# West Musgrave Copper and Nickel Project

July 2022

# Groundwater Monitoring and Management Plan

## VERSION CONTROL

| Revision | Version | Authorisation | Position | Signature | Date |
|---|---|---|---|---|---|
| 2 | Final For Initial Approval (NgC Review) | Justin Rowntree | Sustainability Manager – West Musgrave | | 28/09/2021 |
| | | Daniel Leinfelder | Approvals Manager – West Musgrave | | 28/09/2021 |
| | | Matt Reed | Operations Executive – OZ Minerals | | 28/09/2021 |
| | | Mark Irwin | Projects Executive – OZ Minerals | | 28/09/2021 |
| 3a | Update for alignment to Ministerial Statement 1188, Condition 4-2 | Daniel Leinfelder | Approvals Manager – West Musgrave | | 25/07/2022 |
| | | Jane Macey | General Manager – West Musgrave | | 25/07/2022 |

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Where possible, information contained in this Document is up to date as at July 2022. This was not possible for all supporting appendices, and information based on those appendices, which were prepared by third parties (as discussed in the second paragraph in the Disclaimer above) prior to the Document being finalised.

## COPYRIGHT

## SUMMARY

A summary of the key Environmental Management Plan (EMP) information is presented in Table 1.

**Table 1: Summary of Key EMP Information**

| Project Information | Description |
|---|---|
| Proposal Title | West Musgrave Copper and Nickel Project |
| Proponent Name | OZ Minerals |
| Ministerial Statement No/s and Condition/Clauses | The Ministerial Statement (No. 1188, published 20 April 2022) for the Project was issued pursuant to section 45 of the *Environmental Protection Act 1986* (WA). This described that the proposal described and documented in Volume 1 of the OZ Minerals' referral supporting document (revision 2) dated 1 June 2021 may be implemented and that the implementation of the proposal is subject to the following implementation conditions and procedures (with respect to Inland Waters):<br>**Condition 4-1**: The proponent shall implement the proposal to meet the following environmental outcomes:<br>(1) ensure drawdown does not exceed (one) 1 metre at Linton Bore; and<br>(2) no drawdown related adverse impacts to culturally important vegetation.<br>**Condition 4-2**: The proponent shall revise the *West Musgrave Copper and Nickel Project Groundwater Monitoring and Management Plan* (Revision 2, September 2021) to ensure it is consistent with achievement of the environmental outcomes in condition 4-1. The plan shall:<br>(1) when implemented, substantiate, and demonstrate that condition 4-1 is being met;<br>(2) specify trigger criteria that will trigger the implementation of management and/or contingency actions to ensure achievement of the environmental outcomes in condition 4-1;<br>(3) specify threshold criteria to demonstrate compliance with condition 4-1;<br>(4) specify monitoring methodology to determine if trigger criteria and threshold criteria have been met;<br>(5) specify management and/or contingency actions to be implemented if the trigger criteria required by condition 4-2(2) and/or the threshold criteria required by condition 4-2(3) have not been met (including changes to operations, reduction in extraction and consideration of alternative sources (subject to regulatory approval)); and |

| Project Information | Description |
|---|---|
| | (6) provide a format and timing for the reporting of monitoring results against trigger criteria and threshold criteria to demonstrate that condition 4-1 has been met over the reporting period in the Compliance Assessment Report required by condition 10-6.<br><br>**Condition 4-3**: The proponent shall implement the latest revision of the Groundwater Monitoring and Management Plan which the CEO has confirmed by notice in writing, addresses the requirements of conditions 4-1 and 4-2.<br><br>**Condition 4-4:** The proponent shall not undertake groundwater extraction activities for construction or operation of the proposal until the CEO has confirmed in writing that the revisions to the Groundwater Monitoring and Management Plan required under condition 4-2 meet the requirements of that condition.<br><br>**Condition 4-5**: In the event that monitoring or investigations at any time indicate an exceedance of threshold criteria specified in the Groundwater Monitoring and Management Plan which is confirmed under condition 4-3, the proponent shall:<br>(1) report the exceedance in writing to the CEO within seven (7) days of the exceedance being identified;<br>(2) implement the contingency actions required by condition 4-2(5) within seven (7) days of the exceedance being reported as required by condition 4-5(1) and continue implementation of those actions until the CEO has confirmed by notice in writing that it has been demonstrated that the threshold criteria are being met and implementation of the threshold contingency actions are no longer required;<br>(3) investigate to determine the cause of the threshold criteria being exceeded;<br>(4) investigate to provide information for the CEO to determine potential environmental harm or alteration of the environment that occurred due to threshold criteria being exceeded; and<br>(5) provide a report to the CEO within twenty-one (21) days of the exceedance being reported as required by condition 4-5(1). The report shall include:<br>a) details of threshold contingency actions implemented;<br>b) the effectiveness of the threshold contingency actions implemented against the threshold criteria;<br>c) the findings of the investigations required by conditions 4-5(3) and 4-5(4);<br>d) measures to prevent the threshold criteria being exceeded in the future;<br>e) measures to prevent, control or abate the environmental harm which may have occurred; and<br>f) justification of the threshold remaining, or being adjusted based on better understanding, demonstrating that objectives will continue to be met. |

| Project Information | Description |
|---|---|
| | **Condition 4-6**: The proponent:<br>(1) may review and revise the Groundwater Monitoring and Management Plan; or<br>(2) shall review and revise the Groundwater Monitoring and Management Plan as and when directed by the CEO, including (if directed) in consultation with the NGC.<br>**Condition 4-7**: The proponent shall continue to implement the Groundwater Monitoring and Management Plan, or any subsequent revisions as confirmed by the CEO in condition 4-3, until the CEO has confirmed by notice in writing that the proponent has demonstrated that the environmental outcomes detailed in condition 4-1 have been met. |
| Purpose of the EMP | To provide a management framework for groundwater, specifically to avoid, where possible, otherwise minimise direct and indirect impacts to groundwater dependant ecosystems and beneficial users resulting from the implementation of the West Musgrave Project. |
| Key Environmental Factor | Inland Waters |
| Objective (as relevant to this management plan) | *To maintain the hydrological regimes and quality of groundwater…so that environmental values are protected* |
| Key Provisions of the EMP | See Section 2 |
| Proposed Construction Timing | Commencing 2022, progressing to 2024 |
| EMP Required Pre-construction? | Yes |
| Proposed Operations Timing | 26 years from date of commissioning |

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# 1 CONTEXT, SCOPE AND RATIONALE

This Groundwater Monitoring and Management Plan (GMMP) has been prepared by OZ Minerals to support the assessment, approval and implementation of the Proposal under Part IV of the *Environmental Protection Act, 1986* (WA) (EP Act). Inland waters are protected under the following State legislation:

- *Environmental Protection Act, 1986* (WA)
- *Rights in Water and Irrigation Act, 1914* (WA)
- *Country Areas Water Supply Act, 1947* (WA).

In addition to State legislation, the following policy and guidance statements were considered in the development of this GMMP:

- EPA Statement of Environmental Principles, Factors and Objectives (EPA, 2020b)
- EPA Environmental Factor Guideline – Inland Waters (EPA, 2018)
- Water and Rivers Commission (WRC), Environmental Water Provisions Policy for WA (WRC, 2000).

This GMMP addresses the Notice Requiring Information for Assessment, received from the EPA on 14 April 2021 (the Notice). The Notice requires OZ Minerals to:

> *Provide a Groundwater Monitoring and Management Plan which describes how impacts to groundwater levels, groundwater quality and health of Groundwater Dependent Ecosystems (GDEs) will be managed in accordance with the EPA mitigation hierarchy. The plan should be prepared in accordance with the Instructions on how to prepare Environmental Protection Act 1986 Part IV Environmental Management Plans (EPA, 2020a). Please provide spatial data defining the 2 metre (m) groundwater drawdown contour, the location of the Linton Bore, and the location of the total area of GDEs impacted by the <2 m (sic; greater than 2 m) drawdown as detailed in table 7-19 of the referral documentation.*

This GMMP also addresses, where relevant, the requirements of the Conditions of Approval associated with the issuing of Ministerial Statement No. 1188, published on 20 April 2020, as outlined in Table 1.

### 1.1 Proposal

The West Musgrave Copper and Nickel Project (WMP) is located in the West Musgrave Ranges of Western Australia. The WMP is located approximately 1,300 km north-east of Perth near to the border of South Australia and the Northern Territory. The WMP is within the Ngaanyatjarra Native Title determination, and Class A Reserve No. 17614 (for the Use and Benefit of Aboriginal Inhabitants). The nearest towns include the Indigenous Communities of Jameson (Mantamaru) 26 km north, Blackstone (Papulankutja) 50 km east, and Warburton (Milyirrtjarra) 110 km west of the project (Figure 1).

The project, with a current expected life of approximately 26 years, will consist of:

- Mining of copper and nickel ore from two open cut mine pits using conventional blast, load and haul methods
- Placement of mine waste into permanent waste rock dumps (WRDs) and a dedicated tailings storage facility (TSF) adjacent to mine pit voids
- Milling and processing of ore using floatation to produce two separate copper and nickel concentrates
- On-site power supply using a combination of renewable power infrastructure (photovoltaic solar panels, wind turbines and battery storage) supported by backup thermal power generation
- Development of a process/potable water supply borefield that may include a combination of overland and/or underground pipelines for use during construction and operations
- Miscellaneous infrastructure, including stormwater management infrastructure (bunds and drains), internal roads and service tracks, a dedicated site access road, accommodation village (approximately 450 beds during operations and 1,200 during construction), airstrip, wastewater treatment, landfill and other supporting infrastructure including offices, warehouses and workshops
- Concentrate transport via existing roads and rail networks.

A summary of the key project characteristics is presented in Table 2.

**Table 2: Key Project Characteristics**

| Elements | Location | Proposed Extent Authorised |
|---|---|---|
| **Physical Element** | | |
| Mine and associated infrastructure | Figure 2 | Clearing of up to 3,830 ha of native vegetation within a Development Envelope of 20,852 ha |
| **Operational Element** | | |
| Mining voids | Figure 2 | Below water table mining<br>Nebo pit void to be backfilled above water table post-closure<br>Babel pit void to be a permanent and episodic pit lake post-closure |
| Mining waste (waste rock) | Figure 2 | Placement of waste rock into permanent WRDs |
| Ore processing waste (tailings) | Figure 2 | Disposal of tailings into a TSF and/or Nebo pit void |
| Power supply | Figure 2 | Up to 60 MW (instantaneous load requirement) of fossil fuel electricity generation<br>Up to 100 MW of photovoltaic solar electricity generation<br>Up to 100 MW of wind electricity generation |
| Water supply | Figure 2 | Abstraction of up to 7.5 GL/a of groundwater from the Borefield and through mine pit dewatering |


**Figure 1: Site Location**

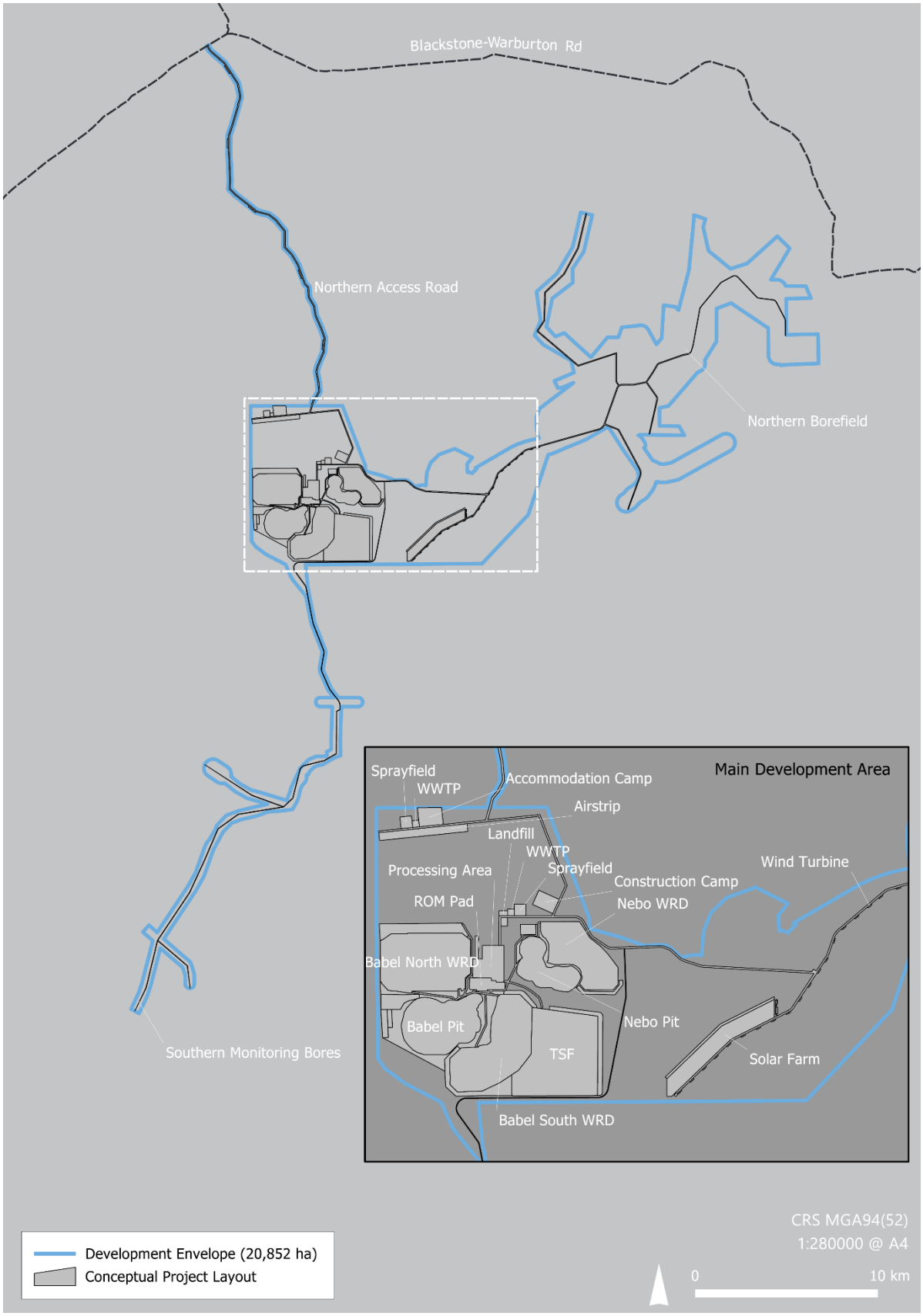


**Figure 2: Location of Key Physical and Operational Elements**

## 1.2 Key Environmental Factor

This GMMP specifically relates to the Water (Inland Waters) factor guidelines. The EPA's Statement of Environmental Principles, Factors and Objectives (EPA, 2020b) lists the following as their objective for Inland Waters (as is relevant to groundwater):

> *To maintain the hydrological regimes and quality of groundwater…so that environmental values are protected*

### 1.2.1 Proposal Activities that May Affect the Environmental Objective

This management plan applies to the management of groundwater to the extent that the interaction of the project may have a negative impact such that the EPA objective may not be achieved. To this end the following credible events have been identified with the potential to result in negative impacts to groundwater, specifically:

- Groundwater abstractions from water supply borefield(s) may result in reduced availability and access to groundwater for beneficial groundwater users, and potential terrestrial groundwater dependent ecosystems (GDEs)
- Mine dewatering during operations may result in reduced availability and access to groundwater for beneficial groundwater users, and potential terrestrial GDEs
- Long-term evaporative loss of groundwater from pit voids that remain after closure may result in reduced availability and access to groundwater for beneficial users, and potential GDEs
- Seepage from waste landforms may impact on groundwater quality to the extent that beneficial uses are compromised
- Long-term interaction between potentially poor-quality pit void water bodies (that form after closure) and groundwater may impact groundwater quality to the extent that beneficial uses are compromised
- Accidental spills of potentially hazardous materials may impact on groundwater quality to the extent that beneficial uses are compromised.

