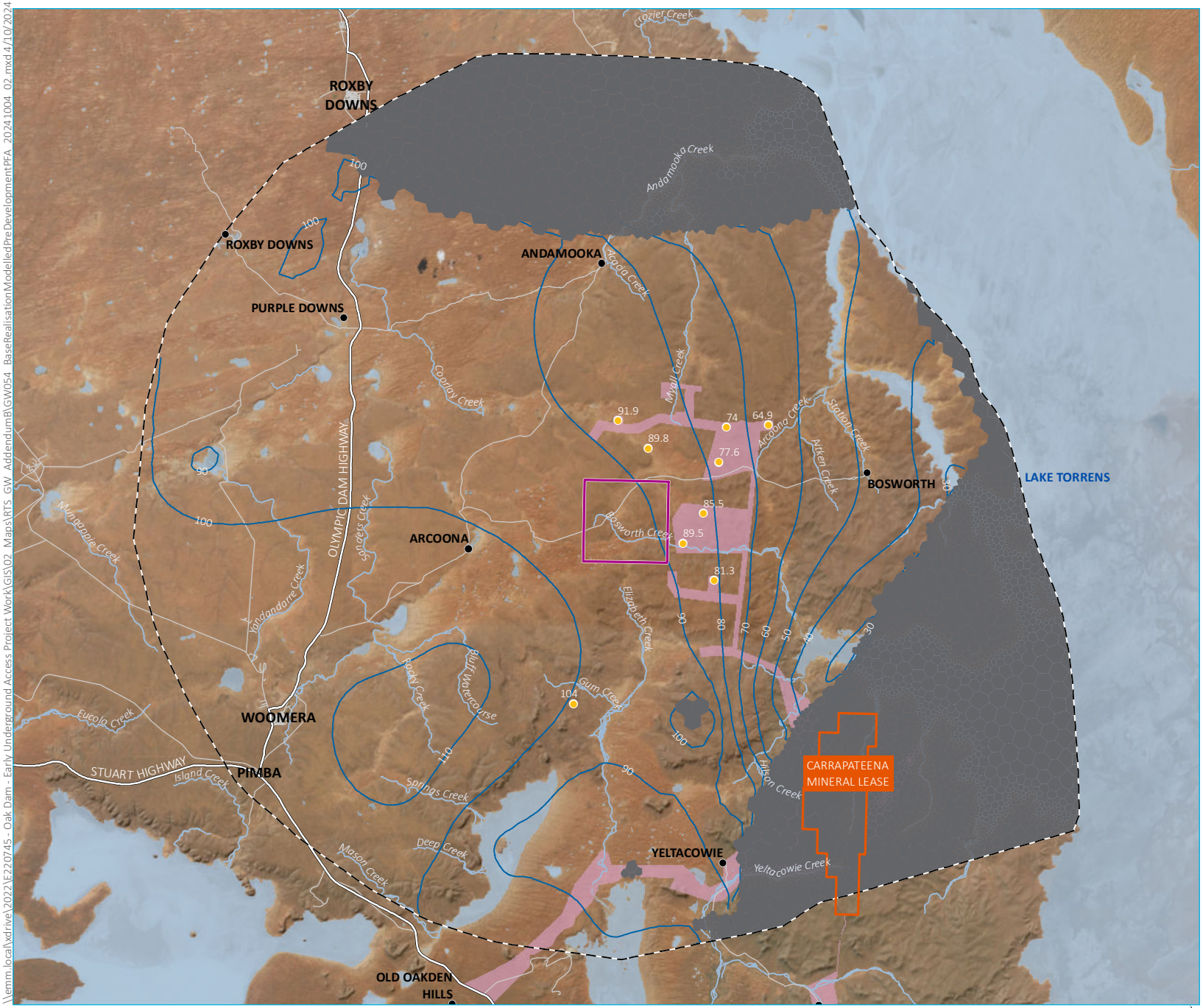
Source: EMM (2024); SARIG (2024); DIT (2024); DEW (2024); ESRI (2024)

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Base realisation modelled pre-development THA potentiometric surface and measured equivalent freshwater head

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Figure 5.3

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KEY

- OKDUGA Project RL
- PFA absent
- Carrapateena Mineral Lease 6471
- Carrapateena MPLs
- Groundwater model extent
- Measured head (mAHD)
- Groundwater level (mAHD)

Existing environment

- Homestead
- Major road
- Minor road
- Named watercourse
- Waterbody

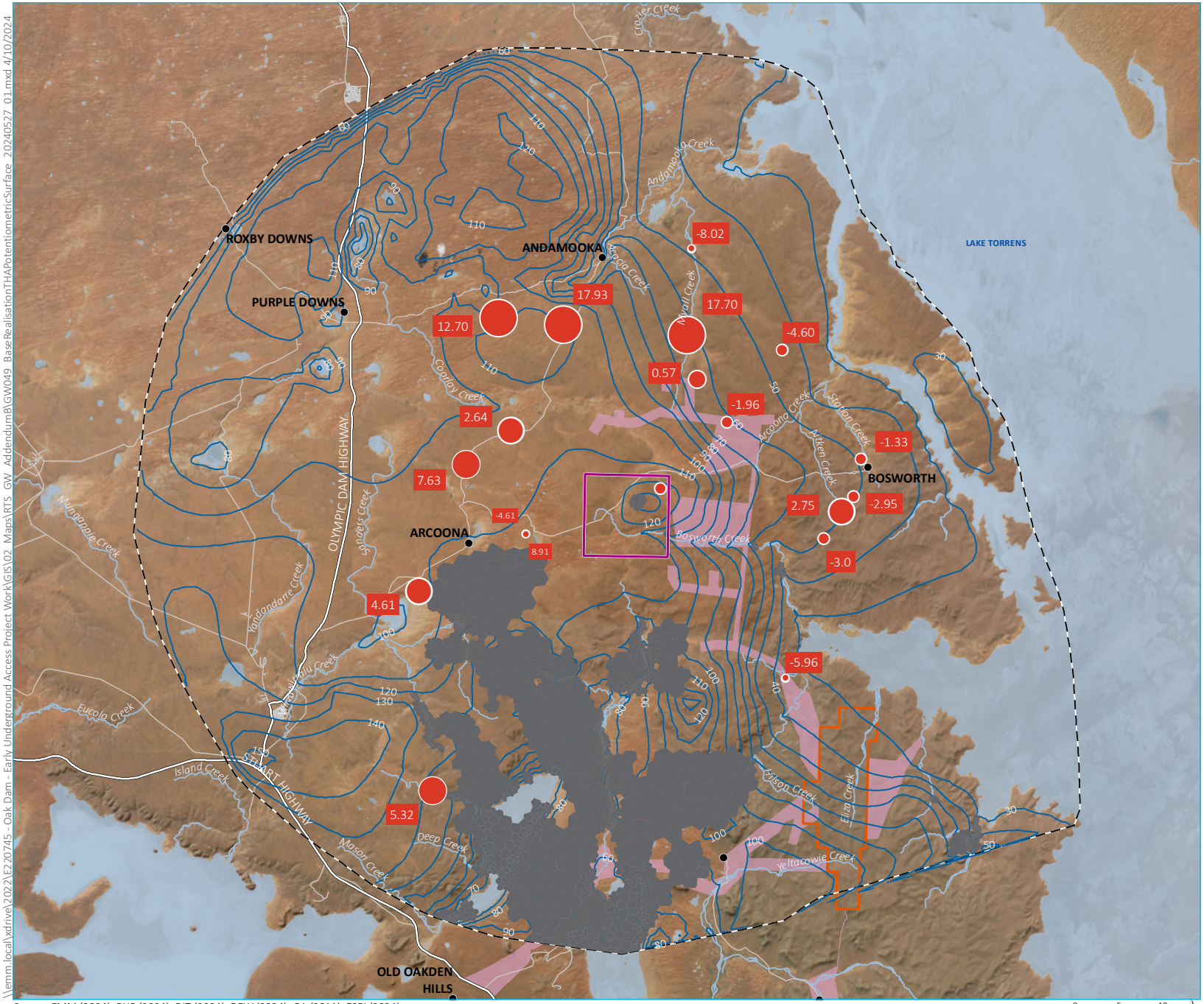
Source: EMM (2024); SARIG (2024); DIT (2024); DEW (2024); ESRI (2024)

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Base realisation modelled pre-development PFA high K upper potentiometric surface and measured equivalent freshwater

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Groundwater Environmental Assessment Addendum
Figure 5.4

EMM creating opportunities



KEY

- OKDUGA Project RL
- THA absent
- Carrapateena Mineral Lease 6471
- Carrapateena MPLs
- Groundwater level (mAHD)
- Major road
- Minor road

Existing environment

- Homestead
- Named watercourse
- Waterbody

Steady state residuals (m)

- -10 - -5
- -5 - 0
- 0 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 22

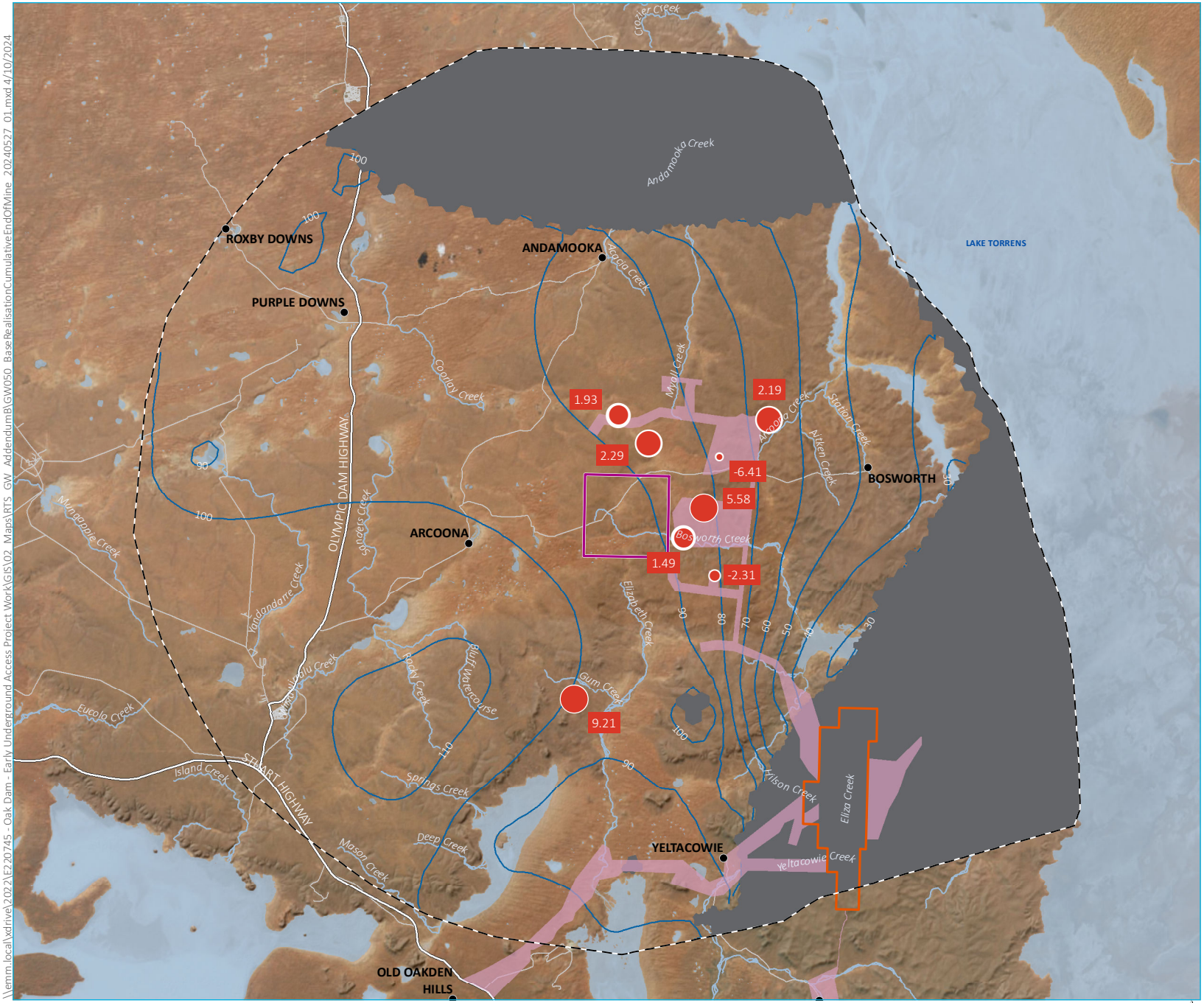
Source: EMM (2024); BHP (2024); DIT (2024); DEW (2024); GA (2011); ESRI (2024)

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Base realisation modelled pre-development THA potentiometric surface and residuals

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Figure 5.5

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Source: EMM (2024); BHP (2024); DIT (2024); DEW (2024); GA (2011); ESRI (2024)

Base realisation modelled pre-development PFA potentiometric surface and residuals

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Figure 5.6

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ii Transient

Scatter plots of modelled versus measured hydraulic head for the complete transient history-matching dataset are presented in Figure 5.7. The majority of the data lie within 10 m of the 1:1 unity line, showing that the modelled heads approximate measured heads well. Modelled groundwater levels in the PFA are fairly accurate and are generally clustered along the line of unity. The largest residuals occur at the regional wells which provided only single steady state targets.

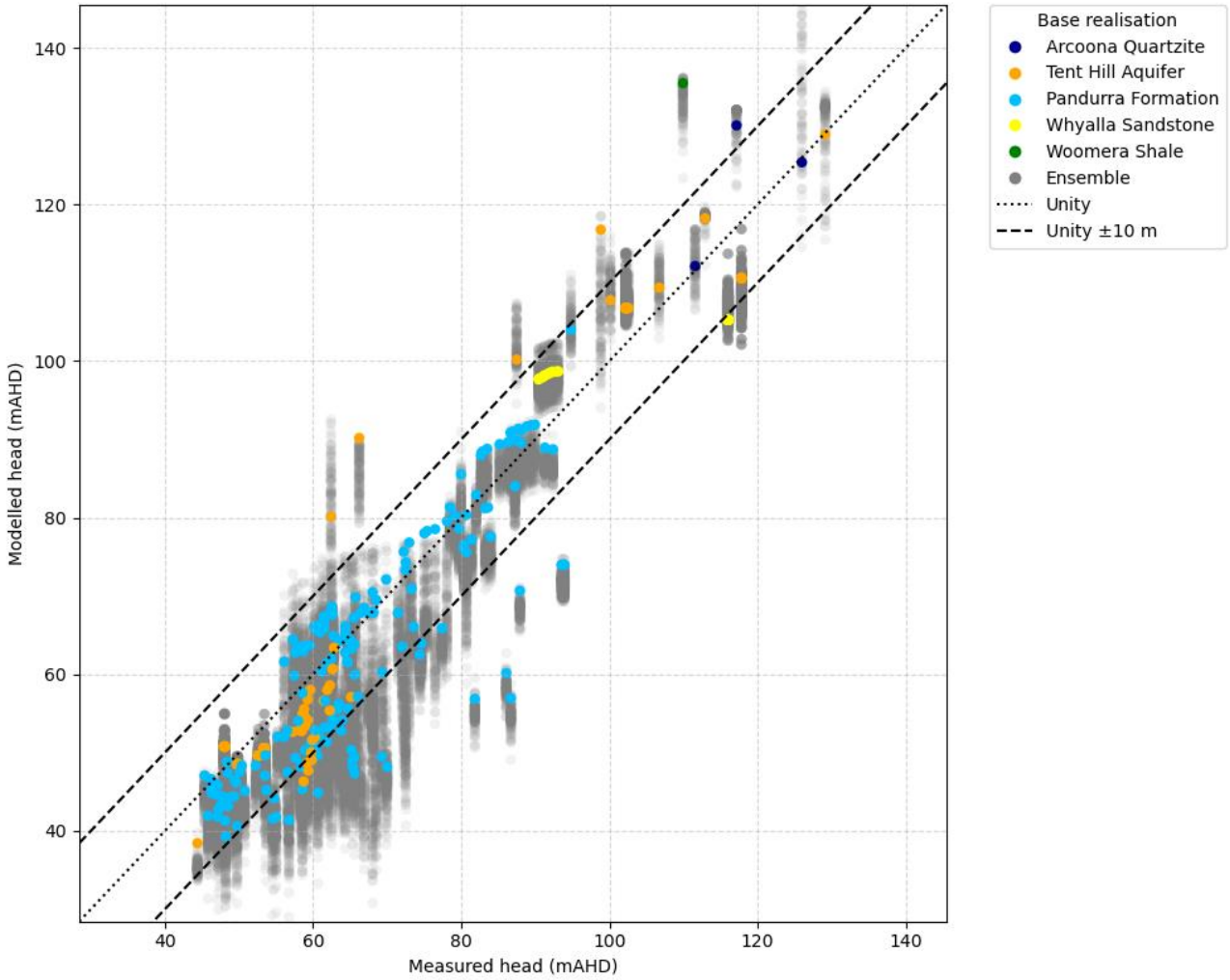


Figure 5.7 Scatter plot of modelled versus measured transient hydraulic heads

Selected hydrographs showing modelled and measured equivalent freshwater head are presented in Figure 5.8. A complete set of hydrographs is provided in Appendix A. The locations of the monitoring wells are shown in Figure 3.1. Generally, the modelled hydrographs in the PFA capture the trends and variability of measured data (as shown by NT 5Ob and ENV N7 in Figure 5.8), where the base realisation and ensemble match the measured data well. However, the mismatch between measured and simulated at NT4 OB (PFA) can be seen on Figure 5.8. Overall, the ensemble is considered to provide an acceptable replication of measured absolute levels and dynamic trends, and be fit-for-purpose with regard to predictive scenario modelling to support a Retention Lease Proposal.

As described in Section 3.4, a density correction was applied to convert depth to water measurements to equivalent freshwater head, and, as the pressure head and salinity in the PFA is quite significant, it resulted in a large density correction. It is possible that, at some locations, the density corrections have raised the equivalent freshwater head artificially high.

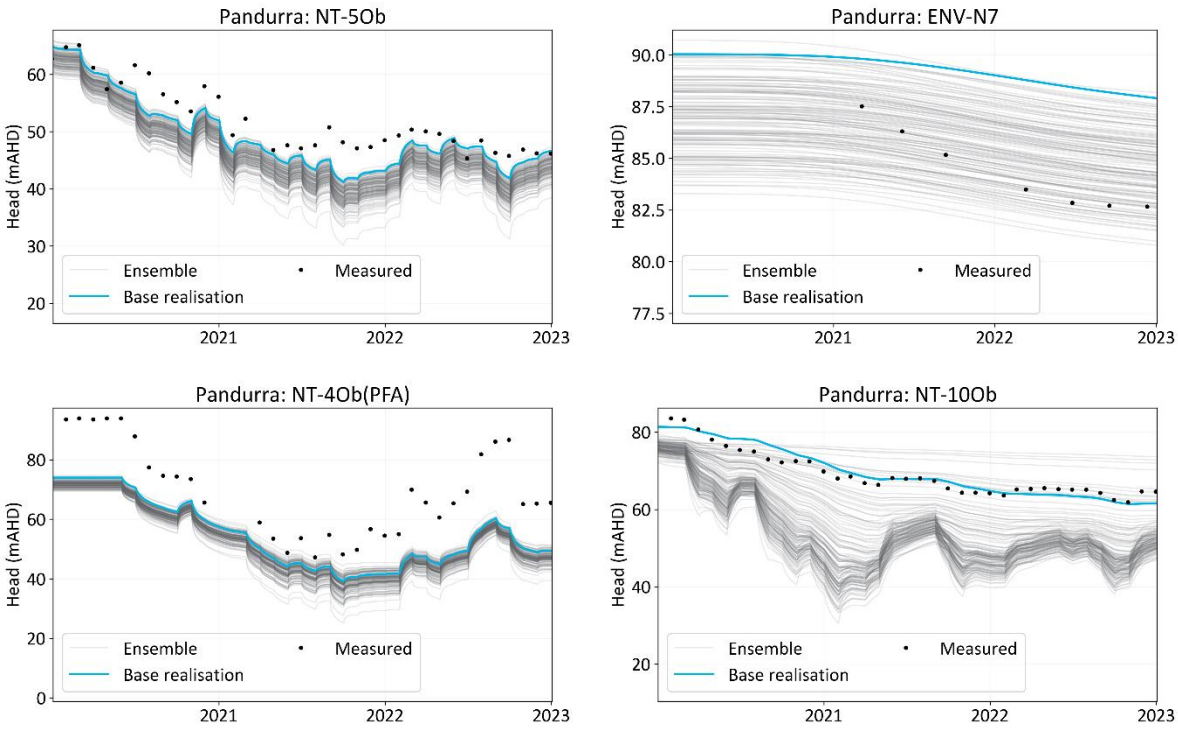


Figure 5.8 Selected hydrographs from history-matching

5.6 Water balance

The modelled water balance for the transient history-matching period is presented in Figure 5.9. The largest fluxes are recharge, evapotranspiration and regional inflows from the general head boundary conditions along the model edge as defined in Figure 4.4 through Figure 4.7. Abstraction from water supply wells increases up to 2021, when it stabilises before declining slightly in 2022. Inflows from storage are primarily balanced by Carrapateena dewatering. Mine dewatering at Carrapateena prior to 2020 was approximated as a single stress period which accounts for the spike at the beginning of the history-matching period. Abstraction data for the Northern Wellfield commenced in 2020 and defined the transient history-matching period for the OKD model.

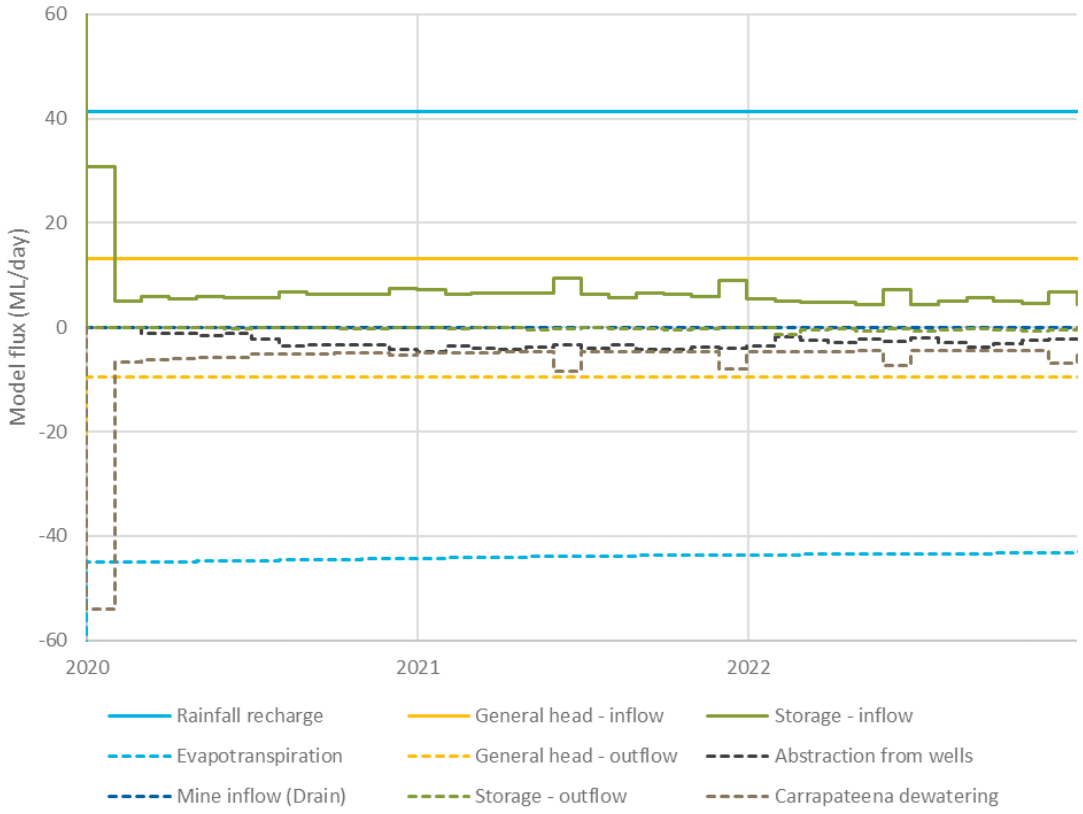


Figure 5.9 Base realisation modelled water balance over the history-matching period

5.7 Adopted hydraulic properties

The PESTPP-IES history-matching process involves algorithmically assigning a value to each varied parameter for each realisation, running all realisations for one iteration, then assigning updated parameter values to improve the match between measured values and model outputs. In this case, iteration five of the PESTPP-IES run was selected as the best ensemble, and the hydraulic parameter values for that iteration are presented in histograms. The 61 parameters, representing horizontal hydraulic conductivity (Kh), vertical hydraulic conductivity (Kv), specific storage (Ss) and specific yield (Sy) for the 15 different HSUs in the model and recharge can be found in Appendix B. The histograms presented in Appendix B show parameter distributions for the entire model footprint, not just at individual pilot points. Spatial distributions of select base realisation hydraulic parameters are also provided in Appendix C.

To interpret the histograms presented in Appendix B:

- The parameter values assigned to each individual pilot point are tallied by frequency for three series:
  - The 'prior' series is shown as a black outline, and shows the pre-history-matching property distribution, which was created by randomly sampling from the initial mean and standard deviation for the property and restricted by assigned minimum and maximum bounds.
  - The 'posterior' series is shown in grey, and shows the post-history-matching property distribution, across all realisations.
  - The 'base realisation' series is shown in blue, and shows the distribution for the base realisation only, with the frequency on the right axis. The lesser number of points in the histogram for the base realisation means it tends to look less like a smooth normal distribution than the other two series.

6 Comparative assessment of predictive modelling results

6.1 Predictive modelling approach

Predictive scenarios were modelled to support assessment of both **incremental** (OKDUGA Project only) and **cumulative** (OKDUGA Project plus the Northern Wellfield, Carrapateena mine and Olympic Dam mine) impacts.

Results are presented in two formats. The first is the 'base realisation' which refers to the realisation with the best statistical match to measurements. Additionally, results are presented in a probabilistic, percentile-based manner. The probabilistic drawdowns present the likelihood of exceeding a drawdown threshold (2 m or 0.2 m) considering all accepted model realisations including the base realisation (135 realisations). The rationale for the percentile-based approach to presenting drawdown from 135 realisations aligns with recommendations by Middlemis and Peeters (2018) that describe the importance of calibrated language and having a consistent and precise language to communicate impacts to decision makers.

Table 6.1 provides a summary of the combined numeric, narrative and visual approach to describing likelihood of drawdown exceeding the threshold values, as a result of the OKDUGA Project. This table provides clarity on how to consider the likelihood bands presented in the modelling outputs provided in Appendix D.

Table 6.1 Combined numeric, narrative, and visual approach for assessing likelihood

Percentile band	Colour code	Outcomes, ranked from small to large
<P10		It is **very unlikely** that drawdown or hydraulic head **exceeds** the threshold.
P10 to P33		It is **unlikely** that drawdown or hydraulic head **exceeds** the threshold.
P33 to P67		It is **as likely as not** the drawdown or hydraulic head **exceeds** the threshold.
P67 to P90		It is **likely** that drawdown or hydraulic head **exceeds** the threshold.
>P90		It is **very likely** that drawdown or hydraulic head **exceeds** the threshold.

6.2 Comparative assessment outcomes

A comparison of the original OKDUGA model and OKD LOM (OKDUGA simulated only) model outputs is provided in Table 6.2. The associated model outputs are provided in Appendix D.

Table 6.2 Comparison between the original OKDUGA model and OKD LOM (OKDUGA simulated only) model outputs

Model output	Analysis of comparison
Base realisation water balance.	The modelled transient water balance of the base realisation through construction and exploration periods of the project is shown in Figure D.1. The water balance for both models show that the steady state water balance is maintained over the prediction period for most components. Abstraction from the Northern Wellfield and inflow to excavations are balanced directly by water from aquifer storage, with negligible change to the other terms. In the OKD LOM (OKDUGA simulated only model), high inflow via regional boundary conditions is balanced by high outflow via evapotranspiration; this is associated with the adoption of equivalent freshwater heads to define boundary conditions and as history-matching targets, which translate to simulation of an upward vertical gradient in parts of the model with discharge via evapotranspiration in areas of shallow watertable.

Model output	Analysis of comparison
Modelled groundwater inflow to project components.	Modelled groundwater inflows to OKDUGA Project components (i.e. the underground decline) for the construction period are presented in Figure D.2 for all model realisations[3], which assumes a Project commencement date of May 2026. A high-level schedule of the OKDUGA Project is included along the top of the figure. Inflows for both models begin to increase after two years aligned with when the OKDUGA Project intersects the first high permeability zone within the LSP (LSP3). The original OKDUGA model had a peak mean volume of 113 L/s, or 9.8 ML/d predicted at the end of construction for the base case realisation. The OKD LOM (OKDUGA simulated only) model has a higher peak mean volume of 219 L/s, or 18.9 ML/d predicted at the end of construction for the base case realisation. This difference in inflow is attributable to changes in the underlying model conceptualisation and design, as well as the fact that the model mesh has not been optimised to the decline design. In particular it has not been specifically refined around the ventilation shafts. The updated modelling still indicates that the HSU of most significance regarding groundwater inflow to excavations is the Upper PFA high K layer, (equivalent to the Upper LSP high K layer (LSP3) in the original model). Excavation of each ventilation shaft still results in a noticeable increase in modelled inflow. As previously explained, the ventilation shafts are excavated directly upwards from the exploration loop, and each intercepts the highly fractured parts of the LSP where more groundwater is anticipated to enter excavations. The P90 inflow rates were more than double that of the P10 in the original OKDUGA model. This was considered reasonable result given the high uncertainty with regard to hydrostratigraphy and associated hydraulic properties at this stage in OKDUGA Project investigations. The OKD LOM (OKDUGA simulated only) model predicts P10 and P90 flow rates that are much closer in range, a result of the updated parameterisation.
Incremental base case drawdown in the THA.	In the original OKDUGA model, predicted drawdown expands following the construction and exploration phases, with only the 0.2 m drawdown contour expanding to the north of the RL Project Area. One hundred years after construction there is further drawdown north of the RL Project Area by up to 1 m, and a separate 0.2 m drawdown area in the west. In the OKD LOM (OKDUGA simulated only) model more drawdown is predicted outside of the RL Project Area, particularly to the east and south-east however it does not extend as far as Lake Torrens or the Carrapateena Arm. Maximum drawdown of 10 m is predicted following the exploration phase, both inside the RL Project Area, as well as to the east. There are also discrete pockets of drawdown, maximum 2 m at end of exploration in the south-west of the RL Project Area in and around areas of inactive cells where the THA is modelled as not being present. These differences in drawdown are attributable to changes in the underlying model conceptualisation and design (including the incorporation of density-corrected heads), as well as the fact that the model mesh has not been optimised to the decline design.
Incremental base case drawdown in the Upper LSP/PFA high K.	In the original OKDUGA model, modelled drawdown expands outward in an approximate circular shape up to 100 years post OKDUGA Project construction. The maximum incremental drawdown within the RL Project Area is greater than 200 m around the OKDUGA Project underground works, required for dry working conditions. Drawdown at the RL Project Area recovers to 2 m by the end of recovery and to 0.2 m near the Carrapateena Arm. In the OKD LOM (OKDUGA simulated only) model, modelled drawdown expands outward in an approximate north-south elliptical shape up to 100 years post OKDUGA Project construction. The maximum incremental drawdown within the RL Project Area is still greater than 200 m around the OKDUGA Project underground works and drawdown at the RL Project Area still recovers to less than 2 m by the end of recovery and to 0.5 m near the Carrapateena Arm. Minor drawdown (0.2m) does reach the extent of the Upper PFA high K layer in the north, as well as the extent of the larger model domain in a small area to the north-east. Again, these differences in drawdown are attributable to changes in the underlying model conceptualisation and design (including the incorporation of density-corrected heads and updated layering), as well as the fact that the model mesh has not been optimised to the decline design.

3 Although an ensemble of 98 accepted realisations were simulated, Figure D.2 just shows the key percentile bands aligned to the narrative described in Table 6.1.

Model output	Analysis of comparison
Mid-range probabilistic (i.e. 33–67% likelihood) incremental drawdown in the THA.	In the original OKDUGA model, the 2 m likelihood exceedance drawdown extent is predominantly confined to the RL Project Area for all time periods. Drawdown is predicted around the exploration loop, the decline entry and an area to the north of the decline entry. The 0.2 m likelihood exceedance drawdown extent expands outside the RL Project Area at the end of exploration and continues to expand 100 years post construction. In the OKD LOM (OKDUGA simulated only) model, the 2 m likelihood exceedance drawdown extent is predominantly confined to the RL Project Area for the end of construction phase but expands further east and south-east at the end of exploration. The 0.2 m likelihood exceedance drawdown extent is more extensive in all directions around the RL Project Area, with the greatest extent observed at the end of recovery, however the drawdown does not extend as far as Lake Torrens or the Carrapateena Arm. Again, there are discrete pockets of drawdown to the south-west of the RL Project Area in and around areas of inactive cells where the THA is modelled as not present.
Mid-range probabilistic (i.e. 33–67% likelihood incremental drawdown in the Upper LSP/PFA high K.	In the original OKDUGA model, the 2 m likelihood exceedance drawdown peaks at the end of the exploration phase, spanning outside the RL Project Area in an approximate circular shape. The extent of the 0.2 m drawdown comprises most of the model area 100 years post construction, however the 2 m drawdown at the same time is confined to around the RL Project Area. Therefore 100 years post construction drawdown is wide ranging but of small magnitude (i.e. less than 2 m). In the OKD LOM (OKDUGA simulated only) model, the 2 m likelihood exceedance drawdown expands outward in an approximate north-south elliptical shape up to the end of exploration, extending almost to the Carrapateena Arm. It contracts significantly during the recovery phase. The 0.2 m likelihood exceedance drawdown is more expansive, reaching the Carrapateena Arm and almost to the edge of Lake Torrens to the north-east.
Cumulative base case drawdown in the THA.	In the original OKDUGA model, the maximum drawdown is up to 5 m at the end of exploration. Drawdown peaks at the end of recovery with drawdown reaching 2 m to the north of the RL Project Area but does not extend to the Northern Wellfield MPL boundary. Drawdown up to 0.2 m is predicted over the Northern Wellfield. At the end of recovery, a separate 0.2 m drawdown area in the west is also predicted. The maximum drawdown has recovered to 2 m, with the extent nearly expanding to the northern arm of Northern Wellfield. In the OKD LOM (OKDUGA simulated only) model much more drawdown is predicted outside of the RL Project Area in the following areas: • North-western model boundary – up to 20 m at the end of recovery, due to the Olympic Dam mine which was not simulated in the smaller original OKDUGA model. • North-east of the RL Project Area – up to 10 m at the end of the exploration phase, due to the interaction with the existing Northern Wellfield (the location of which, both horizontally and vertically has been amended in the updated modelling as detailed in Section 4.5.5). • South-east of the RL Project Area – up to 2 m at the end of the exploration phase, due to the Carrapateena mine which was not simulated in the smaller original OKDUGA model. • South-west of the RL Project Area – again, areas of discrete pockets of drawdown, maximum 2 m at end of exploration in and around areas of inactive cells where the THA is modelled as not present.
Cumulative base case drawdown in the Upper LSP/PFA high K.	In the original OKDUGA model, modelled cumulative drawdown spans most of the model domain and is highest in the RL Project Area, where it exceeds 200 m at the end of exploration. Drawdown of up to 100 m is predicted at the Northern Wellfield production wells. By the end of recovery drawdown still spans most of the RL Project Area, but there has been much recovery over the RL Project Area and Northern Wellfield, where predicted drawdown is less than 10 m. Drawdown of up to 1 m is predicted at the Lake Torrens Carrapateena Arm at the end of recovery and construction. In the OKD LOM (OKDUGA simulated only) model, the modelled cumulative drawdown does not reach the edges of the model domain, aside from small areas to the north-east and the north-west (the latter likely to be influenced by the presence of the Olympic Dam mine, not modelled in the original OKDUGA model. There is less influence of the Northern Wellfield pumping bores on cumulative drawdown observed the Upper PFA high K layer, due to the relocation of some wells, in addition to changes in pumping rates as detailed in Section 4.5.5. Modelled cumulative drawdown is still highest in the RL Project Area, where it exceeds 400 m at the end of construction and exploration. Faster recovery is expected to occur, where drawdown is predicted to be less than 5 m after 100 years. Drawdown of less than 0.5 m is predicted under the Lake Torrens Carrapateena Arm at the end of recovery.

Model output	Analysis of comparison
Mid-range probabilistic (i.e. 33–67% likelihood cumulative drawdown in the THA.	In the original OKDUGA model, the 2 m likelihood exceedance cumulative drawdown expands to the north of the RL Project Area at the end of recovery. The 0.2 m likelihood exceedance cumulative drawdown extent is only slightly greater than the incremental drawdown, and the separate western drawdown zone also eventuates. In the OKD LOM (OKDUGA simulated only) model, both the 2 m and 0.2 m likelihood exceedance cumulative drawdown extents are greater than in the original OKDUGA model, due to the effect of hydrogeological conceptualisation changes to the model (such as incorporation of density corrections), as well as the influence of Olympic Dam mine, Northern Wellfield and the Carrapateena mine that were not previously represented in this layer. The 2 m cumulative drawdown associated with the OKDUGA Project and Northern Wellfield does not reach the Carrapateena Arm or Lake Torrens, while the 0.2 m, cumulative drawdown at the end of exploration just reaches the Carrapateena Arm. Predicted drawdown in this area is also influenced by the Carrapateena mine.
Mid-range probabilistic (i.e. 33–67% likelihood cumulative drawdown in the Upper LSP/PFA high K.	In the original OKDUGA model, the 2 m likelihood exceedance cumulative drawdown extends to Lake Torrens by the end of exploration. The 0.2 m likelihood drawdown extends to Lake Torrens by the end of construction and expands to cover the majority of the model domain by the end of recovery. In the OKD LOM (OKDUGA simulated only) model, the 2 m likelihood exceedance cumulative drawdown does not span the entirety of the model domain, and in fact contracts during the recovery phase – no longer reaching the Carrapateena Arm. The 0.2 m likelihood drawdown is more extensive across the model domain, but again only reaches the model boundary in small areas to the north-east and the north-west (the latter in the vicinity of the Olympic Dam mine, not modelled in the original OKDUGA model).
Groundwater flow contribution to Lake Torrens.	In the original OKDUGA GEA, the modelling indicated that the potential reduction in groundwater outflow from the model area was 2% which translated to a potential reduction of 0.06% of total groundwater contribution to Lake Torrens. In the OKD LOM (OKDUGA simulated only) model an incremental reduction in groundwater flux to Lake Torrens of 0.002 GL/yr is predicted at the end of exploration. This equates to a reduction of 0.2% of the modelled pre-development groundwater flux to Lake Torrens from the model domain (0.97 GL/yr) and 0.002% of the estimated total flow to Lake Torrens.

