GROUNDWATER MANAGEMENT

IRON VALLEY – BELOW WATER TABLE MINE

Prepared for

BC IRON

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Executive Summary

The Iron Valley deposit is located in the central Pilbara, adjacent to the Weeli Wolli Creek and 30 km upstream of the Fortescue Marsh system. Both of these surface water systems are sensitive, requiring careful management of adjacent water resources. These surface water systems are linked to the adjacent groundwater systems, so any changes to the groundwater is likely to have an impact on the surface water. The orebody is a major aquifer and the management of groundwater inflow into the open pit mines and control of the cone of dewatering, will be an important part of any future approvals.

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

- Recent transported unconsolidated sediments and valley fill material.
- Channel Iron Deposit (CID).
- Weeli Wolli Formation.
- Brockman Iron Formation.

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

- A transmissive, mineralised orebody aquifer system capable of delivering high bore yields.
- Areas overlying the orebody aquifer where saturated alluvium will store water that will drain into the main aquifer.
- Connection of the orebody and overlying alluvium to the Weeli Wolli Creek in the south, via the East Fault. The fault will form a strong conduit for flow from the Weeli Wolli Creek to the mine site.
- Connection of the orebody aquifer, via an extension of the orebody aquifer to the north on the FMG tenement, to the Weeli Wolli Creek. Dewatering of the open pits could reverse natural flow gradients and induce inflow from the aquifers underlying the Weeli Wolli Creek in that area.
- The orebody aquifer is surrounded to the east and west by comparatively massive, low permeability shales and BIFs, which are not likely to be a source of significant aquifer storage.
- The dyke acts as a low transmissivity barrier to groundwater flow to the north.
- Prevailing groundwater conditions have been altered by historical and ongoing excess water disposal by BHPB and Rio Tinto to the southern areas of the Weeli Wolli Creek.

The development and calibration of a numerical model (taking into account data from historical studies and new data collected during fieldwork carried out in 2015) allowed predictions to be made of the dewatering required to keep the open pits dry during mining and the impacts that the pumping would have on regional groundwater levels. Predicted pumping rates, mine site usage and excess water disposal rates are shown in Table ES1.

The dewatering rates are relatively high, due to the strong connection of the orebody to the Weeli Wolli Creek. As the mine water demand is less than the required dewatering, there will be a water surplus that will need to be disposed. Review of all possible disposal options, has identified the disposal to the adjacent Weeli Wolli Creek as the most suitable option.

Table ES1: Water Balance Summary (Annual Average Rates in kL/d)

Year	Total Dewatering	Maximum Water Demand	Surplus Disposal to the Weeli Wolli Creek
2016	62,707	15,700	47,007
2017	63,175	15,700	47,475
2018	60,166	15,700	44,466
2019	58,129	15,700	42,429
2020	22,263	15,700	6,563
2021	31,695	15,700	15,995
2022	30,305	15,700	14,605
2023	30,369	15,700	14,669
2024	42,756	15,700	27,056
2025	38,340	15,700	22,640

Disposal to the Weeli Wolli Creek is the most practical option from a mining perspective, but also has environmental benefits. By disposing of water in an area between the mine site and the saline bedrock water of the Fortescue Valley, a groundwater mound is developed, which stops saline bedrock water being drawn in towards the areas of pumping. Over the life of the mine, the majority of the water pumped from the dewatering system, is derived from the Weeli Wolli Creek system. As a result, disposal back to the Weeli Wolli Creek is returning water back to the original source.

The elongated north south trending orebody aquifer and the associated East fault, together with low permeability material to the east and west of the aquifer, results in a cone of depression that is elongated north to south. Similarly, the aquifer strike also required the siting of ex-pit dewatering bores at the northern and southern ends of the open pits, together with a number of in-pit bores. Dewatering bore locations will have to be changed throughout the mine life, to accommodate the different pits and the proposed backfilling programme.

Once mining stops (10 year mine life), the water levels in the pits will recover relatively quickly (generally within 10 years), due to the East Fault connection to the Weelli Wolli Creek. Even though pit-infilling is planned, not all of the pits will be infilled to above the resutling groundwater levels. As a result, pit lakes will develop for the C1, C3, C5, N1, N2 and N3 pits. These pits are predicted to be throughflow lakes. As a result, saline lake conditions are not expected to develop.

During the mine life, dewatering will lower groundwater levels around the mine site and in parts of the Weeli Wolli Creek (in the south where the fault enters the Weeli Wolli Creek), which could influence the existing GDE populations. Similarly, there are areas where the disposal will raise water levels in the Weeli Wolli Creek to surface, resulting in surface water flow taking place over a distance of 6 km from the discharge locations. Should Rio Tinto proceed with the development of their Pocket and Billiard Mine, their excess water disposal will override the predicted drawdown in the Weeli Wolli Creek from Iron Valley dewatering, resulting in surface water flow that would extend to approximately 23 km downstream from the Weeli Wolli / Marillana Creek confluence.

After the Iron Valley mining ends, water levels will recovery relatively quickly at the mine site to the equilibrium level (within 10 years), but will not recover to the same pre-mining water levels. The removal of the dyke barrier during mining, together with evaporation from the pit lakes that develop post-mining, results in water levels to the south of the dyke being deeper than before mining, while water levels to the north of the dyke recover to shallower levels than before mining started. Water levels in the Weeli Wolli Creek system recover within 2 years, without Rio Tinto's discharge. Should the Pocket and Billiard Mine proceed, the disposal will last for a further 6 years post the end of the Iron Valley mine, continuing to generate surface flow along the Weeli Wolli Creek.

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1 Background

1.1 Iron Valley Project

BC Iron (BCI) have already assessed the option of mining the existing orebody located above the water table and have received Ministerial approval to proceed. BCI would now like to assess the option of mining below the water table.

The Iron Valley deposit is located in the central Pilbara, adjacent to the Weeli Wolli Creek and 30 km upstream of the Fortescue Marsh system (Figure 1.1). Both of these surface water systems are sensitive, requiring careful management of adjacent water resources. These surface water systems are linked to the adjacent groundwater systems, so any changes to the groundwater is likely to have an impact on the surface water. With the orebody known to be a major aquifer, the management of groundwater inflow into the open pit mines and control of the cone of dewatering, will be an important part of any future approvals.

1.2 Key Issues

The key issues related to assessing the hydrogeology and hydrology and in gaining approval to mine below the water table are:

- Whether or not the orebody aquifer extends north and south beyond the proposed pits (this will effect the extent of the drawdown and long term pumping requirements for dewatering or water supply).
- Connection of a potentially extended orebody aquifer, to the Weeli Wolli Creek to the north and south of the pits, and the associated recharge to the pits from stream flow events.
- Management of groundwater inflow into the open pits, with specific concerns related to the linkage between a potential northern extension of the orebody aquifer and the sediments linked to the Weeli Wolli Creek.
- Disposing of the excess water from mine dewatering.
- Potential dewatering impacts on the adjacent Weeli Wolli Creek.
- Changes to the salt water aquifer system associated with the Fortescue Marsh.
- Potential impacts of dewatering on groundwater dependent ecosystems (GDEs) including vegetation and stygofauna.
- The contribution of the mine to cumulative impacts on the Weeli Wolli Creek system.
- Diversion of intercepted upstream surface water flow paths.
- Management of stormwater runoff generated on the mine site.
- Water resources management after mine closure.

1.3 Study objectives

The study would be aimed at:

- Confirming the prevailing surface and groundwater conditions.

- Identifying the potential impacts that would be associated with the proposed below water table mining, including dewatering, surface water control and excess water disposal.
- Commenting on the contribution of the mine development to cumulative impacts on the Weeli Wolli Creek system.
- Reporting on measures to mitigate the impacts identified.

1.4 Study Tasks

Overall, the study tasks have been split into:

- Surface water management assessment.
- Groundwater fieldwork to provide data that will be used to update to the current understanding.
- Groundwater model development and modelling of inflows, drawdown and changes to the groundwater system.
- Excess water assessment (volume and disposal options).
- Additional modelling of water management options – to reduce impacts (during and after mining).
- Consideration of the water aspects of mine closure and in particular assessing the implications of adopted closure strategies (e.g. backfilling or not backfilling mine-voids).
- Reporting.

2 Surface Water Assessment

The surface water assessment of this study was undertaken by the Soil Water Group (SWG), under contract to AQ2. The SWG have historical experience at Iron Valley, having completed the Surface Water Management study as part of the above water table mining submissions.

2.1 Introduction

The change from above water table (AWT) mining to below water table (BWT) mining will result in a change to the mine layout and infrastructure and thus requires an updated assessment of the surface water management required and the volume of stormwater generated from the active mine site. A surface water assessment has already been completed for the AWT mining option (URS, 2012), and the SWG have finalised the surface water management measures for the current AWT mining operations, which are currently being implemented on site. The BWT mine essentially requires larger pit footprints and waste dumps within the same tenement boundary.

Based on the assumption that the BWT mine remains within the same tenement boundary as the AWT mine, it is not anticipated that the natural surface water hydrology or the main creek flood hydraulics need to be remodelled in order to adequately assess the potential impacts and required management actions resulting from implementation of the BWT option. As such, this updated Surface Water Assessment utilises the modelling work previously undertaken (URS, 2012), but reassesses the level of surface water interaction and required management within each of the localised site areas proposed to be impacted by implementation of the BWT mining option – no further hydrological modelling was conducted.

2.2 Baseline Surface Water Assessment

The regional and local baseline hydrology at the Iron Valley Project (IVP) has been previously assessed by URS (2012) and SWG (2014, 2015). These baseline studies are summarised in the following sections (2.2.1-2.2.5) to provide context for the assessment of potential impacts and consideration of engineering control measures described for the BWT option in Sections 2.3 and 2.4.

2.2.1 Regional Hydrology

The Iron Valley Project (IVP) is located within the Upper Fortescue River surface water catchment (Figure 2.1). The Upper Fortescue River catchment encompasses an area of approximately 41,880 km^2, and is generally internally draining with all surface water directed toward the Fortescue Marsh. Surface water flows in the Upper Fortescue River catchment (and the Pilbara region in general) are typically ephemeral, being directly related to intense rainfall events, and often associated with cyclonic activity or localised thunderstorms. Flows decay rapidly once rainfall has ceased. The majority of the drainage system upstream of the Fortescue Marsh has negligible baseflow, with stream flows infiltrating the watercourses and recharging the alluvial aquifers during flow events. During rare extreme rainfall events, surface water may overflow the Upper Fortescue River catchment into the Lower Fortescue River catchment through a narrow valley located at the north-eastern end of the catchment.

The Fortescue Marsh is listed in the *Australian Directory of Important Wetlands* (DOE, 2000) as a “Nationally important” wetland as it is a “unique wetland landform in WA”, consisting of “a vast and rarely visited wetland, set between rugged ranges”. The Fortescue Marsh is also a breeding area for Pelicans and Black Swans. No threatened flora or fauna species have been identified within the Fortescue Marsh area.

The Weeli Wolli Creek system, located south of the Fortescue Marsh, drains the Hamersley and Hancock Ranges, which includes the IVP area. The majority of water in the Weeli Wolli Creek system flows northwards into the Fortescue Marsh. The Weeli Wolli Creek has a catchment area of approximately 4,000 km^2, with an approximate main stream length of 112 km from the upper catchment to the outfall. The Weeli Wolli Creek is the second largest contributor to the Fortescue Marsh, and it is estimated that it contributes approximately 11% of total inflows to the Fortescue Marsh. The Weeli Wolli Creek is currently gauged by the Department of Water (DoW) at two locations, Waterloo Bore and Tarina (Site No. 708013 and 708014, respectively), as shown on Figure 2.2.

The IVP is located within the Iron Valley catchment, a small tributary of the Weeli Wolli Creek, which comprises approximately 63 km^2 or <0.2% of the total catchment area of the Fortescue Marsh. There are no permanent gauging stations located within the Iron Valley catchment.

2.2.2 Baseline Surface Water Quality

Available surface water quality data for the Weeli Wolli Creek is presented in Table 2.1. The data includes average historic water quality, as measurements by the Department of Water at the Tarina and Waterloo Bore Gauging Stations (DOW, 2015), an opportunistic water sample collected near Iron Valley by site personnel in February 2014 and water samples collected by WRM (2015). Collection of water samples in this region is difficult, as flows are often intermittent, with zero flow conditions prevailing through most of the year and site access being difficult during high flows. Additional surface water monitoring equipment, capable of automatic collection of water samples during high flow, was installed at Iron Valley in late 2014. No Rainfall-runoff events of sufficient size have occurred since the installation of this equipment, however, future events will be sampled, and the information collected will add to the body of baseline information presented in Table 2.1. The surface water samples collected by WRM, should be seen as being influenced by the upstream disposal by other mining companies.

2.2.3 Local Catchment Characterisation

The IVP is located within the Iron Valley catchment, toward the eastern portion of the Hamersley Ranges. The catchment is typical of the Eastern Pilbara, with rocky hills, small gorges, ephemeral watercourses, and gravely loam valleys. The Iron Valley catchment feeds into the Weeli Wolli Creek, and comprises approximately 1.6% of the Weeli Wolli Creek catchment and <0.2% of the total catchment area of the Fortescue Marsh.

Table 2:1: Baseline Water Quality for the Weeli Wolli Creek

Location		At Tarina	At Waterloo Bore	At Iron Valley	Within Weeli Wolli Creek *	Within Weeli Wolli Creek *
Date	Units	(1997-2008)	(1985-2001)	6 Feb 2014	Dry 2013	Wet 2014
pH	-	7.8	7.6	7.3	7.53	8.08
Conductivity	uS/cm	949	638	440	999	916
TDS	mg/L	-	182	280		
TSS	mg/L	2	-	<5		
Turbidity	NTU	0.6	177	-		
Nitrate as N	mg/L	-	3.00	0.33		
Nitrite as N	mg/L	-	-	0.007		
Ammonia as N	mg/L	-	-	0.03		
TKN	mg/L	0.08	0.10	-		
Total N	mg/L	0.18	1.04	-		
P	mg/L	0.007	0.014	<0.005		
SO_4	mg/L	-	6.7	25	60.6	60.3
K	mg/L	5.0	3.2	5.8	8.9	8.1
Ca	mg/L	34	11	33	56.8	54.3
Mg	mg/L	27	4.8	22	53.8	46.7
Na	mg/L	19	7.5	28	62.2	54.9
Cl	mg/L	37	9.1	43	119.7	98.7
Silica	mg/L	23	19	30		
Bicarbonate (as $CaCO_3$)	mg/L	-	-	160		
Carbonate (as $CaCO_3$)	mg/L	-	-	<5		
Hydroxide (as $CaCO_3$)	mg/L	-	-	<5		
Total Alkalinity (as $CaCO_3$)	mg/L	158	49	160	305.2	268.5
Hardness (as $CaCO_3$)	mg/L	194	47	170	366.7	328.3
Aluminium-Total	mg/L	0.10	0.33	0.02	0.0025	0.0025
Arsenic-Total	mg/L	-	-	<0.001	0.0005	0.0005
Cadmium-Total	mg/L	-	-	<0.0001	0.001	
Chromium-Total	mg/L	-	-	<0.001	0.003	
Copper-Total	mg/L	-	-	0.001	0.004	0.001
Fluoride – Total	mg/L	0.21	0.05	-		
Iron-Total	mg/L	0.03	0.34	0.04	0.0242	0.0052
Mercury-Total	mg/L	-	-	<0.00005		
Manganese-Total	mg/L	0.020	0.063	<0.005	0.0164	0.0013
Nickel-Total	mg/L	-	-	<0.001	0.0005	0.0005
Selenium-Total	mg/L	-	-	<0.001	0.0005	0.0005
Silver-Total	mg/L	-	-	<0.001		
Zinc-Total	mg/L	-	-	<0.001	0.0028	0.0025

- Average values from sample locations WW5-1 to EE5-6 (from WRM, 2015).

Four ephemeral watercourses run through the proposed IVP Area. The associated catchment areas (Figure 2.2) have been identified by computer modelling based on topography (URS, 2012) and verified visually on-site (SWG, 2014). The key physical characteristics of the four watercourses are summarised as follows:

- Catchment C13 (8.3 km^2) represents the southernmost watercourse within the IVP mining lease. The primary surface water flow channel is reasonably well-defined in the east, where the topography is steepest, but fans out downstream as the land surface flattens into the flood plain of the Weeli Wolli Creek.
- Catchment C14 (36.5 km^2) contains the largest of the watercourses within the IVP mining lease. Approximately 67% of the Iron Valley catchment drains through this channel. The primary low-flow channel is relatively well-defined throughout the length, being approximately 20-30 m wide. The lower reaches of C14 widen further, forming braided secondary flow channels as it enters the Weeli Wolli Creek floodplain.
- Catchment C15 (5.3 km^2) runs through the center of the mining tenement. The pre-mine channel is reasonably well-defined in the east, where the topography is steepest, but fans out downstream as the land surface flattens into the flood plain of the Weeli Wolli Creek.
- Catchment C16 (8.4 km^2) represents the northernmost watercourse within the IVP mining lease. Two well-defined main channels are present in the elevated eastern portion of the catchment, but these converge in an area of heavy sediment deposition predominated by sheet flow conditions where any surface water channels are poorly defined.

2.2.4 Baseline Hydrological Modelling

Rainfall-runoff modelling was conducted on the Weeli Wolli Creek catchment and the local Iron Valley sub-catchment (URS, 2012), in order to characterise the key hydrological properties of these ephemeral creek systems. The key outputs from the modelling included estimates of peak flow rate for a range of different sized storm events, and complete storm hydrographs for the critical duration storm event at annual return intervals (ARIs) of 1:50 and 1:100 years.

