SOILWATER CONSULTANTS

INCREASE IN GROUNDWATER ABSTRACTION AT IRON VALLEY - IMPACT ASSESSMENT

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Revision Code*

A - Report issued for internal review

B - Draft report issued for client review

C - Final report issued to client

LIMITATIONS

The sole purpose of this report and the associated services performed by Soil Water Consultants (SWC) was to undertake an impact assessment related to a proposed increase in groundwater abstraction at the Iron Valley Project. This work was conducted in accordance with the Scope of Work presented to Mineral Resources ('the Client'). SWC performed the services in a manner consistent with the normal level of care and expertise exercised by members of the earth sciences profession. Subject to the Scope of Work, the impact assessment was confined to the Iron Valley Project. No extrapolation of the results and recommendations reported in this study should be made to areas external to this project area. In preparing this study, SWC has relied on relevant published reports and guidelines, and information provided by the Client. All information is presumed accurate and SWC has not attempted to verify the accuracy or completeness of such information. While normal assessments of data reliability have been made, SWC assumes no responsibility or liability for errors in this information. All conclusions and recommendations are the professional opinions of SWC personnel. SWC is not engaged in reporting for the purpose of advertising, sales, promoting or endorsement of any client interests. No warranties, expressed or implied, are made with respect to the data reported or to the findings, observations and conclusions expressed in this report. All data, findings, observations and conclusions are based solely upon site conditions at the time of the investigation and information provided by the Client. This report has been prepared on behalf of and for the exclusive use of the Client, its representatives and advisors. SWC accepts no liability or responsibility for the use of this report by any third party.

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1 INTRODUCTION

1.1 IRON VALLEY PROJECT

The Iron Valley Project is located in the Eastern Pilbara Region, approximately 90 km north-west of Newman. The Project is in the same region as a number of operating iron ore mines, including the Rio Tinto Iron Ore (RTIO) Yandicoogina (5 km to the west) and Hope Downs operations (45 km to the south west), BHP Billiton Iron Ore (BHPBIO) Yandi operation (35 km to the west) and Fortescue Metals Group (FMG) Cloudbreak operation (55 km to the north).

Iron Ore Holdings (IOH) is the registered licence holder of the Iron Valley tenement, and Mineral Resources Limited (MRL) are developing the mine on behalf of IOH. A license to abstract 360,000 kL/a of groundwater for mine use currently exists, held by MRL. Recently the site water balance has been re-evaluated and MRL are proposing to apply for an amended license of 720,000 kL to cover the expected water use. The amended license is for a period of 2 years, where after an expected change to mining below the water table will result in a further application for an increase in abstraction, to cover mine dewatering.

1.2 KEY ISSUE

The increased abstraction is likely to result in an increase in the drawdown around the production bores, which could potentially impact on other users, including groundwater dependent ecosystems (GDEs). Condition 6-1 in Ministerial Statement 933 (Department of Environment, 2013) states:

> *6-1 The proponent shall ensure that groundwater drawdown associated with the proposal does not cause long term impacts to the health and abundance of Eucalyptus victrix outside the approved disturbance footprint as shown in Figure 3 of Schedule 1.*

1.3 STUDY METHODOLOGY

This investigation included the following tasks:

- Review of available URS data, particularly information from the historical aquifer testing of the two production bores
- Review of monitoring data collected since the mine started operating, to compare to the predicted URS model results.
- Development of an analytical solutions, to be calibrated against the previous URS drawdown predictions (or if more applicable, against the actual measure drawdown collected by Mineral Resources).
- Use of the calibrated model to predict drawdowns at specified GDE locations
- Supply of the new predictions of water level decline, to be provided to the Soil Water Group, for their assessment of potential impacts to the GDEs.
- Compilation of a report, in line with an H2 level report in support of an updated 5C licence application. The report will not cover all of the background data related to historical assessments, only a limited summary of data relevant to the revised assessment of increased abstraction.

2 BACKGROUND

From a groundwater supply perspective, the relevant information includes climate (particularly rainfall and recharge), surface water interactions with the groundwater system, aquifer conditions and the conceptual hydrogeological model. Details on these aspects are covered below, based predominantly on the information presented in more detail in the report on the initial application to abstract water for the project (URS, 2013).

2.1 CLIMATE

The mine is located in located in a region of semi-arid climate, with hot summers and mild winters. Maximum daily summer temperatures fluctuate between 35˚C to 45˚C, with daily average maximum temperatures of 25˚C experienced during winter.

Rainfall in the region is low and associated with irregular thunder storms and cyclones. The majority of rainfall occurs between the months of December and March (Newman Aero Bureau of Metrology (BOM) Station # 007176), with an annual rainfall average of 310 mm. The majority of the rain falls in summer, with January and February experiencing a monthly average of 50 mm and 80 mm respectively. Evaporation rates are high (3,200 to 3,600 mm/annum).

Recharge from rainfall to the groundwater system is low, only approximately 0.5 to 1.5 % of annual rainfall (URS, 2013). During the period that groundwater abstraction has taken place (since September 2013), there have been two months of high rainfall (Dec 2013 and January 2014) (Table 1), during which groundwater recharge would have been expected. During the rest of the period recharge would have been limited, if at all.

Table 1: Rainfall over the last 2 years (Newman, Station No. 71716)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2013	83.8	39.0	24.8	2.4	10.6	69.0	9.6	0.0	0.2	3.4	7.4	72.6	322.8
2014	220.2	18.2	3.0	8.4	18.4	0.2	29.6	0.2	0.0	6.8	46.8	11.2	363.0

2.2 SITE HYDROLOGY

The Weeli Wolli Creek is the most significant surface water feature around the mine site, located to the west of the mine. The Creek only flows after major rainfall events. The proposed mine footprint intercepts three minor ephemeral drainage channels that flow from the elevated hills to the west, to Weeli Wolli Creek. These channels are part of a local catchment area of approximately 64 km^2 (Iron Valley Catchment) which is a small part (1.6%) of the larger Weeli Wolli catchment of 4,000 km^2 (URS, 2012). These three channels will be diverted around the mine workings, so as not to impact flows to Weeli Wolli Creek. Any stormwater generated within the operational mine area will be directed to retention ponds for reuse and evaporation.

2.3 GEOLOGY

The geology of the Iron Valley Project consists of alluvium and detritals in the valley base, overlying Banded Iron Formation (BIF). The BIF consists of shales, mineralised shales and mineralised BIFs, intruded in places by and dolerite dykes. A major north-south faults passes through the centre of the ore body.

The geology of the area is dominated by the following geological units:

- Recent transported unconsolidated sediments and valley fill material (Quaternary and Tertiary alluvium),
- Weeli Wolli formation geology;
- Brockman Iron Formation (Members - Yandicoogina Shale, Joffre, Mt Whaleback and Dales Gorge);

A description of these units is provided below.

2.3.1 Quaternary Formation

The Quaternary alluvium consists of soil and BIF fragments. The thickness varies across the study area, with a thickness between 5 and 35 m (URS, 2011a).

2.3.2 Tertiary Formation

The Tertiary is subdivided into three units:

- Tertiary Alluvium: red clay
- Tertiary Detritals: coarse to medium size fragments of Hematite, Goethite Hematite and Maghemite

The Tertiary deposits vary between 10 and 42 m in depth across the Project area (URS, 2013).

2.3.3 Weeli Wolli Formation

The Weeli Wolli Formation consists of chert and shale with minor BIF bands, intruded by dolerite sills. The sills can be between 1 and 70 m in thickness. The Weeli Wolli Formation is approximately 300 m in thickness.

2.3.4 Brockman Iron Formation

The Brockman Iron Formation is divided into four members (Yandicoogina Shale, Joffre, Mt Whaleback and Dales Gorge) and is ore body at the mine site.

- Yandicoogina Shale Member – consists of interbedded chert and shale, locally intruded by dolerite sills (60 m thick).
- Joffre Member – predominantly BIF units with minor thin shale bands (approximately 360 m thick).
- Whaleback Shale Member – consists of a lower zone of four alternating macrobands of shale and BIF and an upper, main zone with mesobands of alternating chert and BIF.
- Dales Gorge Member – alternating assemblage of BIF and shale macrobands.

2.4 GROUNDWATER CONDITIONS

The alluvium/detritals and the mineralized BIF horizons make up the important aquifers in the study area. Exploration drilling logs indicate that the thickness of the alluvium/detritals units vary from 10 to 42 m, although the unconsolidated sediments overlying the Weeli Wolli Creek channel (to the east of the mine site), may be deeper. Groundwater within these aquifers is likely to be in hydraulic connection with the weathered and fractured bedrock of the Brockman and Weeli Wolli Formations, especially the main ore body aquifer. The non-mineralized BIF Formations (the massive shales and banded iron formations) are likely to have moderate to low hydraulic conductivities, while the mineralised zones are likely to have higher hydraulic conductivities.

The ore body is bisected on the northern part of the tenement, by an east-west striking dolerite dyke. Water level differences on either side of this dyke, suggest that the dyke has a low hydraulic conductivity and acts as a hydraulic barrier to groundwater flow.

2.4.1 Depths

Water levels measured show a distinct difference in groundwater levels on opposite sides of the dyke Static water levels have been measured at depths ranging from 6 to 18 m below surface in the monitoring bores located south of the dolerite dyke (Figure 1). In monitoring bores north of the dyke, static water levels have been measured at depths ranging from 26 to 43 m (Figure 1).

Recharge from the high rainfall events in December 2013 and January 2014 appears to have caused a rise in water levels in some of the bores (see graphs for MBH, MBK, MBA, in Appendix A). Unfortunately there is a gap in the data measured, so it is difficult to see the true extent of the impacts associated with the recharge events.

2.4.2 Flow directions

Regionally, the direction of groundwater flow in the region is from south to north, following the direction of the Weeli Wolli Creek. On a local scale, flow is from the south-west to the north-east, with flow “damming-up” behind the dolerite dyke. As a result of the damming effect, it is likely that there is a deflection of shallow flow through the alluvium, along the creek system into which bore MBK has been drilled.

2.4.3 Aquifer characteristics

Preliminary work undertaken by URS (2011a) included a summary of regional aquifer characteristics, based on their conceptual understanding of the groundwater system (see Table 2).

The URS conceptual model has the highest hydraulic conductivities (20 m/day) occurring in the alluvial deposits around Weeli Wolli Creek and in the north-south striking fault zone. The next most permeable formations are the valley fill material (2 m/day) and then the mineralized BIF ore (1.6 m/day). The remainder of the bedrock has a permeability below 0.1 m/day.

The highest specific yields were set for the ore and mineralised material (0.05), the valley fill/detritals and the alluvial material at (0.01). The remainder of the bedrock was set at 0.001.

2.4.4 Groundwater Quality

The groundwater quality is fresh to marginal, with total dissolved solids (TDS) ranging between 410 and 600 mg/L (URS, 2013). The water is slightly alkaline with a filed measured pH ranging between 7.46 and 8.31.