7 OKDUGA Project updated assessment of effects

An updated assessment of effects for the OKDUGA Project, based on the comparison of the original OKDUGA model and OKD LOM (OKDUGA simulated only) model outputs as detailed in Table 6.2, is provided in Table 7.1. The assessment of effects presented below has not materially changed from that presented in the June 2024 iteration of this report.

Table 7.1 Updated assessment of effects

Receptor	Updated assessment of effects analysis
Third party landholder bores	Groundwater utilisation by landholders is sparse. Where groundwater is used, it is predominately sourced from local groundwater systems in perched Quaternary sediments that are hydraulically separate from the THA. The modelled drawdown in the THA can represent areas of shallow groundwater, particularly in highland areas where Quaternary sediments have not accumulated, but there are no active third-party landholder bores that overlie areas of greater than 2 m incremental or cumulative drawdown in the THA. No impacts to third party landholders bores are predicted. Notwithstanding this BHP will undertake a bore census to confirm the status of bores, particularly at Arcoona and Bosworth stations including usage during drought conditions (Section 8.4).
GDEs	Terrestrial vegetation considered to be potential GDEs are typically located adjacent to creeks and accumulations of sediments that can hold water for a period of time. Incremental drawdown in the THA extends to mapped terrestrial GDEs to the south (in the vicinity of Elizabeth Creek), south-east (creek line north of Salt Creek) and east (associated with Bosworth Creek) of the RL Project Area (refer to Figure D.3). The greatest drawdown, up to 5 m at the end of exploration, occurs around a portion of Bosworth Creek. Cumulative THA drawdown is observed at mapped terrestrial GDEs to the north and further east of Bosworth Creek (attributable to the Northern Wellfield), south-east around Salt Creek (largely attributable to the Carrapateena Mine), and south-west at Lake Richardson (refer to Figure D.9). The reliance of these mapped GDEs on the THA has not been confirmed. Due to the high salinities (average 22,651 µS/cm) and great depths to the THA in the region, terrestrial vegetation potentially relying on groundwater likely utilise water from the shallow Quaternary sediments rather than deeper groundwater (OZ Minerals 2017). Due to the high salinity of the deeper fractured rock aquifers it is unlikely deep-rooted vegetation identified within the OKDUGA Project utilise such groundwater resources. Rather, it is more likely that deep-rooted vegetation, such as eucalyptus woodlands, can potentially access shallow and freshwater sources in perched Quaternary sediments such as surficial lenses or bank storage where recharge water sits within the soil profile that is not part of a typical groundwater system. Ecological field surveys undertaken for the nearby Carrapateena Mine confirmed terrestrial vegetation relies on rainfall run-off, creek flows and shallow groundwater, and this vegetation is mostly associated with creek lines and springs (OZ Minerals 2017). Two springs fed by the fractured rock aquifer (PFA) that may support GDEs are located along Salt Creek. Incremental drawdown does not extend to these two springs, however with the influence of the Carrapateena mine cumulative PFA drawdown of up to 0.5 m does at the end of the construction and exploration phases, based on the conservative assessment from the Upper PFA high K layer. These GDEs occur near creek lines, and the GDEs and potential reliance on groundwater has not been ground truthed. BHP will continue to undertake targeted GDE studies as part of the PRD forward works plan to determine the plant species and potential reliance on groundwater within the OKDUGA Project Area and at areas identified to be potentially impacted by groundwater drawdown.

Receptor	Updated assessment of effects analysis
Lake Torrens	Based on a groundwater balance, Jacobs (2016a) estimated that the groundwater contribution to Lake Torrens from the west is approximately 3.3 gigalitres per year (GL/yr), representing approximately 3% of the total water contribution (i.e. approximately 110 GL/yr). Furthermore, groundwater evaporates upon discharge to Lake Torrens as evident by the predominately dry conditions in the Lake. Modelled base case incremental THA drawdown does not extend to Lake Torrens; for the cumulative case drawdown up to 0.2 m is predicted under the Carrapateena Arm that could be considered associated with the OKDUGA project as well as the Carrapateena mine. Modelled base case incremental PFA drawdown up to 1 m is predicted under the Carrapateena Arm, while for the cumulative case drawdown around 2 m is predicted under the Carrapateena Arm and central western edge of Lake Torrens. Potential reductions in groundwater level could result in reductions in groundwater discharge to parts of Lake Torrens (consistent with the GEA for the Proposal). The updated groundwater modelling predicts an incremental reduction in groundwater flux to Lake Torrens of 0.002 GL/yr at the end of exploration. This equates to a reduction of 0.2% of the modelled pre-development groundwater flux to Lake Torrens from the model domain (0.97 GL/yr) and 0.002% of the estimated total groundwater flow to Lake Torrens. The impact is still considered minor as groundwater contribution to Lake Torrens from the west comprises only 3% of the total water balance and groundwater is not considered to sustain the lake water levels.
Indigenous communities	Indigenous communities may have heritage and cultural relationships with groundwater, Lake Torrens and/or GDEs in the OKDUGA Project Area. BHP will continue to undertake, cultural heritage assessments in accordance with the *Aboriginal Heritage Act 1988* (SA) and the agreed procedures and protocols for heritage management with the KAC, KYA and BDAC Indigenous Groups. Identification of Aboriginal cultural heritage values will continue to be compiled through background research, predictive modelling, Aboriginal consultation, archaeological field investigations and anthropological assessments. However, the current groundwater modelling has indicated that potential impacts to Lake Torrens and potential GDEs are minimal (i.e. not significant).

8 Impact assessment

8.1 Impact significance criteria

The impact significance criteria is presented in the Environmental Impact Assessment Framework (EIAF) Appendix A to the Proposal. Criteria relevant to the assessment of the groundwater related impact significance is presented in Table 8.1.

Table 8.1 Consequence definitions and significance determination

Severity level	1	2	3	4	5
Environmental value	**Not significant**		**Significant**		
Groundwater quantity impacting GDEs, landholders, future users).	No, or negligible reduction or change in quantity available to current and potential receptors.	Local (on-site) reduction or change in water quantity that can be immediately (within one year) remediated.	Local (on-site) reduction or change in water quantity that can be remediated in the long term (during exploration).	Widespread (regional) reduction or change in water quantity available to current and potential receptors that can be remediated during exploration.	Regional reduction or change in quantity available to current and potential receptors that cannot be remediated during exploration.
Groundwater quality impacting (GDEs, landholders, future users).	No or minimal reduction in water quality, where water quality objectives are maintained.	Local (on-site) reduction in water quality (exceeding water quality objectives) that can be remediated within one year.	Local (on-site) reduction in water quality (exceeding water quality objectives) that can be remediated in the long term (during exploration).	Widespread (regional) reduction in water quality (exceeding water quality objectives) at location of current or potential receptors that can be remediated during exploration.	Regional reduction in water quality at location of current or potential receptors that cannot be remediated during exploration.

8.2 Impact assessment

The updated impact significance is summarised in Table 8.2. The impact significance presented below has not materially changed from that presented in the June 2024 iteration of this report.

Table 8.2 Groundwater related impact assessment

Potential impact event	Impact significance	Significance justification	Uncertainty
Potential reduction in groundwater contribution Lake Torrens.	2	Up to 2 m reduction in PFA groundwater levels near Lake Torrens, potentially resulting in reductions in groundwater contribution to Lake Torrens (consistent with the GEA for the Proposal). The updated groundwater modelling predicts an incremental reduction in groundwater flux to Lake Torrens of 0.002 GL/yr at the end of exploration. This equates to a reduction of 0.2% of the modelled pre-development groundwater flux to Lake Torrens from the model domain (0.97 GL/yr) and 0.002% of the estimated total flow to Lake Torrens. The impact is still considered minor as groundwater contribution to Lake Torrens from the west comprises only 3% of the total water balance and groundwater is not considered to sustain the lake's water level. BHP will develop a groundwater monitoring network to measure water quality and water levels for the OKDUGA Project (Section 8.4).	Moderate – predicted modelling based on improved but still minimal existing baseline data, moderately understood hydrostratigraphy. Changes to assumptions are unlikely to materially alter the outcomes of the effects assessment for this receptor.
Potential drawdown in the THA underlying potential mapped terrestrial GDEs.	2	Up to 5 m reduction in THA groundwater level underlying potential mapped terrestrial GDEs. The reliance of these GDEs on the THA has not been confirmed and is considered unlikely given the groundwaters salinity. BHP will continue to undertake targeted GDE studies to determine the plant species and potential reliance on groundwater within the OKDUGA Project Area and at areas identified to be potentially impacted by groundwater drawdown.	Moderate – predicted modelling based on improved but still minimal existing baseline data, moderately understood hydrostratigraphy. Changes to assumptions are unlikely to materially alter the outcomes of the effects assessment for this receptor.
Potential drawdown in the LSP underlying two springs with potential terrestrial GDEs.	2	Up to 0.5 m reduction in PFA groundwater level underlying two springs along Salt Creek (mainly due to the cumulative influence with Carrapateena mine). BHP's Carrapateena Project has approval to impact on these two springs with associated biodiversity offsets.	Moderate – predicted modelling based on improved but still minimal existing baseline data, moderately understood hydrostratigraphy. Changes to assumptions are unlikely to materially alter the outcomes of the effects assessment for this receptor.

Potential impact event	Impact significance	Significance justification	Uncertainty
Cultural heritage and indirect effects, where potential impacts to Lake Torrens and GDEs impact.	2	BHP has, and will continue, to consult with the KAC on the OKDUGA Project and potential reductions in groundwater supply to Lake Torrens and GDEs. BHP respects the cultural rights of the Traditional Owners and would not disclose results of cultural information.	Moderate – BHP has undertaken, and will continue to undertake, Cultural Heritage Assessments with KAC in accordance with the *Aboriginal Heritage Act 1988* (SA). Identification of Aboriginal cultural heritage values have been, and will continue to be, compiled through background research, predictive modelling, Aboriginal consultation, archaeological field investigations and anthropological assessments. Oak Dam will implement a Cultural Heritage Management Plan (CHMP) as part of its overall Environment and Community Management Plan (ECMP) to ensure the ongoing protection of cultural heritage through the development of a cultural heritage management system.

8.3 Management and mitigation

Each confirmed impact event is required to have a description of proposed management and mitigation measures applied, aimed at either breaking the source-pathway-receptor linkage (i.e. avoiding the impact) or otherwise reducing the impact significance to as low as reasonably achievable. These are presented in the following sections.

8.3.1 Impact significance level 1 and 2 (not significant)

The following management and mitigation measures are proposed for the potential direct impacts:

- Mitigation of PFA drawdown and potential reduction in groundwater contribution to Lake Torrens is not necessary given the predicted impact is minor and groundwater does not sustain Lake water levels. BHP will develop a groundwater monitoring network to measure water quality and water levels for the OKDUGA Project (Section 8.4).
- Mitigation of groundwater level drawdown at the potential GDEs require should further investigations confirm whether affected vegetation is an important plant community type and has some reliance on groundwater from the THA, where drawdown is predicted. This may include offsets if required. BHP will continue to undertake targeted GDE studies to determine the plant species and potential reliance on groundwater within the OKDUGA Project Area and at areas identified to be potentially impacted by groundwater drawdown (Section 8.4).

8.3.2 Impact significance level 3, 4 and 5 (significant)

Not applicable.

8.4 Forward work plan

A forward workplan, proposed in Table 8.3, outlines the potential groundwater uncertainties or data gaps, and the proposed approach to address.

Table 8.3 Forward work plan

Data uncertainty	Proposed approach
Areas of mapped GDE rely on satellite imagery and have not been ground truthed	BHP will continue to undertake targeted GDE studies to determine the plant species and potential reliance on groundwater within the OKDUGA Project and at areas identified to be potentially impacted by groundwater drawdown. The targeted GDE investigations is proposed to be undertaken as follows: • Survey of potential GDE / vegetation species sites within the lower reaches of the Bosworth Creek • Sampling and comparison of stable oxygen and hydrogen isotopes of plant water and surface/groundwater samples collected • Analysis of the chemical composition (major cations and anions) of water samples collected. • Assessment and reporting of GDE survey and laboratory results to determine if vegetation is using groundwater and if so, to what extent is the vegetation reliant upon groundwater – a conceptual model would be developed for each site to present potential processes occurring for these for vegetation water uptake • Past trend assessment (i.e. monitoring) using sentinel remote sensed data paired with water sampling locations and selected control sites.
Cultural heritage	BHP will continue to undertake, cultural heritage assessments in accordance with the *Aboriginal Heritage Act 1988.* Identification of Aboriginal cultural heritage values will continue to be compiled through background research, predictive modelling, Aboriginal consultation, archaeological field investigations and anthropological assessments.
OKDUGA Project aquifer properties	Additional drilling and/or laboratory testing may be undertaken to further refine groundwater hydraulic properties within the OKDUGA Project Area.
Hydrogeological conceptualisation	The conceptual hydrogeological understanding in the OKDUGA Project Area will be updated to reflect additional drilling investigations.
Landholder bores	BHP will undertake a bore census to confirm the status of bores, particularly at Arcoona and Bosworth stations including usage during drought conditions. The bore census is proposed to be undertaken as follows: • record bore details (i.e. bore owners name, pastoral station, unique identification / registered number of the bore, photograph of headworks, GPS coordinates) • record standing water level (SWL) • where a bore is equipped and/or pumping record: – pump details (i.e. equipment, pump depth, etc.) – duration of pumping and rest periods – maximum pumping rates • record groundwater quality parameters (i.e. pH, electrical conductivity (EC), total dissolved solids (TDS)) • consultation with the pastoral landholder on bore water usage, including during drought conditions.
Groundwater monitoring	BHP will develop a groundwater monitoring network to measure water quality and water levels for the OKDUGA Project.
Groundwater modelling calibration	BHP will undertake calibration of the OKDUGA groundwater model with additional drilling and operational monitoring data within two years of the decline development intersecting groundwater.

9 Conclusion

All available data have been used to inform the hydrogeological conceptualisation, model history-matching and predictions. Based on the DEM/DEW comments received in May 2024 and August 2024, BHP has undertaken a number of groundwater model reviews (i.e. boundary conditions, measured groundwater levels, density corrections, etc) with no material change to model predictions or predicted impacts to sensitive receptors.

An ensemble-based predictive uncertainty analysis has been employed to explore potential changes to groundwater conditions associated with exploration activities, with a conservative risk-based approach applied to the impact assessment. This approach aligns with industry best practice by making predictions consistent with the hydrogeological conceptualisation and constrained by model performance against measured data, allowing for wider ranges of predictions in areas with less information.

The OKDUGA Project is intended to provide a means to obtain more local data, which will further inform the conceptual understanding of the groundwater system and provide a data-driven basis for updating any future modelling should the Project proceed to a future MLP. As the supporting data grow, uncertainty in predictions can be reduced through history-matching to the expanded dataset.

Following completion of the assessment of effects investigation, it was determined that there were four confirmed impact events during construction, exploration and recovery, specifically:

- Minor potential reduction in groundwater contribution to Lake Torrens, where groundwater does not sustain Lake water levels.
- Potential drawdown in the THA underlying potential GDEs, where the actual reliance on groundwater and plant type is yet to be determined.
- Minor potential cumulative drawdown in the PFA underlying two watercourse springs along Salt Creek that are partially supported by groundwater discharge from the fractured rock aquifer, however BHP's Carrapateena Project has approval to impact on these two springs with associated biodiversity offsets.
- Potential cultural heritage effects, and indirect effects where impacts to groundwater, Lake Torrens and GDEs materialise impacting Indigenous cultural heritage values.

These events were assessed to quantify the likely significance of the impact against the EIAF impact significance criteria and all were determined to be not significant. The following mitigation and management measures are proposed to minimise the impact significance:

- BHP will conduct additional drilling and/or laboratory testing will be undertaken to further refine groundwater hydraulic properties within the OKDUGA Project Area.
- The conceptual hydrogeological understanding in the OKDUGA Project Area will be updated to reflect additional drilling investigations.
- BHP will undertake a bore field census to confirm the status of bores, particularly at Arcoona and Bosworth stations including usage during drought conditions.
- Further investigation of potential GDEs to confirm whether vegetation is an important plant community type with some reliance on groundwater from the THA. BHP will develop a groundwater monitoring network to measure water quality and water levels for the OKDUGA Project.
- BHP has, and will continue, to consult with the KAC on the OKDUGA Project and potential reductions in groundwater supply to Lake Torrens and GDEs.

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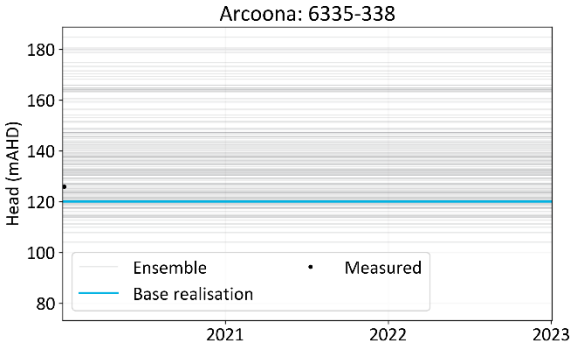
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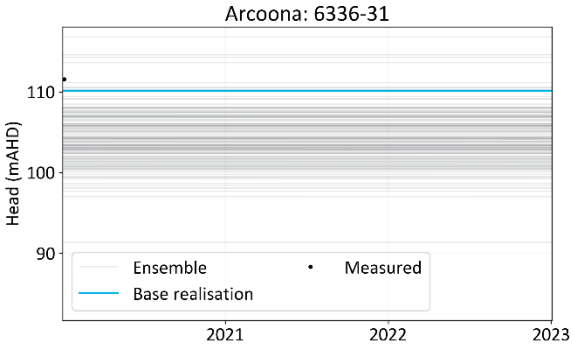
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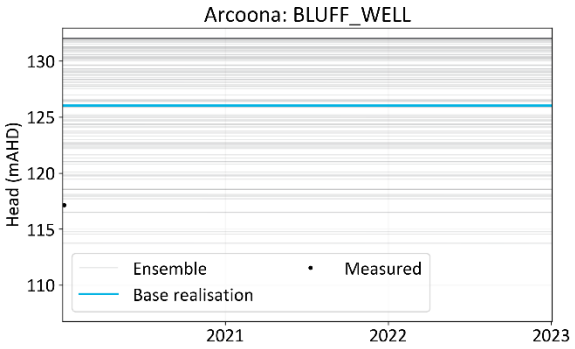
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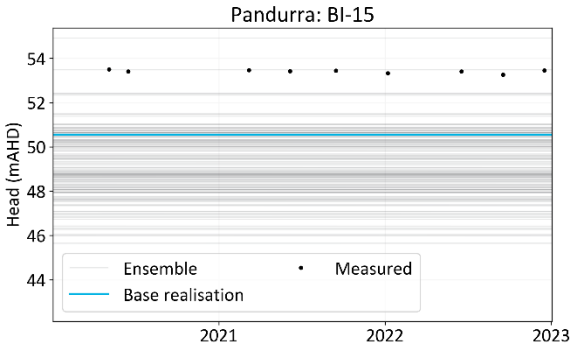
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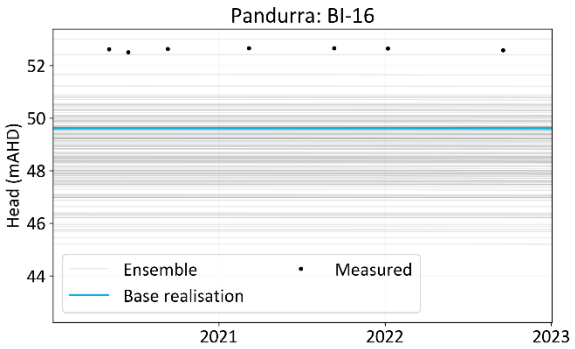
EMM
creating opportunities

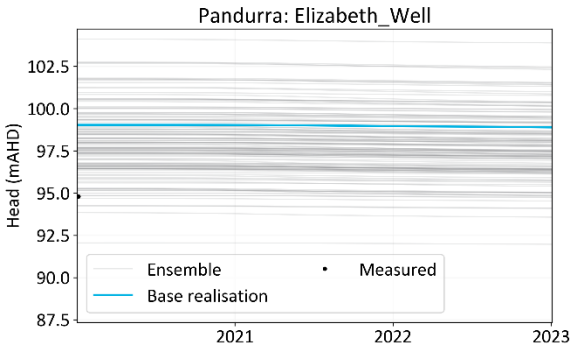

Arcoona: 6335-338
Head (mAHD)
180
160
140
120
100
80
2021
2022
2023
Ensemble
Measured
Base realisation

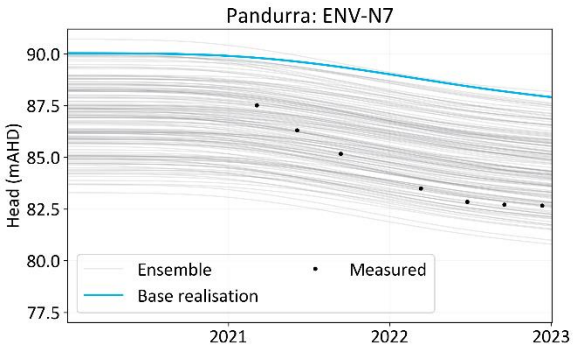

Arcoona: 6336-31
Head (mAHD)
110
100
90
2021
2022
2023
Ensemble
Measured
Base realisation

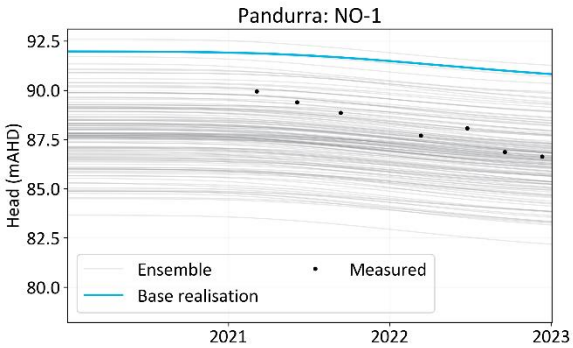

Arcoona: BLUFF_WELL
Head (mAHD)
130
125
120
115
110
2021
2022
2023
Ensemble
Measured
Base realisation

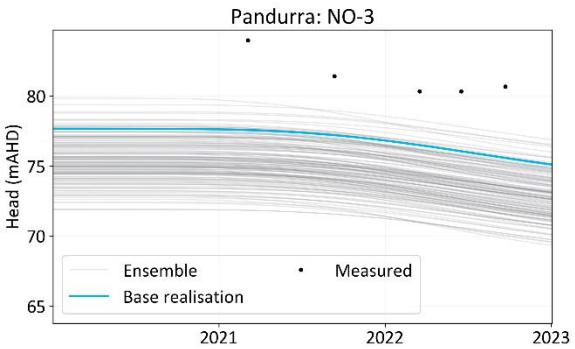

Pandurra: BI-15
Head (mAHD)
54
52
50
48
46
44
2021
2022
2023
Ensemble
Measured
Base realisation

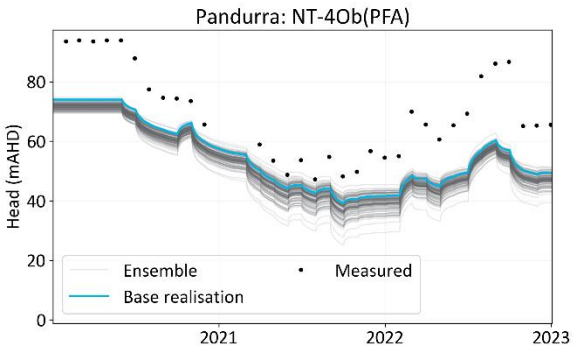

Pandurra: BI-16
Head (mAHD)
52
50
48
46
44
2021
2022
2023
Ensemble
Measured
Base realisation

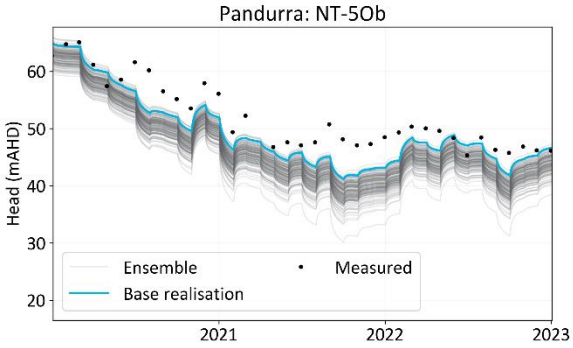

Pandurra: Elizabeth_Well
Head (mAHD)
102.5
100.0
97.5
95.0
92.5
90.0
87.5
2021
2022
2023
Ensemble
Measured
Base realisation

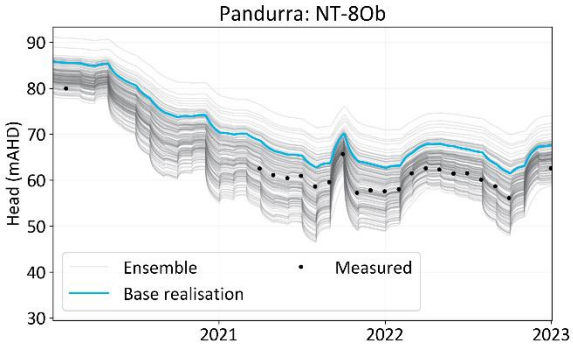

Pandurra: ENV-N7
Head (mAHD)
90.0
87.5
85.0
82.5
80.0
77.5
2021
2022
2023
Ensemble
Measured
Base realisation

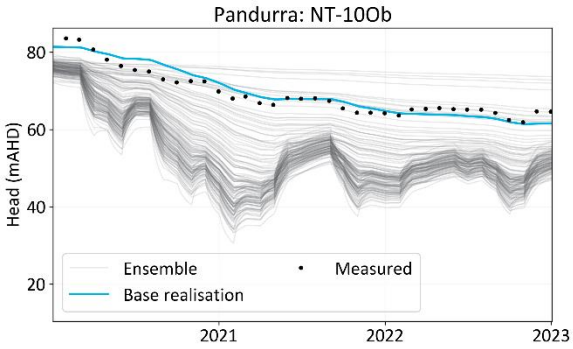

Pandurra: NO-1
Head (mAHD)
92.5
90.0
87.5
85.0
82.5
80.0
2021
2022
2023
Ensemble
Measured
Base realisation

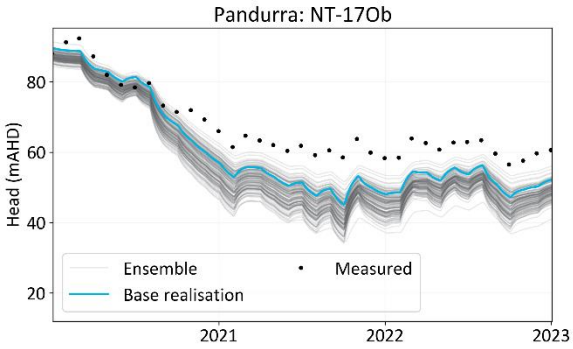

Pandurra: NO-3
Head (mAHD)
80
75
70
65
2021
2022
2023
Ensemble
Measured
Base realisation

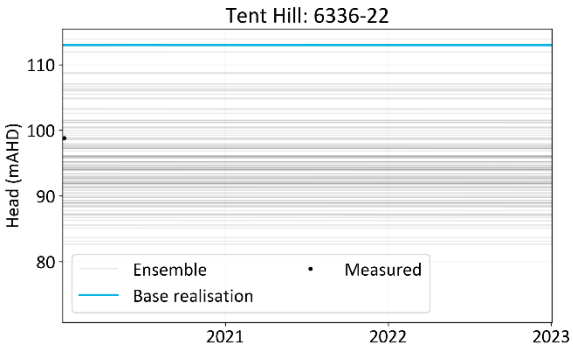

Pandurra: NT-4Ob(PFA)
Head (mAHD)
80
60
40
20
0
2021
2022
2023
Ensemble
Measured
Base realisation

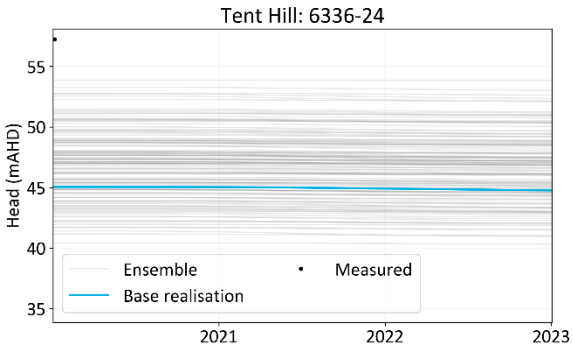

Pandurra: NT-5Ob
Head (mAHD)
Ensemble
Measured
Base realisation
2021
2022
2023

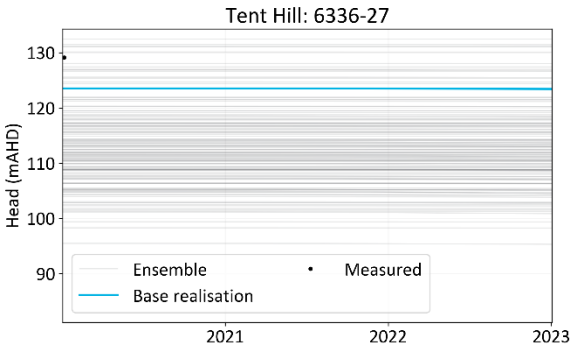

Pandurra: NT-8Ob
Head (mAHD)
Ensemble
Measured
Base realisation
2021
2022
2023

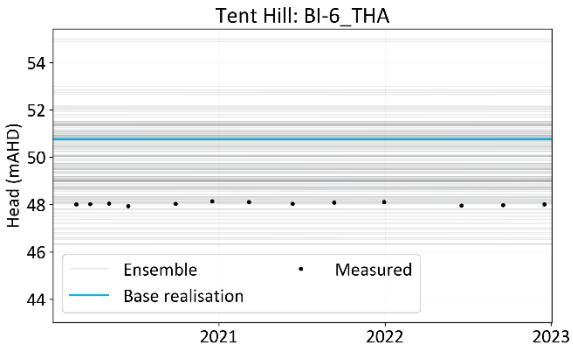

Pandurra: NT-10Ob
Head (mAHD)
Ensemble
Measured
Base realisation
2021
2022
2023

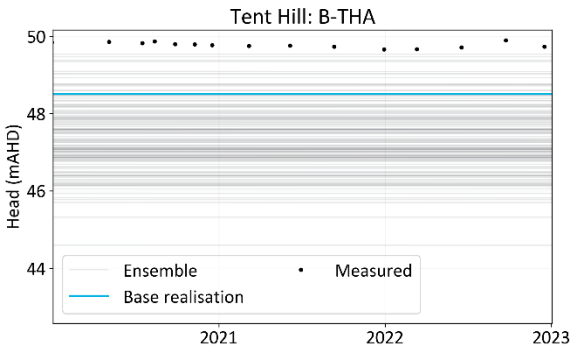

Pandurra: NT-17Ob
Head (mAHD)
Ensemble
Measured
Base realisation
2021
2022
2023

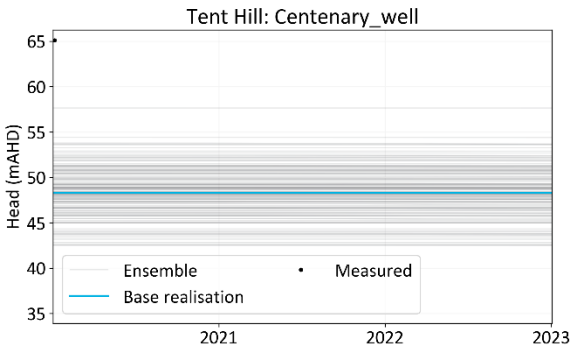

Tent Hill: 6336-22
Head (mAHD)
Ensemble
Measured
Base realisation
2021
2022
2023

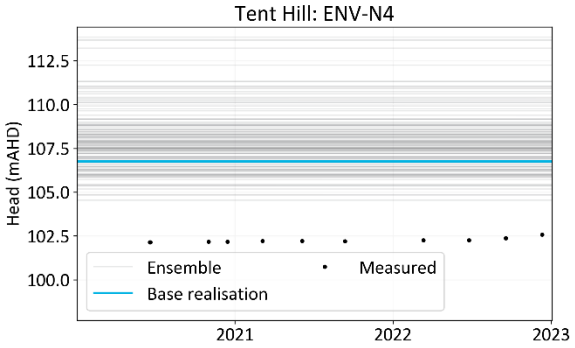

Tent Hill: 6336-24
Head (mAHD)
Ensemble
Measured
Base realisation
2021
2022
2023

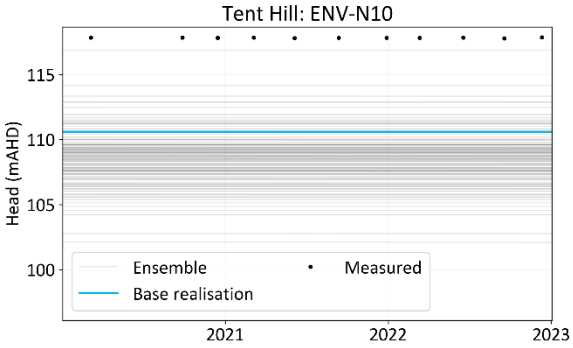

Tent Hill: 6336-27
Head (mAHD)
Ensemble
Measured
Base realisation
2021
2022
2023

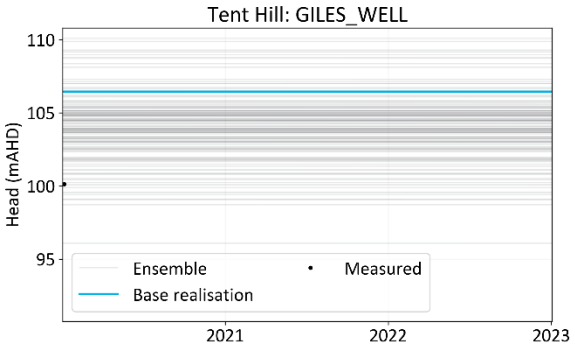

Tent Hill: BI-6_THA
Head (mAHD)
Ensemble
Measured
Base realisation
2021
2022
2023

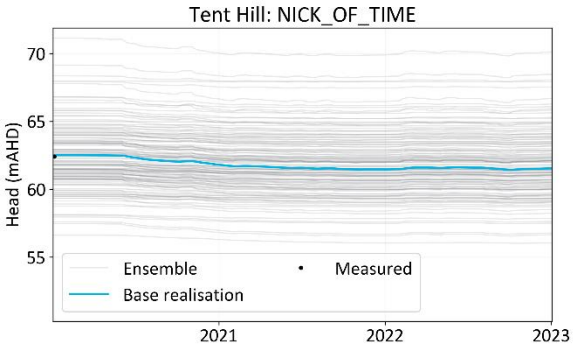

Tent Hill: B-THA
Head (mAHD)
Ensemble
Measured
Base realisation
2021
2022
2023

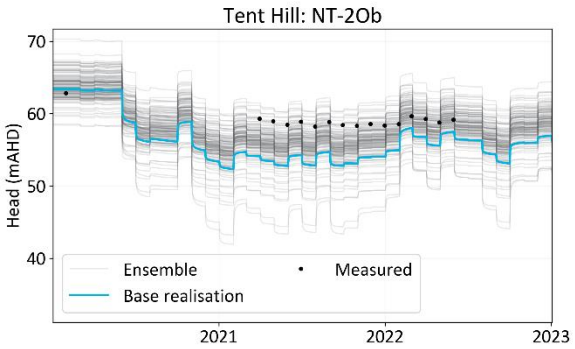

Tent Hill: Centenary_well
Head (mAHD)
Ensemble
Measured
Base realisation
2021
2022
2023

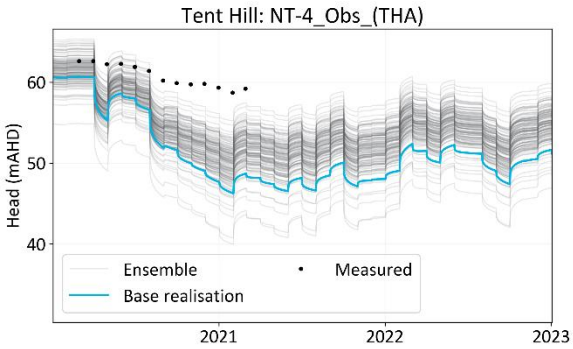

Tent Hill: ENV-N4
Head (mAHD)
112.5
110.0
107.5
105.0
102.5
100.0
Ensemble
Measured
Base realisation
2021
2022
2023

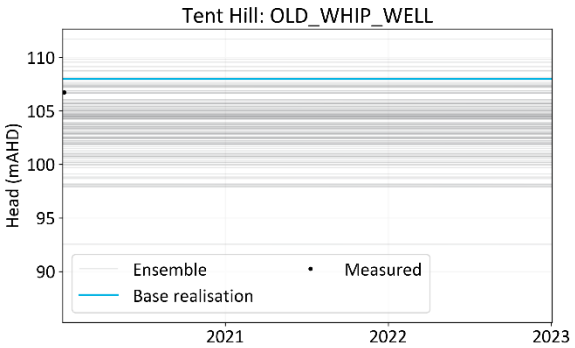

Tent Hill: ENV-N10
Head (mAHD)
115
110
105
100
Ensemble
Measured
Base realisation
2021
2022
2023