The model employed the Laurenson non-linear runoff routing procedure to predict a sub-catchment stormwater runoff hydrograph for an actual event (recorded rainfall time series) or design storm. The standard method of rainfall-runoff characterisation as described in Australian Rainfall and Runoff (AR&R) (Pilgrim, 2003) was used to characterise the hydrology of the project area. The model used the Intensity-Frequency-Duration (IFD) data, together with dimensionless storm temporal patterns and other AR&R data to produce design runoff hydrographs. The hydrological model utilised loss models to generate excess rainfall and estimate hydrographs based on rainfall, catchment, channel and flood plain characteristics.

2.2.4.1 Catchment Losses

In order to represent rainfall infiltration (or loss) to catchment soils, an initial and continuing loss model was utilised during hydrological modelling. The Initial Loss (IL) is the depth of rainfall (in mm) lost to the soil before runoff commences and the Continuing Loss (CL) is the rate at which rainfall loss to the soil occurs (in mm/hr) after the IL has been reached. The Australian Rainfall and Runoff (AR&R) IL and CL values for the Pilbara region are presented in Table 2.2 for a range of ARI and the equivalent annual exceedance probability (AEP) (URS, 2012).

Table 2:2: Initial Loss (IL) and Continuing Loss (CL) values for the Pilbara Region

ARI (years)	2	5	10	20	50	100
AEP	0.39	0.18	0.10	0.05	0.02	0.01
Mean IL (mm)	22	40	52	47	32	10
Mean CL (mm/hr)	5	5	5	5	5	5

2.2.4.2 Catchment Roughness (Manning's n)

Manning's n values were used to characterise the roughness of the various land systems within the Weeli Wolli Creek catchment. The initial value was based on photographic evidence, aerial images and Department of Agriculture Land Systems classification maps. The initial value was used in a hydrological model (XPRafts) to derive the calibrated Manning's n value of 0.038. This value has been applied to the sub-catchments, with a Manning's n value of 0.03 being applied to all the link units in the hydrology model (URS, 2012).

2.2.4.3 Design Rainfall

The CRC-FORGE method was used to derive design storm depths for the 1:50 and 1:100 year design storms, as recommended in Book IV of AR&R (Pilgrim, 2003). The CRC-FORGE rainfall depths were distributed over the AR&R temporal pattern for various rainfall durations (URS, 2012).

A critical storm analysis, the comparison of peak discharges generated from varying storm durations, found that the critical storm was of 24 hrs duration for the entire Weeli Wolli Creek as well as the individual sub-catchments. Total rainfall depths for the critical 1:50 and 1:100 year ARI design storms were determined to be 128.4 mm and 165.8 mm, respectively (URS, 2012).

2.2.4.4 Hydrological Model Validation

The validation of the baseline hydrological model was based on a 1999 rainfall event recorded as Tropical Cyclone John, which passed over the Weeli Wolli Creek Catchment. The surface water flows generated by this event were recorded at the Tarina gauging station. Validation of the model was undertaken by using the observed 1999 rainfall and adjusting the losses and roughness coefficients to match the recorded peak flow for this event, peaking at 2,100 m/s at Tarina station. It is important to note that the peak flow for this event was estimated using the recorded water level and an extended rating curve, and therefore represents a best estimate (URS, 2012).

The validated model was used to estimate peak flow discharge rates for a range of rainfall events using design rainfall intensities for the Weeli Wolli Creek Catchment, based on regional parameters identified in Australian Rainfall & Runoff (Pilgrim, 2003).

2.2.4.5 Simulated Flow Hydrographs

The critical duration hydrographs were derived for each of the local sub-catchments and the main Weeli Wolli Creek channel using a runoff-routing model and the input parameters described previously (URS, 2012). Simulated peak flows for the mine site sub-catchments are presented in Table 2.3 and flow hydrographs are presented in Figure 2.3. These results suggest that 1:100-yr peak flows ranging from 20 to 300 m^3/s are possible within the IVP disturbance area.

Table 2:3: Modelled peak flow rates in selected Iron Valley watercourses

Catchment (Figure 2.2)	Base flow (m^3/s)	1:50-yr peak (m^3/s)	1:100-yr peak (m^3/s)
C13	0	30.4	50.2
C14	0	168.0	306.1
C15	0	7.6	14.2
C16	0	18.7	29.4
Weeli Wolli Creek	0	3,107	5,684

2.2.5 Baseline Hydraulic (Flood) Modelling

A 2-dimensional hydrodynamic flow model was developed, utilising TUFLOW modelling software (TUFLOW version: 2011-09-AF-iDP-w64), to produce a baseline flood map for the 1:50 year and 1:100 year ARI critical duration rainfall events (URS, 2012). The model was used to simulate the catchment flood characteristics, including:

- Extents of flooding for selected ARI events.
- Depths of flood water for selected ARI events.
- Natural attenuation of flood waters.
- Flow velocities.

The grid size utilised in the hydraulic modelling was 10 m by 10 m (based on 20 m LiDAR topography) (URS, 2012).

2.2.5.1 Hydraulic Roughness

A composite Manning's n value of 0.04 was selected to represent roughness in the channels and floodplains of the Weeli Wolli Creek catchment (URS, 2012).

2.2.5.2 Hydrographs / Model Inflows

The catchment hydrographs generated by the hydrological model were applied to the model domain for the 1:50 year and 1:100 year ARI flood events. Appropriate scaling factors were applied to account for split catchment flow, or where only a portion of the total sub-catchment affected the site. This is described further in the original baseline report (URS, 2012).

2.2.5.3 Downstream Boundaries

The hydraulic model has two downstream boundaries where the water flows out of the system. These boundaries are so called "free flow" boundaries where discharge is calculated based on the average slope and water level. The boundaries are located some 6 km downstream of the project site and therefore are not expected to affect water levels at the areas of interest (URS, 2012)

2.2.5.4 Baseline Flood Simulations

The simulated baseline flood extents and maximum water depths for the 1:100 year ARI flood event are shown on Figure 2.1 (URS, 2012). In general, the project tenement is expected to fall outside of the

1:100-yr floodplain of the main Weeli Wolli Creek channel, and is thus not considered to be at risk of major, regional-scale flooding. However, the four secondary watercourses, C13-C16, identified as flowing through the project tenement are still expected to produce significant volumes of flood water during extreme storm events. Flooding of up to 0.5 m is expected within the mining tenement during a 1:100-yr storm within the C13, C15 and C16 watercourses. Flooding of 1.0-1.5 m depth, and extending laterally by up to 500 m is expected in the mining tenement in the path of the much larger C14 catchment.

2.3 Assessment of Potential Impacts on Surface Water System

The Iron Valley Project mine site layout for the AWT mining option is presented in Figure 2.5, and the proposed BWT mining option is presented in Figure 2.6. As depicted, the proposed BWT mine infrastructure would occupy a greater proportion of the mining tenement (approximately 90% of the tenement) as compared to the AWT option (50% of the tenement), and would intersect more of the identified surface water catchments. In addition, disposal of excess dewatering water, extracted from the mine pits, will also occur with implementation of the BWT mining option. A greater degree of surface water management is therefore expected to be required for the BWT mine option.

The specific risks and potential management requirements related to surface water are discussed in more detail in the following Sections.

2.3.1 Changes to Flow Pathways

Given the extent of proposed activity at the site, all four of the identified surface water catchments crossing the tenement (C13-C16) would be impacted by mine infrastructure (i.e. mine pits and waste rock dumps) under the proposed BWT mining option. It is therefore expected that nearly all of the surface water flow intersecting the site would need to be managed in some way, both during site operation and post-closure. The following primary interactions between surface water and mine infrastructure are expected to occur:

- Catchment C13 is proposed to be completely intersected by the southern-most mine pit (Figure 2.7). As this mine pit will be excavated directly across the valley, it is likely that the majority of the surface water runoff from this catchment will be directed into the mine pit, if unmanaged. There is potential for the majority of the flow from this catchment to be diverted around the southern end of the pit. This mine pit will be backfilled, once completed, and surface water will thus only need to be managed during Operation. It is envisaged that the flow path across the backfilled pit will be re-installed.
- Catchment C14 is proposed to be mostly intersected by the proposed waste dump footprint (Figure 2.8). As this catchment represents around 70% of the total water flow through the project area, some form of management or diversion will be required in order to avoid very large volumes of water (estimated 5,000 ML for a 1:100-yr storm) backing up against the up-slope edge of the waste dump, causing widespread flooding, and subsequent infiltration into and

through the waste dump. An exclusion zone in the waste dump will need to be allowed for, to accommodate flow from this catchment through the mining area.

- Catchment C15 is proposed to be mostly covered by waste rock material, and the area integrated into the final landform (Figure 2.9). Therefore, the majority of potential surface water runoff from this catchment will be essentially eliminated. As waste dumps are typically constructed with flat or inward-sloping tops, and consist primarily of coarse material with high permeability, the majority of rainfall falling on this catchment is expected to infiltrate the waste dump, rather than running along the surface and into the main pit void, as is the case with the current AWT mine operation. Some small sub-catchments (up to 7 ha) would be trapped on the west side of the waste dump such that water may pond against the waste dump following large storm events.
- Catchment C16 is proposed to be intersected by the Northern-most mine pit (Figure 2.10). The northern half of this catchment will be able to be diverted around the northern side of the proposed pit, out onto the natural floodplain, and is not expected to impact the operation. However, as this mine pit will be excavated across the southern half of the catchment (in a valley setting), diversion of this portion of the catchment may not be practicable and the majority of the surface water runoff from this half of the catchment may end up flowing into the mine pit.

Site activities are not expected to have any impact on the flow direction of the main Weeli Wolli Creek channel, which lies outside of the mining tenement.

2.3.2 Reduction in Catchment Runoff

The overall volume of rainfall-runoff generated on site for the BWT mining option is expected to be less than both the Baseline and AWT mining scenarios. The following four runoff-interception mechanisms account for the potential reduction:

- The increased surface area of the pit voids (total of around 417 ha) means that more rainfall will be captured within the pits during storm events. During the active mining phase, rainfall entering the mine pits will not be “lost”, as it will be dewatered and discharged back to the Weeli Wolli Creek (see Section 2.3.3). However, upon site closure, direct rainfall onto the remaining mine pit voids will remain in the pit or be evaporated.
- Depending on how the runoff from Catchment C16 is managed (i.e. diversion versus spillway options), runoff from these creek lines may enter the mine pits, thus reducing the total volume of runoff entering the Weeli Wolli Creek (around 100 ha of catchment area is expected to be intercepted by the Northern pit). During the active mining phase, any runoff water entering the pit will not be “lost”, as it will be dewatered and discharged back to the Weeli Wolli Creek (see Section 2.3.3). However, upon site closure, any runoff from this catchment that drains into the remaining mine pit void will remain in the pit or be evaporated.
- As waste dumps are typically constructed with flat or inward-sloping tops, and consist primarily of coarse material with high-permeability, the majority of rainfall falling on the constructed

landforms is expected to infiltrate. This will effectively eliminate around 40 ha of the catchment from the site rainfall-runoff regime.

- The waste dumps will additionally cut off approximately 105 ha of catchment area that would have otherwise flowed through the tenement. This total area comprises many small catchments of ≤ 7 ha in size along the western edge of the project tenement. Although the majority of Catchment C14 will pass through the gap in the waste dump, one larger sub-catchment, which is 68 ha in size, will also be trapped by the waste dump in a local valley. Any runoff water intercepted by the waste dumps would pond temporarily against the side of the waste dump until it drained or was evaporated.

The total potential catchment area that may be intercepted by the BWT mining option is therefore approximately 1,022 ha. This represents around 16% of the Iron Valley Catchment (6,300 ha), and less than 0.5% of the total Weeli Wolli Creek Catchment (400,000 ha).

2.3.3 Dewatering Discharge Volume

During the active mining phase, groundwater entering the mine pits will be dewatered and used for dust suppression or discharged to the Weeli Wolli Creek. The predicted (modelled) average dewatering rates for 10 years of BWT mining are presented in Table 2.4

As dewatering is likely to be conducted year-round, it is likely to result in a small “baseflow” of between 0.2-0.5 m^3/s in the Weeli Wolli Creek in the vicinity of the mine site (Table 2.4). It is understood that there is negligible natural baseflow in the Weeli Wolli Creek in the area downstream of the mine tenement, with measurable flow only occurring during and shortly after (i.e. within a few days of) significant rainfall events (DOW, 2015). During dry periods, the dewatering “baseflow” is only expected to exist within close proximity to Iron Valley, with the majority of water infiltrating into the Weeli Wolli Creek bed after a short distance. Peak flood flows in the Weeli Wolli Creek are several orders of magnitude greater than this artificial baseflow (over 5,000 m^3/s for a 1:100-yr flood), and will not be affected by the discharge.

The expected total annual volume of dewatering water to be discharged is also summarised in Table 2.4, and ranges from around 2,000-17,000 ML/yr. By comparison, the average annual flow for the Weeli Wolli Creek at Iron Valley (i.e. the Waterloo Bore gauging station) is around 33,000 ML/yr. However, as the majority of the natural flow occurs during larger storms, a much greater proportion of rainfall-generated creek flow is expected to be transmitted downstream and into the Fortescue Marsh in comparison to the dewatering discharge. As previously discussed, due to the relatively small, continuous flow of dewatering water, the majority of the dewatering discharge is likely to infiltrate into the Weeli Wolli creek bed prior to reaching the Fortescue Marsh.

Table 2:4: Predicted Average dewatering discharge to the Weeli Wolli Creek (from the proposed Iron Valley BWT mine)

Year	Average Dewatering Discharge Rate*			Total Discharge Volume (ML)
	(kL/d or m^3/d)	(m^3/hr)	(m^3/s)	
2016	47,007	1,959	0.54	17,158
2017	47,475	1,978	0.55	17,328
2018	44,466	1,853	0.51	16,230
2019	42,429	1,768	0.49	15,487
2020	6,563	273	0.08	2,395
2021	15,995	666	0.19	5,838
2022	14,605	609	0.17	5,331
2023	14,669	611	0.17	5,354
2024	27,056	1,127	0.31	9,875
2025	22,640	943	0.26	8,264

* Only includes the expected groundwater volume to be dewatered, additional water from stormwater runoff into the mine pits will also likely be pumped and disposed (see Section 2.3.4). Prediction details are provided in Section 4.8.

2.3.4 Stormwater Volumes

2.3.4.1 Mine Pits

During the active mining phase, rainfall and runoff water entering the mine pits will not be "lost" from the local hydrological system, as it will be dewatered (along with groundwater dewatering) and discharged back to the Weeli Wolli Creek (via sediment trap). This will likely result in changes to the timing of water flows into the Weeli Wolli Creek, i.e. dewatering will likely be conducted at a relatively constant rate, whilst the natural streams have variable hydrographs, with long periods of low-to-no flow, and very high peaks in flow occurring during or shortly after a storm.

The volume of stormwater runoff that may enter each mine pit has been estimated for a range of 72-hr design storms, including the 1:1-yr, 1:50-yr, and 1:100-yr ARI storm events (Table 2.5). The total volume has been split into two components: (1) direct rainfall onto the pit and (2) rainfall-runoff into the pits from upstream catchments. The direct rainfall component was calculated from published IFD data (BOM, 2014), and the total open surface area at the mine pit crest. Runoff volumes were estimated from modelled stream flow hydrographs for the critical duration storm event (URS, 2012).

Table 2:5: Estimated Stormwater Volumes Generated from a Range of 72-hr Design Storms

Mine Pit	1:1-yr Storm Volume		1:50-yr Storm Volume		1:100-yr Storm Volume	
	Direct Rainfall[1] (m^3)	Runoff[2] (m^3)	Direct Rainfall[1] (m^3)	Runoff[2] (m^3)	Direct Rainfall[1] (m^3)	Runoff[2] (m^3)
East Pits	21,000	0	109,000	0	131,900	0
North Pit	68,100	10,600	354,700	60,600	428,700	99,900
Central Pit	89,100	0	463,900	0	560,600	0
South Pit	39,900	44,000[3]	207,900	252,100[3]	251,300	415,500[3]
TOTAL	272,700		1,448,500		1,887,900	

Notes: [1] Direct rainfall volume calculated from published IFD data (BOM, 2014), and the total open surface area at the mine pit crest, [2] Runoff volume estimated from modelled stream flow hydrographs for the critical duration storm event (URS, 2012), [3] Assumes no diversions are put in place (with diversions, runoff volume would be nil).

2.3.4.2 Waste Dumps

Waste dumps are typically constructed with flat or inward-sloping tops, and consist primarily of coarse-grained material with high-permeability. Therefore, the majority of rainfall falling on the proposed 442 ha waste dump footprint is expected to infiltrate, rather than run along the surface, and will thus generally not need to be managed as stormwater.

Small drains may be warranted along the base of the waste dumps in order to capture any runoff that occurs off the outer slopes of the landforms. If the dumps are properly designed and constructed, the volume of runoff should only be minor, however, it is likely to be sediment-laden. Thus, sediment traps may also be warranted at locations where the drains discharge off-tenement or into a natural creek line (this is discussed further in Sections 2.3.5 and 2.4.6).

2.3.4.3 Infrastructure Areas

The stormwater regime within the infrastructure areas is not expected to change appreciably between the AWT and BWT mining options, as the site layout will not be heavily modified. Localised rainfall runoff within infrastructure areas is likely to present an ongoing challenge, particularly during the large monsoonal or tropical storm events that occur within the region, as the site is relatively flat. However, existing surface water control measures are expected to be sufficient.