### 1.2.2 Site Specific Environmental Values

Two environmental values have been identified in the project area, these are:

- Beneficial use – drinking water supplies (groundwater) provided by Jameson (Mantamaru) community bores and Linton Bore
- Potential terrestrial GDEs.

The location and spatial distribution of these environmental values are presented in Figure 3. Other potential environmental values that have been considered but found not to be present in the project area are described in OZ Minerals (2021).

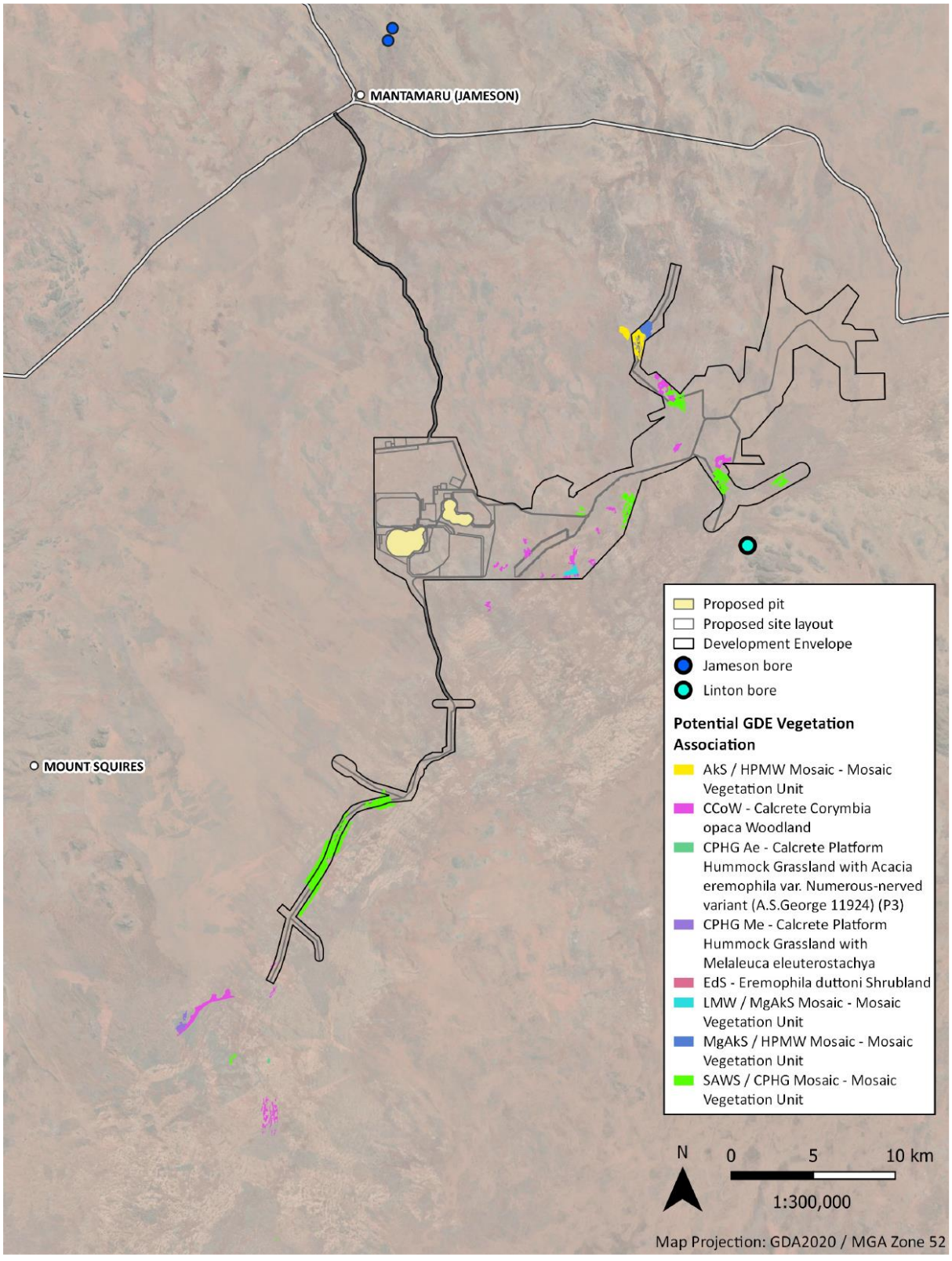


**Figure 3: Location of Identified Groundwater Related Environmental Values**

### 1.3 Condition Requirements

Revision 3 of the GMMP (this document, dated July 2022) has been updated to reflect the Implementation Conditions associated with the granting of Ministerial Statement 1188, published 20 April 2022, specifically Conditions 4-1 through 4-7 inclusive, as presented in Table 1.

Cross-reference of this GMMP with the requirements of Condition 4-2 of the Ministerial Statement is presented in Table 3.

**Table 3: Condition 4-2 References**

| Condition No. | Requirement | Section Addressed |
|---|---|---|
| 4-2(1) | [The plan shall] when implemented, substantiate, and demonstrate that condition 4-1 is being met; | • Table 12, Outcome 2 for Condition 4-1(1) – Linton Bore<br>• Table 12, Outcome 5 for Condition 4-1(2) – Culturally Important Vegetation |
| 4-2(2) | [The plan shall] specify trigger criteria that will trigger the implementation of management and/or contingency actions to ensure achievement of the environmental outcomes in condition 4-1 | |
| 4-2(3) | [The plan shall] specify threshold criteria to demonstrate compliance with condition 4-1 | |
| 4-2(4) | [The plan shall] specify monitoring methodology to determine if trigger criteria and threshold criteria have been met | |
| 4-2(5) | [The plan shall] specify management and/or contingency actions to be implemented if the trigger criteria required by condition 4-2(2) and/or the threshold criteria required by condition 4-2(3) have not been met (including changes to operations, reduction in extraction and consideration of alternative sources (subject to regulatory approval)) | Section 2.4 (trigger criteria actions) and Section 2.5 (threshold criteria contingency actions) describe the process should either a nominated trigger or threshold be exceeded. Table 10 details the nominal management / contingency actions that may be applied as a result of exceedance of a criterion. |
| 4-2(6) | [The plan shall] provide a format and timing for the reporting of monitoring results against trigger criteria and threshold criteria to demonstrate that condition 4-1 has been met over the reporting period in the Compliance Assessment Report required by condition 10-6. | • Table 12, Outcome 2 for Condition 4-1(1) – Linton Bore<br>• Table 12, Outcome 5 for Condition 4-1(2) – Culturally Important Vegetation |

### 1.4 Rationale and Approach

This GMMP outlines how groundwater levels, groundwater quality and the health of potential terrestrial GDEs will be managed and where relevant monitored, to verify the effectiveness of the management measures and to ensure potential impacts associated with the proposed construction and operation of the WMP are minimised. The approach taken includes consideration of:

- Baseline studies relating to hydrogeology, flora and vegetation, terrestrial GDEs and a groundwater effects assessments (OZ Minerals, 2021; Appendices B1, B2, D2 and D4)
- Hydrogeological numerical modelling (OZ Minerals, 2021; Appendix D3)
- Hydrochemical numerical modelling (OZ Minerals, 2021; Appendix D7 and Appendix D12)
- Relevant assumptions and uncertainties.

A further program of groundwater drilling, pump testing and hydrogeology modelling is ongoing and forms part of the definitive feasibility study. This additional groundwater program is scheduled for completion in early 2022. Results from this ongoing work have increased the accuracy of hydrogeological modelling assumptions and have been considered in this plan. The final report from the additional groundwater program will form the basis of further water licensing and approvals for the WMP (e.g. 5C licensing under the *Rights in Irrigation and Water Act, 1914* (WA) (RIWI Act).

### 1.4.1 Survey and Study Findings

Several studies and surveys have been undertaken to systematically characterise the West Musgrave hydrogeological regime (including hydrostratigraphy, groundwater quantity and quality, identification of groundwater-related environmental values, and assessing the effects of mine-related water affecting activities that have the potential to impact on these environmental values. These studies are summarised in the following sections and are provided in detail in the EPA Section 38 Referral (OZ Minerals, 2021; Appendix D).

#### 1.4.1.1 Mine-Related Water Affecting Activities

Mine-related water affecting activities relevant to the project include:

- Mine pit development – interruption of groundwater systems
- Mine dewatering – abstraction of groundwater to provide safe access to the Nebo and Babel deposits. This water would be used to meet mine and process water demands
- Mine and process water supply – abstraction of groundwater from abstraction bores to supplement water supply sourced from dewatering
- Materials storages (e.g., TSF, WRDs, topsoil, ore stockpiles) – potential sources of contaminants that may enter the water table
- Supporting facilities – accommodation, airstrip, renewable energy infrastructure.

#### 1.4.1.2 Groundwater Conceptualisation

The project is located within the Musgrave Geological Province. The key aquifers of the project area are associated with the Tertiary sediments of the Kadgo Paleovalley (Table 4). The Kadgo Paleovalley is represented by a main arterial paleovalley with multiple smaller tributaries along its length (Figure 4) that are incised into weathered and fractured basement rocks. A detailed hydrogeological baseline assessment is provided in the EPA Section 38 Referral (OZ Minerals, 2021; Appendix D2).

**Table 4: Key Hydrostratigraphy Summary (Youngest to Oldest)**

| Formation | Description |
|---|---|
| Calcrete | Often occurs above the water table or only partially saturated.<br>Typically 1 to 15 m thick. |
| Garford aquifer and aquitard | Unconfined to semi-confined, interbedded fine sands, silts and clay, thick basal clay sequence separating unit from deeper Pidinga aquifer. Up to 90 m thick. |
| Pidinga aquifer | Confined, sands and gravels with interbedded fine sediments, occurs only in deeply incised sections of Kadgo Paleovalley and is absent in tributary branches.<br>Typically more than 60 m thick. |
| Basement aquifer and aquitard | Typically gabbro regolith and fractured rocks, degree of weathering and fracturing reduces with depth. Drains to paleovalley aquifers. |

Groundwater flows generally from the north to the south, where it discharges to the Officer Basin groundwater system approximately 50 km from the Main Development Area. The depth to the water table typically ranges between four and nine metres, depending on topography, and groundwater quality is fresh to brackish with salinity (as electrical conductivity) ranging between 950 and 4,500 $\mu$S/cm.

Nitrate concentrations in groundwater are naturally high compared to other parts of WA, ranging between 20 and 130 mg/L. Although suitable for livestock (ANZECC, 2000), these concentrations of nitrate may mean groundwater is unsuitable for human consumption without treatment (NRMMC, 2021). Groundwater drawn from the Jameson (Mantamaru) bores (Figure 3) has equally high nitrate levels and, as such, is not suitable for human consumption. A reverse osmosis plant is used to treat water that is then supplied to the community. Median concentrations of copper, nickel and zinc in groundwater are below drinking water guideline values (ANZECC, 2000) at 0.002, 0.001 and 0.02 mg/L, respectively.

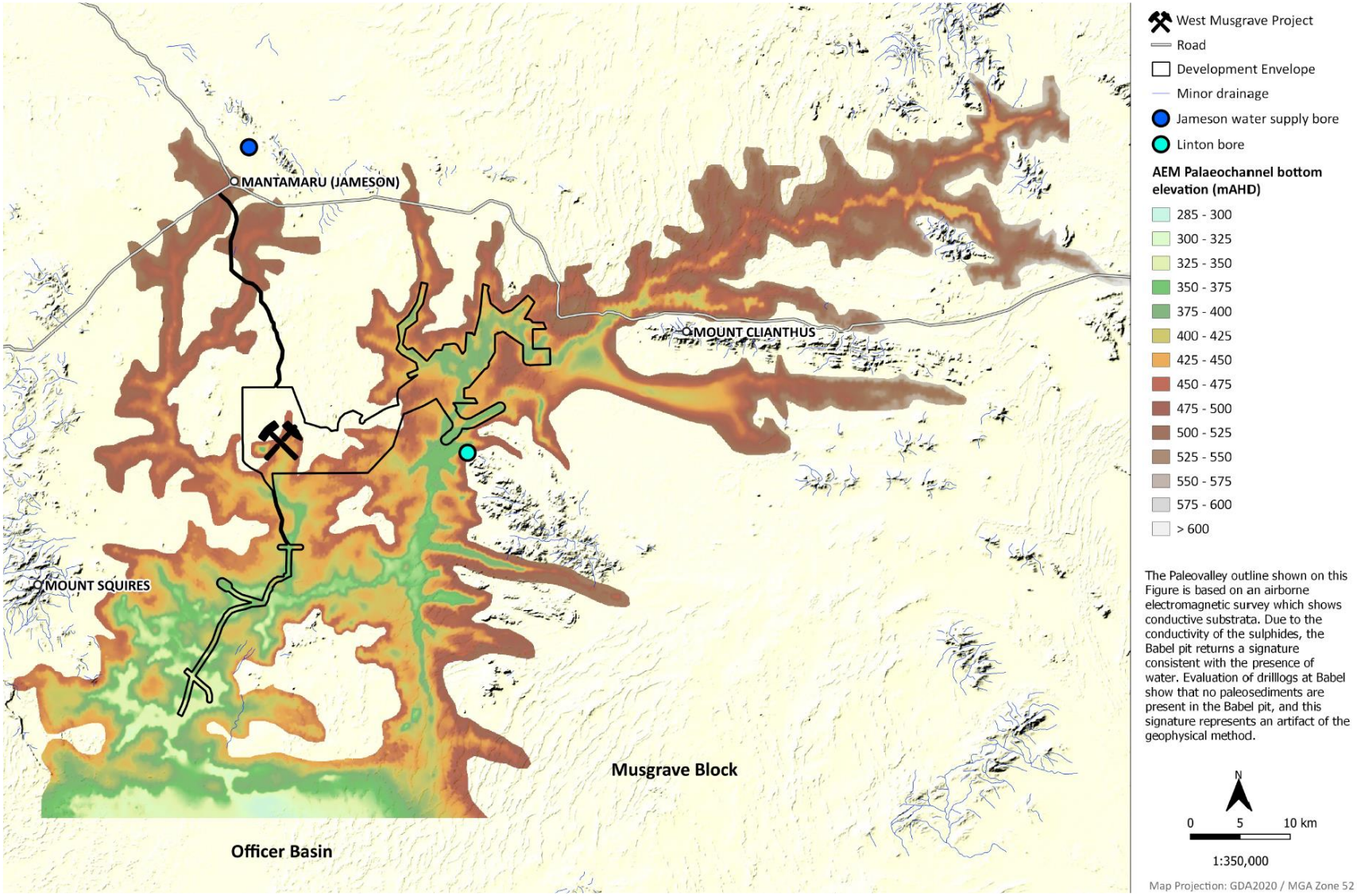


**Figure 4: Kadgo Paleovalley**

#### 1.4.1.3 Interactions Between the Project and Groundwater

### Groundwater Abstractions

The proposed mine water supply borefield (the Northern Borefield) would be located within the Kadgo Paleovalley. Production bores would be constructed to draw water from the deeper (confined) Pidinga paleochannel aquifer. Depressurisation of the Pidinga aquifer may induce leakage of some groundwater from the shallower Garford paleochannel aquifer (predominantly from the basal clay sequence) as well as from the regolith and fractured bedrock into which the paleovalley is incised, resulting in some drawdown of the water table around the Northern Borefield. Figure 5 presents the spatial extent of the predicted 2 m water table drawdown contour around the Northern Borefield during mining. The maximum predicted water table drawdown within the borefield area is approximately 5 m at the site of abstraction bores. Groundwater in the borefield has been modelled to return to within 10% of pre-mine levels following the cessation of borefield abstraction.