Groundwater quality work undertaken by other mining companies to the north of the Iron Valley Project, indicates that a wedge of saline groundwater (high TDS) potentially exists to the north of the tenement, associated with the Fortescue Marsh system (URS, 2012).

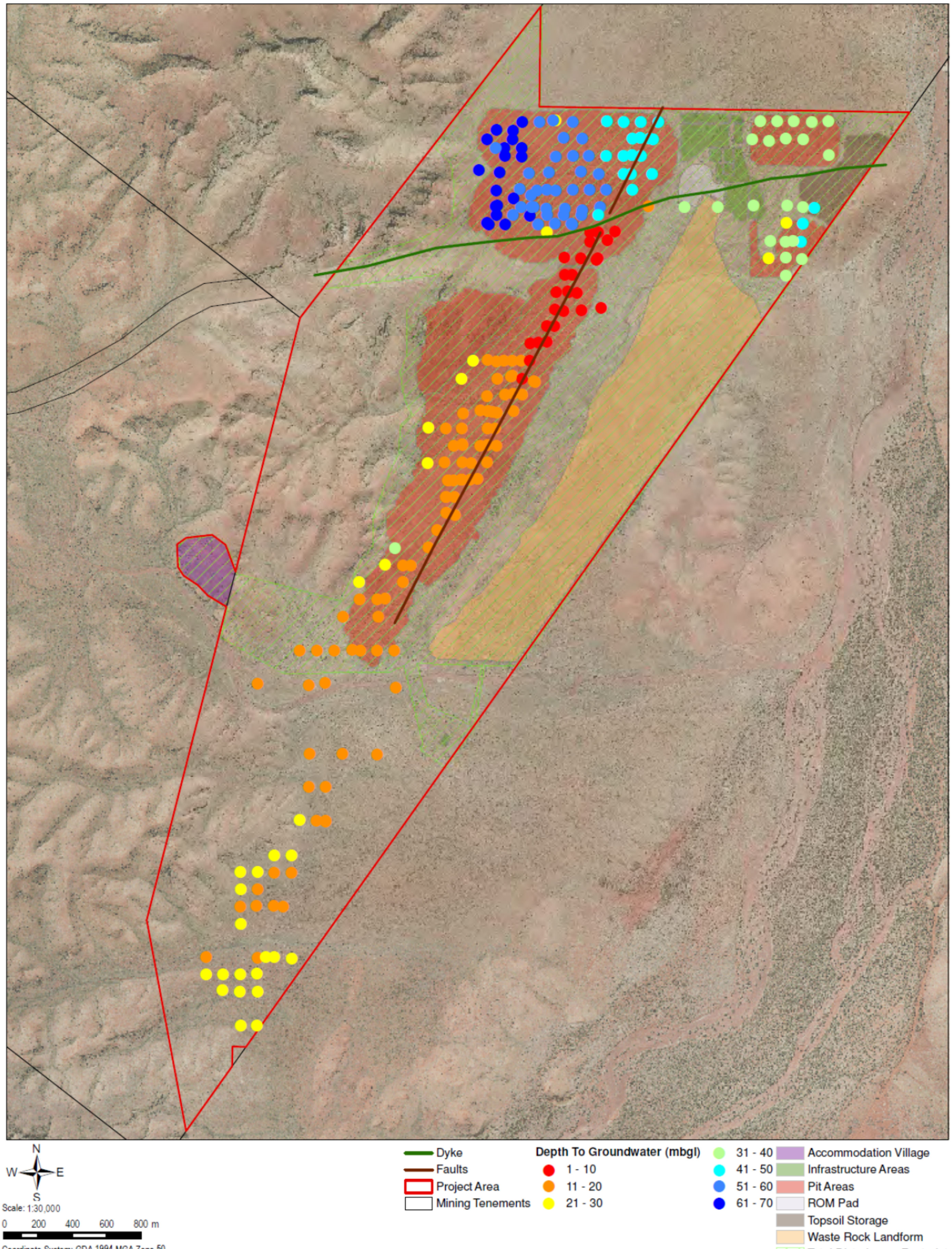
Table 2: Aquifer characteristics

Unit	Horizontal Hydraulic Conductivity (m/d)	Horizontal Hydraulic Conductivity (m/d)	Specific Yield (dimensionless)
Alluvium	20	2	0.01
Valley Fill	0.03	0.003	0.001
Ore body Fault	20	20	0.05
Mineralise BIF Ore body	1.6	0.16	0.05
Fresh Brockman Formation	0.001	0.0001	0.001
Weathered Brockman Formation	0.15	0.015	0.001
Fresh Weeli Wolli Formation	0.05	0.005	0.001
Weathered Weeli Wolli Formation	0.03	0.003	0.001
Dolerite dyke	1 x 10-5	1 x 10-5	0.0001

2.4.5 Conceptual Groundwater Understanding

The key aspects of the conceptual groundwater understanding for the Iron Valley site includes:

- A transmissive, mineralized ore body aquifer system capable of delivering high bore yields.
- Areas where saturated alluvium and detritals overly the main ore body aquifer and are in hydraulic contact with the main aquifer.
- Recharge to the two aquifers, from the Weeli Wolli Creek (especially to the north-east of the ore body) or from creeks that cross over the ore body.
- The ore body aquifer is surrounded by comparatively massive, low permeability shales and BIFs, which are not likely to be a source of significant aquifer storage.
- Groundwater flows are south to north, with the dyke acting as a low transmissivity barrier to groundwater flow.



Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010).

Mineral Resources	Figure 1: Static water levels across the Iron Valley Project (URS, 2013)	soilwater GROUP
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3 WATER SUPPLY PLAN

3.1 HISTORICAL PLAN

It was anticipated that the Project water requirements would be 360,000 kL/a, for dust suppression (200,000 kL/a) and the accommodation village requirements of 160,000 kL/a.

3.2 UPDATED WATER SUPPLY PROPOSAL /PLAN

Recently the site water balance has been re-evaluated and MRL are proposing to apply for an amended license of 720,000 kL/a to cover the expected water use. The amended license is for a period of 2 years, after which an expected change to mining below the water table will result in a further application for an increase in abstraction, to cover mine dewatering. The water supply is to be sourced from the two existing production bores (PB1 and PB2). The increased abstraction equates to an increase in the abstraction rates from the two pumping bores from an average rate of 5.7 L/s per bore, to 11.4 L/s per bore.

3.2.1 PRODUCTION BORE DETAILS

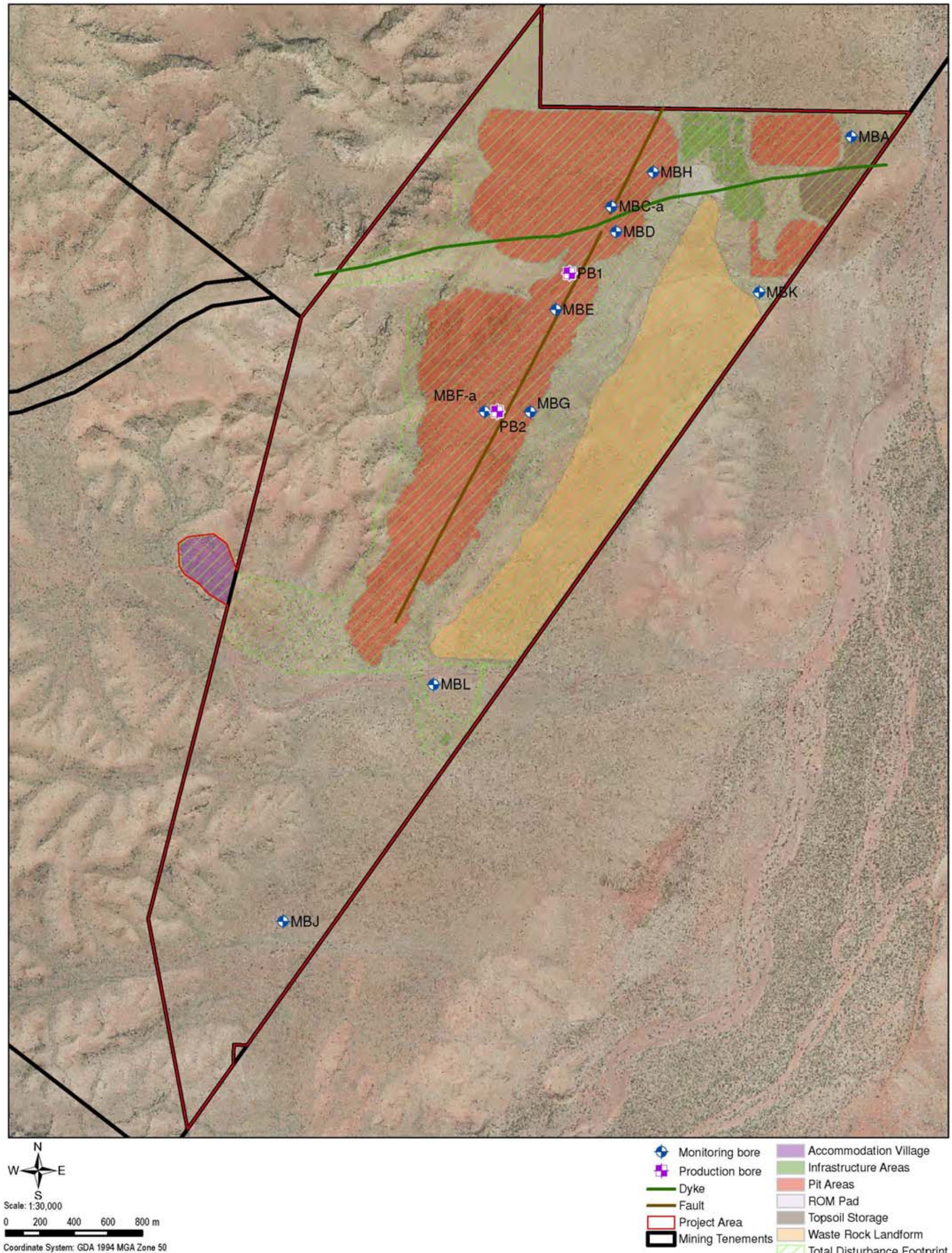
The production bores (details in Table 3) were constructed using 255mm (ID) diameter slotted casing. The boreholes are designed to water abstract from the Brockman Iron Formation. Production bore yields were measured up to 80 L/s during development by airlifting. Bore logs are provided in Appendix B, whilst a map showing the location of the two production bores is provided in Figure 2.

Table 3: Production Bore Details

Bore	Easting (m)	Northing (m)	Total Depth (mbgl)	Top of Screen (mbgl)	Bottom of Screen (mbgl)	TDS (mg/L)	EC (µS/cm)	pH	SWL (mbgl)
PB1	738127	7485007	142.5	58.0	142.5	-	-	-	6.15
PB2	737704	7484194	170.0	58.5	154.5	430	860	7.98	11.35

3.2.2 CURRENT ABSTRACTION

Abstraction rates since the start of mining (see Table 4) have been slowly increasing and are now close to the increased rates required.



