Groundwater Dependent Ecosystem (GDE) Monitoring and Management Plan

Lake Vermont – Meadowbrook Project

Prepared for

Bowen Basin Coal *on behalf of* AARC Pty Ltd

Prepared by

3d Environmental

Rev 3_05 October 2023.

3D Environmental
Landscape & Vegetation Science

Project No. 2023_9

Project Manager: David Stanton

Client: Bowen Basin Coal Pty Ltd / AARC Pty Ltd

Purpose: Groundwater dependent ecosystem monitoring and management plan for the Lake Vermont – Meadowbrook Project

Draft	Date Issued	Issued By.	Purpose
Revision 1	30 August 2023	David Stanton	First Draft GDEMMP for comment.
Revision 2	18 September 2023	David Stanton	Second draft incorporation updates and stygofauna management plan
Revision 3	05 October 2023	David Stanton	Final Document

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Contents

Figures

Tables

List of Abbreviations

Abbreviation	Description
DCCEEW	Department of Climate Change, Energy, Environment and Water (Commonwealth)
DES	Department of Environment and Science (Qld)
DoEE	Department of Environment and Energy (Commonwealth)
EA	Environmental Authority
EIS	Environmental Impact Statement
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth)
EPBC Approval	Approval granted by the Commonwealth under the EPBC Act
EP Act (Water)	Environmental Protection Act (Qld) 1994
ESCP	Erosion and Sediment Control Plan
EWR	Environmental Water Requirement
GDE	Groundwater Dependent Ecosystem
GDEMMP	Groundwater Dependent Ecosystem Monitoring and Management Plan
GMMP	Groundwater Management and Monitoring Plan
LAI	Leaf Area Index
LWP	Leaf Water Potential
ML	Mining Lease
MNES	Matters of National Environmental Significance, as defined under the EPBC Act.
NDVI	Normalised Difference Vegetation Index
PER	Public Environment Report
REMP	Receiving Environment Monitoring Program
SMP	Soil Moisture Potential
WMP	Water Management Plan

Glossary

Alluvial aquifer	An aquifer comprising unconsolidated sediments deposited by flowing water usually occurring beneath or adjacent to the channel of a river.
Aquifer	A geological formation or structure that stores or transmits water to wells or springs. Aquifers typically supply economic volumes of groundwater.
Base flow	Streamflow derived from groundwater seepage into a stream.
Capillary fringe	The unsaturated zone above the water table containing water in direct contact with the water table though at pressures that are less than atmospheric. Water is usually held by soil pores against gravity by capillary tension.
Confined aquifer	A layer of soil or rock below the land surface that is saturated with water with impermeable material above and below providing confining layers with the water in the aquifer under pressure.
Perched groundwater system	A groundwater system or aquifer that sit above the regional aquifer due to a capture of infiltrating moisture on a discontinuous aquitard.
Phreatic zone	The zone of sub-surface saturation separated from the unsaturated zone in unconfined aquifers by the water table.
Phreatophyte	Plants whose roots extend downward to the water table to obtain groundwater or water within the capillary fringe.
Obligate phreatophyte	A plant that is completed dependent on access to groundwater for survival.
Evapotranspiration	The movement of water from the landscape to the atmosphere including the sum of evaporation from the lands surface and transpiration from vegetation through stomata.
Facultative phreatophyte	A plant that occasionally or seasonally utilises groundwater to maintain high transpiration rates, usually when other water sources are not available.
Fractured rock aquifer	An aquifer in which water flows through and is stored in fractures in the rock caused by folding and faulting.
Fluvial	Relating to processes produced by or found in rivers.
Groundwater	Those areas in the sub-surface where all soil or rock interstitial porosity is saturated with water. Includes the saturated zone and the capillary fringe.
Water table	The upper surface of the saturated zone in the ground, where all the pore space is filled with water.
Groundwater dependent ecosystems (GDE)	Natural ecosystems which require access to groundwater on a permanent or intermittent basis to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services (Richardson et al. 2011).
Infiltration	Passage of water into the soil by forces of gravity and capillarity, dependent on the properties of the soil and moisture content.
Leaf water potential (LWP)	The total potential for water in a leaf, consisting of the balance between osmotic potential (exerted from solutes), turgor pressure (hydrostatic pressure) and matric potential (the pressure exerted by the walls of capillaries and colloids in the cell wall).
Leaf area index (LAI)	The ratio of total one-sided area of leaves on a plant divided by the area of the canopy when projected vertically on to the ground.
Percolation	The downward movement of water through the soil due to gravity and hydraulic forces.
Permeability	A materials ability to allow a substance to pass through it, such as the ability of soil or rocks to conduct water under the influence of gravity and hydraulic forces.
Preferential flow	Movement of surface water rapidly from surface to aquifer along preferential flow paths, bypassing older moisture in the upper soil profile.
Unconfined aquifer	An aquifer whose upper surface is at atmospheric pressure, producing a water table, which can rise and fall in response to recharge by rainfall.

Soil water potential	A measure of the difference between the free energy state of soil water and that of pure water. Essentially a measure of the energy required to extract moisture from soil.
Stable isotope	An isotope that does not undergo radioactive decay.
Surface water	Movement of water above the earths' surface as runoff or in streams.
Transpiration	The process of water loss from leaves, through stomata, to the atmosphere.
Terrestrial GDE	Terrestrial vegetation supported by sub-surface expression of groundwater (i.e. tree has roots in the capillary fringe of groundwater table).
Vadose zone	The unsaturated zone, above the water table in unconfined aquifers.
Water Potential	The free energy potential of water as applied to soils, leaves plants and the atmosphere.

1.0 Introduction

1.1 Background

3d Environmental has been engaged by Bowen Basin Coal Pty Ltd (the 'Proponent') to prepare a Groundwater Dependent Ecosystem (GDE) Monitoring and Management Plan (GDEMMP) for the proposed Lake Vermont – Meadowbrook Project (The Project). The Project proposed to mine underground metallurgical coal and proposes a small open-cut pit towards the final stages of the mine on tenure that immediately adjoins the northern boundary of the existing Lake Vermont Mine, 25 kilometres (km) northeast of the township of Dysart and 160 km southwest of Mackay. The Project area occupies Mineral Development Licence (MDL) 429 and MDL303 (**Figure 1**).

As a component of the approval process for The Project, a Groundwater Dependent Ecosystem (GDE) assessment was undertaken by 3d Environmental (2023a) which identified the presence of Terrestrial GDEs (TGDEs) associated with the riparian fringe of Boomerang and Phillips Creek, as well as the likelihood of groundwater dependent vegetation associated with a High Ecological Sensitivity (HES) wetland within the area of predicted groundwater drawdown. This GDEMMP has been developed in response to this finding.

1.2 Purpose of the Management Plan

This GDEMMP has been prepared to address and manage the uncertainties associated with the environmental impacts of the Project on GDEs through the development of consistently applied monitoring actions, analysis and reporting of data trends. Corrective actions (mitigations) are described for implementation when statistically significant impacts on GDE function caused by mining activity are detected. The plan is to be used as a reference for management actions prior to construction, during construction and operation, extending though stages of project rehabilitation, decommission and post operation. As this plan applies to a specific two-year 'baseline' assessment phase of monitoring an additional purpose is to provide increased certainty to the findings of the EIS assessment (3d Environmental 2023a), ensuring that post baseline GDE monitoring focuses specifically on ecosystems that are groundwater dependent. The GDEMMP also includes a stand-alone plan for management and monitoring of values for Stygofauna, prepared by AARC (2023c) based on findings of Stygoecologica (2022) and included in **Appendix A**.

1.3 Objectives

Objectives of this GDEMMP are described as follows:

1. Characterise GDEs that are likely to be impacted by The Project in terms of ecological function, interaction with surface water and interaction with groundwater as presented in 3d Environmental (2023a).
2. Provide a synopsis of the potential risks to GDE integrity posed by project related mining activities and address uncertainties in GDE response and function that may be resolved through longer-term temporal monitoring.
3. Identify biophysical parameters that can be applied to the monitoring of GDE function that can be repeated objectively and consistently throughout the life of the mining project to measure GDE health.
4. Describe the most appropriate actions to measure changes to biophysical function of GDEs that may indicate a decline in GDE health and provide a statistically robust framework that

can demonstrate whether impacts to GDEs are associated with mining activities or influenced by natural variation.

5. Develop triggers that may be used to initiate the application of corrective actions, which can be refined over time as monitoring data is collected.
6. Develop a suite of corrective actions that may be applied to ameliorate impacts to GDEs and prevent or repair declining GDE health.
7. Provide additional actions for the monitoring and management of stygofauna communities as presented as a stand-alone plan in **Appendix A**.

1.4 Relevant Legislation

The Project will be assessed under the bilateral agreement between the Commonwealth and the State of Queensland using the EIS prepared under the EP Act, and it is intended that this GDEMMP satisfies both state and federal provisions.

1.4.1 Queensland Legislation

Environmental Protection Act 1994: Bowen Basin Coal was granted EA approval under the Environmental Protection Act 1994 (EP Act) for the Lake Vermont Mine for 5 million tonnes per annum (Mtpa) run of mine (ROM) coal with ML 70331 granted in October 2005. Construction and mine development activities are scheduled to commence subject to and following the approval of the proposed amendments to the existing environmental authority (EA) and granting of an ML over the existing MDL 303 and MDL 429. In July 2019 Bowen Basin Coal applied to the Department of Environment and Science (DES) under sections 70 and 71 of the EP Act for approval to voluntarily prepare an EIS. This application was supported by the preparation of an Initial Advice Statement, outlining the resource, operations and infrastructure of the proposed Project. Under section 72 of the EP Act, DES approved the application on 26 August 2019.

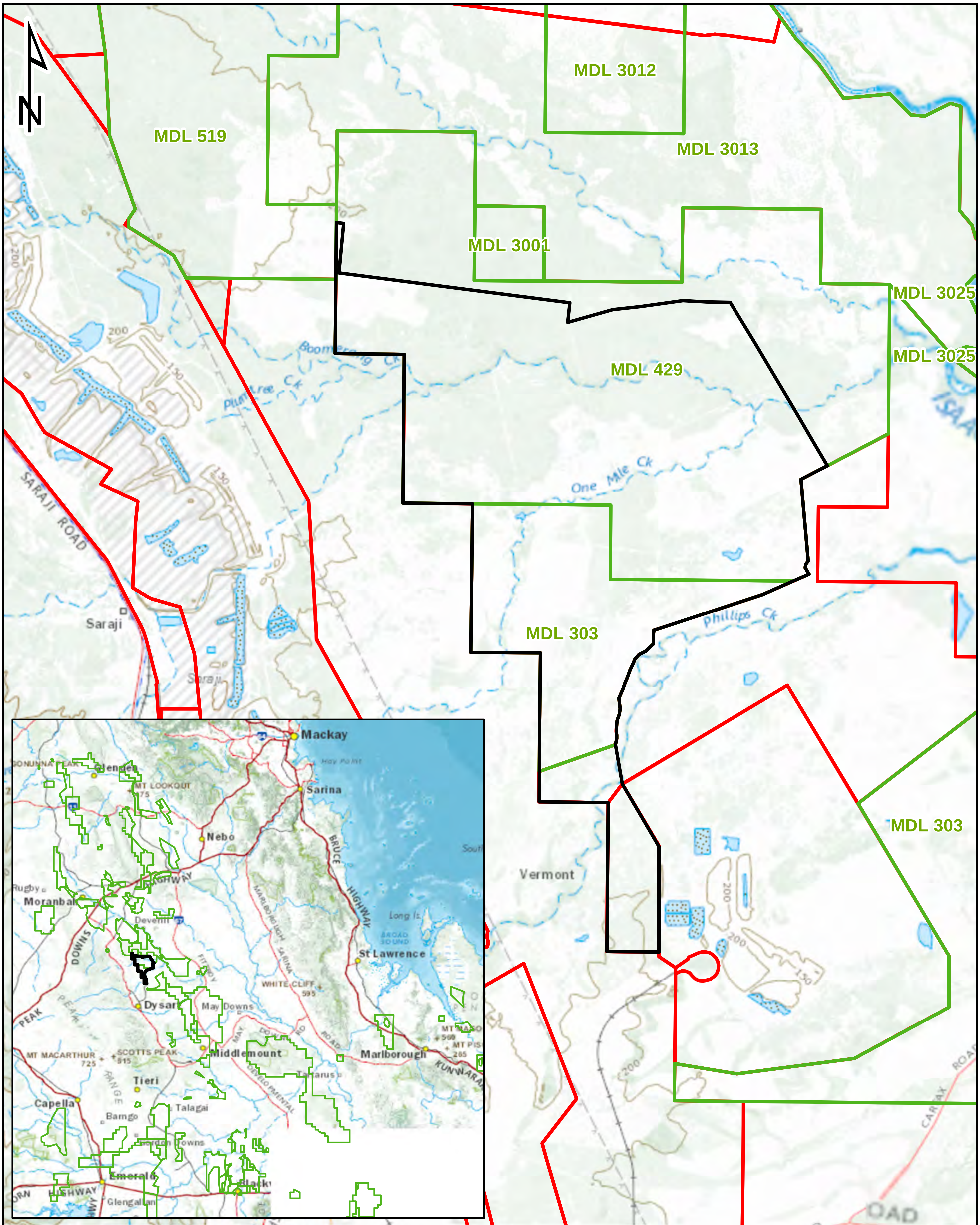
1.4.2 Federal Legislation

Environment Protection and Biodiversity Conservation Act 1999: The Project was referred on 23rd July 2019 to the Commonwealth Department of the Environment and Energy (DoEE) (EPBC 2019/8485). On 22nd November 2019, the Minister for the Environment determined the Project to be a controlled action under the EPBC Act. The controlling provisions are sections 18 and 18A (listed threatened species and communities), sections 20 and 20A (Listed migratory species) and sections 24D and 24E (a water resource, in relation to coal seam gas development and large coal mining development). The Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act) provides for the protection of environmental values, prescribed under the Act as Matters of National Environmental Significance (MNES). Any action that will or may cause a significant impact on MNES is subject to assessment approval process under the EPBC Act. In June 2013, the EPBC Act was amended to capture water resources as MNES. Under the amendment, water resources include groundwater and surface water, and organisms and ecosystems that depend on it to maintain ecological function and condition. These ecosystems are otherwise termed GDEs and are captured under the water trigger. The regulatory guideline *Significant impact guidelines 1.3: Coal seam gas and large coal mining developments – impacts on water resources (DoEE 2013a)* identify a 'significant impact' as 'an impact which is important, notable, or of consequence, having regard to its context or intensity'. This GDEMMP addresses the uncertainties that are associated with the nature and significance of impacts to GDEs through provision of comprehensive monitoring protocols, including development of 'early warning' triggers which can be used to identify a decline in GDE health.

1.5 Relationship with other plans and management controls

This GDEMMP interacts with the following impact assessments and plans which directly aim to monitor, avoid and / or minimise impact to water and ecology:

1. **Lake Vermont Water Management Plan (LVWMP):** Water management measures are contained in the LVWMP which provides an overarching mechanism for:
    a. Groundwater monitoring and management including
        i. The establishment of groundwater quality and level triggers, which will be applied for prior to Project construction commencement and updated within the existing LVWMP.
        ii. The installation of additional groundwater monitoring bores within the Quaternary and Tertiary sediments at the confluence of Ripstone and Boomerang Creeks, at sites that are adjacent identified HES wetlands;
    b. The management of surface water and flows which will include:
        i. management of mine affected water (MAW) which will be maintained in a closed system to prevent releases of mine affected water to the environment.
        ii. Updates to the existing LVWMP to include proactive management measures for flood, drought, and severe weather events.
    c. Erosion and sediment control measures through which the impacts of erosion will be implemented in accordance with established erosion and sediment control standards.
    d. The proposed Project Progressive Rehabilitation and Closure Plan (PRCP) which also addresses sediment and erosion control mechanisms.
2. **Lake Vermont Receiving Environment Management Plan (REMP):** Monitors, identifies, and describes any impacts to aquatic ecology and surface water quality values from discharges associated with approved mining activities. The Lake Vermont Mine REMP will be updated to include monitoring of One Mile Creek and Phillips Creek, to identify any potential impact to GDEs from overflow of the sediment dam.
3. **Species Management Program**: A Species Management Program will be developed for the Project, to provide for the management of breeding areas of key conservation species potentially impacted by the Project clearing. Species Management Programs will be developed in accordance with the NC Animals Regulation and be provided for approval by DES prior to vegetation clearance activities that would disturb animal breeding places.
4. Approvals documents for The Project, once granted which will provide conditions for project approval related to environmental management (i.e., environmental authority and approval under the EPBC Act).



Legend

- Project Outline
- Mineral development licence
- Mining_leases

Figure 1. Regional location of assessment area.

Client	AARC Environmental Solutions

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Kilometers

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1.6 Structure of this Document

This GDEMMP intends to compile knowledge on the ecohydrological function of relevant GDEs and scope has been made to update monitoring requirements including methods, timing and interval as the knowledge base increases with each subsequent monitoring survey event. A summary of the key components of this GDEMMP is provided below:

- Section 2: A contextual description of the project in relation to mining layout and project timeframes.
- Section 3: A general description of the existing environment to contextualise hydrogeological and ecological setting with reference to detailed description provided in 3d Environmental (2023a).
- Section 4: Describes in detail the hydro-ecological function of GDEs in the Project area with reference to detailed information in 3d Environmental (2023a).
- Section 5: Provides a summary for what are considered the major risks to GDE health imposed by the ID Project, as presented in 3d Environmental (2023a).
- Section 6: A summary of how the biotic impacts to GDEs may manifest in the environment.
- Section 7: The general approach to the monitoring program.
- Section 8: An overview of monitoring techniques and their application.
- Section 9: A summary of reporting requirements for each monitoring event as well as preparation of a baseline synopsis.
- Section 10: Approach to determining trigger thresholds for which impacts to GDEs are investigated and corrective actions applied where appropriate.
- Section 11: A discussion identifying potential corrective actions that may be applied to ameliorate impacts to GDEs that have been created by mining activities.
- Appendix: Provides the basis for risk assessment, a summary of monitoring methods, monitoring timing and raw data from prior GDE surveys. The Appendix is structured to provide:
  - Appendix A. Lake Vermont Meadowbrook - Stygofauna monitoring and management plan
  - Appendix B. Mining stages and development plans
  - Appendix C. Summary of GDE sampling methods
  - Appendix D. Sampling localities from the EIS assessment.
  - Appendix E. Soil moisture potential and stable isotope results from the EIS
  - Appendix F. Summary structural data from the August 2021 field assessment.
  - Appendix G. GDE monitoring two-year schedule.

2.0 Project Description and Timing

2.1 Project Activities

The primary purpose of The Project is to extend the life of the existing Lake Vermont Mine, at existing (approved) production levels up to 12 million tonnes per annum (Mtpa) of run of mine (ROM) coal, supplementing the future decline in production from the existing open-cut mining operation with output from an adjoining underground operation and a satellite pit. The proposed mine layout is provided in **Figure 2** with the principal components of the proposed mining operation being:

- Underground longwall mining of the Leichardt Lower Seam and Vermont Lower Seam.
- An open cut pit.
- Development of a new infrastructure corridor to link the new mining area to existing infrastructure at the Lake Vermont Mine.
- Development of a Mine Infrastructure Area (MIA).
- Construction of a drift and shafts to provide access to underground operations.
- Development of other supporting infrastructure and associated activities.

2.2 Project Stages and Timing

Figure 3 (from Chapter 3 – Project Description from EIS) shows the life of mine production profile for the Lake Vermont Meadowbrook Complex (including the existing Lake Vermont Mine and the Lake Vermont Meadowbrook Project) with forecasting for the reduction in coal production that will occur at the existing Lake Vermont Mine by combining output from the existing open-cut operations and The Project extension. As the underground extension concludes, mining within the proposed open-cut satellite pit will commence in Project Year 20 to supplement existing operations, with tailing off or production from this point to mining completion in Project Year 30. Mining at the existing Lake Vermont Mine will continue for approximately six years following completion of The Project through the mining of the (already approved) Lake Vermont Mine open-cut satellite pit. Progressive rehabilitation will occur throughout the life of The Project and final rehabilitation and mine closure will occur in conjunction with final mining. Backfilling of the open-cut pit is scheduled to be completed in Year 35 (indicatively 2060), with achievement of a stable post-mining land use in Year 53 (indicatively 2078). The projected layout of The Project in years 2, 7, 12, 17, 22, and 27, and at end of mining, together with the progress of the existing Lake Vermont Mine are provided in **Appendix B**.

3.0 Existing Environment

This section provides an overview of the local and regional setting, including climate, existing and surrounding landuse. For context, detailed information on the following features is described in Lake Vermont Meadowbrook Project – Groundwater Dependent Ecosystem Assessment (3d Environmental 2023).

1. Hydrogeological setting and the major groundwater bearing units (**Section 2.1** of 3d Environmental 2023a).
2. Surface water flows including water quality and flood regimes (**Section 2.2** of 3d Environmental 2023a)
3. Ecological characteristics of the site including potentially groundwater dependent regional ecosystems (REs) and species (**Section 2.3** of 3d Environmental 2023a).

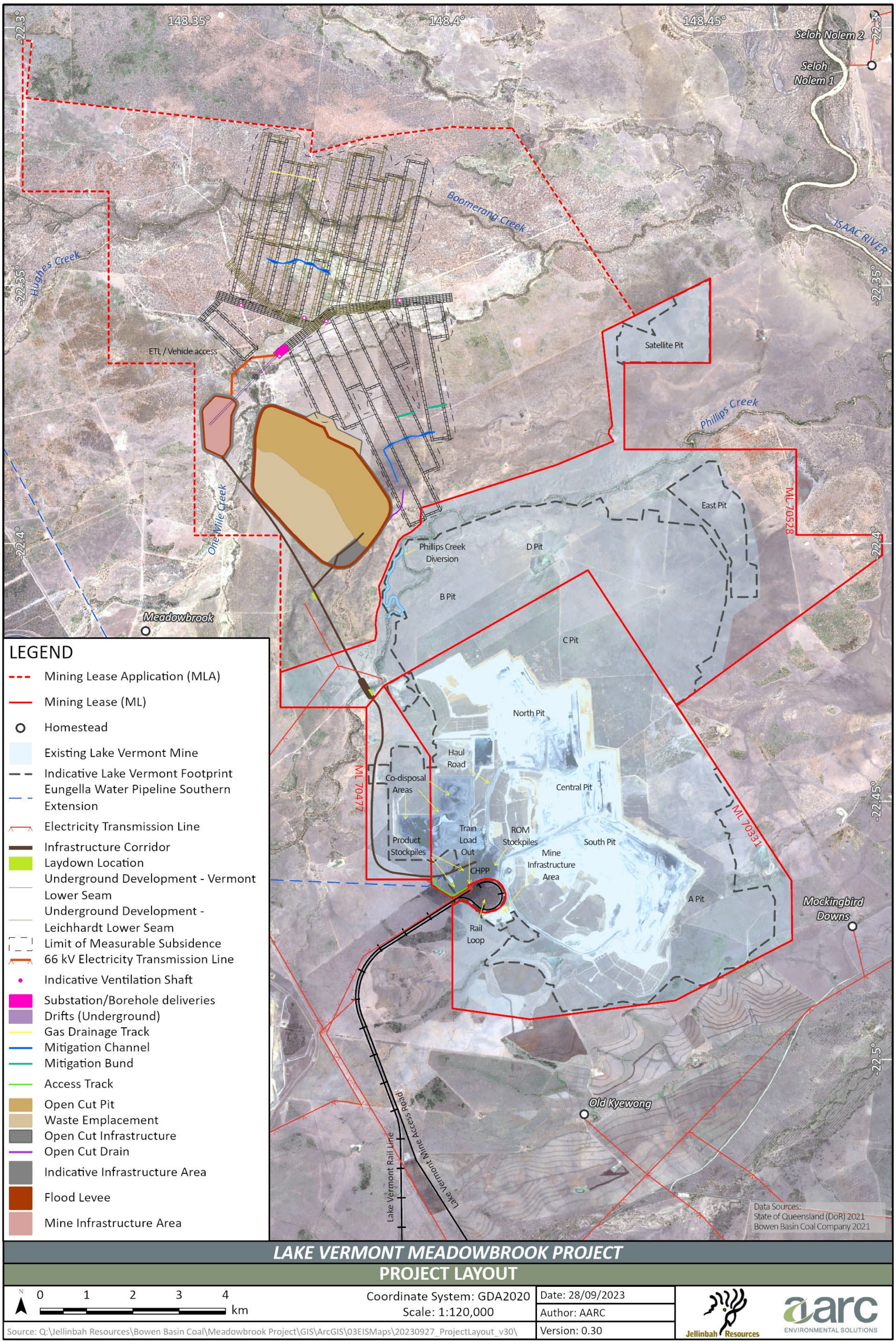

Figure 2. Project layout showing principal components of the mining operation.

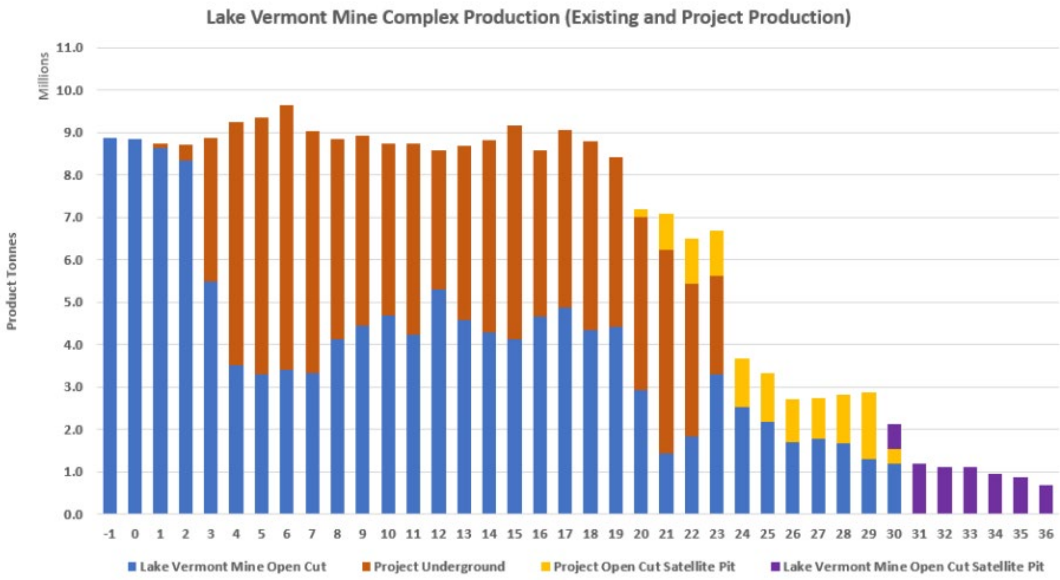

Figure 3. Project stages showing overlap between the open cut and underground stages of the mining operation.