The existing diversion drain, which runs through the centre of the infrastructure area, is expected to be more than sufficient to continue to convey any captured upstream flows. Given that the proposed BWT mine pit and waste dump essentially cut off the majority of the catchment that currently drains toward the site, only minimal rainfall-runoff is expected to flow into the site from upstream. This flow is currently captured by the drain and directed through a sedimentation pond prior to discharge.

2.3.5 Surface Water Quality

2.3.5.1 Dewatering Discharge

During the active mining phase, groundwater entering the mine pits will be dewatered and discharged to the Weeli Wolli Creek. As previously discussed, due to the relatively small, continuous flow of dewatering water being discharged into the Weeli Wolli Creek, the majority of the discharge water is predicted to infiltrate into the Weeli Wolli Creek bed within 6 km of the disposal point (see Section 4.8.2.4), over 25 km from the Fortescue Marsh.

Recent groundwater quality analysis (see Appendix A) is presented in Table 2.6, and may be compared against the measurements collected from the Weeli Wolli Creek (Table 2.1). In general, the groundwater quality within the Iron Valley deposits is similar to the natural creek water – average electrical conductivity (EC) of the groundwater of 681 uS/cm, compared to 675 uS/cm for the surface water. Samples collected by WRM (2015) from the shallow alluvial aquifer system to the east of the BC Iron tenement, during the dry season in 2013 average 999 uS/cm, while wet season samples in 2014 averaged 916 uS/cm.

Total metals in the groundwater (including Al, As, Cd, Cr, Cu, Pb, Hg, Mn, Ni, Se, Ag, Zn) are all below the relevant freshwater quality guidelines for 95% species protection (ANZECC & ARMCANZ, 2004).

Given the relatively high quality of the groundwater at Iron Valley, and the relatively small volume of dewatering water proposed to be discharged to the creek (in comparison to stream flow events or current storage in the Weeli Wolli Creek aquifer system), no appreciable changes to water quality are anticipated in the Weeli Wolli Creek or downstream receptors, including the Fortescue Marsh, due to site dewatering activity.

2.3.5.2 Suspended Sediment

Some site activities may result in an increase in sediment-laden runoff, thereby potentially increasing the sediment load in surface waters. The turbidity levels and sediment load in the Pilbara watercourses are noted as being low for average flow events and extremely high during flood events (Water and Rivers Commission, 2000). As the majority of sediment that is eroded from disturbed areas is likely to be highest during more intense rainfall events, the largest releases of sediment from site are likely to be in proportion to the natural sediment discharge from undisturbed catchments. Further, as the peak flow rate of the Iron Valley catchment is typically only around 5% of the peak flow rate in the Weeli Wolli Creek, the sediment loads generated from the disturbed area of the Project Site are expected to be negligible compared to those generated from the whole of the Weeli Wolli Creek Catchment during a high intensity rainfall event.

MRL is finalising construction and dust management plans, which are intended to reduce sediment liberation from cleared areas. These existing plans will apply to any expansion of site activities, including implementation of the BWT mining option. Design of constructed landforms (i.e. waste dumps) is also important with respect to sediment retention onsite, and this is discussed further in Section 2.4.5.

2.3.5.3 Spills / Other Contamination

As there will not be any on-site chemical processing of extracted ore at the IVP, the potential risks to surface water quality related to spills or leaks are primarily limited to hydrocarbons. It is understood that MRL already has hydrocarbon management and spill response plans in place, which include measures such as tank and fueling area bunding, spill response, incident reporting, etc. These existing plans will apply to any expansion of site activities, including implementation of the BWT mining option.

Therefore, no additional risk to surface water is anticipated due to implementation of the BWT mining option.

Table 2:6: Average Dewatering Water Quality, to be Discharged to the Weeli Wolli Creek

Mine Pit		Central	Eastern	Southern
Bore IDs	**Units**	**(PB1, PB2)**	**(MBA, MBK)**	**(MBJ)**
pH	-	8.3	8.4	8.2
Conductivity	uS/cm	840	865	340
TDS	mg/L	485	505	290
SO4	mg/L	52	54	10
K	mg/L	8	12	8
Ca	mg/L	45	44	19
Mg	mg/L	45	43	15
Na	mg/L	54	69	24
Cl	mg/L	87	106	24
Total Alkalinity (as CaCO3)	mg/L	275	270	120
Hardness (as CaCO3)	mg/L	-	-	-
Aluminium-Total	mg/L	<0.005	<0.005	0.010
Arsenic-Total	mg/L	<0.001	<0.001	<0.001
Cadmium-Total	mg/L	<0.0001	<0.0001	<0.0001
Chromium-Total	mg/L	<0.001	<0.001	<0.001
Copper-Total	mg/L	<0.001	<0.001	<0.001
Fluoride - Total	mg/L	-	-	-
Iron-Total	mg/L	0.069	0.034	0.020
Mercury-Total	mg/L	<0.00005	<0.00005	<0.00005
Manganese-Total	mg/L	0.018	0.027	0.031
Nickel-Total	mg/L	<0.001	<0.001	<0.001
Selenium-Total	mg/L	<0.001	<0.001	<0.001
Silver-Total	mg/L	-	-	-
Zinc-Total	mg/L	0.020	<0.005	<0.005

2.4 Engineering of Surface Water Control Measures

2.4.1 Summary of Current AWT Surface Water Control Measures

A Surface Water Management Plan (SWMP) was developed for the AWT mining option at Iron Valley (SWG, 2014) to ensure that interactions with local surface water features could be managed in a way that meets environmental obligations, maintains productivity and minimises downtime. The specific management practices proposed, are summarised as follows, and are described in more detail in the SWMP:

- Install flood bunding along the southern edge of the proposed Stage 1 mine pit. Based on previous flood modelling (URS, 2012), an approximately 2 m high bund was expected to provide sufficient protection against a 1:100-yr flood event within the C14 watercourse, and provide a barrier between the watercourse and operational areas of the site.

- Install a reinforced bund and "spillway" to manage water flowing into the proposed Stage 1 mine pit (south end of the "Central Pit") from the C15 watercourse. This was intended to allow for the controlled release of water into the pit, and to mitigate erosion of the pit safety bund and pit crest. Surface water entering the pit in this manner was proposed to be pumped out and used for dust suppression or returned to a natural surface water channel.
- Install diversion bunds around the proposed Stage 2 mine pit (north end of the "Central Pit" to divert the 1:100-yr peak flow within the two main branches of the C16 watercourse.
- Construct the majority of infrastructure areas (e.g. ROM Pad) on raised pads to avoid inundation from surface water flows from within the C15 and C16 watercourse catchments. Main access roads also to be raised, and culverts installed at appropriate locations to facilitate the flow of clean surface water across the site.
- Install a "clean water" diversion drain to ensure that water flowing in the lower reaches of the C15 watercourse is routed through the site, and does not interact with site infrastructure.
- Install diversion drains downslope from the stockyard area to direct surface water runoff through a sediment trap prior to returning it to the C15 watercourse.
- Any chemical storage areas, including bulk fuel storage and fueling areas to be self-bunded to capture any spills, and appropriately sized to accommodate the 1:100-yr, 72-hr design storm volume.
- Direct water from the wash-down bay to a sump or "turkey's nest" dam and reused for dust suppression.
- Monitor water flow rate and chemistry at select locations to demonstrate that no significant detrimental changes to the hydrological regime of water entering the Weeli Wolli Creek are occurring.

An overview of these surface water management measures for the AWT mining scenario is shown on Figure 2.5.

2.4.2 Assessment of Surface Water Management Needs for the BWT Option

As the proposed site layout for the BWT option is significantly different than the AWT site layout, surface water management practices require updating. As outlined in Section 2.3, the options for diverting "clean water" flows are reduced for the BWT option, primarily owing to the significant increase in occupied land area, which is proposed to be around 90% of the tenement.

The development of an updated SWMP for the BWT option is most likely warranted. The following general surface water control topics (and associated control measures) are described at a preliminary level in the following sections, and could be elaborated upon in an updated SWMP:

- Clean water diversion.
- Stormwater management – Mine pits.
- Stormwater management – Waste dumps.

- Stormwater management – Infrastructure areas.
- Landform design.
- Sediment basin design.
- Considerations for site closure.

A map showing preliminary locations for the suggested surface water control measures is provided in Figure 2.11.

2.4.3 Clean Water Diversion

All "clean" stormwater runoff should be redirected around site infrastructure, wherever practicable, to (1) avoid contamination of the water, and to (2) protect operational areas of the mine site from inundation and avoid unnecessary pumping of stormwater from the mine pits.

As many of the site catchments are directly intersected by mine pits in the steeper areas of the site, the implementation of diversions may be difficult in some instances. The potential for diversion of clean runoff is summarised as follows for each of the site Catchments (C13-C16):

- Catchment C13 is proposed to be intersected by the Southern-most mine pit (Figure 2.7). During the one year operation planned for the mine no diversion is proposed with any stream flow generated, reporting to the pit. As the pit is proposed to be backfilled after mining, and will only be open for around 2 years, construction of a diversion may not be cost-effective, and it may be decided to allow any seasonal runoff from this catchment to flow directly into the mine pit, with subsequent dewatering occurring as necessary.
- Catchment C14 represents around 70% of the total water flow through the project area. As such, an approximately 60 m wide corridor will be established through the waste dump to allow for large storm flows to pass unimpeded through this catchment (Figure 2.8).
- Catchment C15 is proposed to be mostly covered by waste rock material, and the area integrated into the final landform (Figure 2.9). Therefore, whilst some minor ponding of runoff may occur along the western side of the dump, the majority of potential surface water runoff from this catchment will be essentially eliminated, and will not run into the mine pits or into any potential downstream receptors. No diversion of stormwater runoff is therefore considered to be necessary in this catchment.
- Catchment C16 is proposed to be intersected by the Northern-most mine pit (Figure 2.10). It consists of two sub-catchments, which will likely be managed differently:
    - The northern half of this catchment will be able to be diverted around the northern side of the proposed pit, out onto the natural floodplain. Based on calculations completed as part of the development of the AWT SWMP, a bund height of around 1.5-2.0 m is expected to be sufficient to manage runoff events up to and including the 1:100-yr peak flow event.
    - The mine pit will be excavated directly across the southern half of the catchment (in a valley setting), and there is minimal opportunity to divert the existing flow channel around the mine pit. It would be possible to install a diversion drain by excavation of a

deep drain, which would extend partially through the valley wall. This may warrant further onsite investigation, but is not considered practicable at this stage. Seasonal runoff from this catchment is therefore proposed to be directed into the pit and dewatered, as required.

An existing diversion drain is present within the main infrastructure area of the site. This drain was installed as a flood protection measure, to intercept the Catchment C15 watercourse during the development of the AWT mining operation. This existing drain is expected be more than sufficient to manage runoff from the C15 watercourse during implementation of the BWT operation, as the catchment area requiring management will actually be substantially reduced from the AWT mine site layout (i.e. most of the catchment will be taken up by the expanded mine pit and waste dump, and runoff is therefore expected to be minimal). This drain can be left in place during the BWT operation to convey any minor runoff into the existing sediment trap.

2.4.4 Stormwater / Flood Management

2.4.4.1 Mine Pits

During the active mining phase, rainfall water and around 100 ha worth of runoff (Catchment C16) will enter the mine pits during storm events, and will be dewatered and discharged back to the Weeli Wolli Creek. The volume of stormwater that may enter each mine pit has been estimated for a range of 72-hr design storms, including the 1:1-yr, 1:50-yr, and 1:100-yr ARI storm events, and is presented in (Table 2.5). As any stormwater dewatered from the mine pits is likely to contain a substantial fraction of sediment, it will be discharge via sedimentation basins, as outlined in Section 2.4.8.

After the completion of mining at the site, rainfall will continue to fall into the mine voids, although dewatering will cease.

2.4.4.2 Waste Dumps

Waste dumps are typically constructed with flat or inward-sloping tops, and consist primarily of coarse-grained material with high-permeability. Therefore, the majority of rainfall falling on the proposed 442 ha waste dump is expected to infiltrate the waste dump, rather than running along the surface, and will thus generally not need to be managed as stormwater; (see Section 2.4.5), therefore the volume of any stormwater runoff from the outer slopes should only be minor. However, any runoff that does occur is likely to be sediment-laden, and toe drains and sediment traps may be warranted (see Section 2.4.6), particularly along the eastern edge of the project tenement, which drains towards the Weeli Wolli Creek.

The primary stormwater issue related to the waste dumps will be the intersection of existing creek lines. As previously discussed, an approximately 60 m wide corridor is proposed to be left through the waste dump to allow flood flows in Catchment C14 to pass unimpeded. The precise dimensions of the corridor will likely need to be discussed and agreed with regulators, however the proposed channel width of 60 m is expected to allow for passage of the 1:100-yr flood peak flow rate of approximately 300 m^3/s, with an associated flood depth of around 1.6-1.7 m, and an average flow velocity of around 3 m/s. The sides of the waste dump would need to be armoured with large rock to provide sufficient erosion resistance.

Additional engineering and risk analysis may be required to explore additional channel configurations and better define the morphological dynamics of the final channel (i.e. constraining a river channel has the potential to cause additional erosion of the banks, and additional scour of the river bed, thus lowering the river bed, and leading to potential further erosion or undermining of the banks).

Several other minor catchments are proposed to be intersected by the waste dump footprint. These catchments total approximately 105 ha, comprising many small catchments of ≤ 7 ha in size along the western edge of the project tenement. One larger sub-catchment (part of Catchment C14), which is 68 ha in size, is also intercepted. Any runoff water intercepted by the waste dump in these areas is currently not proposed to be managed, and will be allowed to pond temporarily against the side of the waste dump until it naturally infiltrates or evaporates.

2.4.4.3 Infrastructure Areas

The infrastructure areas have already been established, and have existing surface water management measures in place. As these areas are not expected to require any substantial changes in order to move to BWT mining, the existing measures are expected to be sufficient. As detailed further in the AWT SWMP, the following stormwater management measures have been implemented within the current infrastructure areas, and should be applied to any new infrastructure:

- Sensitive infrastructure constructed on raised pads, and built up at least 1 m above the surrounding landscape to avoid inundation from significant surface water flows from within the C15 and C16 watercourses.
- Pads are gently sloped to facilitate drainage, and all clean water runoff will be returned to the surrounding natural flow paths.
- The main access roads have been raised, and culverts installed at appropriate locations to facilitate the flow of clean surface water across the site.
- Additional drainage has been installed around the stockyard area to control surface runoff from this area, and prevent direct runoff into the surrounding environment.
- A sediment trap has been installed to treat the runoff water from the stockyard area.
- The explosives magazine is self-bunded.
- Any chemical storage areas, including bulk fuel storage, and fueling areas, are self-bunded, and sufficiently sized to hold the entire stored volume, and the 1:100-yr, 72-hr design storm volume.
- Runoff from the wash-down bay is collected in a sump and run through an oil separator prior to discharge into the “turkeys nest” dam and reused for dust suppression.

2.4.5 Landform Design

All landforms (i.e. waste dumps) should be designed and constructed in such a way that minimises excessive surface water runoff and erosion of the outer surface. This will help to reduce the concentration of suspended sediment in any runoff, whilst also limiting the total volume of runoff that is produced. With this in mind, the following should be considered when designing and building the landforms:

- Use suitably erosion-resistant materials to construct the outer land surfaces. In addition to providing a growth medium for rehabilitation species, the outer embankments in particular should be constructed of material which has been demonstrated to exhibit good erosion resistance.
- Shape the batter slopes to an angle that is compatible with the erosion resistance properties of the soils. This is generally between 12-18°, depending on the available soil type.
- A maximum lift height of 10 m is generally recommended in order to limit the overall length of the batter slope. Longer slopes can lead to greater over land flow velocity, which leads to greater sediment detachment rates and gullying. Cross-slope ripping is generally considered to be useful to further slow flow velocity, and increase infiltration.
- Install 10 m wide back-sloping berms between each lift. This further limits downslope flow rates and provides an additional location for water infiltration and sediment deposition.
- Construction of both batters and berms must be conducted carefully to ensure that contouring is accurate and to avoid incorporating any flow concentrating dips and/or rises.
- The upper surface of the landforms should be designed to be inward sloping to trap any rainfall that falls on the upper surface and to prevent it from running down the slopes. The upper surface should be constructed with sufficient capacity for a 1:100-yr, 72-hr rainfall event (i.e. minimum capacity of around 0.5 m depth).

2.4.6 Sedimentation Traps

It should be noted that the IVP is located within an actively eroding landscape, with a number of highly active sediment source and deposition zones being located within the mining lease. As such, any sediment generated within the IVP is not expected to have a significant effect within this type of environment. The use of sediment basins to treat the runoff from key areas of the site is recommended as a pro-active measure designed to align with industry best practice.

Sediment traps are primarily proposed to treat stormwater extracted from the mine pits, and any residual runoff from the disturbed areas of the site (mainly waste dumps) prior to discharge into the surrounding environment. As previously discussed, if the waste dumps are properly designed and constructed (see Section 2.4.5), the volume of any stormwater runoff from the outer slopes should only be minor. However, any runoff that does occur (likely only during very intense rainfall) is likely to be sediment-laden, and toe drains and sediment traps are therefore recommended along the base of the waste dumps in areas which drain towards the Weeli Wolli Creek.