The orebodies targeted by mining of the Nebo pit and Babel pit occur below the water table and therefore require active dewatering to allow safe and efficient access to the ore. The following briefly describes the dewatering process and provides a description of the effects (see OZ Minerals, 2021; Section 7.3.3.2):

- The western half of the proposed Nebo pit is located on a minor tributary of the Kadgo Paleovalley and will intersect up to 90 m of the Garford water table aquifer at this location. The eastern portion of the pit is located adjacent to this minor tributary and will not intersect paleovalley sediments. Mining at Nebo pit will require dewatering of the Garford aquifer to allow access to the orebody. As the Garford aquifer and adjacent / underlying orebody becomes depressurised due to dewatering, groundwater from the Garford aquifer (upstream and downstream) and basement rocks will move toward the pit creating a 'cone' of water table drawdown around the pit. After mining of Nebo is completed, the pit will be backfilled to above the pre-mine water table with waste materials, allowing groundwater to recover to around pre-mine levels and prevent ongoing evaporative losses that would occur if the pit were to be left open.
- The Babel pit is located entirely outside of the Kadgo Paleovalley within the regolith and fractured basement rock. This material will also need to be dewatered, also causing a cone of water table drawdown around the pit, which will combine with the cone of drawdown caused by dewatering of the Nebo pit. After mining, Babel pit will remain open resulting in ongoing evaporative losses of groundwater from the basement rocks.

OZ Minerals' strives to minimise water use and add value when we do, as such OZ Minerals will minimise the potential for water wastage through utilising dewatered water from two open pits and minimise the total water abstraction requirements from the Northern Borefield. In particular, the sequencing of dewatering and mining Nebo pit, which contains most of the mine pit dewatering needs, has been

purposefully scheduled to coincide with the operation of the processing facility to make best use of Nebo pit dewatered water.

Figure 5 presents the spatial extent of the predicted long-term (post-mining) 2 m water table drawdown contour around the former mine pits. Further detail regarding this assessment can be found in Appendix D3 and Appendix D4 of the EPA Section 38 EP Referral (OZ Minerals, 2021).

### Mine Waste Management

Geochemical and physical characterisation of waste rock and tailings has been undertaken to assist in understanding the water-related risks associated with long-term mine waste management. The studies show that tailings are unlikely to generate problematic leachate[1] and that waste rock has generally low levels of potentially acid forming materials. The studies have informed the design of the tailings storage facility (TSF) and waste rock dumps (WRDs) to ensure mine wastes are appropriately contained to minimise any environmental impact.

Hydrochemical numerical modelling has also been undertaken (OZ Minerals, 2021; Appendix D7 and Appendix D12) to assess the fate and transport of any leachate arising from waste storages that may reach the water table. The modelling adopted a number of very conservative assumptions, and predictions relating to effects are also considered conservative. The results show the concentrations of leachate constituents attenuate to guideline levels within short distances of the TSF and WRDs (i.e. within tens to hundreds of metres).

[1] Problematic leachate is defined as leachate with concentrations of Constituents of Concern in excess of adopted guideline values.

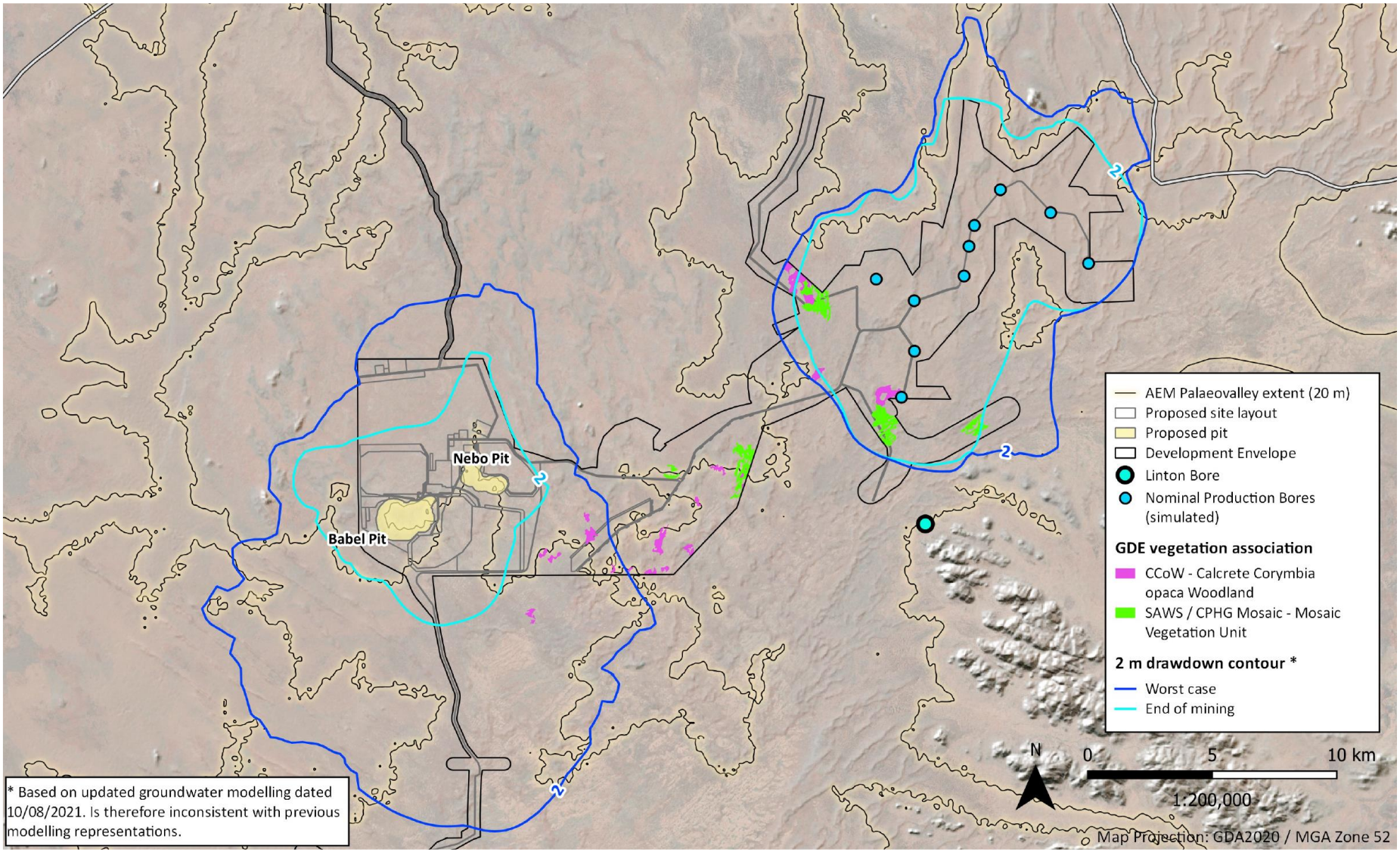


**Figure 5: Estimated Modelled Extent of the 2 m Water Table Drawdown Contour**

#### 1.4.1.4 Interactions Between the Project and Environmental Values

### Community Water Supplies

Groundwater is utilised to meet some or all of community water supply requirements in the broader project area. Community water at the nearest community to the project, Jameson (Mantamaru), is drawn from the community bores approximately 26 km north of the proposed mine. Prior to reticulation for community use, the community bore water is treated using reverse osmosis to remove naturally occurring nitrates.

Linton Bore is located approximately 5 km south-west of the most southern production bore of the Northern Borefield and is used from time to time by the community when visiting the area for cultural activities. The locations of these community water bores are shown on Figure 3. Community water supplies are discussed in more detail in the groundwater baseline assessment undertaken for the EPA Section 38 EP Referral (OZ Minerals, 2021; Appendix D2).

The Jameson (Mantamaru) bores occur approximately 20 km north of the predicted 2 m water table drawdown contours associated with mine-related activities (Figure 5). Publicly available data indicates that the Jameson bores are hosted within fractured rock aquifers which represents a different hydrogeological system to those of the project water supply and dewatering bores. Linton Bore is located on the 'worst case' 1 m water table drawdown contour that is predicted to develop around the Northern Borefield (Figure 5). It is possible that Linton Bore intersects paleovalley sediments, similar to those that will be accessed by the Northern Borefield production bores and the Nebo dewatering bores. It is assessed that Linton Bore water levels may be drawn down by up to 1 m as a result of project water abstraction. Hydrographs indicate that water table drawdown at Linton Bore will be less than 0.1 m/year. For further detailed discussion, refer to the Groundwater Effects Assessment undertaken for the EPA Section 38 EP Referral (OZ Minerals, 2021; Appendix D4).

### Potential Terrestrial GDEs

An assessment of potential terrestrial GDEs in the West Musgrave area has been conducted (OZ Minerals, 2021; Appendix B2). The assessment reviewed the results of a detailed survey of vegetation associations and mosaics, the physical setting where terrestrial GDEs might exist, including landscape, soils and available water sources (soil water as well as groundwater), and an extensive literature review (see OZ Minerals, 2021; Appendix B2). A conceptualisation of groundwater use by potential terrestrial GDEs provides the context for their level of sensitivity to altered groundwater conditions arising from groundwater abstraction and dewatering of mine pits. The approach to assessing whether potential terrestrial GDEs will be adversely affected by mine-related water affecting activities involved the following assumptions:

- Plants will use soil water, when available, in preference to groundwater
- There are no impediments (such as hardpans) to depth of rooting (however, the geological database does indicate calcrete platforms are commonplace throughout the project area which may limit tree rooting depth)
- A typically restricted soil water zone (as evidenced by shallow water tables) combined with an arid climate suggests some degree of groundwater dependence may occur in larger plant species, at least during prolonged drought periods
- Larger tree species will likely have larger environmental water requirements than smaller tree and shrub species, and grasses.

Based on the potential terrestrial GDE assessment (OZ Minerals, 2021; Appendix B2) and the assumptions outlined above, Table 5 lists vegetation associations and mosaics comprising key vegetation species that have been identified as potentially reliant to some degree on groundwater. Figure 3 presents the spatial distribution of these associations/mosaics across the surveyed area. While all potential terrestrial GDE associations identified in the survey area are considered widespread in the landscape, they do not include species or communities of conservation significance. A reduction in health and/or death of vegetation as a result of project-related water-affecting activities, however, may be perceived as an impact to the cultural landscape from the perspective of Traditional Owners, especially in cultural heritage and natural resource priority areas in the vicinity of Cavanaugh Range/Linton Bore.

**Table 5: Potential Terrestrial Groundwater Dependent Ecosystems**

| Vegetation Association/Mosaic | Abbreviation | Located within 2 m Water Table Drawdown Contour |
|---|---|---|
| *Acacia kempeana* Shrubland and Hard pan Mulga Woodland | AkS/HPMW mosaic | No |
| Calcrete *Corymbia opaca* Woodland | CCoW | Yes |
| Calcrete Platform Hummock Grassland Hummock Grassland with *Acacia eremophila* | CPHG Ae | No |
| Calcrete Platform Hummock Grassland Hummock Grassland with *Melaleuca eleuterostachya* | CPHG Me | No |
| *Eremophila duttoni* Shrubland | Eds | No |
| Low Mallee Woodland and *Melaleuca glomerata Acacia kempeana* Shrubland | LMW/MgAkS mosaic | No |
| *Melaleuca glomerata Acacia kempeana* Shrubland and Hard pan Mulga Woodland | MgAKS/HPMW mosaic | No |
| Sand plains with Wattles other than Mulga over Spinifex and Calcrete Platform Hummock Grassland | SAWS/CPHG mosaic | Yes |

The most significant risk posed to terrestrial GDEs (should they be confirmed to be present) in the project area associated with mine-related water affecting activities is removal of access to groundwater for meeting environmental water requirements, i.e. water table drawdown arising from groundwater supply development and mine dewatering. OZ Minerals has relied upon Froend and Loomes (2004) in regard to adopting a threshold for assessing effects of drawdown magnitude on terrestrial phreatophytic vegetation. The threshold assumes that a groundwater drawdown of more than 2 m, regardless of the rate of change, may result in a discernible change to the ecological integrity and biological diversity of these potential terrestrial GDEs. It is noteworthy however that a highly precautionary approach has been taken to assessing potential impacts to potential terrestrial GDEs in and near-to areas extending into cultural heritage and natural resource priority areas in the vicinity of Cavanaugh Range/Linton Bore and other areas as agreed with the Ngaanyatjarra Council. In the vicinity of these cultural heritage and natural resource priority areas near to Cavanaugh Range/Linton Bore a more precautionary approach, of no more than 1 m of groundwater drawdown will be adopted, with rates of drawdown not exceeding 0.2 m/year (above natural variation).

Table 5 and Figure 3 present the vegetation associations/mosaics recoded in the survey area that have key species that may have some form of groundwater dependence and are exposed to reduced groundwater access based on this 2 m drawdown threshold. Table 6 presents details identifying the areas of potential GDEs (vegetation associations/mosaics) that may be impacted by water table drawdown in excess of 2 m in the broader project area and within the 2 m drawdown contour (where drawdown of more than 2 m is predicted).

**Table 6: Potential Terrestrial Groundwater Dependent Ecosystems Located Within Those Areas Where More Than 2 m Drawdown is Predicted**

| Vegetation Association/ Mosaic | Total Mapped Area (ha) | Area Potentially Impacted (ha) | Proportion of Potentially Impacted Area to Mapped Area (%) |
|---|---|---|---|
| CCoW | 455.3 | 175.3 | 38.5 |
| SAWS/CPHG mosaic | 775.9 | 201.3 | 26% |

### 1.4.2 Key Assumptions and Uncertainties

This GMMP has been developed using all relevant and available information at the time of preparation. The key assumptions and uncertainties associated with this current GMMP are described in Table 7.