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Whilst every care is taken by URS to ensure the accuracy of the digital data, URS makes no representation or warranties about its accuracy, reliability, completeness, suitability for any particular purpose and disclaims all responsibility and liability (including without limitation, liability in negligence) for any expenses, losses, damages (including indirect or consequential damage) and costs which may be incurred as a result of data being inaccurate in any way for any reason. Electronic files are provided for information only. The data in these files is not controlled or subject to automatic updates for users outside of URS.

Mineral Resources Limited	Figure 2: Production and monitoring bores for the Iron Valley Project	soilwater GROUP
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Table 4: Water Supply Abstraction rates

Month	Water Abstraction (kL/month)		Water Abstraction (L/s)	
	PB1	PB2	PB1	PB2
01/09/2013	4,060	-	2	0
01/10/2013	23,799	-	9	0
01/11/2013	24,319	-	9	0
01/12/2013	23,578	-	9	0
01/01/2014	22,836	-	9	0
01/02/2014	24,986	-	10	0
01/03/2014	27,346	12,847	11	5
01/04/2014	26,609	15,280	10	6
01/05/2014	11,375	16,240	4	6
01/06/2014	12,050	15,312	5	6
01/07/2014	16,325	19,185	6	7
01/08/2014	9,475	21,048	4	8
01/09/2014	28,416	24,910	11	10
01/10/2014	27,913	26,014	11	10
01/11/2014	26,224	29,535	10	11
01/12/2015	38,718	30,197	15	12

4 IMPACTS RELATED TO PROPOSED ABSTRACTION

4.1 IMPACTS PREDICTED HISTORICALLY

The preliminary groundwater flow model developed for the area (URS, 2011c) was used to predict abstraction of 360,000k L/a for a period of seven years. Drawdown was predicted based on the pumping of 1,000 kL/day from a virtual production bore located approximately mid-way between production bores PB01 and PB02. The predicted drawdown preferentially propagates along the main north-south fault and throughout the ore body aquifer to the south of the dolerite dyke (Figure 2). The greatest drawdown predicted is 8 m south of the dolerite dyke in the ore body aquifer. North of the dyke, drawdown is less than 2 m, while drawdown towards the east, does not reach the alluvium of the Weeli Wolli Creek.

4.2 IMPACTS MONITORED SINCE PUMPING STARTED

Pumping from the two production bores started in September 2013 (PB1) and January 2014 (PB2). Regular water level monitoring started in February 2014. Review of data since February 2014, suggests that water levels have dropped slightly (under 3 m). The drawdown data does not show a clear distance – drawdown relationship, with some bores that are further away from the productions bores having a greater drawdown than bores that are closer to the pumping. This suggests a heterogeneous aquifer, with variable permeability both vertically and horizontally. Mineral Resources have confirmed that pumping is only taking place from bores PB1 and PB2. As a result, the larger drawdown in the monitoring bores further away from the production bores, are expected to be related to natural conditions. It is noteworthy that the bores with the greatest drawdowns are all adjacent to creeks where recharge would have taken place during the larger recharge events in December 2013 and January 2014. Part of the drop in water levels at these locations may therefore be associated with a recession in water levels, post recharge.

The graphs of water level drawdown since pumping started are provided in Appendix A and have been used to calculate the aquifer permeability resulting from the pumping undertaken over the last year, using the formula:

$$T = 2.3\ Q/(4\pi\Delta S)$$

Where,

T = aquifer transmissivity

Q = daily pumping rate (m^3/day)

ΔS = the drawdown per log cycle

Table 5 shows the actual measured decrease in water levels at each bore (Appendix A for individual bore graphs), as well as the calculated T and k values. Monitoring bore locations are provided in Figure 2.

Table 5: Measured Drawdown and calculated Aquifer transmissivity (T) and hydraulic conductivity (k)

Monitoring Bore	Measured drawdown since the start of pumping	Calculated T	Calculated k[1]
MBA	2.04	17	0.17
MBC	2.41	17	0.17
MBD	1.961	92	0.92
MBE	0.76	71	0.71
MBF	0.87	76	0.76
MBG	0.74	72	0.72
MBH	0.72	17	0.17
MBJ	0.79	24	0.24
MBK	3.93	6	0.06
MBL	1.12	48	0.48

Note: [1] Based on an aquifer thickness of 100m.

These T and k values should be seen as bulk parameters for the whole aquifer system and are underestimates, as they are based on the measured abstraction rates from the closest production bore. As the drawdown will also be influenced by the pumping of the second production bore, T and k values would be slightly higher, probably in line with the k value in Table 1 for the mineralized ore body aquifer.

4.3 PREDICTION OF FUTURE IMPACTS

Prediction of drawdown impacts at each of the monitoring bores, for the increased water supply abstraction was undertaken, utilizing the T data derived from the abstraction over the last year and the calculated ΔS at the revised pumping rate. ΔS was calculated from:

$$\Delta S = (2.3\ Q)/T4\pi$$

Where,

T = aquifer transmissivity for each bore (as indicated in Table 5)

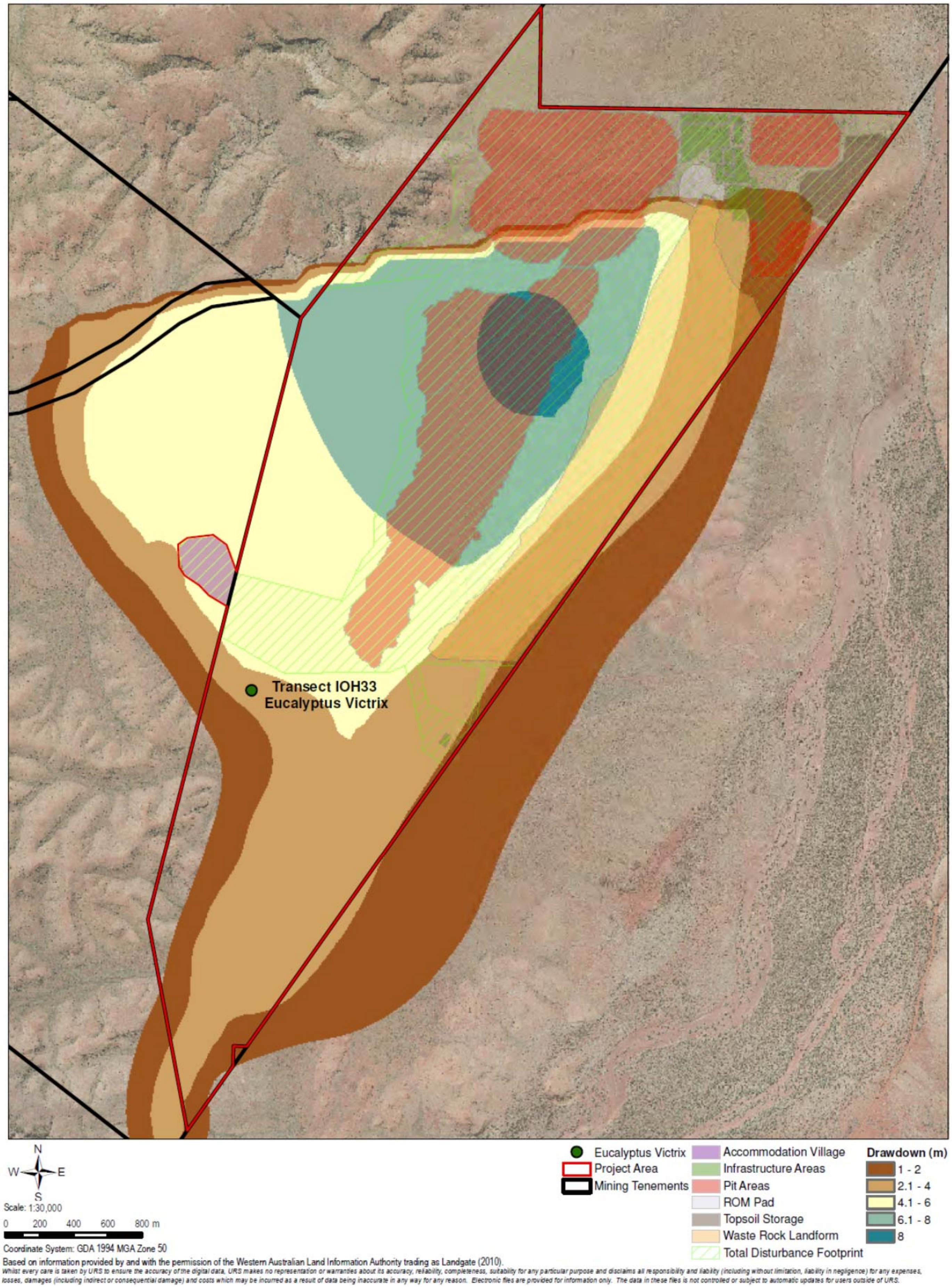
Q = daily pumping rate per bore, namely 28,500 m^3/day

The calculated ΔS (see Table 6) was then plotted against the actual drawdown data measured at each of the monitoring bores (Appendix A), to give an indication of the predicted change in water level at that bore. Mineral Resources application to pump 720,000 m^3/a, is for a period of 2 years, by which time an increased abstraction application is anticipated, as mining advances below the water table, thus requiring dewatering.

Table 6: ΔS and predicted total drawdown

Monitoring Bore	ΔS (Drawdown per log cycle - see Appendix A)	Predicted total drawdown at the bore, after 2 years of pumping at the increased rate (m)
MBA	10.1	6.4
MBC	10.1	6.6
MBD	1.9	2.1
MBE	2.4	1.6
MBF	2.3	1.8
MBG	2.4	1.3
MBH	10.1	4.2
MBJ	7.3	4.3
MBK	27.4	13.0
MBL	3.6	2.4

These calculated drawdowns do not take into account recharge from rainfall events, which would reduce the amount of drawdown.



Mineral Resources	Figure 3: Predicted drawdown at the Iron Valley Project (URS, 2013)	soilwater GROUP
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4.4 IMPACTS ON OTHER USERS

There are no other groundwater users in the area of predicted drawdown.

4.4.1 IMPACTS ON VEGETATION

No Threatened Ecological Communities, Priority Ecological Communities, Declared Rare Flora or Priority Flora were identified during the field surveys (URS, 2012). The vegetation types identified within the project area are known to exist broadly across the Pilbara region. One potentially groundwater dependent species has been identified in the project area, *Eucalyptus victrix* (Astron, 2013). Under Ministerial Statement (MS) 933 (Condition 6-1) groundwater dependent ecosystems (GDEs) are required to be managed such that no long-term impacts to the health and abundance of *E. victrix* outside the approved disturbance footprint occurs. *E. victrix* is classified as a facultative phreatophyte, meaning that it preferentially uses stored soil water and opportunistically uses groundwater during times of limited rainfall or drought-like conditions (Astron, 2012).

