Doral

APPENDIX 4E

AQ2 (2020d) DRAFT GDE MANAGEMENT PLAN

YALYALUP MINERAL SANDS PROJECT

GDE MANAGEMENT PLAN

Prepared for

DORAL MINERAL SANDS

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1 INTRODUCTION

1.1 Background

Doral Mineral Sands Pty Ltd (Doral) proposes to develop the Yalyalup mineral sands mine, located approximately 11 km south-east of Busselton, Western Australia (Figure 1). The Yalyalup mineral sands deposit is located within Retention Licence R70/0052, which covers an area of approximately 2,290 hectares, halfway between Iluka's Tutunup South Mine (closed in 2018) and Cristal's (Tronox) Wonnerup Mine (operating and northern extension).

The expected Yalyalup mine life is six years, comprising three and a half years of mining and the remainder being startup and closure. Some mining will occur below the groundwater level and at times, dewatering of the open-cut pits will be required to provide dry mining conditions.

A draft Environmental Review Document (ERD) was submitted to the Department of Water and Environmental Regulation (DWER) on 6th December 2019. The DWER and other relevant government agencies have recently reviewed Doral's draft ERD and have requested further information regarding the proposed mining and potential impact management strategies on Groundwater Dependent Ecosystems (GDE) occurring within the Proposal Area (Ecoedge, 2019). GDEs at the northern end of McGibbon Track have been identified as being potentially impacted by the proposed mining (Figure 2).

This document describes a Groundwater Dependent Ecosystem Management Plan (GDEMP) for the Yalyalup project, that will support the ERD assessment, in light of the potential predicted impacts and adequacy of the proposed management measures.

1.2 Requirements for the Management Plan

The GDE along McGibbon Track comprise a narrow strip of native vegetation within the City of Busselton road reserve that contains occurrences of three threatened ecological communities and several conservation significant flora species. The threatened ecological communities along McGibbon Track identified by Ecoedge to represent GDEs include:

1. SWAFCT02 Southern Wet shrublands
2. SWAFCT10b Shrublands on southern ironstones

Additionally, the threatened ecological communities SWAFCT01b (Southern *Corymbia calophylla* woodlands on heavy soils), identified along McGibbon Track, is not considered a GDE. However, it does support riparian tree species.

Ecoedge has also identified the threatened ecological communities SWAFCT09 (Dense shrublands on clay flats), located at the western end of Princefield Road to represent GDEs.

All of these communities are listed as threatened ecological communities (TEC) under the Western Australian *Biodiversity Conservation Act 2016* and SWAFCT09 and SWAFCT10b are also listed as threatened under the Federal *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

In addition to recognising the conservation status of the vegetation communities, the GDEMP also addresses specific requirements arising from review of the Environmental Scoping Document (ESD):

- ESD Requirement 2: to provide information on the hydro(geo)logical setting of the GDE and potential changes related to dewatering
- ESD Requirement 4: where possible, to provide information on the conservation status of the GDE vegetation along McGibbon Track
- ESD Requirement 4: to provide information on potential management techniques employed to protect the GDE

1.3 Objectives and Scope of this Plan

The objectives of this plan are to define:

- the hydro(geological) setting of the GDE along McGibbon Track.
- the vegetation community of the GDE along McGibbon Track and its conservation significance.
- source and extent of change-risk to the GDE as caused by mining activities
- the proposed monitoring network to assess changes in the GDE, including:
  - vegetation monitoring
  - hydro(geo)logical monitoring
- management techniques that be employed to protect the GDEs from potential impact
- triggers and thresholds that related to the implementation of management techniques
- further assessments required during the early stages of implementing this GDEMP prior to the predicted drawdown impacts of mining.

1.4 Implementation and Review

1.4.1 Implementation

It is recommended that monitoring of the parameters identified in this plan commence as soon as practicable to confirm baseline conditions and support on going refinement of the GDEMP.

This initial revision of the GDEMP identifies the principles that underpin management techniques and the objectives of those management techniques. However, further study is required in the detailed design of these management techniques; this should occur as part of the initial implementation of the GDEMP.

1.4.2 Review

It is recommended that this GDEMP is subject to annual review covering:

- The correlation between monitored parameters and observed vegetation health (prior to impact dewatering). This stage of review will ensure the monitored parameters reflect baseline conditions in the GDE.
- The correlation between triggers, thresholds and management intervention and observed vegetation health (during dewatering). This stage of review will ensure the efficacy of the plan in protecting the GDE.

1.4.3 Duration

It is recommended that this management plan is implemented and reviewed until mining is complete and the groundwater levels have returned to a natural range of variation.

2 MONITORING & EVALUATION FRAMEWORK

2.1 Adaptive Management

Monitoring and evaluation for environmental management effectiveness uses the principles of active adaptive management. Active adaptive management is recognised as the most effective contemporary approach for the conservation of natural areas (McCarthy and Possingham, 2006; Hockings et al., 2006). Active adaptive management places an explicit value on learning about the effectiveness of management by monitoring its outcomes and is highly applicable to environmental management since it assumes that it is impossible to have all knowledge regarding the management unit or ecosystem. (McCarthy and Possingham, 2006).

The Monitoring and Evaluation framework includes the following elements:

- Determine the pressures or threats to the vegetation (pressure or change-risk);
- Understand the current state of vegetation that may be affected by modified groundwater levels resulting from mine dewatering and reinjection activities (State);
- Evaluate and select adaptive management responses to achieve a target vegetation state (i.e. avoiding unacceptable changes to the vegetation that are apparently attributable to the mining process, and that are not apparent in the reference area(s)), as described in Section 8.1 (Response).

These elements collectively comprise the Pressure-State-Response model used when applying an adaptive management approach for protecting environmental values in natural areas. This provides a framework for planning and implementing environmental management actions.

2.2 Leading and Lagging indicators

The monitoring framework will comprise leading and lagging indicators:

- Leading indicators will identify changes to the hydrological conditions that may ultimately manifest as vegetation stress. The leading indicators will allow pre-emptive intervention.
- Lagging indicators will allow verification of the success of management interventions and provide redundancy in the identification of change-risks.

3 EXISTING ENVIRONMENT

3.1 Climate and Ecohydrological Setting

The Yalyalup project area has a Mediterranean type climate, characterised by hot dry summers and cold wet winters. The nearest Bureau of Meteorology (BoM) weather station with long-term data averages is Busselton Aero (Station No. 9603) and Busselton Shire (Station No. 9515), approximately 5 and 10 km, respectively to the north-east of the study area.

In the Yalyalup area, the long-term average annual rainfall (1998-2020) is 680 mm, with rainfall being greatest during the winter months (May to September). Conversely, monthly annual pan evaporation data for Busselton shows that evaporation is lowest during the months of May to August and highest during the dry summer months, with a mean pan evaporation of about 1,220 mm.

Long-term rainfall and pan evaporation data are shown in Figure 3 and summarised in Table 3.1.

Table 3.1: Annual Average Rainfall and Evapotranspiration

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Mean Rainfall (1998-2020) Busselton Aero	14.6	4.9	20.5	34.3	100.3	126.8	133.4	108.4	73	31.3	21.5	10.4	679.4
Long-term average Pan Evaporation (Busselton)	189	160	133	78	53	42	47	56	69	99	129	164	1219

All units in mm / month

A Budyko model (e.g. Trancoso et al 2016, Budyko 1974) has been used to characterise the energy / water balance for the Yalyalup area and to provide an estimate of catchment-scale actual evapotranspiration (which will control the type of vegetation that can sustainably develop).

Key ecohydrological characteristics are summarised in **Error! Reference source not found.**.

Table 3.2: Ecohydrological Setting of the Yalyalup Area

Rainfall Period	Rainfall	PET	Aridity Index	Classification	Budyko ET
Annual Average	679	1219	0.56	Dry	566

Aridity Index (UN formula) = P/PET

Actual catchment average ET estimated using Budyko method

Rainfall and ET in mm / year

The aridity index (ratio of potential evapotranspiration to rainfall) is 0.56 and the area can be classified as dry (sub-humid). The Budyko estimate of ET provides an assessment of the actual annual average evapotranspiration across the catchment.

3.2 Vegetation

Ecoedge (2020) have identified three groundwater dependent ecosystems (GDEs) as occurring within the Yalyalup Development Envelope (YDE). Vegetation Unit A2 is a woodland of *Corymbia calophylla* (sometimes with *Eucalyptus marginata* or *E. rudis*) with scattered *Melaleuca preissiana* or *Banksia littoralis* over an open shrubland. The occurrence of Vegetation Unit A2 along McGibbon Track is inferred to be part of SWAFCT02 (Southern wet shrublands) and is listed as an 'Endangered' Threatened Ecological Community (TEC) by DBCA.

Vegetation Unit B1 is a tall shrubland of *Acacia saligna*, *Banksia squarrosa* subsp. *argillacea*, *Calothamnus quadrifidus* subsp. *teretifolius* and *Kunzea micrantha* (with scattered emergent *Eucalyptus rudis*) over scattered native herbs. It occurs in stands adjacent to vegetation unit A2 on McGibbon Track and on Princefield Rd just outside the YDE, and is inferred to be a part of SWAFCT10b (Shrublands on southern Swan Coastal Plain Ironstones (Busselton Area)). SWAFCT10b is listed as a 'Critically Endangered' TEC by DBCA and as 'Endangered' under the EPBC Act.

Vegetation Unit C3 is a tall open shrubland that may include *Acacia saligna*, *Jacksonia furcellata*, *Kingia australis*, *Melaleuca osullivanii*, *M. preissiana*, *M. viminea* and *Xanthorrhoea preissii* on seasonally wet grey-brown sandy loams. A degraded stand occurs along Princefield Rd and is likely part of SWAFCT09 (Dense shrublands on clay flats), listed as 'Vulnerable' by DBCA and 'Critically Endangered' under the EPBC Act. However, the condition of this stand is too degraded to be confidently inferred as an example of this TEC.