Sediment traps are recommended for the following general locations, and preliminary siting of the traps is shown on Figure 2.11:

- Dewatering discharge locations.
- Stockyard (already installed).
- Downslope edge of the waste dump.

- Along Catchment C14.

The exact locations and design requirements for the sediment traps should be refined upon further site investigation, analysis of final waste dump designs, and in consultation with site engineers.

Many of the other exposed waste dump slopes drain towards mine pits, or will be rock armoured (e.g. along Catchment C14) and thus will not require specific management of the sediment load. As previously discussed, a sediment trap has already been designed and installed to handle runoff from the stockyard area, so no further design recommendations are presented here for the infrastructure area. Additional, temporary sediment traps may be required on any temporary diversion structures or temporarily exposed section of waste dump slope as the mine pit is developed; this should be assessed against the final mine plan / staging and incorporated into the SWMP.

2.4.7 Considerations for Site Closure

The following surface water management aspects should be considered with respect to site closure:

- Rainfall and runoff entering the mine pits will no longer be dewatered and discharged to the Weeli Wolli Creek. This will have the following impacts on the surface water regime of the site:
    - It will enhance the development of post-mine pit lakes. These lakes will develop in the absence of any surface water runoff (due to groundwater inflow), however, the lakes will reach an equilibrium level more quickly with surface water input.
    - Approximately 900 ha of catchment area will be effectively removed from the surface runoff system. During operation of the mine site, this water was returned to the surface via dewatering pumps, but this will not occur in the post-mine environment. This represents around 14% of the Iron Valley Catchment area (6,300 ha).
- Rainfall falling on the waste dumps is considered to be effectively removed from the surface runoff system. This includes an additional 400 ha of catchment area, representing another 6% of the Iron Valley Catchment area (6,300 ha).
- Any permanent surface water management features that are to be left in place after cessation of mining must allow for eventual site relinquishment. This means they cannot require significant ongoing maintenance, and must be engineered and constructed to a sufficient standard so as to remain effective into the foreseeable future.
- Infrastructure (roads, buildings, stockpiles, etc.) will likely be removed from the infrastructure area, and the land surface rehabilitated back to its pre-mine condition. Surface water management in this area will therefore no longer be required, and the existing drains and sediment traps in the infrastructure area will most likely be filled in and reshaped along with the remainder of the area.
- It may be warranted to leave the proposed drains and sediment traps associated with the waste dump in place to manage infrequent sediment releases after site closure. The sediment traps will lose their effectiveness as they fill with sediment over time, however, sediment releases should also be reduced with time, as the waste dump rehabilitation progresses.

- The proposed diversion bund around the northern mine pit will likely be left in place at site closure, potentially forming part of the pit abandonment bund. This should be constructed with this in mind, so reworking is not required after cessation of mining.
- The Southern mine pit is proposed to be backfilled with mine waste prior to site closure, and surface water management infrastructure will therefore not be needed in this area post-closure.
- The southern portion of the Central mine pit is proposed to be backfilled with mine waste prior to site closure. The reshaping and rehabilitation of this surface should be conducted in such a way as to minimise erosion of the final land surface. This will likely mean that the surface should be gently back-sloped toward the center of the backfilled area, so as to minimise any surface water runoff from this area.

3 Groundwater Data Review

3.1 Review of previous work

Previous studies of the site hydrogeology were undertaken by URS for the above water table mining case and submitted as part of the mining approvals (reports listed in the References at the end of this report). Their initial assessments were based on limited available site data, with site specific aquifer parameter information only obtained from packer tests undertaken in two geotechnical bores. Historical groundwater work included the installation of ten monitoring bores and two production bores, but no permeability testing of these bores took place. URS made a number of recommendations for extensive fieldwork, to collect site specific hydrogeological information, which would allow future reporting at a greater level of certainty. The data collected during the URS studies, together with the data collected during the AQ2 study, allowed the development of the hydrogeological conceptual model, as discussed in Section 3.3.8 below.

3.2 Fieldwork Undertaken

After review of all available reports and data, AQ2 proposed the following fieldwork:

- Permeability testing of all monitoring bores installed previously.
- Sampling of all the monitoring bores tested.
- Installation of 50 mm pvc casing into two existing, open RC mineral exploration bores to north of the dyke and permeability testing of these bores.
- Aquifer testing of the two production bores, to determine hydrogeological properties of the aquifer.
- Installation of 50 mm casing into four selected open mineral exploration bores that pass through the pit walls and permeability testing of these bores, to ascertain the pit wall hydraulic properties.
- Logging of the saltwater transition in bores to the north and north-east of the mine site, where access is possible. Down the hole conductivity profiling to take place, to identify the transition from fresh to saline water.
- Drilling and testing of one shallow monitoring bore at the southern edge of the open pit, to ascertain alluvial depth and connection to the orebody aquifer.

The field work proposed was discussed and the approach confirmed with the Department of Water on February 17th 2015. A report covering the fieldwork undertaken is provided in Appendix A. The results from the fieldwork assisted in developing the hydrogeological conceptual understanding for the site.

3.3 Background Hydrogeology

3.3.1 Geology

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.

- Brockman Iron Formation (Members - Yandicoogina Shale, Joffre, Mt Whaleback and Dales Gorge).

A description of these units is provided below.

3.3.1.1 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, 2011).

3.3.1.2 Tertiary Formation

The Tertiary sediments are subdivided into two units

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

The Tertiary deposit thickness varies between 10 and 42 m across the Project area (URS, 2013).

3.3.1.3 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 and where mineralised is part of the orebody at the mine site.

3.3.1.4 Brockman Iron Formation

The Brockman Iron Formation is divided into four members (Yandicoogina Shale, Joffre, Mt Whaleback Shale and Dales Gorge) and where mineralised is part of the orebody 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).
- Mt 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.

3.3.2 Aquifer delineation

The aquifers on site are linked to the geological formations and the alteration of the permeability of the units due to weathering, faulting, dyke intrusion and chemical alteration. The orebody is predominantly hosted within the Joffre Member of the Brockman Iron Formation, with some hosted in the Weeli Wolli Formation.

The aquifer delineation has been based on all available data, including:

- Geological mapping for the region (Figure 3.1).
- The geotechnical report for the site (Pells Sullivan Meynink, 2011).
- URS reports (as listed in References).

- Information from the work of Dogramaci et al (2014) covering recharge along the Weeli Wolli Creek.
- Data provided by MRL (resource drilling and intervals where Fe grade was greater than or equal to 50%).

The pertinent features influencing the hydrogeological understanding are:

- Faulting (the East Fault) between the Weeli Wolli Formation and Brockman Iron Formations, with a northern strike slip of the Weeli Wolli Formation to within the surrounding Brockman Iron Formation.
- Intrusion of a SW-NE trending dyke, through a second fault striking east-northeast across the northern extent of the site.
- Alluvial sediments associated with the Weeli Wolli Creek and its tributaries.
- The CID located under the Weeli Wolli Creek alluvium.
- Water level data collected since 2013, showing limited water level drawdown (<3 m), notwithstanding the two production bores on site having recently been pumped at 15 L/s (~1,300 kL/d) each on a continuous basis for the last two years (Soil Water Group, 2015a).
- Chemical and weathering alteration of the orebody, increasing the permeability of the unit.

The alluvium/detritals and the mineralised 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. 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 orebody aquifer. The non-mineralised 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 orebody is bisected on the northern part of the tenement, by an east-west striking dolerite dyke, while a north-south trending fault along the eastern side of the orebody (East Fault) provides hydraulic connection between the orebody and the Weeli Wolli Creek system in the south.

3.3.3 Water levels

Water levels prior to mining were measured in all possible mineral exploration bores (URS, 2011), which clearly showed the impact that the dolerite dyke has as a barrier to groundwater flow to the north. 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 (data in Appendix A). In monitoring bores north of the dyke, static water levels have been measured at depths ranging from 26 to 43 m (Figure 3.2).

The latest water level data (from existing monitoring bores measured in 2015), confirms the trend of shallow water levels on the southern side of the dyke (<15 m below surface) and deeper water levels on the northern side (30 to 50 m below surface).

3.3.4 Flow Directions

Generally, groundwater flow mirrors the topography and the path of the Weeli Wolli Creek, with flow from the southwest to the northeast across the site. The dyke does cause some deflection of flow towards the Weeli Wolli Creek, at the eastern end of the dyke (Figure 3.3).

3.3.5 Aquifer Parameters

Aquifer parameters have been selected (Table 3.1), based on the preliminary work undertaken by URS (2011), together with the aquifer testing undertaken during the fieldwork carried out during this project.

Table 3:1: Aquifer Characteristics

Aquifer Unit	Hydraulic Conductivity (m/d)	Specific Yield (%)
Weeli Wolli Creek Alluvium (main channel)	20	10
Weeli Wolli Creek Alluvium (minor tributary)	0.1	5
Weeli Wolli Creek Outwash	1	5
Scree	0.01	0.1
Channel Iron Deposit	45	5
Fault Underlying Channel Iron Deposit/Weeli Wolli Creek	30	1
Brockman Iron Formation	0.001	0.1
Mineralised Brockman Iron Formation (orebody)	3.0	5
Sub-Mineralised Brockman Iron Formation (orebody)	0.5	5
Weeli Wolli Formation	0.001	0.1
Mineralised Weeli Wolli Formation (orebody)	3.0	5
Sub-Mineralised Weeli Wolli Formation (orebody)	0.5	5
East Fault (adjacent to orebody aquifer)	100	15

The highest hydraulic conductivities (units of metres per day or m/d) are expected within the mineralised orebody, the East Fault zone, the Weeli Wolli Creek alluvium and the CID below the Weeli Wolli Creek. These aquifer units will be conduits for the greatest groundwater flow volumes. The bedrock on either side of the orebody will be far less permeable and provide limited groundwater flow prior to dewatering and limited inflow during the open pit dewatering.

The highest specific yields were set for the mineralised orebody, the East Fault, the alluvium and the CID material.

3.3.6 Water Chemistry

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 field 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). During the current fieldwork, electrical conductivity profiling was undertaken in bores on the Fortescue Metals Group (FMG) tenement directly north of the Iron Valley mine site. Data from the profiling, together with information from bores on the Department of Water (DoW) database, has shown that the water quality in the upper Tertiary aquifers is fresh, where recharged by surface water flow from the Weeli Wolli Creek, but to the north of the Creek, the quality slowly deteriorates with distance away from the Creek, to 6,000 mg/L a distance of 25 km from the Creek. The water quality in the bedrock deteriorates over a much shorter distance, from 500 mg/L within the orebody on site, to 18,000 mg/L, a distance of 5 km from the mine site (see report in Appendix A).

3.3.7 Groundwater Recharge

Recharge is sporadic and mostly associated with the high rainfall linked to major cyclonic events. CSIRO (2015) indicate that median annual recharge varies between 1.02 – 0.33% of median annual rainfall, on a catchment wide basis. On a catchment wide basis, the majority of this recharge takes place along low lying creek environments after rainfall events, with very low recharge to groundwater away from the creek environments. Stream flow along the Weeli Wolli Creek only occurs after rainfall events above a threshold of 36 mm per day (Charles, et al, 2013).

Excess water discharge from mines to the south of the Iron Valley site (in the order of 19.9 GL/annum since late 2007), has raised water levels in the alluvium downstream of the discharge area by up to 20 m (Dogramaci, 2014). This excess water discharge results in permanent stream flow along the Weeli Wolli Creek where no CID underlies the Creek (along a reach extending 13 km downstream of the Weeli Wolli Spring), but thereafter, seepage into the underlying CID results in groundwater levels below the base of the Weeli Wolli Creek bed. A recent survey of the Weeli Wolli Creek by MRL staff in October 2015, observed surface water flow, 3 km south of the current mine site, but no surface water flow opposite the mine site.

3.3.8 Conceptual Groundwater Understanding

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

- A transmissive, mineralised orebody aquifer system capable of delivering high bore yields.
- Areas overlying the orebody aquifer where saturated alluvium will store water that will drain into the main aquifer.
- Connection of the orebody and overlying alluvium to the Weeli Wolli Creek in the south, via the East Fault. The fault will form a strong conduit for flow from the Creek to the mine site.
- Connection of the orebody aquifer, via an extension of the orebody aquifer to the north on the FMG tenement, to the Weeli Wolli Creek. Dewatering of the open pits could reverse the natural flow gradient and induce inflow from the aquifers underlying the Creek in that area.
- The orebody aquifer is surrounded to the east and west by comparatively massive, low permeability shales and BIFs, which are not likely to be a source of significant aquifer storage.
- The dyke acts as a low transmissivity barrier to groundwater flow to the north.

3.3.9 Catchment Water Balance

The conceptual water balance for the Iron Valley groundwater catchment has been developed using a mass balance approach. This approach takes into account current disposal to the Weeli Wolli Creek from existing mining operations, but does not include any future mining options. The water balance accounts for groundwater inflow from upstream systems (derived from infiltration of surface water over the Weeli Wolli Creek and the Marillana Creek surface water catchments), groundwater recharge over the catchment from surface water flows in the Weeli Wolli Creek and natural groundwater discharge to downstream. The groundwater area considered by the current water balance and also used in the groundwater model described in Section 4.0 is shown in Figure 3.4. The section below describes the estimated water balance based on long term average conditions.

Recharge to the groundwater catchment occurs as recharge from surface water flows in the Weeli Wolli Creek. The length and width of the Weeli Wolli Creek flow channel has been estimated as summarised in Table 3.1. Available gauging data is from Waterloo Bore (Department of Water Station number 708013), located on the Weeli Wolli Creek adjacent to the current Iron Valley mine. Sections of the Weeli Wolli Creek used to complete the water balance and the location of the gauging station are shown in Figure 3.4. Analysis of the surface water gauging data from 1984 to 2014, suggests that on average the Weeli Wolli Creek flows for fourteen days of the year. Using a maximum recharge rate of 125 mm per day (while the creek is flowing) averaged over a calendar year (365 days) provides the recharge rates per section of creek as summarised in Table 3.2. This maximum recharge rate from the Weeli Wolli Creek is based on estimated water balances calculated for other parts of the Weeli Wolli Creek catchment.

Recharge to sections 1 to 4 (Table 3.1) is assumed to occur upstream of the Iron Valley site (i.e. 10,068 kL/d). Recharge to sections 5 and 6 (6,712 kL/d) is assumed to occur over the remaining length of the Weeli Wolli Creek within the modelled catchment.

Table 3:2: Weeli Wolli Creek Recharge Areas

Section	Width of Flow Channel (m)	Length of Flow Channel (m)	Average Recharge Rate (kL/d)*
1 (upstream of Iron Valley)	100	3000	1,438
2 (upstream of Iron Valley)	40	2000	959
3 (upstream of Iron Valley)	200	5000	4,795
4 (upstream of Iron Valley)	120	5000	2,877
5 (downstream of Iron Valley)	200	3000	2,877
6 (downstream of Iron Valley)	100	8000	3,836
TOTAL			16,781

* Assuming maximum recharge of 125 mm per day for 14 days a year

Groundwater inflow from upstream systems, has been estimated based on the surface water catchment area upstream of the Iron Valley site (i.e. the Weeli Wolli and Marillana Creek surface water catchments) and long term rainfall. Based on the catchment area to a point just upstream of the Iron Valley site, groundwater inflow is estimated to be 17,890 kL/d. Components of this water balance (quantity (a)) are described in Table 3.3.

Table 3:3: Estimated Catchment Water Balance

Feature	Rate (kL/d)	Comments
Groundwater Inflow		
a) Groundwater Inflow to Just Upstream of the Iron Valley Site (from the Weeli Wolli and Marillana Creek groundwater systems)	17,890	Based on: • Catchment area upstream of 3889.4 km^2 • 0.525% infiltration of average rainfall to groundwater • Long term average rainfall of 320 mm per year
b) Groundwater Recharge from the Weeli Wolli Creek, Upstream of Iron Valley Site	10,068	Recharge from the Weeli Wolli Creek to groundwater from sections 1 to 4 in Table 3.1 above.
c) Groundwater Recharge from the Weeli Wolli Creek Downstream of Iron Valley Site	6,712	Recharge from the Weeli Wolli Creek to groundwater from sections 5 to 6 in Table 3.1 above.
d) Groundwater Inflow at Upstream End of Modelled Catchment (from the Marillana and Weeli Wolli Creek groundwater systems)	7,821	Total catchment inflow to just upstream of Iron Valley (a) minus recharge from reaches 1 to 4 (b)
Groundwater Outflow		
e) Groundwater Outflow to Downstream (towards Fortescue Marsh)	24,602	Groundwater inflow to Upstream (a) plus recharge downstream of Iron valley (c)

The estimated groundwater balance presented in Table 3.3 suggests that:

- Groundwater inflow to the upstream end of the modelled catchment is estimated at 7,821 kL/d. This represents groundwater inflow to the modelled catchment from both the Weeli Wolli and Marillana Creek systems. It is estimated that around 2,000 to 3,000 kL/d of this inflow is from the Marillana Creek groundwater system and the remainder is from the Weeli Wolli Creek groundwater system. This also takes into account discharge to creeks by RTIO and BHPB.
- Total groundwater recharge from the Weeli Wolli Creek over the modelled catchment, resulting from average surface water conditions is estimated at 16,781 kL/d.
- Under steady state conditions (i.e. no long term increase of decrease in groundwater levels across the modelled catchment) groundwater outflow to downstream is assumed to balance all groundwater inflows (24,602 kL/d).

4 Groundwater Modelling

4.1 Objectives

The objective of the groundwater modelling was to predict dewatering requirements and impacts of the Iron Valley mine.