As required by Condition 6-2 of the MS 933 a targeted survey was undertaken by Astron (2013) to determine the spatial extent and health of *E. victrix* inside the expected area of groundwater drawdown. This survey identified a total of 147 individual *E. victrix* trees within the predicted zone of groundwater drawdown. All identified *E. victrix* trees were located along a small drainage line that traversed the Project Area, west to east, immediately to the south of the disturbance area. As part of the impact assessment undertaken by Astron (2013) a total of 57 trees were assessed and the location of these trees is shown in Figure 4.

The depth to groundwater along the drainage line, where the *E. victrix* occurs, is likely to be 9–10 m below ground level (bgl), as identified at Bore MBL (Figure 4). In order to establish the degree of likely groundwater dependence, a Phreatophytic Class Matrix (PCM) was established whereby the dependence on groundwater was determined for a range of likely transpiration rates and soil textures (or plant available water contents – PAWC). It is important to understand that the actual availability of either soil or groundwater, and the preferential extraction of either, is based on its total matric potential which is defined by:

$$\psi_T = \psi_M + \psi_G + \psi_O$$

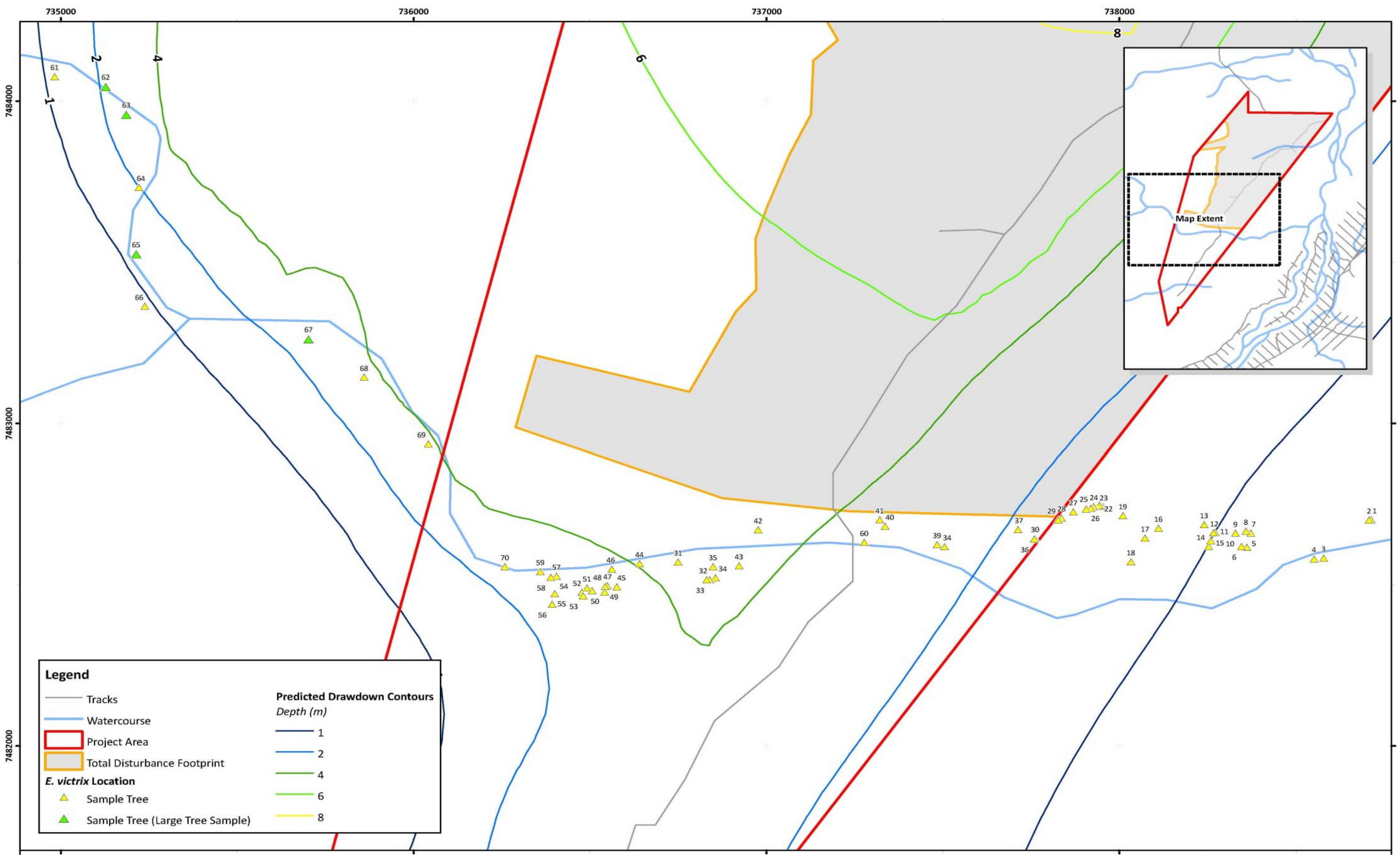
Where,

ψ_T = total matric potential.

ψ_M = matric potential – relates the suction in which water is held in the soil pores and is ultimately a function of soil moisture content, such that as soil dries water is held in increasingly smaller pores which exerts a greater suction on the water.

ψ_G = gravitational potential – relates to the depth below the soil surface, such that groundwater or more specifically capillary fringe water at 15 m depth has a gravitational potential of -15 m kPa which is equivalent to the permanent wilting point (PWP).

ψ_O = osmotic potential – can be ignored given the non-saline nature of the soils and groundwater.



MINERAL RESOURCES LIMITED	Figure 4: Location of *E. victrix* in relation to the proposed mine operation and groundwater drawdowns	soilwater GROUP
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Based on the above understanding, and given that the depth to groundwater is at 9–10 m below the soil surface, *E. victrix* will preferentially use moisture stored within the soil profile until it has dried to approximately 1,000 kPa (equivalent to 10 m) matric suction, after which it requires less energy to extract the 'more free' (i.e. lower matric suction) groundwater (or more specifically capillary fringe water) at 10 m depth.

The developed PCM for the *E. victrix* is provided in Table 7. It is uncertain what the transpiration rate for *E. victrix* is; hence a range from 500–700 mm/yr was chosen, which from experience covers the majority of tree species within the arid Pilbara and Goldfields region (this is in contrast to > 1,000 mm/yr for trees in the southwest whereby water availability is non-limiting). From the PCM it can be seen that if the *E. victrix* transpires only 500 mm/yr, and the soil has a modest 7% PAWC (i.e. 0.07 m^3/m^3), then it only has to access 7.14 m of the soil profile to be non-phreatophytic (i.e. Class 4 GDE). If on the other hand the *E. victrix* transpires 700 mm/yr then it would need to root to a depth of 10 m to be considered non-phreatophytic, and if roots were restricted to 8 m depth (i.e. by groundwater) then it would be 80% reliant on soil moisture and 20% reliant on groundwater.

To be conservative, if it is assumed that the *E. victrix* transpires 700 mm/yr, and that the PAWC of the soils along the drainage line range varies from 6–8% (i.e. 0.06 – 0.08 m^3/m^3), then this species is expected to be classified as a Class 3 GDE from the PCM, which implies that 80% of its water requirements are met by the soil, and it is only 20% reliant on groundwater. If the soil properties were such that the overall PAWC was ≥ 8% then it is likely that the *E. victrix* is actually non-phreatophytic (i.e. Class 4).

Table 7: Developed Phreatophytic Class Matrix (PCM) for the *E. victrix* at Iron Valley

Phreatophytic Class		Required rooting depth or Depth to groundwater (in meters)								
Soil	PAWC	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10
	Soil type		Sand			Clay		Sandy Loam – Sandy Clay		
Transpiration Rate = 500 mm										
Class 1	20% Soil 80% Groundwater	5.00	3.33	2.50	2.00	1.67	1.43	1.25	1.11	1.00
Class 2	50% Soil 50% Groundwater	12.50	8.33	6.25	5.00	4.17	3.57	3.13	2.78	2.50
Class 3	80% Soil 20% Groundwater	20.00	13.33	10.00	8.00	6.67	5.71	5.00	4.44	4.00
Class 4	100% Soil	25.00	16.67	12.50	10.00	8.33	7.14	6.25	5.56	5.00
Transpiration Rate = 600 mm										
Class 1	20% Soil 80% Groundwater	6.00	4.00	3.00	2.40	2.00	1.71	1.50	1.33	1.20
Class 2	50% Soil 50% Groundwater	15.00	10.00	7.50	6.00	5.00	4.29	3.75	3.33	3.00
Class 3	80% Soil 20% Groundwater	24.00	16.00	12.00	9.60	8.00	6.86	6.00	5.33	4.80
Class 4	100% Soil	30.00	20.00	15.00	12.00	10.00	8.57	7.50	6.67	6.00
Transpiration Rate = 700 mm										

Class 1	20% Soil 80% Groundwater	7.00	4.67	3.50	2.80	2.33	2.00	1.75	1.56	1.40
Class 2	50% Soil 50% Groundwater	17.50	11.67	8.75	7.00	5.83	5.00	4.38	3.89	3.50
Class 3	80% Soil 20% Groundwater	28.00	18.67	14.00	11.20	9.33	8.00	7.00	6.22	5.60
Class 4	100% Soil	35.00	23.33	17.50	14.00	11.57	10.00	8.75	7.78	7.00

When considering potential impacts on the GDE, the higher the GDE Class (i.e. less reliance on groundwater) the lower the potential impact or the more resilient the vegetation is to changes in groundwater level. Based on this, Froend Bowen and Associates (2004) developed a response curve/impact assessment tool to predict likely effects on terrestrial vegetation in response to changing water table levels (Figure 5).