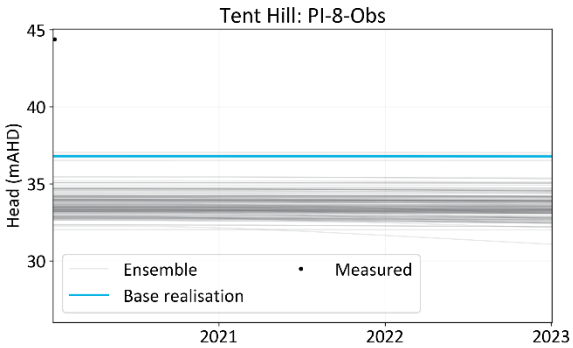

Tent Hill: GILES_WELL
Head (mAHD)
110
105
100
95
Ensemble
Measured
Base realisation
2021
2022
2023

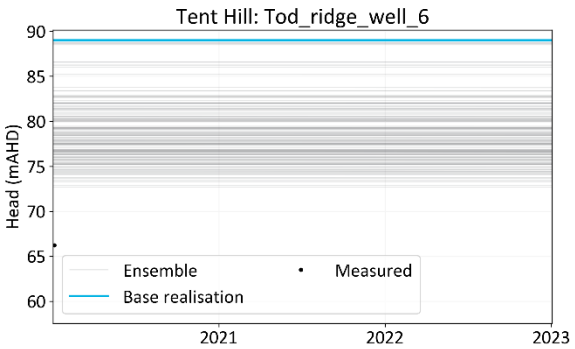

Tent Hill: NICK_OF_TIME
Head (mAHD)
70
65
60
55
Ensemble
Measured
Base realisation
2021
2022
2023

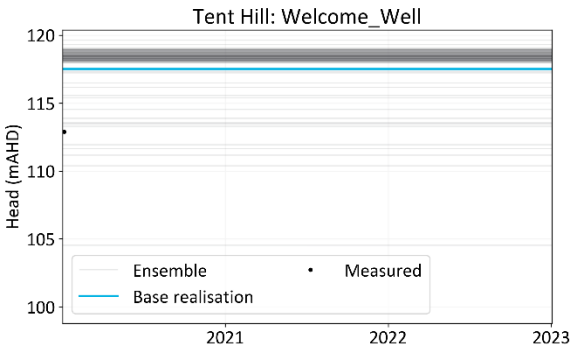

Tent Hill: NT-2Ob
Head (mAHD)
70
60
50
40
Ensemble
Measured
Base realisation
2021
2022
2023

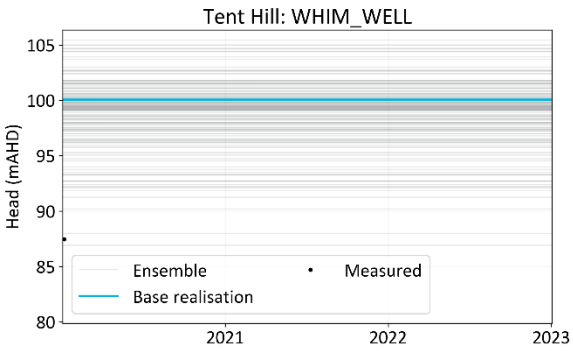

Tent Hill: NT-4_Obs_(THA)
Head (mAHD)
60
50
40
Ensemble
Measured
Base realisation
2021
2022
2023

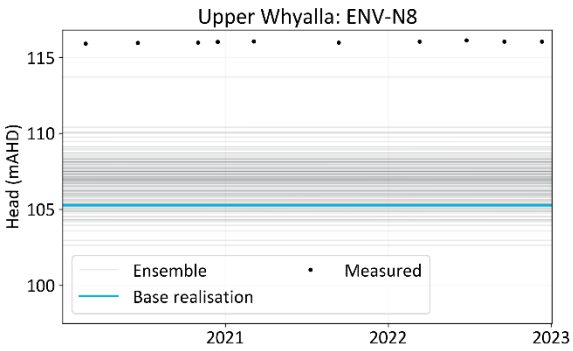

Tent Hill: OLD_WHIP_WELL
Head (mAHD)
110
105
100
95
90
Ensemble
Measured
Base realisation
2021
2022
2023

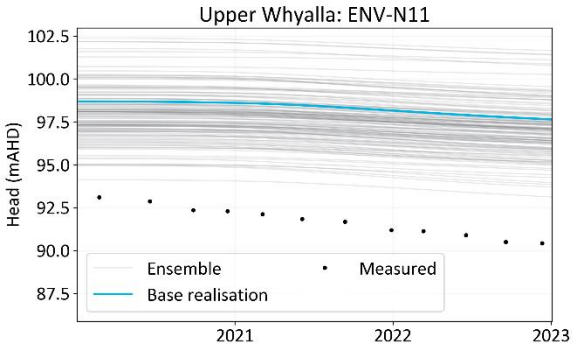

Tent Hill: PI-8-Obs
Head (mAHD)
45
40
35
30
Ensemble
Measured
Base realisation
2021
2022
2023

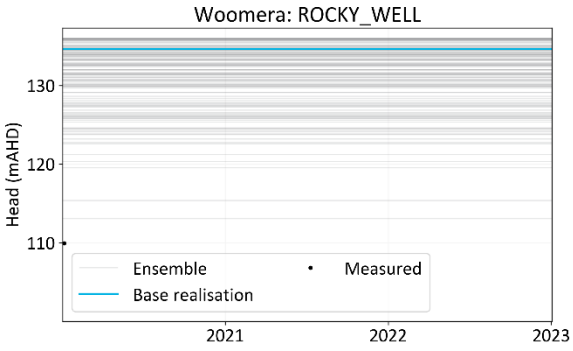

Tent Hill: Tod_ridge_well_6
Head (mAHD)
90
85
80
75
70
65
60
Ensemble
Measured
Base realisation
2021
2022
2023


Tent Hill: Welcome_Well
Head (mAHD)
120
115
110
105
100
Ensemble
Measured
Base realisation
2021
2022
2023


Tent Hill: WHIM_WELL
Head (mAHD)
105
100
95
90
85
80
2021
2022
2023
Ensemble
Measured
Base realisation

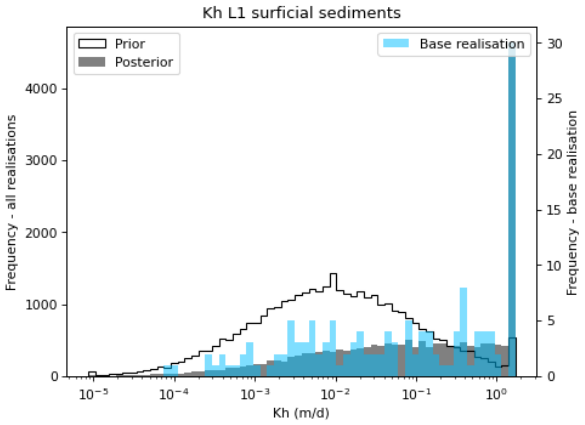

Upper Whyalla: ENV-N8
Head (mAHD)
115
110
105
100
2021
2022
2023
Ensemble
Measured
Base realisation

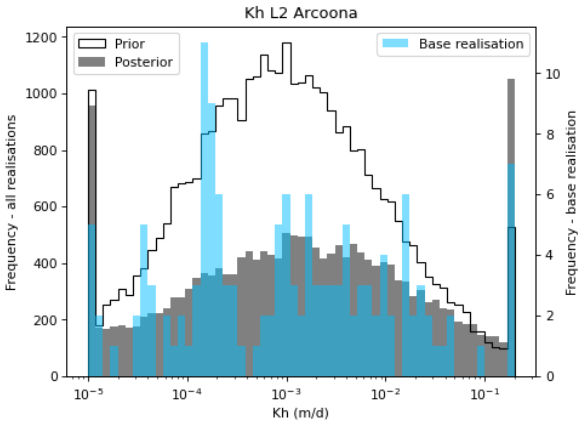

Upper Whyalla: ENV-N11
Head (mAHD)
102.5
100.0
97.5
95.0
92.5
90.0
87.5
2021
2022
2023
Ensemble
Measured
Base realisation

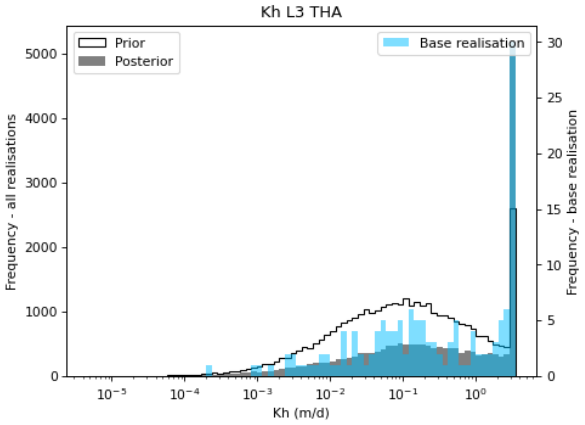

Woomera: ROCKY_WELL
Head (mAHD)
130
120
110
2021
2022
2023
Ensemble
Measured
Base realisation

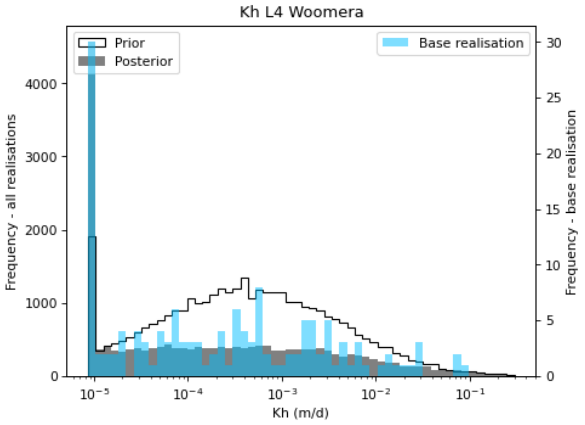
Appendix B
Parameter histograms

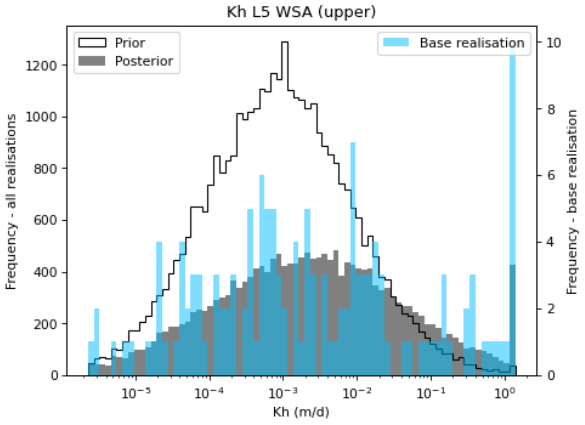
EMM
creating opportunities

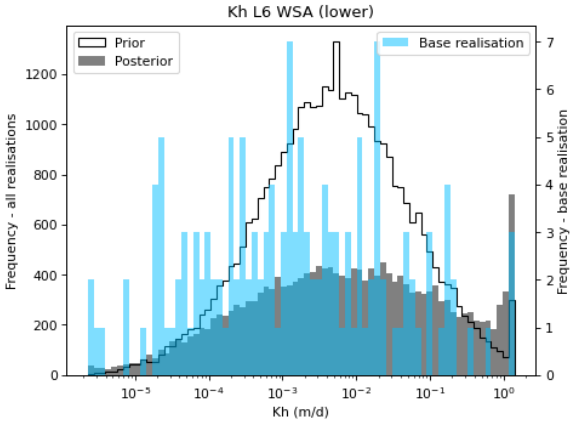

Kh L1 surficial sediments
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh (m/d)

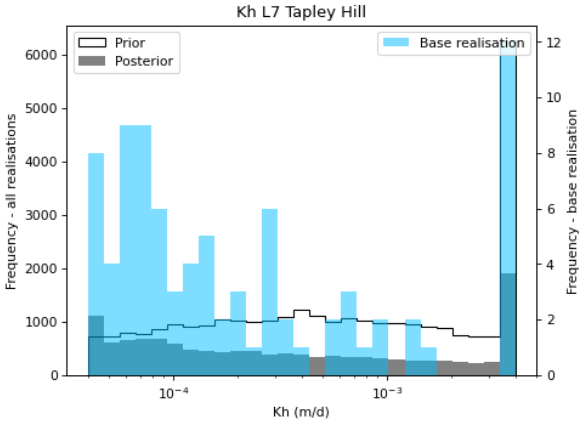

Kh L2 Arcoona
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh (m/d)

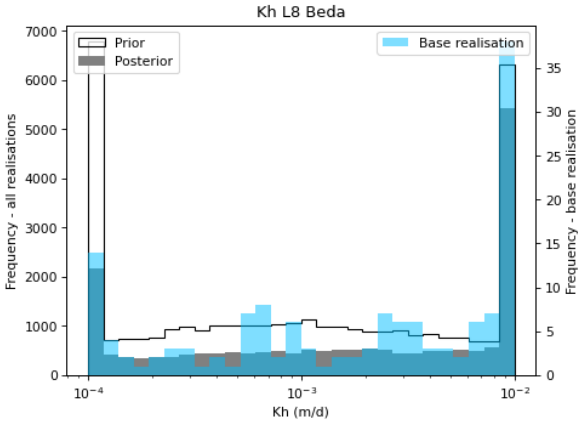

Kh L3 THA
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh (m/d)

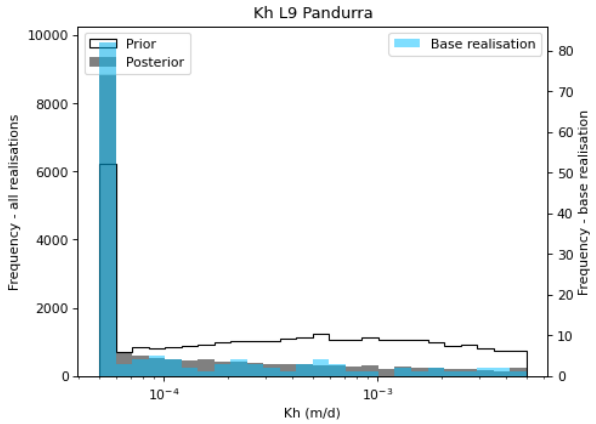

Kh L4 Woomera
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh (m/d)

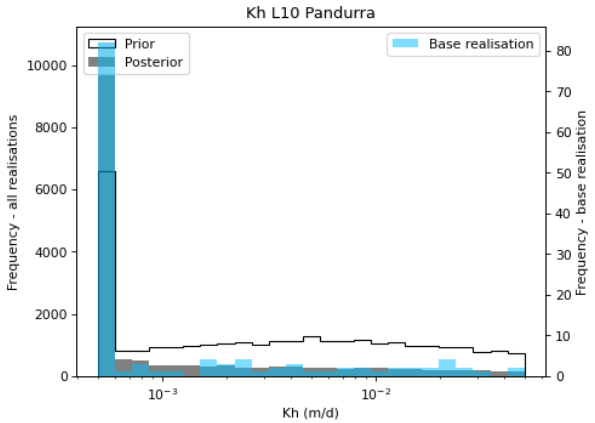

Kh L5 WSA (upper)
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh (m/d)

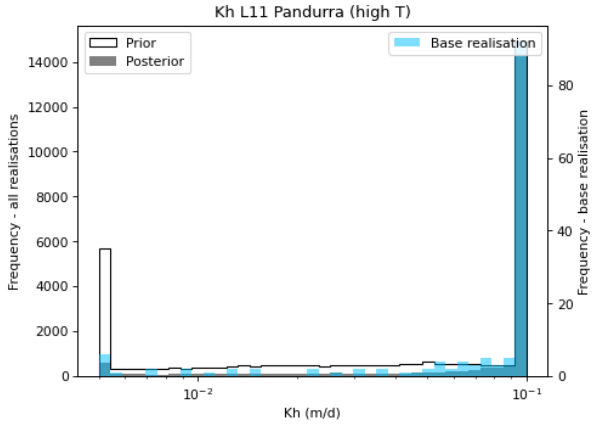

Kh L6 WSA (lower)
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh (m/d)

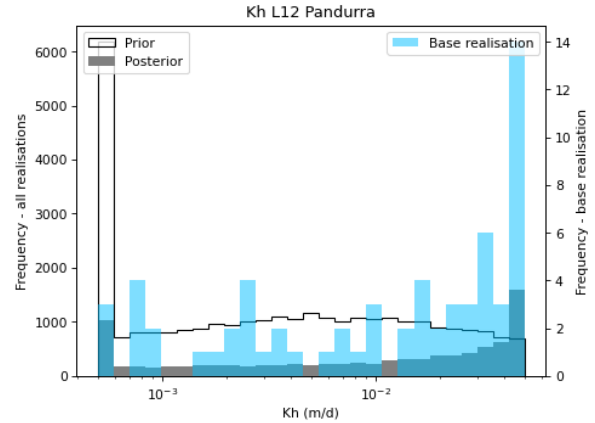

Kh L7 Tapley Hill
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh (m/d)

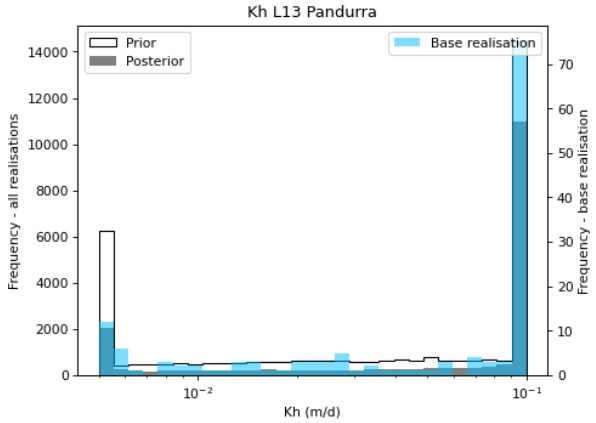

Kh L8 Beda
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh (m/d)

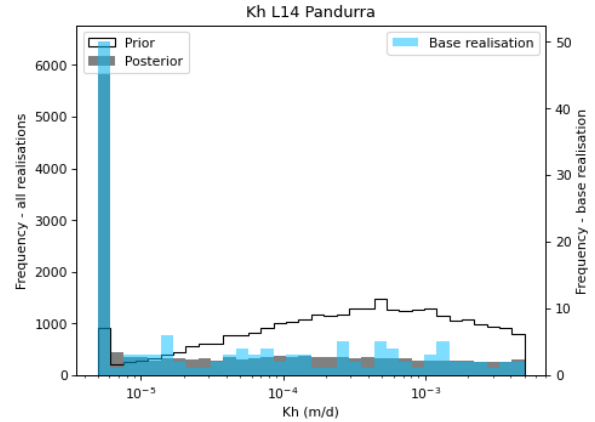

Kh L9 Pandurra
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh (m/d)

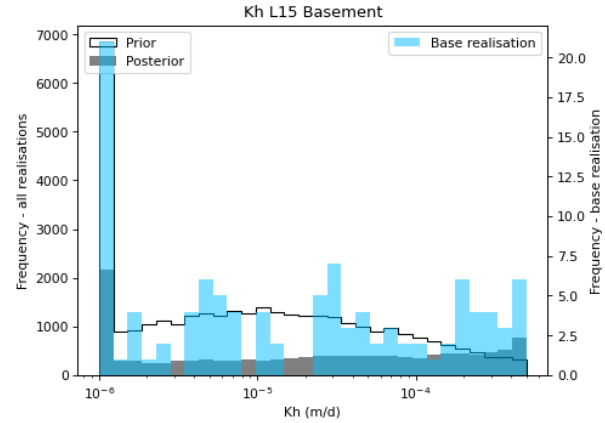

Kh L10 Pandurra
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh (m/d)

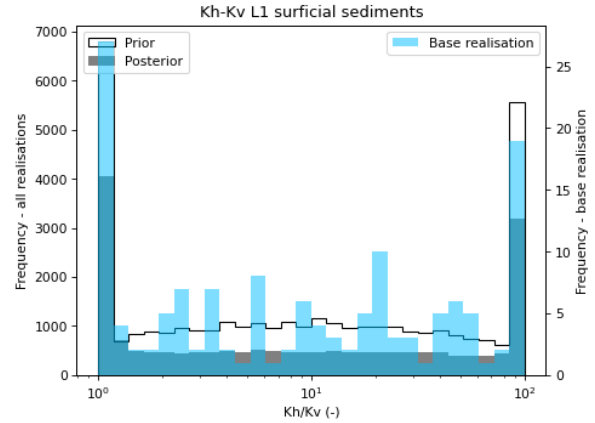

Kh L11 Pandurra (high T)
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh (m/d)

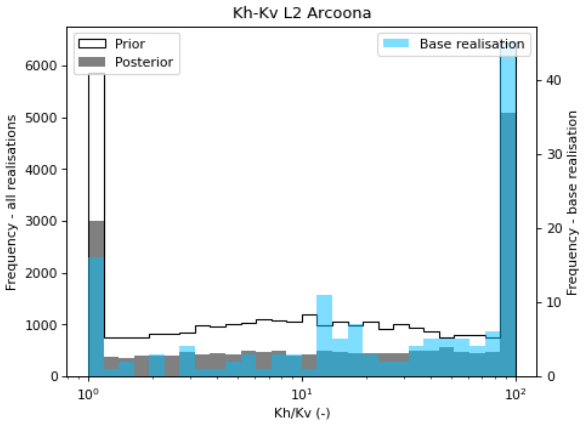

Kh L12 Pandurra
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh (m/d)

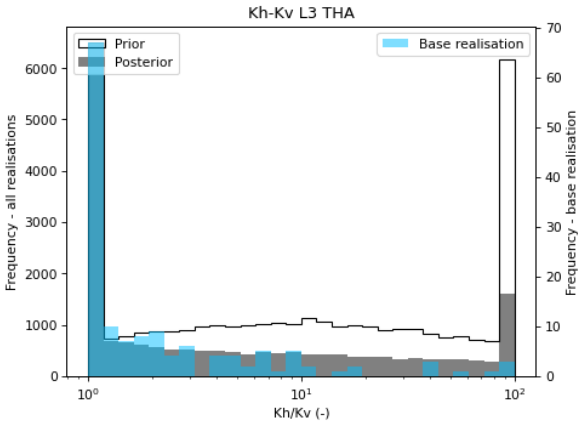

Kh L13 Pandurra
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh (m/d)

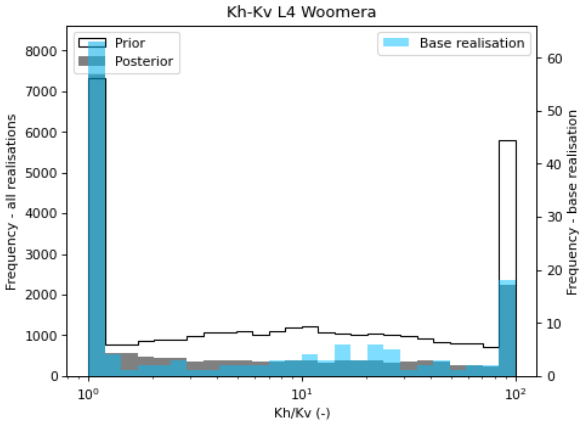

Kh L14 Pandurra
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh (m/d)

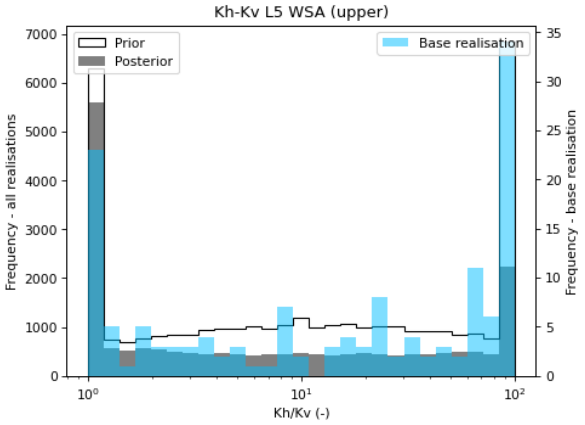

Kh L15 Basement
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh (m/d)

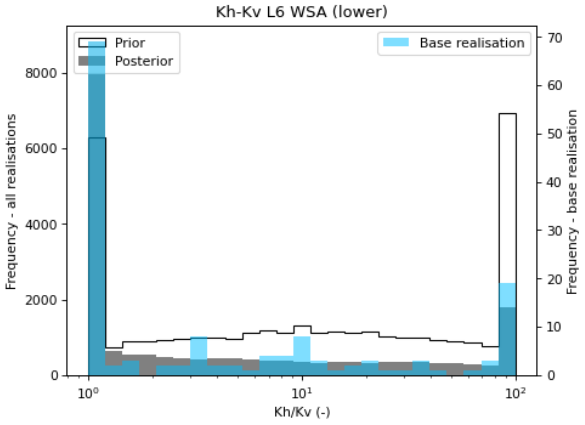

Kh-Kv L1 surficial sediments
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh/Kv (-)

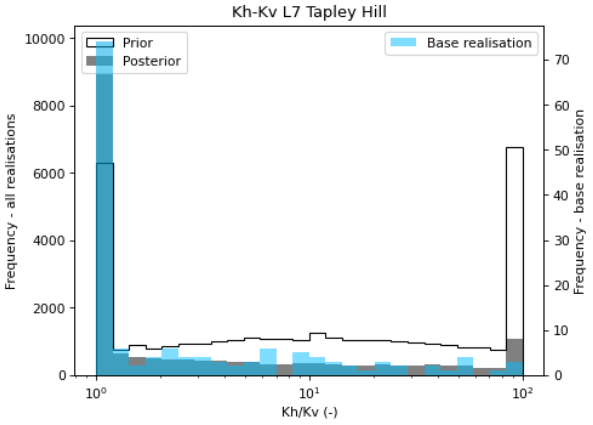

Kh-Kv L2 Arcoona
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh/Kv (-)

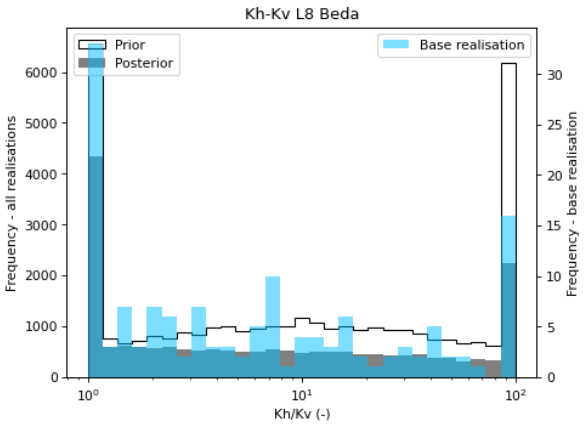

Kh-Kv L3 THA
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh/Kv (-)

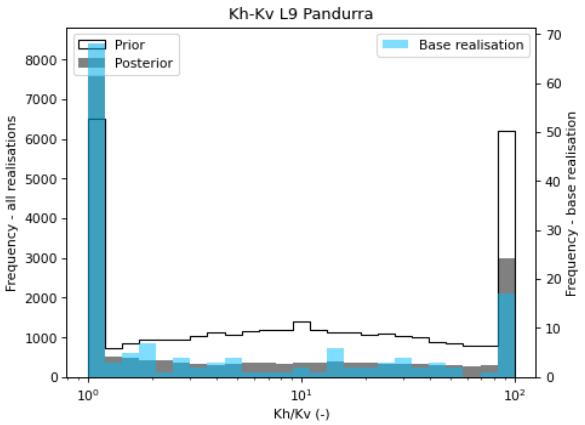

Kh-Kv L4 Woomera
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh/Kv (-)

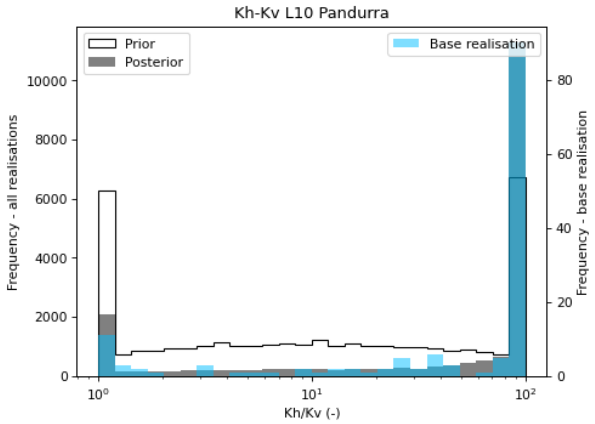

Kh-Kv L5 WSA (upper)
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh/Kv (-)

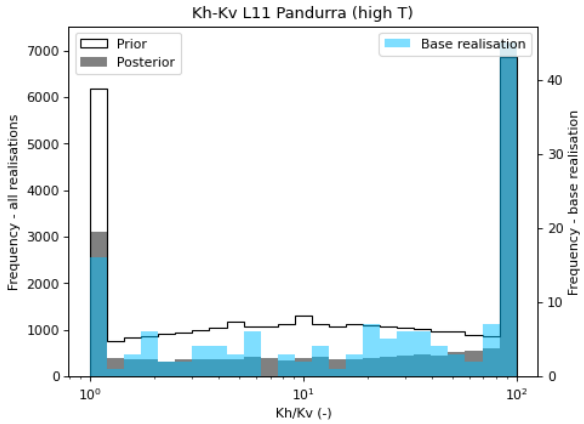

Kh-Kv L6 WSA (lower)
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh/Kv (-)

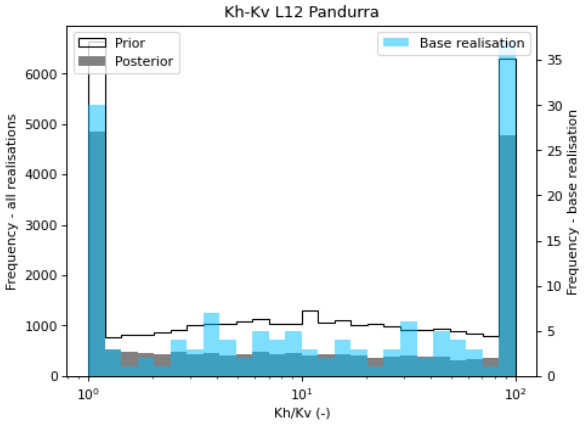

Kh-Kv L7 Tapley Hill
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh/Kv (-)

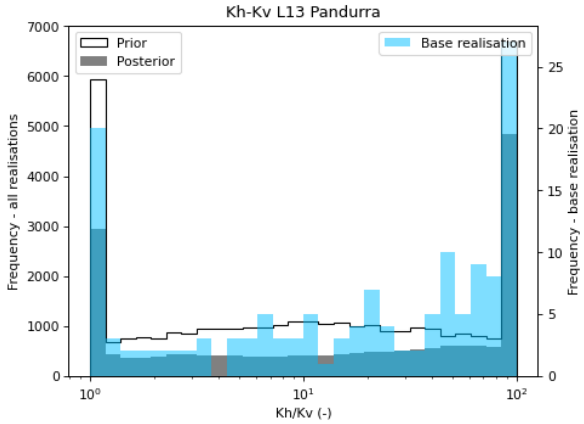

Kh-Kv L8 Beda
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh/Kv (-)

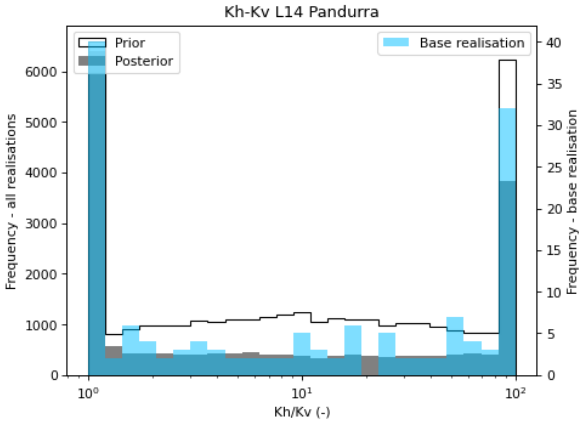

Kh-Kv L9 Pandurra
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh/Kv (-)

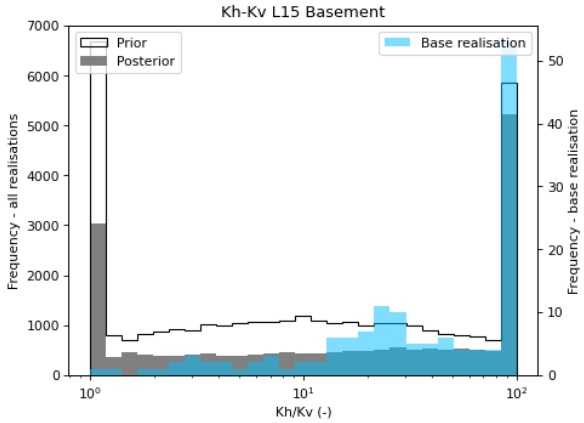

Kh-Kv L10 Pandurra
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh/Kv (-)

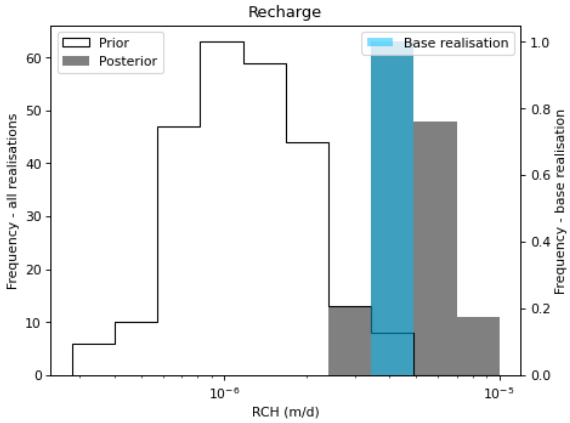

Kh-Kv L11 Pandurra (high T)
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh/Kv (-)

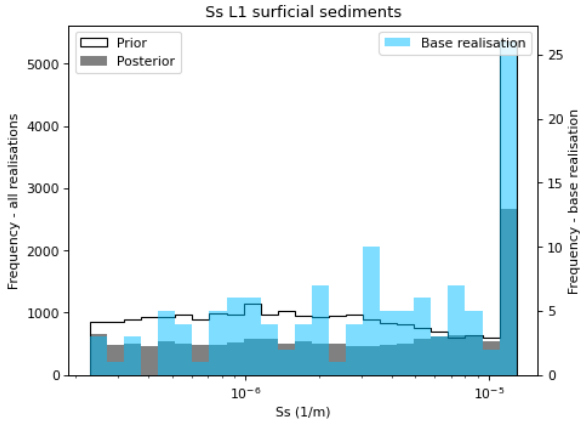

Kh-Kv L12 Pandurra
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh/Kv (-)

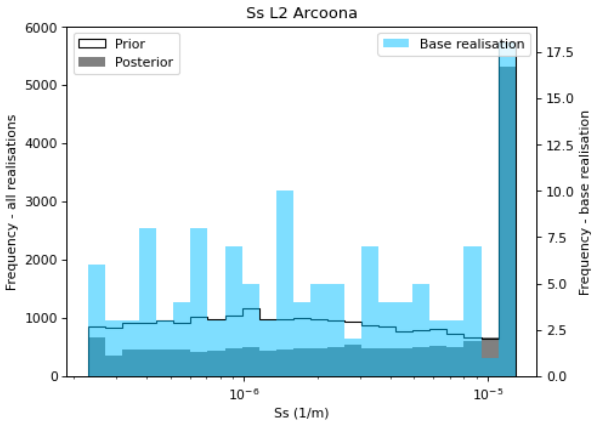

Kh-Kv L13 Pandurra
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh/Kv (-)

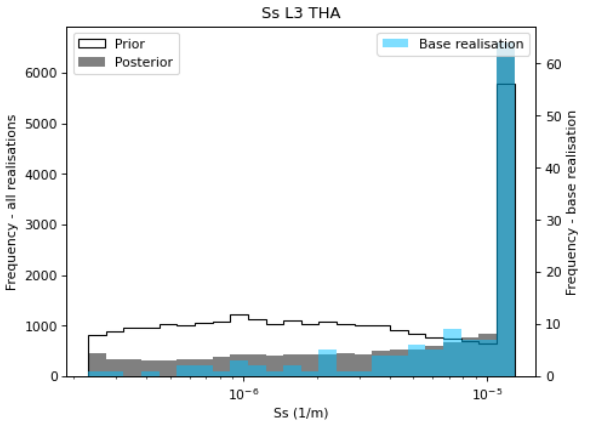

Kh-Kv L14 Pandurra
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh/Kv (-)

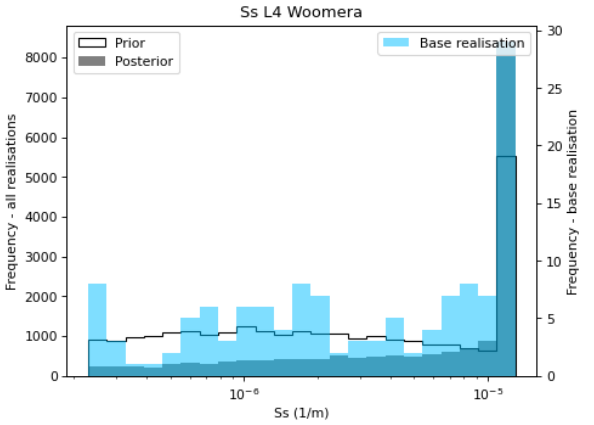

Kh-Kv L15 Basement
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Kh/Kv (-)

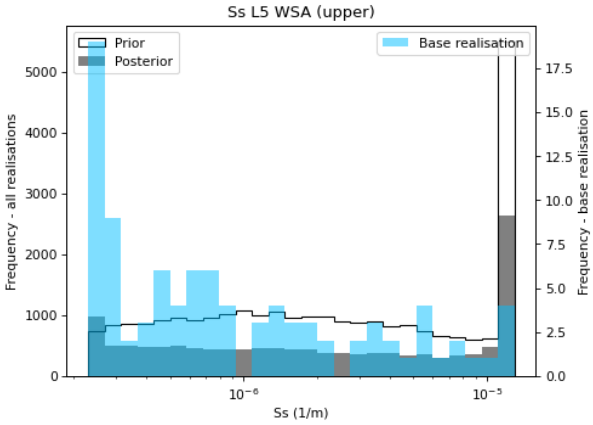

Recharge
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
RCH (m/d)