**Table 7: Key Assumptions and Uncertainties Associated with WMP Groundwater Management**

| ID | Assumption/Uncertainty | Description |
|---|---|---|
| A1 | Groundwater conceptualisation | The Development Envelope and surrounds have been the subject of several groundwater studies and investigations. It is assumed that these investigations and studies have adequately characterised the hydrogeological regimes in terms of quantity, quality and potentially dependent environmental values in the project area; and estimated, through hydrogeological and hydrochemical numerical modelling, the drawdown associated with mine pit dewatering and borefield abstractions, and water quality effects of potential leachate migration away from waste landforms. The assumption is supported by the hydrogeological numerical model independent peer-review. While a process of due diligence has occurred relating to the accuracy of this numerical model for impact predictions, Uncertainty 1 also notes the inherent uncertainty associated with hydrogeological modelling, and a further program of work to confirm model accuracy has been highlighted in Table 8. |
| A2 | Impact assessment | The conceptual groundwater model has adequately assessed the effect of Northern Borefield groundwater abstractions from the deep Pidinga aquifer on Garford aquifer water table elevation and drawdown extent, and the dewatering effects on Garford aquifer and basement water table elevations and drawdown extent. The assumption is supported by the hydrogeological numerical model independent peer-review. |
| A3 | Ecosystem health | It is assumed that, for the purposes of this GMMP, ecosystem health is related to access to appropriately defined Environmental Water Provisions (EWP) (WRC, 2000) represented by water table depth and groundwater quality. |
| A4 | Terrestrial GDE assessment | The terrestrial GDE assessment identified the presence of 376.6 ha of potential terrestrial GDEs inside the 2m water table drawdown contour that may be affected by the project water affecting activities. See also Uncertainty 2 (below) which notes that 50% of the 2 m groundwater drawdown contour has not yet had groundwater dependent vegetation surveyed. A work program to reduce this uncertainty is highlighted in Table 8. |
| U1 | Location of the 2 m drawdown contour | The hydrogeological numerical model has been informed by data collected from 20 groundwater test bores, a program of geological drilling and geophysical methods. Uncertainty is inherent in most hydrogeological models and will be further refined as part of ongoing geophysical test work, model refinements, and through the adaptive management of the borefield during the project operations; in particular assessing borefield predictions against hydrographs to confirm that the borefield is behaving as predicted. |

| ID | Assumption/Uncertainty | Description |
|---|---|---|
| U2 | Vegetation survey effort | While flora and vegetation surveys have been undertaken in much of the area encompassing the predicted 2 m drawdown contour, large areas remain unsurveyed due to the significant size of the updated 'worst case' 2m groundwater drawdown contour (Appendix C) and challenges of gaining cultural heritage access in the project timeframes, particularly in the area near to the Cavanaugh Range/Linton Bore. As a result, there may be some additional areas of potential terrestrial GDEs that remain unsurveyed within the predicted 2 m drawdown contour. Table 8 documents additional work planned to reduce this uncertainty. Results from this additional work will inform future updates to this management plan. |
| U3 | Terrestrial GDE assessment | The terrestrial GDE assessment has relied on literature, remote-sensing imagery and professional judgement to identify vegetation associations/ mosaics that may represent terrestrial GDEs that could be impacted by the project. Field studies (e.g. measurements of leaf water potentials, etc) could supplement this data to further reduce uncertainty. Table 8 highlights additional work planned to reduce this uncertainty. Results from this additional work will inform future updates to this management plan. |
| U4 | Vegetation-specific Environmental Water Provisions | Further studies, coupled with ongoing monitoring, is required to better understand the tolerance of terrestrial GDEs to water table drawdown, and thereby inform the EWP required to sustain ecosystem function. Table 8 highlights additional work planned to reduce this uncertainty. Results from this additional work will inform future updates to this management plan. |

To provide assurance on our current understanding of potential GDEs, and the approach to further reduce uncertainties, a review was undertaken by AQ2 (OZ Minerals, 2021; Appendix B2 Addendum 1) and is also provided here as Appendix A. The review was undertaken to confirm the adequacy of the approach taken, and to assist with identifying the appropriate next steps to reduce uncertainty associated with the potential presence of GDEs at WMP.

The review concluded that in a number of regards the existing assessment may have identified larger areas of GDEs than may be the case. In addition, the review has identified a number of further actions to reduce uncertainties associated with the existing GDE assessment. These additional actions are considered in this GMMP. Table 8 identifies a number of studies proposed to reduce the level of uncertainty relating to the presence of potential terrestrial GDEs, and responses in vegetation to changes in environmental water availability. These studies have been developed as environmental objectives (management objectives) and their output would be used to inform ongoing monitoring and management initiatives and where necessary any updates to trigger criteria and threshold criteria proposed in this GMMP.

With the exception of the natural resource priority areas in the vicinity of Cavanaugh Range/Linton Bore and other areas as agreed with the Ngaanyatjarra Council where a precautionary approach will be taken of assuming potential impacts to potential GDEs of groundwater drawdown of 0.5 m; based on the

existing and available published science, semiqualitative GDE studies, and peer-review of the existing GDE work, for all other areas the 'worst case' 2 m drawdown contour has been retained as the 'area of potential impact to groundwater dependent vegetation'. Notwithstanding, Table 8 has identified provisions for updating these limits to a site-specific criteria should additional GDE work confirm groundwater dependence, and where ecohydrology studies indicate that impacts could be realised with drawdown of the water table by less than 2 m.

**Table 8: Terrestrial Groundwater Dependent Ecosystem Uncertainty Studies**

| **Uncertainties identified in** Table 7 | **EPA Factor: Inland Waters**<br>**Objective: To maintain the hydrological regimes and quality of groundwater…so that environmental values are protected**<br>**Key Environmental Values: Ecosystem health of potential groundwater dependent terrestrial vegetation and beneficial use of groundwater**<br>**Key Impacts and Risks:**<br>• **Change to groundwater quality and quantity adversely impacts beneficial use and ecosystem health. The changes may arise due to:**<br>○ **Groundwater drawdown associated with groundwater supply development and mine dewatering**<br>○ **Evaporative losses of groundwater from final pit voids, and interaction between pit void(s) and groundwater** | | |
|---|---|---|---|
| **Uncertainty** | **Management Actions** | **Monitoring** | **Timing** |
| **Uncertainty 1:** The hydrogeological numerical model has been informed by data collected from 20 groundwater test bores, a program of geological drilling and geophysical methods. Uncertainty is inherent in most hydrogeological models and will be further refined as part of ongoing geophysical test work, model refinements, and through the adaptive management of the borefield during the project operations, in particular assessing borefield predictions against hydrographs to confirm that the borefield is behaving as predicted. | • Monitor rates of drawdown from bores located near to abstraction sites (inside of borefield and mine area groundwater contours) against end of operations hydrographs to confirm that predicted water table drawdown is not significantly different than predicted. Note: where rates of drawdown across the monitoring network are significantly different to those modelled across hydrographs a revision of the hydrogeology model will be triggered to confirm any potential deviation in groundwater contours against existing predictions (as presented herein). | • Water levels at mine monitoring bores MMB-05 to MMB-08 using transducer, dipping or similar.<br>• Water levels at borefield monitoring bores BMB-06a to BMB-09a and BMB-06b to BMB-09b using transducer, dipping or similar. | Monthly monitoring of water levels for the first two years of operation or until stabilisation has been reached and the drawdown contours are behaving consistently with hydrographs.<br>Review against hydrographs to occur quarterly.<br>Conformation of whether hydrogeology model updates are needed will occur following the collection of 12 months of data. |
| **Uncertainty 2:** While flora and vegetation surveys have been undertaken in much of the area encompassing the predicted 2 m drawdown contour, some areas remain unsurveyed largely due to cultural heritage access restrictions. As a result, there may be some additional areas of potential terrestrial GDEs that remain unsurveyed within the predicted drawdown contours. | • Map and report previously unmapped potential terrestrial GDE associations within the 2 m water table drawdown contours, the 0.5 m water table drawdown contours in proximity to natural resource priority areas in the vicinity of Cavanaugh Range/Linton Bore and in any other priority areas as agreed between the Ngaanyatjarra Council and OZ Minerals, (this may require reliance on the use of high-resolution imagery).<br>• The Ngaanyatjarra Ranger Team will be invited to participate in any on ground flora and vegetation survey activities (subject to fair and reasonable commercial terms) | Vegetation mapping using high-resolution aerial imagery, and where necessary, and where access allows, ground truthing using the establishment of vegetation survey quadrates. | Prior to the commencement of mine dewatering and borefield abstraction. |
| **Uncertainty 3:** The terrestrial GDE assessment has relied on literature, remote-sensing imagery, and professional judgement to identify vegetation associations/mosaics that may represent terrestrial GDEs that could be impacted by the project. Field studies (e.g. measurements of leaf water potentials, etc) could supplement this data to further reduce uncertainty. | • Undertake field-based terrestrial GDE assessments to identify the degree of groundwater dependence (if any) of key plant species within vegetation associations and mosaics identified as possible terrestrial GDEs to determine environmental water requirements.<br>• Field-based terrestrial GDE assessments of a stand of Desert Oaks (*Allocasuarina decaisneana*) known as Exclusion Zone 2, 7.6 km from the main development area (outside all known drawdown contours).<br>• Invite the Ngaanyatjarra Council (and their associated specialists) to be involved in the scoping of terrestrial GDE assessments.<br>• The Ngaanyatjarra Ranger Team will be invited to participate in any field-based terrestrial GDE survey activities (subject to fair and reasonable commercial terms) | Conduct the following analysis on a minimum of 10 potential terrestrial GDE trees (or as otherwise agreed with EPA or an appropriately qualified ecohydrology specialist) within each identified potential terrestrial GDE (as described in Table 5):<br>• Leaf water potential (LWP) measurements<br>• Stand/stem basal area calculation<br>• Measure isotopic composition of groundwater, soil water and plant (xylem) water | Prior to the commencement of mine dewatering and borefield abstraction. |
| **Uncertainty 4**: Further studies, coupled with ongoing monitoring, is required to better understand the tolerance of terrestrial GDEs to water table drawdown, and thereby inform the EWP required to sustain ecosystem function. This work would support the setting of site-specific criteria for EWPs.<br>Note: ongoing assessment of EWP would only be required should the baseline assessment (detailed in Uncertainty 3) confirm that identified potential terrestrial GDE associations, are groundwater dependent. | • Assess environmental water requirements of potential terrestrial GDEs and quantify suitable EWPs for all identified terrestrial GDEs identified within the impacted area (i.e. within the 2 m drawdown contour).<br>• Based on these studies refine water table drawdown and groundwater quality EWP that are considered protective of ecosystem health and update trigger criteria, threshold criteria and management within this GMMP as required. The Ngaanyatjarra Council will be invited to comment on the establishment of site-specific criteria for GDE EWPs<br>• The Ngaanyatjarra Ranger Team will be invited to participate in any field-based terrestrial GDE survey activities (subject to fair and reasonable commercial terms) | Undertake ongoing seasonal monitoring, for a period adequate to reduce uncertainty, comprising:<br>• LWP<br>• Water table depth (continuous data collection using a transducer or similar) | Ongoing seasonal monitoring to be undertaken quarterly following the commencement of mine dewatering and borefield abstraction. |

### 1.4.3 Management Approach

The management approaches discussed in this document are based and developed around the mitigation hierarchy of avoid and minimise to ensure impacts to environmental values have been avoided or reduced to as low as reasonably practicable. In particular the management approach is based on the following actions:

- A baseline monitoring and trigger-location bore network
- Establishing appropriate environmental criteria for trigger and threshold levels (provisional triggers are provided, to be confirmed after further input from the Swan-Avon Region Branch of Government of Western Australia's Department of Water and Environmental Regulation (DWER))
- Periodic reviews of the hydrogeological numerical modelling and groundwater monitoring based on operational data
- Ongoing refinement of uncertainty through further information gathering and test-work where necessary
- Adaptive management of the water abstraction infrastructure (pumping locations and rates) to meet the trigger and threshold levels
- Delaying or avoiding certain abstraction regions to comply with trigger and threshold levels.

This GMMP uses outcome-based provisions to ensure the EPA's objectives for Inland Waters is achieved.

### 1.4.4 Rationale for Choice of Environmental Criteria

Site-specific environmental criteria are based on the following rationale.

**Impact of groundwater drawdown on potential terrestrial GDEs:** Potential terrestrial GDEs and their locations in the landscape have been identified from flora and vegetation surveys and a semi-quantitative review of the vegetation's potential reliance on groundwater (OZ Minerals, 2021; Appendix B2). The most significant risk posed to potential terrestrial GDEs in the project area associated with mine-related water affecting activities is removal of access to the water table (capillary fringe) for meeting environmental water requirements i.e., water table drawdown arising from groundwater supply development and mine dewatering and the rate of drawdown is too fast to allow adaptation by the vegetation to account for this rate of change. A trigger level of 68% of the predicted drawdown level expected to impact potential terrestrial GDEs is proposed[2], whereby trigger-reporting, increased monitoring and further assessments are activated.

**Impact of groundwater drawdown on beneficial groundwater users**: Hydrogeological assessments predict that existing groundwater users accessing Jameson (Mantamaru) community Bore and Linton

[2] 68% represents one standard deviation from the mean of the baseline level

Bore will not be impacted by groundwater drawdown (OZ Minerals, 2021; Appendix D). However, a precautionary approach is adopted whereby triggers are used to validate these assumptions. Proposed provisional triggers are based on modelled water table drawdown contours.

**Validating hydrochemistry numerical modelling outputs:** Hydrochemistry assessments indicate that existing groundwater users will not be impacted by potential groundwater contamination arising from waste landforms. However, a precautionary approach is adopted whereby triggers are used to validate model assumptions. A hydrochemical study (OZ Minerals, 2021; Appendix D7 and Appendix D12) conducted to assess the fate of potential contaminants in groundwater that may arise from waste landform seepage identified three key constituents of concern (copper, nickel and sulfate) that could occur at concentrations in seepage waters that exceed adopted guidelines for protection of water quality (NRMMC, 2021). Proposed provisional triggers are based on the hydrochemistry numerical modelling and baseline water quality data and include copper, nickel and sulfate as well as salinity (as electrical conductivity). Table 9 presents the adopted trigger and threshold criteria.

**Table 9: Proposed Trigger Criteria and Threshold Criteria for Water Quality**

| Parameter | Garford Aquifer | | Basement Hydrostratigraphic Unit (HSU) | |
|---|---|---|---|---|
| | Trigger[1] | Threshold[2] | Trigger[1] | Threshold[2] |
| Electrical conductivity ($\mu$S/cm) | 2,600 | 3,000 | 1,500 | 1,700 |
| Copper (mg/L) | 2 | 3 | 0.5 | 4 |
| Nickel (mg/L) | 0.9 | 3 | 0.5 | 4 |
| Sulfate (mg/L) | 250 | 270 | 120 | 150 |

Notes: 1. Based on 80$^{th}$ percentile for reported values for all water samples collected from specific HSU
2. Based on maximum reported value for all water samples collected from specific HSU

### 1.4.5 Rationale for Choice of Trigger Level Actions and Threshold Contingency Actions

Site specific management targets are based on the following rationale.

**Impact of groundwater drawdown on potential terrestrial GDEs:** Proposed provisional triggers are based on the hydrogeological numerical model predictions. A trigger level of 68% of the predicted drawdown is proposed, whereby trigger-reporting, increased monitoring and further assessments are activated along with early contingency actions (if deemed necessary). A threshold level equal to the predicted drawdown is proposed as the compliance limit. In addition, the rate of water table drawdown in cultural heritage and natural resource priority areas in the vicinity of Cavanaugh Range/Linton Bore will be limited to less than 0.2 m/year (over and above natural variation).

Example mitigation and contingency measures, should these triggers and thresholds be met, are shown in Table 10.

**Impact of groundwater drawdown on beneficial groundwater users**: Proposed provisional triggers are based on the hydrogeological numerical model predicted water table drawdowns. Triggers are based on comparison of regional-response data.

Example mitigation and contingency measures should these triggers and thresholds be met are shown in Table 10. If unexpected drawdown impacts to existing groundwater users accessing Jameson (Mantamaru) community Bore and Linton Bore are identified, OZ Minerals would provide alternative water sources.

**Validating hydrochemistry numerical modelling outputs:** To confirm that hydrochemistry impact extent is no greater than that predicted by the hydrochemistry numerical model:

- A trigger criteria equal to the 80$^{th}$ percentile reported concentration for each identified analyte (see Table 9) and evidence of an increasing trend is proposed for groundwater samples collected from individual monitoring bores at the extent of the hydrochemical numerical model. Reaching this trigger criteria would activate increased monitoring and further assessments.
- A threshold criteria of 100% of the maximum reported concentration for each identified analyte (see Table 9) and evidence of an increasing trend is proposed for groundwater samples collected from individual monitoring bores at the extent of the hydrochemical numerical model. A threshold level equal to 100% of the maximum concentration is proposed as the compliance limit.

Example mitigation and contingency measures, should these triggers and thresholds be met, are shown in Table 10.