The model developed was updated from an earlier URS model (2011) and then used to predict:

- Dewatering rates required to achieve dry mining conditions (i.e. groundwater levels below the projected base of mining throughout the life of the mine).
- The potential for dewatering to deliver site water supply requirements.
- The impact of disposal strategies used to manage excess dewatering above site water supply requirements.
- Regional groundwater drawdown resulting from dewatering and potential water level increases associated with disposal of excess water above water supply requirements.
- Water level recovery after the cessation of mining, associated with empty and/or partially infilled mine voids.

Key features of the updated groundwater model are described in detail in the following sections and summarised below. The model includes:

- The aquifers associated with the Weeli Wolli Creek, the underlying CID and the orebody aquifer (mineralised Brockman Iron and Weeli Wolli Formations).
- Recharge to the aquifer system from surface water flows in the Weeli Wolli Creek.
- Dewatering of the orebody aquifer.
- Groundwater inflow from the upper Weeli Wolli Creek catchment.
- Groundwater outflow to downstream.

4.2 Model Setup and Extent

The original URS groundwater model utilised the Modflow SURFACT (Version 4.0, Hydrogeologic Inc., 1996), groundwater modelling code operating under the Visual Modflow graphical user interface. For the current work, the Modflow SURFACT groundwater modelling code was retained, however all model updates were completed using the Groundwater Vistas graphical user interface (Version 6, Environmental Simulations Inc., 1996 to 2011). Groundwater Vistas was selected as it offers flexibility for model data input and manipulation and model output formats.

The extent of the model domain and the location of model boundaries are shown in Figure 4.1 and summarised in Table 4.1. The model and all associated data are specified using the GDA94 (Zone 50) coordinate system. The model domain covers an area of 23 km west to east and 23 km north to south. The model extent is unchanged from the previous model set up, however the boundary conditions have been updated to reflect the updated hydrogeological understanding. Updates to assigned model boundaries conditions are discussed further in Section 4.4 below.

Table 4:1: Extent of Model Domain

	Easting (m)*	Northing (m)*
North West	729,290	7,492,295
North East	751,900	7,492,295
South West	729,290	7,469,975
South East	751,900	7,469,975

*GDA 94 Zone 50

A minimum model cell size of 50 m is assigned in the mine area (refer Figure 4.1), to represent the orebody aquifer geometry and groundwater gradients that will develop as dewatering progresses. A maximum cell size of 100 m is assigned close to model boundaries. The model grid includes 280 rows and 283 columns over six model layers resulting in a total of 475,440 model cells and 336,766 active model cells.

4.3 Model Geometry

Three additional model layers, in addition to the three model layers included in the original model, were added to represent the orebody geometry, as well as the geometry of the Weeli Wolli Creek aquifer and the underlying CID aquifers. Model layers are a subdued reflection or topography, or are flat lying. Model layer geometry is summarised in Table 4.2. Contours of the top of layer 1 (topographic surface) and the base of model layers 1 to 5 are shown in Figures 4.2 to 4.4. The base of layer 6 (the lower layer) was set uniformly to 200 mAHD.

The orebody aquifer geometry was defined by data provided by Mineral Resources (resource drilling and intervals where Fe grade was greater than or equal to 50%). A low permeability dyke is also included (approximately west to east) across the model domain. The low hydraulic conductivity dyke is simulated using the Horizontal Flow Barrier (HFB) Package in Modflow SURFACT. Details of the HFB Package are discussed further in Section 4.5.3.

Aquifer property zones and the low permeability dyke (represented by the HFB package), for model layers 1 to 6 are shown in Figures 4.5 to 4.10. A schematic model section from west to east across the model domain is shown in Figure 4.11.

Table 4:2: Model Layer Summary

	Aquifer Units	Layer Geometry
1	Alluvial aquifers, orebody aquifer (mineralised Brockman Iron and Weeli Wolli Formation), East Fault, basement (Brockman Iron and Weeli Wolli Formation)	Top of layer represents ground surface. Base of layer set to simulate a saturated thickness of ~20 m in the alluvial aquifer and around 30 m in the southern part of the orebody aquifer (total model layer thickness ~50 m)
2	CID, orebody aquifer (mineralised Brockman Iron and Weeli Wolli Formation), East Fault, basement (Brockman Iron and Weeli Wolli Formation)	Layer thickness of 30 m
3	CID, orebody aquifer (mineralised Brockman Iron and Weeli Wolli Formation), East Fault, basement (Brockman Iron and Weeli Wolli Formation)	Layer thickness of 50 m
4	Fault under Weeli Wolli Creek, orebody aquifer (mineralised Brockman Iron and Weeli Wolli Formation), East Fault, basement (Brockman Iron and Weeli Wolli Formation),	Layer thickness of 50 m
5	Orebody aquifer (mineralised Brockman Iron and Weeli Wolli Formation), basement (Brockman Iron and Weeli Wolli Formation)	Layer thickness of 45 m
6	Orebody aquifer (mineralised Brockman Iron and Weeli Wolli Formation), basement (Brockman Iron and Weeli Wolli Formation)	Layer thickness of 40 m to 75 m. Base of layer set at 200 mAHD

4.4 Groundwater Inflow and Outflow

4.4.1 Groundwater Throughflow

The locations of all model boundaries are shown in Figure 4.1. The highest measured groundwater levels are recorded in the southern part of the orebody aquifer (~478 mAHD in Iron Valley monitoring bores) and south east of the orebody aquifer along Weeli Wolli Creek (~485 mAHD at RTIO monitoring bores, Dogramaci et al, 2014). The general direction of groundwater flow is as follows:

- From south to north along the aquifers associated with the Weeli Wolli Creek and the underlying CID and the East Fault toward the Fortescue Marsh.
- From areas of higher topographic elevation toward the Weeli Wolli Creek (i.e. from the west and east towards the Weeli Wolli Creek).
- From south to north along the Iron Valley orebody aquifer and across a west east trending low permeability dyke.

Groundwater inflow to the modelled catchment from the upper parts of the Weeli Wolli Creek catchment (including the Marillana Creek catchment) is simulated by a fixed head boundary along the southern model boundary. The groundwater level elevation of this boundary is set at 485 mAHD consistent with water levels measured at nearby Rio Tinto groundwater monitoring locations (Dogramaci et al, 2014).

This assigned groundwater level reflects water levels resulting from long term surplus water disposal in the upper parts of the Weeli Wolli Creek catchment and downstream of the Weeli Wolli Spring and along the Marillana Creek. Available data suggests that in the early 1990s, water levels at the southern model boundary location were up to 15 m lower than the currently assigned elevation.

Groundwater outflow from the modelled catchment to downstream, is simulated by a constant head groundwater outflow boundary. The elevation of this boundary is set at 415 mAHD, consistent with water level monitoring at bore NMB1009 (which is located just upstream of the downstream model boundary). Close to the location of the downstream/northern model boundary, water level elevations have been measured between 410 mAHD and 417 mAHD.

All other model boundaries are set as the no flow type and are aligned with surface water catchment boundaries or set perpendicular to the inferred direction of groundwater flow.

4.4.2 Recharge

In additional to groundwater inflow from the upper Weeli Wolli catchment, the groundwater system is also recharged from surface water flows in the Weeli Wolli Creek. Recharge to groundwater from surface water flows is assumed to be concentrated on the flood plain of the Weeli Wolli Creek and is represented by the modelled recharge distribution shown in Figure 4.12. The application of this recharge rate in the calibrated model is discussed further in Section 4.5.1 and Section 4.5.2.

4.4.3 Discharge to Weeli Wolli Creek

The Weeli Wolli Creek is also modelled as a groundwater outflow boundary across the model domain (refer Figure 4.1). Groundwater discharge to the Creek is simulated using the River Package (RIV) in Modflow SURFACT. This package uses a water level elevation relationship to calculate groundwater flow to or from the modelled Creek and the underlying aquifer. For the current model set up, the Creek boundary is assumed to simulate groundwater flow from the aquifer to the Creek only (i.e. groundwater fed flows from the underlying aquifer to the Weeli Wolli Creek). Recharge from surface water flows in the Weeli Wolli Creek is described in Section 4.4.2 above.

To simulate the discharge, each modelled Creek cell is assigned a base elevation (RBOT), a bed conductance (C) and a stage (HRIV). As it is assumed that the only water in the Creek is supported by groundwater fed flows, RBOT is set equal to HRIV and the modelled aquifer head (h) underlying a modelled Creek cell is greater than the modelled base of the Creek. The rate of discharge from the aquifer to the Creek is calculated using Equation 1:

(1) $QRIV = C*(HRIV - h)$ (i.e. assuming $h > RBOT$ which is equal to HRIV)

For this case the calculated QRIV is negative consistent with a flow direction from the aquifer to the Creek.

The stream bed conductance is calculated by equation 2:

(2) $C = K*L*W/b$

Where K = hydraulic conductivity of river bed material (in m/d)

L = length of the Creek across or with the model cell (in m)

W = width of the Creek (m)

B = thickness of Creek bed (m)

Creek bed conductance values of 500 m^2/d to 2500 m^2/d are assigned along the modelled length of the Weeli Wolli Creek. These values were not adjusted as part of model calibration and as a result, are not considered to be calibrated, but represent an estimate of the stream bed characteristics of the Weeli Wolli Creek when there is groundwater flow from the underlying aquifer to the Weeli Wolli Creek.

4.5 Groundwater Pumping

Groundwater pumping from bores PB1 and PB2 commenced in September 2013. The bores were installed to pump from the orebody aquifer, south of the dyke. The locations of the bores are shown in Figure 4.12. The Modflow SURFACT Well (WEL) Package was used to represent abstraction from these bores. Pumping rates were assigned at actual monthly recorded rates from September 2013 to December 2014.

4.6 Model Calibration

Model calibration is the process by which the parameters of a numerical model are adjusted, within realistic limits to provide the best match to measured data. This process involves testing and refining the aquifer properties and boundary conditions of the model to improve the match between observed data and simulated values. The Iron Valley groundwater model was calibrated using a manual or trial and error approach.

An initial steady state model was completed to generate a set of initial or pre development groundwater levels (as indicated in Figure 3.2), that reflect groundwater conditions prior to the start of pumping from the orebody aquifer (from PB1 and PB2). This model included initial estimates for aquifer parameters and boundary conditions (including rainfall recharge). These water levels were then used as initial conditions for the transient calibration, which was run for the period January 2012 to December 2014. Any changes to aquifer parameters which could be justified based on predicted groundwater responses and current hydrogeological understanding, were then made to both the steady state and transient models.

The groundwater level data available for model calibration was provided from a number of sources, including the following:

- Water levels collected from mineral exploration bores, located mainly across the proposed mining area.
- Water levels collected from FMG's monitoring bores on the tenement to the north of the Iron Valley mine site.

- Water levels collected from monitoring bores installed as part of the current hydrogeological investigations.
- Water levels from production bores.

While data from across the modelled catchment is available to calibrate the model to pre-development conditions, time varying or transient data, including measured water levels and groundwater pumping is only available for the proposed mine area for the period January 2012 to December 2014. In general water level monitoring is available from hydrogeological monitoring bores over the period February 2012 to July 2015, however groundwater pumping data is only available from September 2013 when pumping commenced to December 2014. As a result, the transient or time varying model calibration was completed for the period January 2012 to December 2014.

4.6.1 Steady State Calibration

The location of bores used for calibration of the steady state model are shown in Figure 4.13 and Figure 4.13a. Contours of predicted groundwater levels for pre development or steady state conditions are shown in Figure 4.14. Monitoring locations where water levels are over predicted in the model calibration are shown in green while monitoring locations where water levels are under predicted are shown in blue.

The contours of predicted water level show the general direction of groundwater flow from south to north along the Weeli Wolli Creek and reflect the contour pattern shown in Figure 3.3. South of the dyke along the length of the measured and modelled orebody, aquifer water levels are generally between 475 mAHD and 480 mAHD. North of the dyke, measured and modelled water levels are lower at between 435 mAHD and 440 mAHD. The inclusion of a low hydraulic conductivity dyke results in a water level drop of close to 35 m over a very short distance in the northern area of the proposed mine.

Predicted water levels along the Weeli Wolli Creek are higher than the predicted water levels to the east of the Creek. This is due to the large recharge volumes (from RTIO/BHPB disposal and flood flows in the Weeli Creek). The groundwater flow direction, however, still generally follows topography along the Weeli Wolli Creek. It is not anticipated that a large volume of groundwater will flow through the low hydraulic conductivity basement area east of the Weeli Wolli Creek. Additionally, the paucity of groundwater level data to the east of Weeli Wolli Creek prevents further calibration of groundwater levels in this area.

The model predicted steady state water balance is presented in Table 4.3. The model replicates the analytical water balance estimate for the catchment (Section 3.3.9) with 8,600 kL/d flowing into the modelled catchment from upstream.

Recharge from the Weeli Wolli Creek assigned to the steady state calibrated model reflects the following:

- The recharge distribution shown in Figure 4.12 and the estimated geometry of Weeli Wolli Creek flow channels as summarised in Table 3.2.

- A maximum creek recharge rate of 125 mm/day which is assumed to occur 14 days a year (consistent with flow records from Waterloo Bore gauging station) spread over a calendar year (i.e. 365 days).

Table 4:3: Modelled Steady State Water Balance

Component	In (kL/d)	Out (kL/d)
Groundwater Inflow from Upstream	8,600	0
Recharge	16,800	0
Groundwater Outflow to Downstream		25,400
Total	25,400	25,400

4.6.2 Transient Calibration

The location of bores used for transient model calibration are shown in Figure 4.15. Measured and modelled water levels across the model domain are shown in Figures 4.16 to 4.21. The model calibration performance is described below.

4.6.2.1 Mine Area South of Dyke

Measured and predicted water levels south of the dyke are shown in Figures 4.16 to 4.19. With the exception of MBD, which is located very close to or just downstream of the dyke, water levels gradients south of the dyke are flat along the strike of the orebody aquifer. At MBE / MBF (Figure 4.16) and MBJ (Figure 4.17), measured water levels prior to the start of pumping are around 478 mAHD. These monitoring locations are more than 3 km apart and illustrate the flat water levels across the area of the orebody aquifer south of the dyke, as the water levels “dam up” behind the low permeability dyke.

Pumping from the orebody aquifer from PB1 and PB2, located south of the dyke (shown in Figure 4.12) commenced in 2014. Monitoring at MBE, MBF (Figure 4.16) and MBG (Figure 4.17) shows a drawdown response of less than 1 m in response to pumping. This very small pumping response and the flat water levels over the orebody aquifer (north to south) suggests a source of strong inflow to the aquifer – this inflow could only be simulated in the model by the inclusion of a transmissive fault (the East Fault) running from north to south along the orebody aquifer, connected to the Weeli Wolli Creek.

Measured water level trends and magnitudes are matched at MBE, MBF and MBG (i.e. locations in the proposed area of mining). The seasonal response to recharge in the Weeli Wolli Creek at MBJ is also matched. The general water level trend at MBL is also matched, however water levels are under predicted by 3 m. There is little data available for the calibration period for MBM, MBN and MBO (Figure 4.18) and MBP, PB01 and PB02 (Figure 4.19), however predicted water levels are of a similar magnitude to measured water levels from either the beginning or just after the calibration period.

4.6.2.2 Mine Area North of Dyke

Measured and predicted water levels north of the dyke are shown in Figures 4.19 and 4.20. Measured water levels show a seasonal response that is not replicated by the model (MBA, MBC and MBH shown in Figure 4.20). This suggests that there is some additional recharge in the area north of the dyke or there is hydraulic connection to the Weeli Wolli Creek that is not included in the current model set up. At MBK, which is located on a tributary of the Weeli Wolli Creek, the seasonal response is replicated, however water levels are over predicted by up to 6 m. At other monitoring locations north of the dyke water levels are generally over predicted by up to 6 m with the exception of MBC where the water level magnitude is reproduced by the current model set up (Figure 4.20).

4.6.2.3 Transient Recharge

Over the calibration period, recharge is assigned from the Weeli Wolli Creek for periods when flow at the Waterloo Bore gauging station (Department of Water gauging station 708013, east of the proposed East Pits), is more than 100,000 kL/d. This results in recharge applied for a period of 24 days in 2012, 8 days in 2013 and 24 days in 2014 over the three-year calibration period.

4.6.2.4 Water Balance

Modelled water balances for mid December 2013 (end of the dry season and prior to recharge) and February 2014 (after wet season recharge) are presented in Table 4.4.

The model predicted water balance for the end of the dry season predicts groundwater inflow and outflow rates consistent with the steady state water balance (Table 4.3). Declining water levels throughout the catchment are associated with the removal of water from storage. Groundwater pumping of less than 1,000 kL/d is less than 5% of the predicted catchment water balance.

Table 4:4: Model Predicted Water Balances for Dry and Wet Season

	Water Balance Component	**In (kL/d)**	**Out (kL/d)**
End of Dry Season (mid December 2013)	Storage	14,300	90
	Groundwater Inflow	10,800	0
	Groundwater Outflow	0	24,250
	Rainfall Recharge	0	0
	Discharge to Weeli Wolli Creek	0	0
	Groundwater Pumping	0	760
	Total	**25,100**	**25,100**
End of Wet Season (February 2014)	Storage	2,120	377,765
	Groundwater Inflow	900	0
	Groundwater Outflow	0	38,310
	Rainfall Recharge	413,955	0
	Discharge to Weeli Wolli Creek	0	0
	Groundwater Pumping	0	900
	Total	**416,975**	**416,975**

The model predicted water balance for the end of the wet season shows the rate of recharge from the Weeli Wolli Creek and an associated increase in groundwater storage as water levels rise across the alluvial aquifer. As a result of the Weeli Wolli Creek recharge, groundwater inflow from upstream is predicted to decrease and groundwater outflow to downstream is predicted to increase. However, there is no predicted discharge to the Weeli Wolli Creek (as groundwater fed base flow to the creek) as a result of wet season recharge, or over the model calibration period. Similar to the dry season water balance, groundwater pumping is a very small proportion of the predicted water balance.