3.1 Site Setting

The Project located on the boundary between the Northern Bowen Basin and Isaac-Comet Downs subregions of the Brigalow Belt North Bioregion. The Brigalow Belt North Bioregion is an ecologically complex area characterised by clay soils interspersed with Tertiary plateaus, sand plains, basalt plains and some more expansive ranges formed on sandstone and granite. Vegetation is typically dominated by forests and woodlands of *Acacia harpophylla* (Brigalow), *Acacia shirleyi* (lancewood) eucalyptus woodlands and grassland habitats. The region surrounding The Project area has been extensively cleared of native vegetation to accommodate pastoral activities, although some intact tracts of woodland persist mostly to the north of The Project area. Narrow fringes of continuous riparian vegetation have generally been retained along the larger watercourses, occasionally buffered by broader areas of floodplain woodland. Coal mining has been a more recent activity in the region, emerging in the 1970's as a major industrial activity. The Project description (AARC 2023a) identified several coal mines and projects approved in the region including amongst others:

- Saraji Mine approximately 5 km to the west
- Saraji East Project (proposed) on land adjoining the western boundary of the Project
- Olive Downs approximately 2 km to the north and Olive Downs North approximately 40 km to the north
- Winchester South Project (proposed) approximately 8 km to the north-northwest
- Eagle Downs approximately 13 km to the north-west
- Vulcan Complex approximately 20 km to the north-west
- Peak Downs approximately 25 km to the north-west
- Daunia approximately 35 km to the north

The Project interacts directly with the Saraji Mine, and the proposed Saraji East Project (underground extension), sharing common catchments of Philllips, One Mile, Hughes and Boomerang Creeks flowing east-west from Saraji to Lake Vermont. (**Figure 4**).

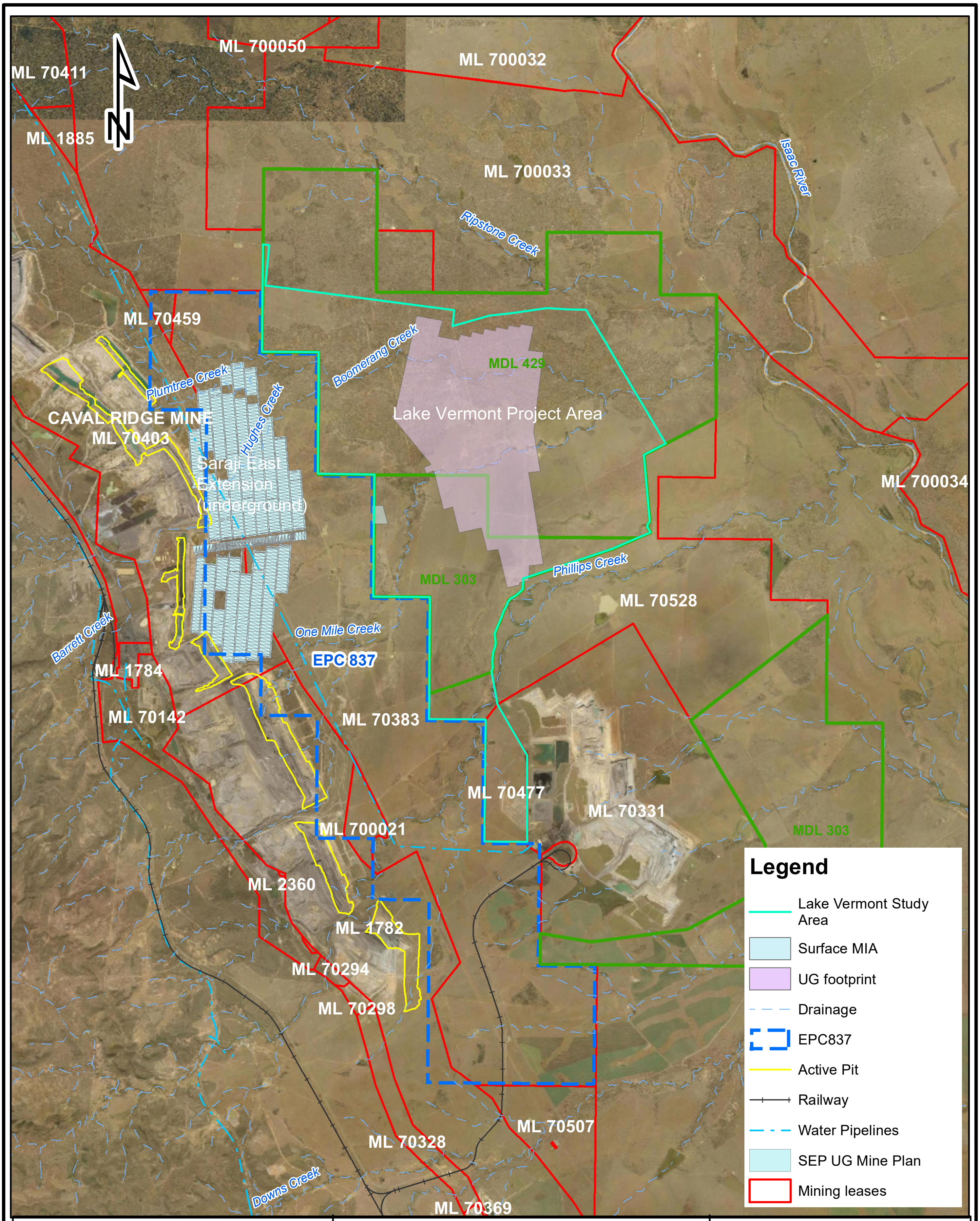

Figure 4. Location of the Lake Vermont-Meadowbrook project relative to the proposed Saraji East Extension

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3.2 Climatic Considerations

The region is sub-tropical with average temperatures recorded in Moranbah of between 21.1°C and 34.8°C in the summer months, and 8.9°C and 25.2 °C in the winter months. The long-term average rainfall (31 years of data between January 1990 and August 2021) from the Booroondarra Recording Stanton (BOM Recording Station 35109; Lat: 22.82° S / 148.49° E), 29km to the south of Dysart is 606.2 mm (SILO 2022) with a pronounced wet season. Approximately 75% of the annual rainfall is recorded between November and March, inclusive (BoM 2022). Plant growth in the region is strongly limited by moisture rather than temperature (Hutchinson et al. 1992) which is reflected in the evapotranspiration rates at the Moranbah Water Treatment Plant for the 2015 – 2021 period being considerably higher than rainfall for all except for the wettest months. Between January 2015 and August 2022, the largest offset between rainfall and evapotranspiration occurs between October to December during the build-up to summer storms (**Figure 5**).

The region has experienced several significant drought events, many of which have resulted in tree dieback. The early to mid-1990's drought, the worst on record for north Queensland, and the millennium drought from 2000 through to 2007 both resulted in substantial dieback of native woodland habitats, typically affecting ironbark woodlands and most severely on basaltic substrates (Fensham et al 2009a). **Figure 6** demonstrates the major climatic cycles in terms of Cumulative Rainfall Departure (CRD) (Weber and Stewart 2004), representing a cumulative departure of monthly rainfall from the long term mean monthly rainfall (1990 to 2021) January 1990 to August 2021) from point data at Moranbah Water Treatment Plant (SILO 2021) (consistent with the location of BOM Recording Station 35109). Strongly decreasing rainfall trends between 1990 to 1996; and 2000 to 2007 representing major drought periods are strongly evident, interspersed with periods of above average rainfall between January 1998 and January 2001, January 2010 and July 2012, and January 2016 to March 2017, which were considerably wetter than average conditions. Following a strongly decreasing rainfall trend between March 2017 and March 2021, there has been as slight upward inflection in the CRD curve potentially indicating transfer to a wetter climatic cycle in more recent years.

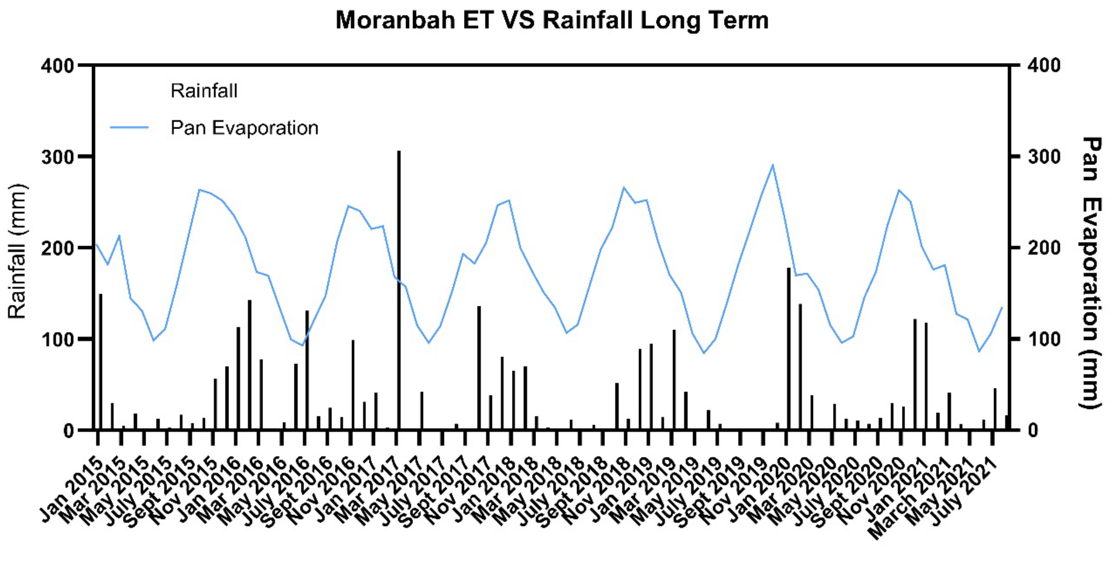


Figure 5. Evapotranspiration trends on a seasonal basis for Moranbah Water Treatment Plant for January 2015 through to August 2021.

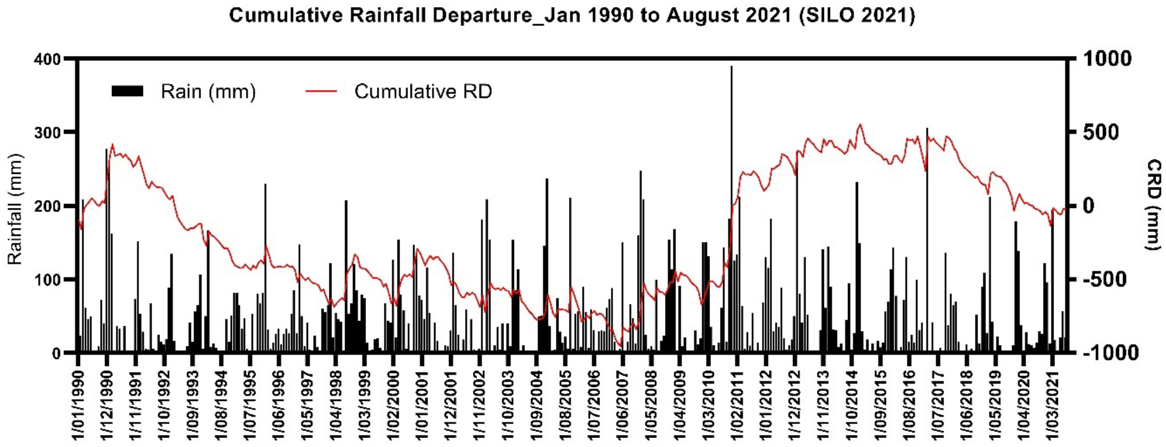


Figure 6. Cumulative rainfall departure calculated for the Moranbah Water Treatment Plant from January 1990 to August 2021.

3.3 Topography and Drainage

The Lake Vermont – Meadowbrook project area forms a landscape of gently undulating plains interrupted by narrow drainage features and scattered wetlands. The broad rises are formed by thick sequences of Pleistocene to Tertiary age cracking clay and residual silts and loams to the north of Phillips Creek, and sandier residuals on broad Tertiary rises to the south. The well-developed floodplain deposits of the Isaac River intrude marginally into the north-eastern portion of the Project Area attenuated upstream along Boomerang and Ripstone Creeks, where a complex system of floodplain wetlands has developed at the confluence. All creek systems in the Project Area, including the Isaac River to the east are strongly seasonal, flowing only after high intensity rainfall events with surface flows disappearing quickly into the streambed sands as surface flows recede. Slopes of all creeks are extremely low, ranging from 0.1 to 0.15% at One Mile and Boomerang Creeks respectively. From the western boundary of MDL429 east to the Isaac River, the landform falls from 160m to 180m AHD, over approximately 13.6 km which represents an overall slope of 0.147%.

3.4 Surface Geology

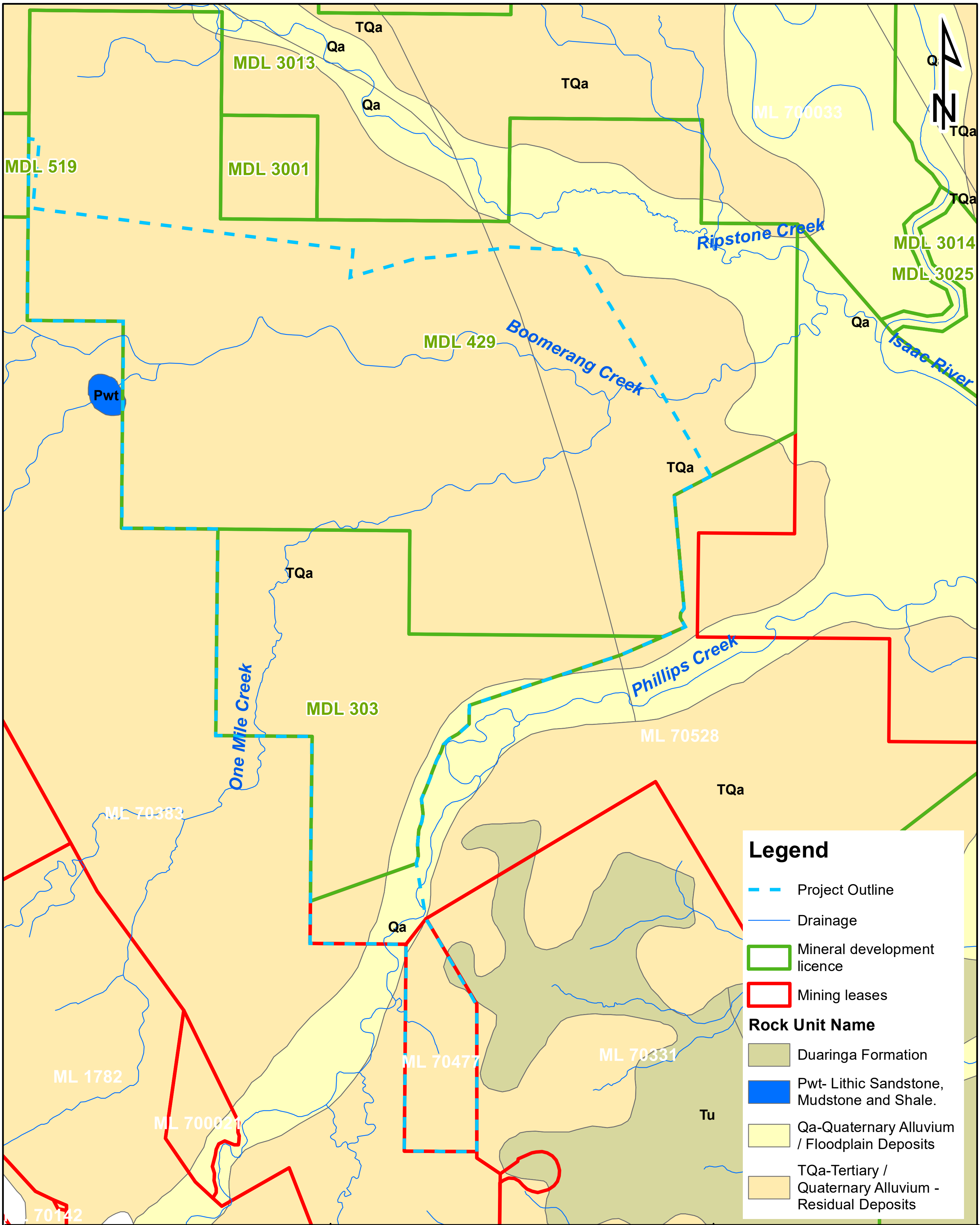
The project area is covered in a blanket of Cainozoic sediments, including Quaternary and Tertiary age alluvial sands, clayey sands and clays. These lithologies have variable thickness that ranges from 2 to 80m, and an average thickness of 26m (Minserve 2017). The Cainozoic sediments mainly comprise alluvial sands, clayey sands, and clays, with a basal layer in some locations of sand and gravel. JBT (2023) notes that the thickness of the Cainozoic sediments increases from 35m-45m to the south of Boomerang Creek to more than 60m to the north. While significant Quaternary age alluvium is not mapped within MDL429 in available surface geology mapping (DNRME 2018) (see **Figure 7** for reference), a thick sequence of Quaternary Age alluvium is associated with the Isaac River floodplain in the eastern portion of the tenement, and this attenuates upstream along the Tributaries of Ripstone Creek and Phillips Creek in available surface geology mapping (DNRME 2018). JBT (2023) also observes that significant Quaternary age alluvium is associated with Boomerang

Creek, estimated to be up to 14m thick although conclude that it is difficult to discern from the thicker sequences of Tertiary sediments as both units have a sandy structure.

Solid geology, which includes economic coal seams, comprises Triassic and Permian age sedimentary rocks which include:

1. the upper unit of the Triassic Age Rewan Group
2. the late Permian Rangal Coal Measures
3. the underlying late Permian Fort Cooper Coal Measures forming the basal group.

The economic coal seams are hosted in the Rangal Coal Measures which has two prominent coal seams which dip gently to the northeast, including the Leichhardt Lower (LHL) seam with an average thickness of 2.9 meters, and the Vermont Lower (VL) seam with an average thickness of 5.8m. The economic coal seams sup-crop into the Tertiary sediments at the location of the proposed Meadowbrook open cut pit, though dips deeply to the north-east where they will be subject to proposed underground mining operations.



Source: Detailed Surface Geology Qld 1:100 000 (DNRM 2018

Figure 7. Surface geology in the Lake Vermont - Meadowbrook Project Area

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Kilometers

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4.0 The Distribution and Hydro-ecological Function of GDEs at Lake Vermont-Meadowbrook

The potential occurrence of GDEs has been mapped at a national level by the Bureau of Meteorology (BOM), providing the GDE Atlas (BOM 2020). Further discussion of the GDE mapping presented in BOM (2020b) is provided in the EIS Assessment Report (3d Environmental 2023a). Detailed descriptions of field verified GDEs described in the Lake Vermont-Meadowbrook project area, including block model conceptualisations and cross sections have been developed and described in Section **5.0** of the Lake Vermont-Meadowbrook Groundwater Dependent Ecosystem Assessment Report (3d Environmental 2023a) and should be referred to for more detailed conceptual information. In summary, two Terrestrial GDE types are identified in the project area being:

1. Type 1 GDEs: Includes drainage features with developed alluvial landforms that host variable groundwater volumes and are seasonally recharged via surface flows and flooding. This includes Phillips Creek, Boomerang Creek, and the Isaac River.
2. Type 2 GDE: This represents the conceptualised perched groundwater lens that lies below GDE Assessment Site 3, located on a mapped HES wetland. Percolation of groundwater through the alluvial soils occurs when surface water is recharged, and the infiltrating surface water is captured above an aquitard at the alluvial unconformity. Tree roots of river red gum and coolibah are utilising this freshwater lens, which possibly only remains viable for several months following rainfall. The perched freshwater lens is inferred to be >6m below the surface based on detail from soil auger sampling.

The location of Type 1 and Type 2 GDE features is shown in **Figure 8,** which shows their occurrence associated with Phillips Creek, Boomerang Creek, the Isaac River. HES Wetland 8 (from JBT 2023) near the confluence of Ripstone and Boomerang Creek forms the sole representation of a Type 2 GDE. While confirmed Type 1 GDEs are associated exclusively with RE11.3.25 and the single mapped Type 2 GDE with RE11.3.27, areas of confirmed GDEs fringe areas of the Poplar Box Woodland and Brigalow Threatened Ecological Communities (TECs), both listed as Endangered under the EPBC Act (See **Figure 8**).

5.0 Major Risks to GDE Function

A detailed assessment of the potential risks to GDEs is developed in **Section 6.2** and **Section 6.3** of the Lake Vermont-Meadowbrook Groundwater Dependent Ecosystem Assessment Report (3d Environmental 2023a) and this document should be consulted if additional detail or specific information is required. The major risks to GDE function include:

1. Drawdown of the groundwater in the Tertiary and alluvial groundwater systems associated with development of the underground mining void and open cut pit where drawdown in most intense (>20m). This drawdown extends eastward toward the Isaac River where drawdown of 2m to 5m is propagated below HES Wetland 8 and HES Wetland 9, the former being the only representation of a Type 2 GDE in the Project area.
2. Surface subsidence above longwall panels affecting the channel of Boomerang Creek, effectively interrupting the timing and frequency of low magnitude surface

flows through ponding, and increased leakage from the perched alluvial groundwater system to the Tertiary aquifer as a result of surface fracturing.

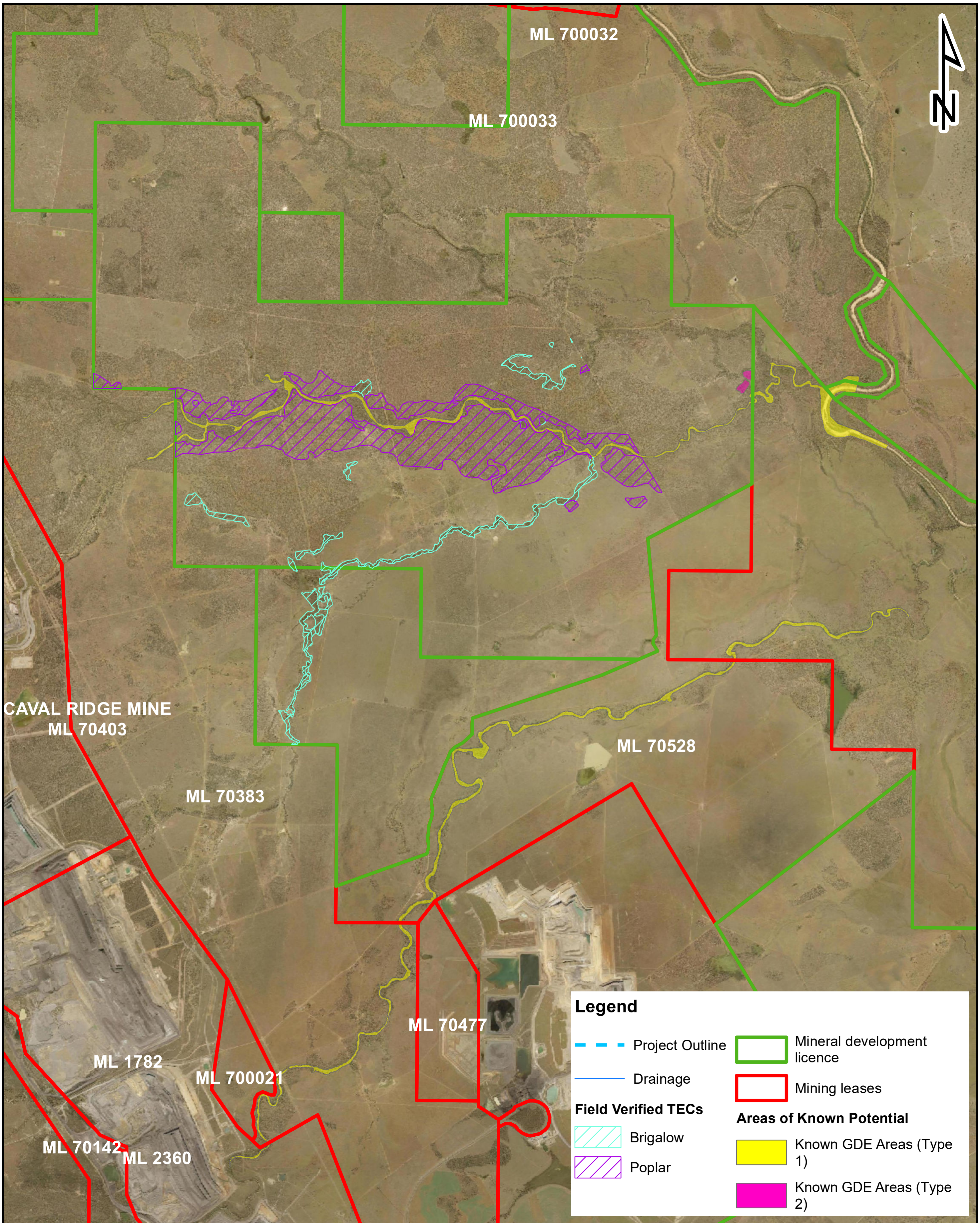
3. Decreases in channel velocity, bed shear and stream power, causing reductions in sediment transport capacity in each trough which may lead to temporary increases in downstream erosion and subtle changes to the timing and magnitude of surface flows.

Within the area of surface subsidence, multiple potential impact pathways including groundwater drawdown, fracturing and leakage of the perched aquifer, and subtle changes to the timing and volume of surface flows may interact to increase the risk of impact. Ameliorating factors include the capacity of riparian vegetation, which comprises facultative phreatophytes such as forest red gum (*Eucalyptus tereticornis)* and weeping tea tree (*Melaleuca fluviatalis)*, to adapt to changing water availability and utilise moisture from both saturated and non-saturated water sources (see **Section 2.2.3** of 3d Environmental 2023a).

To recognise that the level of risk to GDE function varies across the Project Area dependent on the interactions between groundwater drawdown, surface subsidence, and impact to surface flows, four risk zones are identified as described in **Table 1** with spatial representation of Risk Zones provided in **Figure 9** (see **Section 6.6** of 3d Environmental 2023a).

Table 1. GDE Risk Zones based on degree of groundwater drawdown, subsidence and changes to surface flows.

Rank	GDE Risk Zone	Likelihood of Unmitigated Impact	Description
1	Zone 1	Likely	>20m drawdown in the Tertiary aquifer acting in conjunction with subsidence related impacts to perched water tables and ponding, and changes to timing of surface flows. .
2	Zone2	Possible	>5 to 20m groundwater drawdown in Tertiary aquifer and >2m drawdown in recent alluvial sediments. Subtle changes to timing of surface flows and flow magnitude.
3	Zone3	Unlikely	<5m to 1m drawdown in the Tertiary aquifer. Insignificant changes to surface flow timing and magnitude.
4	Zone4	Highly Unlikely	Outside the zone of groundwater drawdown



Source: AARC (2023); 3d Environmental (2023a)

Figure 8. Location of field verified TECs relative to known GDE Areas.