**Table 10: Nominal Mitigation and Contingency Measures**

| Criteria Type | | Example Mitigation and Remedial Measures |
|---|---|---|
| Trigger | Water Quantity | • Initiate implementation of the contingency measures within 2 weeks of the exceedance being identified<br>• Perform QA/QC check, re-sample and confirm criteria have been exceeded, if exceedance confirmed:<br>○ Increase frequency of monitoring to understand trend, continue with this until sufficient information and data available to revert to previous frequency<br>○ Implement early intervention if trend analysis indicates threshold criteria are likely to be exceeded (see below for examples)<br>• Assess possible causes of criteria exceedance<br>• Assess implications of exceedance and whether adverse threat is posed to Environmental Values (EV)<br>○ Re-evaluate appropriateness of trigger and threshold criteria<br>○ Adjust trigger and threshold criteria if required and amend this GMMP to reflect change<br>• Recalibrate/refine or update numerical models (hydrogeological or hydrochemistry) to provide predictions of groundwater system response to project water affecting activities and early implementation of mitigation and remedial measures<br>• Personnel training and awareness promotion in regard to the potential for adverse water management outcomes<br>• Determine the need for early instigation of any of the following (for groundwater levels):<br>○ Reduce pumping from individual production bores and redistribute pumping to other production bores where capacity exists and possible drawdown effects do not pose a risk to EV, and/or<br>○ Lower pumps in community bores to access more available drawdown, and/or<br>○ In consultation with the community, replace shallow community production bore(s) with deeper bores to access deeper aquifer intersections (where available), and/or<br>○ In consultation with the community, provide alternate sources of water to replace community supplies.<br>• Determine the need for early instigation of any of the following (for groundwater quality):<br>○ Minimise supernatant on tailings storage facility<br>○ Increase pumping from tailings storage facility underdrainage system, interception bores, sumps, or other contributing sources. |
| | Water Quality | |

| Criteria Type | | Example Mitigation and Remedial Measures |
|---|---|---|
| | Potential terrestrial GDEs | Should groundwater levels reach 68% of water table drawdown predicted in the hydrogeological assessment, or a drawdown rate of greater than 0.2 m/year occurs at Linton Bore the following activities would be employed within 2 weeks of the exceedance being notified:<br>• Commence vegetation health assessments as detailed in Table B1 and Appendix B.<br>• Should vegetation health assessments indicate a project derived impact to vegetation outside of the predicted 2 m drawdown contour, or south of Linton Bore, the contingencies listed below (in thresholds) would be employed as appropriate<br>Note: trigger actions relating to potential terrestrial GDEs would only occur in the event that baseline terrestrial GDEs assessments (see Uncertainty 3 above) confirm the presence of GDEs. |
| Threshold | General | • Perform QA/QC check, re-sample and confirm criteria have been exceeded<br>• If exceedance confirmed, increase frequency of monitoring to demonstrate mitigation and remedial actions are effective<br>• Maintain intervention until approval to cease is notified by appropriate regulatory agency |
| | Water Quantity | • Initiate implementation of the contingency measures within 48 hours of the exceedance being identified<br>• Northern Borefield and Regional<br>○ Reduce pumping from individual production bores and redistribute pumping to other production bores where capacity exists and possible drawdown effects do not pose a risk to EV, and/or<br>○ Lower pumps in community bores to access more available drawdown, and/or<br>○ Replace shallow community production bore(s) with deeper bores to access deeper aquifer intersections (where available), and/or<br>○ Provide alternate sources of water to replace community supplies |
| | Water Quality | • Nebo dewatering borefield<br>○ Optimise dewatering rates to achieve, rather than exceed, mining objectives<br>○ Consider re-injection upstream or downstream to protect identified EV<br>• Waste landforms<br>○ Commission recovery borefields to manage water table rise and water quality decline, if required and appropriate<br>• Recalibrate/refine numerical models (hydrogeological or hydrochemistry) to provide predictions of groundwater system response to mitigation and remedial measures |

| Criteria Type | | Example Mitigation and Remedial Measures |
|---|---|---|
| | Potential terrestrial GDEs | Initiate implementation of the contingency measures within 48 hours of the exceedance being identified<br>Should vegetation health assessments indicate a project derived impact to vegetation outside of the predicted 2 m drawdown contour, a water table drawdown of greater than 1 m at Linton Bore or a drawdown rate of greater than 0.2 m/year at Linton Bore, the contingencies listed above for Water Quantity would be employed as appropriate<br>Note: trigger actions relating to potential terrestrial GDEs would only occur in the event that baseline terrestrial GDEs assessments (see Uncertainty 3 above) confirm the presence of GDEs. |

# 2 MANAGEMENT OUTCOMES

This GMMP has considered outcome-based criteria to measure the performance of hydrogeology and hydrochemistry assumptions and, where performance is not met based on the required trigger criteria and threshold criteria, adaptive management would be employed to avoid, or minimise potential impacts to environmental values, in as so far to ensure that EPA's inland water objectives are met. In addition, through the adaptive management approach, emerging research and technology will be continuously reviewed to identify further measures to proactively control and mitigate potential impacts to groundwater.

## 2.1 Environmental Criteria

Two levels of criteria are considered for the outcome-based component of this GMMP, they include:

- Trigger criteria which provide an early indicator metric to which further actions should be taken in advance of the environmental outcome being compromised.
- Threshold criteria which measure the achievement of the environmental outcome. A failure to meet threshold criteria signals the environmental outcome is possibly not being met and implies non-compliance.

**Table 11: Environmental Criteria for Outcome-Based Management**

| | |
|---|---|
| **Trigger Criterion** | • 68% of water table drawdown predicted in the hydrogeological assessment<br>• Drawdown at Linton Bore is greater than 0.1 m/year (over and above natural variation)<br>• P80 reported (baseline) concentrations for EC, Cu, Ni and $SO_4$ in groundwater sampled from Garford and fractured rock HSUs downstream of the TSF |
| **Threshold Criterion** | • Water table drawdown equal to, or greater than, that predicted in the hydrogeological assessment<br>• Drawdown at Linton Bore is greater than 0.2 m/year (over and above natural variation)<br>• Maximum reported (baseline) concentrations for EC, Cu, Ni and SO4 in groundwater sampled from Garford and fractured rock HSUs downstream of the TSF |

## 2.2 Monitoring

This section describes how OZ Minerals will undertake monitoring to determine the performance against the environmental criteria. Table 12 describes monitoring provisions, Figure 6 presents a locality plan for the proposed monitoring network and Table 13 presents nominal completion details for individual monitoring bores comprising the proposed monitoring network. Table 14 provides the proposed framework to assess the health of potential terrestrial GDEs between the 2 m and 0.5 m water table

drawdown contours should the outcome described for groundwater in Table 12 not be met. Further details of the monitoring parameters and approach can be found in Appendix B.

OZ Minerals will be responsible for monitoring, maintenance and upkeep of monitoring bores. Production bores will be fitted with a flow meter as per Government of Western Australia's Department of Water's (DoW) Measuring the taking of water (DoW, 2016). Meters will be properly maintained to ensure that accurate readings can be taken. Meter reading data will be reviewed for QA/QC purposes and maintained in a database.

**Table 12: Outcome-based EMP for Groundwater**

**EPA Factor: Inland Waters**

**Key Environmental Values: Ecosystem health of groundwater dependent terrestrial vegetation and beneficial use of groundwater**

**Key Impacts and Risks:**

- **Change to groundwater quality and quantity adversely impacts beneficial use and ecosystem health. The changes may arise due to:**
  - **Groundwater drawdown associated with groundwater supply development and mine dewatering**
  - **Evaporative losses of groundwater from final pit voids, and interaction between pit void(s) and groundwater**
  - **Seepage from mine waste landforms (TSF and WRDs)**
  - **Release of water or hazardous materials from potential contaminant sources (including WRDs, TSF, hazardous goods storage areas and equipment)**

| Outcome | Criteria | Response Action | Monitor | Frequency | Reporting |
|---|---|---|---|---|---|
| **Outcome 1:** Groundwater management infrastructure operates as per design to minimise adverse impacts to environmental values | **Trigger Criteria:**<br>• 68% of the predicted drawdown at 2 m water table drawdown contour, and/or a reference site near Jameson over two consecutive monitoring events<br>• Monitoring bores within drawdown contours (inside of borefield and mine area groundwater contours) against end of operations hydrographs to confirm that predicted water table drawdown is not significantly different than predicted. Note: where rates of drawdown across the monitoring network are significantly different to those modelled in hydrographs a review or revision of the hydrogeology model will be triggered to confirm any potential deviation in groundwater contours against existing predictions (as presented herein).<br><br>**Threshold Criteria:**<br>• Equal to the predicted drawdown at 2 m water table drawdown contour and/or a reference site near Jameson at any single monitoring event; and subsequent investigations determine that the impacts are likely a result of the implementation of the proposal | See Table 10 | • **Indicator:** Groundwater levels<br>• **Method:** Field collection or automation of groundwater level using a transducer or manual dipping. EC and pH would also be collected.<br>• **Location** (Figure 6)**:**<br>○ Monitoring bores at the 2 m water table drawdown contour:<br>- Mine: MMB-01 to MMB-04<br>- Northern Borefield: BMB-01 to BMB-04 and BMB-06a)<br>- Near Jameson: CMB-01<br>- Control sites: CMB-01 to CMB-04<br>○ Monitoring Bores within the drawdown contours used to confirm accuracy of drawdown predictions:<br>- Mine: MMB-05 to MMB-08<br>- Borefield: BMB-06a to BMB-09a and BMB-06b to BMB-09b<br>• The Ngaanyatjarra Ranger Team will be invited to participate in any field-based water monitoring activities (subject to fair and reasonable commercial terms) | Monthly data collection,<br>A review of this frequency will occur on an annual basis<br>Quarterly review of drawdown against hydrographs<br>Determination of whether hydrogeology model update is required will occur at the end of 12 months of data collection. | • Annual compliance assessment report (if the Plan is conditioned under the EP Act) (DWER – Compliance Branch)<br>• Annual Aquifer Assessment Report (DWER – Swan-Avon Region)<br>• Triennial (every three years) Aquifer Review (DWER – Swan Avon Region) |
| **Outcome 2:** Groundwater management infrastructure will be managed to ensure groundwater table drawdown is no greater than 1 m south of Linton Bore (towards the Cavanaugh Range) | **Trigger Criteria:**<br>• 68% of the predicted 1 m drawdown at a monitoring bore adjacent to Linton Bore over two consecutive monitoring events (in comparison to a reference bore).<br>• And/or rate of drawdown at Linton Bore is greater than 0.1 m/year (over and above natural variation) over a 12-month period.<br><br>**Threshold Criteria:**<br>• Equal to the predicted 1 m water table drawdown at a monitoring bore adjacent to Linton Bore at any single monitoring event (in comparison to a reference bore); and subsequent investigations determine that the impacts are likely a result of the implementation of the proposal<br>• And/or rate of drawdown at a site adjacent to Linton Bore is greater than 0.2 m/year (over and above natural variation) over a 12-month period. | See Table 10 | • **Indicator:** Groundwater levels and hydrograph[3]<br>• **Method:** Field collection or automation of groundwater level using a transducer or manual dipping. EC and pH would also be collected.<br>• **Location** (Figure 6)**:**<br>○ Monitoring bores near Linton Bore (BMB-00)<br>○ Control sites: CMB-01 to CMB-04<br>• The Ngaanyatjarra Ranger Team will be invited to participate in any field-based water monitoring activities (subject to fair and reasonable commercial terms) | Monthly data collection<br>A review of this frequency will occur on an annual basis<br>Quarterly review of drawdown against hydrographs | |

[3] Rate of drawdown will be measured against an analogous geological reference site. If an analogous geological reference site can not be identified the rate of drawdown will be measured as a 'continual downward trend above natural variation over the course of 12 months that is greater than or equal to the specified trigger and threshold levels'.

| Outcome | Criteria | Response Action | Monitor | Frequency | Reporting |
|---|---|---|---|---|---|
| **Outcome 3:** No adverse impacts to groundwater quality outside of assessed impact areas as a result of implementing the proposal | **Trigger Criteria:** An exceedance of groundwater quality guideline values (see Table 9) in comparison to reference sites over two consecutive monitoring events<br><br>**Threshold Criteria:** An exceedance of site-specific background threshold criteria in any single monitoring event in comparison to reference sites; and subsequent investigations determine that the impacts are likely a result of the implementation of the proposal | See Table 10 | • **Indicator:** Hydrochemistry concentrations<br>• **Method:** Field sample collection and laboratory analysis<br>• **Location** (Figure 6)**:**<br>○ Selected reference sites as 'threshold locations' downstream of key project infrastructure (TSF, WRD and processing plant)<br>○ Selected reference sites as 'control locations' upstream from key project infrastructure<br>• The Ngaanyatjarra Ranger Team will be invited to participate in any field-based water monitoring activities (subject to fair and reasonable commercial terms) | Quarterly | |
| **Outcome 4**: No adverse impact to confirmed terrestrial GDEs outside of the 2 m water table drawdown contour<br><br>Note:<br>This outcome would only be relevant should the baseline potential terrestrial GDE program confirm the presence of GDEs, and if confirmed, this outcome would only occur should the trigger criteria for Outcome 1 be triggered | **Trigger Criteria:** A statistically significant[4] difference in primary parameter (Appendix B) trends at sites of confirmed terrestrial GDEs between the 2 m and 0.5 m water table drawdown contours compared to baseline monitoring values over two consecutive monitoring events<br><br>**Threshold Criteria:** A statistically significant[4] difference in primary parameter (Appendix B) trends at sites of confirmed terrestrial GDEs between the 2 m and 0.5 m water table drawdown contours compared to reference sites over four consecutive monitoring events; and subsequent investigation determine that the impacts are likely a result of the implementation of the proposal | See Table 10 and Table 14 | • **Indicator:** Vegetation health and condition (Appendix B)<br>• **Method:** Visual assessment of vegetation health (photos and visual assessment), collection of leaf water potential data, and/or more regional methods such as NDVI or LiDAR to evaluate tree heights.<br>• **Location** (Figure 6)**:**<br>○ At locations of confirmed terrestrial GDEs between the 2 m and 0.5 m water table contours (TBA based on uncertainty surveys detailed in Table 8)<br>○ Control sites away from key project infrastructure, and their potential impacts (if available)<br>• The Ngaanyatjarra Ranger Team will be invited to participate in any field-based water monitoring activities (subject to fair and reasonable commercial terms) | In the event that groundwater trigger criteria detailed in Outcome 1 or Outcome 2 are triggered, visual assessments and collection of leaf water potential would occur quarterly | • Annual compliance assessment report (if the Plan is conditioned under the EP Act) (DWER – Compliance Branch)<br>• Exceedance reporting (on trigger and threshold criteria) (DWER – Compliance Branch)<br>• Reporting on contingencies |
| **Outcome 5**: No adverse impact to vegetation within the Desert Oak Heritage Exclusion Zone | **Trigger Criteria:** A statistically significant[4] difference in vegetation health and condition at designated monitoring sites within exclusion zone 2 (Appendix B) compared to baseline monitoring values over two consecutive monitoring events<br><br>**Threshold Criteria:** A statistically significant[4] difference in vegetation health and condition at designated monitoring sites within the exclusion zone 2 (Appendix B) compared to baseline monitoring values over four consecutive monitoring events and subsequent investigation determine that the impacts are likely a result of the implementation of the proposal | | • **Indicator:** Vegetation health and condition (Appendix B)<br>• **Method:** Visual assessment of vegetation health (photos and visual assessment).<br>• **Location** (Exclusion Zone 2)<br>• The Ngaanyatjarra Ranger Team will be invited to participate in any field-based vegetation health monitoring activities (subject to fair and reasonable commercial terms) | Annual | • Annual compliance assessment report (if the Plan is conditioned under the EP Act) (DWER – Compliance Branch)<br>• Exceedance reporting (on trigger and threshold criteria) (DWER – Compliance Branch) |