4.6.3 Aquifer Parameters

Aquifer parameters assigned to the calibrated steady state and transient models are summarised in Table 4.5. The modelled aquifer parameter distributions are shown in Figures 4.5 to 4.10. Aquifer parameters are assigned consistent with measured data and similar hydrogeological environments. Hydraulic conductivity values assigned to the Weeli Wolli Creek alluvium, CID and the faults underlying the CID are at the high end of the range associated with these materials. These high values were required to reproduce the analytical water balance presented in Table 3.3. The hydraulic conductivity assigned to the East Fault is also at the higher end of the range and was required to reproduce the limited drawdown response to ongoing pumping, as well as maintain the measured drop in water levels across the dyke, of close to 35 m.

The dyke was represented with the HFB package with a K'/B' term of 3.33×10^{-10} day^{-1} representing a hydraulic conductivity (K') between model cells of 1×10^{-8} m/d and a thickness of 30 m.

Table 4:5: Modelling Aquifer Parameters

Aquifer Unit	Layer	Horizontal Hydraulic Conductivity (m/d)	Vertical Hydraulic Conductivity (m/d)	Specific Yield (%)	Specific Storage (m^{-1})
Weeli Wolli Creek Alluvium (main channel)	1	20	2	10	-
Weeli Wolli Creek Alluvium (minor tributary)	1	0.1	0.01	5	-
Weeli Wolli Creek Outwash	1	1	0.1	5	-
Scree	1	0.01	0.001	0.1	-
Channel Iron Deposit	2 and 3	45	4.5	5	0.000002
Fault Underlying Channel Iron Deposit/Weeli Wolli Creek	4	30	3	1	0.000002
Brockman Iron Formation	1 to 6	0.001	0.001	0.1	0.000002
Mineralised Brockman Iron Formation (orebody)	1 to 5	3.0	3.0	5	0.00002
Sub-Mineralised Brockman Iron Formation (orebody)	2 to 3	0.5	0.5	5	0.00002
Weeli Wolli Formation	1 to 6	0.001	0.001	0.1	0.000002
Mineralised Weeli Wolli Formation (orebody)	1 to 5	3.0	3.0	5	0.00002
Sub-Mineralised Weeli Wolli Formation (orebody)	2 to 3	0.5	0.5	5	0.00002
Fault (adjacent to orebody aquifer)	1 to 4	100	100	15	0.00002

- Denotes parameters not required for unconfined aquifer

4.7 Other Model Details

Other details of model set up are outlined below:

- As outlined in Section 4.5, over the model calibration period, stress periods were set to reflect the duration of recharge events and monthly pumping records. As a result, some stress periods were up to a month long (28 to 31 days), while other stress periods varied in length between 1 and 27 days.
- The Modflow SURFACT Automatic Time Stepping (ATO) package was used for all transient (time varying) simulated with the following parameters:
    - An initial time step length of 0.2, 1 of 5 days was used, depending on the length of the stress period (related to recharge events and pumping records).
    - A minimum time step of 1 x 10^{-10} days and a maximum time step length of 30 days
    - A multiplier factor of 1.2 and a reduction factor of 2.0.
    - These result in a maximum time step length of up to 5 days.
- The model was also run with the Modflow SURFACT Block Centred Flow 4 (BCF4) package using the Variably Saturated Flow Option (Pseudo Soil Relations) to accommodate re saturation.
- The model was run with the Pre-Conjugated Gradient 5 (PCG5) solver along with the following parameters:
    - Number of outer iterations = 200
    - Number of inner iterations = 20
    - Maximum orthoganilisations = 20
    - Head change criterion = 0.005 m
    - Relative Convergence Criterion = 0.1
    - Newton Raphson Linearalisaton (Backtracking Factor) = 0.9
    - Newton Raphson Linearalisaton (Residual Reduction Factor) = 1

4.8 Model Predictions

Model predictions were completed using the calibrated model to estimate dewatering requirements (i.e. groundwater abstraction required to maintain groundwater levels below the base of mining) and the impacts that the dewatering and any excess water disposal would have on regional water levels over the proposed mine life from 2016 to 2025. Model predictions were also completed for groundwater recovery following the end of mining over a closure period from 2026 to 2115.

4.8.1 Prediction Set Up

4.8.1.1 Dewatering

Dewatering predictions were completed for two preliminary mine plans and schedules and then updated for a final mine schedule (provided by MRL on December 10th 2015). The results of the preliminary predictions were provided to MRL for review only. The details of the final mine plan schedule and the other assumptions linked to the modelled Base Case, are provided below, with final dewatering prediction results discussed in Section 4.9 below.

Model predictions were completed to estimate dewatering requirements associated with the mining schedule provided by MRL (Table 4.6). Mining below the regional water table is scheduled to commence in late 2016, with the dates in Table 4.6 assumed to be December of each calendar year. The locations of each of the different pit areas are shown on Figure 4.22.

Table 4:6: Iron Valley Mining Schedule (Pit Depth in mAHD)

Open Pits	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
C1	500	470	470								
C2		470	400	390							
C3			480	410							
C4				320							
C5					460	440	400	350		280	
E1	480		430				420				
E2									450	340	300
N1				410	390	340					
N2						450	430	420	310		
N3									460		280
S1					350						
S2					350						

Other details of the Base Case model prediction are summarised below:

- Initial water level conditions for dewatering predictions were taken from the end of the model calibration period.
- No further water supply pumping (from PB1 and PB2) was included in model predictions, as dewatering will provide the water supply.
- Elevations assigned to the upstream groundwater inflow boundary and the downstream groundwater outflow boundary were unchanged from the steady state and transient calibration models.
- Over the prediction period it was assumed that the recharge processes observed in 2012 and 2013 would occur over the prediction period (i.e. this two-year sequence was repeated five times to represent the ten-year prediction period). This sequence assumed 24 days of recharge to groundwater from the Weeli Wolli Creek flows during years 1, 3, 5, 6 and 9 and 8 days of recharge to groundwater from flows in the Weeli Wolli Creek during years 2, 4, 6, 8 and 10. Recharge events were assumed to occur during February of each calendar year.
- Predictions were run using time increments that reflected an elapsed time of a month, or the period of expected recharge from the Weeli Wolli Creek (i.e. 24 and 8 days).
- Dewatering from mining areas below the regional water table via in-pit and ex-pit bores was simulated using the Evapotranspiration (ET) package Modflow SURFACT, with the ET rate set to replicate individual bore pumping rates, the ET surface set consistent with a minimum water level at pumping locations and an extinction depth of 0.1 m. Individual bore yields were set consistent with pumping required to achieve water level below the projected base of mining. As a result, pumping rates at some locations were set to replicate pumping from more than dewatering bore. This approach allowed the simulation of some advanced dewatering. Proposed dewatering bores and locations are shown in Figure 4.22.

- In areas where pumping rates were expected to be highly variable, due to rapid changes in individual pit depth development and changes in the locations of pits being mined, or as a result of recovering water levels in nearby pits, dewatering requirements were also estimated using the Drain (DRN) package Modflow SURFACT. Drain elevations and extents were set consistent with the schedule provided and final pit shells. Dewatering via drains was included at C5, E1 and E2 pits (refer to Figure 4.22 for locations).
- The start of mining below the water table and the first requirement for dewatering is assumed to commence in September 2016.
- Pumping from individual mine areas was assumed to cease the year following the completion of mining to accommodate infilling.
- Dewatering was used to satisfy site water demand (a maximum of 15,700 kL/d). Dewatering in excess of demand was disposed as follows:
  - Water demand was taken from combined dewatering at Pits C1, C2, C3, C4, C5, N1, N2 and N3. Any surplus dewatering was discharged to Weeli Wolli Creek at Disposal Locations 4 and 5 (50% of surplus at each location, as shown in Figure 4.22).
  - All dewatering from S1 and S2 was discharged to the Weeli Wolli Creek at Disposal Location 1 (location shown in Figure 4.22).
- Disposal of surplus dewatering was simulated using the Recharge package in Modflow SURFACT. All surplus was assumed to recharge the Weeli Wolli Creek at the respective disposal locations over a Creek length of approximately 500 m.
- The Tailings Storage Facility (TSF) is assumed to operate from September 2016 until the end of mine life in December 2025, with seepage at a constant rate of 3 L/s (1.5 L/s from the northern and southern sections of the TSF). Seepage recharge to the underlying aquifer is distributed over the entire foot print of the TSF. Water levels in the immediate TSF area are constrained to not exceed groundwater level in the TSF area via the use of drain cells, set at an elevation consistent with ground level over the entire foot print of the TSF.

A number of additional prediction scenarios were completed to assess the impact of different operational and catchment conditions as outlined below:

- To assess the impact of maintaining ex-pit dewatering south of C4 after the end of mining in 2019, the Base Case prediction was updated to assume that pumping from bores south of C4 was maintained from 2020 onwards (the Base Case prediction assumed that pumping south of C4 ceased at the end of 2019 once the area was infilled). This case was run to assess what impact the ongoing use of ex-pit bores would have, compared to using in-pit bores.
- To minimise water level changes in the Weeli Wolli Creek area, the surplus water disposal strategy was modified to include disposal of water previously disposed at Disposal Location 5 to Disposal Location 1, once dewatering finished at pits S1 and S2 at the end of 2019 (i.e. from January 2020 onwards).
- The impact of surplus water disposal from Rio Tinto's proposed Pocket and Billiard development was assessed by assuming that around 25% of their maximum proposed surplus recharged the modelled extents of the Marillana and Weeli Wolli Creeks (shown in Figure 4.21) from January

2018 until the end of the Iron Valley mine life. Rio Tinto (2015) have predicted a total surplus disposal to the Weeli Wolli Creek of around 232,000 kL/d and recharge to the Creek aquifer of around 60,000 kL/d.

- To predict the water level changes associated with dewatering and groundwater development in the catchment, separate from the climactic variability included in model predictions, the model was also run for a No Development Case. For this prediction, the Base Case prediction was run without any groundwater pumping or surplus water disposal.

Details of these predictions are also summarised in Table 4.7.

Table 4:7: Summary of Model Predictions

Prediction	Inclusions
Base Case	Dewatering from Iron Valley Surplus disposal from Iron Valley Operation of the TSF Climatic Variability (recharge from the Weeli Wolli Creek).
On-going ex Pit Dewatering	Dewatering from Iron Valley and dewatering south of C4 from 2020 to 2025 Surplus disposal from Iron Valley Operation of the TSF Climatic Variability (recharge from the Weeli Wolli Creek).
Surplus Disposal to DL1, not DL5	Dewatering from Iron Valley Surplus disposal from Iron Valley, including disposal east of pits S1 and S2 from 2020 onwards Operation of the TSF Climatic Variability (recharge from the Weeli Wolli Creek).
Surplus Disposal from Rio Tinto's proposed Pocket and Billiard Operation	Dewatering from Iron Valley Surplus disposal from Iron Valley Operation of the TSF Climatic Variability (recharge from the Weeli Wolli Creek). Recharge from the Weeli Wolli Creek from Rio Tinto's Pocket and Billiard Operations.
No Development	Climatic Variability (recharge from the Weeli Wolli Creek).

Model predictions required iteration between runs, to identify the most suitable operating practices – these include dewatering requirements, site water use and associated disposal requirements for excess water. This required several model runs to predict the potential for recirculation of water disposed to the Weeli Wolli Creek back to the Iron Valley mine area and the potential for additional surplus disposal.

4.8.1.2 Closure

The Iron Valley mine plan suggests that over the life of the mine, infilling will be incremental. Infilling of some mined out areas will be complete when some parts of the mine are still operational (for example at C2, C4, S1 and S2). Other mine areas will be infilled to above the pre-mining water levels at the end of mine life, with some mined out areas partially infilled (i.e. to levels below pre-mining water levels).

A post mining closure prediction was completed for a period of 90 years (required to predict recovery to final equilibrium water levels).

Details of the closure prediction are summarised below:

- Infilling of mined out areas is scheduled throughout the mine life and will be incremental in nature. The following assumptions have been made with regard to the placement of infill material in mined out areas:
    - Infilling of the S1 and S2 mine areas is competed once dewatering ceases at the end of 2019 (i.e. infilling is rapid enough such that it is ahead of water level recovery). Final infill levels are above the pre-mining water table in the S1/S2 mine area (infill level of 500 mAHD versus pre mining water table of 476 mAHD).
    - Infilling of the C2 and C4 mine areas is completed once dewatering ceases at the southern end of C4 in 2019 (and similar to S1/S2 infilling is rapid enough such that it is ahead of water level recovery). Final infill levels are above the pre-mining water table is the C2/C4 mine area (infill level of 500 mAHD versus pre mining water table of 476 mAHD).
    - Dewatering continues at C5, N1, N2, N3, E1 and E2 until the end of mine life. By 2026, C5, N1, N2 and N3 is infilled to 440 mAHD (i.e. less than the pre-mining water level). As a result, pit void lakes are simulated in C5, N1, N2 and N3. By 2026 E1 and E2 are infilled to above the pre-mining water table (assumed to be at least 450mAHD).
- In the majority of infilled areas, infill material is assumed to have similar aquifer parameters to undisturbed orebody aquifer (aquifer hydraulic conductivity and storage). In areas where the final pit intersects the modelled extend of the East Fault (in pits C4 and C5), these infilled areas are also assigned aquifer parameters of undisturbed orebody.
- It is assumed that the final landforms associated with infilled at S1, S2, C2, C4, E1 and E2 are engineered such that these areas do not receive additional rainfall recharge (incident or from creeks) after mine closure.
- The geometry of final mine voids at C5, N1, N2, and N3 is included by altering the geometry of the immediate mine area and assigning the pit "void" areas elevated values of aquifer hydraulic conductivity and specific yield (10,000 m/d and 100%). These parameters are implemented from the start of the closure prediction (i.e. January 2026 onwards).
- The dyke, located between C5 and N1, is assumed to be mined out where intersected by the final pit shell. To simulate the impact of this, the Horizontal Flow Barrier included in the calibrated model and model predictions, where intersected by the final pit shell, was removed (from layers 2 and 3). A length of 500 m was removed layer 2 and 200 m removed from layer 3.
- Once a pit void lake is predicted to develop, it is subject to evaporation equivalent to evaporation expected from an agricultural dam in the area, of 2.3 m/year. This is around 75% of Class A Pan Evaporation for the region (Department of Agriculture, 1987).
- Prior to development of pit void lakes in the voids, but after dewatering ceases, the mine voids are assumed to receive rainfall run off of 20% of annual average rainfall recharge from the pit walls (i.e. bounded by the pit crest/waste infill area). Once the pit void lake breaks through the infill surface, recharge is assigned to the pit void lake surface at 100% of average rainfall recharge.

- Initial water level conditions for the closure prediction were taken from the end of the Base Case prediction.
- Elevations assigned to the upstream groundwater inflow boundary and the downstream groundwater outflow boundary were unchanged from the Base Case prediction.
- Over the closure period it was assumed that the recharge processes observed in 2012 and 2013 would occur over the prediction period (i.e. this two-year sequence was repeated forty-five times to represent the 90-year prediction period).
- Predictions were run using time increments that reflected an elapsed time of a month, or the period of expected recharge from the Weeli Wolli Creek (i.e. 24 and 8 days).
- There was no further dewatering or surplus water disposal included in the closure prediction.
- Similar to the dewatering predictions, a No Development Case was completed to predict the water level changes associated with mine closure in the catchment. For this prediction, the No Development prediction was run for a further 90 years post mining, with no groundwater development included prior to the closure period and no changes included for infilled or mine void areas.

4.8.2 Base Case Results

4.8.2.1 Dewatering Predictions

Prediction of the water level response to pumping for selected observation locations was undertaken for the Base Case scenario – the modelled observation locations are shown in Figure 4.22. The water levels at each of the observation locations and the pit floor elevations for the selected pit, are shown in Figures 4.23 to 4.26. Water levels across the mine area are predicted to decrease consistent with ongoing pumping. In some mine areas, water levels are drawn below the projected base of mining in advance (for example advanced dewatering at C5, Figure 4.24 and N1, N2 and N3, Figures 4.25 and 4.26) consistent with the simulation of dewatering from bores. At other locations, dewatering via in-pit sumps (simulated by drains in the model) is completed, as required by the current mine plan (for example the deeper parts of C5 and E1 (Figure 4.24)).

Predicted annual average dewatering rates for the Base Case Prediction from bores, sumps (drains) and total dewatering is shown in Figure 4.27. Total maximum dewatering rates are predicted during 2016 at around 63,000 kL/d and remain above 60,000 kL/d until the end of 2018. After this time, as mining is complete at C2/C4 in 2018 and at S1/S2 in 2019 dewatering rates are predicted to decrease to around 30,000 kL/d. When mining commences at E1 and E2, dewatering rates are predicted to increase to a maximum of 45,000 kL/d in 2024.