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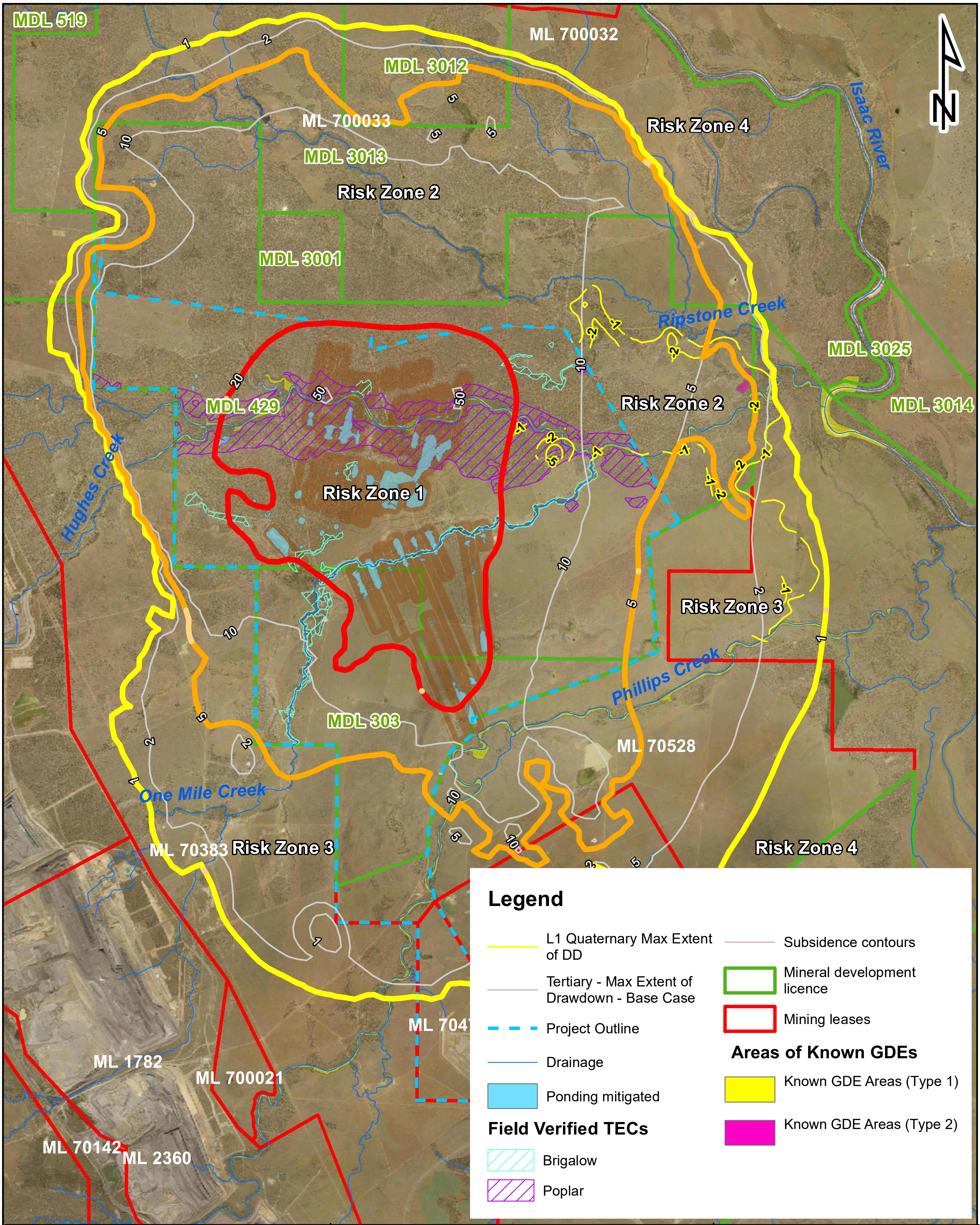

Source: 3d Environmental (2023a)

Figure 9. GDE Risk Zones relative to groundwater drawdown, surface subsidence and ponding.

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6.0 Biophysical Response to Reduced Water Availability / Quality

Eamus et al (2009) provides a conceptual assessment of the major stressors that contribute to declining GDE health. Reduced water availability is the major determinate of GDE health and the flow-on effects of this are outlined in **Figure 10**. Based on conceptualisations provided in **Section 6.3** and risk assessment completed in **Section 6.6** of 3d Environmental (2023a), an unmitigated 'moderate' risk of impact to GDE function is associated with the Risk Area 1, where known GDEs fringing Boomerang Creek overlap with areas of maximum groundwater drawdown, surface subsidence and surface ponding. The risk of impact can be linked to:

1. Drawdown of the Tertiary and alluvial aquifer resulting in more rapid drainage of the perched aquifer associated with the Boomerang Creek channel.
2. Compounding impact of groundwater drawdown and increased leakage of the perched aquifer associated with surface cracking within subsiding land surfaces.
3. Subtle changes to the interval and timing of low magnitude surface flows within areas of subsidence as well as short-term downstream erosion.

In an unmitigated 'worst case' scenario when maximum drawdown and surface subsidence coincides with a period of drought, the predicted impact would be of 'moderate' magnitude in Risk Zone 1 (maximum groundwater drawdown and surface subsidence), which in the context of the risk assessment detailed in **Section 6.6** of 3d Environmental (2023a) would result in:

> *'Plant stress linked to mining activity that results in the reduction in volume and duration of groundwater supporting a GDE system that does not result in more than 25% dieback of mature canopy trees (defined as a canopy tree with DBH >60cm). Impact is reversible with mitigation.'.*

The decrease in groundwater availability associated with drawdown of the water table, and seasonal dryness extending into the summer months when transpiration is highest will likely be sufficient to trigger stomatal closure and reduction in Leaf Area Index (LAI)[1]. Over an extended period with sustained conditions of drought, increasing levels of plant mortality may occur and in a general context, these adverse physiological responses may ultimately result in the conversion of a diverse, functioning habitat to a simplified system with reduced ecological value (Doody et al 2009). As detailed in **Figure 10,** the time taken for the first measurable impacts on vegetation due to reduction of moisture availability to manifest may take months, with habitat conversion due to dieback of the original canopy taking many years to decades with the rate of dieback dependent on climatic controls. However, detectable changes in vegetation health would likely be apparent within months to a few years. Many of the physical responses of vegetation to reduced water availability can also occur because of natural seasonal variation and hence any monitoring program must have capacity to distinguish what is natural variation from impacts that result from anthropogenic disturbance to the hydrogeological regime.

[1] Leaf Area Index is ratio of total one-sided area of leaves on a plant divided by the area of the canopy when projected vertically on to the ground.

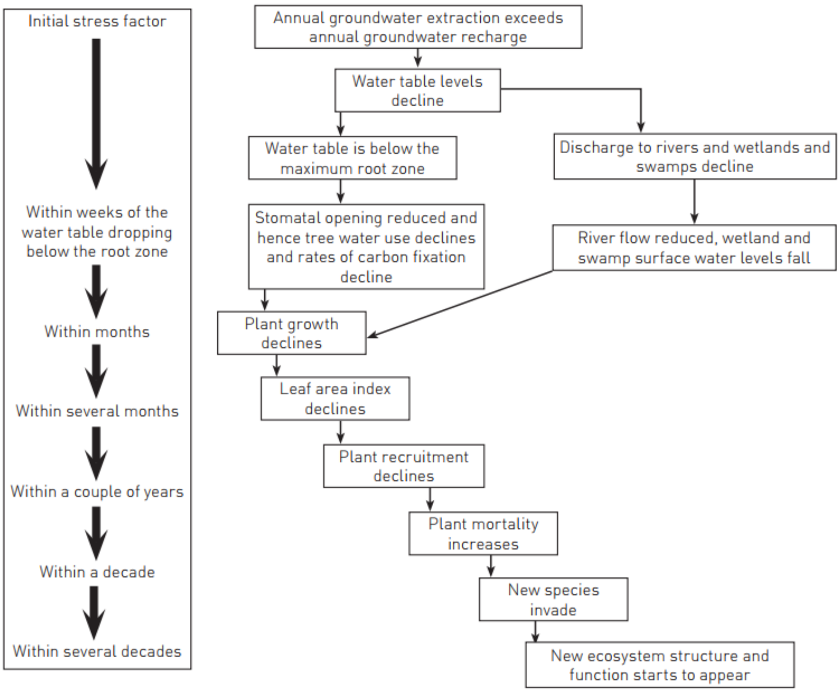

Figure 10. Schematic outline of the response of plants and communities of plants to reduced availability of groundwater from Eamus (2009).

7.0 Approach to Monitoring and Management Program

7.1 Overview

This document provides a framework for the management and monitoring of GDEs associated with the Lake Vermont – Meadowbrook Project Area including areas both within the area of predicted groundwater drawdown and areas outside the drawdown footprint to the east near the Isaac River. While areas of mapped Terrestrial GDEs to the east of The Project downstream along Boomerang and Phillips Creek are relatively unaffected by mining related impacts, upstream localities are heavily influenced and impacted by activities associated with the Saraji Mine and would not be considered suitable control sites.

A sequential approach to monitoring and management has been applied which allows for adaptive implementation of monitoring and management protocols reliant on results of prior assessment activities. The major components of the GDEMMP include provision to:

- Apply monitoring and assessment techniques that support development of an environmental baseline for GDE function commencing prior to operations, including upstream and downstream control sites for GDE monitoring. An initial baseline assessment phase will be undertaken to add certainty to the findings of the EIS assessment (3d Environmental 2023).
- Produce a statistically robust multi-parameter dataset that can be used to validate perturbations in GDE function that fall beyond thresholds of natural seasonal variation.
- Allow a flexible approach to monitoring which is subject to ongoing review and allows methods to be adapted based on results of lead-up monitoring and data analysis.
- Utilise biophysical and ecological parameters to establish:

    - an appropriate ecological trigger threshold, applied to indicate requirement for further investigation or corrective action; and
    - an appropriate disturbance level threshold applied to indicate requirement for offsets should corrective actions not be successful.
- Develop a comprehensive suite of management actions and corrective measures which will be applied if a breach of trigger threshold is identified, noting that the suite of management actions implemented will depend on impacts identified, and all may not be required for any given breach of a trigger threshold.
- Assess the effectiveness of management actions and corrective measures, determine if significant residual impacts to MSES or MNES have occurred, and where significant residual impacts have occurred, provide offsets.

The approach is consistent with the GDE Toolbox approach (Richardson 2011a and 2011b) which recommends a sequential assessment, as outlined below:

- Stage 1 – GDE location, classification, and basic conceptualisation. The focus of Stage 1 is to gain a baseline understanding of where potential GDEs exist including classification of GDE type and ecohydrological function.
- Stage 2 – Characterisation of groundwater reliance. Stage 2 assessment builds on conceptual information provided in Stage 1 to characterise the degree of reliance of the GDE on groundwater.
- Stage 3 – Characterisation of ecological response to change: During Stage 3 assessment, knowledge of baseline ecohydrological function is utilised to describe and quantify likely changes to biophysical function and health of GDEs if impacts to groundwater regimes manifest.

The GDE characterisation undertaken by 3d Environmental (2023a) as a component of the Lake Vermont – Meadowbrook EIS process meets the requirements of Stage 1, the outcomes of which are described in accordance with conceptual models provided in **Section 5.2** and **Section 6.3** of the EIS report. Ongoing adjustment of the ecohydrological models may be required as the monitoring program develops, and ecological data is collected and analysed.

Stage 2 and Stage 3 of the monitoring program will rely on collection of temporal data to support characterisation of baseline ecohydrological function. Seasonal monitoring events will allow for baseline data to be acquired to predict trends in GDE function and identify impacts that extend beyond the range of natural variation.

7.2 Approach

The monitoring and management program has been separated into two stages:

- Two years of intensive data collection during which the GDE monitoring program will be refined investigative thresholds will be defined (see **Section 10**).
- The period after 2 years, comprising the remainder of operations and the post mining period, which will utilise data collected in the initial two years to re-assess the developed thresholds.

The process for establishing thresholds is described in **Section 10**, involving collection of data from the impact site (i.e., drawdown area) and two control sites downstream from the mining impact area (i.e., outside the area of drawdown) on Phillips Creek and Boomerang Creek, plus and addition control upstream on Boomerang Creek that is outside the influence of project related drawdown, though will be influenced by groundwater drawdown associated with the Saraji East Project. The thresholds for impact are linked to vegetation health and provide a comparison between the control and impact sites. Should the established thresholds be exceeded, this will trigger an investigation that will make use of other monitoring data (See **Section 10.2**) that considers the bio-physical function of groundwater dependent vegetation, groundwater, and surface water to determine the cause of a threshold exceedance. If drawdown of the groundwater table is found to be the cause of the threshold exceedance, then mitigation measures (see **Section 11**) will be implemented, and the effect of mitigation measures monitored. If mitigation measures are not effective, habitat quality data from a GDE 'habitat quality' monitoring program will need to be used to assess whether there has been a significant residual impact to riparian habitat and any threatened species that may be associated with it. The GDE habitat quality monitoring program will need to be established in conjunction implementation of this GDEMMP and draw upon assessment of biocondition and derived assessment of habitat quality prescribed in Eyre et al (2015) and DES (2020). Biocondition should be monitored:

1. Biannually for two years to establish the seasonal baseline range of biocondition scores for habitats associated with GDE monitoring sites proposed within the GDEMMP.
2. Every two years in the dry season following establishment of baseline biocondition scores.

If mitigation measures are not effective, habitat quality data from the 'habitat quality' monitoring program will be used to assess whether there has been a significant residual impact to habitat quality.

The initial two years of intensive data collection aims to refine habitats for ongoing monitoring (i.e., focus on areas of confirmed groundwater dependency) and develop thresholds for monitoring and impact assessment, including provision of a dataset to support investigative action if decline in GDE health is detected. The initial event of the 2-year baseline should be completed upon project approval, although prior to project construction to allow monitoring data to be calibrated to a pre-disturbance threshold. For post baseline monitoring, while the process remains the same, sites that do not demonstrate groundwater dependence can be excised from the program, and thresholds may be amended to reflect alternative parameters for monitoring and / or the threshold values attached to those parameters.

8.0 Monitoring and Analysis Techniques

The GDE Toolbox – Part 2 (Richardson 2011b) provides a suite of technically robust tools to identify GDEs and determine their ecological water requirements. These tools are based on established methods repeated in studies within Australia and abroad, many of which are published in peer-reviewed scientific journals. Many of these tools were applied in the EIS GDE characterisation (3d Environmental 2023a) and for the purpose of baseline characterisation, are recommended for inclusion as a component of ongoing monitoring. **Table 2** provides a list of tools used in the GDE characterisation and describes their purpose and ongoing relevance to monitoring. Several additional methods adapted from the GDE Toolbox have also been included, being recommended components of an ongoing monitoring program. Technical details of recommended assessment methods are provided in **Appendix C.**

Table 2. Assessment methods that will be applied during GDE monitoring.

Assessment Method	Utilised in ID GDE Characterisation	GDE Toolbox Method No.	Method Description	Primary Utility
Conceptual modelling	Yes	Tool 2	Aims to conceptualise the interactions between biotic factors (e.g., trees) and abiotic (e.g., soil, surface water and groundwater). Conceptualisation formalises the understanding of the major components of a GDE system and allows impact pathways to be contextualised.	Conceptualisation and informing monitoring program design and implementation.
Leaf water potential	Yes	Tool 3	LWP provides the primary biophysical measure of tree water availability and defines a continuum between the relationship of soil, water and plant. Trees associated with high water availability will have a high (least negative) LWP. LWP provides an indication of which trees have access to a saturated or near saturated water source, although does not identify the nature of the source (i.e., groundwater, saturated pockets in the soil, surface water from stream pools).	Site based assessment with some application for seasonal monitoring to identify plant water deficits. Used in conjunction with Leaf Area Index (LAI).
Stable Isotopes of water in plants	Yes	Tool 4	The stable isotopic signature (2H and 18O) of the dominant water source for a tree will be imparted on its hydraulic architecture, typically measured in twigs. The stable isotope signature in twigs may be directly analogous to a single water source if that source provides a predominant contribution to a trees water requirement. It may also be a combination of a number or sources, requiring a mixing model to be employed to calculate relative contributions of each water source.	Identifies plant water sources. Monitoring application in the initial two-year baseline investigation to: 1. Determine the proportions of various water sources used by tree in response climate controls. 2. Determine how these contributions change over a seasonal cycle to fully evaluate the GDE risk profile.
Leaf Area Index	No	Tool 1, Tool 2	Leaf Area Index (LAI) is a ratio of the total leaf area within a canopy to the ground area covered by the canopy. It is a measure of canopy vigour and the	A fundamental application used in monitoring, in conjunction with remote sensing, to measure

Assessment Method	Utilised in ID GDE Characterisation	GDE Toolbox Method No.	Method Description	Primary Utility
			rationale applied is that plants with access to permanent sources of water (i.e., groundwater) will have greater vigour and LAI than vegetation that has only periodic access to groundwater resources (e.g., Zolfagher 2014). LAI is likely to vary on a seasonal basis if the sustaining source of moisture is variable, or the groundwater is only seasonally utilised.	seasonal variation in vegetation health.
Remote sensing	No	Tool No 1	Assessment utilises the Normalised Difference Vegetation Index (NDVI) as a measure of canopy health and vigour, that can be directly correlated to LAI. It is a widely accepted method and with advances in satellite technology, has the capacity to assess the health of individual trees rather than landscapes.	Application for long-term monitoring once baseline conditions have been established.
Site based groundwater monitoring	Yes – for data from regional groundwater units including the Permian coal measures, weathered Tertiary sediments and recent alluvium from Boomerang Creek extending east to the Isaac River.	Tool No 10, 13	Local installation of groundwater monitoring bores targeted to monitor the groundwater source which the GDE is utilising. Additional monitoring bores will be proposed to specifically target groundwater / GDE interaction. Groundwater monitoring will include collection of EC and other water equality data.	Long term monitoring applications as a basis to draw correlations with biotic assessment parameters (e.g. LAI). Used to determine mechanisms of groundwater recharge into and discharge from the Isaac River.
Surface Water Monitoring	Yes - Ongoing monitoring under the developed REMP.	Tool No 10	Ongoing monitoring of surface water flows and quality from dedicated monitoring points (see **Section 2.2** of 3d Environmental 2023a).	Long term monitoring applications to draw correlations between surface flows and recharge of groundwater, particularly in the alluvial and Tertiary groundwater systems.
GDE Habitat Quality Monitoring Program	No – Habitat quality scores will need to be measured to characterise the pre-impact baseline	n/a	Permanent GDE habitat quality monitoring sites will need to be established as per methods detailed in Eyre et al (2015) and DES (2020). These sites will need to be established to complement proposed GDEMMP monitoring sites. Species specific habitat indices will also	Site based assessment with some application for seasonal monitoring to assess changes in habitat quality in the riparian

Assessment Method	Utilised in ID GDE Characterisation	GDE Toolbox Method No.	Method Description	Primary Utility
	ecological condition of known and potential GDEs.		be assessed in line with Queensland Government's Guide to Determining Terrestrial Habitat Quality – a toolkit for assessing land-based offsets under the Queensland Environmental Offsets Policy, Version 1.3. (see **Section 8.1**).	zone. Monitoring undertaken to inform whether: • changes in GDE health have resulted in changes in biocondition or habitat quality for potentially impacted REs, TECs or listed species. • changes in biocondition or habitat quality are in exceedance of disturbance thresholds and require offsets. • remediation measures, if required, have benefited habitat quality

8.1 Site Selection and Application

Data collection will occur in all GDE Risk Areas. Proposed monitoring methods are in **Section 8.3** (statistical analysis), **Section 8.4** (stable isotopes), **Section 8.5** (NDVI analysis), **Section 8.6** (groundwater) and general procedural information is provided in **Appendix C** as listed below:

1. LWP and SMP provided in **Appendix C1**
2. Stable Isotope analysis in **Appendix C2**
3. Measurement of field-based LAI in **Appendix C3**
4. NDVI assessment in **Appendix C4**

While the distribution of field verified GDEs is a primary driver for the allocation of monitoring areas, overlap with field verified TECs, HES wetlands as well as GDE mapping represented in the GDE Atlas (BOM 2020) has also been given consideration, providing additional temporal context and certainty to the GDE assessment. This is discussed in more detail in **Section 2.2.2** of the EIS report (3d Environmental 2023a).

Figure 11 shows the location of proposed GDE monitoring areas relative to groundwater bores and areas of predicted surface subsidence. The location of proposed GDEMMP monitoring areas relative to Risk Zones identified in 3d Environmental (2023a) is provided in **Figure 12**, while **Figure 13** shows the location of GDE monitoring areas relative to potential GDE mapping from the GDE Atlas (BOM 2020b). **Table 3** summarises the purpose of each GDE monitoring locality including Risk Zone, catchment, and target ecosystem while **Table 4** provides details of the monitoring program including parameters for assessment and the number of sites. The program includes GDE monitoring areas within areas of highest risk (Risk Zone 1) to lowest risk (Risk Zone 4) where proposed control sites are located. To aid data continuity, proposed GDE monitoring areas overlap with GDE assessment sites from the EIS (3d Environmental 2023a) and are co-located with groundwater monitoring bores where possible. The location of sampling points from the EIS assessment is provided in **Appendix D**.

Table 3. Details of proposed GDEMMP monitoring localities.

GDEMP Monitoring Site	Catchment	Purpose	Site from EIS Study*	RE	TEC	Relevant Monitoring Bores
Risk Zone 1						
4	Boomerang Creek	Riparian	9	11.3.25	NA	W3_MB1
5	Boomerang Creek	TEC	10	11.3.2	NA	W3_MB2
6	Boomerang Creek	TEC	NA	11.3.2	Poplar Box	W12_MB1
7	Boomerang Creek	Riparian	NA	11.3.25	NA	W4_MB1
8	Boomerang Creek	Riparian	16	11.3.25	NA	W4_MB2
9	Boomerang Creek	TEC	NA	11.3.2	Poplar Box	
11	One Mile Creek	Brigalow_Riparian	17	11.3.1	Brigalow	NIL
Risk Zone 2						
3	Boomerang Creek	Riparian	8	11.3.25	NA	W14_MB1
15	One Mile Creek	Brigalow_Riparian	NA	11.3.1	Brigalow	W14_MB2
12	One Mile Creek	Brigalow_Riparian	NA	11.3.1	Brigalow	NIL
13	Phillips Creek	Riparian	18	11.3.25	NA	2394_MB1
16	Boomerang Creek	Riparian	NA	11.3.25	No	W4_MB1
Risk Zone 2 / 3						
2	Ripstone_Boomerang	HES Wetland 8	3	11.3.27	NA	NIL
Risk Zone 4						
1	Ripstone_Boomerang	Control (downstream)	NA	11.3.25	NA	NIL
10	Boomerang Creek	Control (upstream)	NA			
14	Phillips Creek	Control (downstream)	NA	11.3.25	NA	NIL

*Includes groundwater monitoring bores installed into alluvium and weathered Tertiary sediments.

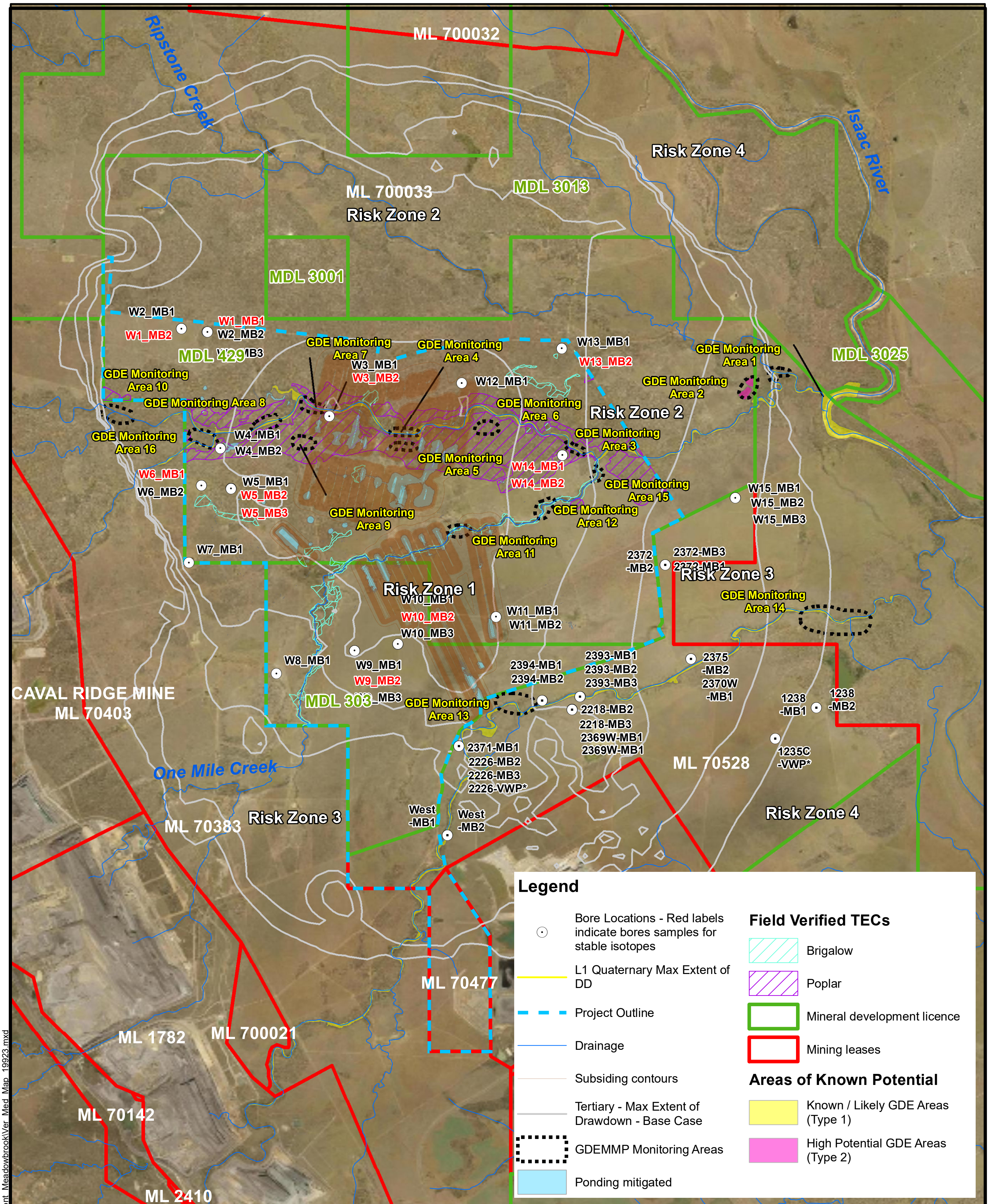

Figure 11. Location of proposed GDE Monitoring Areas relative to monitoring bores and areas of surface subsidence.