The occurrence of Vegetation Unit A1 on McGibbon Track is inferred to be part of SWAFCT01b (Southern *Corymbia calophylla* woodlands on heavy soils) and is not considered a GDE. However, it does support phreatophytic tree species. Four obligate phreatophytic tree species and four significant phreatophytic shrubs or herb species have been recorded within or near to the YDE:

- *Melaleuca rhaphiophylla* (Swamp paperbark) is an obligate phreatophyte that occupies habitats between low and high watermarks along rivers and streams, and fringes of wetlands. It can tolerate flooding or waterlogging for extended periods throughout the year. This species has only been recorded in completely degraded stands and paddocks within the YDE.
- *Eucalyptus rudis* (Flooded gum) occupies habitats similar to *Melaleuca rhaphiophylla*, but will tolerate flooding for shorter periods and avoids permanent waterlogged sites. It occurs in Vegetation Units A2 and B1.
- *Melaleuca preissiana* (Modong) occupies sites above high watermark in riparian vegetation and in winter-wet habitats. It does not tolerate soils that are waterlogged for extended periods and was recorded in Vegetation Units A1 and A2.
- *Banksia littoralis* (Swamp banksia) occurs in habitats with perennially high water availability. Within the YDE, it was recorded in Vegetation Unit A2.
- *Banksia squarrosa subsp. argillacea* (Whicher Range Dryandra) occurs in Vegetation Unit B1. It is listed as 'Vulnerable' by DBCA and 'Endangered' under the EPBC Act. Nine plants have recorded by Ecoedge (2020), which is a decline from the 14 plants recorded in the Interim Recovery Plan for the species (DBCA 2004).
- *Verticordia plumosa* subsp. *vassensis* (Vasse Featherflower) occurs in the Princefield Rd reserve in an occurrence of Vegetation Unit B1. It is listed as 'Endangered' by both the DBCA and under the EPBC Act. The population was estimated by Ecoedge to be around 30 plants, compared to the estimated 200 plants in 1996 and 100+ plants in 2006 (Ecoedge (2020).
- *Calothamnus quadrifidus* subsp. *teretifolius* (P4) occurs in Vegetation Unit B1 along McGibbon Track, where 70 plants have been recorded. It has also been recorded outside the YDE.
- *Loxocarya magna* (P3) also occurs in Vegetation Unit B1, where 32 plants were recorded by Ecoedge (2020).

3.3 Vadose Zone

3.3.1 Physical Characteristics of the Alluvium

The particle-size distribution (PSD) of the alluvium is the principal control on its hydraulic properties. In particular, the PSD controls the matric-pressure / moisture-retention relationship that affects tree-water use from the vadose zone. The PSD was analysed from 1090 bores across the project area. Soil samples were collected at each bore at 1 m increments and the analysis was undertaken for the top 3 m of soil (i.e. the material that forms the bulk of the vadose zone and shallowest aquifer). Six material types have been identified in the geological logging:

- Clay
- Sandy Clay
- Clayey Sand
- Silty Sand
- Sand
- Ironstone / Laterite

The PSD of samples that are predominantly ironstone (laterite) are not summarised in the table nor are they included for further analysis because the PSD of a disturbed sample is not representative of the in-situ characteristics of this material. Details of the granular materials are provided in Table 3.3.

Table 3.3: Summary of Particle Size Distribution

Sample / Site	% Passing				Total Fines
	Clay	Silt	Sand	Gravel	
Clay	26%	6%	51%	17%	83%
Sand	2%	11%	81%	6%	94%
Sandy Clay	19%	8%	60%	13%	87%
Clayey Sand	12%	8%	74%	6%	94%
Silty Sand	4%	15%	75%	6%	94%

Total fines = proportion of total sample mass that is clay, silt and sand

The samples are poorly sorted (i.e. comprise a range in particle sizes). All samples have a significant sand component ranging between 50% for the finest graded samples to 81% for the coarsest graded samples. Thus, regardless of the distinction made in the geological logging between clay and sand units (which was undertaken from a mineral perspective), all samples can be considered sandy and have hydraulic properties that are influenced by this substantial sand component.

3.3.2 Unsaturated Zone Hydraulic Properties

Unsaturated hydraulic properties of the alluvium have been estimated from the PSD analysis using a methodology developed by the USDA (Saxton and Rawls, 2006). The results are summarised in Table 3.4.

The specific yield of the alluvium ranges between 24% and 36% with an average value of 29%. The porosity of the sands has an average value of 38%. As the sand becomes unsaturated, some moisture is retained in the pore-space where it is held under a negative pressure (or tension). At –33 kPa, the pressure at which gravity drainage ceases, and the field capacity (i.e. the specific moisture content at this pressure) is estimated to be around 8%. It is estimated that when matric pressure is -2,500 kPa and close to the point at which the trees lose turgor (i.e. the pressure at which hydraulic failure in the tree may occur), the moisture content will be less than 1%.

In summary, this means:

- Infiltrating rainwater will start to move through the profile when the moisture content exceeds 8% (i.e. a relatively low moisture content that means water will move through the profile readily).
- After a rainfall event, when gravity drainage of the soil profile stops, there will only be 8% moisture content within the vadose zone as plant available water.
- The moisture release curve for the sands is likely to be rapid with very little moisture (i.e. plant available water) remaining as the vadose zone dries and the matric pressure becomes significantly negative.

It is unlikely the transpiration flux associated with the observed vegetation communities would be supported by the moisture available in the vadose-zone alone (i.e. without groundwater use).

The saturated horizontal hydraulic conductivity ranges between 1 and 5 m/d. Percolation through the vadose zone will decline very quickly once the alluvium starts to dry and moisture content and matric pressure decrease; at -30 kPa (the matric pressure at which gravity drainage will stop), the hydraulic conductivity is 1 x 10^{-5} m/d; this reflects the relatively low moisture content at field capacity.

The estimated capillary fringe is small and ranges between 0 cm and 20 cm. This means there will be very little capillary rise and tree roots will be very close and sensitive to groundwater levels (where the trees rely on groundwater as a component water-source).

Table 3.4: Hydraulic Properties of the Sandy Vadose Zone at Yalyalup

Sample	Moisture Content			Water Yields and Availablity			Water Movement			
	Porosity (0 kPa) (%)	Field Capacity (-30 kPa) (%)	M. raph. limit (-2500 kPa) (%)	Specific Yield (%)	Vadose Yield (to -2500 kPa) (%)	Total Tree-Available Water (%)	Capillary Fringe (cm)	Hydraulic Conductivity (m/d) - Saturated	Hydraulic Conductivity (m/d) - Unsaturated @ -30 kPa	Hydraulic Conductivity (m/d) - Unsaturated @ -200 kPa
Clay	34.1	10.0	0.7	24.1	9.3	33.4	22.7	1.8	7.3E-04	7.0E-07
Sand	39.8	5.1	0.1	34.8	5.0	39.7	0.5	5.2	1.1E-04	2.2E-08
Sandy Clay	41.3	5.4	0.3	35.9	5.1	41.0	0.5	4.3	2.4E-05	1.6E-08
Clayey Sand	37.2	12.4	6.4	24.8	6.0	30.9	7.2	0.9	2.2E-08	2.6E-10
Silty Sand	38.5	7.7	1.5	30.7	6.2	37.0	4.2	2.2	3.8E-06	1.3E-08
Geometric Mean	**38.0**	**7.6**	**0.6**	**29.4**	**6.1**	**36.0**	**2.5**	**2.5**	1.4E-05	**1.6E-08**

Moisture content % vol/vol
Tree Water Availablility = water release between fully-saturated conditions to turgor loss (~-2500 kPa), % vol/vol
Parameters derived from PSD analysis using Saxton Rawls (2006) methodology

3.4 Groundwater

3.4.1 Hydrogeology

The hydrogeology of the Yalyalup project area has been documented in detail in the Hydrogeological Assessment report (AQ2, 2019). The Yalyalup project is wholly located within the Busselton-Capel Groundwater Area for the Superficial and Leederville aquifers and within the Busselton-Yarragadee Groundwater Area for the Yarragadee aquifer.

Three major aquifers have been identified within the Yalyalup project (ordered from shallow to deep), namely:

- Superficial;
- Leederville;
- Yarragadee.

The Bassendean Sand, Guildford Formation and Yoganup Formation form an unconfined Superficial aquifer, with a maximum saturated thickness of 9 m in the study area. The permeability of the superficial aquifer is variable and depends on sediment type, with saturated sands having higher permeability than clays. At the project, the Yoganup Formation forms the main portion of the aquifer, while the Bassendean Sand is generally saturated when water levels rise in the wet season. The Guildford Formation is of lower permeability, owing to its more clayey nature. The high sand content in all the superficial units at the site mean they are in hydraulic connection and behave as a single aquifer unit. There is no evidence of any perched aquifer at the site.

It should be noted that the Leederville and Yarragadee aquifers are not discussed in this GDE Management Plan.

3.4.2 Groundwater Levels

The water levels in the superficial aquifer across the site slope in a north-westerly direction under a low hydraulic gradient, which closely reflects the site topography. The groundwater flow direction is generally towards the coast.

The pre-mining water table elevations, as measured in the Superficial monitoring bores (both Doral's monitoring bores, other private users and DWER monitoring bores) across the site, are close to surface in a range of between 15.6 and 34.8 mAHD (i.e. depths to water of between 0 and 4.7 mbgl). In the project area, low-lying areas are often waterlogged during winter (i.e. the water table rises to ground surface). Although very long term annual rainfall indicates a drying climate, rainfall and subsequently aquifer recharge experienced in recent years is still sufficient to fill the Superficial aquifer and a long-term trend of decline in water levels due to change in climate is not observed in the project area.

The groundwater level hydrograph (Figure 4) for selected monitoring bores close to the McGibbon Track, indicates the following:

- Pre-mining depth to water in the Superficial aquifer in McGibbon Track area ranged between 0 to 3.45 mbgl (generally, between 0 and 2.5 mbgl along the McGibbon Track);
- Highest water level elevations were recorded in August or September and lowest in May or June;

- Seasonal cycles of water table variations associated with the winter-dominated rainfall recharge to the aquifer are evident;
- The seasonal water level variations were between 1.4 and 2.6 m, with general seasonal variations of 1.2 to 1.9 m along the McGibbon Track;
- The depth to water in summer ranges between 1.5 to 2.1 mbgl, while in winter ranges between 0 to 0.7 mbgl;
- Variations in depth to water can be generally correlated with variations in rainfall, with the minimum depth to water fluctuating greatly compared to the maximum depth to water.

3.5 Ecohydrological Conceptual Model

3.5.1 Key Elements of the Model

The area is characterised by overstorey vegetation comprising *Melaleuca rhaphiophylla*, *Eucalyptus rudis*, *Melaleuca preissiana* and *Banksia littoralis.* Mid-storey vegetation also includes *Banksia squarrosa subsp. Argillacea* and *Verticordia plumosa* subsp. *Vassensis.* The vegetation occurs in obligate phreatophytic communities with the species mix depending on the degree of water logging and substrate characteristics; "A2-type communities" are associated with shallow groundwater and sandy soil while "B1-type communities" are associated with shallow groundwater and ironstone in the substrate.

The root zone has been estimated by comparing the groundwater hydrographs and the hydraulic properties of the soil. The root systems will not tolerate permanent saturation (as oxygen-stress and root die-back occurs) and thus are likely to occur in the zone that is saturated for only a few months a year. The root system is also likely to develop where connection is retained with the capillary fringe (as the communities comprise obligate phreatophytes); this would mean they will remain within less than 0.5 m of the water table (i.e. <0.5 m from the average seasonal low groundwater levels). The root systems are also likely to exhibit some degree of plasticity on a seasonal basis. On balance, this means the rooting depth is likely to be in the range 1 m to 1.3 mbgl (based on the measured hydrograph from monitoring bore YA_MB08S); there will be local variations based on local hydrologic setting.