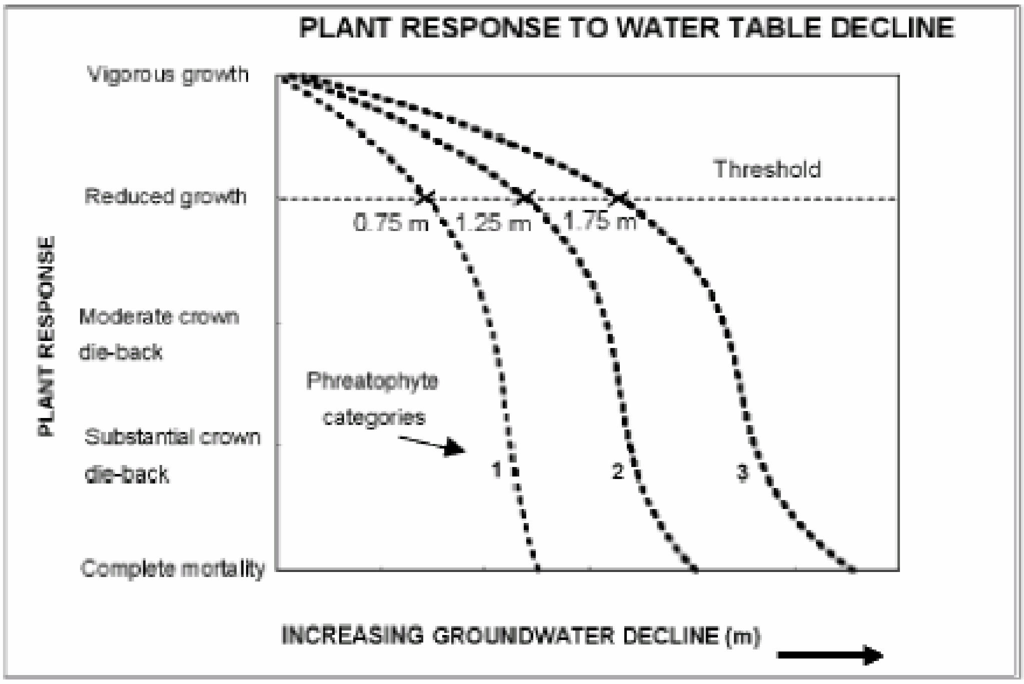
Using the response curve/impact assessment figure shown in Figure 5, it can be seen that for a Class 3 GDE (which E. victrix has been classified) can tolerate a drawdown of 1.75 to 3 m before visible signs if impact are exhibited (i.e. crown die-back).

As predicted in Section 4.3, a drawdown of 2.4 m is expected, over a 2 year period, under the E. victrix in response to increased groundwater abstraction. This is within the expected tolerable range for a Class 3 GDE, and therefore negligible impact on these trees is expected as a result of the proposed activity.

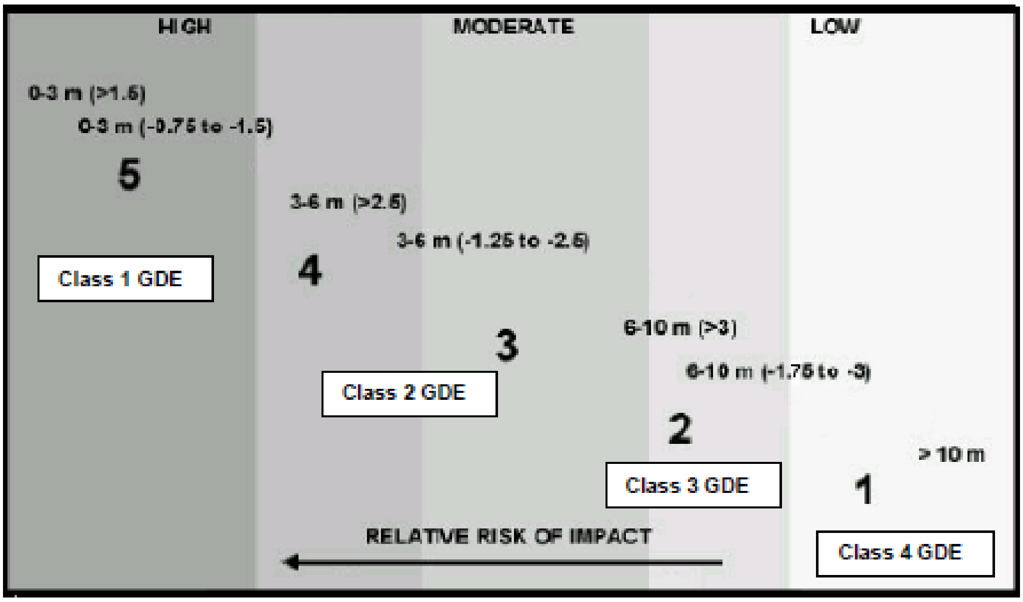
4.4.2 Impacts on Stygofauna / trogolofauna

The predicted drawdowns shown in Section 4.3 (Table 6) represents < 10% of the total aquifer thickness and therefore there is still adequate stygofauna habitat available following drawdown. Consequently, no impact on stygofauna is expected. Similarly, no impact on troglofauna is expected to occur as although groundwater levels, and associated capillary fringe, decrease in response to groundwater abstraction, no change in soil humidity (i.e. key habitat factor) will occur; hence troglofauna habitat remains unchanged during the proposed activity.

a)



b)



Predicted groundwater drawdown levels for each GDE Class shown in Brackets.
Figure adapted from Froend Bowen and Associates (2004).

Mineral Resources Limited	Figure 5: Response curve/impact assess classes developed by Froend Bowen and Associates (2004) for terrestrial vegetation	soilwater GROUP
Increase in Groundwater Abstraction at Iron Valley – Impact Assessment		

4.5 MANAGEMENT OF POTENTIAL IMPACTS

The potential for environmental impacts associated with groundwater abstraction will be managed by:

- Limiting groundwater usage to potable supply and dust suppression.
- Restricting groundwater abstraction to demand.
- Preferentially using stormwater runoff, where appropriate, for dust suppression to reduce demand.
- Ongoing monitoring.

Groundwater abstraction will be undertaken in accordance with the licence terms and conditions set out in the revised Operating Strategy for this proposed activity. The overarching environmental management objectives for the site that are of relevance for groundwater abstraction include:

- Maintain the quality and quantity of water so that existing and potential uses, including ecosystem maintenance, are protected.
- Ensure that alterations to groundwater flow and quality do not have an adverse impact on beneficial or environmental uses of the water and that the integrity, function and environmental values of the watercourses are maintained.

The management objectives in relation to groundwater abstraction include:

- Limit abstraction to demand.
- Comply with monitoring requirements as stated in this Operating Strategy.
- Ensure groundwater drawdown does not cause long-terms impacts to the health and abundance of *Eucalyptus victrix* outside the approved disturbance footprint

4.6 MONITORING PLAN

Monitoring of groundwater usage and potential impacts on *E. victrix* are managed by the following documents:

- Groundwater Operating Strategy (GOS) – this sets out the monitoring requirements for groundwater levels and water quality (i.e. bores to monitor, frequency of monitoring and parameters to assess).
- GDE Survey Methodology developed by Astron (2013) – this applies a Before-After, Control-Impact (BACI) approach and sets out what trees to monitor, the parameters to monitor and how to utilize this data to establish impact.

5 CONCLUSIONS

Based on this hydrogeological assessment and prediction of expected dewatering following an increase in abstraction from 360,000 kL/a to 720,000 kL/a, groundwater drawdowns in the monitoring network at Iron Valley are likely to be <5 m after 2 years. Groundwater responses in monitoring bores adjacent to drainage lines will experience greater fluctuation (i.e. up to 13 m), but this is likely due to preferential recharge following major storm events.

Groundwater levels under the drainage line where *E. victrix* occurs, is expected to only be 2.4 m after 2 years. Although this species has been identified as groundwater dependent, it is likely that it is a Class 3 Phreatophyte, whereby 80% of its annual transpiration requirements are met by moisture stored, and annually recharged, in the deep soil profile. This soil moisture is preferentially extracted over groundwater, due to its lower total water potential. Given its reliance primarily on soil moisture, *E. victrix* can likely tolerate drawdowns of up to 3 m before any visible signs of impact are expressed. Consequently, there is a low risk of impact on *E.victrix* in response to increasing groundwater abstraction to 720,000 kL/a.

6 REFERENCES

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URS, 2011a. *Final Report Iron Valley Iron Ore Project Phase 1 Pre-Feasibility Groundwater Assessment (Modelling)*, Ref 42907456/01/1, 4 August 2011.

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APPENDICES

APPENDIX A

ADDITIONAL WATER LEVEL DATA

	PB1			PB2			MBA				MBC			
Date	**Water Level form collar**	**Collar Height (m)**	**mBGL**	**Water Level form collar**	**Collar Height (m)**	**mBGL**	**Water Level form collar**	**Collar Height (m)**	**mBGL**	**Drawdown**	**Water Level form collar**	**Collar Height (m)**	**mBGL**	**Drawdown**
11/11/2011			6.6											
2/12/2011			6.3											
6/12/2011													30.8	
10/12/2011													31.4	
24/1/2012			6.1			11.7							36.3	
2/12/2012			6.2						29.6				35.6	
11/12/2012														
4/2/2012						11.4			29.6				36.5	
1/09/2013														
1/10/2013														
1/11/2013														
1/01/2014														
3/02/2014							26.7	0.5	26.1	0.0	39.4	0.4	39.0	0.0
16/03/2014							27.3	0.5	26.7	0.6	39.1	0.4	38.6	-0.4
11/04/2014							27.7	0.5	27.1	1.0	39.2	0.4	38.7	-0.3
18/05/2014							27.7	0.5	27.1	1.0	38.7	0.4	38.2	-0.7
28/06/2014							27.7	0.5	27.2	1.0	39.0	0.4	38.5	-0.5
27/07/2014							27.6	0.5	27.1	0.9	39.5	0.4	39.0	0.0
31/08/2014							27.7	0.5	27.2	1.1	39.2	0.4	38.8	-0.2
21/09/2014							27.5	0.5	27.0	0.8	39.3	0.4	38.9	-0.1
18/10/2014							27.8	0.5	27.3	1.1	40.2	0.4	39.7	0.7
22/11/2014							28.3	0.5	27.8	1.6	40.6	0.4	40.1	1.1
19/12/2014							28.6	0.5	28.0	1.9	40.9	0.4	40.4	1.4
19/1/2015							28.7	0.5	28.2	2.1	41.1	0.4	40.7	1.7