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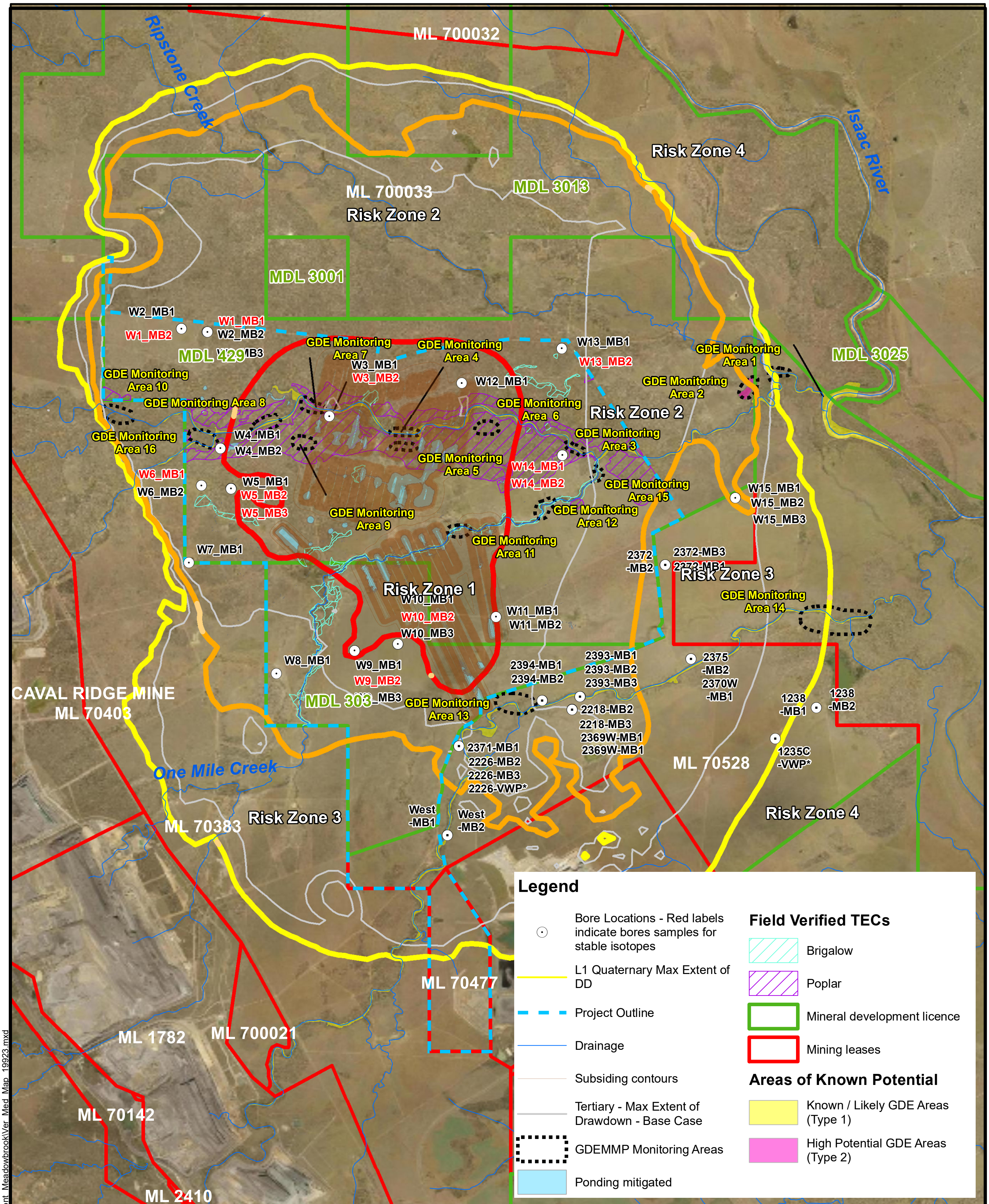

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Figure 12. Location of proposed GDE Monitoring Areas relative to Risk Zones, surface subsidence, known GDEs and TECs.

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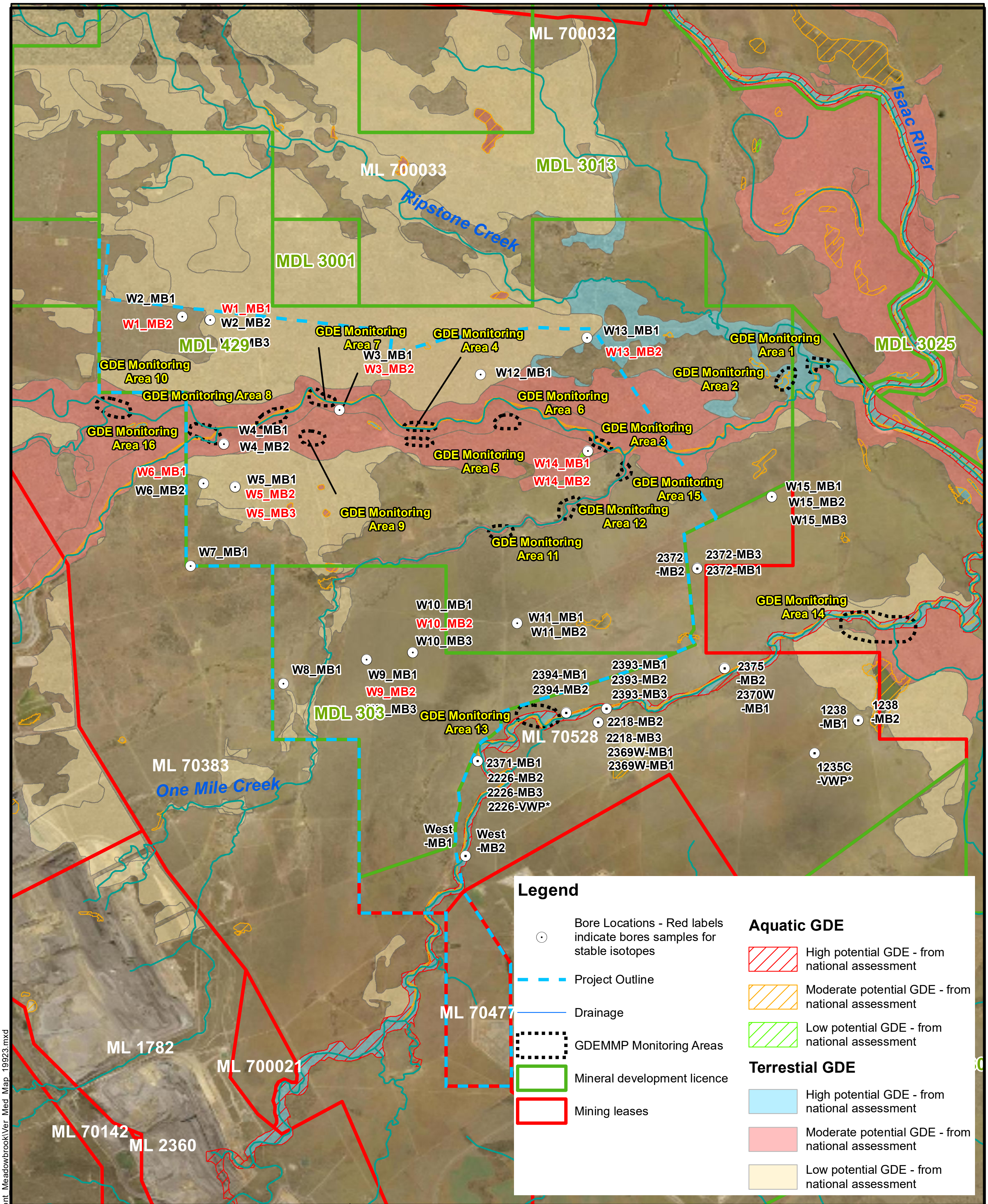

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Source: BOM GDE Atlas (2020).

Figure 13. The location of proposed GDE monitoring areas relative to potential GDE mapping produced by BOM (2020b)

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Table 4. Proposed GDE sampling program

Sampling Method	Sampling Locality	Sampling Intensity
LAI	Risk Zone 1	A minimum of 28 permanently located capture points within areas of maximum predicted groundwater drawdown and surface ponding including: a) Twelve capture points within the area of field verified Terrestrial GDE associated with the frontage of Boomerang Creek. This includes GDE Monitoring Areas 4, 7 and 8 within RE11.3.25. The most relevant groundwater monitoring bore is W3_MB1 and W3_MB2. b) Four capture points associated with GDE Monitoring Area 5, which overlaps with a broader expanse of Poplar Box Woodland TEC (RE11.3.2). The most relevant groundwater monitoring bore is W3_MB2. c) Eight capture points associated with GDE Monitoring Area 6 and Area 9, targeted to provide temporal assessment of the groundwater dependence of the Poplar Box TEC (RE11.3.2). The most relevant groundwater monitoring bore for GDE Monitoring Area 9 is W4_MB2 and W3_MB2, and W14_MB1 for GDE Monitoring Area 6. d) Four capture points placed within areas of the Brigalow TEC (RE11.3.1) associated with One Mile Creek at GDE Monitoring Area 11. GDE Monitoring Area 11 corresponds to GDE Site 17 from the EIS assessment (3d Environmental 2023a) and was assessed to not represent a GDE. There are no appropriate groundwater monitoring bores within vicinity of this proposed monitoring location.
	Risk Zone 2	A minimum of 20 permanently located capture points including: a) Eight capture points within the area of field verified Terrestrial GDE associated with the frontage of Boomerang Creek. This includes GDE Monitoring Area 3 (downstream from the zone of subsidence) and GDE Monitoring Area 16 (upstream from the zone of subsidence) located within RE11.3.25. The most relevant groundwater monitoring bore is W4_MB2 for GDE Monitoring Area 16, and W14_MB2 for GDE Monitoring Area 3. b) Eight capture points placed within areas of the Brigalow TEC (RE11.3.1) associated with One Mile Creek with the proposed location at GDE Monitoring Area 12 and Monitoring Area 15. W14_MB1 is the most appropriate groundwater monitoring bore within vicinity of GDE Monitoring Area 15. c) Four capture points associated within the area of field verified Terrestrial GDE on Phillips Creek. The proposed location is GDE Monitoring Area 13 within RE11.3.25 and 2394_MB1 provides a relevant groundwater monitoring bore.
	Risk Zone 3	A minimum of 4 permanently located capture points at the locality of GDE Monitoring Area 2, targeted to assess HES Wetland 8 (RE11.3.27), which was verified as a likely Type 2 GDE in the EIS assessment (3d Environmental 2023a) (GDE Site 3). There are no groundwater monitoring bores in the vicinity of this assessment locality.

Sampling Method	Sampling Locality	Sampling Intensity
	Risk Zone 4	A minimum of twelve permanent capture localities including: a) Four capture points within the area of field verified Terrestrial GDE associated with the frontage of Boomerang Creek (RE11.3.25) upstream from its junction with the Isaac River at GDE Monitoring Area 1[2]. b) Four capture points placed within the area of field verified Terrestrial GDE associated with the frontage of Phillips Creek (GDE Monitoring Area 14). c) Four capture points within the area of field verified terrestrial GDE on Boomerang Creek at GDE Monitoring Site 10. d) GDE Monitoring Area 1 and GDE Monitoring Area 14 are proposed as control sites, outside the footprint of predicted groundwater drawdown. e) GDE Monitoring Site 10 is proposed as an upstream control site on Boomerang Creek, although this locality will likely be impacted by drawdown associated with development of the Saraji East Project. f) There are no groundwater monitoring bores in the vicinity of these three proposed control sites (1, 10 and 14) and placement of a monitoring bore will likely be difficult at GDE Monitoring Area 1.
LWP[3]	Risk Zone 1	A minimum of 28 permanently located LWP monitoring trees within areas of maximum predicted groundwater drawdown and surface ponding including: a) Twelve LWP monitoring trees within the area of field verified Terrestrial GDE associated with the frontage of Boomerang Creek at s GDE Monitoring Areas 4, 7 and 8 within RE11.3.25. b) Twelve LWP monitoring trees associated with GDE Monitoring Areas 5, 6 and 9 which overlap with a broader expanse of Poplar Box Woodland TEC (RE11.3.2). c) Four LWP monitoring trees located within areas of the Brigalow TEC (RE11.3.1) associated with One Mile Creek at GDE Monitoring Area 11.
	Risk Zone 2	A minimum of 20 permanently located LWP monitoring trees including: a) Eight LWP monitoring trees within the area of field verified Terrestrial GDE associated with the frontage of Boomerang Creek. This includes GDE Monitoring Area 3 (downstream from the zone of subsidence) and GDE Monitoring Area 16 (upstream from the zone of subsidence) located within RE11.3.25. b) Eight LWP monitoring trees placed within areas of the Brigalow TEC (RE11.3.1) associated with One Mile Creek at GDE Monitoring Area 12 and GDE Monitoring Area 15. c) Four LWP monitoring trees associated within the area of field verified Terrestrial GDE on Phillips Creek at the location of GDE Monitoring Area 13.

[2] Note GDE Monitoring Area 1 is in a remote area that may be difficult, or impossible to access after seasonally wet periods. This may limit the capacity for field sampling at this locality in some seasons.

Sampling Method	Sampling Locality	Sampling Intensity
	Risk Area 3	a) A minimum of 4 permanently located LWP monitoring trees at the locality of GDE Monitoring Area 2, targeted to assess HES Wetland 8 (RE11.3.27), which was verified as a likely Type 2 GDE in the EIS assessment.
	Risk Area 4	A minimum of twelve permanent LWP monitoring trees including: a) Four LWP monitoring trees within the area of field verified Terrestrial GDE associated with the frontage of Boomerang Creek (RE11.3.25) near its junction with the Isaac River at GDE Monitoring Area 1[3]. b) Four LWP monitoring trees placed within the area of field verified Terrestrial GDE associated with the frontage of Phillips Creek (GDE Monitoring Area 14). c) Four LWP monitoring trees within the area of field verified terrestrial GDE on Boomerang Creek at GDE Monitoring Site 10.
Stable Isotopes[4]	All localities	The aim of the stable isotope program will be to determine the relative proportion of each moisture source being utilised by groundwater dependent vegetation and is to be completed as a component of the 2-year intensive data collection period. Further details of the purpose of the stable isotope sampling program are provided in **Section 8.4** which details the methods to be applied. Sampling for stable isotopes will be completed for a minimum: a) 21 trees within Risk Area 1 including: a. Three trees at each of GDE Monitoring Areas 4, 7 and 8 (9 trees in total). b. Three trees selected at GDE Monitoring Area 5. c. Three trees selected at GDE Monitoring Area 6 and Area 9 (6 trees in total). d. Three trees selected for One Mile Creek at GDE Monitoring Area 11 b) A minimum of fifteen trees from Risk Area 2 including: a. Three trees selected at both GDE Monitoring Area 3 and GDE Monitoring Area 16 (six trees in total on Boomerang Creek). b. Three trees selected from GDE Monitoring Area 12 and Monitoring Area 15 on One Mile Creek (Brigalow TEC) (six trees in total). c. Three trees selected from GDE Monitoring Area 13 on Phillips Creek. c) A minimum of three trees from the HES Wetland (Wetland 8) at GDE Monitoring Area 2. d) A minimum of three trees from each of the control sites located at GDE Monitoring Area 1 (Boomerang Creek Downstream), GDE Monitoring Area 14 (Phillips Creek) and GDE Monitoring Area 10 (Boomerang Creek Upstream) (nine trees in total). Stable isotope sampling will cover: e) Twigs from 48 representative trees across all risk areas including control sites.

[3] Note GDE Monitoring Area 1 is located in a remote area that may be difficult, or impossible to access after seasonally wet periods.

[4] Collection of LWP and the analysis of stable isotopes was completed in the EIS assessment (3d Environmental 2023a) and hence can be augmented with the intensive data collection period.

Sampling Method	Sampling Locality	Sampling Intensity
		f) Surface water from flows, if available at time of survey. g) Groundwater stored in riverbed (bank) sand aquifer in the river channel. h) Groundwater from alluvial monitoring bores collected during routine sampling events. i) Soil samples from auger holes, including 7 auger holes (three in the drawdown area; Two outside drawdown area; Two at control sites). j) Rainfall undertaken opportunistically.
NDVI Capture	Approximately 100km^2 capture to cover the relevant parts of the Lake Vermont-Meadowbrook Project Area ensuring the full extent of the GDE monitoring area to be covered (including control sites).	High resolution imagery from the WorldView 3 and WorldView 4 satellites (0.3m resolution, 4 -16 band multispectral) is recommended and will allow detailed monitoring of canopy vigour at extremely fine scale. The application of NDVI Imagery for the purpose of monitoring GDE / Vegetation health is discussed in **Section 8.5**. Localities will be established for permanent monitoring of NDVI to coincide with areas proposed for GDE monitoring. Established transects will be 100m length with measurement of NDVI completed at 1m centres along transect.
Groundwater Monitoring Bores	GDE monitoring bores as part of the dedicated groundwater monitoring program.	Monitoring bores which are applicable to monitoring of impacts to GDEs include existing bores W3_MB2, W4_MB2, W14_MB2, 2394_MB1. Additional dedicated GDE monitoring bores should be considered at the following monitoring localities: 1. GDE Monitoring Area 1 (Control Site on Boomerang Creek) and GDE Monitoring Area 14 (Control Site on Phillips Creek). 2. GDE Monitoring Area 11 and GDE Monitoring Area 12 on One Mile Creek. 3. GDE Monitoring Area 2 within or adjacent to HES Wetland 8. The capacity to construct groundwater monitoring bores at these locations will be dependent on seasonal accessibility. Monitoring of groundwater quality will be undertaken in accordance with the Lake Vermont - Meadowbrook groundwater monitoring program and will include parameters detailed in **Section 10.2.4**.

8.2 Interactions with Established Monitoring Programs and Parameters

The following interactions with monitoring programs that are either existing, or will be developed as a component of the ID project approval process:

1. **Surface water:** Surface water quality and environmental flows will be a component of the Lake Vermont Meadowbrook Project Water Management System (WMS) including a Receiving Environment Monitor Plan (REMP), allowing for early detection of any impacts water quality and employment of appropriate corrective actions. Surface flow and water quality datasets will be used, in conjunction with other parameters, to inform the baseline

characterisation of Terrestrial GDEs on Boomerang and Phillips Creeks and assess project impacts.

2. **GDE habitat quality:** A GDE habitat quality monitoring program will need to be developed to complement, although be separate from, this GDEMMP. Habitat quality sites, utilising methods prescribed in Queensland Government's Guide to Determining Terrestrial Habitat Quality – a toolkit for assessing land-based offsets under the Queensland Environmental Offsets Policy, Version 1.3 (DES 2020) to complement 'early warning' vegetation parameters assessed as a component of this GDE monitoring program. The GDE habitat quality monitoring program will assist measurement of the significance of project related impacts to GDEs. At a minimum, the GDE habitat quality monitoring program should establish one permanently maintained habitat quality site for each of the 14 proposed GDE Monitoring Areas.
3. **Groundwater:** The groundwater monitoring program is described in JBT (2023). The program covers operation of the monitoring bore network established as part of the EIS groundwater investigations and will be continued throughout the life of the Project. Records of groundwater levels and water quality from monitoring bores will continue to provide baseline information for groundwater fluctuations in response to rainfall and surface flows. These measurements will be used to distinguish groundwater drawdown resulting from proposed mining activities from natural fluctuation and provide a basis for investigation that can be related to the health and function of GDEs. Further information on the groundwater monitoring network including existing and proposed bores and water quality parameters is provided in **Section 8.6**.

8.3 Detection of Trends and Statistical Analysis

The BACI (Before After / Control Impact) provides a statistically robust survey design to test for environmental change in response to disturbance. The method takes a single impact site and a single control site (outside the impact area) before and after the management or impact has occurred to detect environmental change. In this regard, the proposed monitoring program includes:

1. Seven GDE monitoring areas (comprising multiple trees and LAI capture points) within the zone of maximum groundwater drawdown (>20m) and subsidence (Risk Area 1) (see **Table 1**).
2. Four monitoring areas within the area of groundwater drawdown ranging from >5m to 20m, though outside the area of predicted subsidence (Risk Area 2).
3. One monitoring area within the area of predicted groundwater drawdown that ranges from >2m to 5m (Risk Area 3).
4. Two monitoring areas proposed as control sites outside the footprint of modelled groundwater drawdown (Risk Area 4).

Statistical analysis will need to consider interactions between multiple datasets to establish baseline conditions and allow identification of statistically significant deviations from these conditions that may be associated with ID Project mining activities. The most critical interactions will be between biotic health (typically measured in LAI, LWP and NDVI) and abiotic factors such as groundwater levels and salinity. Statistical tests applied to analysis of data will depend on whether datasets are normally distributed and may include bivariate analysis of two datasets (e.g., NDVI and LAI) applying a Pearson or Spearman Correlation. 'T-tests' will be applied to identify significant differences in mean values between sampling localities. More complex statistical analysis may be applied if investigative actions are required including multivariate analysis of variance (PERMANOVA) to interacting datasets.

The overriding purpose of the data collection and subsequent statistical analysis is to provide representation of natural variation in the system applied to both biotic factors and abiotic controls and allow appropriate trigger thresholds to be proposed, which are further discussed in **Section 9.0**.

8.4 Application of Stable Isotopes to Determine Relative Contribution of Various Moisture Sources Utilised by Groundwater Dependent Vegetation.

The two-year intensive data collected period will be used to refine existing information on the sources of water utilised by groundwater dependent vegetation, including relative contribution each moisture source makes to a trees total water budget. While it may not be possible to precisely determine these proportions, it will be possible to determine the dominant sources of moisture utilised by trees at any sampling event. The process will involve:

1. Collection of xylem stable isotope samples from all trees proposed as permanent monitoring points (see **Table 4**) to determine isotopic signatures. To maximise to capacity to identify variations in moisture sources, trees proposed for sampling should be located at various geomorphic positions relative to the stream bank or targeted wetland.
2. Collection of soil samples for stable isotope analysis from eight dedicated auger holes, three within Risk Area 1, two within Risk Area 2, one within Risk Area 3 (HES wetland) and one at each of the control sites (outside of drawdown area). Augers should be:
    a. A maximum depth of 6m, or down to intersection with basement rock or groundwater strike.
    b. Sampled at 0.5m intervals down the soil profile.
3. Collection of groundwater held in riverbed (bank) aquifer associated with the Isaac River channel for stable isotope analysis.
4. Opportunistic collection of rainfall for stable isotope analysis.
5. Opportunistic collection of water from surface flows in Boomerang, One Mile and Phillips Creeks for stable isotope analysis.
6. Collection of groundwater from groundwater monitoring bores identified in **Section 8.1, Table 4**.

At a minimum sampling will need to be undertaken on a biannual basis, with collection of rainfall and surface water to be undertaken opportunistically throughout the baseline assessment period.

While comparison of stable isotope signatures in biplots, as completed during the EIS assessment (3d Environmental 2023a), provides a rapid means to identify the predominant sources of moisture utilised by vegetation, analysis of time series (seasonal) datasets may provide a measure of the water source partitioning of trees (i.e., the proportions used of each potential moisture source) during the various seasons. The Line Conditioned Excess method (Petit and Froend 2018) provides the simplest analysis technique, which relies on establishment of a local meteoric water line (LMWL) applying the method of Crosbie (2012), which can be used to identify stable isotope datasets that have undergone significant evaporative fractionation. To test for evaporative isotopic enrichment, the line-conditioned excess (or precipitation offset as per Evaristo et al., 2015) of soil moisture, xylem water, groundwater and other collected water sources will need to be calculated (lc excess = [δ2H − a δ18O – b]/S where a and b are the slope and intercept of the LMWL, and S is the standard deviation of both δ2H and δ18O values). Where lc excess values are close to zero, it indicates values similar to rainfall that have not been affected by high rates of evaporation (as per Petit and Froend 2018). By comparing the lc-excess for soil moisture, surface flows, stored groundwater in the channel, groundwater, and xylem water, it will be possible to identify which moisture sources are significantly different from each other. This provides a fingerprinting tool for the comparison of the lc-excess for xylem moisture to groundwater and other potential moisture sources will enable the 'degree of similarity' to be calculated, and identification of the dominant source of moisture utilised during typical seasonal variation. More importantly, it will make it possible to identify the variety of water sources utilised by trees that occur at various distances from the river channel and positions on the stream bank, allowing impacts to vegetation that result from groundwater vegetation to be more accurately predicted. The basis and process for stable isotope sampling and analysis is provided in **Appendix C2** with raw data from stable isotope sampling undertaken during the EIS assessment provided in **Appendix E.**

8.5 Application of NDVI Analysis

The NDVI datasets will provide a permanent record of vegetation health captured biannually during the intensive data collection period, with capture requirements following the baseline assessment period subject to review and modification where appropriate. To provide analysis of vegetation health that can be repeated precisely between capture events, permanently placed 100m transects will be co-located with GDE monitoring areas detailed in **Table 3**. Using permanent transect start and end points (from either relevant habitat quality sites or other established locations), the NDVI value will be sampled at 1m intervals along each transect (101 points in total from start to end point). This will extract data that can be presented in a line graph, to represent seasonal variation between survey events (see **Appendix C4**). A minimum of fourteen transects in total are to be selected to complement baseline data collected from each of the proposed GDE monitoring areas. The capacity to utilise remote sensing as a monitoring tool may have utility in the more remote or inaccessible sites (e.g., GDE Monitoring Area 1 and GDE Monitoring Area 2), enabling monitoring data to be collected when these sites are otherwise inaccessible due to weather constraints.

8.6 Groundwater Monitoring

The objective of the groundwater monitoring network design was to provide information to conceptualise the site hydrogeology and provide a monitoring network to establish baseline conditions. Of relevance to GDE function, the groundwater monitoring network will continue to provide baseline information concerning fluctuations in the groundwater table as a response to rainfall and surface flows and assist identification of drawdown in the alluvial and Tertiary groundwater systems. Groundwater quality and salinity will form part of the ongoing suite of chemical parameters that will be measured.

At a minimum, continuous groundwater level loggers should be installed in monitoring bores of strong relevance to GDE Assessment including W3_MB2, W4_MB2, W14_MB2, 2394_MB1 and any additional monitoring bores installed for the specific purpose of GDE monitoring or monitoring of groundwater in the alluvium or Tertiary sediments, including at control sites.

Groundwater Quality Parameters: In the context of GDE health, salinity and standing water level are the most critical chemical and physical monitoring parameters. There are currently no water quality guidelines for GDEs that rely on subsurface expression of groundwater. The suite of water quality parameters that are important for vegetation health should be considered as part of the groundwater monitoring program (Australian Government 2013) and would include:

1. Salinity
2. Dissolved oxygen
3. pH
4. nitrogen
5. phosphorus
6. organic carbon

9.0 Reporting, Periodic Review, Timing and Objectives

General program: This GDEMMP proposes methods that will result in collection of baseline ecological and biophysical data that will facilitate increased understanding of the ecohydrological function GDEs mapped within the influence of the Lake Vermont-Meadowbrook Project. During compilation and analysis of monitoring data, information gaps or data trends may be identified that indicate a need to update the GDEMMP approach and methods. To accommodate this requirement:

1. Reporting will be prepared at the completion of each monitoring event which describes:
    a. Methods employed.
    b. Factors that may have influenced data and monitoring results.
    c. Data trends for each of the parameters measured.
    d. Information gaps which may influence the assessment.
    e. Correlations between datasets which characterise ecological function.
    f. Trends which appear abnormal or indicative of unexplained / un-natural decrease in ecological function, warranting further investigation or corrective action.
2. Bi-annual monitoring (four events covering two wet seasons and two dry seasons) should be undertaken for a two-year period, commencing upon project approval and prior to construction.
3. At the completion of four monitoring events (excluding the original GDE assessment associated with the EIS), a consolidated report will be prepared which provides a synopsis of the data collected, including correlations between parameters and statistical analysis (where possible) to identify relationships between parameters and any significant changes to GDE health. The report will also refine habitats for ongoing monitoring where, excising habitats where temporal data does not demonstrate groundwater dependence.
4. Additionally, those GDE Monitoring Areas that can be shown through multiple lines of evidence (LWP, SMP and Stable Isotopes) to conclusively not be utilising groundwater to any significant degree during the two-year baseline period can be excluded from any ongoing monitoring. This may include areas of the Poplar Box TEC and the Brigalow TEC which were assessed to not be dependent on groundwater during the EIS assessment (3d Environmental 2023a).