[4] A statistically significant difference is determined objectively using accepted statistical techniques with significance (P) set at P<0.5

**Table 13: Preliminary Details of Groundwater Monitoring Bores**

| Monitoring Bore | Nominal Completion Depth (mBGL) | HSU | Purpose |
|---|---|---|---|
| CMB-01 (near Jameson) | <18 m | Garford | Control monitoring bores installed outside of impacted areas. These sites will be used to calibrate observations within the monitoring network and account for natural variability and fluctuations. |
| CMB-02 (Blackstone to Warburton Road) | | | |
| CMB- 03 (southern borefield) | | | |
| CMB- 04 (southern borefield) | | | |
| GDE-01 | 18 to 30 m | Basement | Near mine monitoring bore for GDE Ecological Water Requirements (EWR) and impact assessment |
| GDE-02 | | | |
| GDE-03 | 18 to 30 m | Garford | Near Northern Borefield monitoring bore for GDE EWR and impact assessment |
| GDE-04 | | | |
| GDE-05 | | | |
| GDE-06 | 18 to 30 m | Garford | Nominal GDE control sites (to be confirmed). To confirm observed changes in GDEs are reflective of mining related changes rather than natural climatic variations. |
| GDE-07 | | | |
| HC-01 | 12 to 18 m | Garford | Monitoring bore for assessment of groundwater system response (water quality) to potential leakage from mine waste facilities (TSF and WRD) |
| HC-02 | 18 to 36 m | Garford | |
| HC-03 | | Basement | |
| HC-04 | 12 to 18 m | Garford | |
| MMB-01 | 12 to 18 m | Basement | Monitoring bores for assessment of groundwater system response (water quantity) to mine dewatering and depressurisation, and check against numerical model predictions of 2 m drawdown extent |
| MMB-02 | | Garford | |
| MMB-03 | | Basement | |
| MMB-04 | | Garford | |
| MMB-05 | 18 to 80m | Garford | Monitoring bores installed within the Mining Drawdown footprint for assessment of groundwater system response (water quantity) to borefield abstractions, and check against numerical model predictions of maximum drawdowns for validation purposes (to be compared against defined hydrographs for these locations) |
| MMB-06 | | Basement | |
| MMB-07 | | Basement | |
| MMB-08 | | Garford | |
| BMB-00 | 12 to 18 m | Garford | Compliance bore for assessment of potential impacts south of Linton Bore |
| BMB-01 | | | Monitoring bores for assessment of groundwater system response (water quantity) to Northern Borefield abstractions, and check against numerical model predictions of 2 m drawdown extent |
| BMB-02 | | | |

| Monitoring Bore | Nominal Completion Depth (mBGL) | HSU | Purpose |
|---|---|---|---|
| BMB-03 | | | |
| BMB-04 | | | |
| BMB-05 | | | |
| BMB-06a | 18 to 42 m | Garford | Monitoring bores installed within the Northern Borefield footprint for assessment of groundwater system response (water quantity) to borefield abstractions, and check against numerical model predictions of maximum drawdowns for validation purposes (to be compared against defined hydrographs for these locations) |
| BMB-07a | | | |
| BMB-08a | | | |
| BMB-09a | | | |
| BMB-06b | 150 50 180 m | Padinga | |
| BMB-07b | | | |
| BMB-08b | | | |
| BMB-09b | | | |

## 2.3 Proposed Vegetation Health Assessment

**Table 14: Summary of Potential Terrestrial Groundwater Dependent Ecosystem Health Monitoring**

| Vegetation | Sites | Design | Monitoring Parameters | Method | Monitoring Effort | Timing and Frequency |
|---|---|---|---|---|---|---|
| Confirmed terrestrial GDEs identified between the 0.5 and 2 m water table drawdown contours | Confirmed terrestrial GDEs located between the 2 m and 0.5 m water table drawdown contours associated with mine dewatering and the borefield and a number of pre-determined reference sites | • Quadrates containing 10 mature sample trees in a representation of each GDE identified with the 2 m and 0.5 m contour. Quadrat numbers should allow for suitable statistical analysis and should be determined by an appropriately qualified ecohydrology specialist<br>• Representation of each terrestrial GDE vegetation association present within all water table drawdown contours | Groundwater level | Monitoring bores | Bores in close proximity to confirmed terrestrial GDEs (where available) | Quarterly |
| | | | Leaf water potential | Scholander pressure chamber | Three samples per tree,<br>10 trees per quadrat | |
| | | | Condition and health | Visual assessment (Appendix B) and Normalised Difference Vegetation Index (NDVI). A regional assessment tool will continue to be explored including LiDAR and CSIRO wetness index. | Assessment per site | |

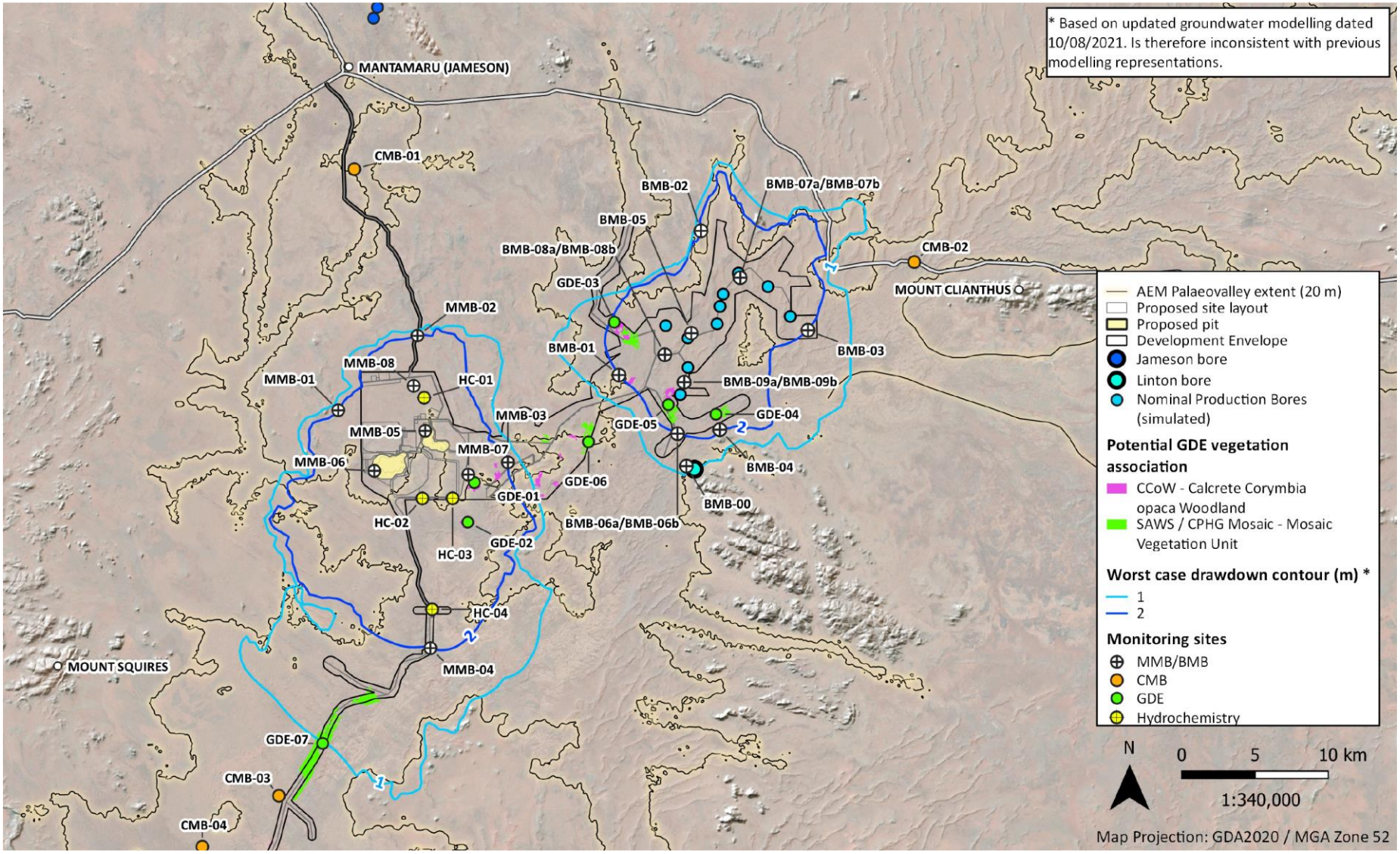


**Figure 6: Proposed Groundwater Monitoring Network**

## 2.4 Implementation of Trigger Criteria Actions

OZ Minerals has developed trigger criteria actions that would be implemented if the associated trigger criterion signals the need for increased mitigation or protection (Table 12). These trigger criteria actions will be implemented by OZ Minerals to mitigate and manage impacts attributable to the project so they once again will meet trigger criteria and safeguard threshold criteria.

## 2.5 Implementation of Threshold Criteria Contingency Actions

OZ Minerals has developed threshold criteria contingency actions that would be implemented if the associated threshold criteria signals that the environmental outcome may be exceeded (Table 12). The threshold criteria contingency actions will be implemented to manage aspects of the project and achieve the environmental outcome and manage any impacts attributable to the project to below trigger criteria and threshold criteria, thereby bringing OZ Minerals back into compliance.

In accordance with Condition 4-5 of Ministerial Statement No. 1188 (20 April 2022), in the event that monitoring or investigations at any time indicate an exceedance of threshold criteria specified in Table 12, OZ Minerals will:

1. Report the exceedance in writing to the CEO of the EPA within seven (7) days of the exceedance being identified
2. Implement the relevant contingency actions described in Table 10, or equivalent, within seven (7) days of the exceedance being reported and continue implementation of those actions until the CEO of the EPA has confirmed by notice in writing that it has been demonstrated that the threshold criteria are being met and implementation of the threshold contingency actions are no longer required
3. Investigate to determine the cause of the threshold criteria being exceeded
4. Investigate to provide information for the CEO of the EPA to determine potential environmental harm or alteration of the environment that occurred due to threshold criteria being exceeded, and
5. Provide a report to the CEO of the EPA within twenty-one (21) days of the exceedance being reported. The report will include:
    a. details of threshold contingency actions implemented
    b. the effectiveness of the threshold contingency actions implemented against the threshold criteria
    c. the findings of the investigations into the causes of the exceedance
    d. measures to prevent the threshold criteria being exceeded in the future

e. measures to prevent, control or abate the environmental harm which may have occurred, and

f. justification of the threshold remaining, or being adjusted based on better understanding, demonstrating that objectives will continue to be met.

## 2.6 Reporting

### 2.6.1 Ngaanyatjarra Council and Ngaanyatjarra People

All reporting discussed in this section will be made specifically available to the Ngaanyatjarra People through the Ngaanyatjarra Council, including where necessary periodic face-to-face meetings to discuss the results and outcomes of monitoring. The Ngaanyatjarra Council will be made aware of any trigger or threshold exceedances within 48 hours of OZ Minerals becoming aware of them.

Where necessary training and support of relevant members of the Ngaanyatjarra People will be supported by OZ Minerals to ensure an understanding of monitoring results and their relevance. Further, opportunities for the involvement of Ngaanyatjarra People in the monitoring activities will continue to be explored as the project is developed.

### 2.6.2 Annual Reporting

A Compliance Assessment Report (CAR) will be submitted to the Compliance Branch at DWER at an agreed date. The CAR will document compliance with conditions of approval including assessment of compliance with management plan requirements where management plans form part of the approval conditions.

Where required, environmental outcomes will be reported against each calendar year in the CAR prepared in accordance with the Post Assessment Guideline for Preparing a Compliance Assessment Report, Post Assessment Guideline No. 3 (OEPA, 2012).

If environmental performance criteria were exceeded during the reporting period, the CAR will include a description of the effectiveness of contingency responses that have been implemented to manage the impact, as well as an analysis of trends.

### 2.6.3 Annual and Triennial Aquifer Review

OZ Minerals will prepare annual and triennial (every three years) groundwater monitoring and management reports for submission to DWER (Swan-Avon Region). The annual and triennial groundwater monitoring and management reports will comply with Operational policy no. 5.12 – Hydrogeological reporting associated with a groundwater well licence (DoW, 2009). The reports will

include an assessment of compliance with the GMMP and may include recommendations for changes to the water management system to maintain compliance with the GMMP.

### 2.6.4 Reporting of Potential Non-Compliances

In the event that monitoring, tests, surveys or investigations indicate an exceedance of a threshold criteria in Table 12, OZ Minerals will report in accordance with the requirements of the relevant Ministerial Statement Condition(s).

# 3 ADAPTIVE MANAGEMENT

Adaptive management is a systematic approach to improving environmental results and management practices during project implementation through the application of learning from monitoring of management actions, or the generation of new information. Adaptive management practices that will be assessed for this management plan include:

- Evaluation of the monitoring program, data and comparison to baseline data and reference sites on an annual basis, or more frequently depending on whether trigger or threshold criteria are exceeded, to verify whether responses to project activities are the same or similar to predictions.
- Evaluation of assumptions and uncertainties of the management and monitoring programs, in particular:
    - Review of results from additional groundwater drilling, and subsequent updates to hydrogeological numerical modelling and their influence on the groundwater drawdown predictions.
    - Review monitoring results against select hydrographs (particularly in priority conservation areas and heritage protection areas in the vicinity of Linton Bore) to confirm that the aquifer is behaving in accordance with hydrogeology model.
    - Review of additional terrestrial GDE work programs described in Table 8 including re-evaluation of threshold criteria and trigger criteria based on whether species are confirmed to be GDEs or not (i.e., Uncertainty 3) and/or demonstrate a statistically significant reduction in health in response to reduced water requirements of less than 2 m (i.e., Uncertainty 4). Should they be required, these changes would be adopted in subsequent revisions of this management plan.
- Re-evaluation of the risk assessment and revision of risk-based priorities resulting from monitoring outcomes (including any updates to the numerical hydrogeology model) as appropriate, including review and updates of trigger criteria and threshold criteria, as necessary.
- Review of data and information gathered over the review period that has increased understanding of the site environment in the context of the regional ecosystem.
- Review of management actions as the project matures and new management measures and technologies become available that may be more effective for environmental management.
- Assessment of changes which are outside the control of the project and the management measures identified (i.e. a new project within the area or region, or regional change that affects management).

In addition, through the adaptive management approach, emerging research and technology will be continuously reviewed to identify further measures to proactively control and mitigate potential impacts to groundwater.

A review of this GMMP will be undertaken following the review of the associated monitoring program and the corresponding results.

### 3.1 Management Plan Review

This GMMP will nominally be reviewed at least every three years from the date of endorsement to ensure that it reflects the then-current situation with regards to groundwater monitoring and management. This GMMP may also be reviewed should any of the following occur:

- As and when directed by the CEO, including (if directed) in consultation with the Ngaanyatjarra Council, as per Condition 4-6(2) of the Ministerial Statement 1188 (20 April 2022).
- The addition or change of infrastructure within the project that has the potential to significantly change the predicted direct or indirect impacts related to groundwater, that was not approved as a part of the project and would require regulatory approval (e.g. the construction of an additional TSF or WRD, the addition of new dewatering or borefield infrastructure).
- Any change in operational practices on site that has the potential to significantly change the predicted direct or indirect impacts related to groundwater, and that was not approved as a part of the project and would require regulatory approval (e.g. an increase in abstraction rate, a change in the construction or operational methodologies associated with the TSF or WRD).
- A change in understanding, status, nature or scale of potential GDEs and/or beneficial users related to this GMMP (e.g. the addition of new third-party groundwater users, identification of additional plant species dependent on groundwater and/or a further understanding of the EWRs and EWPs (WRC, 2000) related to existing identified GDEs).