3.5.2 Ecohydrological Function

The relatively shallow rooting depth, high evapotranspiration demand and poor moisture retention properties of the sandy soil will make the communities sensitive to changes in groundwater levels. By way of a corollary, in a study of vegetation change on the Gnangara Mound, Sommer and Froend (2014) classified species into four hydrotypes based on the hydrological habitat preference of a species. These hydrotypes were defined as:

- Hydrophytes, which are species tolerant of excessive wetness;
- Mesophytes, species that grow optimally on moist sites, but are intolerant of extremes in moisture conditions;
- Xerophytes, which are species with a wide tolerance of hydrological conditions but with maximum development on dry sites; and
- Generalists: species without particular hydrological habitat preferences.

Sommer and Froend (2014) calculated a theoretical overlap between hydrophyte and xerophyte dominated-vegetation types at around 2.4 m depth to groundwater (DGW), with mesophyte abundance highest between 2.5 and 5 m. This is consistent with the observed distribution in the YDE of Vegetation Units A2 and B1, which are dominated by hydrophytes, in habitats where the DGW varies from approximately 1.3 m in winter to 2.2 m in summer.

3.5.3 Ecohydrological Sensitivity

Vegetation dominated by hydrophytes and mesophytes may be less resilient to environmental perturbations (Sommer & Froend 2014). For example, stands containing *Banksia littoralis* may be sensitive to rapid or large increases in DGW (Groom *et al*. 2001) as it has a higher vulnerability to xylem cavitation than congeneric species (Canham *et al.* 2008). Stands with *Melaleuca rhaphiophylla* and/or *Eucalyptus rudi*s may be able to withstand periods of waterlogging but be sensitive to falls in the water table. Although *Melaleuca preissiana* is an obligate phreatophyte, it is likely to be sensitive to permanent decreases in DGW.

The vegetation units within the YDE are likely to be sensitive to significant or rapid changes in DGW. Vegetation Unit A1 contains trees of *Melaleuca preissiana* and Vegetation Unit A2 contains *Melaleuca preissiana*, *Banksia littoralis* as well as *Hakea ceratophylla.* Both vegetation types therefore may be sensitive to decreases as well as increases in DGW. Vegetation Unit B1 overlies the shallow ironstones and contains *Eucalyptus rudis, Banksia squarrosa* subsp. *argillacea*, *Calothamnus quadrifidus* subsp. *teretifolius* and *Loxocarya magna.* A significant increase in DGW may result in a decline in vegetation condition or a decline in the health of plants, including the loss of individuals.

Interim Recovery Plans have been developed for both SWAFCT10b (Vegetation Unit B1) and *Banksia squarrosa* subsp. *argillacea* (DEC 2004, 2005). The key regional threats to SWAFCT10b include dieback, clearing, frequent fire, weed invasion and potentially salinisation and waterlogging. The major regional threats to *Banksia squarrosa* subsp. *argillacea* include clearing, dieback, track maintenance, inappropriate fire regimes, weed invasion and hydrological changes.

4 ENVIRONMENTAL THREATS

4.1 Threatening Processes

4.1.1 Drawdown Risk

Based on the literature outlined previously, key thresholds in relation to changes in groundwater level appear to be:

- Total groundwater level drawdown of more than 0.25 m;
- Rate of groundwater level drawdown (outside of the natural range) at more than 0.1 m per year.

4.1.2 Assessment of Groundwater Drawdown

To provide a clear indication of predicted drawdowns across the project area in relation to the proposed temporal and spatial progress of mining at Yalyalup, several model outputs have been prepared by AQ2 as part of the Hydrogeological Assessment (refer to figures 75 to 103 in AQ2, 2019). A groundwater model was prepared, and predictions were run for a set of wet and dry climatic conditions based on the "wet" and "dry" real rainfall data sets. In this way the dewatering rates and drawdowns were predicted over a range of climatic conditions (i.e. extended periods of below and above average rainfall). In terms of the "worst case" impacts on the GDEs the dry climatic scenario (late autumn) predicted drawdowns have been used.

Overall, dewatering due to mining at the Yalyalup is likely to result in negligible regional scale groundwater drawdowns in the Superficial aquifer. Drawdowns in the Superficial aquifer are predicted to be localised in the immediate area of the active mining (pits), temporary in duration and relatively small. A maximum drawdown of 10.5 m predicted after mining Q2 of 2023, with the 0.1 m drawdown contour falling only marginally outside of the proposed mining disturbance envelop. Long-term post mining effects on water levels are expected to be minimal. The recovery of water levels will commence immediately once mining of each active mine pit is completed, owing to backfilling of mined-out pits. Once all mining areas are completed, dewatering will cease, and water levels will continue to rise until a steady state or equilibrium water level is resumed. The numerical model shows that water levels are predicted to return to pre-mining levels within 18 months of mine closure for both dry and wet climatic scenarios.

4.1.3 Predicted Maximum Water Level Drawdowns along the McGibbon Track

The drawdowns at McGibbon Track are predicted to be evident from Q1 of 2023 (i.e. 18 months since the planned mining commences), and continued to occur until the mining ceases in Q4 of 2024. The magnitude of drawdowns along McGibbon Track vary depending on the proximity of the active mining quarter and the total depth mined to the track are summarized in Table 4.1.

Table 4.1: Summary of Predicted Drawdowns Along McGibbon Track Over the Mine Life

Mining Quarter (Q)	Predicted Drawdown (m) McGibbon Track – Northern Part (vegetation communities A2)	Predicted Drawdown (m) McGibbon Track – Central Part (vegetation communities B1)
Q1_2023	<0.3	0
Q2_2023	<0.25	0
Q3_2023	0.5-5	0.1-0.3
Q4_2023	0.5-3	0.1-0.5
Q1_2024	0.5-2	0.1-0.5
Q2_2024	0.5-1	0.15-0.5
Q3_2024	1-4	0.25-1.5
Q4_2024	0.75-1.5	0.25-1.5

Additionally, four notional monitoring points have been set along McGibbon Track (Figure 5) to obtain the information on the changes of the predicted water level drawdowns during the life of mine operation and during closure. The predicted drawdowns over time along McGibbon Track is presented in Figure 6.

At the northern part of the McGibbon Track, where the vegetation communities A2 has been identified, the maximum water level drawdowns are predicted after mining Q3 of 2023 and are 4 to 5 m (Figure 7). The predicted drawdowns at the central part of the track, where the vegetation communities B1 has been identified are 0.3 m or less.

At the central part of McGibbon Track (the vegetation communities B1), the maximum water level drawdowns are predicted after mining Q3 of 2024 and are between 0.25 and 1.5 m (Figure 8). During mining this quarter, the predicted drawdowns at the northern part of the track (vegetation communities A2) are between 1 and 4 m.

The key points are:

- First water level changes at McGibbon Track are predicted to occur after 18 months since mining commences.
- Areas of >0.25 m water level change are predicted to affect approximately 60% of McGibbon Track GDE.
- Areas of >0.25 m water level change are predicted to affect vegetation communities A2 and B1, with the communities A2 north of McGibbon Track being the most effected and the longest.
- Hydrograph shows rapid rate of water level change of up to 1.5 m/month during mining.

4.2 Potential Impacts

4.2.1 Mining Related

Groundwater modelling predicts the mining operation will temporarily cause groundwater levels to decline and fall outside the seasonally observed range. The magnitude and rate of change exceed thresholds that have been shown in other studies to result in impacts to the vegetation. In the absence of management intervention, the following impacts may occur:

- Complete or partial loss of phreatophytic species due to water stress and hydraulic failure.
- Vegetation health decline including leaf or limb shedding and the introduction of disease.
- Community invasion by weed species.

4.2.2 Management Related

Management intervention may involve the artificial supplementation of plant-available water (e.g. through irrigation). The water regime is defined by both total plant-available-water and plant water sources. Typically, GDE's obtain a significant portion of total plant available water from the vadose zone and root systems are configured to exploit water from both vadose zone and groundwater zone. The relative contribution from each water source may vary on a seasonal basis. For example:

- During the winter when recharge is occurring, the vadose zone will be wetter as rainfall infiltrates. The rise in groundwater levels could result in a portion of the deeper root zone being below the water table (i.e. in fully saturated anoxic conditions where the roots are not active). The systems may use more water from the vadose zone.
- During summer when the vadose zone is drier and groundwater levels recede, the deepest parts of the root system will be in close proximity to the groundwater table and the capillary fringe. The systems may use more water from deeper sources and groundwater.

The root zone may reconfigure and root truncation may occur if the zone of consistently high moisture content or permanent saturation is materially changed during management intervention. This may result in a loss of resilience within the system and an inability to survive the natural range in groundwater levels.

5 ENVIRONMENTAL MANAGEMENT

5.1 Objectives of Management Techniques

Management intervention will have two key objectives:

- Preserve groundwater levels within a range that will maintain system health and robustness;
- Maintain a soil moisture regime that is close enough to natural conditions so as not to result in reconfiguration or truncation of the root systems.

5.2 Management Techniques – Key Success Indicators

Given the identified threats to the vegetation units and conservation-coded species within the YDE, it is the overall objective of the management plan to maintain the botanical values within the site. It is unlikely that no change would be observed during the mining phase even under natural conditions and it is expected that some degree of change may be tolerated to a level that would be recoverable post-mining. Any change in botanical values will also be consistent with the goals set out in the respective Interim Recovery Plans (IRPs) for *Banksia squarrosa* subsp. *argillacea* and Southern Swan Coastal Plain Ironstone Association (Busselton Area) (DBCA 2004, 2005, respectively).

For *Banksia squarrosa* subsp. *argillacea,* the objective of the IRP is to maintain or enhance *in situ* populations. A loss of ten percent of individuals within any population or the number of populations would be considered a failure of the plan. Therefore, the aim of this management plan with regard to *Banksia squarrosa* subsp. *argillacea* is no net loss of individuals within Vegetation Unit B1.

Verticordia plumosa subsp. vassensis does not have an IRP in place for the taxon and so the same aims will be adopted for the population in the Princefield Rd reserve.

For the Southern Swan Coastal Plain Ironstone Association (Busselton Area), the objective of the IRP is to improve or maintain the overall condition of the community with a view of reclassifying it from Critically Endangered to Endangered. Failure of the plan is considered to be a decline in 10% or more of the area covered by the community or a reduction in the number of occurrences. Other criteria of failure include a decline of 10% or more of native plant taxa within any occurrence, an increase in exotic species cover of 10% or more and the level and quality of groundwater falling outside natural parameters. Therefore, the aims of this management plan with regard to the Southern Swan Coastal Plain Ironstone Association (Busselton Area) are restricting any increase of weed cover to less than 10% of that pre-mining; any change in number of native plant taxa present to be less than a 10% decline and groundwater levels and quality will be maintained within an acceptable range of natural levels.