	MBD				MBE				MBF				MBG			
Date	**Water Level form collar**	**Collar Height (m)**	**mBGL**	**Drawdown**	**Water Level form collar**	**Collar Height (m)**	**mBGL**	**Drawdown**	**Water Level form collar**	**Collar Height (m)**	**mBGL**	**Drawdown**	**Water Level form collar**	**Collar Height (m)**	**mBGL**	**Drawdown**
11/11/2011							7.8									
2/12/2011			8.1				7.7									
6/12/2011																
10/12/2011											13.1				13.2	
24/1/2012			7.4				7.4								12.9	
2/12/2012			7.3				7.3				12.6				12.7	
11/12/2012											13.0					
4/2/2012			7.7				7.5				13.2				13.3	
1/09/2013																
1/10/2013																
1/11/2013																
1/01/2014																
3/02/2014	8.7	0.4	8.3	0.0	8.2	0.8	7.4	0.0	12.9	0.5	12.5	0.0	13.0	0.5	12.5	0.0
16/03/2014	8.9	0.4	8.5	0.2	7.9	0.8	7.2	-0.2	12.7	0.5	12.3	-0.2	12.9	0.5	12.4	-0.1
11/04/2014	8.9	0.4	8.5	0.1	7.9	0.8	7.1	-0.3	12.9	0.5	12.5	0.0	12.8	0.5	12.4	-0.2
18/05/2014	8.9	0.4	8.5	0.2	8.0	0.8	7.2	-0.2	13.6	0.5	13.1	0.7	11.8	0.5	11.3	-1.2
28/06/2014	9.2	0.4	8.8	0.5	8.0	0.8	7.3	-0.1	13.3	0.5	12.9	0.4	11.9	0.5	11.4	-1.2
27/07/2014	9.3	0.4	8.9	0.6	8.3	0.8	7.5	0.1	13.1	0.5	12.6	0.2	12.9	0.5	12.4	-0.2
31/08/2014	9.4	0.4	8.9	0.6	8.2	0.8	7.5	0.1	13.4	0.5	12.9	0.4	12.9	0.5	12.4	-0.2
21/09/2014	9.3	0.4	8.8	0.5	8.3	0.8	7.5	0.1	13.2	0.5	12.7	0.3	12.9	0.5	12.4	-0.1
18/10/2014	9.5	0.4	9.0	0.7	8.4	0.8	7.7	0.3	13.5	0.5	13.0	0.5	13.0	0.5	12.5	0.0
22/11/2014	9.6	0.4	9.2	0.8	8.5	0.8	7.8	0.4	13.6	0.5	13.2	0.7	13.1	0.5	12.6	0.0
19/12/2014	9.6	0.4	9.2	0.8	8.6	0.8	7.9	0.5	13.5	0.5	13.1	0.6	13.2	0.5	12.7	0.1
19/1/2015	9.7	0.4	9.2	0.9	8.7	0.8	7.9	0.5	13.6	0.5	13.1	0.7	13.6	0.5	13.1	0.6

	MBH				MBJ				MBK				MBL			
Date	**Water Level form collar**	**Collar Height (m)**	**mBGL**	**Drawdown**	**Water Level form collar**	**Collar Height (m)**	**mBGL**	**Drawdown**	**Water Level form collar**	**Collar Height (m)**	**mBGL**	**Drawdown**	**Water Level form collar**	**Collar Height (m)**	**mBGL**	**Drawdown**
11/11/2011																
2/12/2011																
6/12/2011																
10/12/2011																
24/1/2012																
2/12/2012			42.9				17.3				24.4				9.3	
11/12/2012																
4/2/2012							17.3				24.4				9.3	
1/09/2013																
1/10/2013																
1/11/2013																
1/01/2014																
3/02/2014	41.5	0.6	40.9	0.0	17.5	0.3	17.2	0.0	20.4	0.6	19.8	0.0	9.4	0.6	8.8	0.0
16/03/2014	40.7	0.6	40.2	-0.8	17.8	0.3	17.5	0.3	19.3	0.6	18.8	-1.0	9.2	0.6	8.6	-0.2
11/04/2014	40.7	0.6	40.1	-0.8	15.3	0.3	15.0	-2.2	19.5	0.6	19.0	-0.8	9.2	0.6	8.6	-0.1
18/05/2014	40.9	0.6	40.3	-0.6	Dry	0.3			20.9	0.6	20.3	0.5	8.3	0.6	7.7	-1.0
28/06/2014	40.9	0.6	40.3	-0.6	16.8	0.3	16.5	-0.7	20.8	0.6	20.2	0.4	9.6	0.6	9.0	0.3
27/07/2014	41.0	0.6	40.4	-0.5	18.0	0.3	17.7	0.5	19.9	0.6	19.4	-0.4	9.6	0.6	9.0	0.3
31/08/2014	40.9	0.6	40.3	-0.6	18.2	0.3	17.9	0.7	20.1	0.6	19.5	-0.3	9.8	0.6	9.2	0.4
21/09/2014	40.2	0.6	39.7	-1.3	9.8	0.3			20.0	0.6	19.5	-0.3	9.9	0.6	9.3	0.5
18/10/2014	40.7	0.6	40.1	-0.8	17.8	0.3	17.6	0.3	20.6	0.6	20.1	0.3	10.0	0.6	9.4	0.6
22/11/2014	41.1	0.6	40.6	-0.4	18.1	0.3	17.9	0.6	22.0	0.6	21.4	1.6	10.1	0.6	9.5	0.7
19/12/2014	41.3	0.6	40.7	-0.2	18.2	0.3	18.0	0.7	22.6	0.6	22.1	2.3	10.2	0.6	9.6	0.8
19/1/2015	41.4	0.6	40.9	-0.1	18.3	0.3	18.0	0.8	23.2	0.6	22.7	2.9	10.3	0.6	9.7	0.9

APPENDIX B

BORE LOGS

BORE COMPLETION REPORT

PB01

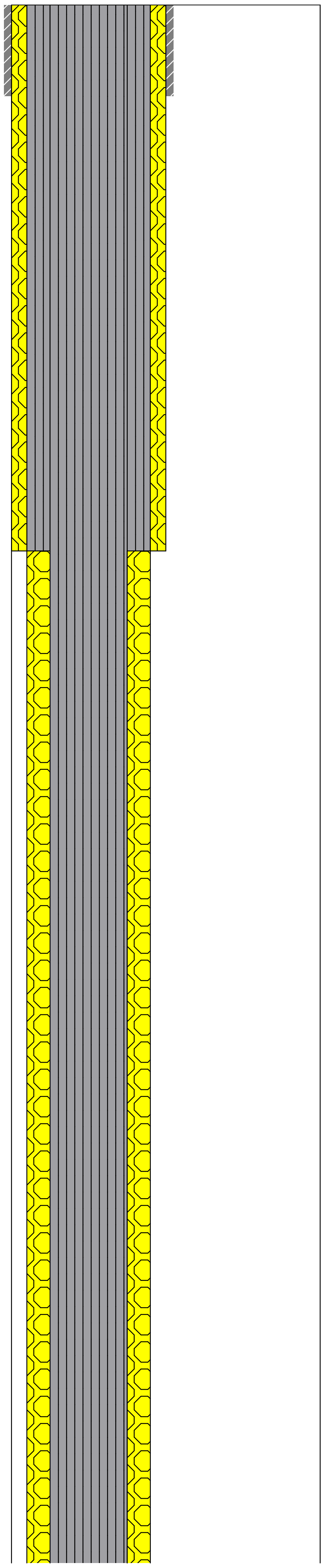
Grid System		Drilling Contractor:	Connector Drilling
Coordinates:	738127 mE 7485007 mN	Drilling Method:	Air Hammer
Ground Elevation:		Hole Diameter:	500 mm 0 - 24 mbgl
Logged By:	F.Carosone		375 mm 24 - 144 mbgl
Start Date:	08.11.2011 Compl. Date: 21.11.2011		
Purpose of Bore:	Production Bore	Total Depth:	144 mbgl
Static Water Level:		Casing - Blank:	0 - 58 mbgl
Water Level Date:		Casing - Slotted:	58 - 144 mbgl

Drilling Rig: IR T65

Geophysical Company:

DEPTH (mbgl) | STRATIGRAPHY | GRAPHIC LOG | LITHOLOGY | BORE CONSTRUCTION | GAMMA LOG (cps) 0–200 | RESISTIVITY (OHM-Metres) SHORT (16") LONG (64") 0–10 | CALIPER (mm) 0–300

Stratigraphy	Lithology
Alluvium	Red-brown alluvium, large chip size.
BIF	Red-brown-orange banded iron formation with dark grey flat chips. Water cut at about 8 m.
BIF	Grey-black banded iron formation with yellow/orange shale.
BIF	Dark grey-black banded iron formation chips with yellow-orange shale.
BIF	Grey-black banded iron formation with orange chips.
BIF and Shale	Light brown-orange banded iron formation with fine shale bands.
BIF and Shale	Dark grey-black banded iron formation with cream-brown-grey microbanded shale.
BIF	Dark grey-black banded iron formation with large microbanded chips.



BORE COMPLETION REPORT

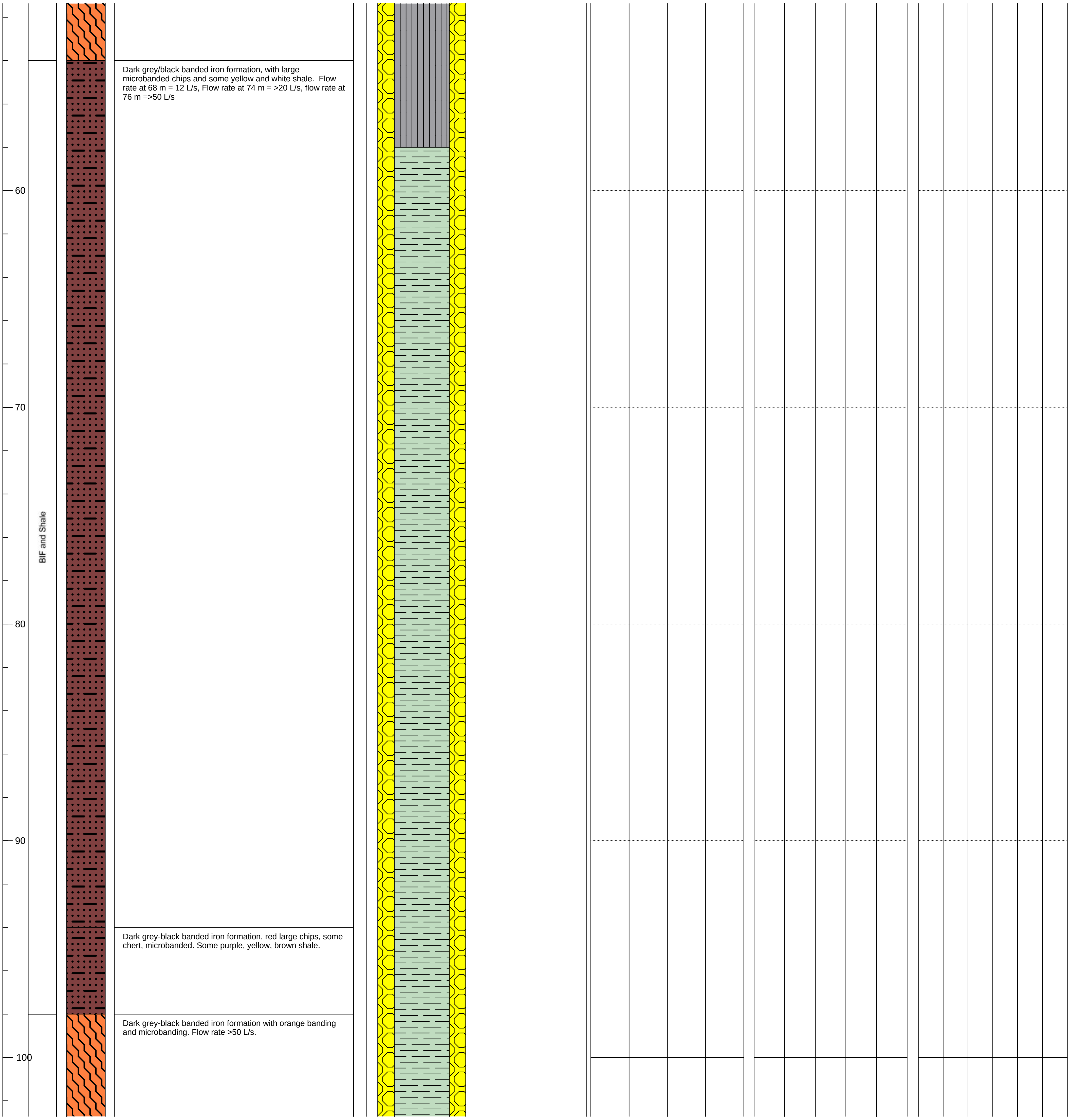
PB01

Grid System		Drilling Contractor:	Connector Drilling
Coordinates:	738127 mE 7485007 mN	Drilling Method:	Air Hammer
Ground Elevation:		Hole Diameter:	500 mm 0 - 24 mbgl
Logged By:	F.Carosone		375 mm 24 - 144 mbgl
Start Date:	08.11.2011 Compl. Date: 21.11.2011		
Purpose of Bore:	Production Bore	Total Depth:	144 mbgl
Static Water Level:		Casing - Blank:	0 - 58 mbgl
Water Level Date:		Casing - Slotted:	58 - 144 mbgl