The four-event intensive data collection period aims to determine the range of natural seasonal variation in the measured parameters, particularly LWP and LAI which are fundamental indicators of plant stress. These parameters can be correlated to the NDVI signature, which may allow future monitoring to be undertaken remotely at an 'on demand' basis, supplemented with field assessment should this be identified as appropriate. Additional field sampling assessments may be required if a significant departure from baseline condition is detected. Reporting and review requirements have been incorporated into a proposed two-year monitoring schedule as per **Appendix G**.

Ongoing monitoring following baseline: Following completion of the two-year (four-event) intensive data collection program, NDVI will be captured on an annual basis during the height of dry season (nominally October / November) to support ongoing monitoring of GDE health. NDVI threshold values will be calculated from correlations to LAI established during the baseline assessment, and annually checked for statistically significant threshold exceedance events that affect the impact site, in the absence of similar affects at the control site. The NDVI capture will be supplemented with field assessment measuring LAI and LWP at those monitoring areas identified for ongoing monitoring including control and impact sites on a two-yearly basis, at the peak of the dry season. Ongoing monitoring will also include monitoring of groundwater bores and habitat quality monitoring, as per details provided in **Table 3** and **Table 4**.

Monitoring completion: A monitoring event that includes field assessment of monitoring parameters should be undertaken to coincide with completion of mining at the Project. This event will include:

1. A comparison to the baseline GDE dataset to identify any significant departure from pre-impact conditions.
2. Provision of a summary memorandum detailing ecological condition of the groundwater dependent vegetation at all dedicated monitoring sites including control and impact and future monitoring requirements.

Providing there has been no significant decline in ecological condition that can be attributed to mining operations, follow up field survey periods will be:

1. Two years from completion of mining operations, timed to coincide with the driest portion of the year (typically September to November).
2. Four years following completion of mining operations, timed to coincide with the driest portion of the year.
3. A final survey event at six years following completion of the mining operation, or when rehabilitation of the mine site has been successfully completed.

Capture of NDVI datasets should continue to be completed on an annual basis to cover the six-year period at completion of mining. Considering the impact of groundwater drawdown on vegetation health can take several years to manifest, a period of six years, or until rehabilitation is successfully completed, should be a sufficient to capture any trend for declining vegetative health that is a result of mining activity.

10.0 Triggers for Investigative Action and Supporting Parameters

While groundwater is an abiotic control on the ecohydrological function of both the Type 1 and Type 2 GDEs in the Project Area, it is the ecological attributes and condition of terrestrial vegetation that defines GDE habitat values. Vegetation indices will be used to provide a baseline for ecological health and define trigger thresholds for initiation of investigative action. The indices used to define trigger thresholds, including potential parameters applied during investigative action are described in following sections. The management framework is intended to be adaptive, with future capacity for update dependent on the ongoing results of the baseline assessment, and any information gaps identified. Data derived from the groundwater monitoring program, specifically water level and water quality data, will provide supporting information to be used in the case that vegetation threshold values are breached, and investigative actions are necessary.

10.1 Vegetative Indices

Section 6.0 (**Figure 10**) identifies a decrease in LAI as an initial indicator of vegetative stress. LAI is a precursor to more intensive impacts to habitat values including canopy dieback and conversion to an alternative ecological state that may manifest over a longer time frame. LAI varies on a seasonal basis dependent on water availability, generally within the space of weeks to months, with the highest values lagging slightly behind moisture recharge events. Doody et al (2015) document typical annual LAI variation in the range of 14% to 35%, with LAI = 0.5 (i.e., 50% foliage to canopy ratio) identified as a potential threshold, indicative of critical water stress beyond which vegetation health rapidly declines. This value is taken from river red gum forest on the Murray River and it may not have similar applicability to the GDEs at Lake Vermont – Meadowbrook. However, the LAI threshold can be adapted based on the results of pre-impact monitoring assessments. The process for thresholds based on LAI applies the following principles:

1. Collection of time series data of LAI from control and impact sites for a period of two years to establish and test thresholds applied to vegetation indices.
2. Identifying appropriate thresholds which will be applied as a trigger for investigation and provide a mechanism to review the appropriateness of the derived trigger.
3. Statistical analysis of time series data to characterise seasonal differences in assessment parameters at control and impact sites to identify if a threshold breach occurs.

The application of a threshold value for LAI intends to provide an ‘early warning’ which will trigger a requirement for investigation to identify causal factors. This will allow mitigations to be applied to restore vegetation health if a threshold breach is linked to mining activities. NDVI may similarly be utilised to define a trigger threshold where it can be correlated to field measured LAI, supported by a suitable period of data collection. Where a threshold breach occurs, appropriate baseline data from a range of biotic and abiotic parameter will be available to provide a sound basis for investigation. **Figure 14** details the process and decision framework from initial data collection through to corrective actions in the case that a threshold breach can be linked to mining activity. The initial two years of the assessment covers wet and dry season surveys, to provide a baseline against which future vegetation condition trends can be assessed. The two-year baseline assessment and decision-making process are as follows:

1. Establish the proposed monitoring sites to capture LAI and supporting biophysical data (LWP and NDVI) at the proposed monitoring area in an initial GDE monitoring event prior to construction of the mine. The proposed location of the impact and control sites has been previously identified in **Section 8.1** and **Table 3**.
2. Establish an appropriate trigger threshold value based on the percentile method detailed in DSITI (2017). The proposed process for establishment of the investigative trigger thresholds is:
    a. Collect LAI data from the proposed impact and control sites (as per **Table 4**) at permanently located monitoring points in the initial GDE assessment.
    b. Undertake statistical analysis (t-test) to compare dataset means and ensure the appropriateness of the control site for comparative purposes.
    c. If a significant difference is detected between the mean values of control and impact datasets in the initial assessment, the location of the control site will be re-evaluated.
    d. Assuming suitability of the control site, set the lower of the 10^{th} percentile (or LAI of 0.5 as per Doody et al 2015, whatever value is lowest) as a trigger value for investigative action.
3. Collect seasonal data from a follow up assessment to provide an initial (I year) baseline dataset which considers seasonal variation.
4. Undertake an additional two monitoring events in the following year to complete the two-year baseline dataset. This will allow the appropriateness of applied thresholds to be tested and provide sufficient data to test for significant differences in means (t-test) to identify if a threshold breach occurs.

At each stage, decision pathways are provided when threshold breaches are identified, including requirements for investigative action and corrective measures where causal factors can be linked to mining activity. Corrective actions, including potential requirement for biodiversity offsets in a worst-case scenario, are discussed in **Section 11**.

Following the two-year baseline assessment, statistical correlation between various assessment parameters will be drawn, particularly the relationship between LAI and NDVI to allow ongoing monitoring to be completed remotely on an annual basis, and trigger thresholds to be adapted. The full suite of parameters collected during the baseline assessment period, with their relevance, intended application in both the baseline assessment and longer-term monitoring program is provided in **Table 5.** Supporting parameters are further discussed in **Section 10.2**. The process that occurs after the two-year intensive data collection period will follow the same process as shown in the flowchart in **Figure 14.** Instead of using LAI as a threshold parameter however, NDVI may be applied if a suitable statistical correlation with LAI can be confirmed, with a field assessment of LAI and LWP completed every two years as a control measure. Both NDVI and follow up field assessment will be completed in the dry season at impact and control sites to determine if the threshold is exceeded, and if exceeded, trigger the flow chart process for investigation, mitigation (corrective action) and offsets as required.

There is preliminary support for the assessment process described in the Isaac Downs GDE Baseline Assessment Report (3d Environmental 2023b). This assessment was completed after a prescribed two-year baseline assessment period (November 2020 to March 2022). The assessment confirmed the following correlations between monitoring parameters:

1. The most significant data linkage relates to the correlation between LAI and NDVI. At completion of the baseline assessment period, Pearson Correlation (r) identifies a statistically significant 'Moderate' positive correlation between these parameters (r= 0.5469; p=0.001) confirming the complementary nature of these datasets.
2. There is no significant correlation between LAI and LWP values. This is attributed to a significant lag response where an increase in LWP may take several weeks to months to stimulate a commensurate increase in LAI.
3. There is no statistically significant correlation between NDVI and LWP values. Like the described correlation between LAI and LWP, the lack of correlation relates to a lag response between high LWP values and a subsequent response in vegetative productivity that would be evident in an increase in NDVI.

The assessment was also able to successfully identify LAI impact threshold values for Isaac Downs Control Sites (LAI = 0.429), sites outside the groundwater drawdown area (LAI = 0.522) and sites within drawdown area (LAI=0.41).

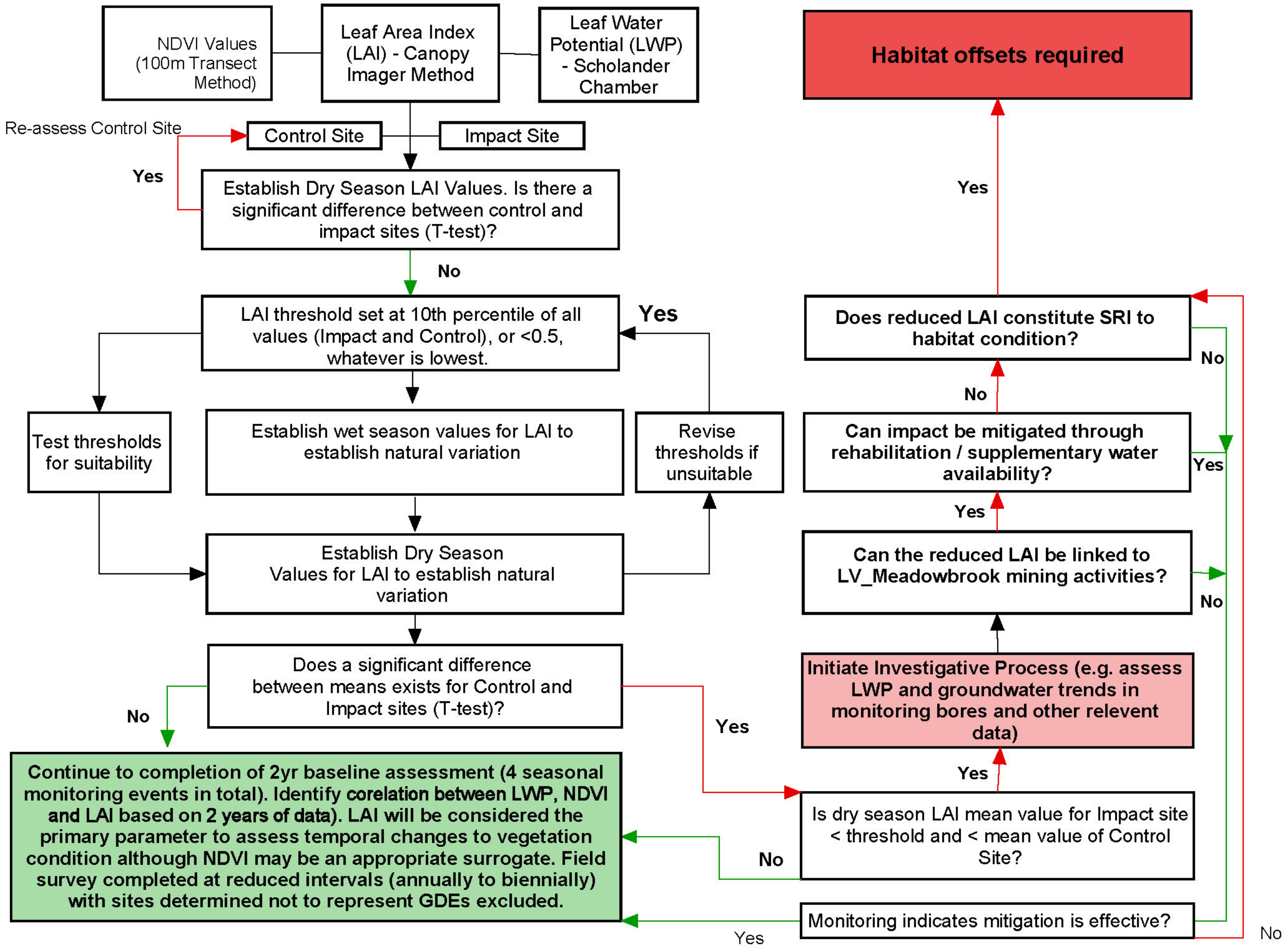

Figure 14. Decision process for application of investigative and corrective actions when trigger thresholds are exceeded for the initial 2-year baseline assessment.

10.2 Supporting Parameters

Supporting parameters are those that will be measured to provide a component of the baseline dataset and will be drawn on to support both the longer-term monitoring program and provide input into investigative action if required. Specifically, these supporting parameters will include LWP, stable isotopes, NDVI and groundwater monitoring data.

10.2.1 Leaf water potential

LWP provides the primary biophysical measure of tree water availability and defines a continuum between the relationship of soil, water, and plant. The relationship between LWP and LAI requires seasonal monitoring to be more confidently defined and any circumstance where LWP remains high and LAI decreases dramatically, indicates factors other than water availability may be influencing the relationship (e.g., insect defoliation). Regardless however, LWP measurements established during the two-year intensive data collection period will be a fundamental consideration for any future investigative action.

10.2.2 Normalised Difference Vegetation Index

NDVI is a measure of vegetation vigour, including a combination of greenness and biomass, which has a direct positive correlation to LAI. A correlation between field-based measurements of LAI and NDVI will be established over the 2-year intensive data collection period, to allow GDE monitoring to be undertaken remotely at a landscape scale on an annual basis. While a statistically significant positive correlation between LAI and NDVI has been demonstrated for the Isaac Downs baseline assessment project (3d Environmental 2023b), this will need to be verified at a site-specific level for Lake Vermont – Meadowbrook. Upon completion of the two- year baseline, trigger threshold values for investigative action will be calculated based on the correlation between LAI and NDVI, and it is proposed that ongoing annual monitoring will utilise high resolution NDVI as a surrogate for field-based LAI / LWP measurements should a suitable correlation be identified, supported by field-based sampling in the dry season on an annual to biennial basis. Further information on the NDVI process is provided in **Appendix C4**.

10.2.3 Stable isotopes

The primary role of stable isotope investigations is to inform how sources of moisture utilised by trees vary on a seasonal basis. The process for identifying dominant water sources using stable isotopes is discussed in **Section 8.4** with the dataset used to identify endpoints where vegetation is utilising groundwater alone, shifting in status to primary utilisation of soil moisture in the unsaturated zone, rainfall or surface water from river flows or wetlands. While stable isotope analysis provides insight into site ecological function, allowing risks to GDE function to be characterised, its relevance to ongoing monitoring diminishes once a seasonal dataset is established as it is not an indicator of plant health. Stable isotope analyses may be applied beyond baseline dataset collection to support investigative actions when a specific requirement or application is identified, allowing status shifts in seasonal water utilisation to be identified.

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10.2.4 Groundwater levels and quality

The collection of groundwater monitoring data which will be useful to characterise GDE function, has been ongoing since the installation of groundwater monitoring bores to extend existing monitoring for the Lake Vermont Project in March to April 2020 providing several years' worth of water level and water quality data for baseline characterisation, with installation of additional monitoring bores proposed. The data will be used to:

1. Monitor linkages between recharge of the alluvial groundwater system, surface flows and rainfall.
2. Establish water quality values, particularly for EC and how these may be influenced by recharge from the various sources.
3. Identify the degree to which the alluvial aquifer is utilised by vegetation (typically through analysis of stable isotopes) on a seasonal basis.
4. Identify ecological response to aquifer recharge including correlations between alluvial aquifer recharge, LAI, LWP, NDVI and climate data.
5. Monitor and quantify the impacts of mine pit development on drawdown in aquifers that support GDEs, particularly the alluvial groundwater system associated with Boomerang Creek (W14_MB2) where the highest risk of impacts occurs.

Water levels and water quality can be directly correlated to LAI to determine the relationship between groundwater and vegetation health. While Eamus (2006) defines 1500 µS/cm as a measure where salinity becomes toxic to red gum, any impact to the seasonality and water quality of the alluvial aquifer will be directly imparted on LAI and supporting vegetative parameters. The ecological response of vegetation to falling groundwater levels cannot be accurately linked or quantified to specific thresholds as it will be influenced by several factors including:

1. The rate of drawdown which directly influences the capacity of trees to adapt to a declining water table and reduced water availability.
2. Water quality, as the response will be influenced by changes to salinity rather than by water levels alone.
3. Surface water flows including timing and duration of flooding.
4. Site specific adaptions to water stress inherent in the local groundwater dependent vegetation including exposure to drought conditions.

Hence thresholds for investigative action that relate to groundwater levels and quality are not proposed in this GDEMMP, which otherwise relies on vegetation indices which define GDE health and function. The chosen vegetation parameter (LAI) will provide a rapid response to detrimental impacts of groundwater drawdown (within weeks), with data from the groundwater monitoring program providing the basis for investigative action as required.

Groundwater Quality Parameters: In the context of GDE health, salinity and standing water level are the most critical chemical and physical monitoring parameters. There are currently no water quality guidelines for GDEs that rely on subsurface expression of groundwater that characterise the Lake Vermont – Meadowbrook Project Area. The suite of water quality parameters that are important for vegetation health which will be monitored at bores will include:

1. Salinity
2. Dissolved oxygen
3. pH
4. nitrogen
5. phosphorus
6. organic carbon

In addition, groundwater monitoring will continue to sample water levels and quality monthly in accordance with the currently operating groundwater monitoring program, with continuous monitoring of standing water levels in selected monitoring bores measured with pressure transducers.

Table 5. Assessment parameters, application, and analysis.

Data collection method	Purpose	Analysis methods / metrics
Primary Parameter		
LAI	Primary parameter used to measure plant stress and vegetation response to decreasing groundwater.	Threshold to be set at the lower of the 10th percentile for all LAI data from the initial dry season survey (or 0.5 from Doody et al 2015, whichever is lower). A threshold response for investigative action will be triggered when: 1. The LAI at the impact site falls below the threshold value. 2. T-test indicates significant differences between means of control and impact sites, and 3. Impact site has a lower mean LAI value. The initial establishment of the trigger threshold will be undertaken in the first dry season assessment to be undertaken and relies on the means between impact and control sites to be comparable at the initial survey.
Supporting Parameters		
LWP	A measurement of water availability to trees, which will provide an important correlate with LAI and a baseline dataset to support a future requirement for investigative action. Supporting data which can be used to determine if any future LAI threshold trigger events are related to plant water availability.	1. Pearson / Spearman's correlation to establish if there is a statistical relationship between LAI and LWP as a basis for inclusion in investigative action, if required. 2. Application of a T-test to identify if significant differences between means of control and impact sites exist during the initial dry season assessment.
NDVI	A remotely sensed measurement of vegetation productivity that describes the greenness and the relative density / health of forest biomass.	Confirming the relationship between NDVI, LAI and LWP through application of Pearson's / Spearman's correlation. Longer term application to remotely monitor GDE health at completion of the 2yr intensive data collection period supplemented with field survey.
Stable Isotopes of twig xylem, soil,	Application as a tracer to identify the predominant sources of water utilised by trees. Useful to determine	Biplot comparisons of stable isotope values ($\delta^{18}O$ and $\delta^{2}H$) of tree xylem, groundwater and soil moisture to identify phase shifts.

Data collection method	Purpose	Analysis methods / metrics
groundwater and surface water.	how tree / water interaction varies on a seasonal basis as groundwater levels fluctuate. Most applicable in the baseline characterisation phase though may be useful supporting information if investigative actions are initiated.	Calculation of lc-excess as per **Section 8.4** to identify how the water sources of trees varies along the Isaac River frontage.
Groundwater monitoring data	The groundwater monitoring program, focused on the monitoring of the alluvial and Tertiary groundwater systems for the purpose of GDE health will: 1. Monitor linkages between recharge of the alluvial aquifer, surface flows and rainfall. 2. Establish water quality values, and the influence of aquifer recharge events from various sources. 3. Assist identification of the degree to which the alluvial and Tertiary groundwater systems is utilised by vegetation on a seasonal basis. 4. Identify ecological response to aquifer recharge including correlations between alluvial / Tertiary groundwater system recharge, LAI, LWP, NDVI and climate data. 5. Monitor and quantify the impacts of underground and open cut mining development on drawdown in groundwater systems that support GDEs, particularly the groundwater system associated with alluvium on Boomerang Creek.	1. Water quality measurement (as per Section **10.2.4**) associated with routine water sampling schedules. 2. Analysis of water levels and water quality in alluvial and Tertiary groundwater systems against vegetative indices including LAI and LWP through correlation testing (Pearson / Spearman's). 3. Pressure inducers (data loggers) installed into selected monitoring bores to continuously record water level changes.

11.0 Potential Corrective Actions and Adaptive Management

Corrective actions that halt or reverse impacts to GDEs are not well developed in literature and the suggested measures will require testing monitoring to determine / confirm their effectiveness if they are to be applied. Where impacts to GDEs are identified that can be related to mining activities, corrective actions should be taken to ameliorate the source of impact. Corrective actions will include treatment of affected vegetation through restoration of moisture supply, or infill planting to restore canopy gaps that have been created because of vegetation dieback.

11.1 Restoration of Tree Water Supply

Direct water injection: While there have been few case studies that have applied direct injection into the root zone, Berens et al (2009) investigated direct injection of fresh water into a saline aquifer on the Murray and found that while the trial resulted in temporary freshening of the capillary fringe, it had limited influence on tree condition as the radial extent of freshening (approximately 10 m) did not intersect with the root zone of salinity stressed trees. Therefore, application of this technique is likely to be practical for localised areas only where impacts are detected in scattered trees or scattered groups of trees rather than application in broader scale impact mitigation.

Infiltration of surface water: Where impacts to the health of groundwater dependent vegetation is detected through LAI measurement that can be attributed to mining activities, it may be possible to restore water supply in critical portions of the tree root zone through enhancing natural infiltration. This would include:

1. Construction of a shallow trench (1m) depth within the drip zone (margins of canopy reach) of affected vegetation.
2. Flooding the trench with fresh water, where it meets water quality objectives (e.g. supply of water from sediment ponds to where it meets low flow WQO of < 720 µS/cm).

Trench construction involves disturbance of the upper soil profile and may result in damage to tree root architecture if inappropriately placed. Ecological advice should be sought prior to trench construction to ensure adverse impacts are minimised.

11.2 Infill Planting

Forest red gum (*Eucalyptus tereticornis)* and weeping tea tree (*Melaleuca fluviatilis)* are the dominant groundwater dependent species occupying the banks of Boomerang Creek in Risk Zone 1, mixed with smaller proportions of river oak (*Casuarina cunninghamiana)*. These are the major riparian species that are likely to demonstrate groundwater reliance in the Project Area. Wetland 8, providing representation of a Type 2 GDE in the east of the Project Area, is also formed by a fringe of coolibah (*Eucalyptus coolabah).* Forest red gum is ecologically adaptable, occurring on dry hillslopes as well as floodplains and is a significant plantation species. Malik and Sharma (2004) found that the species has a strong capacity to extract moisture from the shallow soil profile (0 – 150cm) in the 426mm rainfall belt and Kallarackel and Somen (1997) identified that growth rates are not limited by water deficit. The adaptive capacity of other species is lesser known, although both weeping tea tree and coolibah have capacity to tolerate periods of soil drying, and coolibah can adapt to clay soils which are seasonal droughted. As an initial measure, trials using locally sourced forest red gum seedlings, a dominant riparian species on Boomerang Creek, should be undertaken to determine:

1. If infill planting of forest red gum in canopy gaps has capacity to ameliorate impacts caused by potential tree dieback.
2. Whether trees that have been planted in dry soil regimes have greater capacity to withstand environmental stressors than older established trees that have adapted over long periods to specific ecological water requirements (EWRs).

Small scale trials will commence upon approval of the GDEMMP, through planting of forest red gum and river red gum seedlings into existing canopy gaps. This will require some maintenance through drier periods until seedlings have established. Trials do not need to be extensive and will focus on the capacity of the species to survive, through planting of scattered trees into existing canopy gaps.

11.3 Monitoring of Corrective Actions

Where injection of fresh water into the tree root zone is applied as a management measure, the following approach to confirming the effectiveness of the measures should be considered:

1. Measurement of pre-impact LWP and LAI of trees where treatment is applied. Pre-impact canopy health can also be measured using NDVI imagery captured prior to treatment.
2. Repeat measurements for LAI and LWP to be taken at 1 month, three months and six months following treatment to measure vegetative response.
3. Ongoing annual monitoring of crown health of individual trees using high resolution NDVI in accordance with annual monitoring program post baseline assessment, supplemented with field measurements of LWP and LAI every two years.

Plantings will be checked for disease and loss of vigour:

1. At least weekly for the first month including any watering requirements to aid establishment.
2. Monthly for the next 5 months, and;
3. Annually following the initial six months, in conjunction with the annual GDE monitoring program.
4. Records must be kept of the above works.

11.4 Triggers for Ecological Offset

In the absence of positive results from mitigation measures and / or infill planting, and degradation of GDEs that can be directly attributed to mining activity, the requirement for biodiversity offsets will be assessed based on impacts to habitat condition. Disturbance thresholds that indicate a requirement for offsetting of GDEs and listed species (including habitat for koala and greater glider) will be developed after completion of the 2-year baseline assessment, in consultation with the Department of Climate Change, Energy, the Environment and Water (DCCEEW), incorporated into an updated post baseline GDEMMP (see **Appendix G**). Triggers and requirements for offsets will be guided by the baseline biocondition information gathered in the habitat quality assessment using the QLD habitat quality assessment methodology (Queensland Government's Guide to Determining Terrestrial Habitat Quality – a toolkit for assessing land-based offsets under the Queensland Environmental Offsets Policy, Version 1.3) (DES 2020).

To adequately assess whether any detected reduction in habitat quality constitutes a threshold exceedance requiring an offset, it may be necessary to continue monitoring over an extended period (nominally 2 years). This will ensure that the original exceedance event represents a trend toward longer term decline in habitat condition or is a short-term perturbation that can be corrected with application of appropriate mitigation, or a return to normal climatic regimes.

Relevant EPBC Act listed species are identified in the Lake Vermont Meadowbrook Terrestrial Ecology Assessment (AARC 2023b) and assessment of the significance of impact should be guided by the proposed habitat quality assessment program.

The decision-making process which determines the level of action required has been provided in **Figure 14**, which indicates ecological offset as a final measure applied to compensate habitat loss. The management framework is intended to be adaptive, with future capacity for update dependent on the ongoing results of the baseline assessment, and any future information gaps identified.