The success of the management plan for the GDEs within the YDE will be assessed against criteria for each of the following parameters:

- Species functional type composition
    - No measurable change in functional type composition. The composition of native taxa within a GDE shall remain predominantly hydrophytic. an increase in mesophytes or xerophytes may be an indication of an alteration in hydrology.
- Species mortality
    - Mortality of individuals will remain below 15% for dominant species. No net mortality of Threatened taxa.

- Species richness
    - <10% decline in native species richness
- Vegetation density/cover and abundance
    - Reduction in cover of native taxa to be less than 10%
- Vegetation height and diameter
    - Reduction in height or cover of Threatened taxa to be kept below 10%

5.3 Management Techniques

The supplementation of water to offset groundwater level drawdown beneath the GDEs will be the key management technique. The following are relevant to the supplementation technique:

- The vadose zone moisture cycle is related to rainfall recharge and should be unaffected by changes in groundwater level.
- Management will focus on preservation of groundwater availability within the root zone of the GDE community.

Techniques for sub-surface supplementation will be based on supplementing water to the aquifer with materially affecting the vadose zone. Techniques will include an optimal combination of:

- Infiltration from trenches excavated parallel to and in proximity (i.e. either side) of McGibbon Track.
- Infiltration from subsurface field drains laid in trenches excavated parallel to and in proximity (i.e. either side) of McGibbon Track. This option may be beneficial over trenches in avoiding ground stability and trafficability issues.
- Lines of shallow spearpoints parallel to and in proximity of McGibbon Track.

It is envisaged that surface irrigation would be used either only periodically or in the event urgent intervention is required.

5.4 Detailed Design of Management Techniques

The existing groundwater model should be used to estimate infiltration volumes that are required to offset drawdown in areas of the GDE that are predicted to suffer a groundwater level decline of more than 0.25 m below normal autumn level or at a rate that exceeds 0.1 m/yr.

It should be noted that preservation of the groundwater level in the area of the GDE (that would otherwise be affected by dewatering) may result in increased dewatering rates.

Once the volume of water required has been determined, the most efficient method of delivering this water to the subsurface can be determined and the overall scheme can be designed. This determination will involve the engineering assessment of the capacity and efficacy of the options outline above to deliver the required volumes of water to the subsurface.

6 MONITORING PROGRAM

6.1 Parameters

Monitoring will comprise a combination of hydrological parameters and quantitative and qualitative vegetation measurements, ecophysiological measurements and health assessments using qualitative criteria. The monitoring programme is summarised in Table 6.1 and the detailed methodology for each component is described below.

6.2 Groundwater Levels

Groundwater levels will be monitored in a network of 6 bores; the bore locations are summarised in Table 6.2 and shown in Figure 9.

6.3 Vegetation Monitoring

To meet the objectives for botanical values within the YDE outlined in Section 5.2, monitoring will be undertaken of the status of the Threatened Flora populations, the use of groundwater by phreatophytic species within the respective GDEs on McGibbon Track, and the condition and diversity of the vegetation units along McGibbon Track.

Leaf Water Potential (LWP) monitoring

The species to be targeted for Leaf Water Potential (LWP) have been selected because they are common and representative of the canopy and midstorey structural layers of the GDEs potentially at risk. It was considered that measurement and observation of the water status in these species would be representative of the overall communities' response to water deficit as a result of dewatering.

Monitored species within Vegetation Unit A2 will be:

3. *Acacia saligna*;
4. *Hakea ceratophylla*;
5. *Banksia littoralis* (tree)

Monitored species within Vegetation Unit B1 will be:

1. *Acacia saligna*;
2. *Calothamnus quadrifidus subsp. teretifolius*; and
3. *Eucalyptus rudis* (tree)

Vegetation Health Monitoring

The species selected for LWP monitoring will also be assessed for health monitoring using visual inspection and assessed using a scale based on that used by Lay and Meissner (1985) (Table 6.3). Photographs will also be taken of all the monitored trees and shrubs every three months, starting in Spring 2020.

Table 6.1: Monitoring Frequency

Monitoring Parameter	Period: Baseline Freq	Baseline Trigger	Active Dewatering Freq	Active Dewatering Trigger	Active Dewatering Response	Objectives / Remarks
Hydrological						
Groundwater Level	Monthly	n/a	Weekly	< Avg lowest level	Increased veg monitoring	Increased risk when GWLs fall below natural range
Rate of change			Weekly	>1.5 cm / wk	Supplementation	Managing rate of GWL change
Absolute change			Weekly	> 25 cm	Supplementation	Managing absolute GWL change
Leaf Water Potential						
Pre-Dawn	Quarterly	n/a	Quarterly	< lowest baseline meas (~0.5 Mpa)	Supplementation	Monitoring GDE connection with GWL Species of GDE wetland (A2-community): - Acacia saligna - Hakea ceratophylla - Banksia littoralis
Pre-Dawn after GW level trigger (during dewatering)			Fortnightly	< lowest baseline meas (~0.5 Mpa)	Supplementation	Ironstone species (B1 community): - Acacia saligna - Calothamnus quadrifidus - Eucalyptus rudis
Midday	Quarterly	n/a	Quarterly			Use in calculation of rehydration index
Midday after GW level trigger (during dewatering)			Fortnightly			Use in calculation of rehydration index
Rehydration index	Quarterly	n/a	Quarterly	<0.4	Supplementation	Monitor tree water stress
Rehydration index after GW level trigger (during dewatering)			Fortnightly	<0.4	Supplementation	(RI = (MD - PD)/MD)
Vegetation Health						
Weed coverage (25 m^2 quadrats)	Annual	n/a	Annual	>10% increase		
Native understorey cover (25 m^2 quadrats)	Annual	n/a	Annual	>10% reduction in: - species diversity - ground cover - height	Mgt review supplementation	Spring monitoring period Verification of succesful management
Visual health - mid/over storey trees	Quarterly	n/a	Quarterly	>2 place reduction in health score	Mgt review supplementation	Verification of succesful mgt

Table 6.2: GDE Monitoring Bore Locations

Bore ID	Easting (m)	Northing (m)	Depth to Base of Superficial Formation (mbgl)	Proposed Drilled Depth (mbgl)	Minimum Depth to Water (mbgl)	Maximum Depth to Water (mbgl)	Maximum Drawdown Q3_2023 (m)	Maximum Drawdown Q3_2024 (m)	Predicted Maximum Depth to Water During Mining (mbgl)	Status
GDE_A	358885	6271010	4.3	4.0	0.25-0.75	2.4	0.2	0.5	2.9	to be installed
GDE_B	358720	6271155	6.6	6.4	0.2-0.7	2.4	1.3	3.0	5.4	to be installed
GDE_C	358600	6271570	8.1	6.0	0.1-0.6	1.75	3.0	0.9	4.75	to be installed
GDE_D	359070	6270790	6.0	5.5	0.2-0.4	2.4	0.0	0.0	2.4	to be installed
GDE_E	359470	6271780	8.0	5.0	0.2	1.5	0.0	0.3	1.8	to be installed
YA_MB08S	358589	6271310	9.7	9.4	0.2-0.75	2.1	6.0	1.5	8.1	operational

Table 6.3: Visual Health Scale used in the Yalyalup Monitoring (After Lay & Meissner, 1985)

Score	Description
0	Dead shrub.
1	Shrub/Tree with <20% of original canopy; most main branches dead; remaining leaves mostly dying off.
2	Shrub/Tree with 21- 40% of original canopy present; some main branches dead (50 - 80% canopy); abundant leaf yellowing (>41% canopy)[1].
3	Shrub/Tree with 41-60% of the original canopy present; some smaller dead branches evident (21-40% canopy); moderate amount of leaf yellowing (21-40% canopy) .
4	Shrub/Tree with 61 – 80% of the original canopy present; occasional dead branches (< 20% of canopy); small patches of leaf yellowing (< 20% of canopy) .
5	Shrub/Tree with >81% of the original canopy present; healthy overall; little or no leaf yellowing.

Threatened Flora

Monitoring of Threatened taxa populations (*Banksia squarrosa* subsp. *argillacea* and *Verticordia plumosa* subsp. *vassensis*) will be undertaken using the health scores described in Table 6.2 as this approach will be non-invasive.

All individuals of *Banksia squarrosa* subsp. *argillacea* will be tagged and monitored every three months.

Up to 10 individuals of *Verticordia plumosa* subsp. *vassensis* will be tagged and monitored every three months. It is noted that the density of vegetation prevents access to all individuals in this occurrence of this taxon. To prevent trampling and opening of the vegetation that may allow ingress of weeds, only plants that can be assessed without degrading the vegetation stand be monitored.

Vegetation Condition Monitoring

Floristic monitoring plots (5 m x 5 m quadrats) will be established at 50 m intervals within Vegetation Units A2 and B1. The interval may be shorter within Vegetation Unit B1 to allow for the establishment of at least 4 quadrats. Monitoring is to occur each year during spring. Within each 25 m^2 quadrat the point intercept method will be used to determine the relative abundance of native and non-native herbaceous species. The presence and estimated cover values of woody taxa within each quadrat will also be recorded.

6.4 Monitoring Frequency

The monitoring frequency is summarised in Table 6.1. Monitoring frequencies fall into two broad categories: baseline / pre-dewatering and during active dewatering.

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[1] Depending on the time of year, yellowing leaves may or may not be present. In summer and early autumn, almost all dead leaves may fall or be blown off the plant.

6.4.1 Baseline / Pre-Dewatering

Groundwater levels will be monitored and reviewed at least monthly to confirm seasonal sequences.

Vegetation health monitoring will occur quarterly. Baseline flora and vegetation monitoring will be conducted prior to the commencement of mining.

Baseline monitoring includes:

- Qualitative vegetation health assessments of trees (*Eucalyptus rudis*, *Melaleuca preissiana*, *Banksia littoralis*) along McGibbon Track following an adapted method from Souter *et al*. (2009) and Backstrom *et al*. (2010);
- Quantitative weed cover and qualitative native species cover/abundance assessments along McGibbon Track;
- Quantitative water status assessments using pre-dawn and midday leaf water potential measurements for selected species along McGibbon Track;
- Quantitative depth to groundwater measurements in GDEs.

6.4.2 During Periods of Drawdown

Groundwater levels will be monitored and reviewed at least weekly during periods of active dewatering in the vicinity of the McGibbon Track.

Vegetation health monitoring will continue with quarterly monitoring until groundwater level triggers are exceeded. The key trigger for increased vegetation monitoring will be when groundwater levels fall lower than the average "low" water level (i.e. the average water level recorded during autumn).