Drilling Rig: IR T65

Geophysical Company:

DEPTH (mbgl)	STRATIGRAPHY	GRAPHIC LOG	LITHOLOGY	BORE CONSTRUCTION	GAMMA LOG (cps) 0 – 200	RESISTIVITY (OHM-Metres) SHORT (16") LONG (64") 0 – 10	CALIPER (mm) 0 – 300



Dark grey/black banded iron formation, with large microbanded chips and some yellow and white shale. Flow rate at 68 m = 12 L/s, Flow rate at 74 m = >20 L/s, flow rate at 76 m =>50 L/s

Dark grey-black banded iron formation, red large chips, some chert, microbanded. Some purple, yellow, brown shale.

Dark grey-black banded iron formation with orange banding and microbanding. Flow rate >50 L/s.

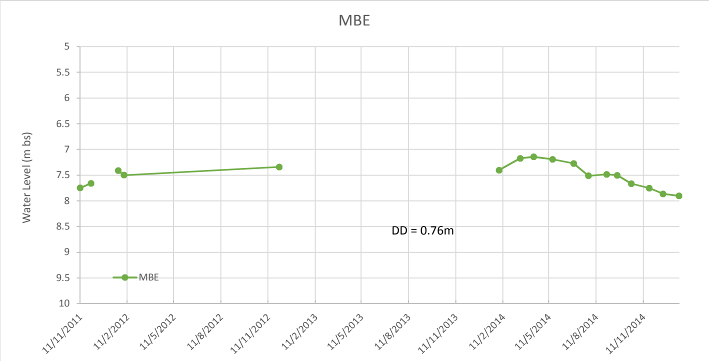
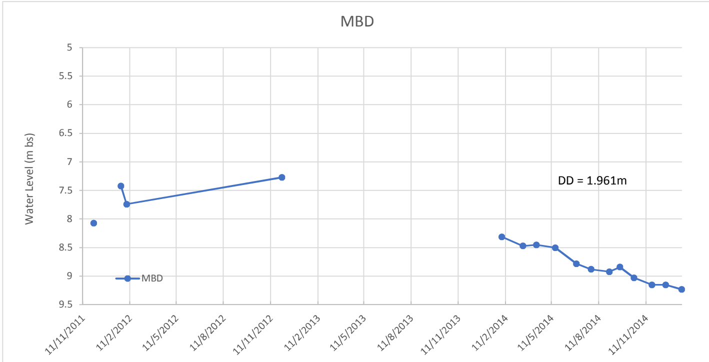
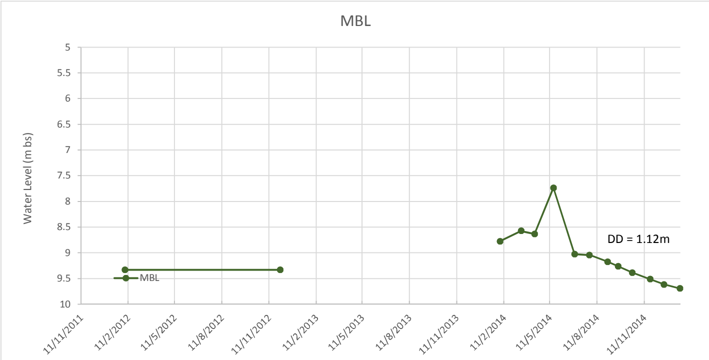
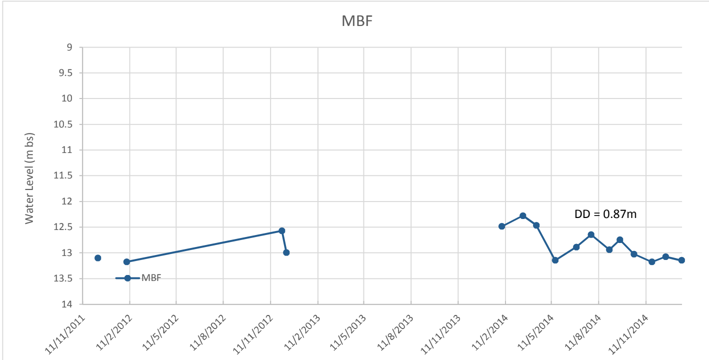
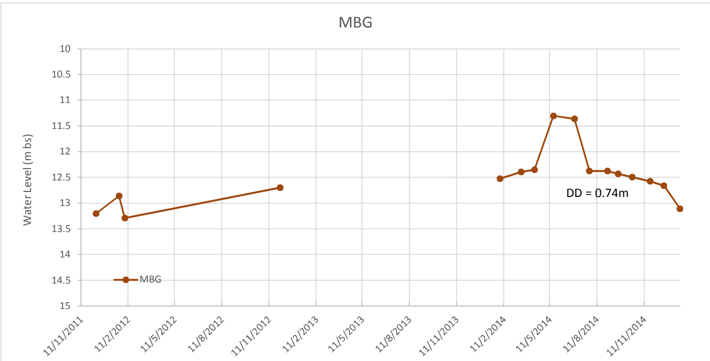
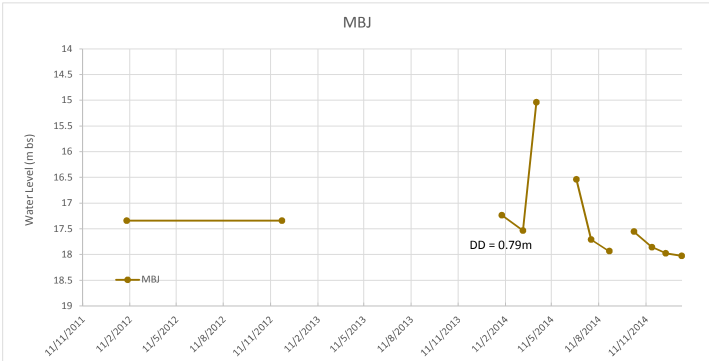
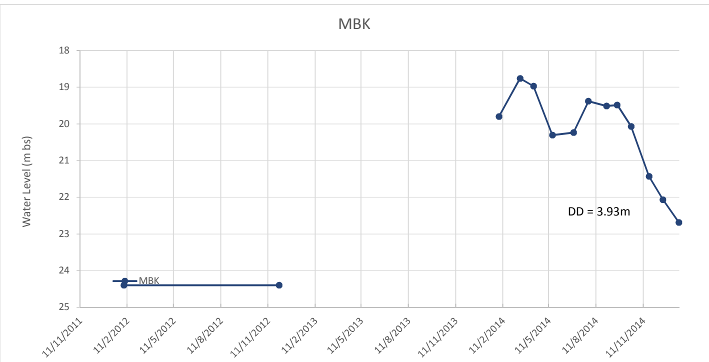
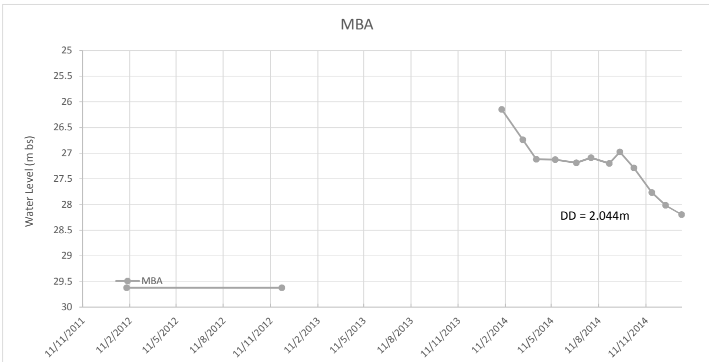
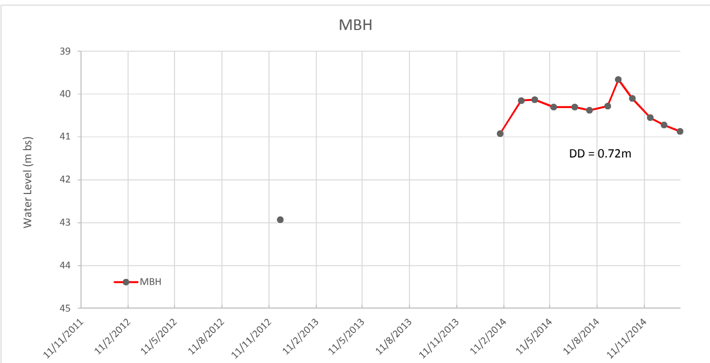
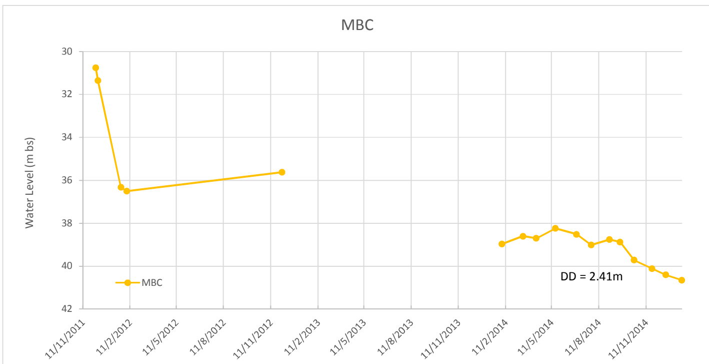
IRON ORE HOLDINGS LTD