Over the life of the mine, dewatering is sufficient to provide the highest projected water demand (15,700 kL/d) with the exception of a period between January and April 2020. During this time, dewatering and mining is assumed to be complete at C2/C4 and ongoing dewatering at other areas is not sufficient to satisfy the water demand. Over this period, advanced dewatering from E2 can be used to satisfy the water demand. However, if dewatering from other areas was maintained (for example C2/C4 and S1/S2), pumping from E2 would not be required.

Predicted dewatering rates, water demand and surplus disposal rates (as annual average rates) are presented in Table 4.8. Also presented are the rates of surplus disposal at Disposal Locations DL1, DL4 and DL5.

Table 4:8: Water Balance Summary (Annual Average Rates in kL/d)

Year	Total Dewatering	Maximum Water Demand	Surplus	Disposal to DL1	Disposal to DL4	Disposal to DL5
2016	62,707	15,700	47,007	15,010	15,999	15,999
2017	63,175	15,700	47,475	15,010	16,233	16,233
2018	60,166	15,700	44,466	15,010	14,728	14,728
2019	57,129	15,700	42,429	22,094	10,168	10,168
2020	22,263	15,700	6,563	0	3,282	3,282
2021	31,695	15,700	15,995	0	7,998	7,998
2022	30,305	15,700	14,605	0	7,303	7,303
2023	30,369	15,700	14,669	0	7,335	7,335
2024	42,756	15,700	27,056	0	13,528	13,528
2025	38,340	15,700	22,640	0	11,320	11,320

Predicted groundwater levels at the three disposal locations are shown in Figure 4.28, while the location of the disposal areas are shown on Figures 4.22 and Figure 6.1. Also shown in Figure 4.28 are predicted water levels at the three disposal locations for the No Development Case.

At DL1 water levels for the Base Case are predicted to be a maximum of 5 m greater than those predicted for the No Development Case by 2019. Once surplus disposal to DL1 ceases in late 2019 (when mining at S1 and S2 is complete), water levels are predicted to decrease in response to ongoing dewatering of Pit C5. Base Case water levels are predicted to decrease and are below those predicted for the No Development Case from mid-2020 onwards. By the end of mining in December 2025, Base Case water levels in the Weeli Wolli Creek alluvium at DL1 are 8 m less that those predicted for the No Development Case.

At DL4, water levels are predicted to increase until early 2018, when water levels are predicted to be nearly 10 m higher than water levels predicted for the No Development Case. Thereafter, surplus volumes discharged to DL4 decrease until mid-2020 and water levels are predicted to decrease by 10 m, although they are still 5 m higher than those predicted for the No Development Case. A further decrease in water levels is predicted from mid-2020 until the end of mining with water levels for the Base Case predicted to be 5 m greater than those predicted for the No Development Case. From early 2018 onwards water levels are predicted to decrease, however by the end of mining water levels at this location are still 5 m greater than the water levels predicted for the No Development Case.

At DL5, similar to DL4, Base Case predicted water levels are predicted to increase almost 15 m above those predicted for the No Development Case by early 2018. Water levels decrease from 2018 to 2019 and increase from 2019 to 2025 in response to ongoing disposal. By 2025 m water levels for the Base Case are 12 m greater than those predicted for the No Development Case.

4.8.2.2 Water Balance

The model predicted water balance at the end of mining for the Base Case Prediction and the No Development Case for the end of December 2025 are shown in Table 4.9. The model predicted water balance suggests that by the end of mine life, just over 50% of the water abstracted is removed from groundwater storage, with the remaining 15,000 kL/d resulting from groundwater inflow through the southern model boundary (i.e. the groundwater inflow has increased from 8,600 kL/d in the No Development Case to 27,580 kL/d for the Base Case). Groundwater outflow from the downstream model boundary has also increased (from 25,600 kL/d for the No Development Case to 33,350 kL/d for the Base Case), as a result of ongoing surplus water disposal to the Weeli Wolli Creek.

Table 4:9: Model Predicted Water Balances for Base and No Development Cases December 2025

	Water Balance Component	In (kL/d)	Out (kL/d)
Base Case	Storage	21,780	320
	Groundwater Inflow	27,580	
	Groundwater Outflow		33,350
	Rainfall Recharge		
	TSF Recharge	260	
	Surplus Disposal to the Weeli Wolli Creek	20,130	
	Dewatering (including excess from TSF)		36,080
	Total	69,750	69,750
No Development	Storage	17,100	100
	Groundwater Inflow	8,600	0
	Groundwater Outflow	0	25,600
	Rainfall Recharge	0	0
	Groundwater Pumping	0	0
	Total	25,700	25,700

4.8.2.3 Predicted Drawdown

Contours of model predicted drawdown at the end of each year of mine life (Year 1 to 10 or December 2016 to December 2025) are presented in Figures 4.29 to 4.38. Drawdown is calculated by subtracting predicted water levels across the model domain at the end of each year, from water levels predicted by the No Development Case at the end of the same year of mine life. Water level decreases due to dewatering are represented by positive drawdown, while water level increases, or mounding, resulting from disposal or the operation of the TSF, are represented by draw up or negative values of drawdown.

Over the life of the mine the greatest amount of predicted drawdown is predicted in the immediate mine areas. Drawdown in the mine area is predicted to increase from 30 m at the end of 2016 (Figure 4.29) to between 150 m and 200 m be the end of 2025 (Figure 4.38).

Drawdown is predicted to extend east of the mine area to the Weeli Wolli Creek and to the north and south along the alluvial aquifer. At the end of 2016, drawdown of 1 m is predicted to extend over a 14 km length of the Weeli Wolli Creek (Figure 4.29). This drawdown is mitigated in part by disposal at DL4 and DL5, where water level increases of up to 4 m are predicted. Additionally, a water level increase of up to 20 m is predicted under the TSF, as seepage saturates the low permeability bedrock below the facility.

As disposal and dewatering continue, drawdown in the Weeli Wolli Creek system is mitigated by ongoing excess water disposal. By 2019 (Figure 4.32) drawdown of between 10 m and 20 m is predicted south east of the mine, however this drawdown does not extend north due to the impact of ongoing disposal at DL4 and DL5. By 2025 (Figure 4.38) the water level decrease around DL1 is predicted to still be 10 m, but over a smaller area, closer to the model disposal location. The area decreases as pumping from the S1/S2 pits stops at the end of 2019.

4.8.2.4 Predicted surface water flow in the Creek

An analytical water balance model was prepared to predict the distance that dewatering discharge would travel downstream as surface water flow, from the discharge point. The model split the alluvium creek aquifer into a number of consecutive downstream “storage buckets”, and used a cumulative monthly time series of estimated total creek discharges to fill each bucket and track how far downstream the discharges would fill. Water losses from the model included evapotranspiration and seepage out of the aquifer, with the magnitude of these losses increasing as the discharge volume continued downstream. All excess dewatering was assumed to be discharged to a single point for the purposes of this modelling exercise. The input parameters for the model were:

- Alluvium thickness – 15 m
- Alluvium width – 400 m
- Alluvium specific yield – 25%
- Evapotranspiration – 10 mm/d
- Seepage – 12.5 mm/d

The model predicts that the seepage front from the dewatering discharge would extend by approximately 6 km downstream of the discharge point. There three discharge points that are proposed for Iron Valley (DL1, DL4 and DL5 on Figure 4.22), although location DL1 is only used for 4 years. For the majority of the mine life the discharge is split 50/50 between DL4 and DL5. As a result, the discharge at each location, will result in a wetting front that discharges 3 km downstream from each location. The total wetting front for the Iron Valley disposal will extend 6 km downstream of location DL4.

4.8.3 Results - Additional Dewatering Scenarios

The results of the additional dewatering predictions described in Table 4.7 are described below.

4.8.3.1 Extended Ex Pit Dewatering South of C2 and C4

For this prediction, the dewatering from bores immediately south of Pits C2 and C4 was extended past the end of the C2/C4 Pit life and into the period over which the pits would be infilled. The prediction was designed to assess the impact of ongoing ex-pit pumping rates, compared to in-pit dewatering rates from active pits further north (Pit C5).

Predicted dewatering rates for the Base Case and the ex-pit Dewatering Case are shown in Figure 4.39 as annual average rates. In-pit dewatering for C5 (in the Base Case) requires lower overall dewatering rates than the Extended Ex-Pit Dewatering case. The difference between total dewatering for these two cases is a maximum of 15,000 kL/d in 2020, reducing to a difference of less than 5,000 kL/d between early 2021 and the end of mine life.

4.8.3.2 Surplus Dewatering at DL5

For this prediction, once dewatering ceases at S1/S2 in 2019 and there is no surplus disposal to the Weeli Wolli Creek (to DL1), all dewatering previously disposed at DL5 is disposed to DL1. The impact of this change on predicted drawdown across the catchment is shown in Figure 4.40 and should be compared to the Base Case drawdown shown in Figure 4.38. The following comparisons can be made:

- Predicted drawdown from dewatering at Iron Valley, to the south east of the mine in the Weeli Wolli Creek area, has been reduced by the extra disposal to DL1. By the end of 2025 the extent of the 5 m and 10 m drawdown contours (along the Weeli Wolli Creek) have been reduced by 1.4 km. Additionally, the extent of the 1 m and 2 m drawdown contours to the north along the Weeli Wolli Creek have been reduced by 2.5 km and 3.5 km respectively.
- The mounding in the Weeli Wolli Creek north of DL5 has been reduced to 2 m, compared to the Base Case where an increase of up to 10 m of mounding was predicted.

4.8.3.3 RTIO Surplus Disposal

Predicted dewatering rates for the RTIO Surplus Disposal Case and the Base Case prediction are shown in Figure 4.41. As would be expected with more water flowing down the Weeli Wolli Creek, higher dewatering rates (and surplus disposal rates) are predicted for the Iron Valley mine, when compared to the Base Case Prediction. The predicted dewatering rates are not significantly impacted by RTIO surplus disposal until 2018 when the RTIO Surplus Case predicts total dewatering that is around 1,000 kL/d more than the Base Case. By 2020 the RTIO Surplus Case predicts dewatering that is around 10,000 kL/d higher. Apart from a brief peak in early 2024, associated with dewatering at E2, dewatering for the RTIO Surplus Case is around 10,000 kL/d more than the Base Case from 2023 to the end of mine life in 2025. The increase in dewatering will not significantly impact operational dewatering, varying between an extra 5 - 30% of the Base Case dewatering requirement.

Predicted water levels at disposal locations DL1, DL4 and DL5 for the RTIO Surplus Disposal Case and the Base Case are presented in Figure 4.42. At all disposal locations the predicted water level increases rapidly after the start of the RTIO surplus disposal. At DL1 the predicted water level is 20 m higher for the RTIO Surplus Disposal case and 15 m higher at DL4 and DL5. The ongoing disposal is predicted to result in groundwater fed flows in the Weeli Wolli Creek (i.e. as predicted discharge from the aquifer to the Weeli Wolli Creek boundary condition as groundwater levels reach the Weeli Wolli Creek bed elevation). Over the period of RTIO's disposal (2018 to 2025) this discharge is predicted to be on average 30,000 kL/d. It is noted that there is significant uncertainty in this estimate as the characteristics of the Weeli Wolli Creek boundary condition have not been calibrated. This is discussed further in Section 4.9.

Contours of model water level drawdown/mounding at the end of mine life (December 2025), taking into account Rio Tinto's disposal, are presented in Figure 4.43. For the RTIO Surplus Disposal Case, drawdown from dewatering at Iron Valley is less than for the Base Case, being limited to the areas to the west of the Weeli Wolli Creek. i.e. no drawdown in the Weeli Wolli Creek alluvium. However, over a significant length of the Weeli Wolli Creek, a water level increase of 10 m is predicted, with an increase of up to 20 m to the east of the Northern pits. As outlined above, this water level increase is constrained as groundwater levels reach the modelled ground elevation and there is groundwater discharge to the Weeli Wolli Creek.

4.8.4 Closure Predictions – Base Case

Once dewatering and excess water disposal stops at the end of mining, water levels start to recover back to pre-mining conditions. Predicted water level hydrographs for the life of the mine (January 2016 to December 2025) and the closure period (January 2026 to December 2115) are shown at key observation locations across the mine area (including disposal locations) in Figures 4.44 to 4.48 (observation locations are shown in Figure 4.22).

The predictions show that when dewatering ceases at the end of mine life (at the end of 2025), water levels across the mine area recover rapidly, with the majority of groundwater recovery completed by mid-2028. The following observations are made regarding predicted water levels across the mine:

- Post mining water level recovery back to equilibrium conditions, is influenced by the removal of the dyke flow barrier during mining and by the development of pit lakes in those cases where in-filling is to levels below the recovered groundwater level. In all cases, water levels to the south of the dyke, recovery to a deeper post recovery level, due to the removal of the barrier, which previously dammed up flow from the south to the north. However, to the north of the dyke, the removal of the barrier results in shallower post mining water levels than before mining started.
- In the mine areas associated with Pits C1, C2, C3, C4 and C5 (Figures 4.44 and 4.45) water levels recover rapidly once dewatering ceases. Once predicted water levels reach the infilled level of the C5 void (440 mAHD) in mid-2028, the rate of groundwater recovery is predicted to decrease. The remainder of the groundwater recovery of 10 to 15 m, is predicted from mid-2028 to the end of 2115. Final equilibrium water levels in the C1 to C5 areas are around 25 m lower than those predicted for the No Development Case, due to ongoing evaporation from the combined N1/N2/N3/C5 pit void lakes and the lack of the dyke flow barrier.
- Predicted water levels for the N1, N2 and N3 mine areas are shown in Figures 4.46 and 4.47. Water levels are predicted to recover rapidly until 2028, and are predicted to recover to be above the pre-mining / No Development levels. This increased recovery is due to the removal of the dyke between the C and N mining areas. Predicted water levels in the N1/N/N3 mine areas are around 15 m higher than those before mining started.
- Predicted water levels in the E1 and E2 pits (shown in Figure 4.45 and 4.46 respectively) are predicted to recover rapidly after the cessation of dewatering. At E1, water levels are predicted

to recover from 2028 onwards, with full recovery to equilibrium levels complete by 2035. At E2, water levels are predicted to recover 100 m by early 2027, with further recovery to final equilibrium levels predicted by 2035. Final equilibrium water levels for E1 and E2 are predicted to be similar to water levels predicted for the No Development Case.

- Predicted water levels for the S1 and S2 mine areas are shown in Figure 4.47. Water levels are predicted to recover rapidly after the end of dewatering in 2019 and similar to other areas water levels are predicted to recover further until 2028. Although the S1/S2 mine area is infilled, equilibrium water levels reached in 2028 are around 13 m lower than the No Development Case water levels.
- Predicted water levels at DL1, DL4 and DL5 are shown in Figure 4.48. Water levels are predicted to recover to new equilibrium levels by 2040 at DL4 and by 2055 at DL1 and DL5. Equilibrium water levels show the same seasonal variation as No Development water levels, however water levels are predicted to be around 4 m lower at DL1 and 1 m lower at DL4. Equilibrium water levels at DL5 are predicted to be similar to No Development water levels.

Predicted water levels contours at the end of 2115 are shown in Figure 4.49. Predicted water levels generally show the resumption of groundwater throughflow conditions in the catchment. In the area of the C5/N1/N2/C3 void, there is still groundwater outflow from the northern part of the mine void, so the open pits do not form groundwater sinks.

The model predicted water balance for the end of 2115 for the No Development and Base Case predictions is presented in Table 4.10. Predicted flow components for storage change and groundwater outflow are comparable for both cases. However, for the Base Case the evaporation from the pit void lake and the excess water disposal to the Weeli Wolli Creek, results in an increased groundwater inflow into the modelled catchment and an increased outflow through the Creek alluvium, compared to the No Development Case.

Table 4:10: Model Predicted Water Balances for Base and No Development Cases - December 2115

	Water Balance Component	In (kL/d)	Out (kL/d)
Base Case	Storage	17,100	
	Groundwater Inflow	13,900	
	Groundwater Outflow		24,800
	Rainfall Recharge	1,200	
	Evaporation		7,500
	Total	**32,200**	**32,300**
No Development	Storage	17,200	100
	Groundwater Inflow	8,600	0
	Groundwater Outflow	0	25,700
	Rainfall Recharge	0	0
	Total	**25,800**	**25,800**

4.9 Uncertainty Analysis

The model used to complete the dewatering and closure predictions above, was developed and calibrated using the data available and is based on the current understanding of the hydrogeological system. To investigate some of the uncertainty in the model predictions, associated with the assigned model parameters, a limited uncertainty analysis was completed. This involved changing key parameters in both the steady state and transient model calibrations and completing updated Base Case predictions. The uncertainty runs completed are summarised in Table 4.11 below.

Table 4:11: Summary of Uncertainty Runs

Uncertainty Case	Description
1	Specific yield of orebody aquifer increased from 5% to 10% Specific yield of fault east of orebody increased from 15% to 20%
2	Hydraulic conductivity of scree increased to 0.1 m/d from 0.01 m/d Specific yield of scree increased to 5% from 1%
3	Hydraulic conductivity of orebody aquifer increased from 3 m/d to 5 m/d. Hydraulic conductivity of sub-mineralised orebody aquifer increased from 0.5 m/d to 1 m/d.
4	Hydraulic conductivity of East Fault decreased from 100 m/d to 50 m/d

The uncertainty analysis completed did not involve recalibration of each model. For most of the cases, the calibration performance was generally very similar to the calibrated case (with the exception of Uncertainty Cases 1 and 4). Full details of the changes made to the calibrated models and the results of model calibration performance are given in Appendix B.