7 PROPOSED MANAGEMENT RESPONSE TRIGGERS & CONTINGENCY MEASURES

7.1 Rationale for Triggers

This management plan has been designed to include the following:

- Leading indicators of risk such that management intervention can pre-empt the development of vegetation water stress:
  - Hydrological triggers provide warning of the onset of a water regime that may cause water tress to develop.
  - Ecophysiological triggers within the vegetation community provide a direct measure of current water status.
- Lagging indicators designed to provide redundancy in risk identification and allow verification of success of management interventions.

Triggers have been designed around parameters that may be affected by mining-induced changes to the water regime (i.e. groundwater levels and associated plant hydration status). Soil moisture is not included as a monitoring parameter because it is influenced by infiltrating rainfall and this will not be affected by mining.

7.2 Hydrological Triggers

Groundwater level is the key hydrological parameter. The following trigger-response mechanism will be used:

- The commencement of dewatering in the vicinity of McGibbon Track will trigger increased groundwater monitoring frequency.
- If groundwater levels fall below the average low annual measured water level (i.e. below the typical autumn groundwater level), then there is a risk water levels will fall below the root zone and water stress and / or hydraulic failure may occur from the inability of root systems to respond to changing hydrological regime. This will trigger increased monitoring frequency of vegetation. With respect to groundwater levels:
  - If total groundwater level decline subsequently reaches 0.25 m below the average low annual measured water level (i.e. below the typical autumn groundwater level), then supplementation will be triggered.
  - If the rate of decline continues at more than 1.5 cm per week, then supplementation will be triggered.

7.3 Vegetation Triggers

7.3.1 Leading Indicator Triggers

Leaf water potential is the key parameter to quantify instantaneous tree water status. Leaf water potential measurements should include:

- Pre-dawn leaf water potential (which provides a proxy for water availability in the root zone and hydraulic connection with the water table). If the pre-dawn becomes more negative than the lowest level measured during the baseline monitoring period (and there is active dewatering and associated drawdown), then water supplementation will be required. The actual pre-dawn threshold will be confirmed during the baseline period; it is likely to be -0.5 MPa or higher.

- Midday leaf water potential will be measured to provide an indication of transpiration water demand. The midday and pre-dawn leaf water potentials will be used in combination to determine rehydration. If the rehydration index falls below 0.4 (and there is active dewatering and associated drawdown), then water supplementation will be required.

The management response when leaf water potential triggers are exceeded will be water supplementation.

7.3.2 Lagging Indicator Triggers

Vegetation health will be a lagging indicator. Sustained health scores will be used to verify the success of management intervention. A decline in vegetation health during active dewatering will be used as a fail-safe mechanism to identify areas where management intervention has not worked or where the change risk has not been identified by the monitoring network.

The vegetation health trigger will be:

- Visible declines in health score during period of dewatering - decline in health score of 2 categories.
- Greater than 15% reduction in abundance of dominant species (during active dewatering).
- Weed increase as a community component by 10%.

For all trigger-exceedances, the management response will be that water supplementation is required.

7.4 Management Response

The management response comprises two tiers:

- Increased monitoring - The observation of operational dewatering impacts on adjacent bores or the exceedance of some hydrological triggers will require more frequent monitoring of ecophysioloigcal parameters.
- Water supplementation - Indications of water stress or exceedance of some hydrological parameters will require water supplementation.

7.5 Supplementation

Exceedance of absolute or rate-of-change triggers in groundwater levels will require water supplementation.

Exceedance of vegetation health parameters or vegetation water status (as measured by pre-dawn LWP or rehydration index) will require supplementation to return groundwater levels to within the natural range within the area of the GDE.

Final design for the supplementation scheme will be completed during implementation of this GDEMP. Supplementation will be based on a combination of:

- Surface irrigation.
- Subsurface irrigation in proximity to the groundwater table through either trenches or shallow spear-points.

The supplementation scheme will have the following design criteria:

- To supply enough water to offset declines in groundwater levels (i.e. to maintain levels within the natural range under the GDEs along McGibbon Track. This will be determined using the existing groundwater model.
- To prevent sustained periods of excessive inundation of the vadose zone that may result in water logging or reconfiguration of the root systems within the GDEs. This will be achieved by the use of sub-surface supplementation.
- To be operationally effective and not subject to excessive clogging that may limit infiltration capacity. This will be assessed during engineering design of the scheme based on aquifer parameters derived during previous groundwater investigations.
- To incorporate a monitoring programme that can be used to confirm the efficacy of the supplementation system. This will be achieved by the monitoring programme outlined in this plan.
- To utilise water of sufficient quality so as not to result in acidification or dieback within the GDEs along McGibbon Track. In this regard, supplementation water will be sourced from the Yarragadee aquifer.

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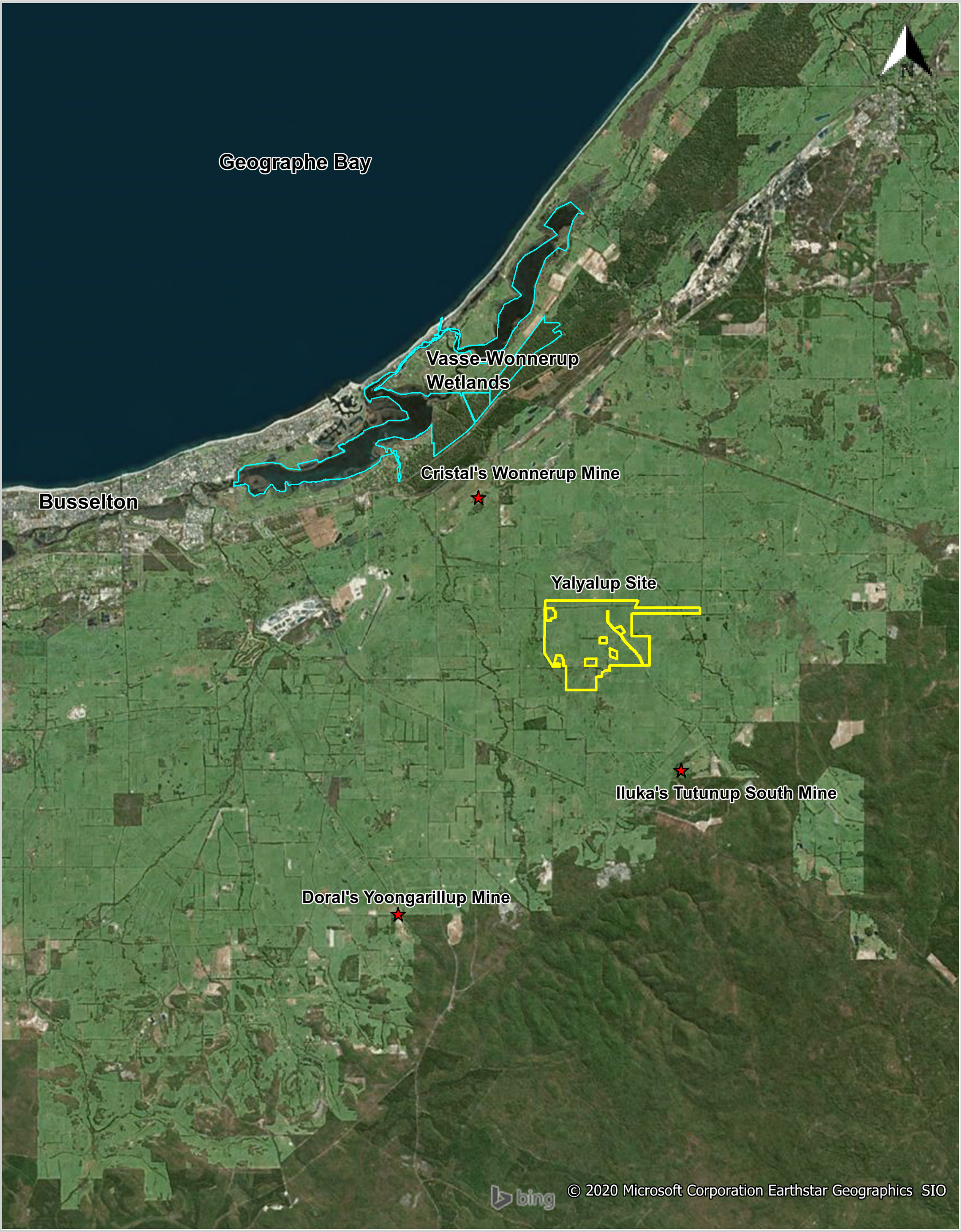
FIGURES