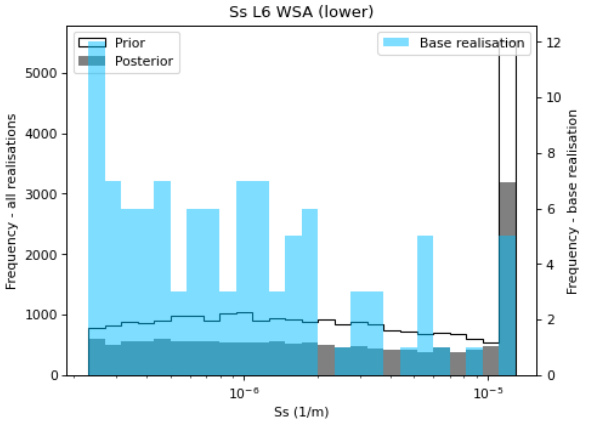

Ss L1 surficial sediments
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Ss (1/m)

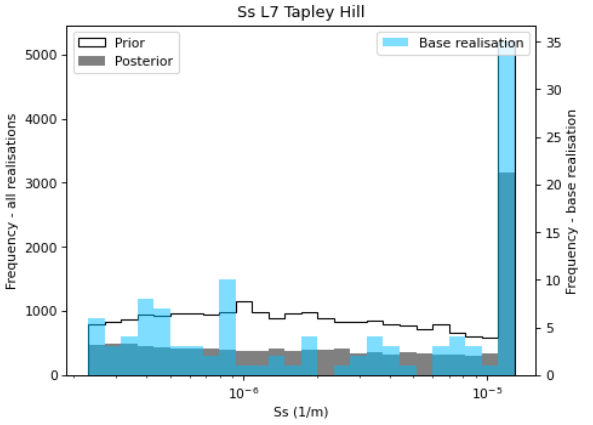

Ss L2 Arcoona
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Ss (1/m)

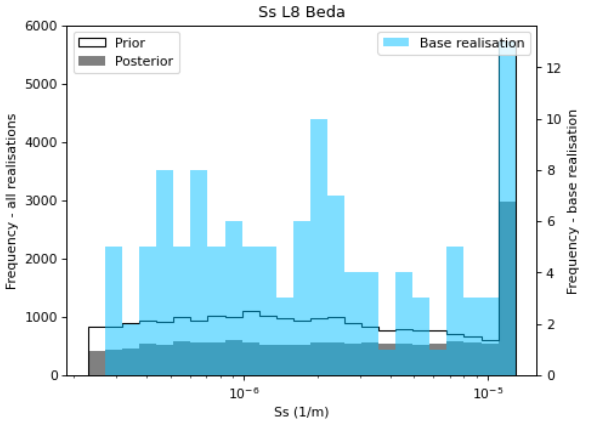

Ss L3 THA
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Ss (1/m)

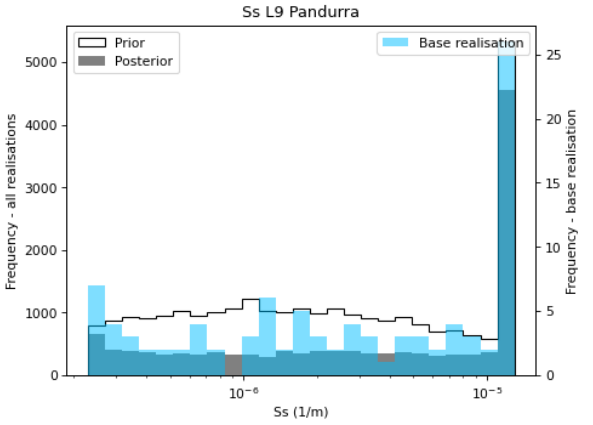

Ss L4 Woomera
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Ss (1/m)

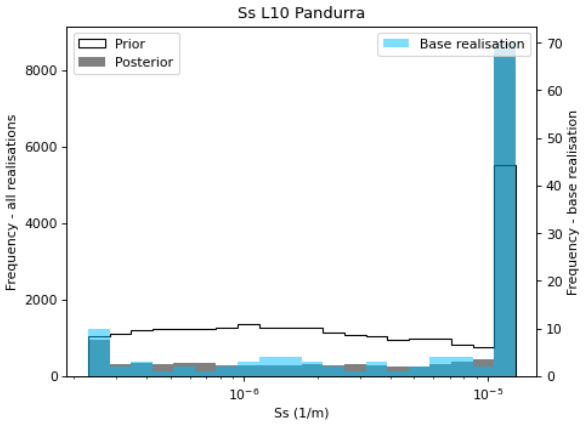

Ss L5 WSA (upper)
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Ss (1/m)

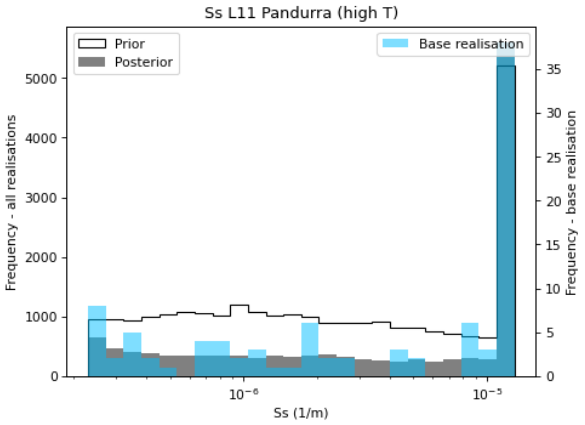

Ss L6 WSA (lower)
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Ss (1/m)

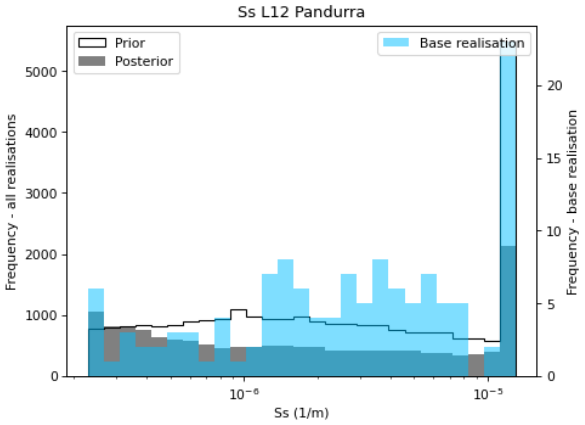

Ss L7 Tapley Hill
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Ss (1/m)

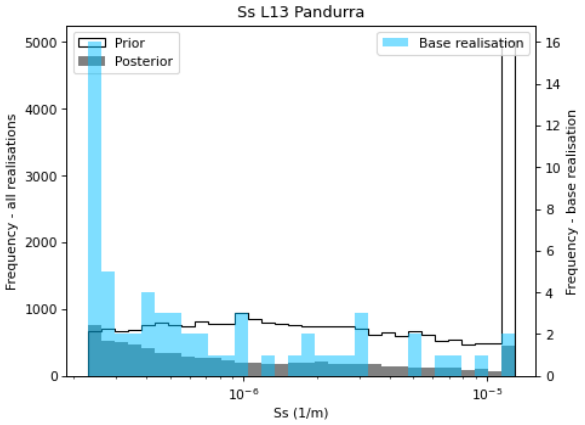

Ss L8 Beda
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Ss (1/m)

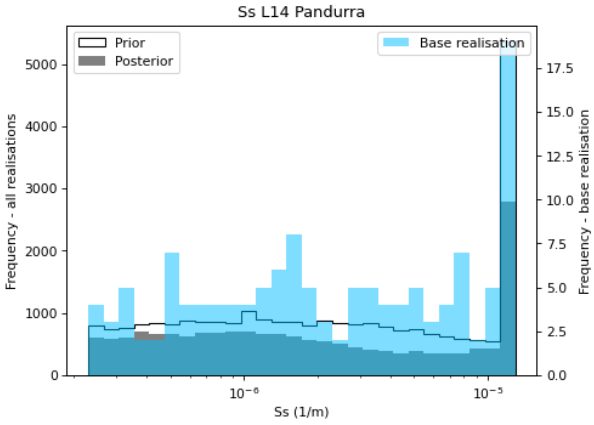

Ss L9 Pandurra
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Ss (1/m)

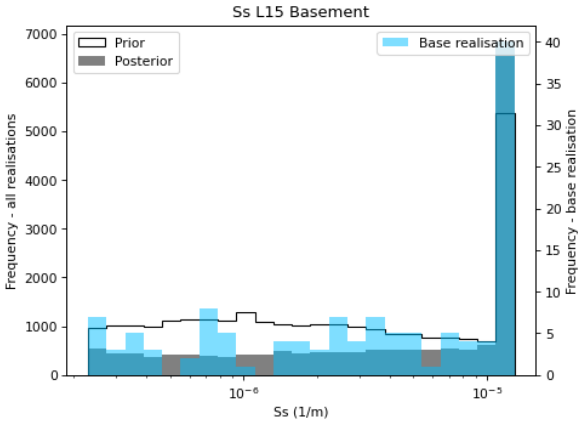

Ss L10 Pandurra
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Ss (1/m)

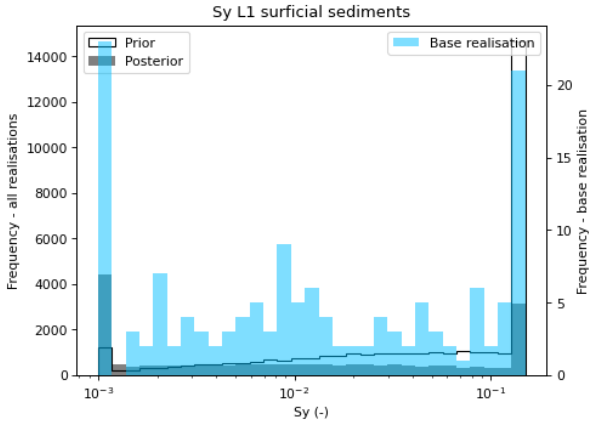

Ss L11 Pandurra (high T)
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Ss (1/m)

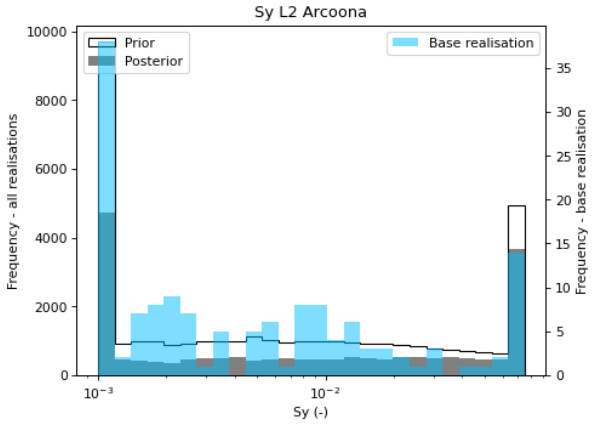

Ss L12 Pandurra
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Ss (1/m)

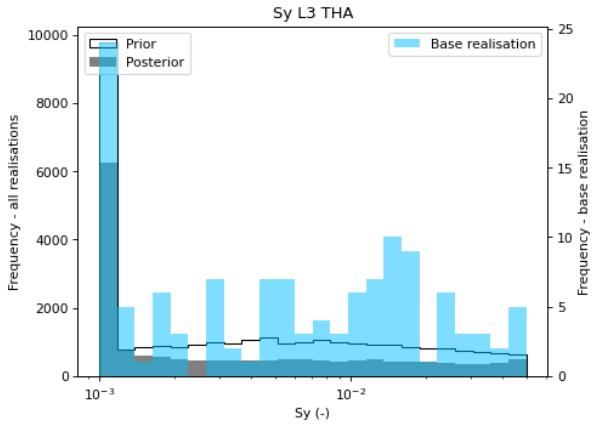

Ss L13 Pandurra
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Ss (1/m)

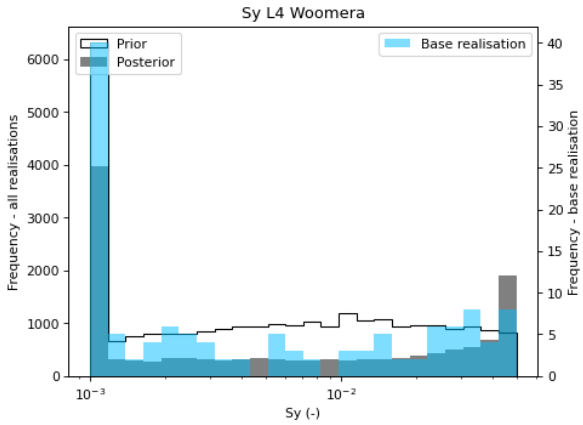

Ss L14 Pandurra
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Ss (1/m)

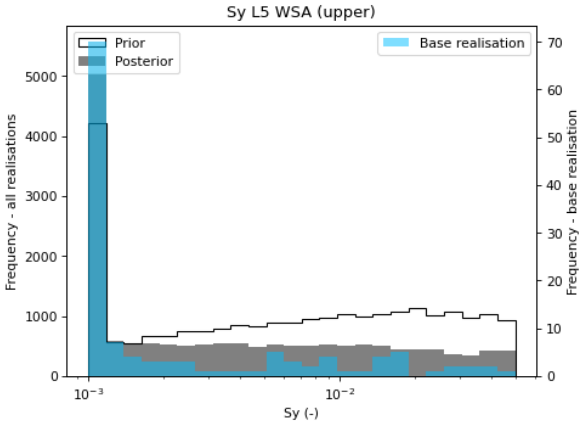

Ss L15 Basement
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Ss (1/m)

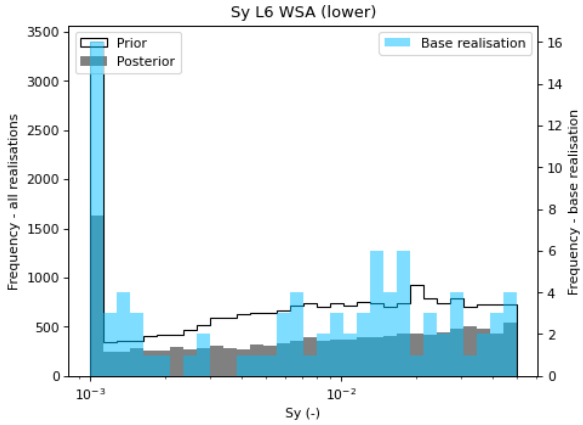

Sy L1 surficial sediments
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Sy (-)

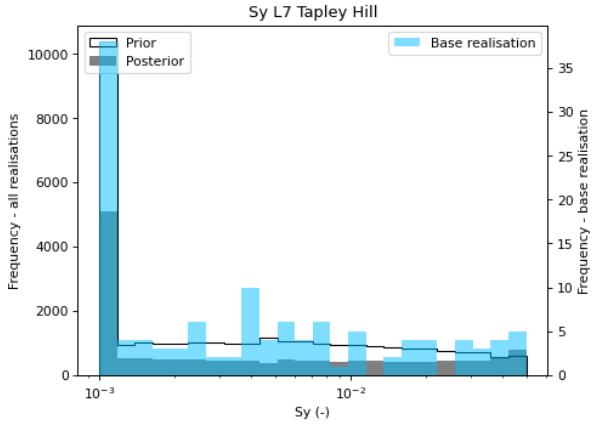

Sy L2 Arcoona
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Sy (-)

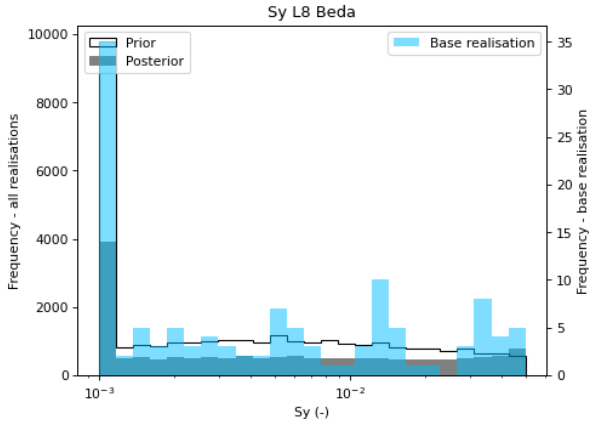

Sy L3 THA
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Sy (-)

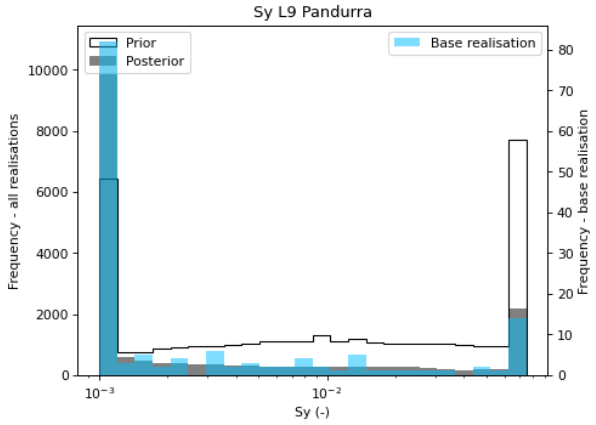

Sy L4 Woomera
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Sy (-)

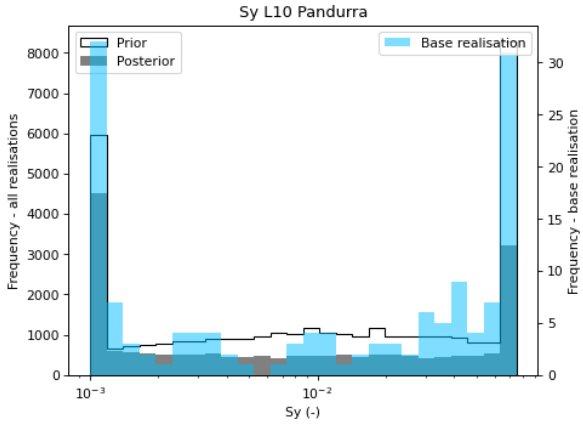

Sy L5 WSA (upper)
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Sy (-)

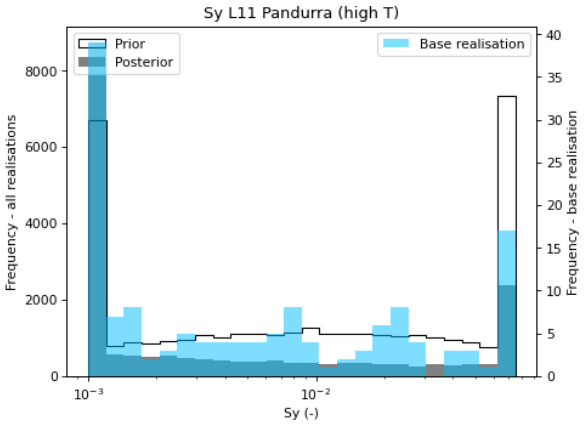

Sy L6 WSA (lower)
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Sy (-)

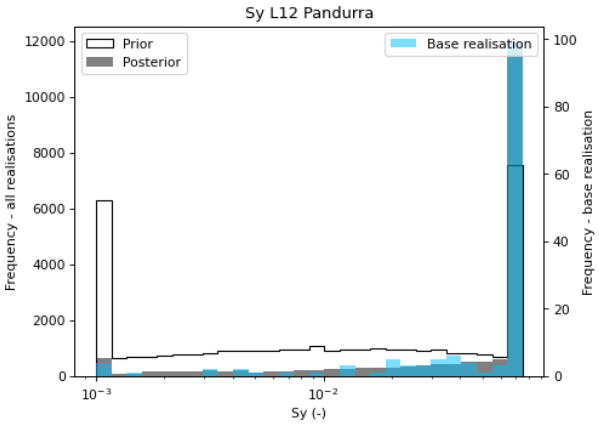

Sy L7 Tapley Hill
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Sy (-)

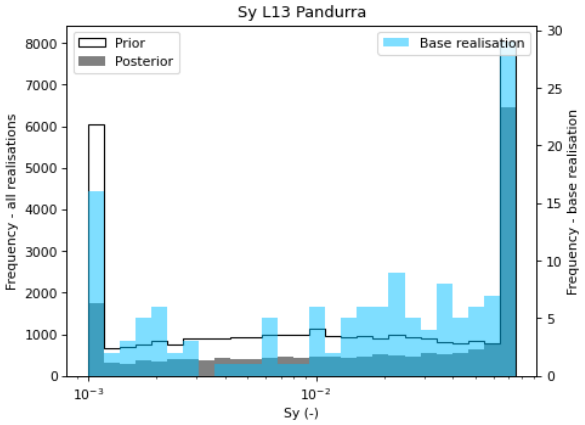

Sy L8 Beda
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Sy (-)

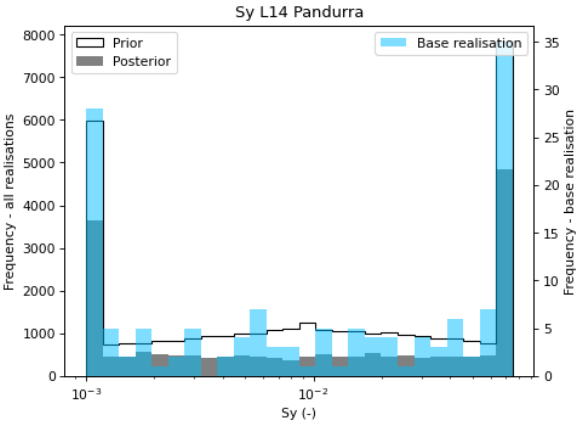

Sy L9 Pandurra
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Sy (-)

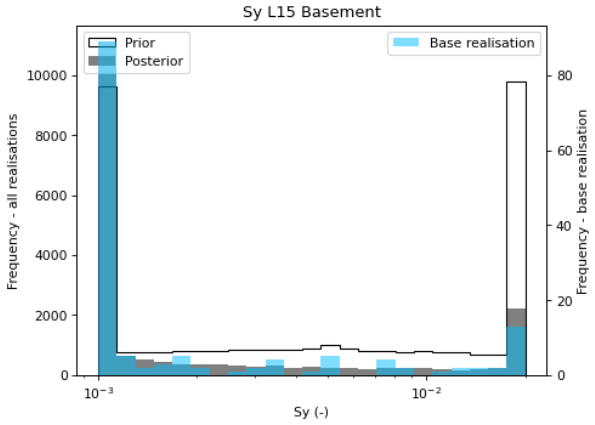

Sy L10 Pandurra
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Sy (-)


Sy L11 Pandurra (high T)
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Sy (-)


Sy L12 Pandurra
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Sy (-)


Sy L13 Pandurra
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Sy (-)

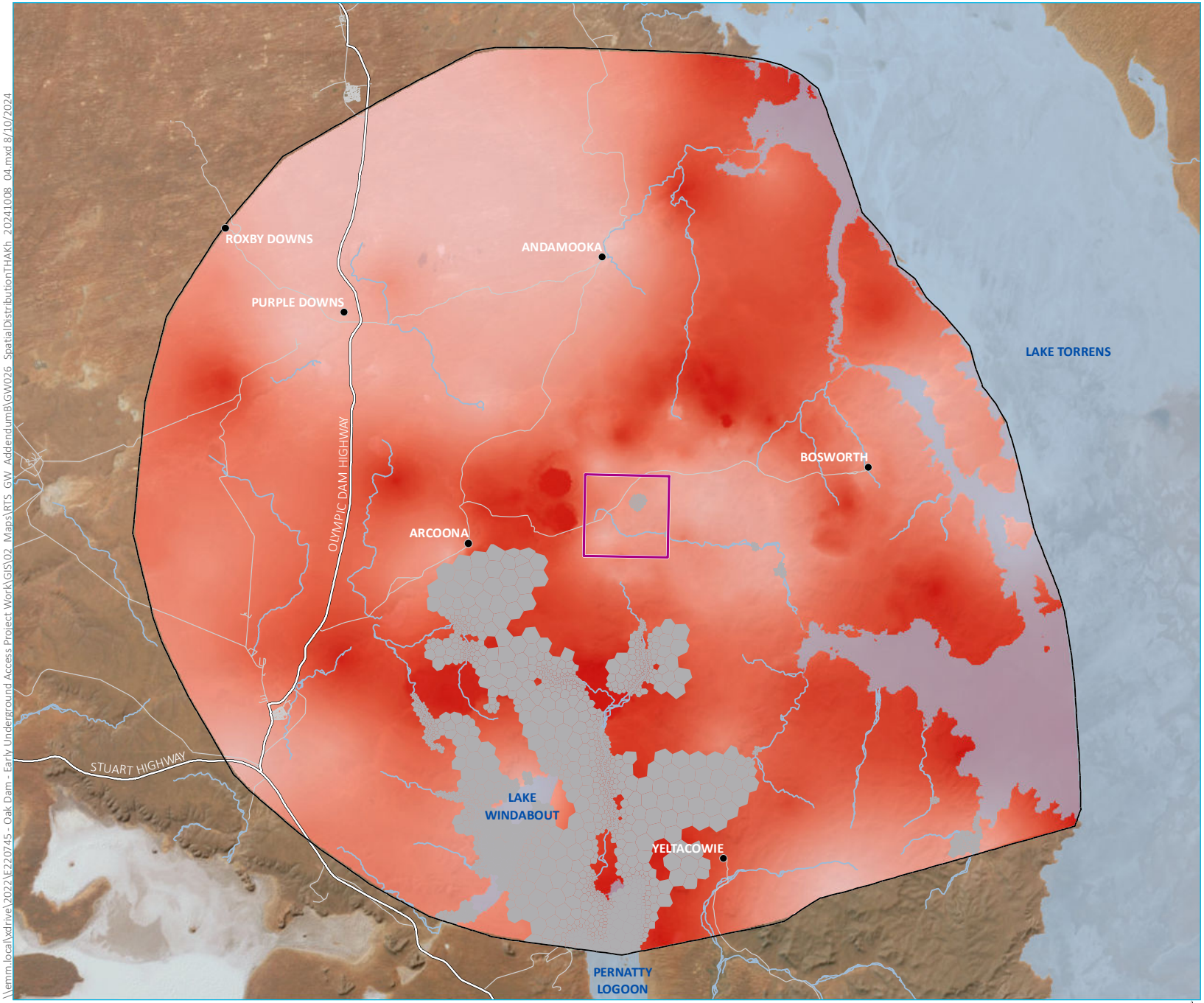

Sy L14 Pandurra
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Sy (-)


Sy L15 Basement
Prior
Posterior
Base realisation
Frequency - all realisations
Frequency - base realisation
Sy (-)

Appendix C

Spatial distribution of select base realisation hydraulic parameters

EMM
creating opportunities



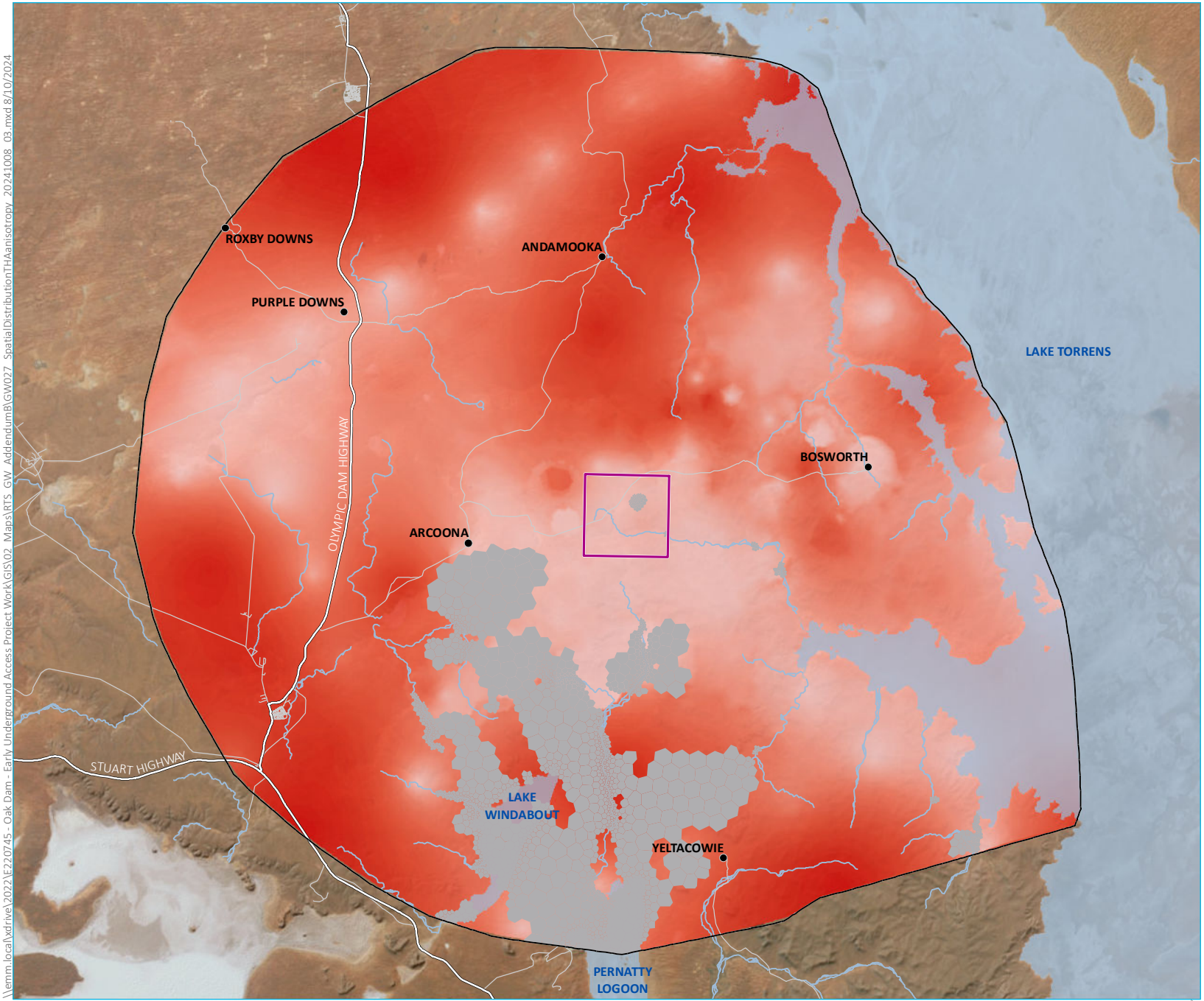
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Source: EMM (2024); BHP (2024); DIT (2024); DEW (2024); GA (2011); ESRI (2024)

Base realisation THA Kh

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Groundwater Environmental Assessment Addendum
Figure C.1

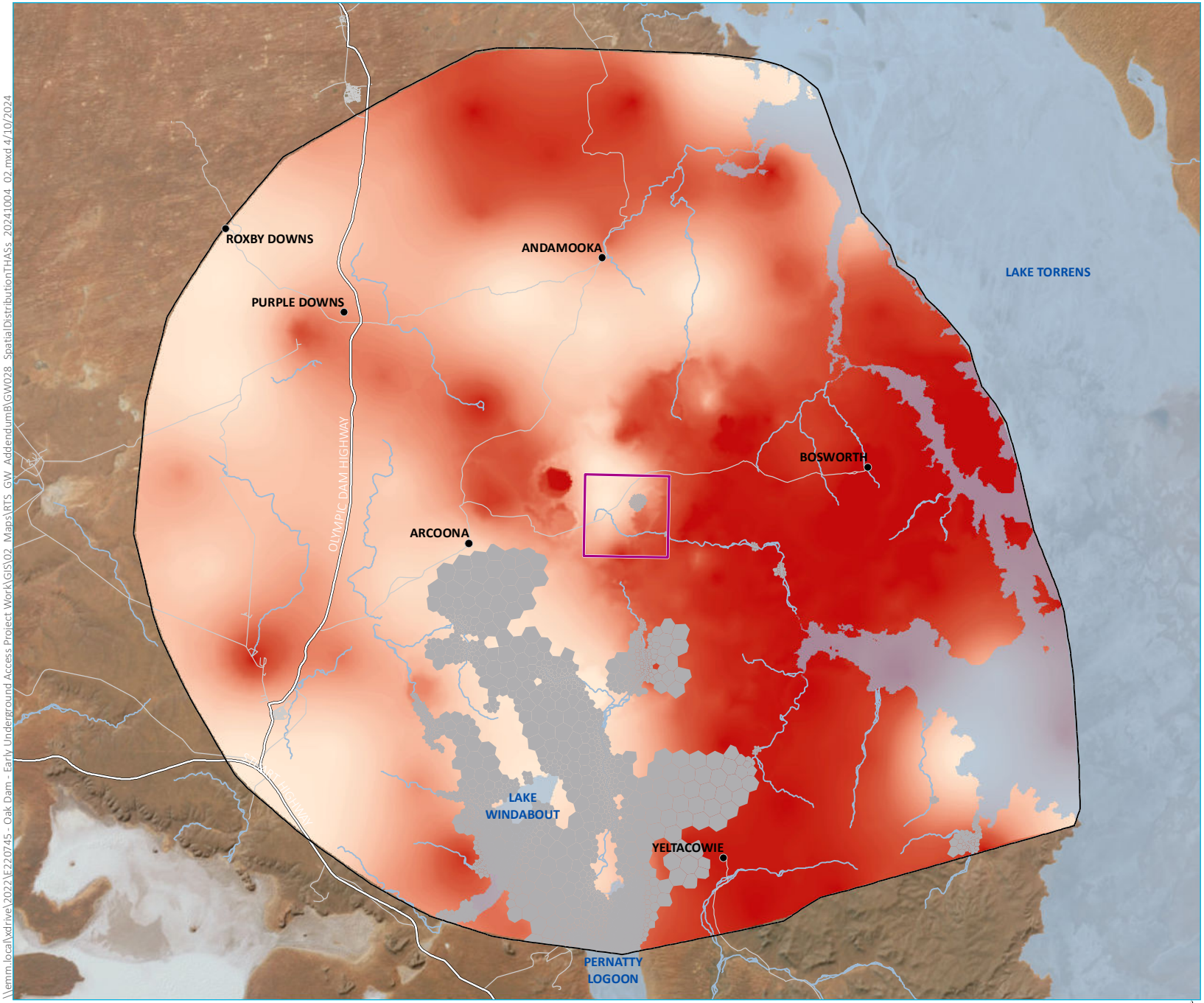
EMM
creating opportunities



Base realisation THA anisotropy

OKDUGA Proposal Response Document
Groundwater Environmental
Assessment Addendum
Figure C.2

EMM
creating opportunities



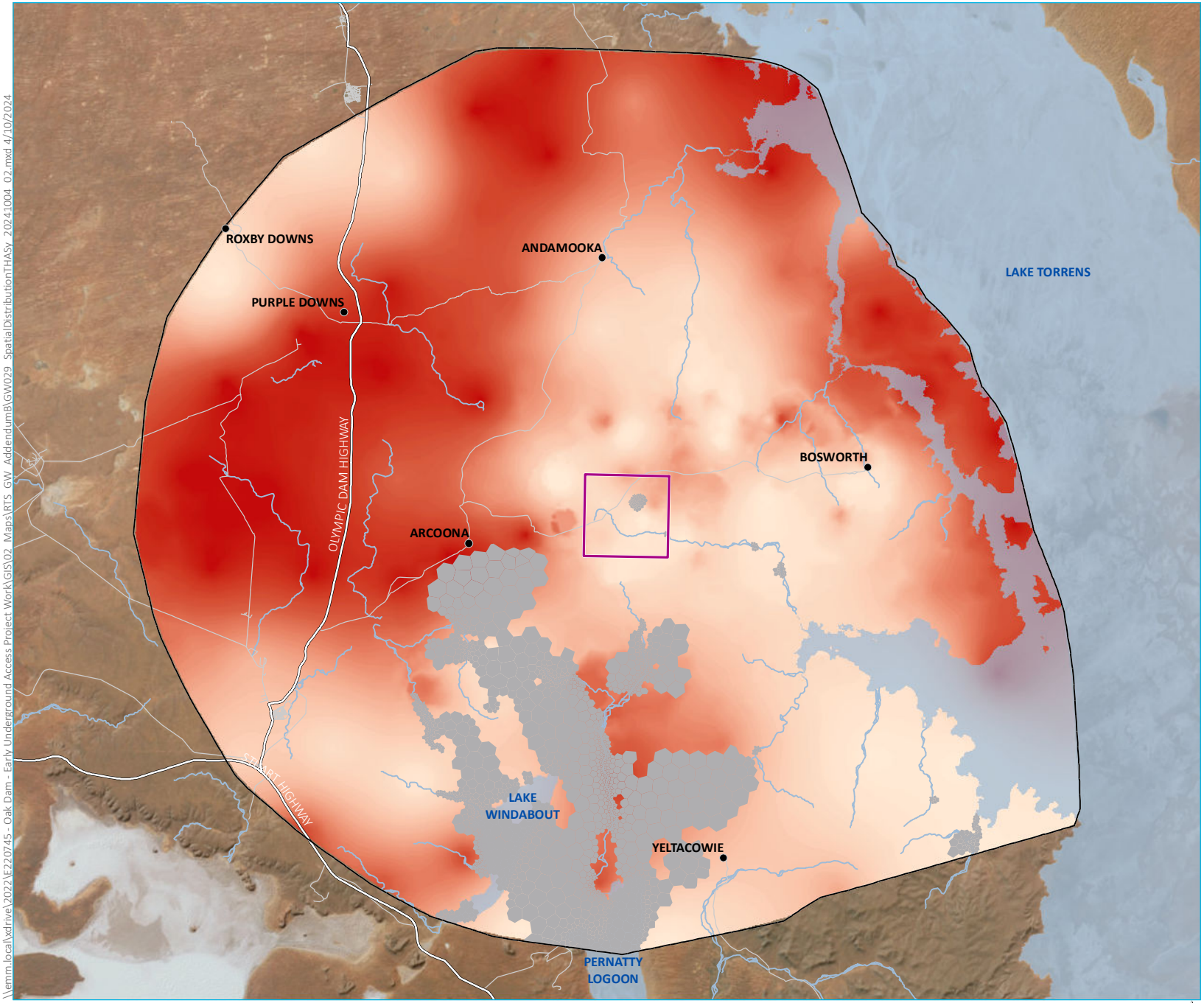
\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02 Maps\RTS GW AddendumB\GW028 SpatialDistributionTHASs 20241004 02.mxd 4/10/2024