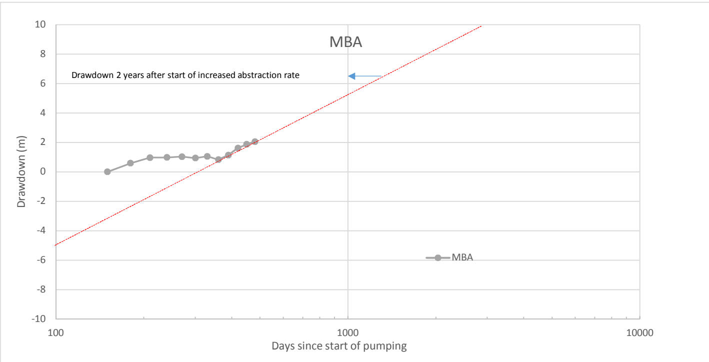
IRON VALLEY GROUNDWATER

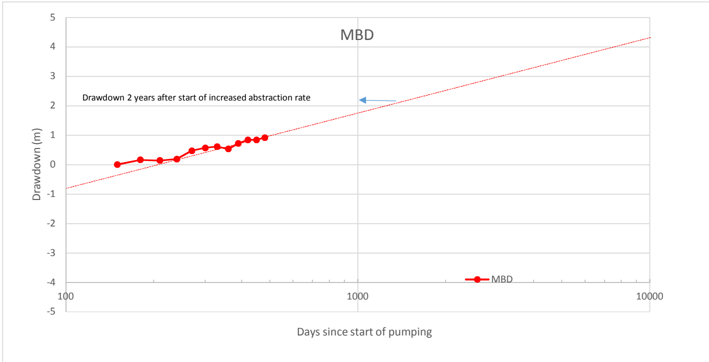
Draft

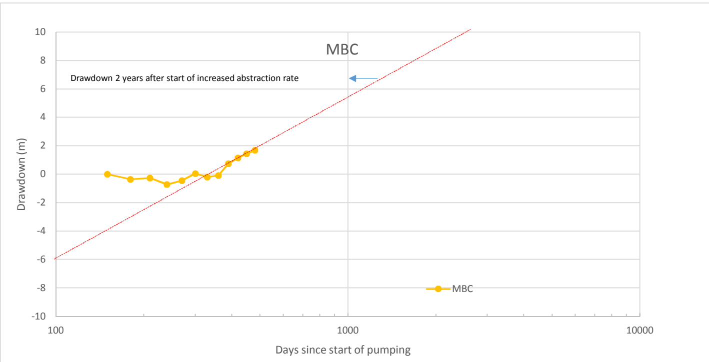
APPENDIX C

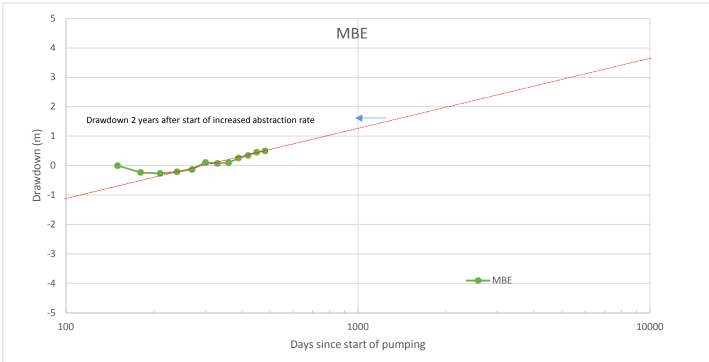
DELTA S FUTURE WATER LEVEL CURVES

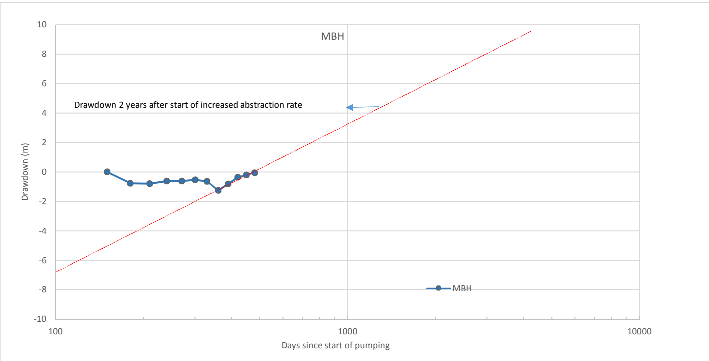

MBE
Water Level (m bs)
DD = 0.76m
MBE

MBD
Water Level (m bs)
DD = 1.961m
MBD

MBL
Water Level (m bs)
DD = 1.12m
MBL

MBF
Water Level (m bs)
DD = 0.87m
MBF

MBG
Water Level (m bs)
DD = 0.74m
MBG

MBJ
Water Level (m bs)
DD = 0.79m
MBJ

MBK
Water Level (m bs)
DD = 3.93m
MBK

MBA
Water Level (m bs)
DD = 2.044m
MBA

MBH
Water Level (m bs)
DD = 0.72m
MBH

MBC
Water Level (m bs)
DD = 2.41m
MBC

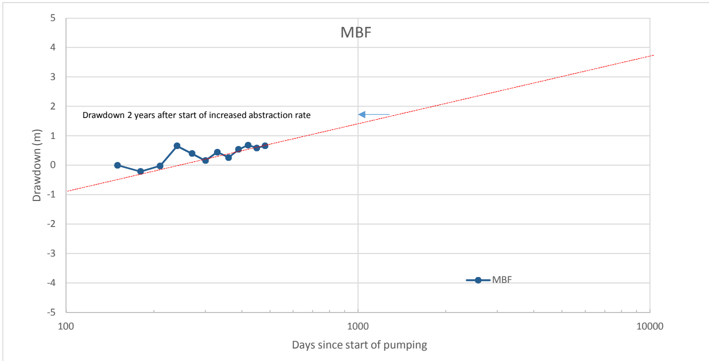

MBA
Drawdown 2 years after start of increased abstraction rate
Drawdown (m)
10
8
6
4
2
0
-2
-4
-6
-8
-10
100
1000
10000
Days since start of pumping
MBA

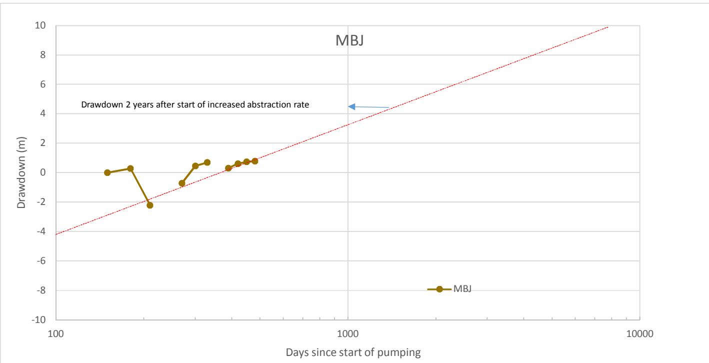

MBD
Drawdown 2 years after start of increased abstraction rate
Drawdown (m)
5
4
3
2
1
0
-1
-2
-3
-4
-5
100
1000
10000
Days since start of pumping
MBD

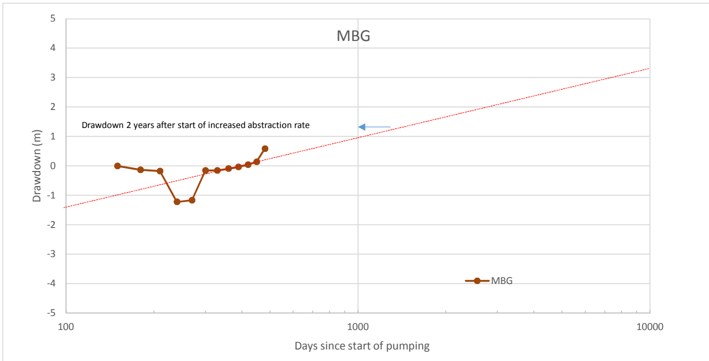

MBC
Drawdown 2 years after start of increased abstraction rate
Drawdown (m)
10
8
6
4
2
0
-2
-4
-6
-8
-10
100
1000
10000
Days since start of pumping
MBC

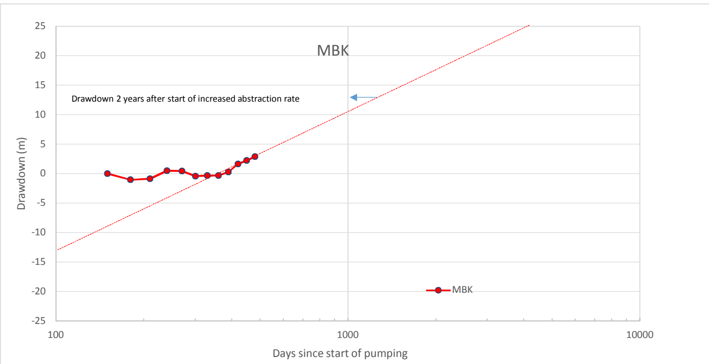

MBE
Drawdown 2 years after start of increased abstraction rate
Drawdown (m)
5
4
3
2
1
0
-1
-2
-3
-4
-5
100
1000
10000
Days since start of pumping
MBE

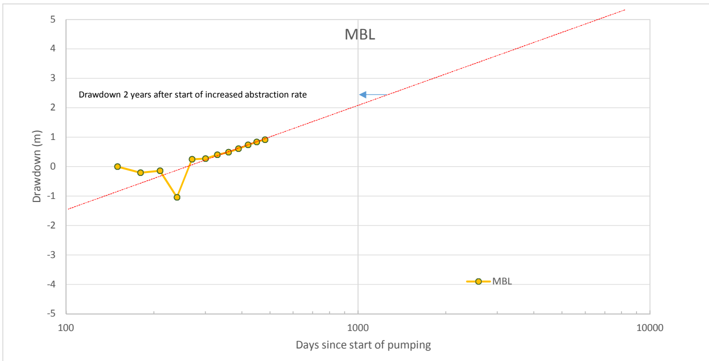

MBH
Drawdown 2 years after start of increased abstraction rate
Drawdown (m)
10
8
6
4
2
0
-2
-4
-6
-8
-10
100
1000
10000
Days since start of pumping
MBH


MBF
Drawdown 2 years after start of increased abstraction rate
Drawdown (m)
5
4
3
2
1
0
-1
-2
-3
-4
-5
100
1000
10000
Days since start of pumping
MBF


MBJ
Drawdown 2 years after start of increased abstraction rate
Drawdown (m)
10
8
6
4
2
0
-2
-4
-6
-8
-10
100
1000
10000
Days since start of pumping
MBJ


MBG
Drawdown 2 years after start of increased abstraction rate
Drawdown (m)
5
4
3
2
1
0
-1
-2
-3
-4
-5
100
1000
10000
Days since start of pumping
MBG


MBK
Drawdown 2 years after start of increased abstraction rate
Drawdown (m)
25
20
15
10
5
0
-5
-10
-15
-20
-25
100
1000
10000
Days since start of pumping
MBK


MBL
Drawdown 2 years after start of increased abstraction rate
Drawdown (m)
5
4
3
2
1
0
-1
-2
-3
-4
-5
100
1000
10000
Days since start of pumping
MBL