Legend

Proposed Yalyalup Distrubance Boundary

Scale

0 5

kilometres

Scale 1:150,000

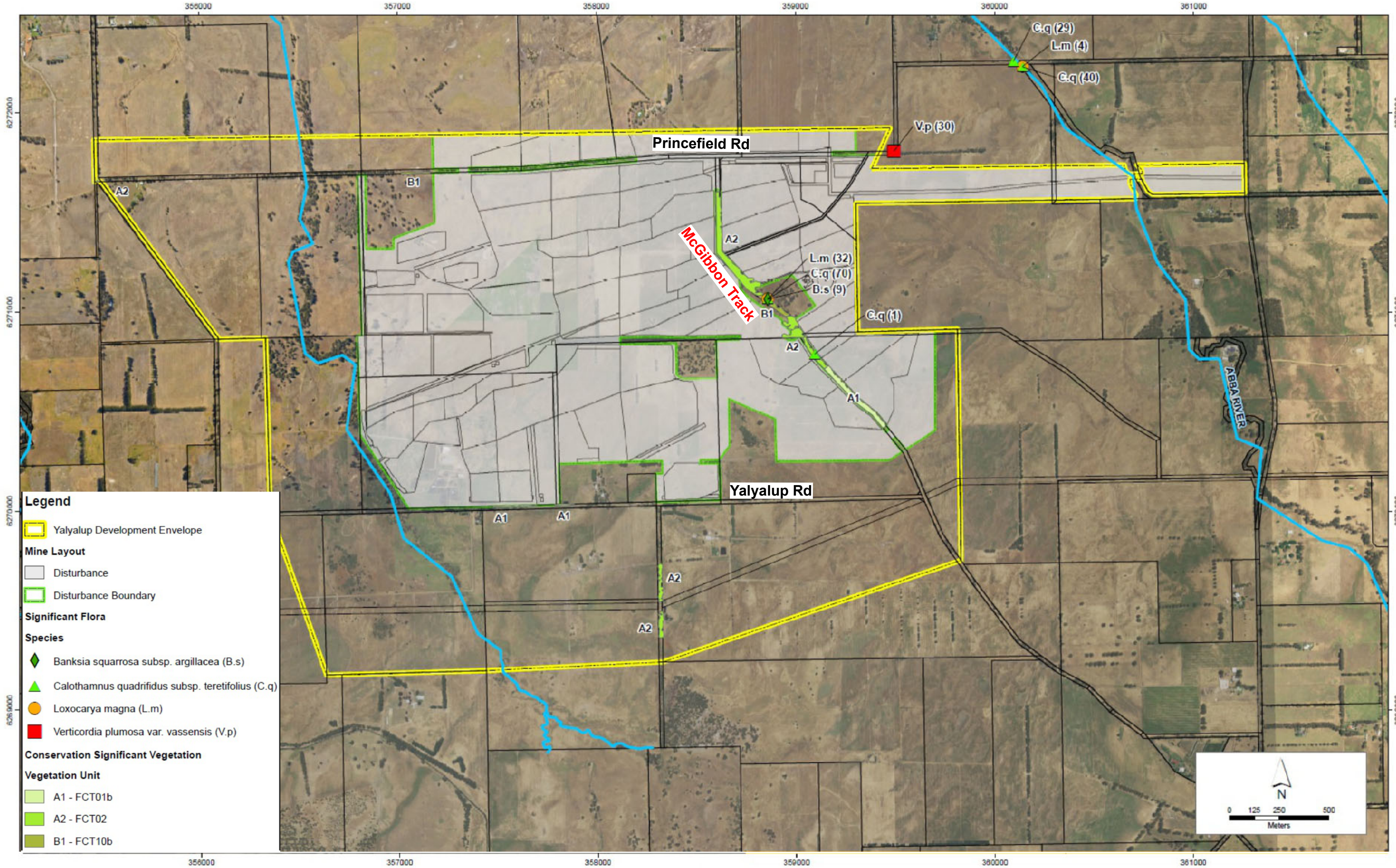
AQ2

FIGURE 1

REGIONAL LOCATION OF THE YALYALUP MINERAL SANDS PROJECT

AUTHOR:	GC	REPORT NO:	022	**NOTES & DATA SOURCES:** Mine outline provided by Doral
DRAWN:	GC	REVISION:	A	
DATE:	04/05/20	JOB NO:	136H	

Location: F:\136\4.GIS\Workspaces\



LOCATION MAP

AUTHOR: BK
DRAWN: BK
DATE: 12/5/20

REPORT NO: 022
REVISION: A
JOB NO: 136H

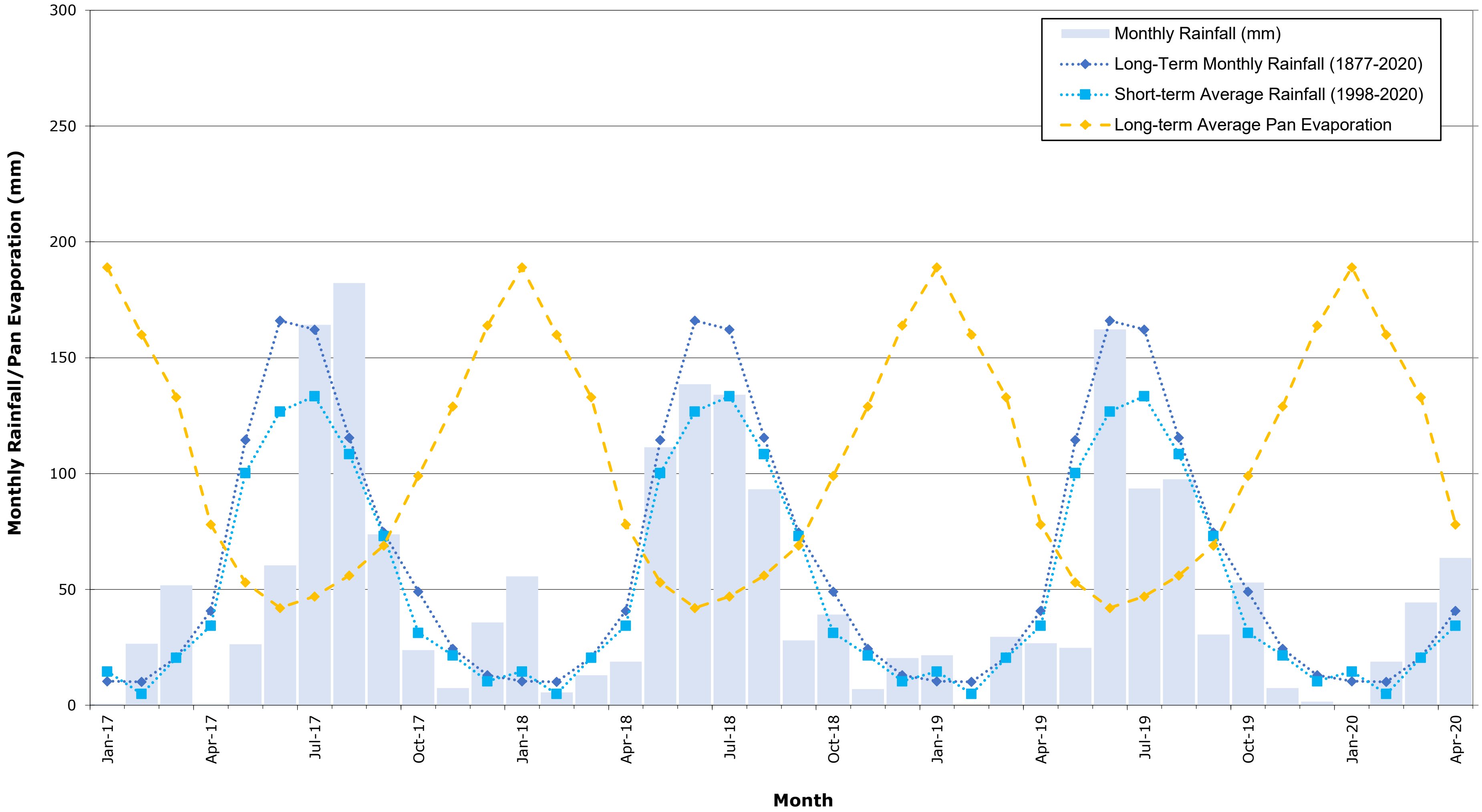
NOTES & DATA SOURCES:
Figure taken from Figure 4-3
Doral ERD, 2020