Source: EMM (2024); BHP (2024); DIT (2024); DEW (2024); GA (2011); ESRI (2024)

Base realisation THA Ss

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Groundwater Environmental
Assessment Addendum
Figure C.3

EMM
creating opportunities



KEY

- OKDUGA Project RL
- Groundwater model extent
- THA absent

Existing environment

- Homestead
- Major road
- Minor road
- Named watercourse
- Waterbody

Specific yield (Sy)

- 0.05
- 0.01
- 0.005

Source: EMM (2024); BHP (2024); DIT (2024); DEW (2024); GA (2011); ESRI (2024)

0 25 50 km

GDA2020 MGA Zone 53

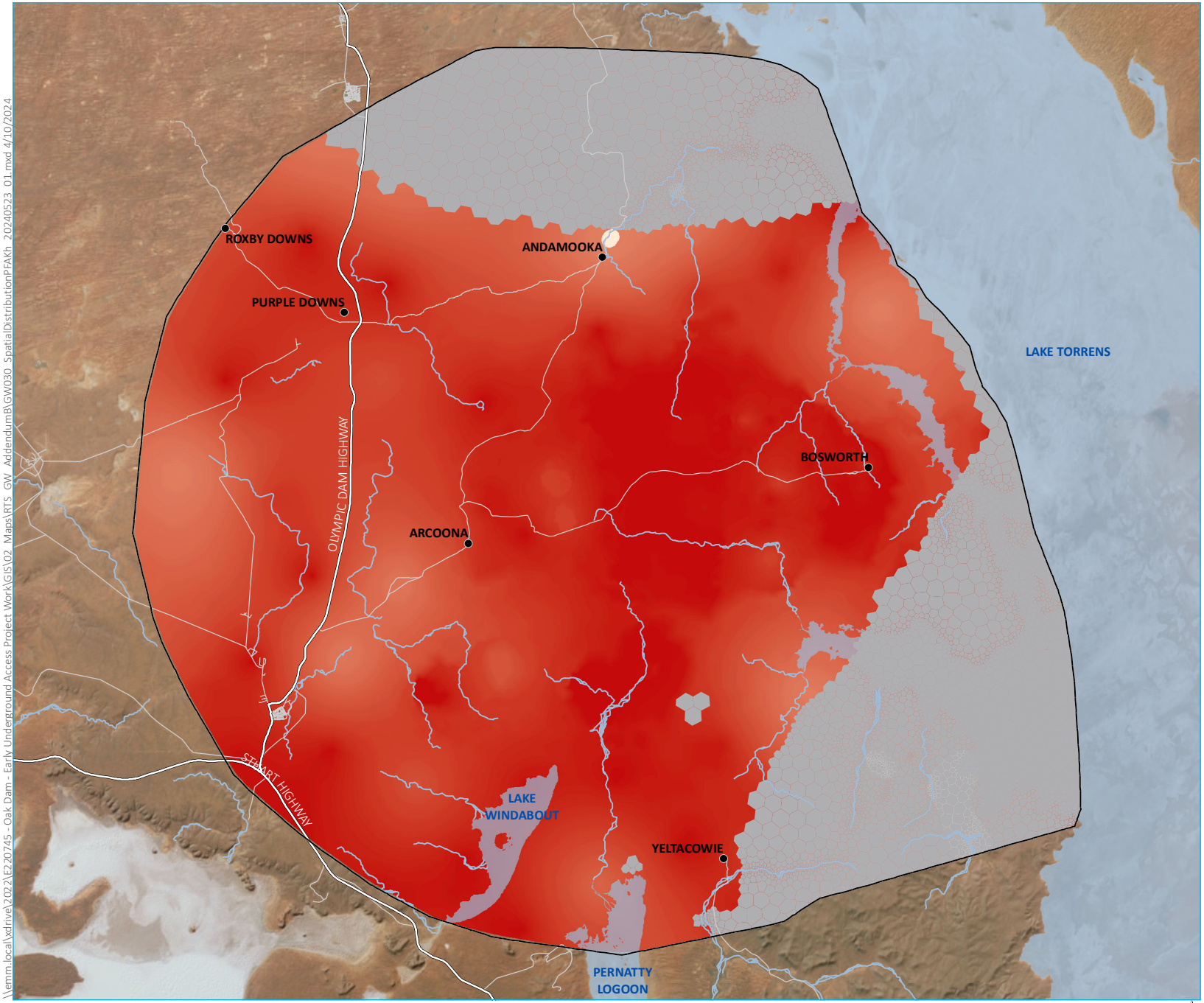
N

Base realisation THA Sy

OKDUGA Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure C.4

EMM creating opportunities

\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02 Maps\RTS GW AddendumB\GW029 SpatialDistributionTHASy 20241004 02.mxd 4/10/2024



KEY

- OKDUGA Project RL
- Groundwater model extent
- PFA absent

Existing environment

- Homestead
- Major road
- Minor road
- Named watercourse
- Waterbody

Conductivity (Kh, m/d)

0.1
0.01
0.001
0.0001

\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02_Maps\RTS_GW_AddendumB\GW030_SpatialDistributionPFAKh_20240523_01.mxd 4/10/2024

Source: EMM (2024); BHP (2024); DIT (2024); DEW (2024); GA (2011); ESRI (2024)

0 25 50 km

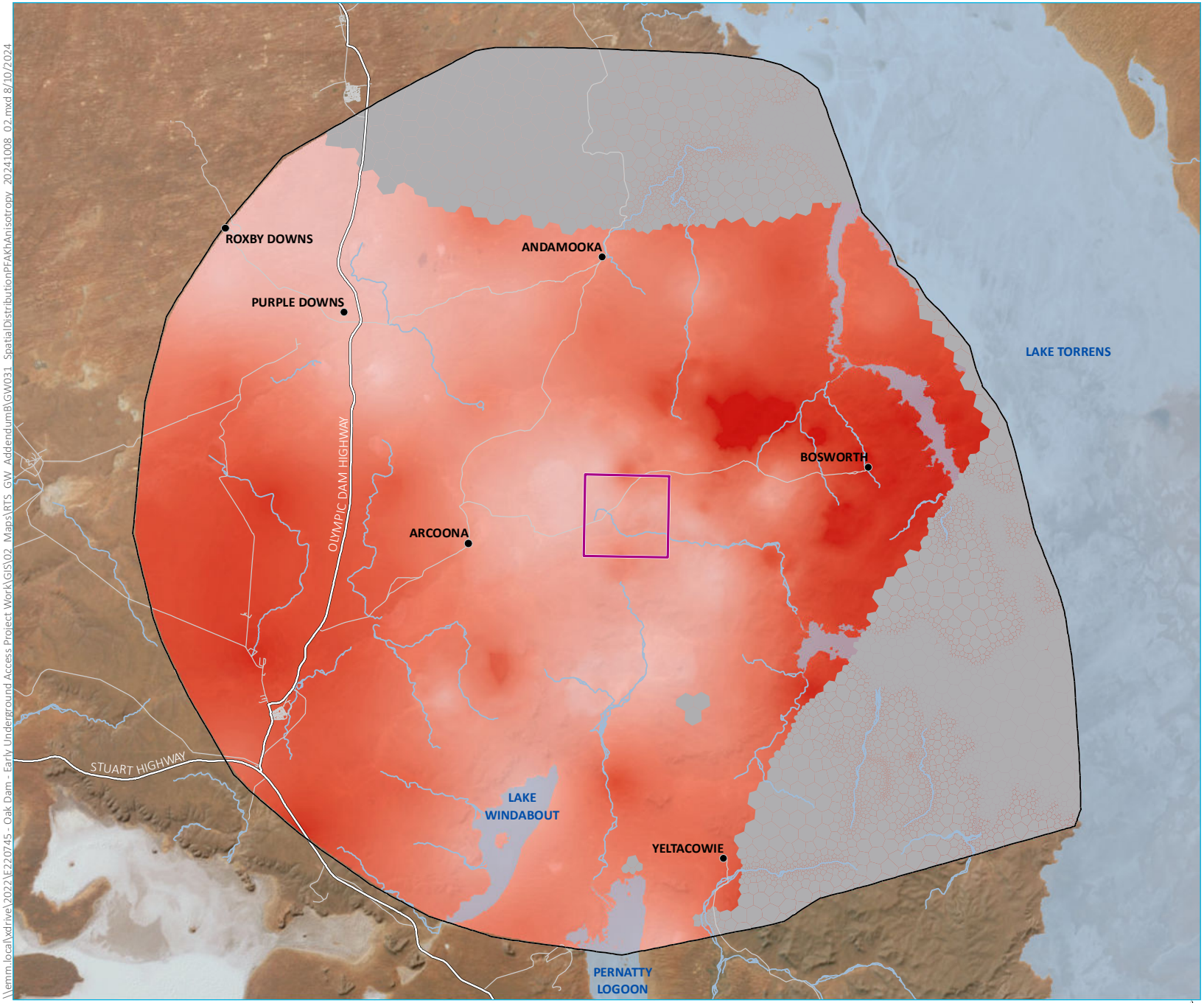
GDA2020 MGA Zone 53

N

Base realisation Upper PFA
High K Kh

OKDUGA Proposal Response Document
Groundwater Environmental
Assessment Addendum
Figure C.5

EMM
creating opportunities



KEY

- OKDUGA Project RL
- Groundwater model extent
- PFA absent

Existing environment

- Homestead
- Major road
- Minor road
- Named watercourse
- Waterbody

Anisotropy (Kh/Kv)

100

1

\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02 Maps\RTS GW AddendumB\GW031 SpatialDistributionPFAKhAnisotropy 20241008 02.mxd 8/10/2024

Source: EMM (2024); BHP (2024); DIT (2024); DEW (2024); GA (2011); ESRI (2024)

0 25 50 km

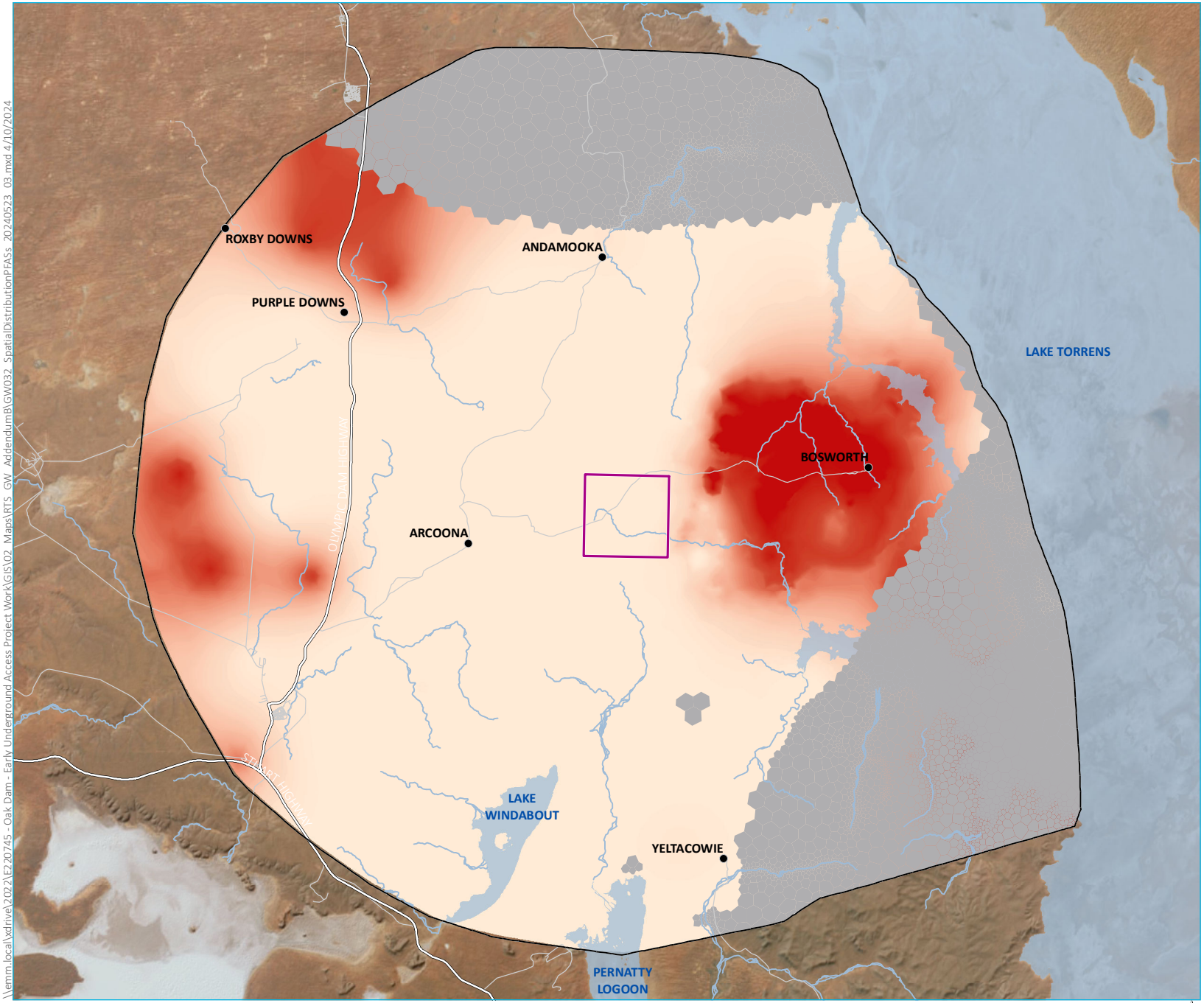
GDA2020 MGA Zone 53

N

Base realisation Upper PFA high K anisotopy

OKDUGA Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure C.6

EMM creating opportunities



KEY

- OKDUGA Project RL
- Groundwater model extent
- PFA absent

Existing environment

- Homestead
- Major road
- Minor road
- Named watercourse
- Waterbody

Specific storage (Ss, 1/m)

- High : 1.3e-05
- Low : 2.3e-07

Source: EMM (2024); BHP (2024); DIT (2024); DEW (2024); GA (2011); ESRI (2024)

0 25 50 km

GDA2020 MGA Zone 53

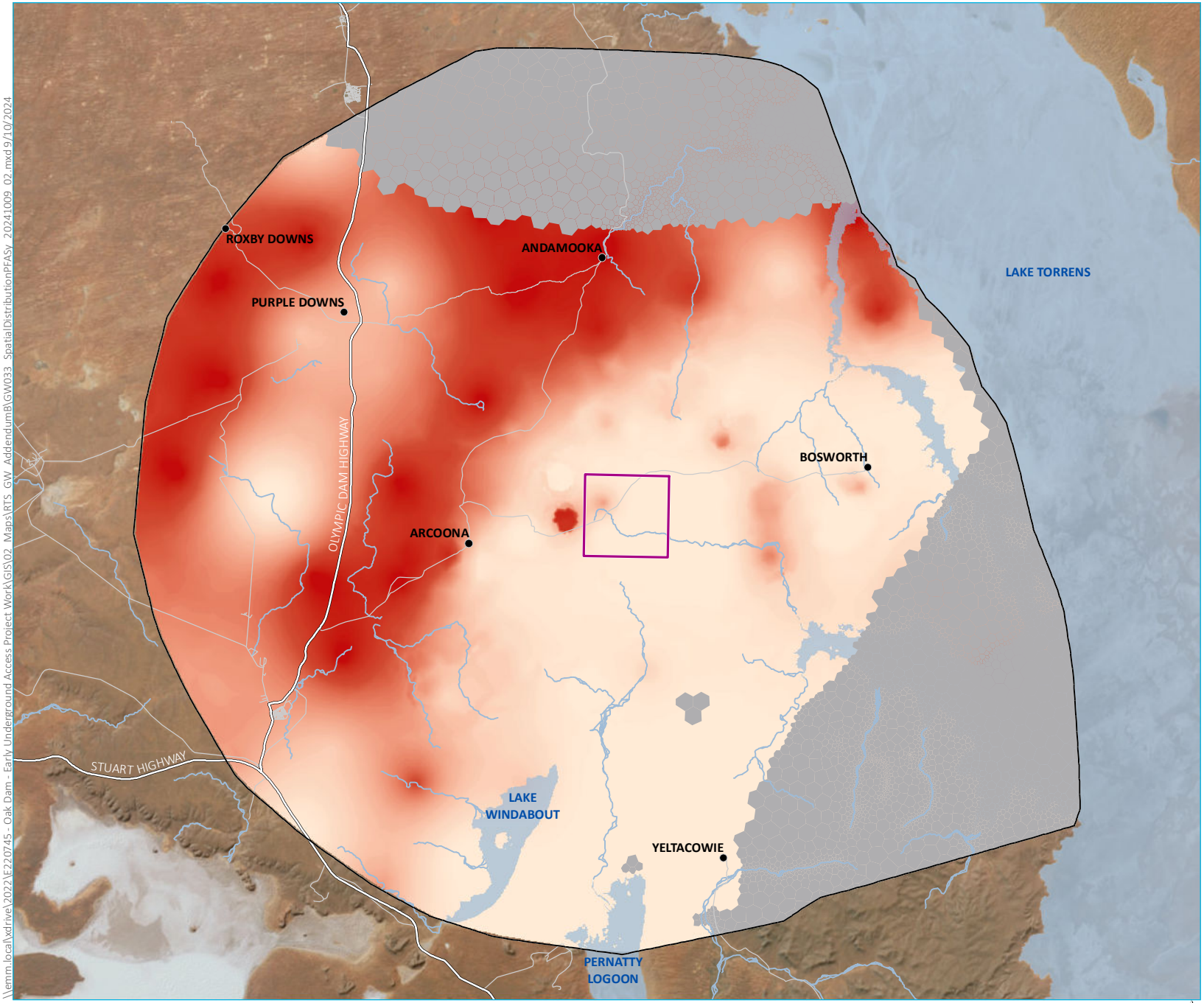
N

Base realisation Upper PFA high K Ss

OKDUGA Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure C.7

EMM creating opportunities

\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02_Maps\RTS_GW_AddendumB\GW032_SpatialDistributionPFASs_20240523_03.mxd 4/10/2024



KEY

- OKDUGA Project RL
- Groundwater model extent
- PFA absent

Existing environment

- Homestead
- Major road
- Minor road
- Named watercourse
- Waterbody

Specific yield (Sy)

- 0.05
- 0.01
- 0.005

Source: EMM (2024); BHP (2024); DIT (2024); DEW (2024); GA (2011); ESRI (2024)

0 25 50 km

GDA2020 MGA Zone 53

N

\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02 Maps\RTS GW AddendumB\GW033 SpatialDistributionPFASy 20241009 02.mxd 9/10/2024

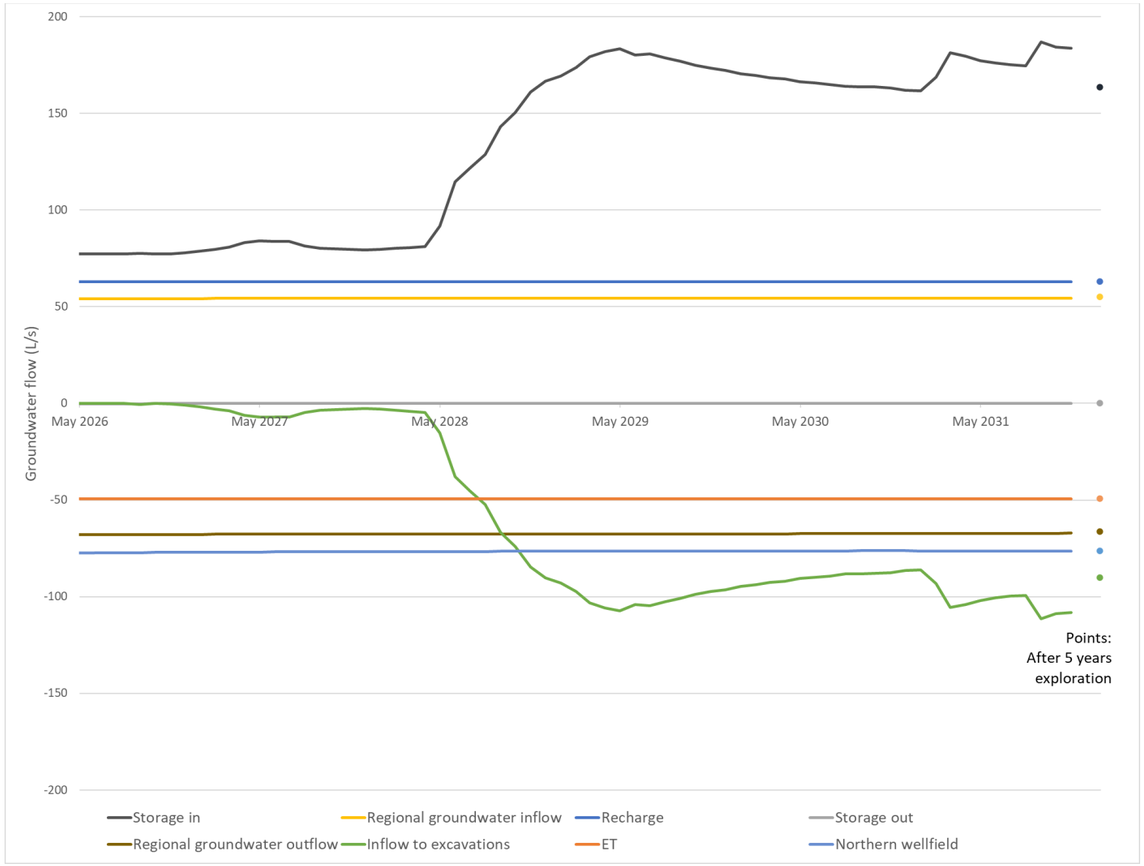
Base realisation Upper PFA high K Sy

OKDUGA Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure C.8

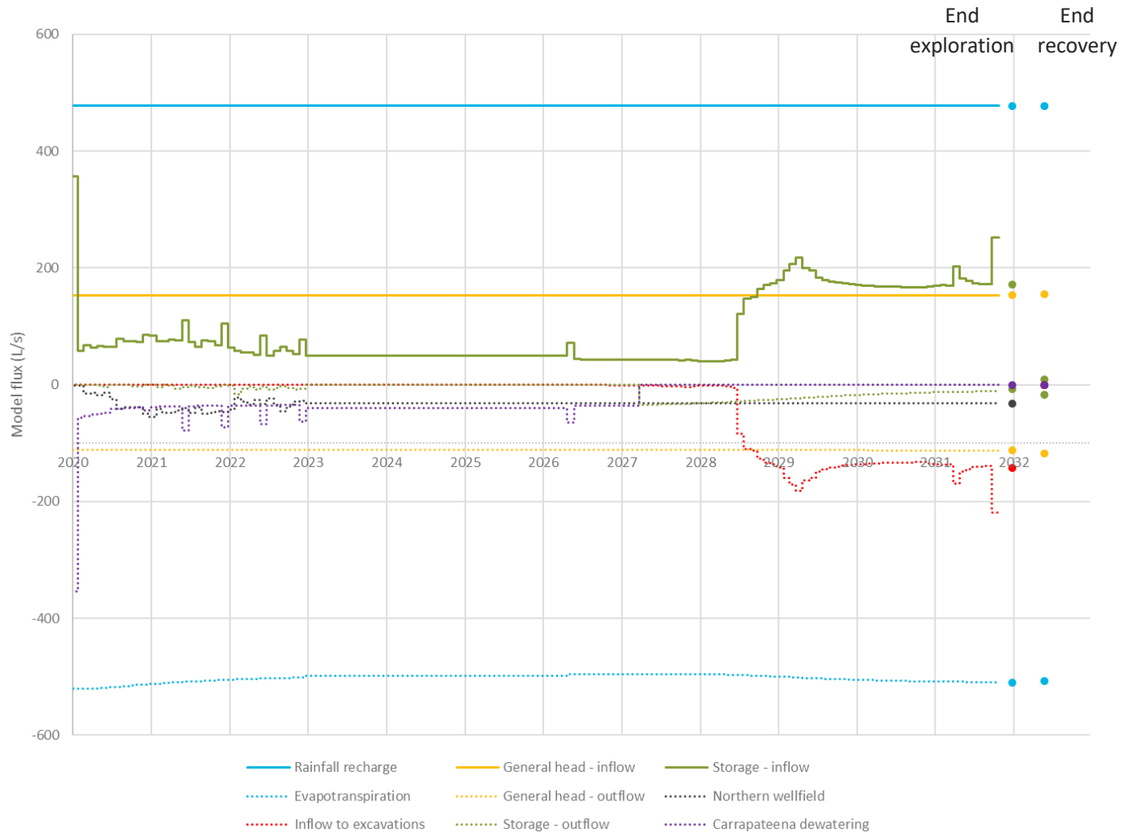
EMM creating opportunities

Appendix D
Model predictions

EMM
creating opportunities

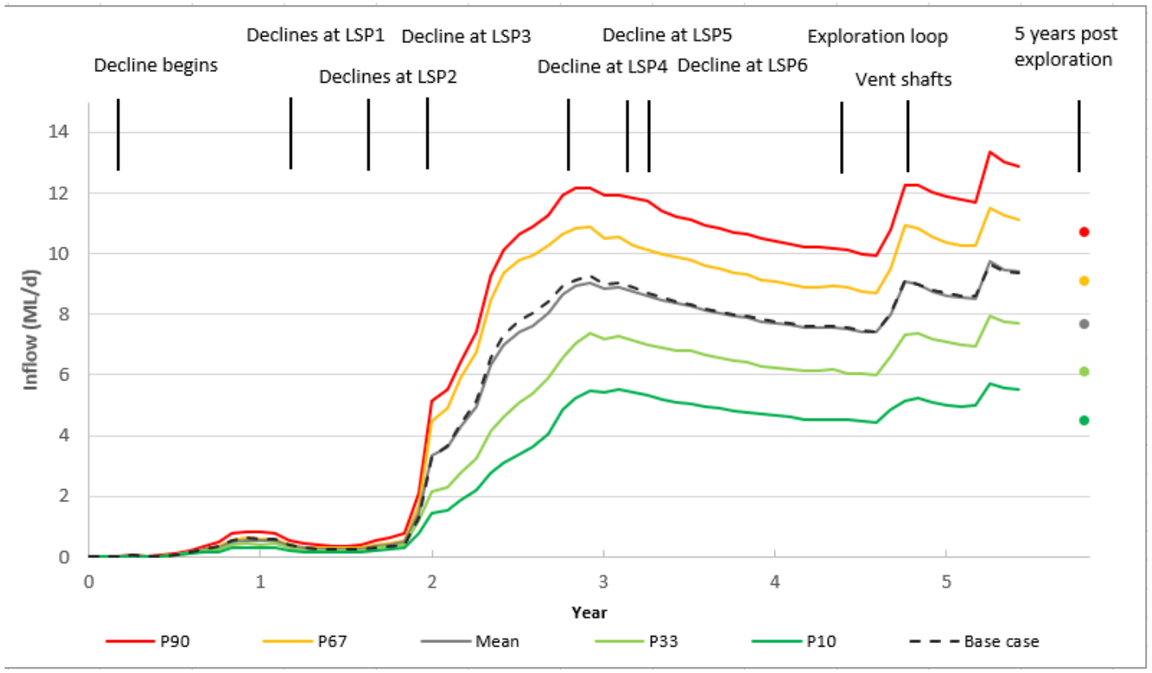


Original OKDUGA model

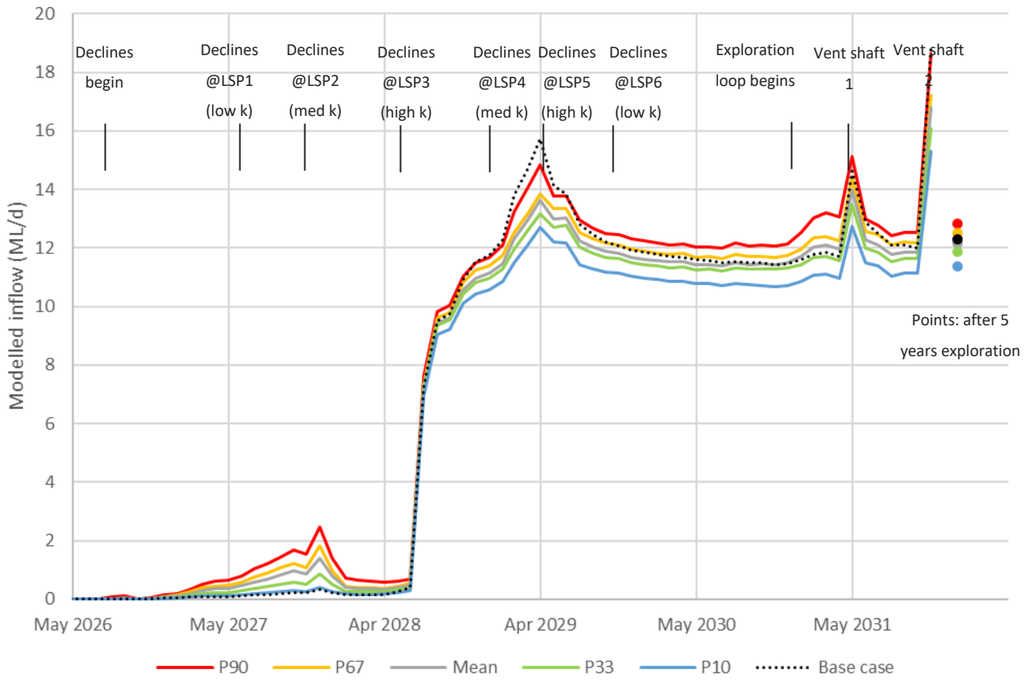


OKD LOM (OKDUGA simulated only) model

Figure D.1 Modelled base realisation transient water balance



Original OKDUGA model



OKD LOM (OKDUGA simulated only) model

Figure D.2 **Modelled groundwater inflow to project components**



\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02_Maps\RTS_GW_AddendumB\GW002_IncrementalBaseCaseDrawdownTHA_20240522_01.mxd 23/05/2024

Source: EMM (2024); BHP (2024); SARIG (2023); DEW (2023);GA (2011); ESRI (2024)

0 25 50 km

GDA2020 MGA Zone 53

N

KEY

- Retention Lease (RL) Project Area
- Modelled drawdown (m)
- Model boundary
- Surface water body
- Major road
- Minor road

Incremental base case drawdown in the THA - Original OKDUGA model

OKDUGA Project Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure D.3a

EMM
creating opportunities



Source: EMM (2024); BHP (2024); SARIG (2023); DEW (2023);GA (2011); ESRI (2024)

0 25 50 km

GDA2020 MGA Zone 53

N

KEY

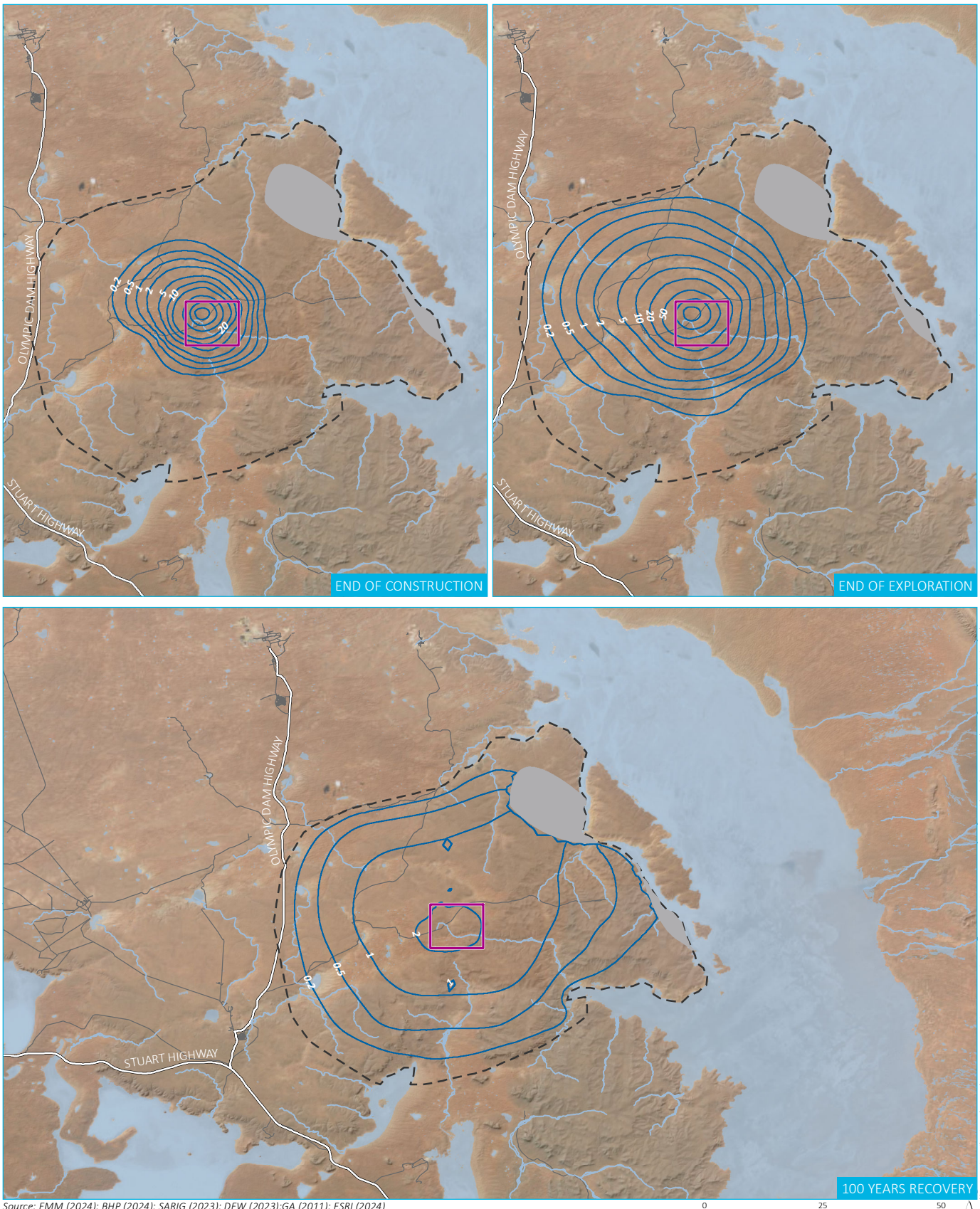
- Retention Lease (RL) Project Area
- Oak Dam LOM model extent
- THA absent
- Modelled drawdown (m)
- Potential Groundwater Dependant Ecosystem (GDE)
- Terrestrial
- Surface water body
- Major road
- Minor road

Incremental base case drawdown in the THA - OKD LOM (OKDUGA simulated only) model

OKDUGA Project Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure D.3b

EMM creating opportunities

\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02_Maps\RTS_GW_AddendumB\GW003_OKDLOMIncrementalBaseCaseDDinTHA_20240520_01.mxd 4/10/2024



Source: EMM (2024); BHP (2024); SARIG (2023); DEW (2023);GA (2011); ESRI (2024)

0 25 50 km

GDA2020 MGA Zone 53

N

KEY

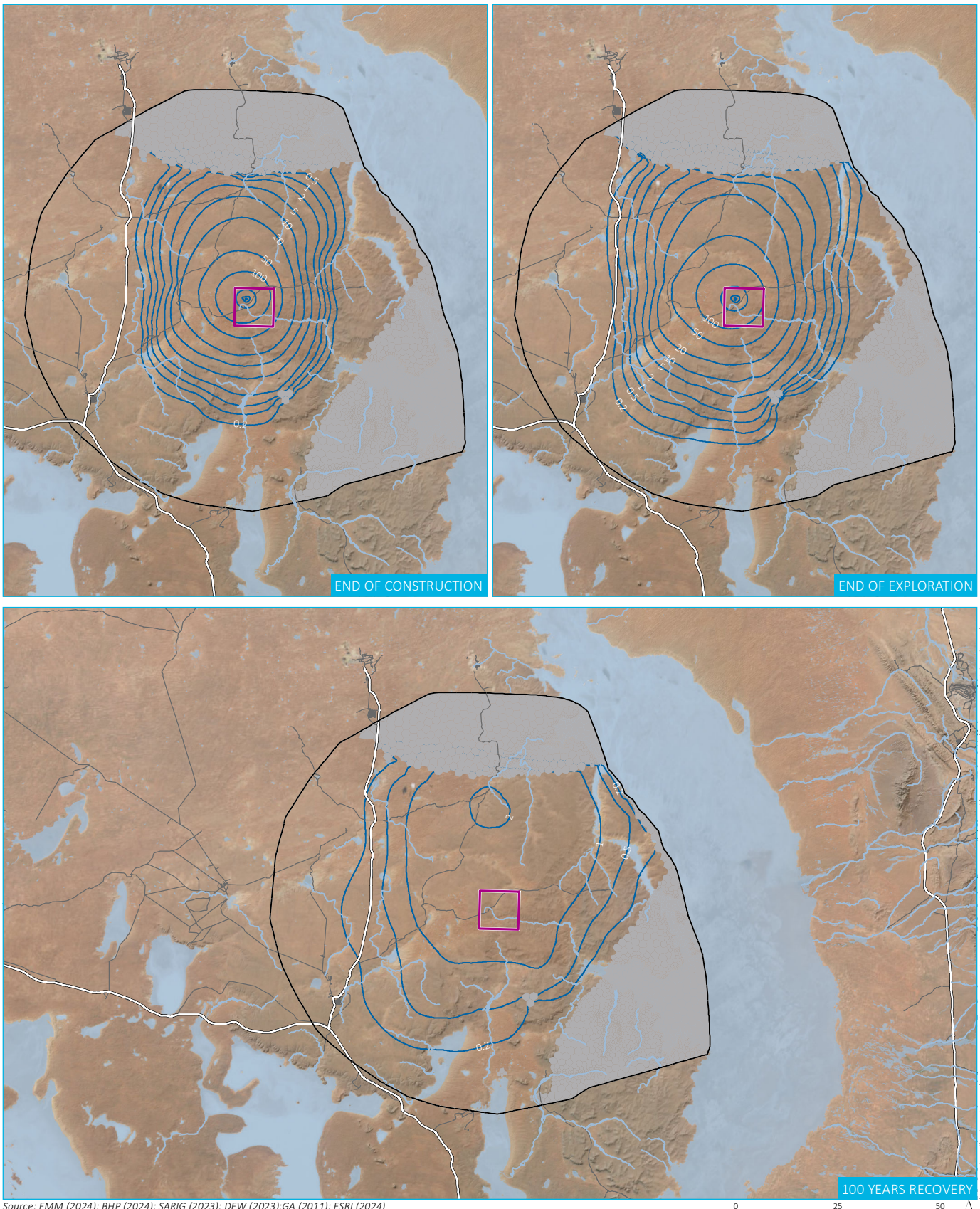
- Retention Lease (RL) Project Area
- LSP absent
- Model boundary
- Modelled drawdown (m)
- Surface water body
- Major road
- Minor road