Any changes to this GMMP may require approval from EPA and may involve consultation with relevant stakeholders.

# 4 STAKEHOLDER CONSULTATION

Extensive consultation has been undertaken associated with the Section 38 Referral under Part IV of the EP Act and thereafter. Details of these consultations are provided in Section 3, Section 6.1.3, Appendix A4 and Appendix A5 of the EPA Section 38 Referral (OZ Minerals, 2021).

Through consultation specifically with the Traditional Owners the following areas were identified as areas of concern to Ngaanyatjarra People, these matters have been specifically considered in this GMMP.

- Potential impacts to community water supply at Jameson (Mantamaru) community 26 km north of the project area. During dedicated on-country consultations, relevant West Musgrave Traditional Owners raised the concern of impacts to the availability and quality of the community water supply at Jameson (Mantamaru), and of the difficulty in understanding the complexities of the groundwater modelling.
- It was noted through consultation with both the Ngaanyatjarra Shire, and with Traditional Owners, that while Linton Bore, which is located 15 km south-east of the Main Development Area, is not inherently significant, it is located on the edge of the Cavanaugh Range which is an important ethnographic area and is also important from a historical perspective. Reduction in access to water at Linton Bore may be perceived as a reduction in the health and vitality of the land to which Traditional Owners feel custodianship and responsibility.
- Potential impacts to tree species resulting from water abstraction e.g. obligate water users. This is particularly apparent for a stand of desert oaks which form part of a significant dreaming trail known as the Marlu dreaming trail located immediately west and south of the Development Envelope. Further, impacts to other potential GDEs may be perceived negatively by the Traditional Owners due to broader cultural associations and custodianship of the land.
- The potential of exposure to mine chemicals either reagents, or through the production of deleterious waste generated from leachate of rock materials.

Consultation specific to this GMMP includes internal peer review with subject-matter experts (MBS Environmental, CDM Smith and AQ2) and meetings with the Government of Western Australia's DWER and EPA.

Multiple reviews of the GMMP have been undertaken by the Ngaanyatjarra Council (environmental and hydrogeological consultant). All relevant feedback acquired during consultation has been considered in the development of this management plan.

# 5 UPDATES TO THE EMP

Revision 3, dated July 2022: First revision after Ministerial Statement granted. Updated to reflect Implementation Conditions associated with the granting of Ministerial Statement 1188, published 20 April 2022, specifically Conditions 4-1 through 4-7 inclusive, as described in Table 1.

# 6 REFERENCES

ANZECC. 2000. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality Volume 1 The Guidelines*. Australian and New Zealand Environment and Conservation Council, Canberra.

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# APPENDICES

# Appendix A GDE Assessment Review

Level 4, 56 William Street
Perth WA 6000

Tel +61 8 9322 9733
www.aq2.com.au

AQ2 Pty Ltd
ABN 38 164 858 075

# Memo

| | | | |
|---|---|---|---|
| **To** | Justin Rowntree | **Company** | Oz Minerals |
| **From** | Duncan Storey / Shane Chalwell | **Job No.** | 314 |
| **Date** | 20/03/2021 | **Doc No.** | 020a |
| **Subject** | Groundwater Dependant Ecosystem Assessment | | |

## 1. BACKGROUND

Oz Minerals (OM) are developing the West Musgrave copper nickel project, in the interior of Western Australia. Prefeasibility studies and environmental approvals have been undertaken and OM are now completing a Definitive Feasibility Study and the environmental management plans that are required to comply with approval conditions. The project area is characterised by shallow groundwater levels and "desert" vegetation; 38 vegetation communities were identified predominantly comprising *Acacia sp* with a *Triodia sp* understorey. In some areas *Melaleuca glomerata* and scattered *Corymbia opaca* also occur within the *Acacia* spp. communities; *M.glomerata* and *C.opaca* have been associated with groundwater dependent ecosystems (GDE) elsewhere. Groundwater modelling has shown that groundwater levels will be drawn-down over parts of the project area, by the combined effects of dewatering and water supply abstraction. One of the environmental conditions requires that terrestrial vegetation will not be affected by drawdown, outside of the <2m groundwater level drawdown zone. To quantify groundwater-vegetation risks, a preliminary desk-top assessment to identify potentially groundwater dependent ecosystems in the project area, was undertaken by CDM Smith (March 2020). This study identified that: 1. the spatial extent of vadophytic vegetation is much greater than potentially phreatophytic vegetation; 2. notwithstanding, potential groundwater use by vegetation occurs in 8 of 35 vegetation communities identified in the project area; and 3. if it does occur, groundwater use is likely to be facultative rather than obligate.

Oz Minerals have asked AQ2 to undertake a review of the assessment of at-risk GDEs completed by CDM Smith. The memo presents a brief summary and review of the previous work and provides recommendations for field measurements to reduce uncertainty and risk in the GDE assessment.

## 2. GDE ASSESSMENT UNDERTAKEN

### 2.1 Vegetation Survey

Western Botanical (2020) identified three associations as potential GDEs within the West Musgrave Project area based on landscape position, species assemblage and the presence of species known to access deep water. These communities were:

- Calcrete *Corymbia opaca* Woodland (CCoW), which occurs over 455 ha of deep sandy swales. Dominant tree and shrub species include *Corymbia opaca, Eucalyptus intertexta, Melaleuca glomerata, Acacia kempeana,* and *Acacia ligulata*.

- *Melaleuca glomerata* with *Acacia kempeana* Shrubland (MgAkS), which occupies 911 ha in the surveyed area and occurs as stands within the broader *Triodia* hummock grasslands.

- Low Mallee Woodland (LMW), which occurs across 4400 ha on calcrete platforms with deep sandy soil and mainly consists of *Eucalyptus gamophylla* and *Eucalyptus oxymitra* patches within a *Triodia basedowii* grassland.

There is also an additional 1765 ha of potential GDE where these associations form as mosaics with other vegetation units.

Analysis by CDM Smith added more communities to the list of potential GDEs based on the height of dominant tree and shrub species and the depth to groundwater. In particular, communities that contain *Corymbia opaca, Eucalyptus intertexta, Melaleuca glomerata, Eremophila duttonii, Acacia maitlandii, Acacia melleodora, Eucalyptus gamophylla* and/or *Hakea lorea* are potential GDEs as these species have been identified as possible groundwater users.

### 2.2 GDE Assessment

CDM Smith undertook a desk-top identification of potential GDEs in the project area (March 2020). The work adopted a 3-staged approach, following the framework presented in the Australian GDE Toolbox (Richardson et al 2011) and involves the increasing focus on areas of potential GDE.

The study combined:

- Vegetation mapping and potentially phreatophytic species (as identified in published literature).
- Depth to groundwater (with shallow depth to groundwater (<2 mbgl) increasing the likelihood of groundwater use).
- Remote sensing data to assess the persistent greenness of each vegetation community.
- Changes in groundwater salinity along flow-lines that may indicate evapotranspirative concentration of salts in groundwater.

The review identified 8 vegetation communities that may use groundwater, within the study area. One of these 8 was defined as a likely obligate phreatophyte while the remainder were defined as potential facultative phreatophytic systems. The 8 vegetation communities covered a relatively small portion of the overall project area (which comprises 35 vegetation communities in total).

The obligate GDE related to the presence of *Eremophila duttonii* shrubland.

Three of the potential facultative GDEs are associated with the presence of calcrete in the substrate with varying keystone vegetation species (including *Corymbia opaca*). Two of the potential GDEs relate to the presence of *Melaleuca glomerata* and the remaining two relate to the presence of various *Acacia sp.*

### 2.3 Review and Comment

The desk-top assessment includes the following assumptions and / or limitations:

- The study focusses on the simple presence rather than abundance of potentially phreatophytic keystone species (which is appropriate from an ecological values perspective). The study assumes the presence of a potential phreatophytic species implies a potential GDE; no account is taken of species density. Species that are present a very low density (if they are keystone species) have the opportunity to develop extensive lateral roots and will have access to large volumes of soil water. In particular, it is noted that the *Corymbia opaca* woodland comprises only 2% tree cover which may allow extensive lateral tree roots. This means the desk top study is likely to be conservative (i.e., identified a larger area of GDE potential than may be the case).
- The determination of the potential for a species to use groundwater is based primarily on a detailed literature review as presented in Appendix A of the report (combined with project specific vegetation mapping). However, the basis of the listed conclusion by the studies in the appendix is not always clear nor is the application of any local context. This means the

desk top study is likely to be conservative (i.e., identified a larger area of GDE potential than may be the case).

- The desk top study notes the limitations of remote sensed data due to pixel size in the data set compared to the relative vegetation density. Over the observed data periods, all vegetation communities (both potentially GDE and non GDE) have relatively similar "greenness indices" (i.e., there is little differentiation). Also, the greenness index is generally higher in a wet period than a dry period. Overall, the greenness index assessment is not a strong diagnostic tool in this circumstance.

- The desk-top assessment does not consider potential causes of the increase in salinity through the project area, other than to note it is a potential indicator of evapotranspirative concentration (which is the case). The extent and scale of salinity increase is interesting though at odds with the extent that may be expected given the relatively small area of potential GDE and low-density vegetation within the potential GDE areas. This warrants further consideration.

- At desk-top level, the study could not consider the ecohydrological water balance and plant-available water. The study has identified areas of risk that require further investigation that will allow application of local context (such as vadose zone plant available water and vegetation density).

## 3. RECOMMENDATIONS

The following recommendations are made to add more confidence to important assumptions that have been used in the work and the assessment of probable GDEs:

- Key aspects of the conceptual ecohydrological model should be measured so that the water fluxes within the system can be quantified:

    - The actual density of trees that may use groundwater within each system should be quantified. This will involve measurements of stand basal area (SBA - trunk or stem ($m^2$) per unit area (ha)) in an appropriate quadrat sampling program.

    - The size of each stem should also be measured, and a size-class distribution (SCD) developed.

    - DBH / SCD / SBA should be recorded by species.

    - For each DBH measurement, sapwood should also be sampled through coring. This will allow a relationship between SBA and sapwood-area to be developed.

    - Pre-dawn and midday leaf water potential measurements should be collected from representative trees to gain an understanding of pre-dawn water status, hydraulic gradients that are driving transpiration, diurnal rehydration, and water stress. Based on the principle of nocturnal hydraulic equilibration between the root zone and soil matric pressure, pre-dawn leaf water potential can also provide an indication of plant water source.

    - Soil water, groundwater and plant xylem water samples should also be subject to isotopic analysis. The comparison of isotopic indicators will provide insight into the relative contribution of each water source to plant available water.

    - Hand-auguring within the potential GDE areas should be attempted to collect soil samples (although it is noted that the presence of hard-pans may limit auger penetration). Samples should be analysed for particle size distribution (including hydrometer analysis for the fines fraction) and moisture content; the latter should

be achievable if the samples are weighed and sealed in the field and then oven-dried in the laboratory.

- Data loggers should be installed in groundwater monitoring bores close to potential GDEs and set for relatively high frequency monitoring (e.g., 10-minute intervals) over a diurnal cycle. A diurnal rise and fall in groundwater level can often be discerned where transpiration from the water table is occurring.

- Develop a quantified conceptual model based on analysis of the above data. Key aspects of this should include:
  - Estimates of stand-level transpiration based on SBA or sapwood area measurements, and published transpiration estimates for the relevant species.
  - Estimate of vadose zone hydraulic properties using pedogenic transfer functions and the soil PSD data. Properties should include matric pressure / moisture content relationships, capillary rise, and unsaturated hydraulic conductivity; the latter will influence the ability for significant water migration to support the capillary fringe or shallow PAW.
  - Estimates of tree water source and water status using the LWP and isotopic data.
  - LWP and isotope data combined with groundwater level data should be used to estimate likely root zones / root depths for the potentially phreatophytic species. In this regard it should be noted that: root systems cannot tolerate permanent saturation and so the persistent groundwater level represents a lower limit to the root depth. Also, the lower the pre-dawn leaf water potential, the drier (and further from the capillary fringe) the root zone is likely to be. Conservatively, if pre-dawn LWP is less than -0.5 MPa, then groundwater connection is very unlikely.
  - A representative rainfall sequence (with respect to frequency and magnitude) should be developed (or adopted from surface water studies that have been completed as part of the project).

- A Hydrus-based numerical ecohydrological model should be developed to simulate the conceptual model as developed above. The model should include the groundwater table as a lower boundary condition and incorporate high levels of root-compensation (which is a common desert phreatophyte adaptation). The prime water input to the model will be the representative rainfall sequence. The modelled "soil" should cover the range as determined from the hand-auguring exercise. The model should be calibrated against all observed and inferred characteristics of the system including:
  - Depth to groundwater and inferred rates of groundwater recharge.
  - Soil moisture content.
  - Transpiration rates.
  - Modelled matric pressure can be compared with observed pre-dawn leaf water potential and used to calibrate both water availability and root depth.

- For unsaturated zone ecohydrological modelling, it is often the case that the combination of model parameters that simulate the observed outcome is unique i.e., each input parameter can only vary through a small range before the model is no longer consistent with field observations. Thus, the model provides a good verification tool for the conceptual model.

- The combination of field data, quantified conceptual model and numerical model should be used to confirm the likelihood and extent of groundwater use for each potential GDE type.

- The model should also be used to simulate the rate and extent of groundwater drawdown that is predicted from associated groundwater modelling. If groundwater use is important to the systems, then rates of transpiration will decline as less groundwater is available. The decline can be correlated to both loss in areal extent (i.e. reduction in SBA) and loss in key species if the model simulates that key matric pressure thresholds are exceeded i.e. if the model simulates prolonged periods with matric pressure below the point at which a tree may lose turgor or suffer embolism, then that species may be at risk.

- In parallel, a review of groundwater salinity and the major ions that compose the groundwater should be undertaken to provide more insight on the increase in groundwater salinity from north to south through the project area. This should include available information on soil, shallow geology and vegetation cover to determine causative factors.

We trust this review meets with your immediate requirements and provides an indication of the next steps to increase confidence and quantification in the understanding of the groundwater-vegetation interaction at West Musgrave. Should you require any further information, please do not hesitate to contact us.

Regards

***Shane Chalwell***

Consulting Ecologist

***Duncan Storey***

Director / Consulting Hydrogeologist

Author: DGS (01/06/21)
Checked: DGS (01/06/21)
Reviewed: DGS (01/06/21)

# Appendix B Vegetation Health Monitoring Guidelines

## B.1 Purpose

The trigger criteria and threshold criteria identified in the GMMP to manage potential impacts to environmental values, namely terrestrial groundwater dependent ecosystems (GDEs) are based on a number of assumptions and uncertainties. In particular, the GMMP relies on limited, to no impact to terrestrial GDEs outside of the 2 m water table drawdown contour. As such the GMMP has developed trigger criteria and threshold criteria aimed at ensuring that water table drawdown does not extend beyond the predicted modelled contours, and should trigger criteria and threshold criteria indicate an exceedance, a number of contingencies have been proposed to bring groundwater conditions within acceptable limits.

This vegetation health monitoring guideline provides a standardised framework for quantifying vegetation health, and changes to vegetation health over time, should groundwater threshold criteria identified in Table 9 of the GMMP be exceeded.