AQ2

FIGURE 2

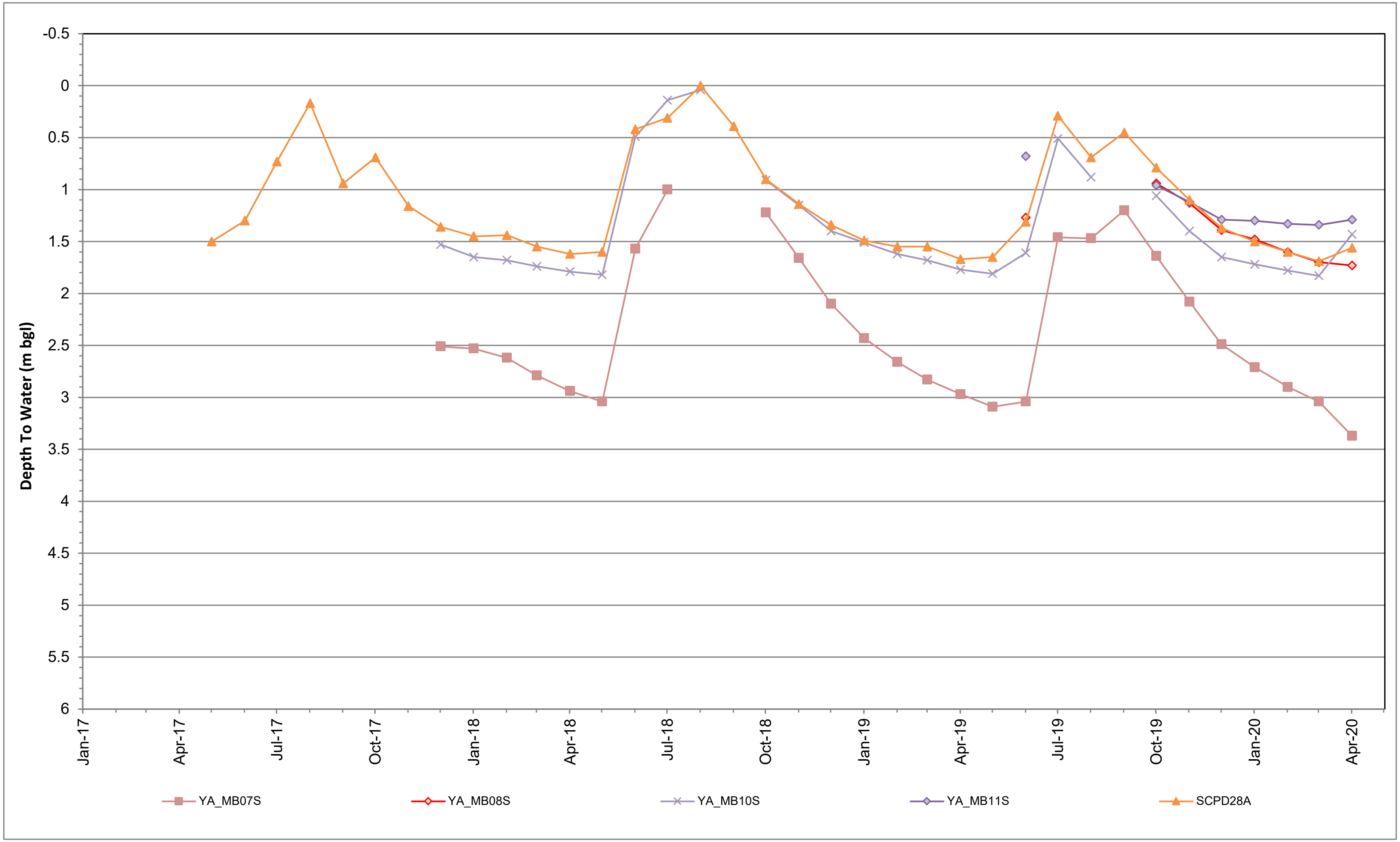
YALYALUP MINERAL SAND PROJECT

LOCATIONS OF GDES



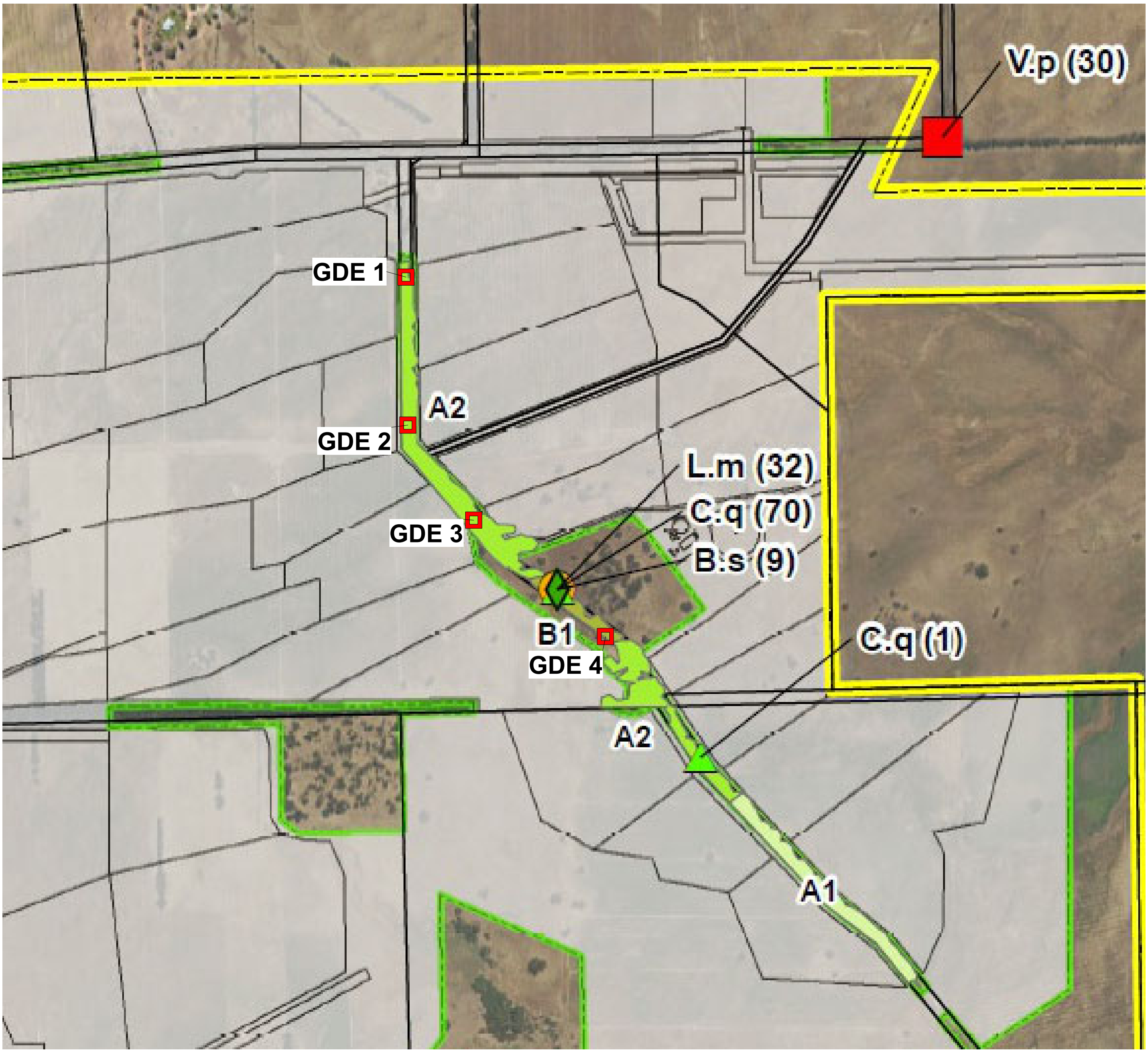
AQ2

BUSSELTON RAINFALL AND PAN EVAPORATION DATA - Figure 3



AQ2

Depth to Water (m bgl) in Superficial Aquifer in Selected Bores Adjacent to McGibbon Track FIGURE 4



LEGEND

Monitoring Bore Location

Notational GDE Monitoring Points

Vegetation Unit A1

Vegetation Unit A2

Vegetation Unit B1

LOCATION MAP

0 500 1000 1500 2000

AUTHOR: BK
DRAWN: BK
DATE: 8/05/20

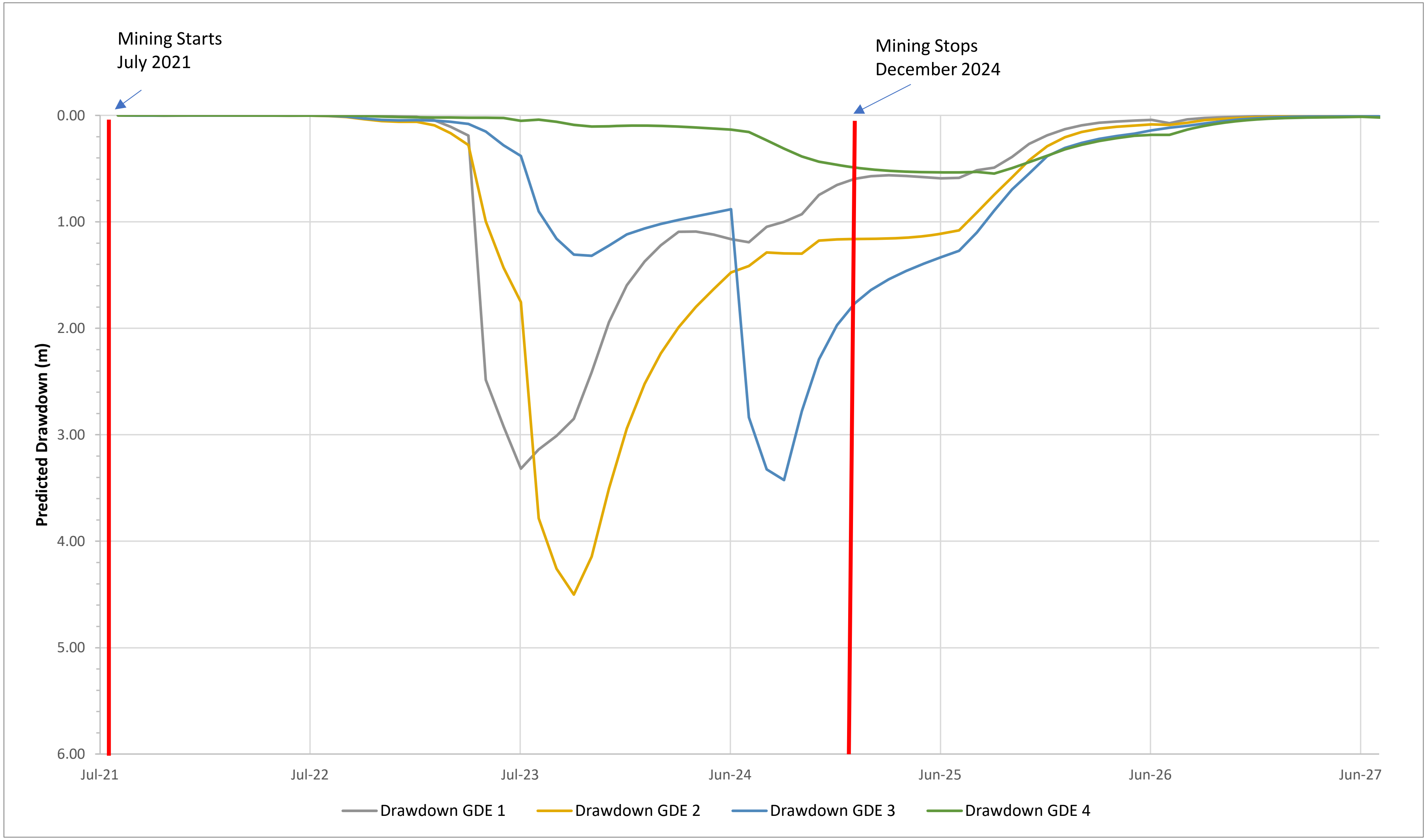
REPORT NO: 022
REVISION: A
JOB NO: 136H

NOTES & DATA SOURCES:

FIGURE 5

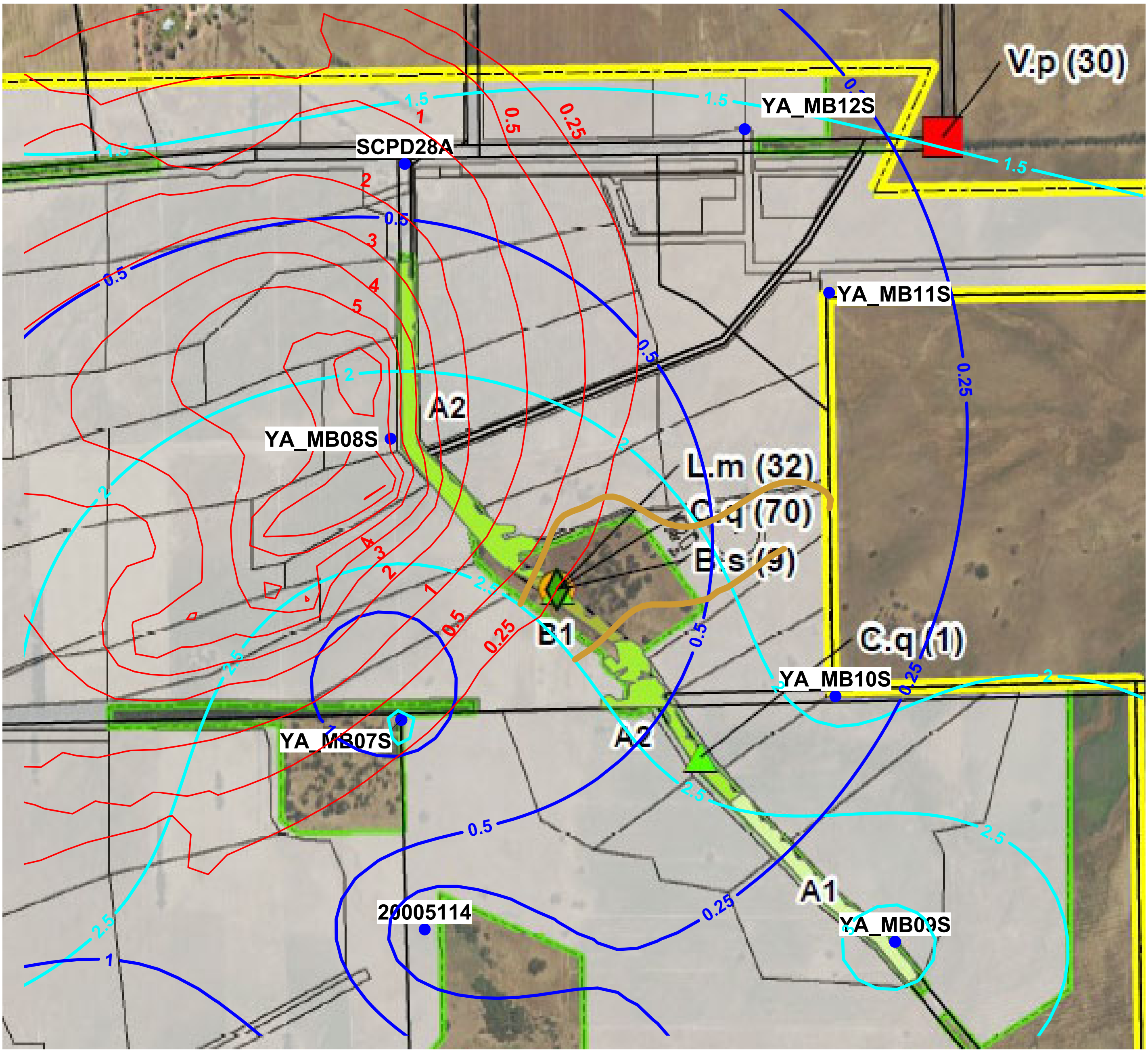
YALYALUP MINERAL SAND PROJECT

LOCATIONS OF NOTATIONAL MONITORING POINTS ALONG MCGIBBON TRACK



AQ2

Predicted Drawdown (m) in the Notational GDE Monitoring Points FIGURE 6



LEGEND

●	Monitoring Bore Location	(line)	Ironstone/Laterite Outcrop Extent
0.5	Minimum Depth to Water (mbgl)	(box)	Vegetation Unit A1
0.5	Maximum Depth to Water (mbgl)	(box)	Vegetation Unit A2
0.5	Drawdown Contours (m) (Q3_2023)	(box)	Vegetation Unit B1