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13.0 Appendices

Appendix A. Lake Vermont Meadowbrook – Stygofauna Monitoring and Management Plan

Lake Vermont Meadowbrook- Stygofauna monitoring and management plan

Background and purpose

The Lake Vermont Meadowbrook Project (the Project) is a new underground and open cut metallurgical coal Project that will serve as an extension of operations at the existing Lake Vermont Mine operation. The Project is located 25 kilometres (km) northeast of the township of Dysart and 160 km southwest of Mackay. The Project area occupies Mineral Development Licence (MDL) 429 and MDL303.

A Stygofauna Assessment was carried out by Stygoecologica (2022) which identified some stygofauna values in the Project area. This monitoring and management plan has been developed in response to this finding and is based on the recommendations of the assessment report. The purpose of this plan is to provide an approach to further characterise and detect any changes to the stygofauna communities.

Relationship with other management plans

This stygofauna management plan will interact closely with the Water Management Plan. The Lake Vermont Water Management Plan will be for the management of impacts to water including:

- Groundwater monitoring and management;
- Surface water monitoring and management; and
- Erosion and sediment control.

Existing environment

Topography

The study area is situated within the Bowen Basin of Central Qld and covers Lake Vermont Meadowbrook Project area and surrounding lands and is located within the catchment of five water sources that are tributaries of Isaac River. These are ordered from north to south and include: Ripstone Creek (third order stream), Boomerang Creek (fifth order stream), Hughes Creek (fourth order stream and tributary of Boomerang Creek), One Mile Creek (third order stream) and Phillips Creek (fourth order stream).

The current land use of the study area is agricultural with the primary industry being beef production and for exploration activities. As described above, several mining operations or projects occur to the north and west of the study area and the Project represents an extension of mining activities at the existing Lake Vermont Mine located to the immediate south. Boomerang Creek, One Mile Creek, and Hughes Creek flow through the neighbouring BMA leases (Saraji Mine, Saraji East Project) upstream of the Project. Ripstone Creek and its tributaries cross the northern sections of MDL 429. Ripstone Creek flows through both the BMA leases and the recently approved Olive Downs Coking Coal Project, before joining with Boomerang Creek and flowing into the Isaac River. Phillips Creek flows through both the BMA leases and other Lake Vermont Mine tenements. Streamflow in the region is highly variable, with periods of flow (typically during December to April) interspersed with long dry spells.

The topography of the study area is dominated by the floodplains of Boomerang Creek and One Mile Creek. The area is relatively flat with only slight undulation, with ground elevations ranging between 166-187 m Australian Height Datum (AHD)

Geology

The Project is dominated by the three major regional geological formations:

1. Cainozoic sediments - The surface geology and the alluvial sediments across most of the Project area is Cainozoic and includes a combination of Quaternary and Tertiary sediments. These are composed of fine sands, silt, clay, and minor gravel. The depth of this formation is highly variable ranging from 2 to 80 m and averaging 26 m. The formation gradually thickens through the southern part of the area to the south of Boomerang Creek) to 35 – 45 m. In the area to the north of Boomerang Creek, the Cainozoic thickness is more than 60 m, with the area of greatest thickness associated with a topographic high (Minserve 2017, JBT Consulting 2022). The Quaternary alluvial sediments generally overlaying the sandier Tertiary sediments. The watertable is generally developed in the Tertiary sediments below the base of alluvium, and the alluvium is likely to be seasonally saturated following direct rainfall recharge and especially following flow events in Boomerang Creek that will provide more direct recharge to the alluvium.

2. Rewan Group – which is an early to mid-Triassic sandstone, mudstone, and conglomerates. The Triassic Sagittarius Sandstone occurs beneath Cainozoic sediments and is the basal formation of the Rewan Group. The unit is up to 300 m thick and is differentiated from the underlying Permian Rangal Coal Measures by a 1 to 3 m thick mudstone, which acts as a regional stratigraphic marker for the base of Rewan (Minserve 2017).

2. Permian Overburden (the Fairhill Formation / Fort Cooper Coal Measures) – which are Permian Age sandstones, conglomerates, mudstones, carbonaceous shales, coal, and cherty tuff. Fort Cooper Coal Measures. The Late Permian Fort Cooper Coal Measures stratigraphically underlie the Rangal Coal Measures with the unit sub cropping beneath Tertiary sediments within the western area of the Project area due to either the dip of the strata or due to faulting (e.g., east of the Isaac Fault) (JBT Consulting 2022).

Groundwater

Geological and hydrogeological units within the area are as follows.

Alluvial Aquifers- Quaternary Alluvial Aquifers

Quaternary alluvium is of limited lateral extent, relatively thin and has not been observed during prior site investigations or geological exploration data, to contain groundwater. It is conceptualised that this is a shallow, ephemeral, losing groundwater system that does not typically contain permanent groundwater as the alluvial flow seeps downwards into the underlying Tertiary sediments (JBT Consulting 2022). The modelled data (JBT Consulting 2022) suggests the only location where the alluvium is permanently saturated is the Isaac River alluvium (SLR 2021a). The alluvium, however, may be of importance as a source of groundwater recharge to underlying units which could explain the predominance of bores in areas beneath surface drainage lines.

Tertiary Sedimentary Aquifer

Tertiary sediments consist of a sub-horizontal blanket and have been previously observed from both exploration and groundwater drilling to be generally dry. However, the basal sand and gravel deposits have been noted to contain localised pockets of groundwater in some instances. The occurrence of these deposits is sporadic, and the continuity of the deposits is not mappable. These pockets of groundwater along Boomerang Creek are potentially biological hotspots.

Triassic Sedimentary (Rewan Group) Aquifer

The Triassic Rewan Group occurs as a discrete lens that is fault-bound to the east by the Isaac Fault and forms the recognised basal confining unit of the hydrogeological Great Artesian Basin and normally conceptualised as being a regional aquitard. The unit is known to contain structures or sandstone lenses that can provide locally useable volumes of water for stock supply. However, in the surrounding region there are no registered bores constructed within Rewan Group sediments. This observation, combined with observations from prior drilling nearby, supports a conceptualisation of this unit as low permeability not forming significant regional groundwater units, and likely unimportant as a potential source of groundwater.

Coal Seam Aquifers-Permian Sedimentary Aquifers

Within the Bowen Basin it is generally accepted that coal seams are more permeable relative to the Permian overburden and interburden material. Bores are often drilled dry until a water-bearing coal seam is encountered, with water rising along the borehole, indicating confined conditions within the coal. Due to the low permeability of the coal measures, groundwater residence time is often long, resulting in occurrences of highly saline groundwater in some areas. It is often the case however, that the coal measures are the first unit where useable volumes of groundwater are encountered.

Stygofauna

Baseline stygofauna monitoring for the Assessment Report (Stygoecologica 2022) identified some stygofauna through monitoring. The location of monitoring bores is presented in Figure 1. The sites where stygofauna were identified can be described as comprising two ecotones:

Ecotone 1 –

These are sites where stygobites were recorded including W3 MB2 and W14 MB1. The following taxa were recorded:

- Oligochaeta (Naididae)
- Copepoda (cyclopidae)

Ecotone 2 –

These are sites where terrestrial fauna were recorded (stygophiles/stygoxenes/edaphobites) including sites W3 MB1, W4 MB1, W5 MB1, W14 MB1. The following taxa were recorded:

- Arachnida
- Collembola
- Diplura
- Insecta

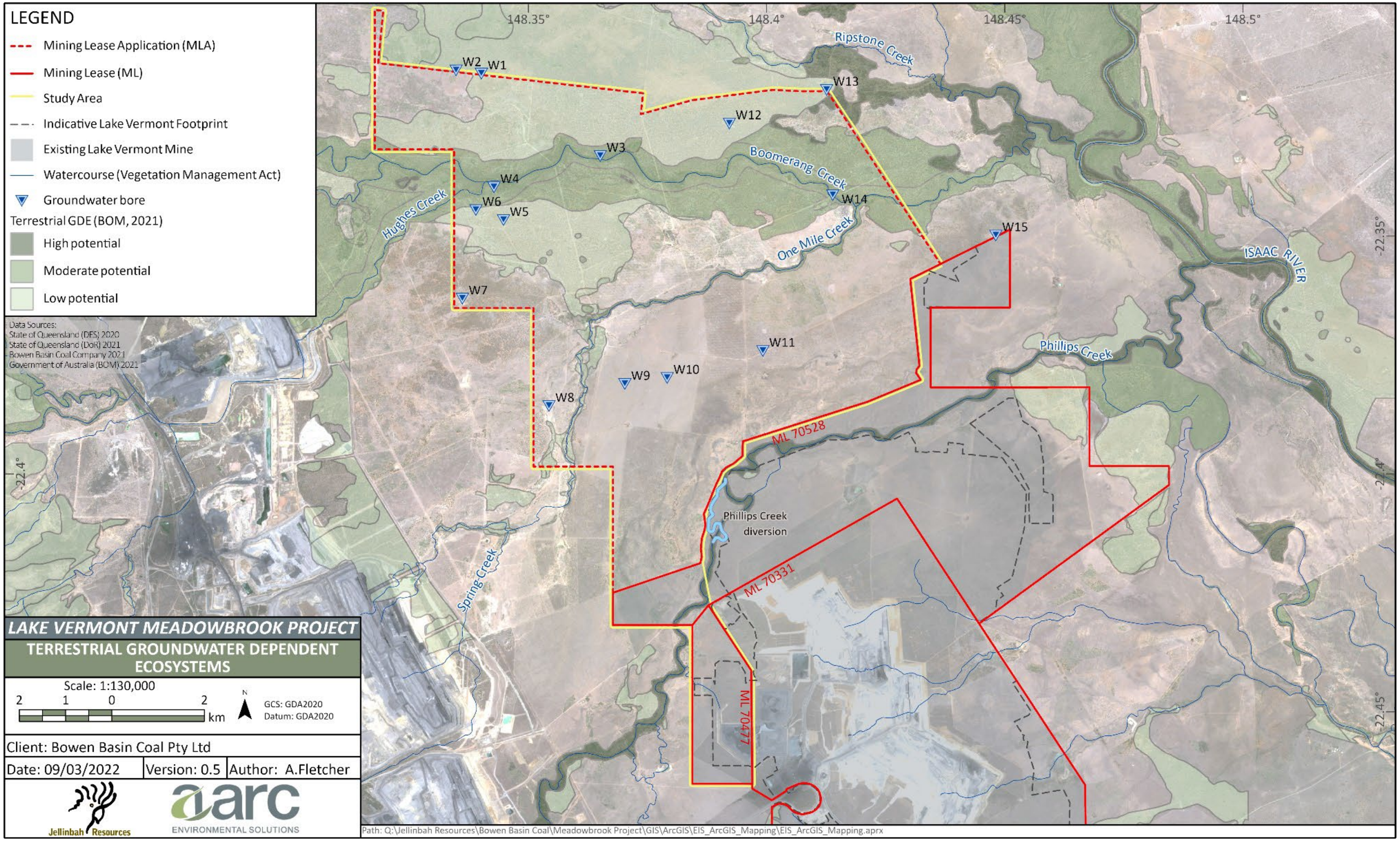

Figure 1 Stygofauna monitoring bore locations

Approach to monitoring and management

Extended baseline stygofauna monitoring and analysis techniques

The approach is a Before/After Control/Impact design approach. This approach requires development of an understanding of the natural predevelopment conditions of the environmental and community parameters for a period before the development commences at both control (reference) sites not affected by the development and potential impact areas. The natural range and thresholds of these parameters prior to the mine development provides data with which to compare the post development environmental conditions and determine if there have been any impacts to the environment.

The baseline monitoring will be conducted annually for two years and represents a continuation of the previously conducted monitoring. This period allows improvement of the determination of the natural ranges of the environmental parameters and community composition in response to changes in seasonality and climate variables as these conditions determine regional and localised aquifer water levels, flow directions and water chemistry conditions.

The result of the additional two years baseline monitoring will be interpreted in conjunction with the previously conducted one-year baseline monitoring (Stygoecologica 2022).

Two standardised sampling methods may be employed:

- Use of a weighted phreatobiology net with mesh size of 150 µm. The net is deployed into the sampling bores and three consecutive hauls from the entire water column is collected. Upon removal from the bore the net is washed of sediment and animals and the contents of the sampling jar (the weighted container at the bottom of the net) are decanted through a 150 µm mesh sieve. The contents of the sieve are then transferred to a labelled sample jar and preserved with 100% ethanol.
- Use of a groundwater bailer. A one meter bailer is deployed into the bore and contacted with the bottom sediments. The contents of the bailer are emptied into a cleaned bucket from which the water is then decanted through a 150 µm mesh sieve. The contents of the sieve are transferred to a labelled sample jar and preserved with 100% ethanol.

All samples are sorted and identified in the laboratory and samples subsequently stored in 100% ethanol. All specimens are identified to the lowest possible taxonomic level, generally to genus, where possible. Specimens are identified under a compound microscope using a combination of current taxonomic works and keys such as Williams (1981) and the taxonomic identification series (Serov 2002) produced by the Murray Darling Freshwater Research Centre as well as the taxonomists expertise and experience.

Physico-chemical monitoring

Water quality parameters including electrical conductivity and pH are collected in the field using a water quality multimeter. Bore depth and water level (SWL) data is each survey using a depth probe in the field during the survey. Physical and chemical parameter data collected in the course of the groundwater monitoring under the Project Water Management Plan is accessed to describe water conditions.

Monitoring sites

Monitoring is conducted at groundwater bores shown in Table 1. The location of monitoring bores are shown in Figure 1. Bores added to the groundwater monitoring bore network will be considered for inclusion in the stygofauna monitoring network, particularly for bores close to One Mile Creek and sites which may serve as reference sites for monitoring.

Table 1 Stygofauna monitoring bore sites

Bore ID	Groundwater unit	Easting (AGD84)	Northing (AGD84)	Collar RL (mAHD)	Casing stickup (m)	Bore depth (m)	Slotted (mbgl)
W1_MB1	Tertiary sediments	637914	7531373	187.09	0.6	45.5	42.6-45.1
W1_MB3	Vermont Seam	637919	7531372	187.18	0.6	124	121.5-124
W2_MB1	Tertiary sediments	637368	7531452	187.92	0.6	42	33-40
W2_MB2	Girrah 1 Seam	637370	7531452	187.93	0.6	110	103-110
W3_MB1	Quaternary alluvium	640470	7529435	176.8	0.6	12	9 - 12
W3_MB2	Tertiary sediments	640468	7529435	176.2	0.6	41	34-41
W4_MB1	Quaternary alluvium	638172	7528735	179	0.6	12	9 - 12
W5_MB1	Rewan Group	638387	7527823	181.15	0.6	50	43-50
W6_MB1	Permian overburden	637758	7527892	179.85	0.6	56	49-56
W11_MB1	Rewan Group	643941	7524860	174.42	0.6	120	113-120
W12_MB1	Tertiary sediments	643268	7530165	166.8	0.6	60	53- 60
W14_MB1	Tertiary sediments	645373	7528515	166.8	0.6	20	14.6-18.6

Trigger for operational stygofauna monitoring and management

The Stygofauna Assessment (Stygoecologica 2022) identified an aquifer where stygofauna were recorded to have a Class G risk ranking i.e., Low Ecological Value/Low Ecological Risk for the current ecological conditions and the risk from the proposed development. The Class G suggests the following actions are required over the life of the development:

1. Protection measures for aquifers and GDEs in the short and mid-term,
2. Baseline risk monitoring in the short and mid-term
3. Ongoing adaptive management and continued monitoring in the long term.

In the event the extended baseline monitoring identifies higher stygofauna ecological value than identified previously by Stygoecologica (2022), the requirement for continued operational phase monitoring and management will be considered. Additional surveys could be conducted above and below the mine lease area and in adjacent catchments/sub catchments such as the Isaac River to determine taxa ranges. Where taxa are identified to have short range distribution and be endemic to the Project area, management may be adopted including standard set of performance indicators and rules to protect the identified ecological assets. The performance indicators may include the following environmental measurements:

- Conduct annual biodiversity hotspot surveys in conjunction with monthly water quality monitoring program to monitor potential changes/impacts to the stygofauna community over the life of the mine until after the mine closure and rehabilitation period.
- Continue ongoing monthly monitoring of water levels, and water chemistry, with the addition of water temperature.

Potential management actions

There are two strategies for managing the risk of an activity to each aquifer (or water source) and GDE. These are:

1. Management actions

- Management actions are the generic management strategies for the protection of GDEs through the protection of the aquifer. These actions use the precautionary principle and are intended as preventative measures. The Precautionary Principle is applied where there are threats of serious or irreversible damage (principle adopted at the 1992 United Nations Conference in Rio on Environment and Development).

2. Mitigation actions

- Mitigation actions differ from management actions in that they are generally additional measures for managing short term or localised impacts. Mitigation actions are likely to be needed when an activity has already had an impact and would require immediate action. Additional funding and resourcing will often be required to ensure their implementation (Serov et. al, 2012).

The management actions to protect the identified subterranean ecological assets should also reflect/include the three components required for subterranean ecosystem health as outlined in Stygoecologica (2022):

1. Stable water quality/physicochemical parameters.
2. Stable water levels and connectivity with surface waterways.
3. Stable Subterranean connectivity and aquifer flow direction patterns.

Administration

Interpretation and reporting

Data will be analysed as they are gathered and aim to identify any trends and patterns including;

- The overall surface and groundwater chemistry, including establishment and modification of trigger values; and
- Subterranean Fauna diversity (species richness and abundance) and community assemblages.

A subterranean fauna monitoring report will be prepared at the completion of each survey period. The subterranean fauna monitoring report will include:

- Executive summary – highlighting key findings;
- Introduction – outlining background information and catchment setting including geology and aquifer description, surface/groundwater interactions, local climate, landuse, etc;
- Monitoring Design – sample site selection (detailing site selection process relevant to this management plan;

- Methods – outlining sampling and analysis methods of assessed parameters including details on QA/QC protocols;
- Results – detailed habitat, groundwater level and quality, subterranean fauna analyses and interpretation of all abiotic and biotic monitoring results
- Discussion; and
- Summary and Recommendations – highlighting any recommended refinements/improvements that could be made to the monitoring program.

Roles and responsibilities

Position	Responsibility
Environmental officer	• Implementation of this management plan • Review the plan and make changes as required • Ensure staff are aware of their obligations under this plan • Undertake/commission stygofauna monitoring as detailed in the Management plan • Maintain site records of all monitoring
Operations manager and site supervisors	• Ensure sufficient resources are available to enable this MMP to be appropriately • implemented. • Ensure the plan is being adhered to on site • Participate in the management of this plan as required

Reviews and revision

The stygofauna monitoring and management plan will be actively managed after the extended two year baseline monitoring and if monitoring continues beyond that time, reviews occurring after the analysis of the monitoring data, and any actions taken to modify the plan.

References

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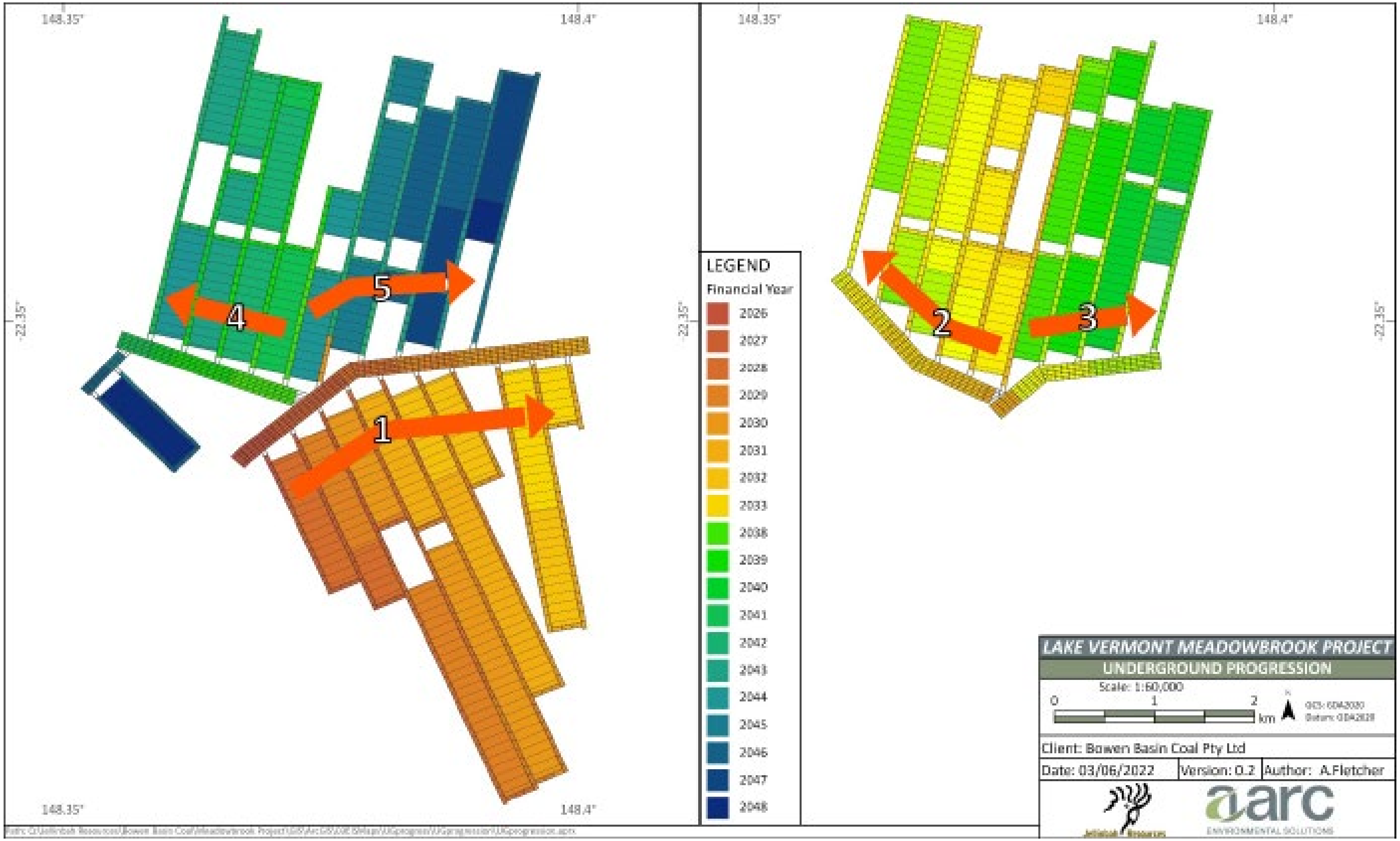
Appendix B. Lake Vermont - Meadowbrook Mining Stages



148.35°
148.4°
-22.35°
1
2
3
4
5
LEGEND
Financial Year
2026
2027
2028
2029
2030
2031
2032
2033
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
LAKE VERMONT MEADOWBROOK PROJECT
UNDERGROUND PROGRESSION
Scale: 1:60,000
0
1
2
km
Client: Bowen Basin Coal Pty Ltd
Date: 03/06/2022
Version: 0.2
Author: A.Fletcher
aarc
ENVIRONMENTAL SOLUTIONS


North Sed Dam 1
Year 22
South Sed Dam
Year 27
North Sed Dam 2
South Sed Dam
Year 29
Final Landform
LEGEND
Mining Lease Application (MLA)
Mining Lease (ML)
Watercourse
Catchment Boundary
Storage
Cleared/Prestrip
Hardstand
Pit
Unrehabilitated Spoil
Contour - 5m
LAKE VERMONT MEADOWBROOK PROJECT
OPEN CUT MINE PROGRESSION
0 1 2 3 4 km
Coordinate System: GDA2020
Scale: 1:85,000
Date: 15/07/2022
Author: M.Laws
Version: 0.2

Appendix C. Sampling Methods

C1. Leaf / Soil Moisture Potential

The measurement of leaf moisture potential will be targeted to specifically assess the interactions between tree roots and soil moisture / groundwater. These measurements will only be undertaken at the chosen localities on selected trees (as per **Section 8.1**) placed specifically to assess for these interactions.

Rationale

Leaf water potential is the total potential for water in a leaf consisting of the balance between osmotic potential, turgor pressure and matric potential. It is defined as the amount of work that must be done per unit quantity of water to transport that water from the moisture held in soil to leaf stomata. It is a function of soil water availability, evaporative demand and soil conductivity.

Measurement of leaf water potential is undertaken by collecting leaf samples at pre-dawn and using a Scholander pressure chamber (pressure bomb) to measure the pressure required to force water from the stem of the leaf. The results of the leaf water potential measurement are then compared to either the soil moisture potential at the same site collected at regular vertical intervals by drilling down to the water table and using a dewpoint potential meter.

It is assumed that trees will be using water from a source that requires the least energy (lowest water potential) to lift water from the soil, through plant xylem to the leaf for transpiration. This will be dependent to a large part on recent rainfall as well as the specific physical attributes of the soil that holds the rooting material. Heavy clays for example, may have a relatively high water content, although this water is hard to extract due to the cohesive forces of the fine particles which hold water very tightly. Clays will thus have a lower water potential than sand which has large pore spaces between the grains and much lower cohesive forces.

It is must also be recognised that trees at the chosen monitoring sites may not be accessing water from one specific source exclusively. Moisture from several horizons within the soil profile may be contributing to tree water requirements, and the predominant source of water may vary on a seasonal basis. To maximise the likelihood of identifying trees that are predominantly using groundwater, it is important that assessments be undertaken in the seasonally driest part of the year.

Methodology

Leaf water potential needs to be measured pre-dawn (prior to sunrise). The basis of this requirement is that pre-dawn measurement provides an estimate of the water potential of the wettest part of the soil profile that contains a significant amount of root matter (Eamus et al 2006). It is assumed that pre-dawn leaf water potential will equilibrate overnight to the portion of the soil profile that has the highest water potential. Hence contemporaneous measurement of both pre-dawn leaf water potential from a canopy tree at a chosen monitoring locality and soil water potential from selected depth intervals down a co-located borehole will provide an indication of the predominant source of water (soil moisture or groundwater) being utilised by trees at the time of survey.

Measurement of Leaf Water Potential

Leaf water potential is measured pre-dawn (prior to 5.30 am in summer) using a Plant Water Potential Gauge (originally referred to as the Scholander pressure chamber or 'Pressure Bomb'). Measurement of leaf water potential requires:

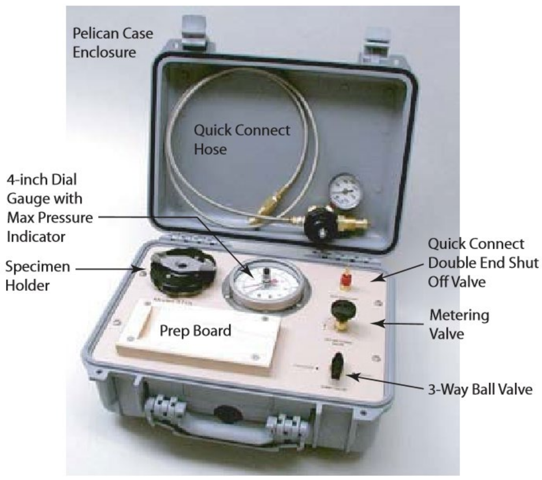
1. Collection of leaves from an accessible part of the tree crown.
2. Preparing of leaf material for insertion into the pressure bomb.
3. Measurement of Leaf Water Potential using the pressure bomb.