Incremental base case drawdown in the Upper LSP high K - Original OKDUGA model

OKDUGA Project Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure D.4a

EMM creating opportunities

\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02_Maps\RTS_GW_AddendumB\GW004_IncrementalBaseCaseDDinLSPhighK_20240522_01.mxd 23/05/2024



Source: EMM (2024); BHP (2024); SARIG (2023); DEW (2023);GA (2011); ESRI (2024)

KEY

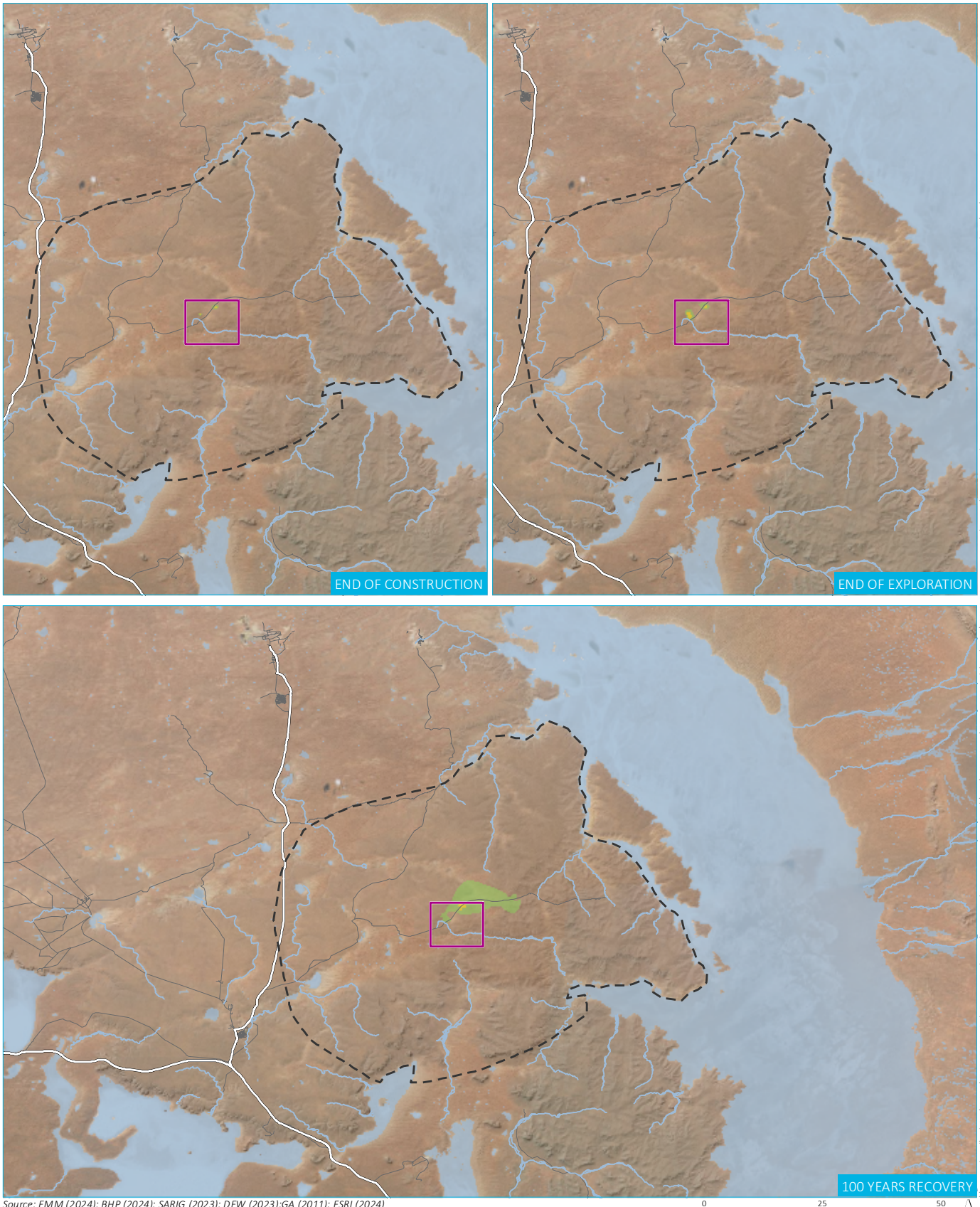
- Retention Lease (RL) Project Area
- Oak Dam LOM model extent
- PFA absent
- Modelled drawdown (m)
- Surface water body
- Major road
- Minor road

Incremental base case drawdown in the Upper PFA high K - OKD LOM (OKDUGA simulated only) model

OKDUGA Project Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure D.4b

EMM creating opportunities

\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02_Maps\RTS_GW_AddendumB\GW005_OKDLOMIncrementalBaseCaseDDinUpperPFAHighK_20240520_03.mxd 3/10/2024



\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02_Maps\RTS_GW_AddendumB\GW006_IncrementalDrawdownExceedanceFor2mDrawdownTHA_20240521_01.mxd 22/05/2024

Source: EMM (2024); BHP (2024); SARIG (2023); DEW (2023);GA (2011); ESRI (2024)

0 25 50 km

GDA2020 MGA Zone 53

N

KEY

- Retention Lease (RL) Project Area
- Model boundary
- Surface water body
- Major road
- Minor road

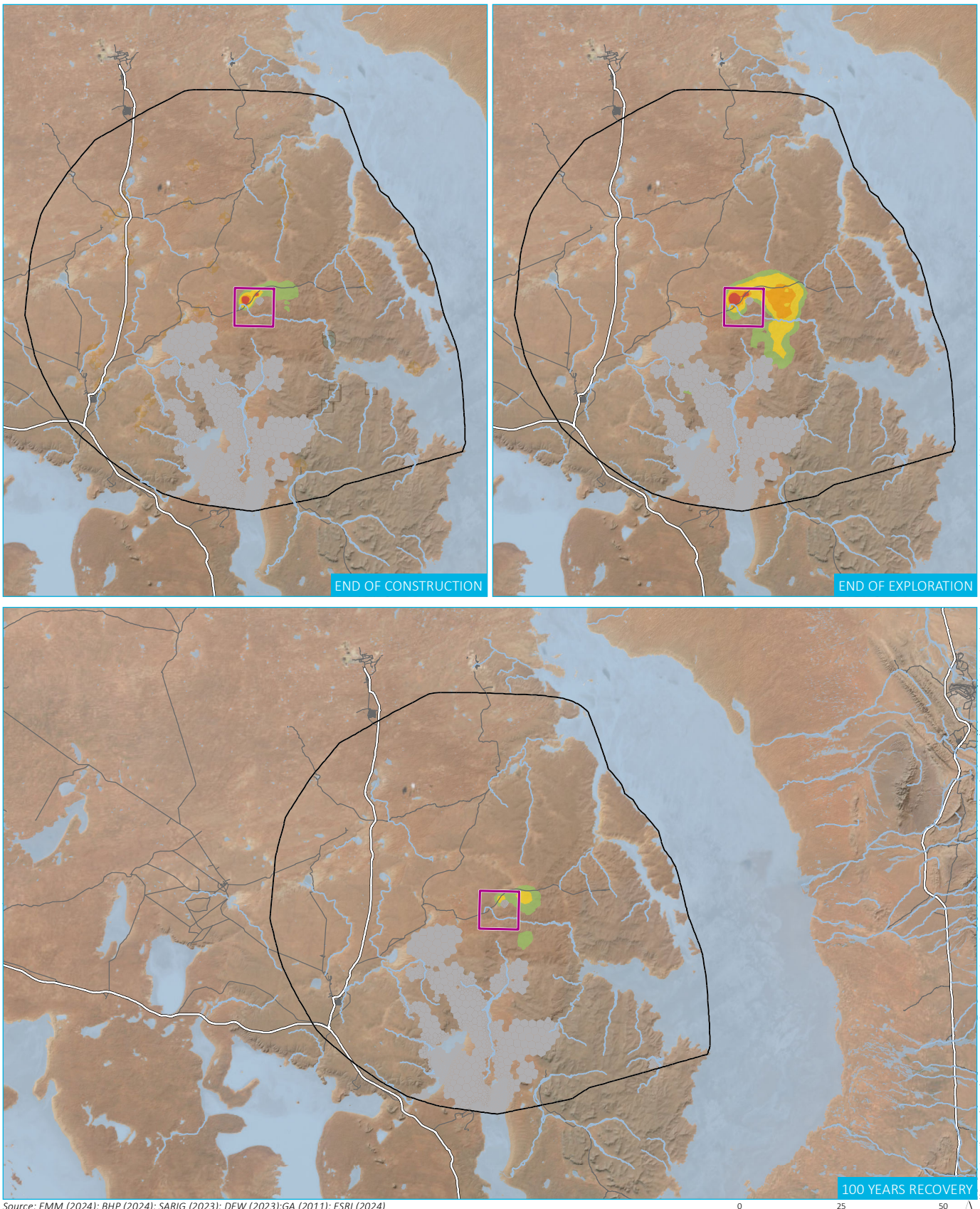
Likelihood

- Unlikley
- As likely as not
- Likely

Incremental drawdown, likelihood of exceedance for 2 m drawdown in THA - Original OKDUGA model

OKDUGA Project Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure D.5a

EMM
creating opportunities



\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02_Maps\RTS_GW_AddendumB\GW007_OKDLOMIncrementalDDLikelihoodExceedanceTHA_20240520_03.mxd 3/10/2024

Source: EMM (2024); BHP (2024); SARIG (2023); DEW (2023);GA (2011); ESRI (2024)

0 25 50 km

GDA2020 MGA Zone 53

N

KEY

- Retention Lease (RL) Project Area
- OKD LOM model extent
- THA absent
- Surface water body
- Major road
- Minor road

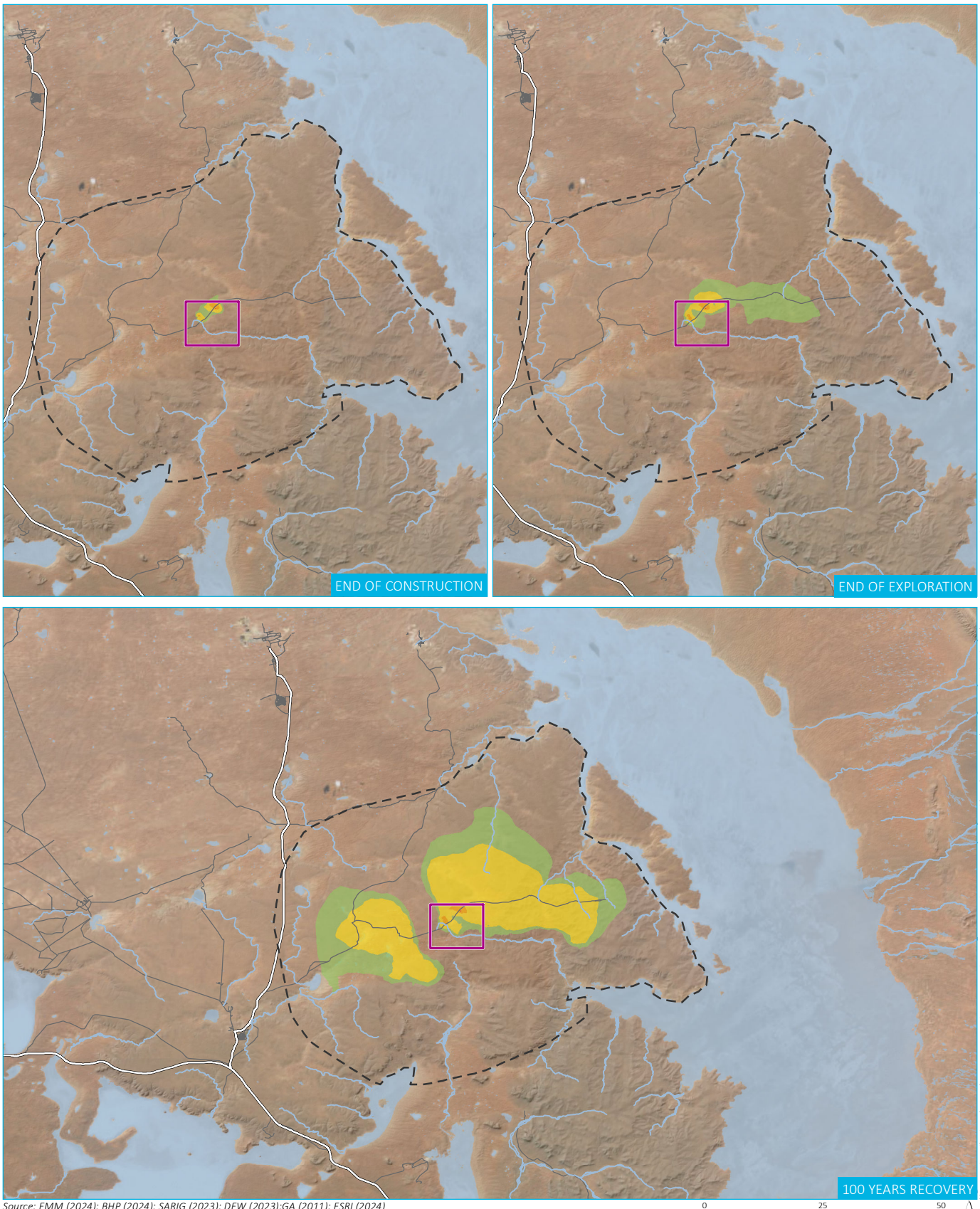
Likelihood

- Unlikely
- As likely as not
- Likely
- Very likely

Incremental drawdown, likelihood of exceedance for 2 m drawdown in THA - OKD LOM (OKDUGA simulated only) model

OKDUGA Project Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure D.5b

EMM
creating opportunities



\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02_Maps\RTS_GW_AddendumB\GW008_IncrementalDrawdownExceedanceFor0_2mDrawdownTHA_20240521_01.mxd 23/05/2024

Source: EMM (2024); BHP (2024); SARIG (2023); DEW (2023);GA (2011); ESRI (2024)

0 25 50 km

GDA2020 MGA Zone 53

N

KEY

- Retention Lease (RL) Project Area
- Model boundary
- Major road
- Minor road
- Surface water body

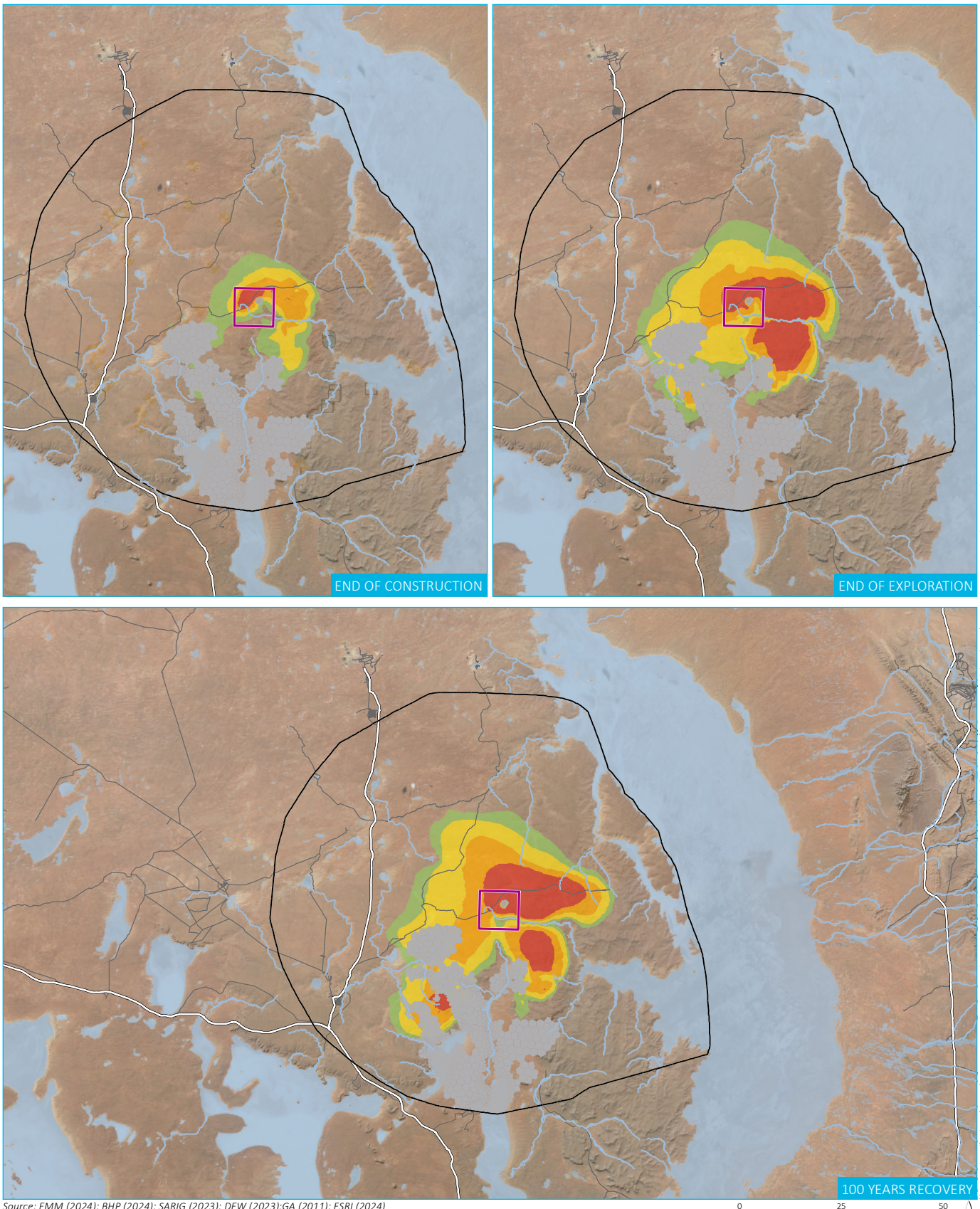
Likelihood

- Unlikely
- As likely as not
- Likely
- Very likely

Incremental drawdown, likelihood of exceedance for 0.2 m drawdown in THA - Original OKDUGA model

OKDUGA Project Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure D.6a

EMM
creating opportunities



Source: EMM (2024); BHP (2024); SARIG (2023); DEW (2023);GA (2011); ESRI (2024)

0 25 50 km

GDA2020 MGA Zone 53

N

KEY

- Retention Lease (RL) Project Area
- OKD LOM model extent
- THA absent
- Surface water body
- Major road
- Minor road

Likelihood

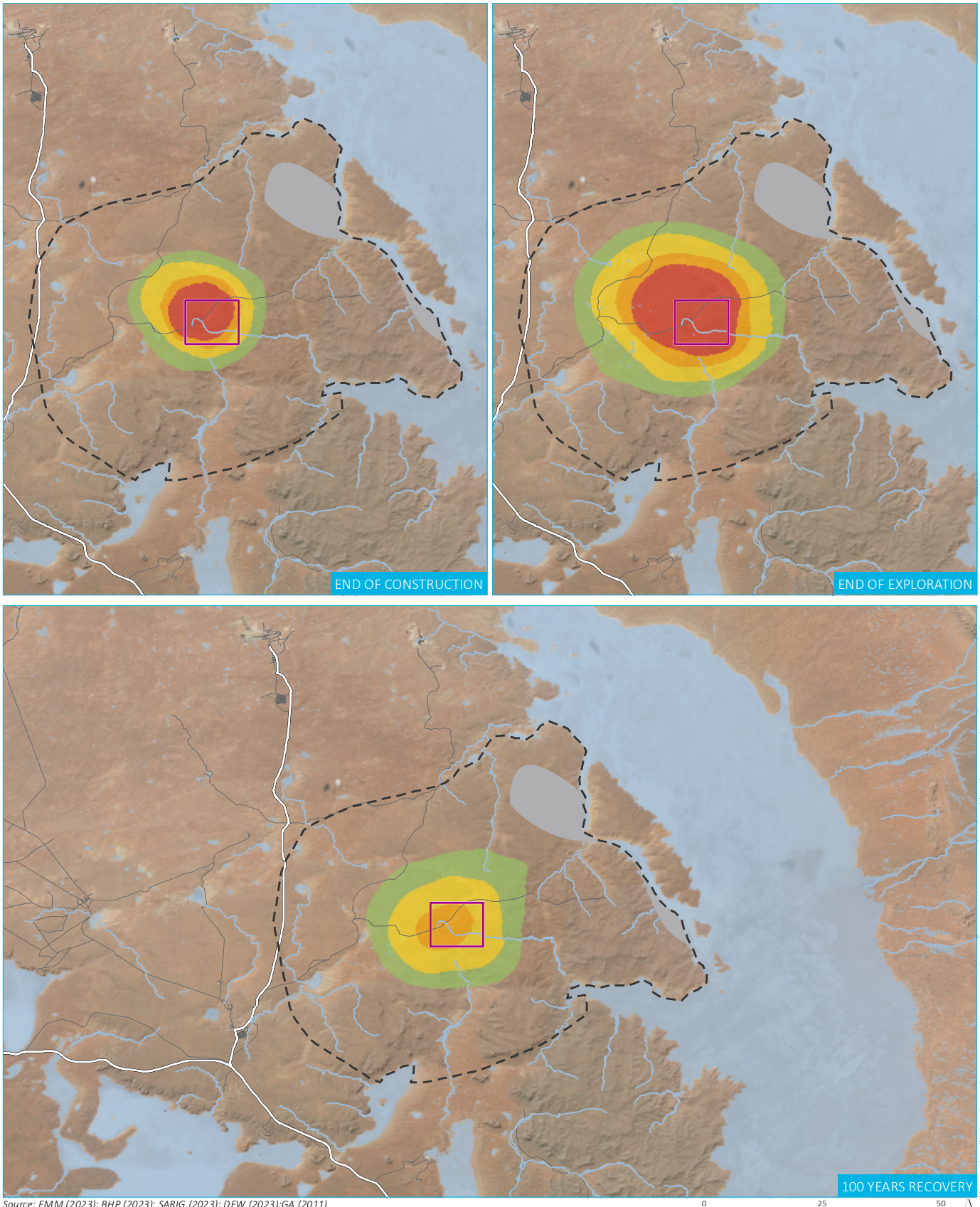
- Unlikely
- As likely as not
- Likely
- Very likely

\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02_Maps\RTS_GW_AddendumB\GW009_IncrementalDDExceedance0_2THA_20240520_02.mxd 3/10/2024

Incremental drawdown, likelihood of exceedance for 0.2 m drawdown in THA - OKD LOM (OKDUGA simulated only) model

OKDUGA Project Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure D.6b

EMM
creating opportunities



Source: EMM (2023); BHP (2023); SARIG (2023); DEW (2023);GA (2011)

0 25 50 km

GDA2020 MGA Zone 53

N

KEY

- Retention Lease (RL) Project Area
- LSP absent
- Model boundary
- Surface water body
- Major road
- Minor road

Likelihood

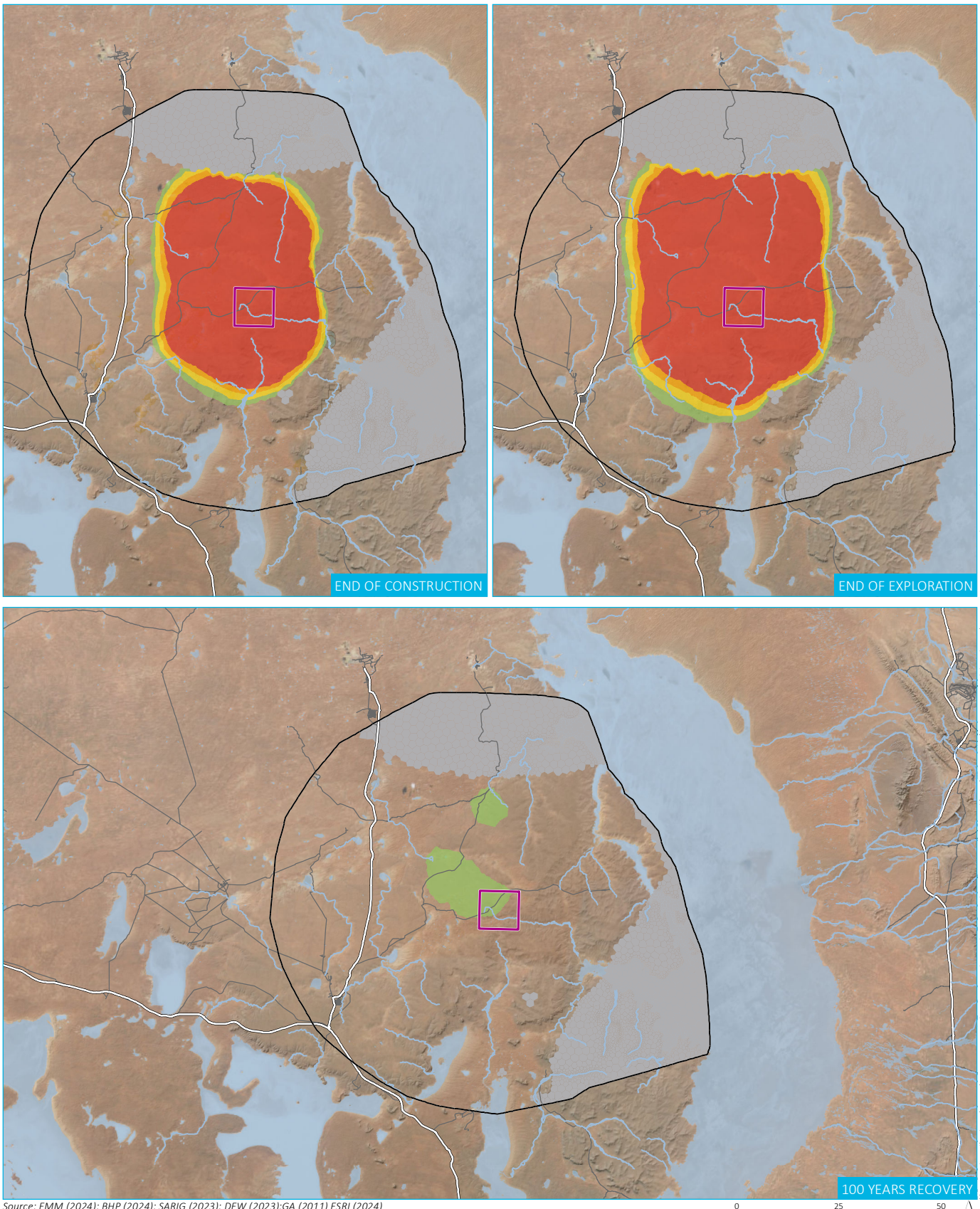
- Unlikely
- As likely as not
- Likely
- Very likely

\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02_Maps\RTS_GW_AddendumB\GW010_IncrementalDDExceedance2mLSPhighK_20240520_01.mxd 21/05/2024

Incremental drawdown, likelihood of exceedance for 2m drawdown in Upper LSP high K - Original OKDUGA model

OKDUGA Project Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure D.7a

EMM creating opportunities



Source: EMM (2024); BHP (2024); SARIG (2023); DEW (2023);GA (2011) ESRI (2024)

0 25 50 km

GDA2020 MGA Zone 53

N

KEY

- Retention Lease (RL) Project Area
- Oak Dam LOM model extent
- PFA absent
- Surface water body
- Major road
- Minor road

Likelihood

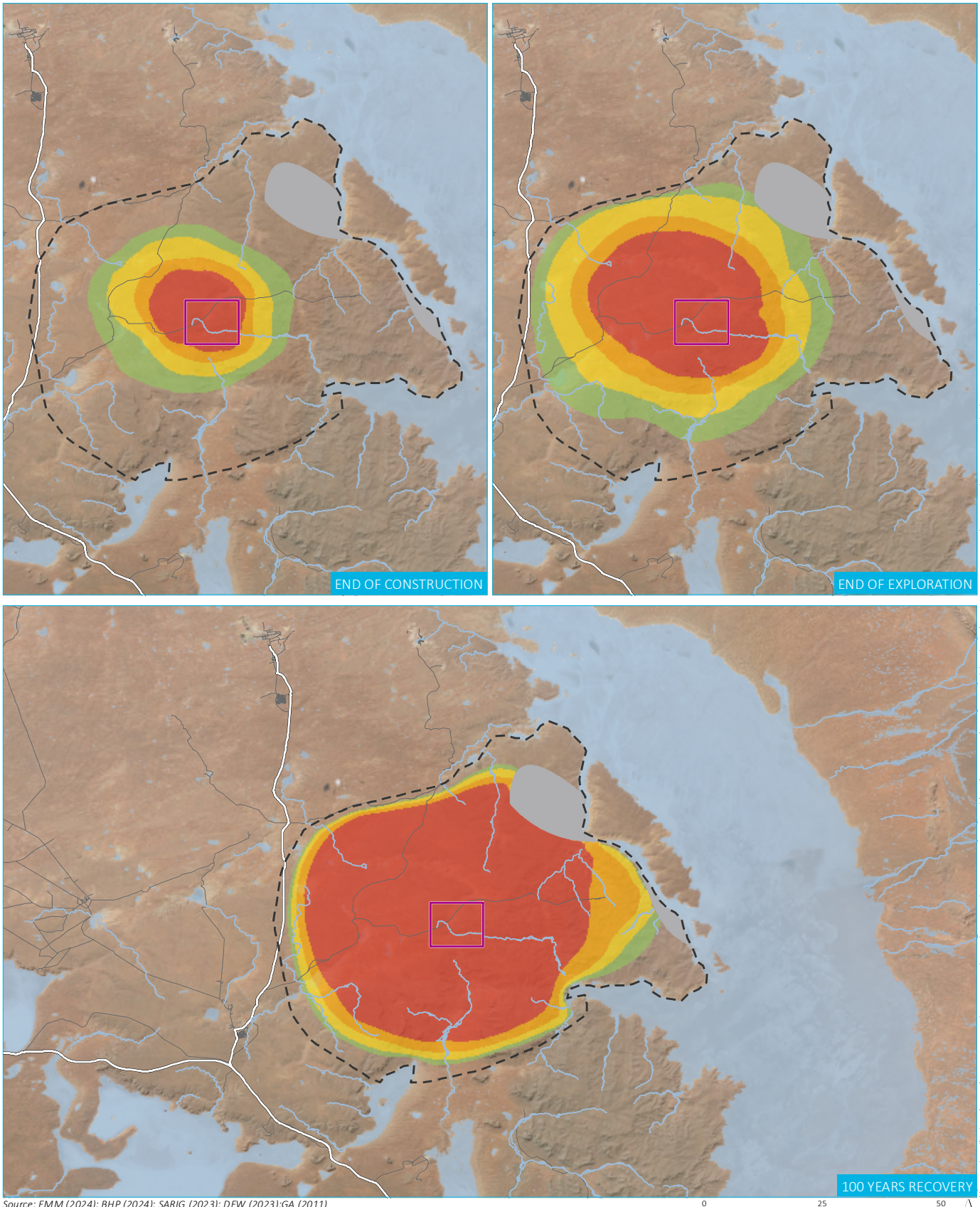
- Unlikely
- As likely as not
- Likely
- Very likely

Incremental drawdown, likelihood of exceedance for 2 m drawdown in Upper PFA high K - OKD LOM (OKDUGA simulated only) model

OKDUGA Project Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure D.7b

EMM creating opportunities

\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02_Maps\RTS_GW_AddendumB\GW011_IncrementalDDExceedance2mPFAhighK_20240520_01.mxd 3/10/2024



Source: EMM (2024); BHP (2024); SARIG (2023); DEW (2023);GA (2011)

0 25 50 km

GDA2020 MGA Zone 53

N

KEY

- Retention Lease (RL) Project Area
- LSP absent
- Model boundary
- Surface water body
- Major road
- Minor road

Likelihood

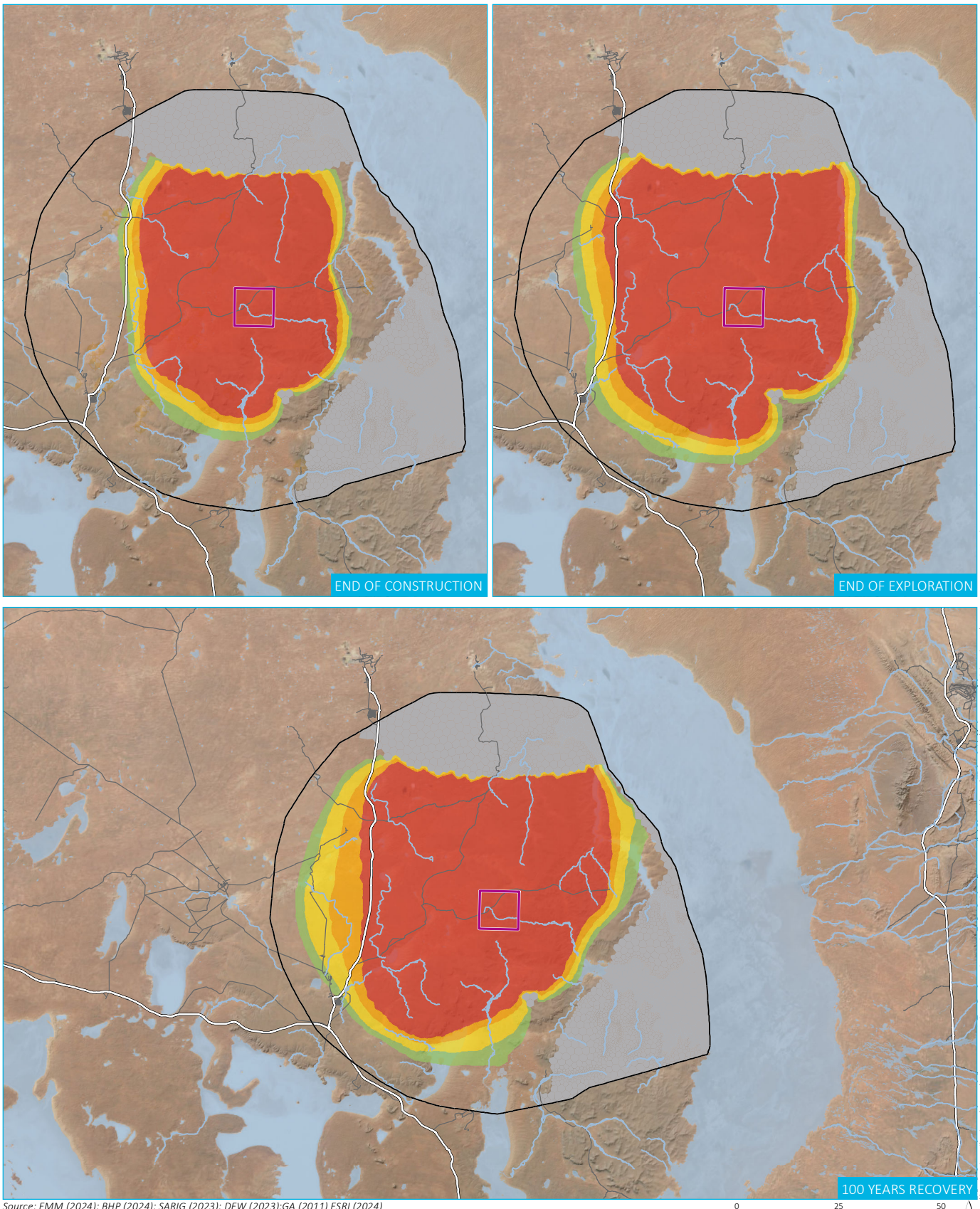
- Unlikely
- As likely as not
- Likely
- Very likely

\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02_Maps\RTS_GW_AddendumB\GW012_IncrementalDDExceedance0_2mLSPhighK_20240520_01.mxd 21/05/2024

Incremental drawdown, likelihood of exceedance for 0.2 m drawdown in Upper LSP high K - Original OKDUGA model

OKDUGA Project Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure D.8a

EMM creating opportunities



\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02_Maps\RTS_GW_AddendumB\GW013_IncrementalDDExceedance0.2mPFAhighK_20240520_02.mxd 3/10/2024

Source: EMM (2024); BHP (2024); SARIG (2023); DEW (2023);GA (2011) ESRI (2024)

0 25 50 km

GDA2020 MGA Zone 53

N

KEY

- Retention Lease (RL) Project Area
- Oak Dam LOM model extent
- PFA absent
- Surface water body
- Major road
- Minor road