LOCATION MAP

0 500 1000 1500 2000

AUTHOR: BK
DRAWN: BK
DATE: 8/05/20

REPORT NO: 022
REVISION: A
JOB NO: 136H

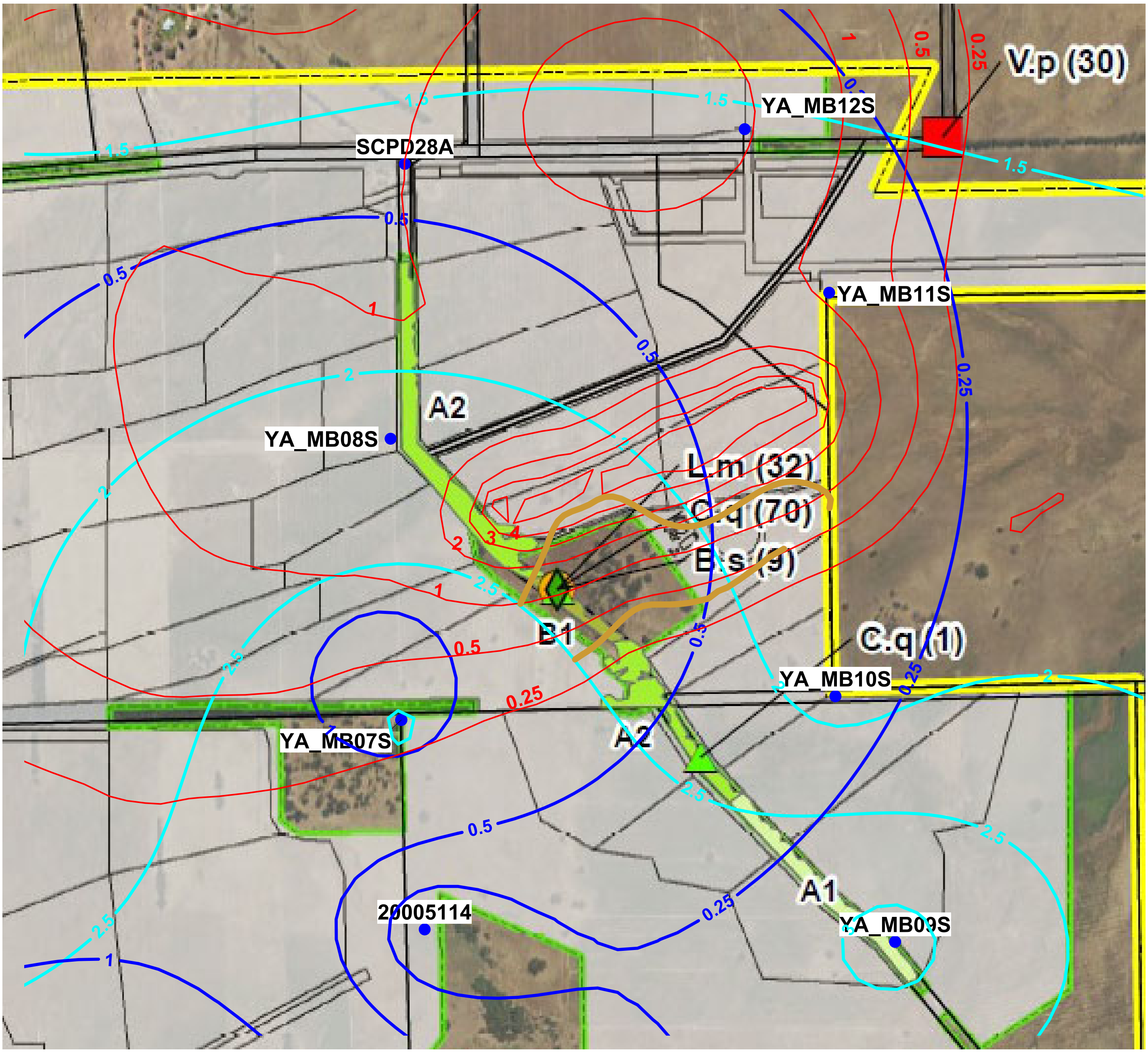
NOTES & DATA SOURCES:

AQ2

FIGURE 7

YALYALUP MINERAL SAND PROJECT

ECOHYDROGEOLOGICAL CONCEPTUAL MODEL WITH MAXIMUM PREDICTED DRAWDOWN FOR VEGETATION UNIT A2



LEGEND

●	Monitoring Bore Location		Ironstone/Laterite Outcrop Extent
0.5	Minimum Depth to Water (mbgl)		Vegetation Unit A1
0.5	Maximum Depth to Water (mbgl)		Vegetation Unit A2
0.5	Drawdown Contours (m) (Q3_2024)		Vegetation Unit B1

LOCATION MAP

0 500 1000 1500 2000

AUTHOR: BK
DRAWN: BK
DATE: 8/05/20

REPORT NO: 022
REVISION: A
JOB NO: 136H

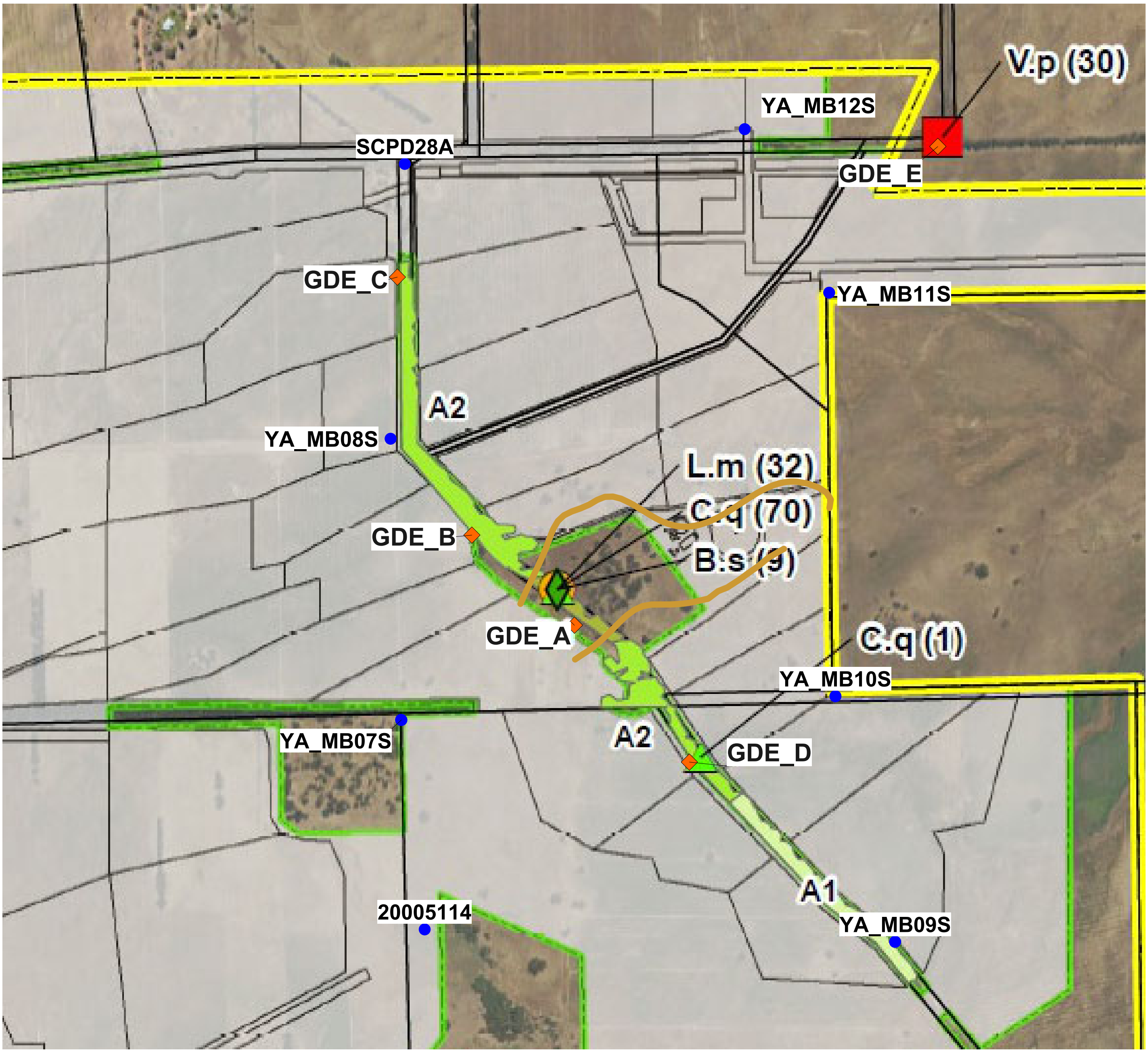
NOTES & DATA SOURCES:

AQ2

FIGURE 8

YALYALUP MINERAL SAND PROJECT

ECOHYDROGEOLOGICAL CONCEPTUAL MODEL WITH MAXIMUM PREDICTED DRAWDOWN FOR VEGETATION UNIT B1



LEGEND

- Monitoring Bore Location
- Proposed GDE Monitoring Bores
- Ironstone/Laterite Outcrop Extent
- Vegetation Unit A1
- Vegetation Unit A2
- Vegetation Unit B1

LOCATION MAP

0 500 1000 1500 2000

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DATE: 8/05/20

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NOTES & DATA SOURCES:

AQ2

FIGURE 9

YALYALUP MINERAL SAND PROJECT

PROPOSED GDE MONITORING BORE LOCATIONS