Collection of Leaf Material: Leaf material is to be collected from the highest accessible portion of the tree crown using an extension pole and attached lopper head (see **Section 8.5.2.2**). Leaf material should be selected that is disease free (as far as practical) and vigorous, preferably with indications of new leaf growth at the growing tips.

Preparation of Leaf Material: A representative sample of healthy leaf is removed from the collected material with sufficient leaf stem (petiole) to allow it to protrude outside the water potential meter (typically 1 to 2 cm). The stem is cut square with a sharp blade and immediately inserted into the water potential metre with the grommet sealed.

Use of the Plant Water Potential Gauge: The preferred Plant Water Potential gauge is the Model 3115 Plant Water Status Console due to its compactness and portability. The device is manufactured in USA (Soil Moisture Equipment Corp.) and distributed in Australia by ICT International (Armidale). The device fits into a 16 x 13 x 7inch Pelican Case and weighs approximately 11kgs which includes the compressed gas cylinder.

Additional Safety and Operational Measures: The Model 3115 console is accompanied with a detailed unit operation manual which describes in detail the required operational procedures. The unit operates on a compressed gas cylinder which should be professionally refilled with compressed N_2. As pressure is applied to the chamber, there is potential for the leaf petiole to be forcefully ejected from the chamber. Hence safety glasses will be required during unit operation.



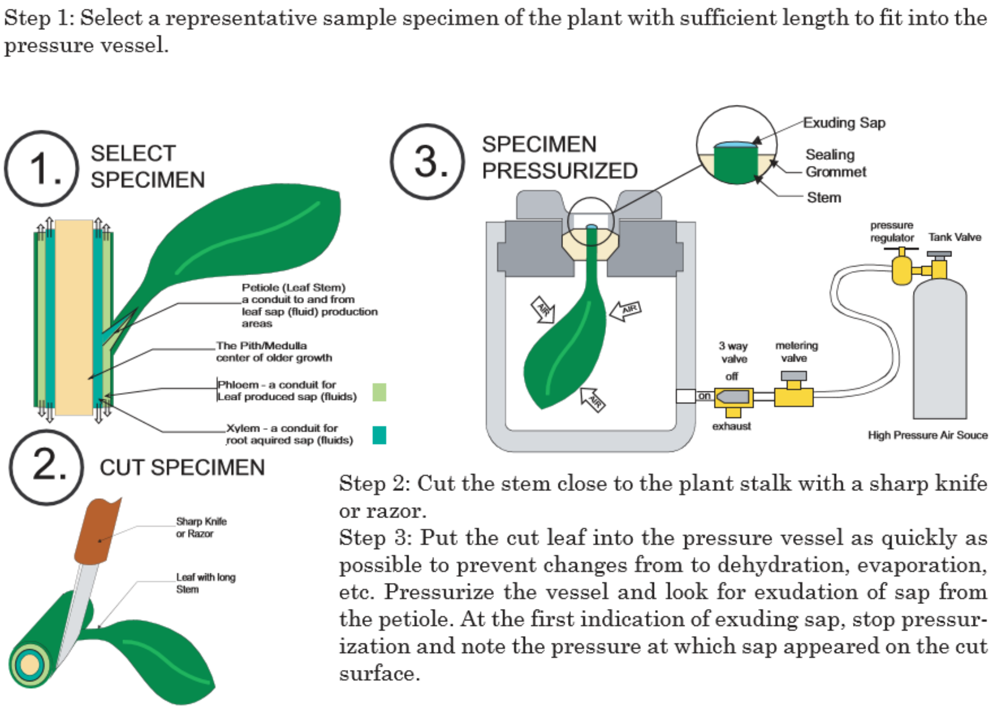
B1. Model 3115 Plant Water Status Console with parts description.

The Water Potential gauge measures leaf or stem water status by the following method:

1. A leaf or stem is collected from the tree that is targeted for assessment.

2. The petiole (leaf stem) is cut and placed in the pressure chamber with the cut stem protruding from the chamber at atmospheric pressure.
3. The vessel is sealed around the petiole and pressure applied via an external gas cylinder.
4. The protruding stem is observed and pressure readings recorded at the first point that water is noted to be exuding from the leaf.
5. The positive pressure applied to the leaf that forced water from the leaf stem is measured. This is the leaf water potential.

The process as supplied by Soil Moisture Equipment Corp (2006) is provided in **Figure 19** below.



B2. Diagrammatic illustration of the use of the Pressure Bomb as per Soil Moisture Equipment Corp. (2006).

Measurement of Soil Water Potential

Soil moisture potential should be measured, utilising a soil auger, in specific cases where results of LWP analysis require additional explaination. This would occur primarily as result of unexpectedly high, or unexpectedly low LWP measurements that cannot be contextualised based on seasonal conditions. The same sampling protocols applied to soil sampling for stable isotopes should be applied to assessment of soil moisture potential. This includes:

1. An initial soil sample taken within the top 10cm of the soil profile.
2. Subsequent sampling at 0.5m intervals down borehole to the top of the Permian basements.
3. Additional measurements taken whenever there is a noted change is soil texture within the soil core (i.e change from clay to sandy clay / loam).

Sampling should be undertaken with a portable hand auger with a maximum expected depth of 5m (BGMB3 is 4.5m depth).

The most convenient method of measuring soil moisture potential is with a portable Dew Point PotentiaMeter which enables measurement to be taken directly on site. Portable devices such as the WP4C uses the chilled mirror dew point technique to measure water potential with the sample being equilibrated with the headspace of a sealed chamber that contains a mirror and a means of detecting condensation on the mirror.

B3. The WP4C Dew Point PotentiaMeter available for hire from ICT International Pty Ltd.

The following protocols are to be followed:

1. A 7ml soil sample is inserted into the sample draw of the potentiaMeter in a 15ml stainless steel sample cup.
2. A soil sample takes between 10 -15mins to analyse.
3. Faster settings (fast mode) should be used for samples with limited water holding capacity such as sand.

The WPC4 unit will require 12V power inverter that plugs into the 12V port of a vehicle if measurements are to be taken in the field. Alternatively, samples can be collected in a sealed sample bag (with air removed) and measurements taken in an office or other areas where there is a reliable power source. The inverter should have a continuous output of at least 140 Watts.

Outputs

The water potential assessments of both leaf (target tree at site) and soil (from soil core) will provided the following data outputs:

1. Pre-dawn leaf water potential measurements of canopy / sub-canopy leaf samples taken with the Pressure Bomb (3115 unit). The output unit will be provided in MPA.
2. Soil moisture potential taken with the portable WPC4 Potentiometer at standard intervals along the drillhole core. The unit output will be measured in MPA consistent with leaf moisture potential. The intervals for measurement will be:
    a. Top 10cm of the soil profile.
    b. At 0.5m intervals from the soil surface to the top of the phreatic zones.
    c. Where noticeable changes in soil texture or moisture content are noted during examination of the core.

The interval for measurement is purposefully coincident with the interval applied to soil sampling for stable isotopes. This will allow for more ready comparison of the results between differing sampling methods and applications.

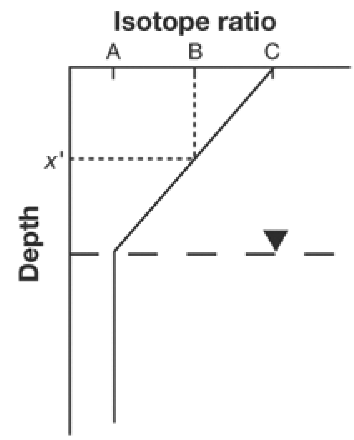
C2. Stable Isotope Analysis

The overaching aim of stable isotope analysis is to determine the degree to which trees utilise groundwater on either a permanent or seasonal basis. It will be applied during the initial phase of the baseline assessment to determine seasonal sources of moisture usage by selected trees, to be phased out once baseline water utilisation patterns are established (minimum of 2 years).

Rationale

Trees may utilise water from a range of sources including the phreatic zone, the vadose zone and surface water and the stable isotopes of water, oxygen 18 (18O) and deuterium (2H) may be a useful tool to help define the predominant source of water used by terrestrial vegetation. The method relies on a comparison between the stable isotope ratios of water contained in plant xylem (from a twig or xylem core) with concentrations in the various sources of water including potential artesian water sources, and shallow soil moisture. The heavier isotopes of 18O and 2H fractionate differently to the lighter isotopes equivalents (16O and 1H). Rainfall has a typically large δ18O and δ2H as it is formed through the process of condensation which concentrates heavier isotopes. Surface water may have an extremely high δ18O if it is subject to a period of strong evaporation, whilst isotopic composition of groundwater will vary dependent on the input source, although tends to be relatively stable as it is not exposed to processes of fractionation.

The isotopic signature of water measured in a trees xylem may result from a combination of sources with varying signatures. As per Eamus et al (2006) below (Figure B4), if an isotopic signature of 'A' is recorded, then water is being sourced from the phreatic zone, and for 'C' at the surface. If an isotopic signature of 'B' is recorded, this may represent water sourced from the middle of the vadose zone (at depth x), or may be a combination of water from a deeper phreatic source (A) or a shallow source (B). Hence there is potential for considerable uncertainty when mixed isotopic signatures occur and it may be necessary to apply a linear mixing model to aid the interpretation (as per Thorburn et al, 1993).



B4. Schematic representation of isotope ratios within soil and groundwater and application in identifying plant water sources (from Eamus et al. 2006).

For a robust application of stable isotopes signatures obtained from plant xylem and soil pore spaces, the following general protocols should be observed:

1. Sampling of plant and soil material will need to be completed during a single sampling event to ensure the results are directly comparable.
2. Sampling of plant xylem material would be completed most efficiently from twigs, collected whilst undertaking leaf water potential measurements. Leaves have tendency to concentrate isotopic concentrations during the process of transpiration and evaporation and hence should not be used.
3. The sampling program is best completed following a period of extended drought / dry conditions to maximise the potential that plants are utilising groundwater sources.
4. Sampling of soil pore water should be undertaken at consistent intervals throughout the vadose zone (the unsaturated zone above the groundwater table) down to the groundwater table. Soil samples are to be collected to the depth of the saturated zone or consolidated bedrock (whichever comes first). Sampling needs to extended beyond the saturated zone to consolidated bedrock in the case that a perched aquifer is identified.

Methodology

Sampling of Soil Pore Water for Stable Isotopes

Method: Soil sampling is to be undertaken at regular intervals along a retrieved soil core to capture signatures for possible isotopic end points (ground water and surface water) and a range of potential plant moisture sources within from the upper soil surface to the top of the phreatic zone. Mensforth et al (1994) completed soil sampling at 0.1m increments to 0.4m depth; 0.2m increments to 2m depth and 0.5m increments to the groundwater surface while others such as O'Grady et al (2006) applied sampling interval of 0.5m down the entire profile. The proposed sampling interval for this assessment is:

1. Initial soil sample taken within the top 10cm of the soil profile.
2. Subsequent soil sampled taken at 0.5m intervals down borehole to the top of the phreatic zone.
3. Additional soil samples take whenever there is a noted change is soil texture within the soil core (i.e change from clay to sandy clay / loam).

Soil sampling should be continued until either the unconfined groundwater table is intersected or the top of the Pleistocene surface halts auger penetration.

Soil sampling protocols: The following protocols for soil sampling are to be applied based on advice from ANU Stable Isotope Laboratory:

1. A minimum 50ml equivalent of soil is to be collected for each sample to be analysed.
2. Samples are to be immediately sealed to prevent evaporation in an airtight container (double bagging recommended).
3. Samples are to be labelled with the drill hole number and sampling depth / interval in a consistent format to aid data entry and recognition
4. Samples are to be kept on ice and transported to a freezer for temporary storage prior to dispatch to the laboratory (at the completion of each hole).

5. Frozen samples are to be dispatched in an a sealed (as airtight as possible) esky via overnight courier.

Equipment: The following equipment will be required by the site geologist / ecologist.

1. Stainless steel spatula for sample collection (paint scraper of putty knife sufficient).
2. Tape measure (15m extendable steel builders measure).
3. Sealable polypropylene containers (30 to 70ml adequate)
4. Permanent marking pens.
5. Esky for sample storage and dispatch.
6. A chest freezer will need to be accessed off site for storage.

Sampling of Xylem Water for Stable Isotopes

This will require twigs to be collected from the outer branches of mature Red Gum (or Poplar Box) trees that are the subject of the assessment. It is anticipated that up to 4 twig samples will be collected from individual trees directly adjacent to the assessment locality. At each site, the following sampling protocols should be observed:Method: Sampling of leaf twigs will be undertaken in conjunction with sampling of leaves for water

1. Outer branches of up to four trees, including the central tree at the assessment locality plus three adjacent trees are to be harvested for twig material.
2. Trees subject to assessment are to be marked with a GPS.
3. Outer branches from each tree will be harvested using an extendable aluminium pole and lopping head. The longest commercially available extension pole is 7.5m giving a maximum reach of approximately 10m.
4. Stem material that is the equivalent to one joint length of the small finger should be sourced (based on advice from ANU). Hence collected branches should contain some stem diameters of at least 10mm.
5. Selected stems are to be cut into maximum 5cm lengths and the bark stripped. One to two stems of 10mm diameter stems will be sufficient although more material will be required for smaller diameter stems.
6. Stems are to be sealed in wide mouth sample containers with leakproof polypropylene closure.
7. Samples should be immediately labelled with the tree number and placed in an iced storage vessel before being transported to a freezer for temporary storage prior to dispatch to the laboratory (at the completion of each hole).
8. Frozen samples are to be dispatched in an a sealed (as airtight as possible) esky via overnight courier.

Equipment: The following equipment will be required by the site geologist / ecologist.

1. An extendable 7.5m aluminium pruning pole with an attached lopper head.
2. High quality secateurs for cutting stem material.
3. 125m wide mouth sample containers with a polypropylene seal cap (up to 16 required).
4. Permanent marking pens.
5. Esky for sample storage and dispatch. May be included with the frozen soil samples.

6. A chest freezer will need to be accessed off site for storage.

Groundwater sampling for stable isotopes

Method: Groundwater samples are to be collected from each groundwater monitoring bore using the low flow method. Groundwater sampling will follow methods described in the Geosciences Australia *Groundwater Sampling and Analysis – A Field Guide* (Sundaram, et al., 2009). Care should be taken not to oxygenate or agitate the sample during pumping or sample collection.

Samples for analysis of stable isotopes should be collected in laboratory prepared 28ml glass McCartney bottles or 15ml Vacutainers and kept cool during storage and transport.

Sample Despatch and personnel

Personnel: Samples are to be collected, bagged and stored by the supervising geologist / ecologist who will also be responsible for the sample dispatch to the receiving laboratory

Dispatch: Samples are to be dispatched directly to the ANU Stable Isotope Laboratory (address provided below).

Hilary Stuart-Williams
Stable Isotope Laboratory
Research School of Biology
R.N. Robertson Building (46)
The Australian National University Canberra ACT 0200 Australia

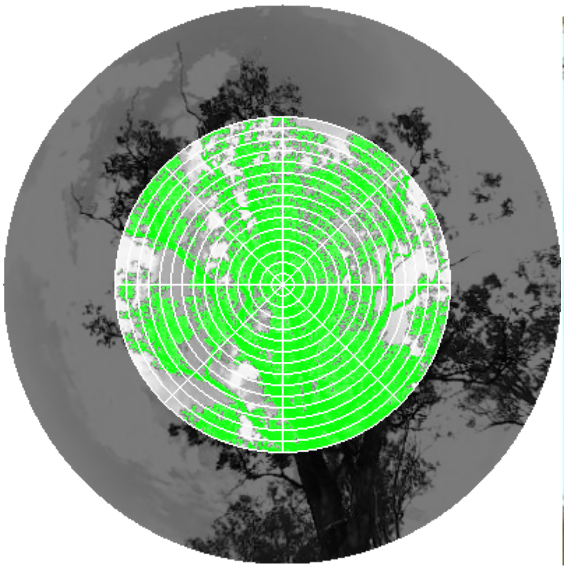
C3. Field Based Assessment of Leaf Area Index

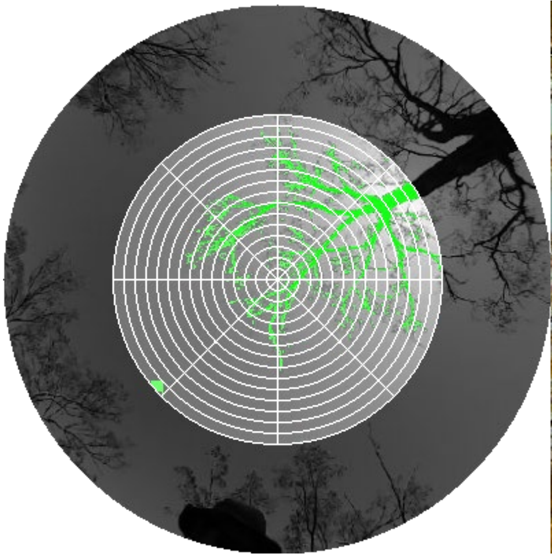
Leaf Area Index (LAI) is a ratio of the total leaf area within a canopy to the ground area covered by the canopy. It is a measure of canopy vigour and the rationale applied is that plants with access to permanent sources of water (i.e. groundwater) will have greater vigour and hence LAI than vegetation that has only periodic access to groundwater resources (e.g. Zolfagher 2014). If a previous permanent groundwater resource is withdrawn (as might occur in a CSG operation), then leaf fall will occur, and LAI will decrease.

Measurement of LAI is typically completed with a hemispherical lens, is labour intensive and utilises specialised software to analyse foliage cover. The CI-110 Plant Canopy Analyzer provides a self-leveling, wide-angled lens to capture hemispherical photographs for the analysis of leaf area index (LAI) and gap fraction analysis and photosynthetically active radiation (PAR). This instrument is integrated with the corresponding software program, and a GPS, allowing for fast and simple analysis, with immediate data available on site including:

- Leaf area index (LAI)
- Leaf angle distribution
- Extinction coefficients
- PAR LAI

The unit provides considerably greater accuracy in LAI measurement than standard hemispherical cameras and is time saving due to the immediate access of data. Raw data outputs are provided below demonstrating a *Eucalyptus populnea* with a canopy density of 83% and a Gap Fraction LAI of 0.8 compared to a stressed *Eucalyptus populnea* with a canopy density of 52% and a Gap Fraction LAI of 0.3 (second row). Zenith angle is set at 45° to filter out adjacent canopy trees and other interference.



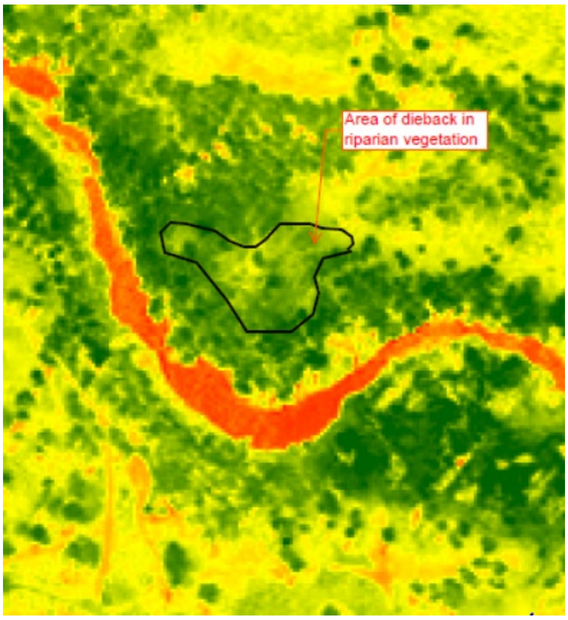
 

B5. Raw data outputs are provided below demonstrating a *Eucalyptus populnea* with a canopy density of 83% and a Gap Fraction LAI of 0.8 compared to a stressed *Eucalyptus populnea* with a canopy density of 52% and a Gap Fraction LAI of 0.3 (second row).

C4. Remote Sensing Methods

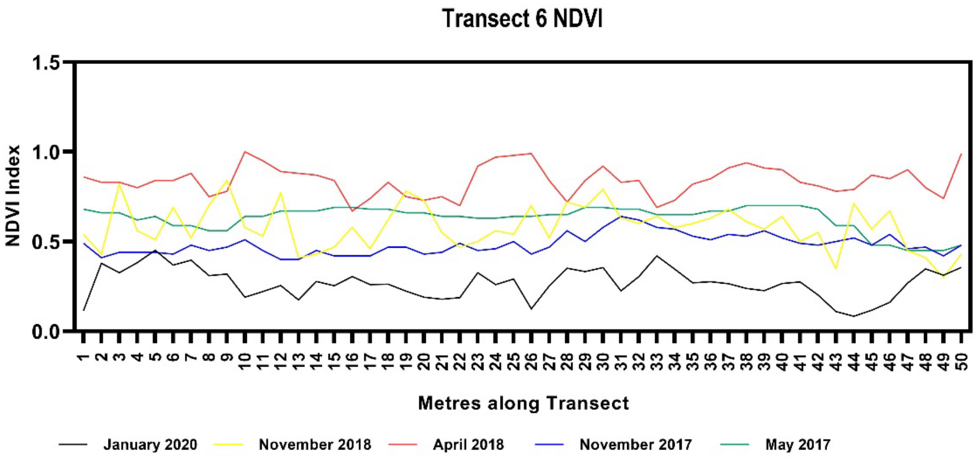
There are remote sensing based assessments used to calculate LAI (TERRA and AQUA satellites), although the spatial resolution of at 250 m x 250 m is not going be useful for the application, due to the fragmented nature of the landscape with large areas of clearing interspersed amongst native woodland.

Recent availability of high- resolution satellite imagery (WorldView-3/WorldView-2 and GeoEye-1; 0.5m Resolution 4-band Pan) to map canopy and foliage dieback in habitats potentially affected by gas seeps. Assessment utilises the Normalised Difference Vegetation Index (NDVI) as a measure of canopy health and vigor. It is a widely accepted method and with advances in satellite technology, has the capacity to assess the health of individual trees rather than landscapes. The strength of the assessment is that it enables the health of riparian (and other GDE) vegetation to be monitored across the entire landscape, rather than just a limited number of individual sites. The landscape-scale capability also has an ability to overcome issues surrounding a lack of site access and provides a long-term monitoring record of vegetation health that can be utilised as reference when a need arises. Capture can be undertaken reactively and can be tasked with a days' notice, providing weather, particularly cloud cover is amenable. An example of high resolution NDVI Imagery showing dieback in riparian vegetation is provided in **A7** (capture date May 2017).



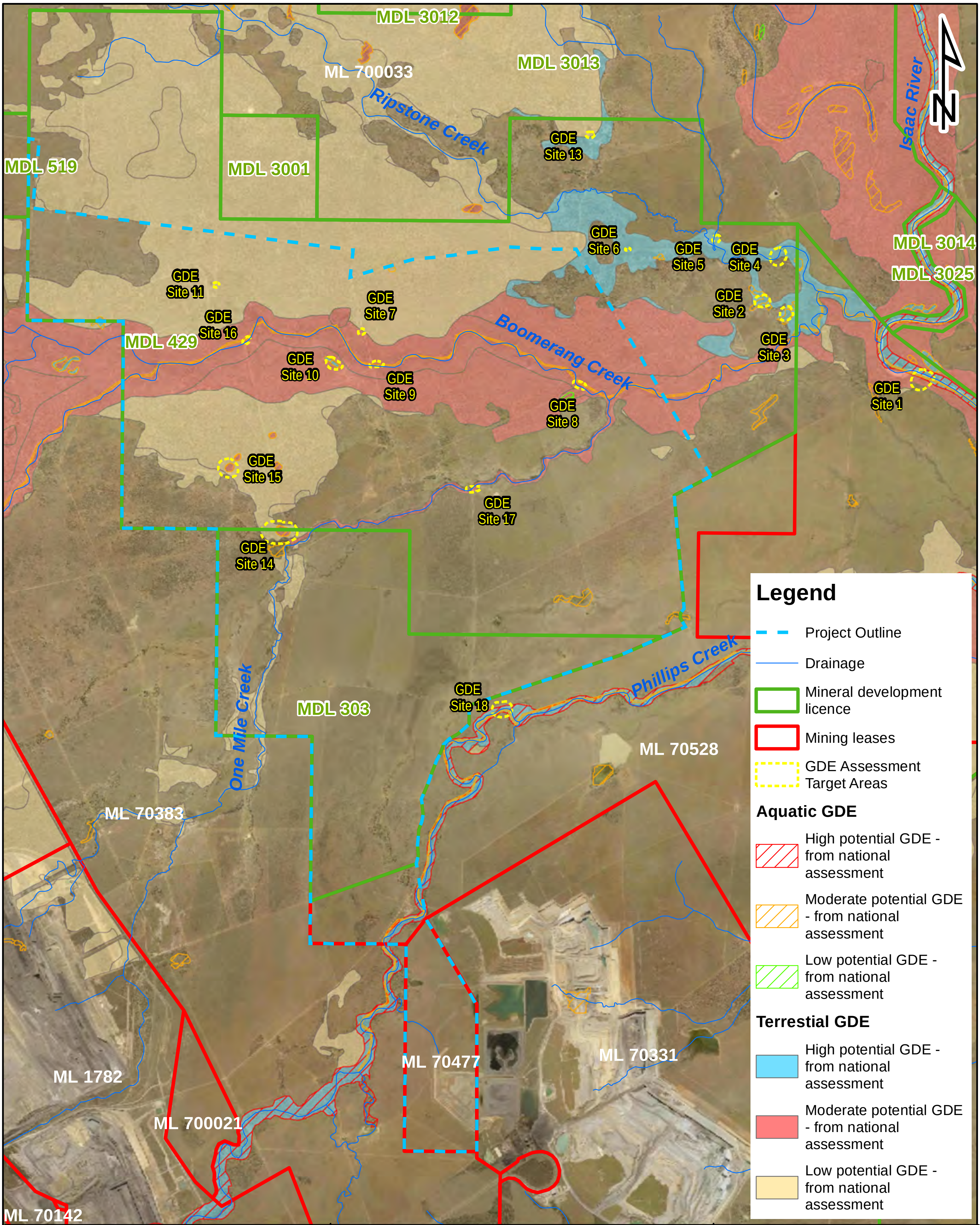
A7. Healthy vegetation in bright green grading to bare ground and water in red. Area of recent canopy dieback is indicated.

Measurements of NDVI values at set intervals along permanently established transects also provides a quantifiable and easily rectifiable measure of vegetation productivity that can be undertaken on a seasonal basis. This would form a component of the baseline dataset against which trends in vegetation productivity and fluctuations in groundwater regime can be correlated. Figure A8 provides an example of a vegetation transect that that has been monitored for vegetation production for period of years, showing the strong decrease in vegetative productivity between May 2017 and January 2020.



A8. Seasonal variations in vegetation productivity, measured using NDVI, showing a decrease in vegetation health over a 2.5yr sampling period for a permanent monitoring transect in the Surat Basin.