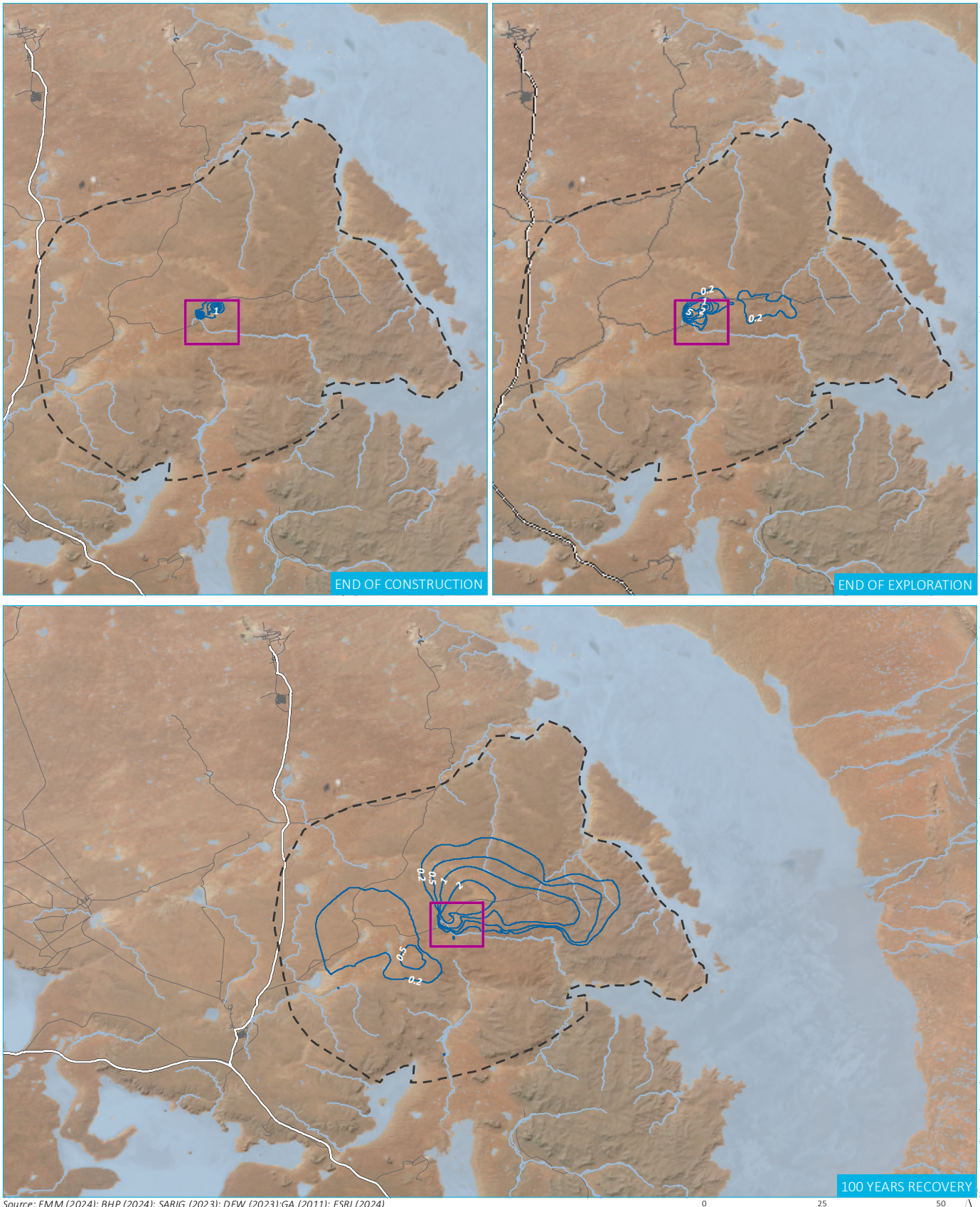
Likelihood

- Unlikely
- As likely as not
- Likely
- Very likely

Incremental drawdown, likelihood of exceedance for 0.2 m drawdown in Upper PFA high K -OKD LOM (OKDUGA simulated only) model

OKDUGA Project Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure D.8b

EMM creating opportunities



Source: EMM (2024); BHP (2024); SARIG (2023); DEW (2023);GA (2011); ESRI (2024)

0 25 50 km

GDA2020 MGA Zone 53

N

KEY

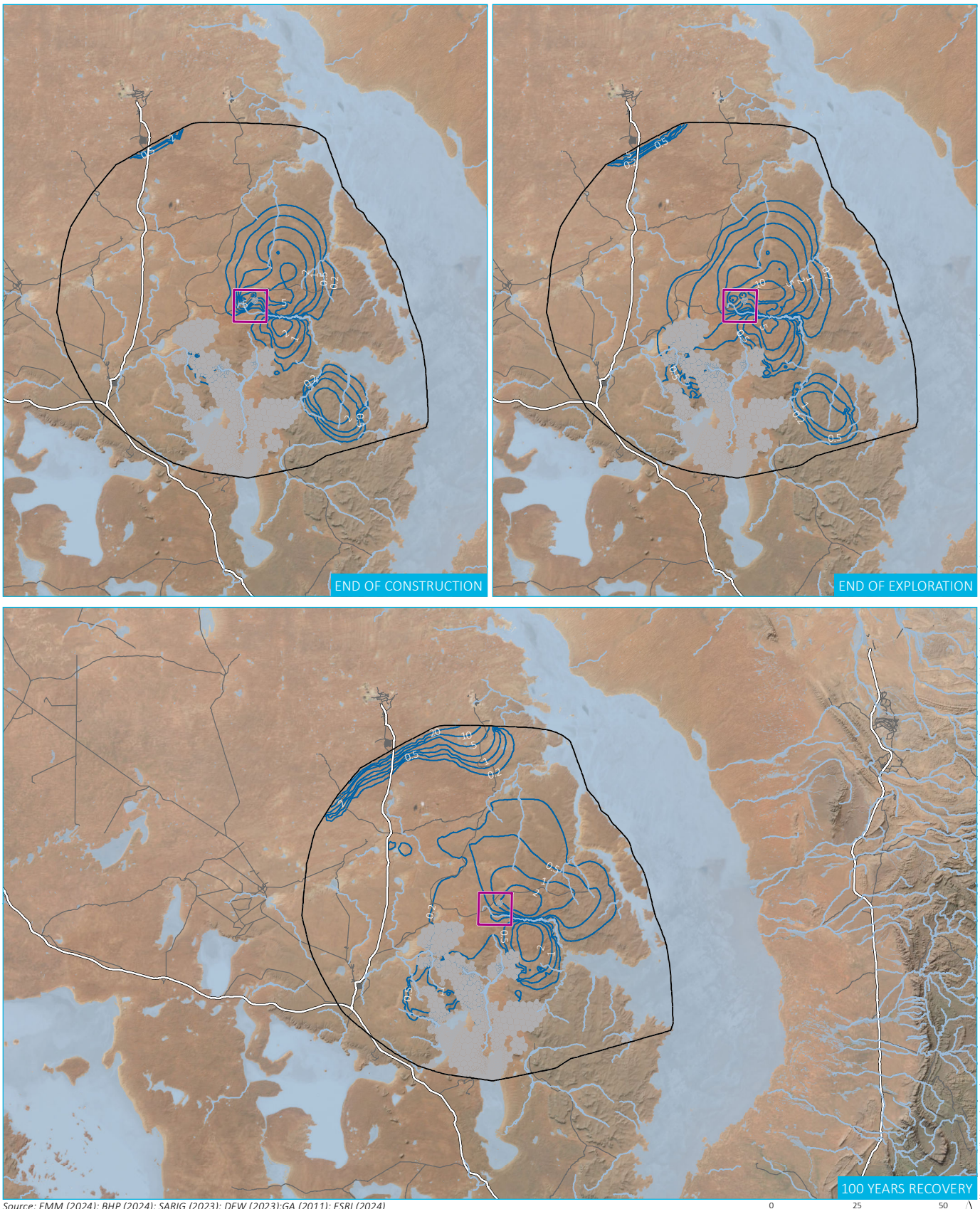
- Retention Lease (RL) Project Area
- Modelled drawdown (m)
- Model boundary
- Surface water body
- Major road
- Minor road

Cumulative base case drawdown in the THA
- Original OKDUGA model

OKDUGA Project Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure D.9a

\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02_Maps\RTS_GW_AddendumB\GW014_CumulativeBaseCaseDrawdownTHA_20240520_01.mxd 21/05/2024

EMM creating opportunities



Source: EMM (2024); BHP (2024); SARIG (2023); DEW (2023);GA (2011); ESRI (2024)

0 25 50 km

GDA2020 MGA Zone 53

N

KEY

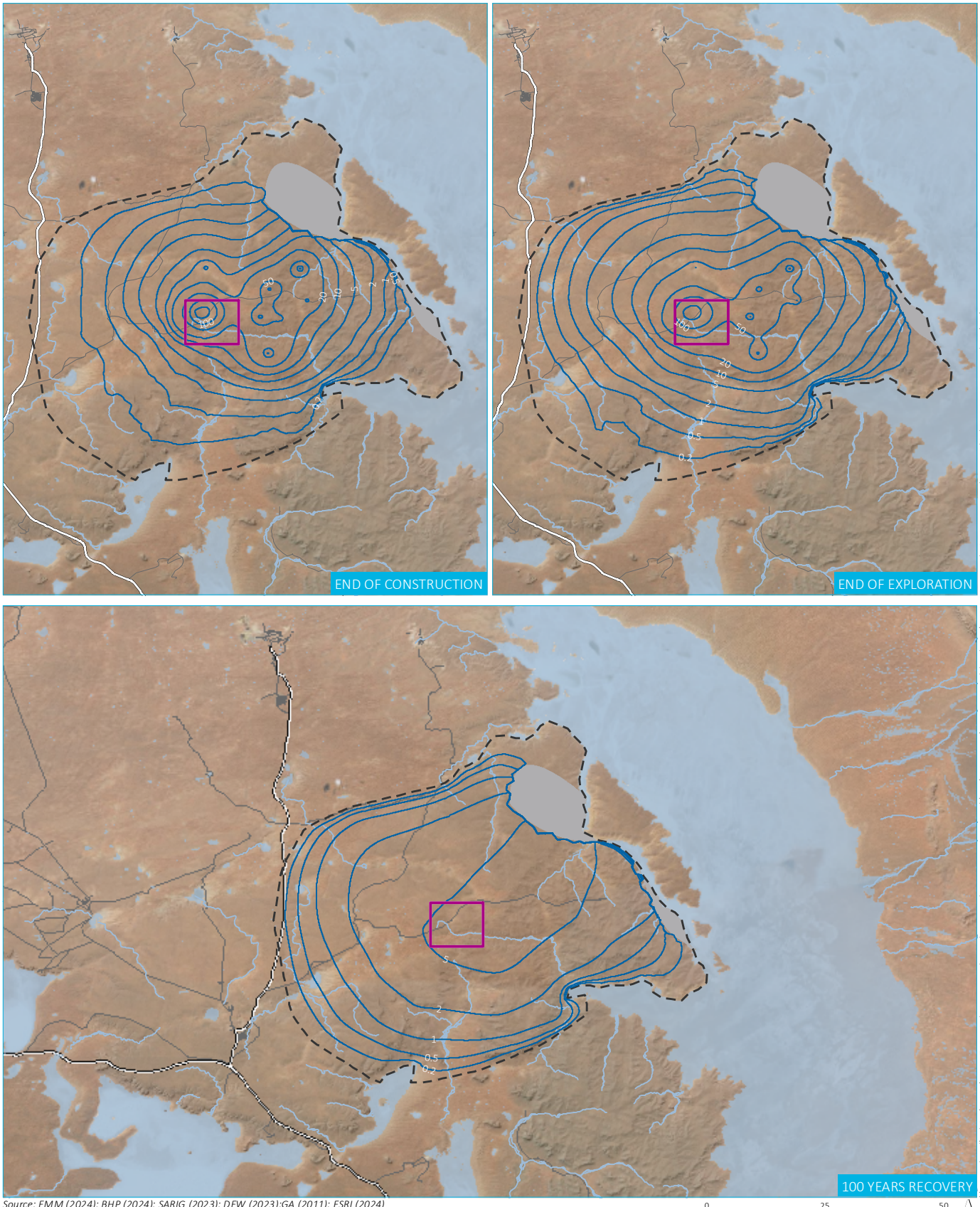
- Retention Lease (RL) Project Area
- THA absent
- Oak Dam LOM model extent
- Drawdown (m)
- Surface water body
- Major road
- Minor road

Cumulative base case drawdown in the THA - OKD LOM (OKDUGA simulated only) model

OKDUGA Project Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure D.9b

\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02_Maps\RTS_GW_AddendumB\GW017_CumulativeBaseDrawdownLSPhighK_20240521.mxd 4/10/2024

creating opportunities



Source: EMM (2024); BHP (2024); SARIG (2023); DEW (2023);GA (2011); ESRI (2024)

0 25 50 km

GDA2020 MGA Zone 53

N

KEY

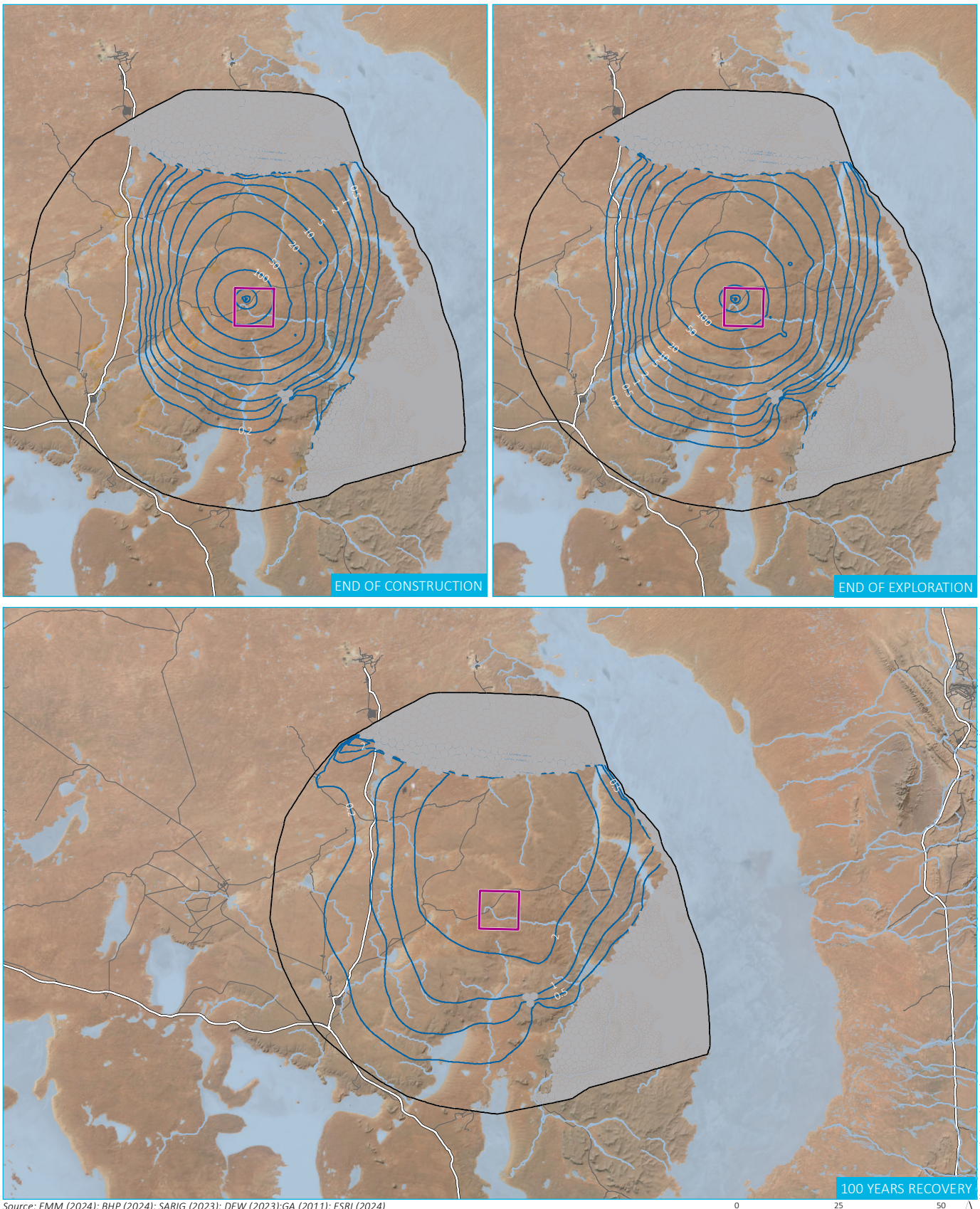
- Retention Lease (RL) Project Area
- LSP absent
- Modelled drawdown (m)
- Model boundary
- Surface water body
- Major road
- Minor road

Cumulative base case drawdown in the Upper LSP high K-Original OKDUGA model

OKDUGA Project Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure D.10a

EMM creating opportunities

\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02_Maps\RTS_GW_AddendumB\GW016_CumulativeBaseDrawdownLSPhighK_20240521.mxd 22/05/2024



Source: EMM (2024); BHP (2024); SARIG (2023); DEW (2023);GA (2011); ESRI (2024)

GDA2020 MGA Zone 53

KEY

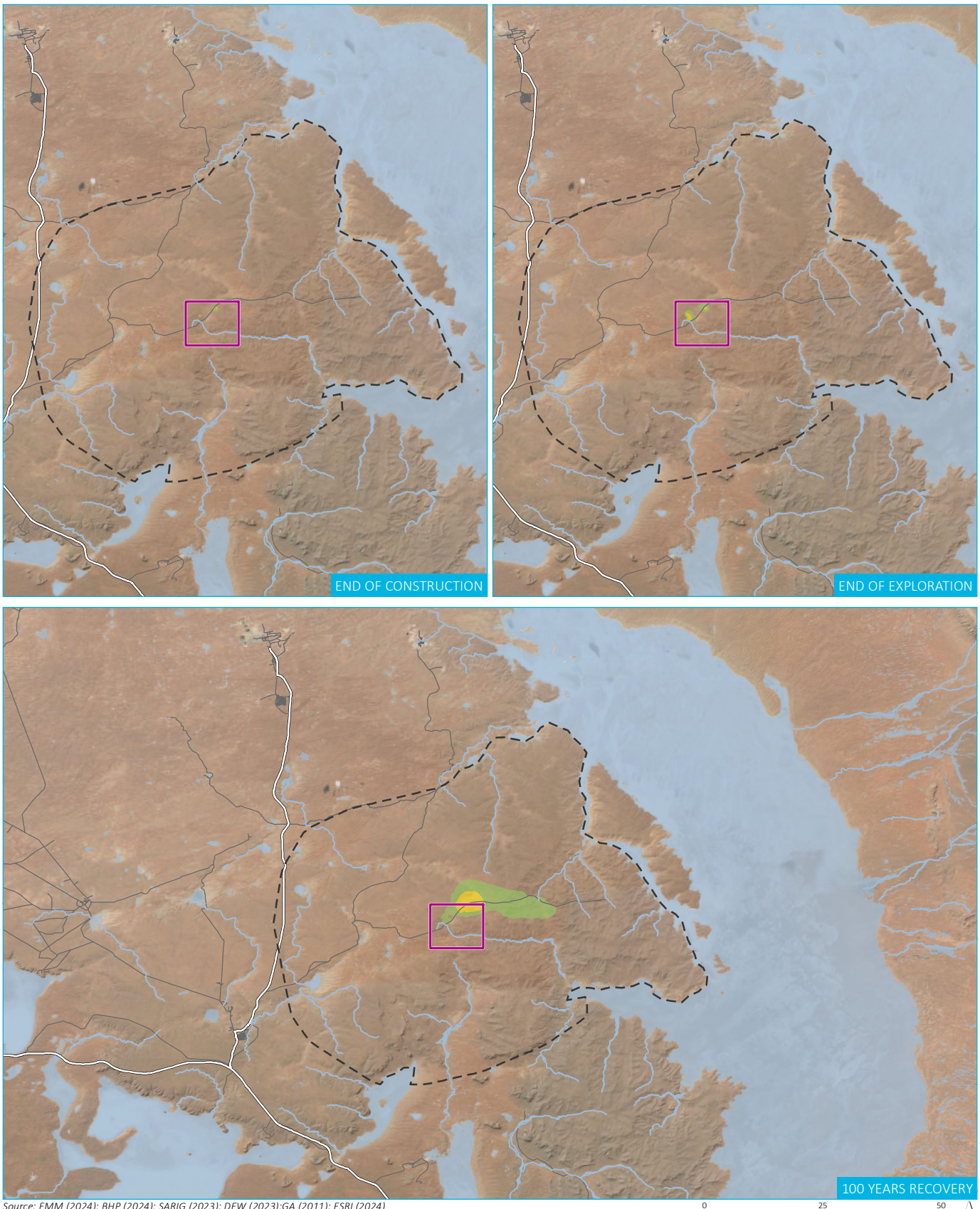
- Retention Lease (RL) Project Area
- PFA absent
- Oak Dam LOM model extent
- Drawdown (m)
- Surface water body
- Major road
- Minor road
- Waterbody

Cumulative base case drawdown in the Upper PFA high K - OKD LOM (OKDUGA simulated only) model

OKDUGA Project Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure D.10b

EMM creating opportunities

\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02_Maps\RTS_GW_AddendumB\GW015_CumulativeBaseCaseDrawdownTHA_20240520_01.mxd 4/10/2024



Source: EMM (2024); BHP (2024); SARIG (2023); DEW (2023);GA (2011); ESRI (2024)

0 25 50 km

GDA2020 MGA Zone 53

N

KEY

- Retention Lease (RL) Project Area
- Model boundary
- Major road
- Minor road
- Surface water body

Likelihood

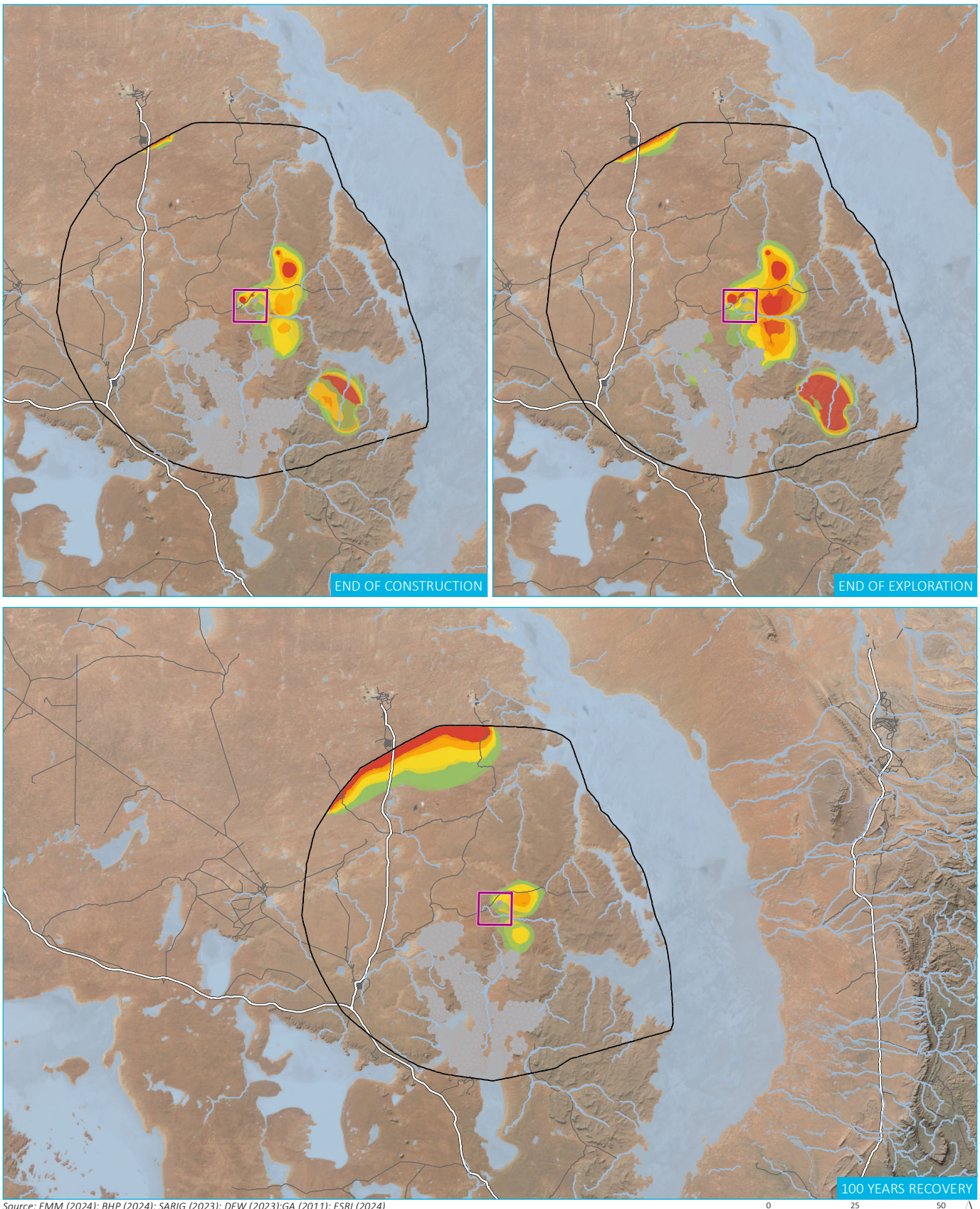
- Unlikely
- As likely as not
- Likely
- Very likely

Cumulative drawdown, likelihood of exceedance for 2 m drawdown in THA - Original OKDUGA model

OKDUGA Project Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure D.11a

EMM creating opportunities

\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02_Maps\RTS_GW_AddendumB\GW018_CumulativeDrawdownLikelihoodOfExceedenceTHA_20240521_01.mxd 23/05/2024



Source: EMM (2024); BHP (2024); SARIG (2023); DEW (2023);GA (2011); ESRI (2024)

0 25 50 km

GDA2020 MGA Zone 53

N

KEY

- Retention Lease (RL) Project Area
- Oak Dam LOM model extent
- THA absent
- Major road
- Minor road
- Surface water body

Likelihood

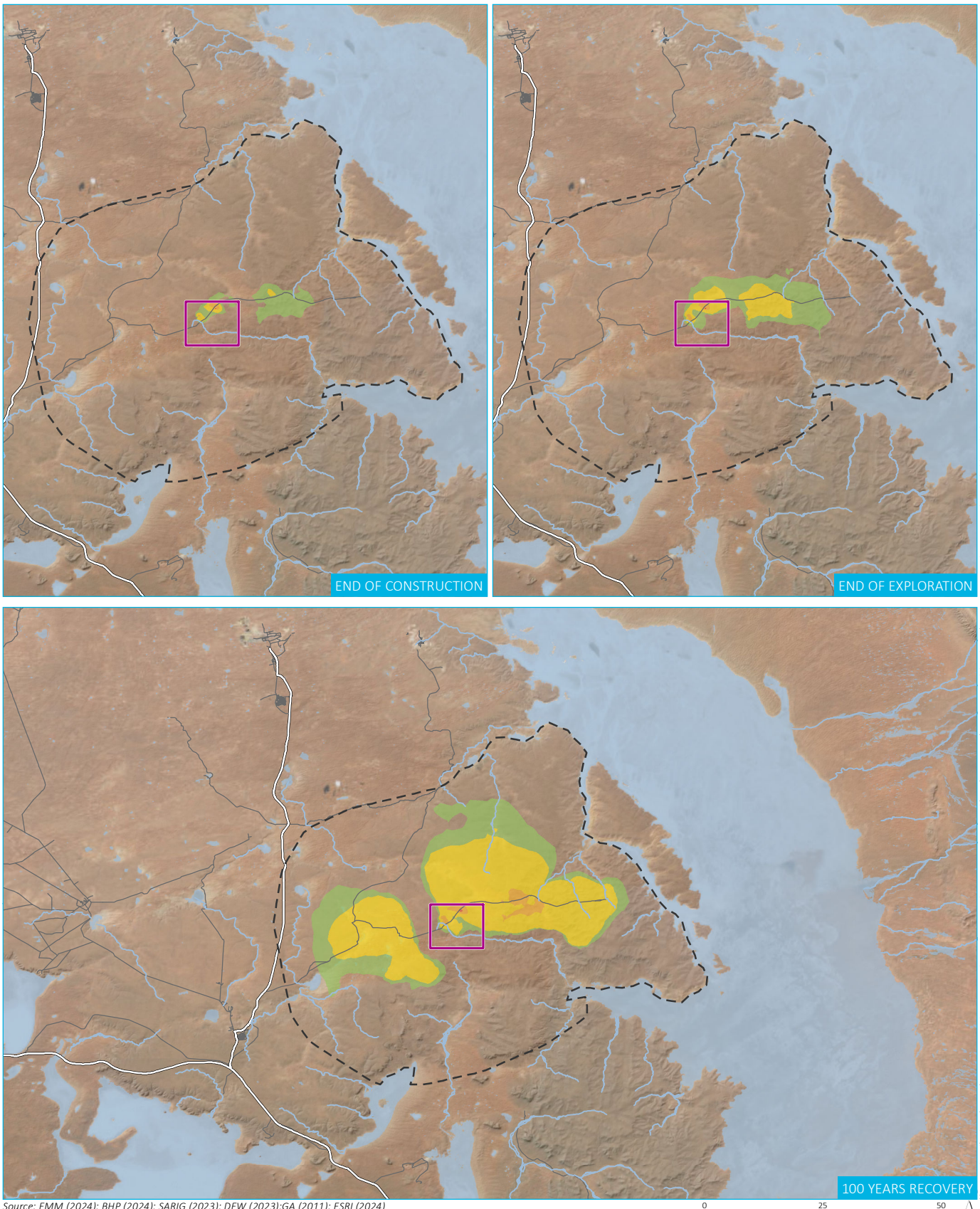
- Unlikely
- As likely as not
- Likely
- Very likely

Cumulative drawdown, likelihood of exceedance for 2 m drawdown in THA - OKD LOM (OKDUGA simulated only) model

OKDUGA Project Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure D.11b

EMM creating opportunities

\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02_Maps\RTS_GW_AddendumB\GW019_CumulativeDrawdownLikelihoodOfExceedenceTHA_20240521_01.mxd 2/10/2024



Source: EMM (2024); BHP (2024); SARIG (2023); DEW (2023);GA (2011); ESRI (2024)

0 25 50 km

GDA2020 MGA Zone 53

N

KEY

- Retention Lease (RL) Project Area
- Model boundary
- Major road
- Minor road
- Surface water body

Likelihood

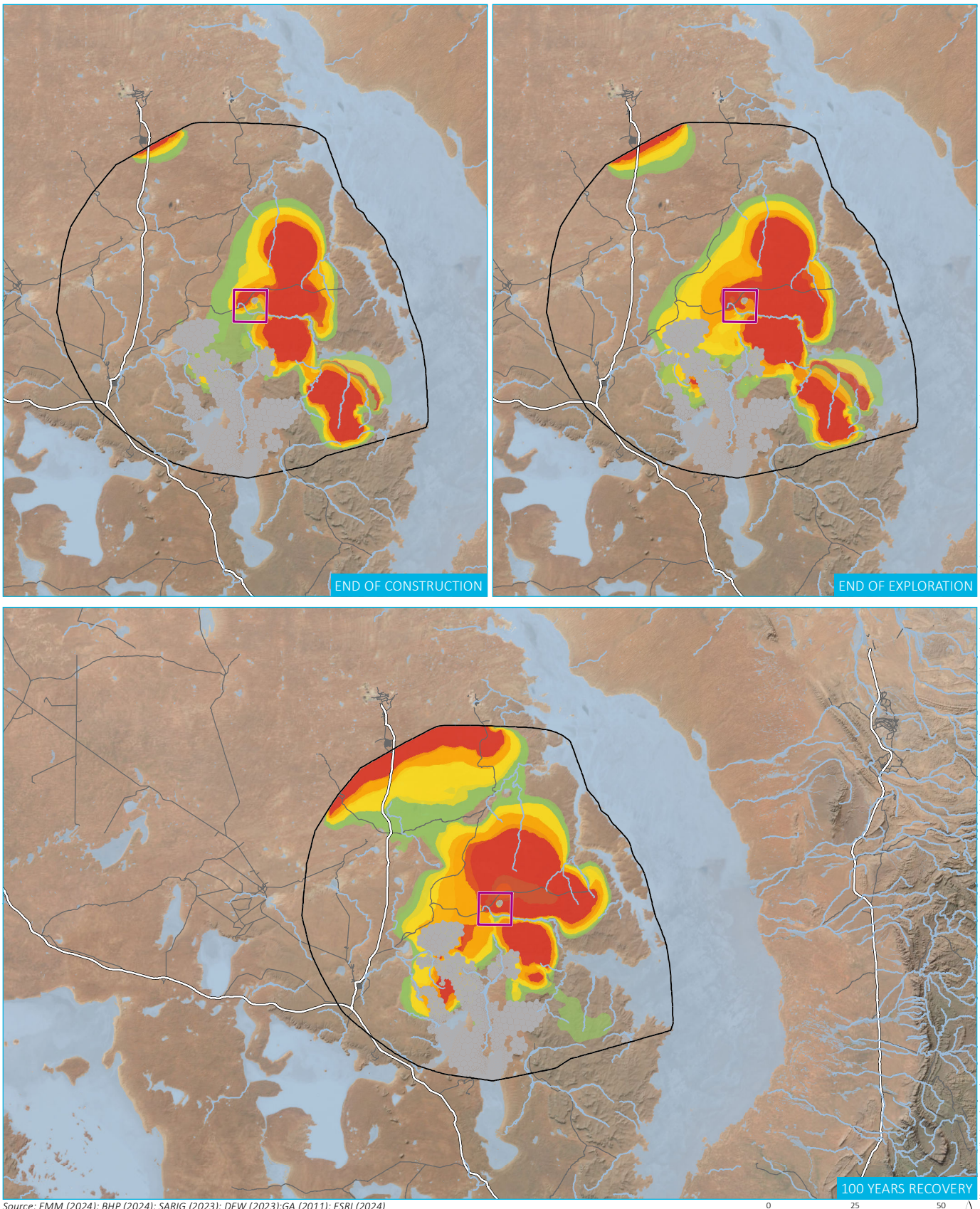
- Unlikely
- As likely as not
- Likely
- Very likely

\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02_Maps\RTS_GW_AddendumB\GW020_CumulativeDrawdownLikelihoodOfExceedence0.2THA_20240521_01.mxd 23/05/2024

Cumulative drawdown, likelihood of exceedance for 0.2 m drawdown in THA - Original OKDUGA model

OKDUGA Project Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure D.12a

EMM creating opportunities



Source: EMM (2024); BHP (2024); SARIG (2023); DEW (2023);GA (2011); ESRI (2024)

0 25 50 km

GDA2020 MGA Zone 53

N

KEY

- Retention Lease (RL) Project Area
- Oak Dam LOM model extent
- THA absent
- Major road
- Minor road
- Surface water body

Likelihood

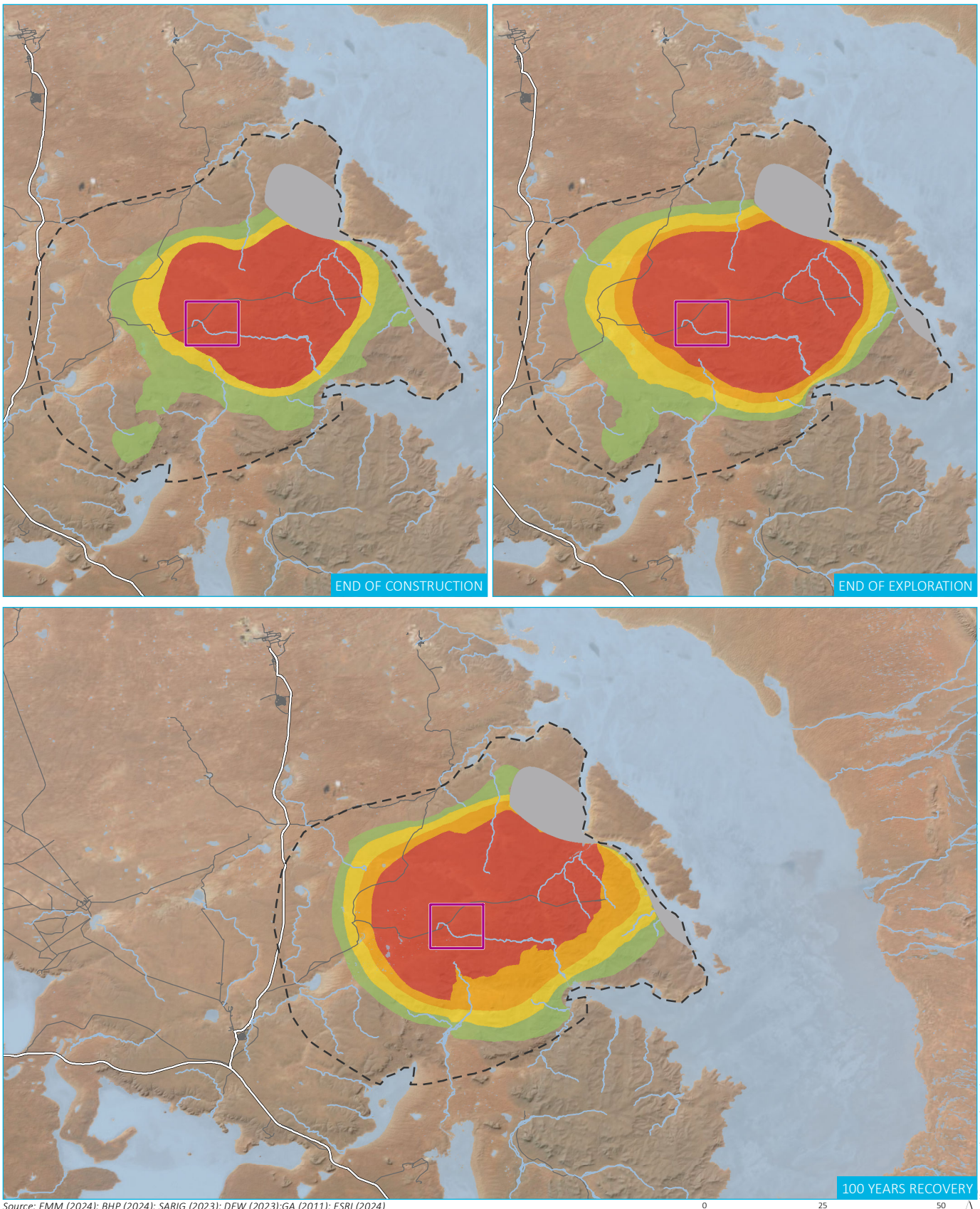
- Unlikely
- As likely as not
- Likely
- Very likely

Cumulative drawdown, likelihood of exceedance for 0.2 m drawdown in THA - OKD LOM (OKDUGA simulated only) model

OKDUGA Project Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure D.12b

EMM creating opportunities

\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02_Maps\RTS_GW_AddendumB\GW021_CumulativeDrawdownLikelihoodOfExceedence0.2THA_20240521_01.mxd 2/10/2024



Source: EMM (2024); BHP (2024); SARIG (2023); DEW (2023);GA (2011); ESRI (2024)

0 25 50 km

GDA2020 MGA Zone 53

N

KEY

- Retention Lease (RL) Project Area
- LSP absent
- Model boundary
- Surface water body
- Major road
- Minor road