## B.2 Baseline Survey

A baseline monitoring survey of potential terrestrial GDEs identified within the predicted 0.5 m water table drawdown contour will occur prior to commissioning of water affecting activities. This baseline will assist in measuring change that may be attributed to project activities. The baseline survey will occur using representative quadrats containing ten mature trees within each terrestrial GDE association and a vegetation health and conditional assessments will be completed, as detailed in Table B1. Should the baseline survey of potential terrestrial GDEs confirm that no GDEs are present, no further vegetation health assessments would occur.

## B.3 Vegetation Health and Condition Assessment

### B.3.1 Vegetation Health Monitoring Parameters and Methods

A set of monitoring parameters and methods has been selected to provide broad coverage of potential changes in vegetation health that may be expected at WMP (Table B1). The advent of new technology may result in changes to sampling methods and analyses employed.

**Table B1: Vegetation Health Monitoring Parameters and Methods**

| No. | Monitoring Parameter | Method |
|---|---|---|
| **Baseline Establishment** | | |
| 1. | Water table monitoring | Construct water table monitoring bore, and gauge depth to water table using an electronic water level dip meter |
| 2. | Condition and Health | Visual assessment of vegetation health (Table B2) |
| | | Remote sensing assessment of condition and health (Section B.3.3) |
| 3. | Water potentials: Leaf water potential | Collect leafy shoots at pre-dawn and midday from mid-canopy to be tested for water potential using a pressure chamber |
| 4. | Stable isotopes of water | Collect twig, soil (at 0.5 m intervals) and groundwater samples and submit to a NATA-registered laboratory for analysis of stable isotopes of water in plant xylem, soil water and groundwater |
| 5. | Photo point monitoring | Photos taken from fixed points |
| 6. | Meteorological data | Data from weather stations installed near monitoring sites |
| **Ongoing Assessment** | | |
| 1. | Water table monitoring | Gauge depth to water table using an electronic water level dip meter |
| 2. | Condition and Health | Visual assessment of vegetation health (Table B2) |
| | | Remote sensing assessment of condition and health (Section B.3.3) |
| 3. | Leaf water potential | Leafy shoots are collected pre-dawn and midday from mid-canopy to be tested for water potential using a pressure chamber |
| 4. | Photo point monitoring | Photos taken from fixed points |
| 5. | Meteorological data | Data from weather stations installed near monitoring sites |

### B.3.2 Vegetation Condition and Health

Vegetation condition and health of potential terrestrial GDEs is assessed using Souter et al (2010) condition rating (Table B2).

**Table B2: Vegetation Health Assessment for Trees and Shrubs (adapted from Souter et al, 2010)**

| Score | Health Ranking | Health Rating/Description |
|---|---|---|
| **Crown Extent and Density** | | |
| 0 | 0% | None |
| 2 | 1–10% | Minimal |
| 3 | 11–25% | Sparce |
| 4 | 26–75% | Medium |
| 5 | 91–100% | Major |
| **Epicormic Growth** | | |
| 1 | Absent | Effect is not visible |
| 2 | Scarce | Effect is present within the assessable crown but not readily visible |
| 3 | Common | Effect is clearly visible through the assessable crown |
| **New Tip Growth Scores** | | |
| 1 | Absent | Effect is not visible |
| 2 | Scarce | Effect is present within the assessable crown but not readily visible |
| 3 | Common | Effect is clearly visible through the assessable crown |
| **Reproduction Scores** | | |
| 1 | Absent | Effect is not visible |
| 2 | Scarce | Effect is present within the assessable crown but not readily visible |
| 3 | Common | Effect is clearly visible through the assessable crown |
| **Leaf Die-off** | | |
| 1 | Absent | Effect is not visible |
| 2 | Scarce | Effect is present within the assessable crown but not readily visible |
| 3 | Common | Effect is clearly visible through the assessable crown |
| **Presence of Mistletoe** | | |
| 1 | Absent | Effect is not visible |
| 2 | Scarce | Effect is present within the assessable crown but not readily visible |
| 3 | Common | Effect is clearly visible through the assessable crown |
| **Bark Condition** | | |
| 0 | Intact | Intact bark |
| 1 | Minor | Minor cracks |
| 2 | Moderate | Moderate bark cracks |
| 3 | Extensive | Extensive bark cracks |
| 4 | Absent | Long-term dead tree |

### B.3.3 Multi-Spectral Imagery

Vegetation health can be measured using remotely-sensed data. There are a number of Indices that can be used, currently the most commonly applied is the Normalised Difference Vegetation Index (NDVI) but other indices may be used as they are developed to provide the most appropriate approach.

NDVI is a vegetation index derived from multispectral imagery to provide a quantitative measure of plant health/vigour. NDVI is a modulation ration between near infra-red (NIR) and red radiation as per the formula NDVI = (NIR – red)/ (NIR +red). Values range from -1 (red dominant) to 1 (NIR dominant). Healthy green vegetation (chlorophyll content) exhibits low red and high NIR reflectance, resulting in positive NDVI values. The multispectral imagery used to derive NDVI measurements is generally captured to a spatial resolution of 0.5 m.

## B.4 Statistical Analysis

Data will be handled in accordance with the data handling protocol developed by OZ Minerals for the project. The protocol will include the requirements as to data storage and protection, data extraction, quality control, analysis, interpretation, reporting and presentation.

Statistical analysis of data will be undertaken where data quantity and quality permits. Where data capture allows, analysis will include univariate or multivariate analysis, as deemed appropriate, to determine whether there are any statistical variations in monitoring data.

A statistically significant difference will be determined objectively using accepted statistical techniques with significance (P) set at $P<0.05$.

Statistical analysis methods for vegetation health monitoring may include:

- Scatterplots for assessing relationships between parameters including identification of situations where statistical inference is not feasible
- Statistical tests such as parametric tests for difference between means (T test, ANOVA) and non-parametric test (Kruiskal Wallas etc.)
- Least Square Means plots (with error bars) may also be used to help interpret p-value results with 95% confidence intervals of the difference between treatments also considered.

### B.4.1 Vegetation Health Monitoring Program Review

This vegetation health and condition monitoring guideline will be reviewed and updated in-line with Section 2.3 of the GMMP.

## B.5 References

Souter N.J., Cunningham S., Little S., Wallace T., McCarthy B. and Henderson M. (2010). *Evaluation of a visual assessment method for tree condition of eucalypt floodplain forests*. Ecological Management and Restoration. Volume 11, No. 3. December 2010.

# Appendix C Vegetation Survey Extent

A summary of total vegetation surveyed within, and outside 'worst case' drawdown contours is shown in Table C1 and Table C2 and Figure C1, along with the total number of hectares of vegetation that remain unsurveyed in each of these drawdown contours. The total potential terrestrial groundwater dependent vegetation recorded during flora and vegetation surveys is provided in Figure C2.

**Table C1: Vegetation surveyed within the 2 m drawdown contour**

| Total Vegetation Surveyed | Total area of 2 m groundwater drawdown contours | Survey inside 2 m groundwater drawdown contour | Survey outside 2 m groundwater drawdown contour | Ha within 2 m drawdown contour that remain unsurveyed |
|---|---|---|---|---|
| 46,263 ha | 40,256 ha | 19,861 ha | 26,402 ha | 20,396 ha (50.7%) |

**Table C2: Vegetation surveyed within the 0.5 m drawdown contour**

| Total Vegetation Surveyed | Total area of 2 m groundwater drawdown contours | Survey inside 0.5 m groundwater drawdown contour | Survey outside 0.5 m groundwater drawdown contour | Ha within 0.5 m drawdown contour that remain unsurveyed |
|---|---|---|---|---|
| 46,263 ha | 111,110 ha | 29,026 ha | 17,037 ha | 81,884 ha (73.7%) |

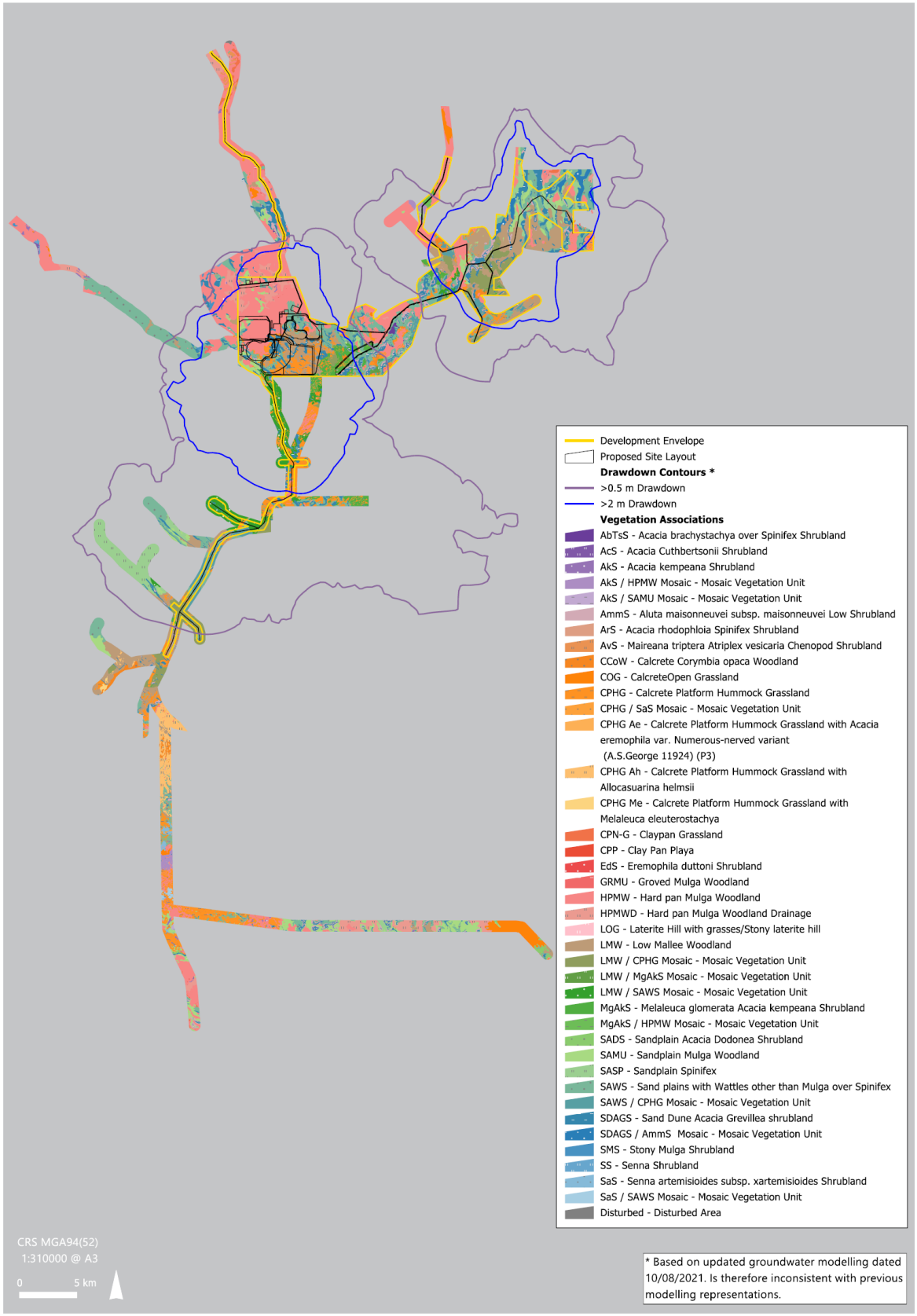


**Figure C1: Total vegetation surveys inside and outside 2 m and 0.5 m drawdown contours**

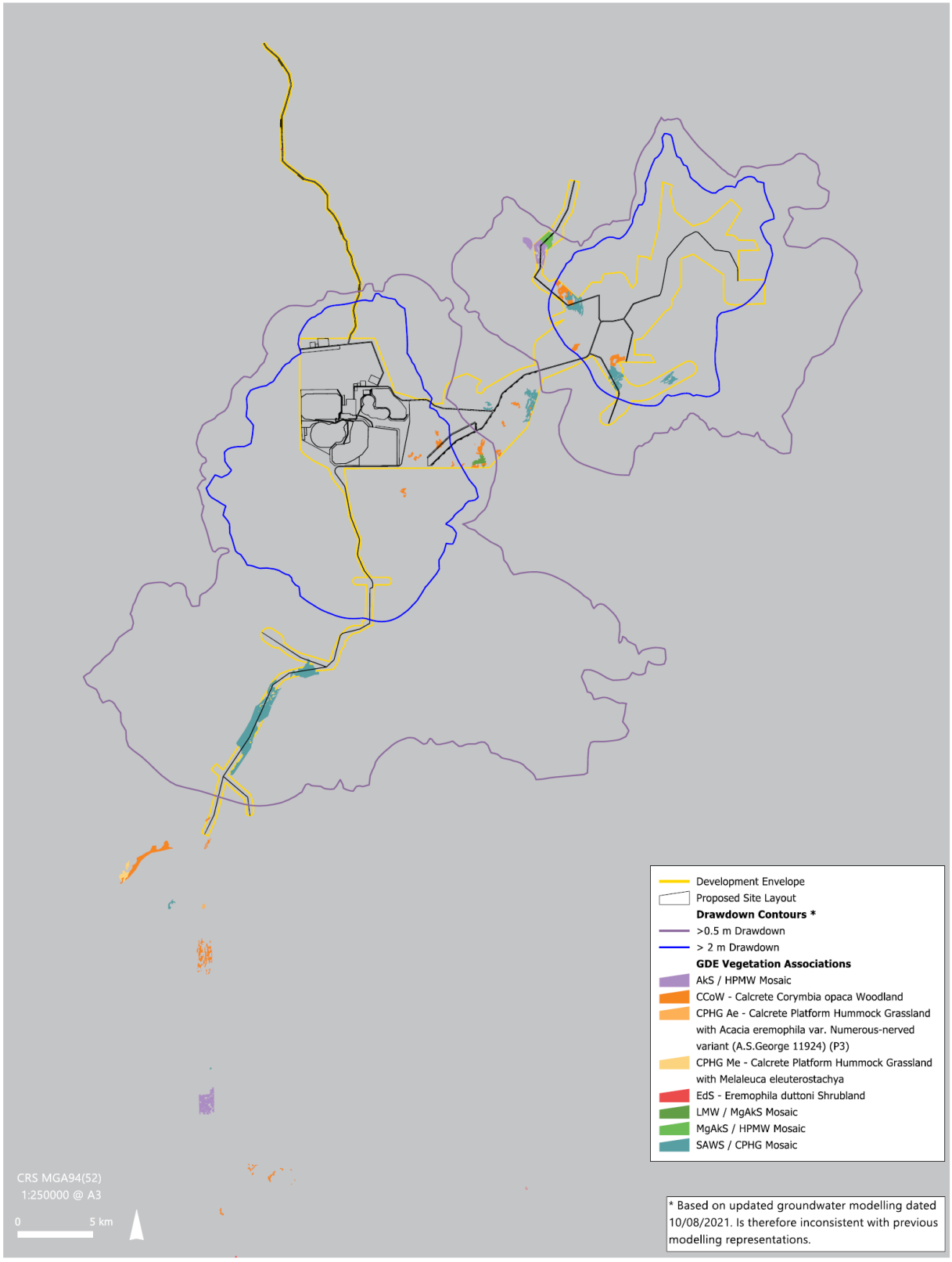


**Figure C2: Total Potential Terrestrial Groundwater Dependent Vegetation recorded during Flora and Vegetation Surveys**