Appendix D. Sampling Localities from the Lake Vermont - Meadowbrook EIS



Source: BOM GDE Atlas (2020).

Appendix C. GDE areas targeted for field assessment.during EIS studies

Client AARC Environmental Solutions

0 1.25 2.5 3.75 5

Kilometers

Scale 1:90,000	Drawn By DG	Checked DS	File Path	Date 25-Mar-22	A4

3D Environmental
Landscape & Vegetation Science

Kenmore, Qld 4069
Mobile: 0447 822 119
www.3denvironmental.com.au

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Appendix E. Raw Data from Soil Moisture Potential and Stable Isotope Analyses

Appendix E1 _ Soil Moisture Potential Raw Data

Specimen Number	GDE Assessment Area	Type	Date Collected	SMP MPA
S16_AU1_0.5	GDE Site 16	Soil	15 Aug-21	-0.55
S16_AU1_1.0	GDE Site 16	Soil	15 Aug-21	-0.33
S16_AU1_1.2	GDE Site 16	Soil	15 Aug-21	-0.31
S16_AU1_1.5	GDE Site 16	Soil	15 Aug-21	-0.24
S16_AU1_2.0	GDE Site 16	Soil	15 Aug-21	-0.11
S16_AU1_2.3	GDE Site 16	Soil	15 Aug-21	-0.13
S16_AU2_0.5	GDE Site 16	Soil	15 Aug-21	-0.87
S16_AU2_1.0	GDE Site 16	Soil	15 Aug-21	-1.45
S16_AU2_1.5	GDE Site 16	Soil	15 Aug-21	-1.42
S16_AU2_2.0	GDE Site 16	Soil	15 Aug-21	-1.39
S16_AU2_2.5	GDE Site 16	Soil	15 Aug-21	-0.86
S16_AU2_3.0	GDE Site 16	Soil	15 Aug-21	-0.69
S16_AU2_3.5	GDE Site 16	Soil	15 Aug-21	-0.42
S16_AU2_3.8	GDE Site 16	Soil	15 Aug-21	-0.33
S16_AU2_4.5	GDE Site 16	Soil	15 Aug-21	-0.11
S16_AU2_5.0	GDE Site 16	Soil	15 Aug-21	-0.27
S16_AU2_5.1	GDE Site 16	Soil	15 Aug-21	-0.11
S16_AU2_5.3	GDE Site 16	Soil	15 Aug-21	-0.17
S3_AU1_0.1	GDE Site 3	Soil	17 Aug-21	-1.38
S3_AU1_0.5	GDE Site 3	Soil	17 Aug-21	-1.5
S3_AU1_1.0	GDE Site 3	Soil	17 Aug-21	-1.47
S3_AU1_1.5	GDE Site 3	Soil	17 Aug-21	-2.15
S3_AU1_2.0	GDE Site 3	Soil	17 Aug-21	-2.07
S3_AU1_2.5	GDE Site 3	Soil	17 Aug-21	-1.93
S3_AU1_3.0	GDE Site 3	Soil	17 Aug-21	-2.47
S3_AU1_3.5	GDE Site 3	Soil	17 Aug-21	-1.59
S3_AU1_4.0	GDE Site 3	Soil	17 Aug-21	-2.21
S3_AU1_4.5	GDE Site 3	Soil	17 Aug-21	-1.56
S3_AU1_5.0	GDE Site 3	Soil	17 Aug-21	-1.33
S3_AU1_5.1	GDE Site 3	Soil	17 Aug-21	-1.42
S3_AU1_5.5	GDE Site 3	Soil	17 Aug-21	-1.01
S3_AU1_6.1	GDE Site 3	Soil	17 Aug-21	-1.55
S8_AU1_0.25	GDE Site 8	Soil	16 Aug 21	-0.75
S8_AU1_0.5	GDE Site 8	Soil	16 Aug 21	-1.29
S8_AU1_1.0	GDE Site 8	Soil	16 Aug 21	-0.64
S8_AU1_1.5	GDE Site 8	Soil	16 Aug 21	-0.46
S8_AU1_1.7	GDE Site 8	Soil	16 Aug 21	-0.22
S18_AU1_0.3	GDE Site 18	Soil	18 Aug-21	-0.9
S18_AU1_0.7	GDE Site 18	Soil	18 Aug-21	-0.6
S18_AU1_1.0	GDE Site 18	Soil	18 Aug-21	-0.6
S18_AU1_1.3	GDE Site 18	Soil	18 Aug-21	-0.54
S18_AU1_1.5	GDE Site 18	Soil	18 Aug-21	-0.53

Specimen Number	GDE Assessment Area	Type	Date Collected	SMP MPA
S18_AU1_1.75	GDE Site 18	Soil	18 Aug-21	-0.55
S18_AU1_2.2	GDE Site 18	Soil	18 Aug-21	-0.31
S10_AU1_0.3	GDE Site 10	Soil	16 Aug-21	-1.27
S10_AU1_0.6	GDE Site 10	Soil	16 Aug-21	-1.26
S10_AU1_1.0	GDE Site 10	Soil	16 Aug-21	-2.21
S10_AU1_1.25	GDE Site 10	Soil	16 Aug-21	-1.18
S10_AU1_1.5	GDE Site 10	Soil	16 Aug-21	-1.14
S10_AU1_1.75	GDE Site 10	Soil	16 Aug-21	-0.76
S10_AU1_2.25	GDE Site 10	Soil	16 Aug-21	-0.65
S10_AU1_0.3	GDE Site 10	Soil	16 Aug-21	-1.27

Appendix E2– Stable Isotope Analytical Results

Sample 2	Site	Material	Depth	δ2H	δ18O
S1-AU1-1.2	S1	Soil	1.2	-27.38	-5.99
S3-AU1-0.5	S3	Soil	0.5	-20.44	-3.91
S3-AU1-1.0	S3	Soil	1.0	-21.58	-3.83
S3-AU1-1.5	S3	Soil	1.5	-22.56	-3.7
S3-AU1-2.0	S3	Soil	2.0	-19.69	-4.71
S3-AU1-2.5	S3	Soil	2.5	-22.57	-4.27
S3-AU1-3.0	S3	Soil	3.0	-16.45	-4.54
S3-AU1-3.5	S3	Soil	3.5	-29.21	-3.91
S3-AU1-4.0	S3	Soil	4.0	-21.18	-4.23
S3-AU1-4.5	S3	Soil	4.5	-21.99	-3.8
S3-AU1-5.1	S3	Soil	5.1	-23.47	-2.86
S3-AU1-5.5	S3	Soil	5.5	-20.84	-4.91
S3-AU1-6.1	S3	Soil	6.1	-15.26	-5.12
S8-AU-0.5	S8	Soil	0.5	-11.43	-5.22
S8-AU1-1.0	S8	Soil	1.0	-12.01	-4.79
S8-AU1-1.5	S8	Soil	1.5	-27.07	-4.54
S8-AU1-1.7	S8	Soil	1.7	-29.17	-5.47
S10-AU1-0.6	S10	Soil	0.6	-25.29	-3.79
S10-AU1-1.0	S10	Soil	1.0	-29.63	-4.28
S10-AU1-1.5	S10	Soil	1.5	-28.96	-4.98
S16-AU2-0.5	S16	Soil	0.5	-19.63	-4.1
S16-AU2-1.0	S16	Soil	1.0	-28.52	-5.72
S16-AU2-1.5	S16	Soil	1.5	-23.28	-6.46
S16-AU2-2.0	S16	Soil	2.0	-23.06	-7.2
S16-AU2-2.5	S16	Soil	2.5	-28.72	-6.98
S16-AU2-3.0	S16	Soil	3.0	-34.73	-7.01
S16-AU2-3.5	S16	Soil	3.5	-33.3	-5.91
S16-AU2-3.8	S16	Soil	3.8	-33.48	-5.64
S16-AU2-4.5	S16	Soil	4.5	-30.47	-5.48
S16-AU2-5.1	S16	Soil	5.1	-30.52	-4.05
S16-AU2-5.3	S16	Soil	5.3	-23.47	-5.48
S16-AU1-0.5	S16	Soil	0.5	-29	-4.65
S16-AU1-1.0	S16	Soil	1.0	-25.55	-4.68
S16-AU1-1.5	S16	Soil	1.5	-35.33	-5.78
S16-AU1-2.3	S16	Soil	2.3	-22.96	-4.84
S18-AU1-0.3	S18	Soil	0.3	-17.87	-4.28
S18-AU1-0.7	S18	Soil	0.7	-19.57	-2.69
S18-AU1-1.0	S18	Soil	1.0	-18.26	-4.17
S18-AU1-1.3	S18	Soil	1.3	-28.72	-4.44
S18-AU1-1.5	S18	Soil	1.5	-24.42	-4.21
S18-AU1-1.75	S18	Soil	1.75	-17.68	-4.75
S18-AU1-2.2	S18	Soil	2.2	-22.2	-5.03

Sample 2	Site	Material	Depth	□^{2}H	□^{18}O
S1_T1	S1	Xylem	NA	-43.45	-6.43
S1_T3	S1	Xylem	NA	-41.52	-4.83
S1_T4	S1	Xylem	NA	-28.61	-3.32
S1_T5	S1	Xylem	NA	-24.64	-2.74
S2_T1	S2	Xylem	NA	-16.69	-1.63
S2_T3	S2	Xylem	NA	-9.46	-0.49
S2_T4	S2	Xylem	NA	-17.38	-2.64
S3_T1	S3	Xylem	NA	-17.37	-2.64
S3_T2	S3	Xylem	NA	-20.04	-2.76
S3_T3	S3	Xylem	NA	-17.27	-2.58
S3_T4	S3	Xylem	NA	-13.56	-2.71
S4_T1	S4	Xylem	NA	-31.54	-3.51
S4_T3	S4	Xylem	NA	-29.75	-5.42
S5_T1	S5	Xylem	NA	-21.33	-2.55
S6_T1	S6	Xylem	NA	-28.56	-3.07
S6_T3	S6	Xylem	NA	-37.18	-3.44
S8_T1	S8	Xylem	NA	-24.8	-2.94
S8_T2	S8	Xylem	NA	-23.66	-3.43
S8_T4	S8	Xylem	NA	-29.51	-3.11
S9_T1	S9	Xylem	NA	-20.72	-3.82
S9_T2	S9	Xylem	NA	-23.99	-2.97
S9_T3	S0	Xylem	NA	-24.8	-3.48
S10_T1	S10	Xylem	NA	-3.47	0.8
S10_T2	S10	Xylem	NA	-19.41	-1.99
S14_T1	S14	Xylem	NA	-14.88	-1.77
S14_T4	S14	Xylem	NA	-13.61	-2.39
S15_T3	S15	Xylem	NA	-11.42	-2.25
S16_T2	S16	Xylem	NA	-16.17	-2.88
S16_T3	S16	Xylem	NA	-20.96	-2.84
S16_T4	S16	Xylem	NA	-21.19	-3.2
S17_T2	S17	Xylem	NA	-14.16	-3.88
S18_T1	S18	Xylem	NA	-25.49	-4.55
S18_T3	S18	Xylem	NA	-23.87	-3.88
S18_T4	S18	Xylem	NA	-19.88	-3.12
S1-SW1	S1	Surface Water	NA	-7.84	-1.41
S2-SW1	S2	Surface Water	NA	19.18	4.56
S10-SW1	S10	Surface Water	NA	17.92	4.15
S14_SW1	S14	Surface Water	NA	19.98	4.72
S16-AU1_GW	S16	Groundwater	NA	-17.28	-3.98
W3-MB2	NA	Groundwater	NA	-28.51	-4.28
W14-MB1	NA	Groundwater		-26.77	-4.42
W1-MB1	NA	Groundwater	NA	-23.32	-3.5
W5-MB3	NA	Groundwater	NA	-28.49	-4.57

Sample 2	Site	Material	Depth	δ^{2}H	δ^{18}O
W8-MB1	NA	Groundwater	NA	-23.13	-3.45
W5-MB2	NA	Groundwater	NA	-31.42	-4.69
W2-MB2	NA	Groundwater	NA	-25.03	-3.68
W9-MB2	NA	Groundwater	NA	-26.1	-3.74
W10-MB2	NA	Groundwater	NA	-28.16	-3.88
W14-MB2	NA	Groundwater	NA	-32.3	-4.95
W13-MB2	NA	Groundwater	NA	-33.5	-4.95

Appendix F. LWP and Tree Structural Measurements from the Lake Vermont – Meadowbrook EIS

Site	Species	Tree Number	Y	X	DBH	Height	Position	LWP	Leaf Water Availability
1	*Eucalyptus camaldulensis*	S1_T1	-22.339651	148.472772	75	20	Mid inner terrace 25m from river channel, 12m above river channel	-0.35	Very High
1	*Eucalyptus camaldulensis*	S1_T2	-22.339784	148.472935	80	25	Top of T2 Terrace, 30m from river channel and 15m above river.	-0.3	Very High
1	*Eucalyptus camaldulensis*	S1_T3	-22.339692	148.473189	90	22	Mid terrace, 8m above channel floor	-0.3	Very High
1	*Eucalyptus camaldulensis*	S1_T4	-22.339778	148.473697	130	20	Inner Terrace, 7m above channel floor and 13m from river	-0.3	Very High
1	*Melaleuca fluviatilis*	S1_T5	-22.339695	148.473601	60	23	Base of inner bench, adjacent to to sandy channel	-0.4	Very High
1	*Eucalyptus populnea*	S1_T6	-22.340042	148.472594	50	18	Top of T2 terrace	-0.6	High
1	*Eucalyptus populnea*	S1_T7	-22.340288	148.472635	55	19	Top of T2 terrace	-0.5	Very High
2	*Eucalyptus coolibah*	S2_T1	-22.327688	148.445592	90	25	2m from edge of surface water body	-0.4	Very High
2	*Eucalyptus coolibah*	S2_T2	-22.327898	148.445586	75	21	15m from edge of surface water body	-0.3	Very High
2	*Eucalyptus coolibah*	S2_T3	-22.327875	148.445432	75	21	5m from edge of surface water body	-0.7	High
2	*Eucalyptus coolibah*	S2_T4	-22.327937	148.445	95	23	2m from edge of surface water body	-0.5	Very High
3	*Eucalyptus camaldulensis*	S3_T1	-22.329701	148.449498	65	23	Central portion of dry wetland depression	-0.2	Extremely High
3	*Eucalyptus camaldulensis*	S3_T2	-22.329659	148.449507	55	21	Central portion of dry wetland depression	-0.2	Extremely High
3	*Eucalyptus camaldulensis*	S3_T3	-22.329637	148.449565	60	23	Central portion of dry wetland depression	-0.15	Extremely High
3	*Eucalyptus coolibah*	S3_T4	-22.329664	148.450125	130	27	Outer eastern margins of dry wetland depression	-0.25	Extremely High
4	*Eucalyptus coolibah*	S4_T1	-22.319583	148.448165	135	24	3m from base of channel floor on inner bench	-1	Moderate
4	*Eucalyptus coolibah*	S4_T2	-22.320119	148.447901	60	18	20m from top of bank, 5m above channel floor. T1 terrace	-0.45	Very High

Site	Species	Tree Number	Y	X	DBH	Height	Position	LWP	Leaf Water Availability
4	*Eucalyptus coolibah*	S4_T3	-22.320434	148.447868	55	19	In channel floor, dry creek bank.	-0.7	High
4	*Eucalyptus coolibah*	S4_T4	-22.320326	148.448093	85	21	Top of terrace, 4m above channel floor just inside inner bench.	-1.1	Moderate
5	*Eucalyptus coolibah*	S5_T1	-22.31732	148.437097	55	18	Dry drainage area. Limited development of riparian vegetation	-1.6	Low
5	*Eucalyptus coolibah*	S5_T2	-22.317472	148.43702	60	19	Dry drainage area. Limited development of riparian vegetation	-1.4	Low
6	*Eucalyptus tereticornis*	S6_T1	-22.319429	148.421966	60	24	Base of overflow depression	-0.7	Moderate
6	*Eucalyptus tereticornis*	S6_T2	-22.319457	148.421796	60	20	Base of overflow depression	-0.55	Very High
6	*Eucalyptus tereticornis*	S6_T3	-22.319381	148.421514	60	15	Base of overflow depression	-0.6	High
7	*Eucalyptus populnea*	S7_T1	-22.333013	148.375616	55	19	Broad undulating loamy plain with no riparian vegetation development	-1.7	Low
7	*Eucalyptus populnea*	S7_T2	-22.333343	148.375621	60	18	Broad undulating loamy plain with no riparian vegetation development	-1.7	Low
8	*Melaleuca fluviatilis*	S8_T1	-22.341684	148.414374	110	23	Edge of channel on low terrace	-0.9	Moderate
8	*Melaleuca fluviatilis*	S8_T2	-22.341596	148.413636	60	23	Directly adjacent to sandy channel floor	-0.15	Extremely High
8	*Melaleuca fluviatilis*	S8_T3	-22.34108	148.413025	80	24	10m from channel floor, 5m above channel.	-1.25	Moderate
8	*Eucalyptus camaldulensis*	S8_T4	-22.341422	148.413685	90	23	15m from channel, 7m above channel floor	-0.5	Very High
8	*Eucalyptus camaldulensis*	S8_T5	-22.341431	148.413206	80	19	8m above channel floor on top of T1 terrace	-0.45	Very High
9	*Melaleuca fluviatilis*	S9_T1	-22.33833	148.378218	40	26	2m above channel floor on inner bench	-0.3	Very High
9	*Eucalyptus camaldulensis*	S9_T2	-22.338267	148.378731	100	25	Top of T1 terrace 10m from edge of bank	-0.42	Very High

Site	Species	Tree Number	Y	X	DBH	Height	Position	LWP	Leaf Water Availability
9	*Eucalyptus camaldulensis*	S9_T3	-22.33836	148.379254	80	20	On direct margins of channel	-0.35	Very High
9	*Melaleuca fluviatilis*	S9_T4	-22.338251	148.378059	50	18	On direct margins of channel	-0.23	Extremely High
9	*Eucalyptus camaldulensis*	S9_T5	-22.338475	148.37751	65	20	Top of T1 terrace 20m from edge of bank	-0.45	Very High
10	*Eucalyptus camaldulensis*	S10_T1	-22.337614	148.370391	90	30	7m from edge of surface water body	-1	Moderate
10	*Eucalyptus camaldulensis*	S10_T2	-22.337832	148.370717	60	22	6m from edge of water body	-0.65	High
10	*Eucalyptus camaldulensis x platyphylla*	S10_T3	-22.338564	148.371307	80	20	In moist portions of the drainage depression	-0.7	High
10	*Eucalyptus camaldulensis x platyphylla*	S10_T4	-22.338568	148.370952	80	15	In moist portions of the drainage depression, 5m from surface water	-0.7	High
11	*Eucalyptus populnea*	S11_T1	-22.325715	148.350359	55	21	Broad undulating loamy plain with no riparian vegetation development	-1.2	Moderate
11	*Eucalyptus populnea*	S11_T2	-22.325711	148.350566	60	20	Broad undulating loamy plain with no riparian vegetation development	-1.4	Low
13	*Eucalyptus cambageana*	S13_T1	-22.300951	148.41519	80	25	Broad drainage depression with no defined channel or riparian vegetation	-1.7	Low
13	*Eucalyptus cambageana*	S13_T2	-22.301042	148.41494	75	23	Broad drainage depression with no defined channel or riparian vegetation	-1.6	Low
13	*Eucalyptus populnea*	S13_T3	-22.300844	148.414804	55	21	Broad drainage depression with no defined channel or riparian vegetation	-1.8	Low
13	*Eucalyptus populnea*	S13_T4	-22.300797	148.415175	60	20	Broad drainage depression with no defined channel or riparian vegetation	-2.5	Extremely Low
14	*Eucalyptus coolibah*	S14_T1	-22.365217	148.361285	110	24	Margins of small drainage line in depression	-1.8	Very Low
14	*Eucalyptus coolibah*	S14_T2	-22.365084	148.361285	70	22	Margins of small drainage line in depression	-1.8	Very Low

Site	Species	Tree Number	Y	X	DBH	Height	Position	LWP	Leaf Water Availability
14	*Eucalyptus populnea*	S14_T3	-22.365208	148.36117	60	19	Margins of small drainage line in depression	-1.1	Moderate
14	*Eucalyptus populnea*	S14_T4	-22.364758	148.361215	80	15	Margins of small drainage line in depression	-2	Very Low
15	*Eucalyptus coolibah*	S15_T1	-22.355737	148.352668	100	23	Margins of circular wetland depression	-1.5	Low
15	*Eucalyptus populnea*	S15_T2	-22.35568	148.353067	70	19	Out edges of wetland depression	-1.8	Very Low
15	*Eucalyptus coolibah*	S15_T3	-22.355508	148.353197	100	18	Inner portion of wetland depression, 80m from margins	-1.1	Moderate
16	*Eucalyptus camaldulensis*	S16_T1	-22.334779	148.355949	85	23	Inner bench immediately above sandy channel	-1.4	Low
16	*Melaleuca fluviatilis*	S16_T2	-22.334901	148.355777	65	20	Inner bench immediately above sandy channel	-0.45	Very High
16	*Eucalyptus camaldulensis*	S16_T3	-22.334973	148.355513	95	23	Top of T1 terrace 20m from river and 8m above channel	-0.23	Extremely High
16	*Eucalyptus camaldulensis*	S16_T4	-22.334847	148.355419	90	20	Mid way up T1 terrace 15m from river and 8m above channel	-0.25	Extremely High
17	*Eucalyptus coolibah*	S17_T1	-22.358121	148.396062	65	22	Top of T1 terrace 5m above clayey channel floor	-1.4	Low
17	*Eucalyptus coolibah*	S17_T2	-22.358154	148.395853	60	18	On low terrace instream, 3m above channel	-0.6	High
17	*Eucalyptus camaldulensis*	S17_T3	-22.358377	148.395573	65	17	Top of T1 terrace 5m above clayey channel floor	-2.5	Extremely Low
18	*Eucalyptus camaldulensis*	S18_T1	-22.394005	148.400023	110	26	Inner bench 2m above sandy channel	-0.45	Very High
18	*Casuarina cunninghamiana*	S18_T2	-22.393769	148.400738	50	23	Inner bench immediately above sandy channel	-0.5	Very High
18	*Eucalyptus camaldulensis*	S18_T3	-22.393615	148.400858	80	22	Top of T2 high terrace 10 -12m above sandy channel	-0.6	High
18	*Eucalyptus camaldulensis*	S18_T4	-22.393532	148.400928	75	19	Top of T2 high terrace 10 -12m above sandy channel	-0.6	High

Appendix G. GDE Monitoring Program for Initial Two Years

Event	Timing	Areas for Monitoring	Parameters Measured	Additional Datasets / Techniques Recommended	Other Interacting Datasets / Data Collection Requirements	Outputs
Monitoring Survey 1 Seasonal assessment being either: 1. Late Wet Season (March to May). 2. Late Dry Season (October to December)	Upon project approval though prior to construction	• Risk Area 1 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 11 • Risk Area 2 ○ 3 ○ 12 ○ 13 ○ 15 ○ 16 • Risk Area 3 ○ 2 • Risk Area 4 ○ 1 ○ 10 ○ 14	• LWP • Stable isotopes (trees, soils, surface water and water in channel sands) • Leaf Area Index	NDVI Imagery to coincide with the survey.	Groundwater monitoring data from identified monitoring bores (water quality and data from pressure transducers). Stable isotope composition of groundwater from selected monitoring bores. Stable isotope data from collected rainfall, if any. Stable isotope data from surface water flows. If any. Rainfall and climate data from automated weather station.	GDE Monitoring Report- Monitoring Event 1.
Monitoring Survey 2 Seasonal assessment being either: 1. Late Wet Season (March to May). 2. Late Dry Season (October to December)	During Project Construction	• Risk Area 1 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 11 • Risk Area 2 ○ 3 ○ 12 ○ 13 ○ 15 ○ 16 • Risk Area 3 ○ 2 • Risk Area 4 ○ 1 ○ 10 ○ 14	• LWP • Stable isotopes (trees, soils, surface water and water in channel sands) • Leaf Area Index	NDVI Imagery to coincide with the survey.	Groundwater monitoring data from identified monitoring bores (water quality and data from pressure transducers). Stable isotope composition of groundwater from selected monitoring bores. Stable isotope data from collected rainfall, if any. Stable isotope data from surface water flows. If any. Rainfall and climate data from automated weather station.	GDE Monitoring Report- Monitoring Event 2.

Event	Timing	Areas for Monitoring	Parameters Measured	Additional Datasets / Techniques Recommended	Other Interacting Datasets / Data Collection Requirements	Outputs
Monitoring Survey 3 Seasonal assessment being either: 1. Late Wet Season (March to May). 2. Late Dry Season (October to December)	During Project Construction	• Risk Area 1 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 11 • Risk Area 2 ○ 3 ○ 12 ○ 13 ○ 15 ○ 16 • Risk Area 3 ○ 2 • Risk Area 4 ○ 1 ○ 10 ○ 14	• LWP • Stable isotopes (trees, soils, surface water and water in channel sands) • Leaf Area Index	NDVI Imagery to coincide with the survey.	Groundwater monitoring data from identified monitoring bores (water quality and data from pressure transducers). Stable isotope composition of groundwater from selected monitoring bores. Stable isotope data from collected rainfall, if any. Stable isotope data from surface water flows. If any. Rainfall and climate data from automated weather station.	GDE Monitoring Report- Monitoring Event 3.
Monitoring Survey 4 Seasonal assessment being either: 1. Late Wet Season (March to May). 2. Late Dry Season (October to December)	During Project Construction / Operation	• Risk Area 1 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 11 • Risk Area 2 ○ 3 ○ 12 ○ 13 ○ 15 ○ 16 • Risk Area 3 ○ 2 • Risk Area 4 ○ 1 ○ 10 ○ 14	• LWP • Stable isotopes (trees, soils, surface water and water in channel sands) • Leaf Area Index	NDVI Imagery to coincide with the survey.	Groundwater monitoring data from identified monitoring bores (water quality and data from pressure transducers). Stable isotope composition of groundwater from selected monitoring bores. Stable isotope data from collected rainfall, if any. Stable isotope data from surface water flows. If any. Rainfall and climate data from automated weather station.	GDE Monitoring Report- Monitoring Event 4.
2 Year GDE Monitoring Review						
2 Year Review - Baseline GDE Monitoring Assessment	At completion of Monitoring Survey 4	NA	NA	NA	NA	– Compilation of data from all surveys – Analysis of baseline

Event	Timing	Areas for Monitoring	Parameters Measured	Additional Datasets / Techniques Recommended	Other Interacting Datasets / Data Collection Requirements	Outputs
						ecohydrological function of field verified GDE areas. – Refinement of GDE mapping, including excision of areas that are demonstrated to not be groundwater dependent for excision. – Correlation between LAI and NDVI (plus other parameters) to provide a baseline for ongoing annual vegetation monitoring. – Identification of sources of water utilised by trees on a seasonal basis through analysis of stable isotope results for multiple parameters. – Review of risk assessment and identification of areas where risk profile is increased / diminished. – Revised GDEMMP issued based on results and outcomes of the 2-year baseline monitoring program.