Likelihood

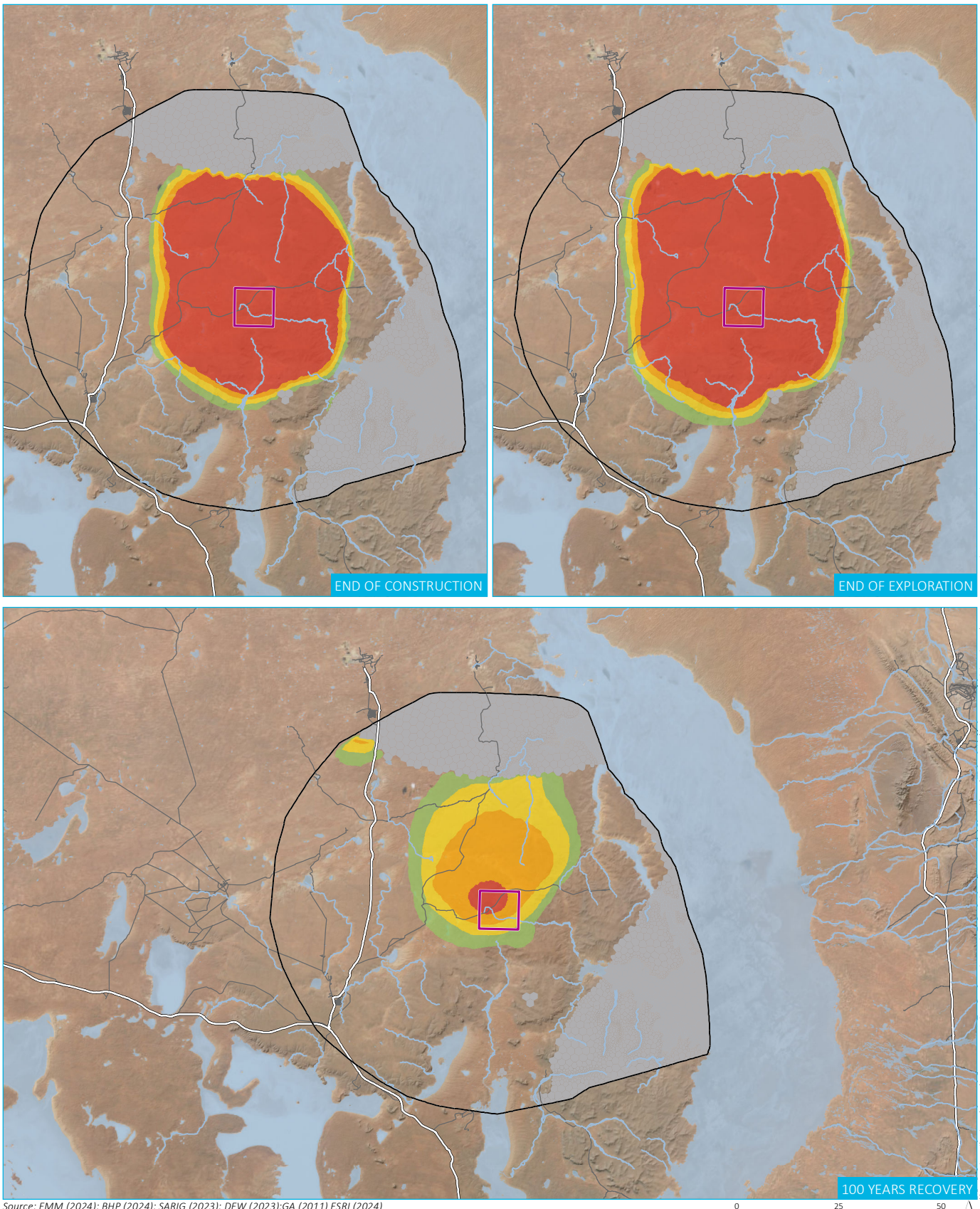
- Unlikely
- As likely as not
- Likely
- Very likely

Cumulative drawdown, likelihood of exceedance for 2 m drawdown in Upper LSP high K - Original OKDUGA model

OKDUGA Project Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure D.13a

EMM creating opportunities

\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02_Maps\RTS_GW_AddendumB\GW022_CumulativeDDExceedance2mLSPhighK_20240521_01.mxd 23/05/2024



\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02_Maps\RTS_GW_AddendumB\GW023_CumulativeDDExceedance2mLSPhighK_20240521_02.mxd 3/10/2024

Source: EMM (2024); BHP (2024); SARIG (2023); DEW (2023);GA (2011) ESRI (2024)

0 25 50 km

GDA2020 MGA Zone 53

N

KEY

- Retention Lease (RL) Project Area
- Oak Dam LOM model extent
- PFA absent
- Surface water body
- Major road
- Minor road

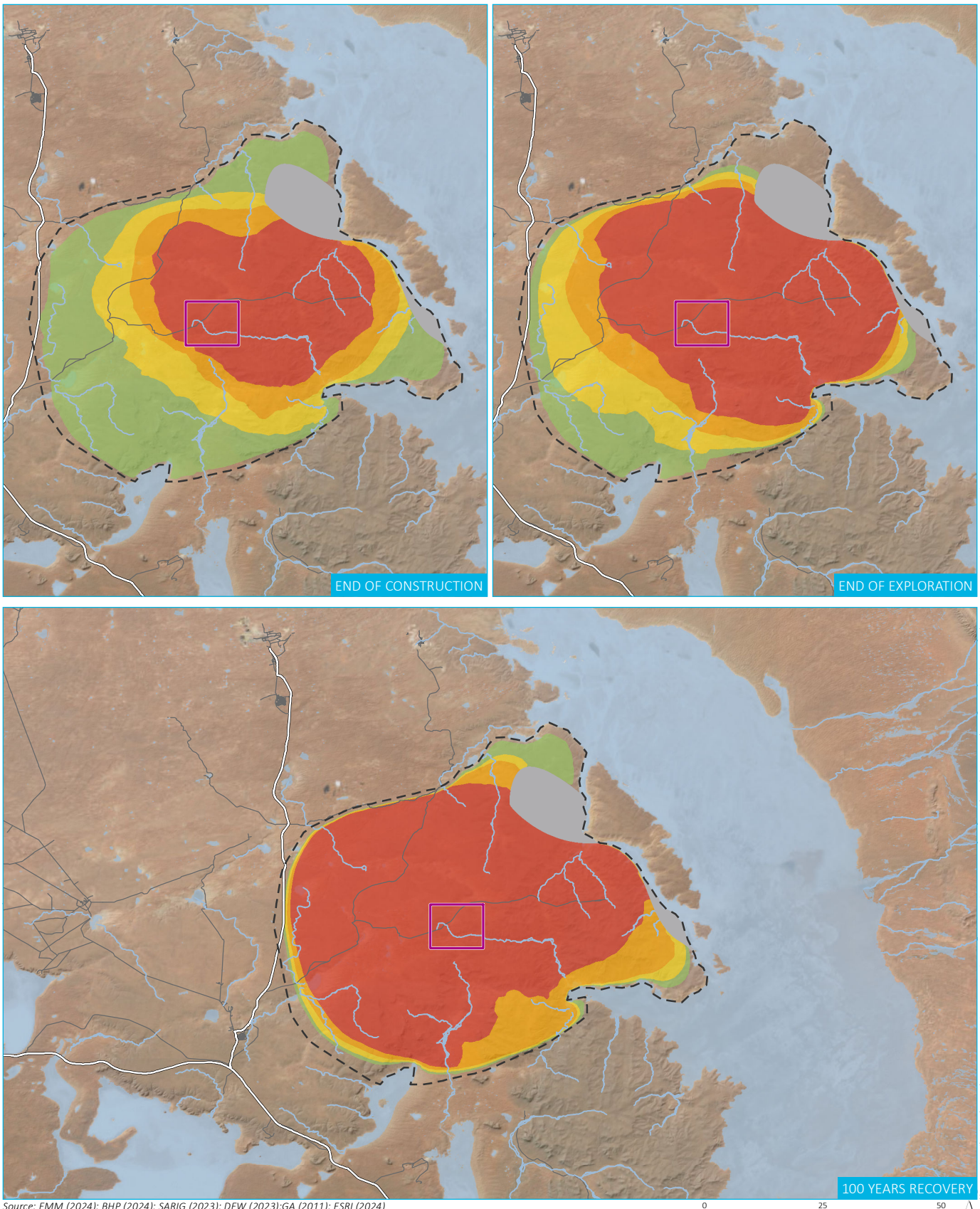
Likelihood

- Unlikely
- As likely as not
- Likely
- Very likely

Cumulative drawdown, likelihood of exceedance for 2 m drawdown in Upper PFA high K - OKD LOM (OKDUGA simulated only) model

OKDUGA Project Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure D.13b

EMM creating opportunities



Source: EMM (2024); BHP (2024); SARIG (2023); DEW (2023);GA (2011); ESRI (2024)

0 25 50 km

GDA2020 MGA Zone 53

N

KEY

- Retention Lease (RL) Project Area
- LSP absent
- Model boundary
- Surface water body
- Major road
- Minor road

Likelihood

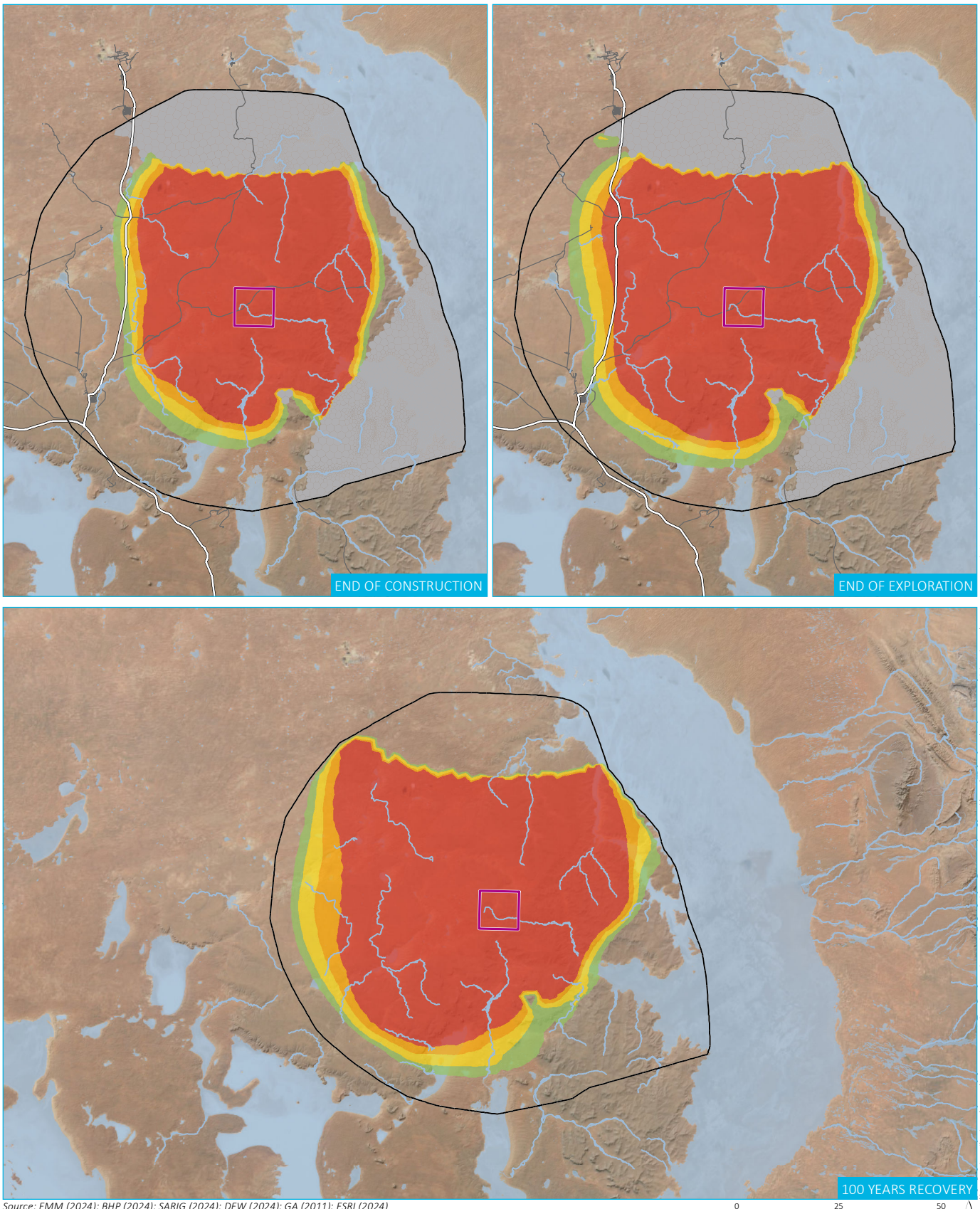
- Unlikely
- As likely as not
- Likely
- Very likely

Cumulative drawdown, likelihood of exceedance for 0.2 m drawdown in Upper LSP high K - Original OKDUGA model

OKDUGA Project Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure D.14a

EMM creating opportunities

\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02_Maps\RTS_GW_AddendumB\GW024_CumulativeDDExceedance0-2mLSPhighK_20240521_01.mxd 23/05/2024



Source: EMM (2024); BHP (2024); SARIG (2024); DEW (2024); GA (2011); ESRI (2024)

0 25 50 km

GDA2020 MGA Zone 53

N

KEY

- Retention Lease (RL) Project Area
- Oak Dam LOM model extent
- PFA absent
- Surface water body
- Major road
- Minor road

Likelihood

- Unlikely
- As likely as not
- Likely
- Very likely

Cumulative drawdown, likelihood of exceedance for 0.2 m drawdown in Upper PFA high K - OKD LOM (OKDUGA simulated only) model

OKDUGA Project Proposal Response Document
Groundwater Environmental Assessment Addendum
Figure D.14b

EMM creating opportunities

\\emm.local\xdrive\2022\E220745 - Oak Dam - Early Underground Access Project Work\GIS\02_Maps\RTS_GW_AddendumB\GW025_CumulativeDDExceedance0-2mLSPhighK_20241001_02.mxd 3/10/2024

Appendix E
Additional data

EMM
creating opportunities

E.1 Density correction data and worked example

Well name	Easting (m)	Northing (m)	Screen/open interval (mAHD) (top)	Screen/open interval (mAHD) (bottom)	Screened HSU/s	Steady state or first head water level (mAHD)	Median Bore TDS (mg/L)[1]	Median Aquifer TDS (mg/L)[1]	Equivalent freshwater head (mAHD)
6335-338	694895.7	6545231.5	Unknown	Unknown	THA	125.8	Not provided	**25,407**	126.0
6336-22	706226.7	6591109.3	Unknown	Unknown	THA	98.1	Not provided	**25,407**	98.8
6336-24	731108.9	6588223.3	Unknown	Unknown	THA	56.6	Not provided	**25,407**	57.2
6336-27	717277.6	6572486.2	Unknown	Unknown	THA	128.2	Not provided	**25,407**	129.1
6336-31	703220.7	6579213.2	Unknown	Unknown	Arcoona Quartzite	111.6	Not provided	Not applicable	111.6[(2)]
BI-15	739246.0	6571493.0	38.0	-485.0	THA	48.1	**29,595**	Not applicable	53.5
BI-16	735857.0	6566722.0	41.5.0	-392.0	THA	45.1	**54,808**	Not applicable	52.7
BI-6_THA	737900.0	6569846.0	24.0	18.0	THA	46.8	**62,998**	Not applicable	48.0
BLUFF WELL	695951.6	6554583.1	Unknown	Unknown	THA	116.9	Not provided	**25,407**	117.2
B-THA	740069.0	6575779.0	-27.0	-33.0	THA	47.4	**41,788**	Not applicable	49.8
Centenary well	720840.0	6599756.0	Unknown	Unknown	THA	64.5	Not provided	**25,407**	65.1
ELIZABETH WELL	707448.8	6548549.1	Unknown	Unknown	Pandurra Formation	74.8	Not provided	**63,017**	94.8
ENV-N10	702000.0	6567263.0	19.0	13.0	THA	116.1	**22,621**	Not applicable	117.8
ENV-N11	702041.0	6567269.0	-196.0	-202.0	Whyalla Sandstone	89.0	**18,607**	Not applicable	93.1
ENV-N4	689809.0	6560753.0	-13.0	-61.0	THA	100.1	Not provided	**25,407**	102.1
ENV-N7	715919.0	6577645.0	-184.0	-422.0	Pandurra Formation	74.9	**51,465**	Not applicable	89.7
ENV-N8	685847.0	6562541.0	-182.0	-260.0	Whyalla Sandstone	94.6	**88,476**	Not applicable	116.0

Well name	Easting (m)	Northing (m)	Screen/open interval (mAHD) (top)	Screen/open interval (mAHD) (bottom)	Screened HSU/s	Steady state or first head water level (mAHD)	Median Bore TDS (mg/L)[1]	Median Aquifer TDS (mg/L)[1]	Equivalent freshwater head (mAHD)
GILES WELL	695186.7	6575179.5	Unknown	Unknown	THA	98.0	Not provided	**25,407**	100.1
Nick of time	720304.0	6589909.0	Unknown	Unknown	THA	62.4	Not provided	Not applicable	62.4[(2)]
NO-1(Obs)	712518.0	6580811.0	-176.0	-332.0	Pandurra Formation	72.5	**63,823**	Not applicable	89.9
NO-2	723972.0	6576080.0	50.0	-71.0	THA	63.1	**17,071**	Not applicable	64.1
NO-3	723973.0	6576068.0	-203.0	-417.0	Pandurra Formation	69.6	**62,211**	Not applicable	87.6
NT-10Ob	723452.0	6562572.0	-122.0	-223.0	Pandurra Formation	68.3	**45,186**	Not applicable	73.6
NT-17Ob	719924.0	6566867.0	70.0	-320.0	Pandurra Formation	71.5	**86,806**	Not applicable	88.1
NT-2Ob	721439.0	6584865.0	40.0	6.0	THA	62.1	**22,984**	Not applicable	62.8
NT-4Obs (THA)	724822.0	6580028.0	-2.7	-8.7	THA	64.3	**19,019**	Not applicable	65.3
NT-4Ob(PFA)	724822.0	6580028.0	-218.7	-264.7	Pandurra Formation	64.2	**126,743**	Not applicable	94.5
NT-5Ob	729605.0	6580278.0	-219.2	-338.2	Pandurra Formation	47.7	**70,589**	Not applicable	65.3
NT-8Ob	722234.0	6570251.0	-50.3	-272.3	Pandurra Formation	76.1	**54,166**	Not applicable	85.9
OLD WHIP WELL	700264.7	6579046.1	Unknown	Unknown	THA	104.3	Not provided	**25,407**	106.7
PI-8-Obs	731480.0	6550904.0	21.2	-2.8	THA	43.7	**24,674**	Not applicable	44.4
ROCKY WELL	687968.7	6546849.0	Unknown	Unknown	THA	109.1	Not provided	**25,407**	109.9
Tod ridge well 6	708680.0	6594213.0	Unknown	Unknown	THA	66.2	Not provided	**25,407**	66.2
Welcome Well	691351.0	6538085.0	Unknown	Unknown	THA	112.5	Not provided	Not applicable	112.5[(2)]

Well name	Easting (m)	Northing (m)	Screen/open interval (mAHD) (top)	Screen/open interval (mAHD) (bottom)	Screened HSU/s	Steady state or first head water level (mAHD)	Median Bore TDS (mg/L)[1]	Median Aquifer TDS (mg/L)[1]	Equivalent freshwater head (mAHD)
WHIM WELL	698870.7	6591854.5	Unknown	Unknown	THA	87.4	Not provided	Not applicable	87.4[(2)]

Notes: TDS value in bold was used to calculate the density-corrected equivalent freshwater head (mAHD)

1. Sourced from laboratory data

2. Watertable - no density correction needed.

Groundwater pressure in locations of variable density can be expressed as an equivalent freshwater head, using the following equation (Post & Simmons 2022):

$$h_i = z_i + h_{p,i} = z_i + \frac{p_i}{\rho_i g}$$

Where $h_{p,i}$ represents pressure head for a piezometer at location *i* containing a fluid column with density ρ_i, so it is the height of the fluid column above the z_i coordinate, typically taken as the centre of the piezometer screen Figure E.1.

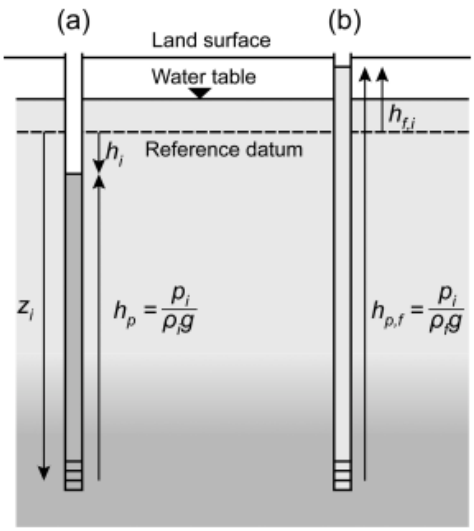


Figure E.1 Density effects

Equivalent freshwater head is therefore calculated using the following equation:

$$h_f = z_i + (h_i - z_i)\frac{\rho_i}{\rho_f}$$

Consider ENV-N7, a monitoring well screened in the Pandurra Formation. Well information is as follows:

- Coordinates 715919E, 6577645N MGA Zone 53
- Surface elevation 128 mAHD
- Top of well casing elevation 129 mAHD
- Top of screen 312 mbgl (-184 mAHD)
- Bottom of screen 550 mbgl (-422 mAHD)
- Middle of screen 431 mbgl (-303 mAHD)
- Number of EC measurements: 27
- Average EC: 69.7 mS/cm
- EC standard deviation: 7.7 mS/cm
- Median EC: 70.5 mS/cm
- Pre-impact hydraulic head 75 mAHD.

In order to calculate equivalent freshwater head, EC measurements are first converted to a total dissolved solids concentration then used to estimate water density.

EC is first converted to TDS with the following formula:

$$TDS = k \times EC$$

Where TDS (mg/L) is the total dissolved solids concentration, *k* is a coefficient and EC (µs/cm) is the electrical conductivity. The value for *k* is assumed to be 0.75 (Rusydi 2018)

Substituting the above in the formula gives the following:

$$TDS = 0.75 \times 67{,}900 = 52{,}274 \frac{mg}{L} = 52.3\ g/L$$

TDS is converted to a density with the following formula:

$$p = p_0 + a'w$$

Where p (g/L) is the density of water, p_0 is the density of water at 0 g/L TDS, *a'* is a coefficient and *w* is the TDS (g/L). The value for *a'* is assumed to be 0.71 (Kohfahl et al. 2015)

Substituting the above in the formula gives the following:

$$p = 998.2 + 0.71 \times 52.3 = 1{,}035.3 \frac{g}{L} = 1035.3\ kg/m^3$$

Data for equivalent freshwater head calculations are therefore as follows:

Reference datum (z_i) -303 mAHD

Hydraulic head (h_i) = 75 mAHD

Density of water (ρ_i) 1035.3 kg/m^3

Density of fresh water (ρ_f) 998.2 kg/m^3

Substituting the above into the formula gives the following:

$$h_f = -303 + (75 - -303)\frac{1035.3}{998.2} = 89.0\ mAHD$$

The equivalent freshwater head at ENV-N7 is approximately 15 m above the hydraulic head. Calculating equivalent freshwater head for the full monitored dataset using the median measured EC gives the hydrograph presented in Figure E.2.

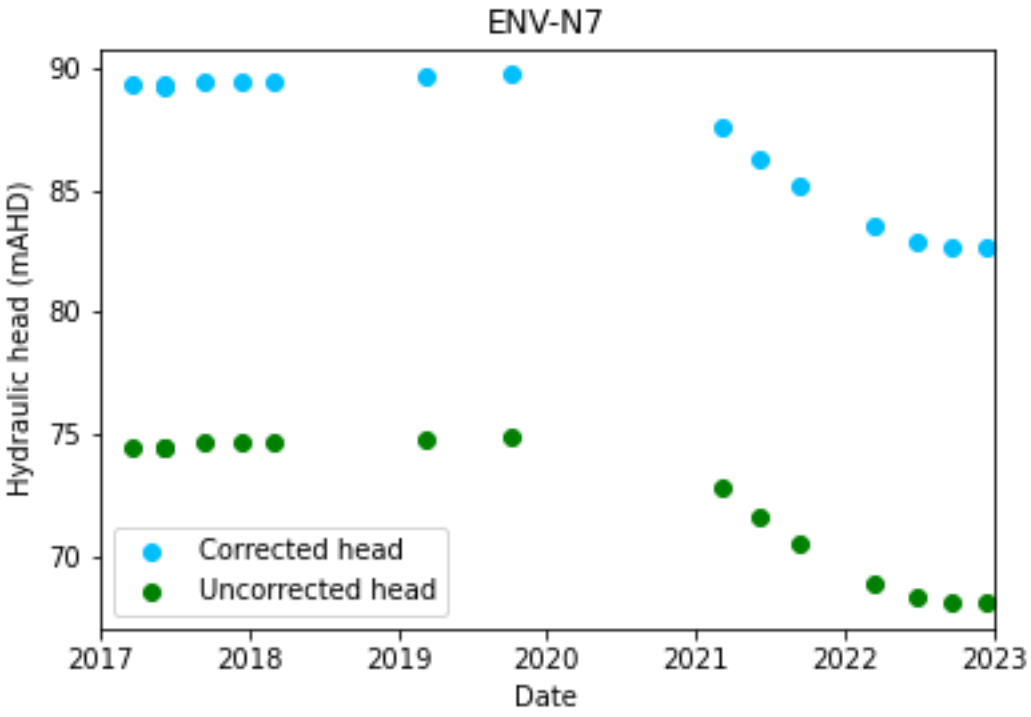


Figure E.2 **ENV-N7 hydraulic head vs. equivalent freshwater head**

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Appendix C
Groundwater monitoring framework updated

Oak Dam Underground Access Project

Groundwater Monitoring Framework (Updated)

Prepared for BHP Olympic Dam Corporation Pty Ltd

October 2024

Oak Dam Underground Access Project

Groundwater Monitoring Framework (Updated)

BHP Olympic Dam Corporation Pty Ltd

E220745 RP27

October 2024

Approved by



Paul Gibbons
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10 October 2024

Ground floor 20 Chandos Street
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This report has been prepared in accordance with the brief provided by BHP Olympic Dam Corporation Pty Ltd and has relied upon the information collected at the time and under the conditions specified in the report. All findings, conclusions or recommendations contained in the report are based on the aforementioned circumstances. The report is for the use of BHP Olympic Dam Corporation Pty Ltd and no responsibility will be taken for its use by other parties. BHP Olympic Dam Corporation Pty Ltd may, at its discretion, use the report to inform regulators and the public.

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1 Introduction

BHP Olympic Dam Corporation Pty Ltd (BHP) is proposing to develop the Oak Dam Underground Access Project (OKDUGA Project) in the far north of South Australia.

The Oak Dam deposit is a deep iron oxide copper-gold (IOCG) mineralised system. Exploration drilling undertaken at Oak Dam, has indicated medium-grade and high-grade copper regions of an orebody commencing at approximately 800 metres (m) below surface that may be economically viable to mine.

The OKDUGA Project has been initiated to progress the opportunity to undertake exploration drilling underground, providing accelerated resource definition and reduced drilling and development costs. Specifically, the OKDUGA Project aims to establish an underground access via twin declines, with the dual purposes of:

- providing an effective and proximal drilling platform to enable efficient mineralisation drilling to define the resource
- enabling characterisation of critical geotechnical ground conditions
- enabling hydrogeological drilling and testing.

1.1 Overview

To undertake the proposed activities, a combined Retention Lease (RL) Proposal and Miscellaneous Purposes Licence (MPL) Management Plans (together, the Proposal) was prepared under the *Mining Act 1971* (SA) (Mining Act) (BHP 2023).

The Proposal was submitted to the Government of South Australia's Department for Energy and Mining (DEM) in December 2023 to address the requirements of both the Mining Act and associated Mining Regulations 2020 (Mining Regulations), with consideration of the information needs described in:

- DEM's *Terms of Reference (TOR) Oak Dam Retention Lease Application in accordance with the Mining Act 1971*, published in The South Australian Government Gazette No. 73 dated 28 September 2023 (DEM 2023)
- DEM's Determination TOR 006 Mineral mine lease/licence applications (DEM 2021) (TOR 006)
- DEM's Mineral Regulatory Guidelines MG2a Preparation of a mining application for metallic and industrial minerals (DEM 2020) (MG2a)
- Environment Protection Authority (EPA), *Guideline 3 – Establishing baseline groundwater quality* (April 2024).

Engineering and feasibility studies indicate that a twin decline is the preferred investment alternative for the underground access strategy to enable the underground drilling program. Access to the decline would be via a box cut and portal development. The Project Area comprises surface infrastructure at the box cut, including the provision for services and constructions to support the access development and operation of the drill rigs. This includes utility facilities, diesel generation plant, refrigeration plant, administration buildings, temporary maintenance buildings, laydown area, concrete batch plant, waste rock landform (WRL), stockpiles, dams, and ponds. Outside of this area (but still within the Project Area), on surface, is a borrow pit area, Accommodation Village, explosives storage, return air raise structures, site access roads and water pipelines.

1.2 Purpose of this report

This updated Groundwater Monitoring Framework (GMF) has been prepared to support the Proposal Response Document Addendum (PRD Addendum).

This report presents conceptual groundwater monitoring locations and proposed groundwater monitoring parameters for the OKDUGA Project to determine baseline conditions by collecting:

- groundwater level measurements
- water quality field measurements, including pH, electrical conductivity (EC), temperature
- water samples for laboratory analysis.

The monitoring locations, parameters and frequencies presented in this GMF are considered preliminary and are subject to further revision as BHP develops the Groundwater Management and Monitoring Plan (GMMP) as part of the program for environment protection and rehabilitation (PEPR).

2 Groundwater monitoring

The OKDUGA Project conceptual groundwater monitoring network is presented in Figure 2.1.

As part of the PEPR additional groundwater monitoring locations may be proposed by BHP in the Groundwater Management and Monitoring Plan.

2.1 Groundwater monitoring infrastructure (conceptual)

Table 2.1 summarises the conceptual location of the proposed groundwater infrastructure, targeted screening aquifers[1] (being the Pandurra Formation Aquifer (PFA) and Tent Hill Aquifer (THA)) and proposed groundwater monitoring parameters for the OKDUGA Project.

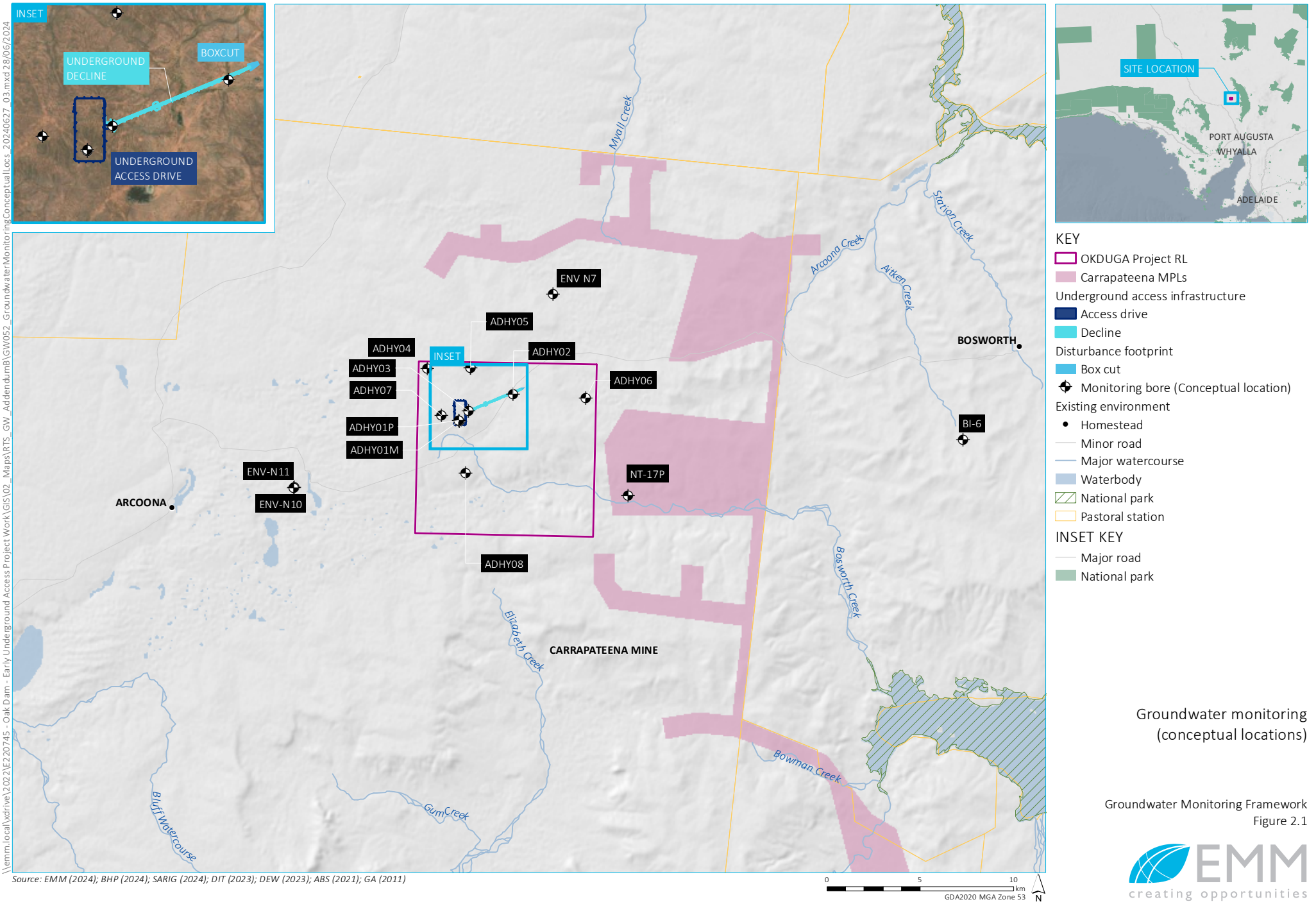
Table 2.1 OKDUGA Project monitoring locations

Bore ID	Easting	Northing	Screened aquifer	Groundwater monitoring parameters
Local monitoring bores (monthly)				
ADHY01P (existing)	710874	6570859	PFA	Water quality suite
ADHY02 (existing)	713777	6572300	THA	Water quality suite
ADHY03 (existing)	711400	6571354	PFA	Water quality suite
ADHY04 (existing)	709188	6573628	PFA	Water quality suite
ADHY01M (existing)	710877	6570832	PFA	Water level/pressure
ADHY05 (existing)	711492	6573666	PFA	Water level/pressure
	711492	6573666	THA	
ADHY06 (proposed)	717664	6572054	PFA, THA	Water level/pressure
ADHY07 (proposed)	709950	6571140	PFA, THA	Water level/pressure
ADHY08 (proposed)	711210	6568018	PFA, THA	Water level/pressure
Regional monitoring bores (quarterly)[2]				
ENV7 (existing)	715919	6577646	PFA	Water quality suite Water level/pressure
ENV10 (existing)	702012	6567254	THA	Water quality suite Water level/pressure
ENV11 (existing)	702041	6567269	THA	Water quality suite Water level/pressure
BI-6 (existing)	737887	6569846	THA PFA	Water quality suite Water level/pressure
NT-17P (existing)	719925	6566855	PFA	Water quality suite Water level/pressure

[1] Datum - GDA 2020Z53 projection

[2] Regional monitoring bores have been, are being, monitored as part of Carrapateena mining operations (including baseline conditions)

Regional groundwater quality is presented in the PRD Appendix B, with ongoing local and regional sampling proposed as part of the PEPR and GMMP to determine baseline conditions.



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Source: EMM (2024); BHP (2024); SARIG (2024); DIT (2023); DEW (2023); ABS (2021); GA (2011)

Groundwater monitoring (conceptual locations)

Groundwater Monitoring Framework
Figure 2.1

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3 Groundwater quality suite

Table 3.1 presents field measurements and laboratory analyses of groundwater samples proposed to be collected during the first two years of the OKDUGA Project monitoring events.

Table 3.1 Groundwater analysis suites

Description	Parameters	Monitoring event
Field parameters	Water levels, electrical conductivity (EC), pH, dissolved oxygen, temperature	Monthly for the first 2 years Biannually post 2 years of monitoring
Laboratory parameters	Acidity, laboratory pH, laboratory TDS Major ions (Ca, Mg, K, Na, Cl, SO_4) Alkalinity (hydroxide, carbonate, bicarbonate, total) Dissolved metals (Al, Sb, As, Be, Bi, Cd, Cr, Cr (VI), Co, Cu, F, Fe, Pb, Li, Mn, Hg, Mo, Ni, Se, Ag, Sr, Th, Ti, U, V, Zn, Zr) Speciated iron (ferrous and ferric iron)	Monthly for the first 2 years Biannually post 2 years of monitoring
	Radionuclides – Ra-226 and Ra-228 Gross alpha and gross Beta	Every 5 years

4 Supporting information

4.1 References

BHP (2024) Oak Dam Underground Access Project Retention Lease Proposal and Miscellaneous Purposes Licence Management Plans Response Document – Appendix B. June 2024.

4.2 Abbreviated terms

4.2.1 Chemical elements

Table 4.1 Chemical elements

Symbol	Name chemical element
Major irons	
Ca	Calcium
Cl	Chlorine
K	Potassium
Mg	Magnesium
Na	Sodium
SO_4	Sulfate
Dissolved metals	
Ag	Silver
Al	Aluminium
As	Arsenic
Be	Beryllium
Bi	Bismuth
Cd	Cadmium
Co	Cobalt
Cr	Chromium
Cr (VI)	Hexavalent Chromium
Cu	Copper
F	Fluorine
Fe	Iron
Hg	Mercury
Li	Lithium
Mn	Manganese
Mo	Molybdenum

Symbol	Name chemical element
Ni	Nickel
Pb	Lead
Sb	Antimony
Se	Selenium
Sr	Strontium
Th	Thorium
Ti	Titanium
U	Uranium
V	Vanadium
Zn	Zinc
Zr	Zirconium

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