The Base Case model was adjusted taking into account the changes listed in Table 4.11 and the dewatering rates were adjusted to achieve the dewatering required, with a corresponding adjustment of surplus disposal rates. Predicted annual average dewatering rates for the Base Case and the four uncertainty runs are presented in Figure 4.50 and provide an estimated range of possible dewatering rates.

As would be expected, when aquifer parameters are increased (higher specific yield or hydraulic conductivity), there is a corresponding increase in total dewatering required. The greatest increases in dewatering are predicted for Uncertainty Runs 1 and 3, the cases in which aquifer storage and hydraulic conductivity parameters are increased to values higher than those supported by investigations to date. The greatest increase in dewatering rates is predicted in 2020 and 2024 with maximum total differences in these two years predicted of 16,000 kL/d and 10,000 kL/d (for Run 1). For Uncertainty Run 2, dewatering is predicted to increase by around 8,000 kL/d in 2024, as mining below the water table proceeds at E2, which unlike the other mining areas, is in direct contact with the shallow scree.

For Uncertainty Run 4, which included a reduction in the aquifer hydraulic conductivity assigned to the East Fault, a significant decrease in dewatering rates is predicted. This result suggests that if there is reduced hydraulic connection along the East Fault to the Weeli Wolli Creek, then ongoing dewatering rates could be significantly lower than the currently predicted rates. It is noted however that the current model calibration is not supported by the assignment of a lower value of hydraulic conductivity of the fault (refer to Appendix B). Despite this however, this result shows the impact on predicted dewatering in the event that the East Fault was less permeable than assumed in the Base Case model predictions.

4.10 Model Limitations and Assumptions

The groundwater flow model was developed consistent with the available data and includes the results of hydrogeological investigations to date. As with all models, there are limitations associated with data availability, conceptualisation and representation of hydrogeological processes. The model includes the known features of the system and is calibrated to available data. However, the predictions are simulations based on available information, including the current mine plan.

The following is a list of model limitations which could be improved as part of future work programs:

- The model was set up to predict dewatering requirements for the Iron Valley mine and prediction regional water level changes. The model does not include detailed local scale features (for example small faults and fractures zones), which may influence short term dewatering rates. In the event that these features are identified to be important impacts on dewatering requirements, it is recommended that these features are added to the groundwater model.
- Recharge to Weeli Wolli Creek is simulated via recharge, and when required the River boundary conditions (in Modflow SURFACT) is used to simulate groundwater fed flows from the underlying aquifer to the Weeli Wolli Creek. A key parameter in this boundary conditions is the river bed conductance. This parameter has not been calibrated and is assigned a value such that the only resistance to groundwater flow is the underlying aquifer. If more reliable estimates of groundwater fed flows into the Weeli Wolli Creek are required, it is recommended that the stream/aquifer interaction boundary conditions in the model are calibrated.
- The calibration of the model to transient pumping data, required the inclusion of a transmissive fault located just to the east of the orebody aquifer. This fault has been identified as part of geotechnical investigations, but it has not been targeted in hydrogeological investigations.

A number of assumptions have been included in model simulations as outlined below:

- The rate of groundwater inflow from the southern model boundary results from ongoing disposal of surplus dewatering from other mining operations into the Weeli Wolli Creek. It is assumed that these groundwater conditions persist during the proposed operational period (2016 to 2025) and over the closure period (2026 to 2115).
- The hydraulic conductivity and specific yield of infill material is assumed to be the same as the in situ properties of the orebody aquifer. This assumption has been made in the absence of any site specific information for the hydraulic properties of infill material.
- Recharge to the infilled areas and final pit voids will vary depending on final pit catchments and run off characteristics of the pit voids and walls. The current prediction includes recharge from the pit crest catchments for open and partially infilled voids and no additional rainfall recharge for voids infilled to above the pre mining water table.

- Evaporation from pit voids lakes is assigned at a rate consistent with agricultural dams. This value may be more or less depending on in-pit conditions.
- Long term closure predictions do not account for potential climate change and the subsequent impact on evaporation and rainfall conditions into the future.
- A low permeability dyke is included between the N1/N2/3 and C5 pits. It is assumed that this dyke is in place during operation, but that dewatering maintains water levels to the south of the dyke (in C5) below the base of mining, until the end of mine life. Once mining and dewatering is complete, it is assumed that the dyke has been mined out across the open pits and that a continuous mine void is formed from the mined out areas of C5 and N1/N2/N3.

5 Dewatering System

The numerical modelling has allowed the prediction of the pumping required to keep the open pits dry during mining, with a combination of ex-pit bores, in-pit bores and in-pit sump pumping. The proposed conceptual dewatering systems for each of the pit areas are described below. Note that pipe and pump selections are conceptual, and have to be refined during a more detailed design phase when individual bore locations and pumping rates are known.

A conceptual design for the proposed excess water disposal option is provided in the section below.

5.1.1 Creek Discharge Locations and Volumes

All groundwater dewatering from the Northern, Centre and Eastern deposits will be pumped to the centrally located mine turkeys nest, from where water can be pumped to supply mine-site demand points. The turkeys nest will provide buffer storage, with the top part of the storage used to pump excess dewatering to the discharge points DL4 and DL5 (Figure 5.1).

Dewatering from the South deposit is proposed to be discharged directly to creek discharge point DL1 (i.e. without supplying water to the turkeys nest).

Table 4.8 shows the predicted annual average excess water from the dewatering system. In 2017, the highest annual average rate of excess dewatering will be generated at the mine site (~47,500 kL/d). This also coincides with the period predicted to require the highest average annual discharge rate from the mine turkeys nest, which is a maximum rate of 32,400 kL/d (375 L/s). A nominal allowance of an additional 20% flow has been applied to the average annual rate, to allow the system to have capacity for short-term increased pumping rates. As such, the adopted design capacity for the excess water pumping system from the mine turkeys nest is 38,900 kL/d (450 L/s).

5.2 Conceptual Engineering Design

5.2.1 S Deposit Pit (S1-S2)

Pumping within the S Deposit pit is proposed to occur from two areas. In the vicinity of area B5 (refer Figure 5.1), a total pumping rate of 15,000 kL/d (175 L/s) is required from mid-2016 until the end of 2019. This will likely require four in-pit bores (with assumed capacity of up to 50 L/s each) to be installed to achieve this pumping rate. For the last half of 2019, pumping from area B6 will also be required at an additional pumping rate of 15,000 kL/d. Pumping from a further four in-pit bores is likely to be required to achieve this.

The discharge from these dewatering bores is proposed to be directed to a creek line adjacent to the S1/S2 pit (discharge point DL1 shown on Figure 5.1). Conceptually, a bore spur pipeline will run from each of the dewatering bores to a trunk main installed from the pit crest to the discharge point. Given that the specific location of the bores has not been confirmed, an allowance of 300 m of pipe per bore spur has been made for costing purposes. Each bore spur will consist of 315DN PN25 PE100 pipe. The PN25 pipe has a pressure rating (de-rated for temperature) of approximately 210 m. The maximum pit depth at S1/S2 is approximately 150 m – as a result, the PN25 pipe should be suitable for use within the pit for the life of the pit (accounting for additional pipe friction losses).

Outside the pit footprint, a common 500DN PN10 PE pipe is required to transfer the dewatering to the creek discharge point located on the edge of the lease boundary. Ideally the water should be piped to the creek line for infiltration into the alluvial aquifer system, but no access across the adjoining tenement has yet been finalised.

Nominally, 110 kW submersible bore pumps have been adopted for capital costing purposes. Refined pump selections would be required to be completed once bores are located, drilled and pump tested.

5.2.2 C Deposit Pit (C1 – C5)

Pumping from four areas within the C Deposit pits is proposed. These areas are:

- B1 – south of C Deposit pit (ex-pit)
- B8 – within C2/C4
- B3 – within C5 pit
- B2 – within C5 pit

An ex-pit dewatering trunk main is proposed, which will run along the east side of the pit footprint to supply a turkeys nest (mine water storage turkeys nest). Spur pipelines from each of the dewatering bores will tie in to this trunk main pipeline. Given the predicted rate of pumping required to dewater the pit, the trunk main will be required to consist of 500DN PN10 PE pipe. This will have capacity for the predicted peak C Deposit dewatering rate of 44,000 kL/d (510 L/s).

Assuming pumping rates of 50 L/s from each of the dewatering bores, spur pipelines from each bore will be required to be 315DN pipe. Spur pipes from in-pit bores would be constructed from PN25 pipe, while a lower pressure class (say PN10) could be used for the ex-pit pipe spurs.

Pumping area B1 requires a total pumping rate of approximately 25,000 kL/d (290 L/s), and will be required to come from six ex-pit bores (assumed 50 L/s per bore). Nominally, 110 kW submersible bore pumps have been adopted for capital costing purposes. Pipework for this borefield would remain outside of the pit footprint.

Pumping area B8 (C2/C4) requires a pumping rate of 15,000 kL/d (175 L/s), and therefore it is assumed four in-pit bores will be required. Nominally, 110 kW submersible bore pumps have been adopted for capital costing purposes. Pit C2/C4 is planned to have a pit depth up to 180 m, and therefore PN25 pipe should be suitable for the life of the pit.

Pumping areas B2 and B3 (C5) each initially require a single pump capable of producing approximately 2,000 kL/d (25 L/s). These bores are planned to be used between mid-2016 and December 2019. At the end of 2019, the planned pit depth is only 40 m, such that the PN25 pipe proposed from each bore has suitable pressure rating. 200DN PN25 pipe is proposed for the bore spur pipelines to connect these smaller capacity bores to the trunk main.

From January 2020 onwards, the required dewatering rate from C5 increases substantially, to reach a maximum rate of dewatering of 33,000 kL/d (380 L/s). At this stage, dewatering of other areas of the C Deposit has ceased. Dewatering from C5 at this rate may require a combination of sump pumping and bore pumps. A capital cost for the dewatering infrastructure required from 2020 onwards has not been included, but the ex-pit trunk main has been sized with capacity for this flow rate. Note that by the end of 2024, the C5 pit depth is planned to be 220 m, such that the static lift for pumping out of the pit base will exceed the pressure capacity of PN25 PE pipe (maximum pressure class PE pipe). If pumping from the pit base were to be required, a re-lift pump station would be required to enable pumping without over-pressurising the PE pipe (and to keep within the pump head capacity of any sump pump units). The timing, location and layout for this future system would be determined in a more detailed design phase, and has not been included in the capital costs.

5.2.3 N Deposit Pit (N1-N3)

Pumping is proposed from two areas to dewater the N Deposit Pit. The two areas are B11a (ex-pit bores) and B12 (in-pit bores).

The B11a ex-pit dewatering borefield is required to pump from mid-2016 and December 2021, before it is rested and restarted again to pump through 2024/2025. For the initial period of use, the required dewatering rate is predicted to be approximately 4,000 kL/d (45 L/s). This could potentially be achieved by a single ex-pit bore. A 315DN PN10 spur pipe would be required. Any changes that may be required to the pumping infrastructure from 2024 onwards to accommodate site rehabilitation and mine closure have not been included in the provided capital cost estimates.

The B12 borefield (in-pit) will operate from 2022 onwards. The peak dewatering rate that is predicted to be required from this borefield is 2,000 kL/d (23 L/s). This is assumed to be pumped from a single bore. The N Deposit pit is planned to be mined to a depth of approximately 200 metres below ground level (mbgl) by the end of 2025. Given the required dewatering rate and pit depth, a 200DN PN25 PE pipe should be suitable for the life of the pit. Note that 200 m of static lift is close to the pressure capacity of PN25 PE pipe, and therefore additional pipeline friction losses that may occur from possible changes to the dewatering system may result in additional future infrastructure costs (such as relift pump stations) which have not been accounted for in the provided capital costs.

Spur pipelines from bores at B11a and B12 will join to from a common pipeline that will discharge to the mine turkeys nest. The common pipe section would consist of 315DN PN12.5 PE pipe, given the relatively low total dewatering rate required from N Deposit Pit.

5.2.4 E Deposit Pit

Total dewatering required from E Deposit is initially required between the start of 2017 and the end of 2021, before it is rested and restarted again to pump through 2024/2025. Dewatering may be required from both dewatering bores and sump pumping, although for costing purposes it is assumed only bore pumping will occur. The required pumping rate for the initial pumping period (to 2021) is up to

7,000 kL/d (80 L/s), but increases to up to 10,000 kL/d (150 L/s) during 2024/2025. The pit depth is generally less than 100 mbgl up to the end of 2021, however it increases to up to 200 mbgl by 2025.

The dewatering system up to the end of 2021 is assumed to comprise of two dewatering bores with capacity to operate at up to 50 L/s each. A single 315DN PN25 PE pipe would run from each bore to outside the pit, where they would join into a common 400DN PN10 PE pipe to discharge to the mine turkeys nest.

5.3 Discharge Infrastructure

AQ2 understands that there is already a water supply system on site that includes some turkeys nest storages. However, we have assumed that a new mine turkeys nest would be required when the dewatering system is operational and have included this in our capital cost estimates. The capacity for this proposed new mine turkeys nest is indicatively 5 ML.

From the mine turkeys nest, the excess dewatering is to be discharged to two discharge points, located at DL4 and DL5 (refer Figure 5.1). The excess water is to be split evenly between these two discharge points (simultaneous discharge to each). As such, a pipeline capacity of 19,500 kL/d (225 L/s) is required to each discharge point.

It is assumed that water will be pumped from the mine turkeys nest to the discharge points. Given the discharge rate required for this system, a separate pump station has been assumed to be required to each discharge point. Common pump units for each discharge pipeline have been assumed to allow interchangeability between the discharge systems. Indicatively, a Sykes CP300i diesel pump unit could be used at each pump station to achieve the conceptual duty point of 225 L/s vs 40 m head. During a more detailed design phase, consideration should be made for the option of pumping to the discharge points directly from the dewatering bores by bypassing the mine turkeys nest, when the turkeys nest is full (and saving the cost of pump units at the turkeys nest).

The discharge pipelines between the diesel pump stations and DL4 and DL5 have been conceptually sized to be 400DN PN12.5 PE pipe. Although this pipe diameter is relatively small for the required flow rate, it is suitable given the short pipeline lengths required and generally falling topography between the indicative turkey’s nest location and the discharge points.

5.4 Dewatering and Dewatering Discharge System Capital Costs

Capital cost estimates for the dewatering systems are summarised in Table 5.1 below and provided in more detail in Appendix C. The total cost is in the order of $14.7 M.

Table 5:1: Capital Cost Estimate

Area	Bore fit-out	Pipework	Turkeys Nest	Discharge System	Total
S Deposit	1,670,000	750,000			$2,420,000
C Deposit	2,364,000	1,439,000			$3,803,000
N Deposit	573,000	175,000			$748,000
E Deposit	441,000	323,000			$764,000
Water Disposal System			282000	1420000	$1,702,000
				TOTAL	**$9,437,000**
Preliminaries					$944,000
EPCM					$1,416,000
Contingency					$2,831,000
				GRAND TOTAL	**$14,628,000**

Please note the following:

- Dewatering may be required from a combination of both bore pumping and pumping from pit base sumps. For this assessment, it is assumed that all dewatering is from dewatering bores.
- Capital costs are high level estimates, as numerous design inputs are currently undefined (bore locations, number of bores, individual bore pumping rates, pumping water levels, pipeline routes etc.). As such, cost estimates provided for individual line items are based on experience from similar past projects and not based on supplier quotes.
- Capital costs assume new infrastructure for each pumping location. There may be opportunities to re-use some dewatering infrastructure between dewatering systems.
- Capital costs exclude the cost of changes to the dewatering system requirements as the pits develop (such as potential requirements for relift pump stations and dewatering bore pump changes).
- All in-pit pipelines have been assumed to consist of PN25 PE pipe, which is the highest pressure capacity PE pipe, which in most of the pits generally provides some contingency in the pressure capacity of the pipe to cover minor pipe scratches, increased flows etc.
- Capital costs exclude operating costs, such as power and maintenance costs, plus costs for the replacement of pumping infrastructure due to damage or large changes to the system operating requirements (flow and pressure, noting the adopted pressure rating of the in-pipe discussed above).
- For the in-pit dewatering borefields, the capital costs include an allowance for 20% more dewatering bores to account for reduced bore utilisation that may occur due to mining activities.
- All disposal locations are at the tenement boundary as shown in Figure 5.1. The disposal locations utilised in the numerical groundwater modelling were further to the east in the Weeli Wolli Creek (shown in Figure 4.22).

6 Excess Water Disposal

6.1 Background

The Water Balance indicates a surplus of dewatering over mine use for the whole mine life during the below water table mining. The numerical modelling was undertaken based on the assumption that excess water would be disposed of to the Weeli Wolli Creek. This assumption was based on an assessment of all the possible options available, as discussed below.

The surplus water will need to be disposed of, in the most practical and environmentally acceptable manner. DoW's aims for mine water management (DoW, 2013a) include:

- Optimising the use of mine dewatering surplus, either on site or off site, to maximise efficiency and reduce adverse effects of releases to the environment.
- Minimising the adverse effects of the abstraction and release of water on environmental, social and cultural values.

DoW (2013b) have listed a hierarchy of disposal alternatives, as follows:

- Use to mitigate impacts.
- Use on site.
- Use by others off site.
- Reinjection.
- Release to the environment.

These options are discussed below, with a comparison between the different options shown in Table 6.1.

6.2 Disposal Options

6.2.1 Mitigation of mining impacts

During the mine life, water will be used on site to help ameliorate mining impacts during normal operational practices. These uses include:

- Water for dust suppression
- Water to assist in plant regrowth on rehabilitated areas

Additionally, disposal practices (discussed below) can be used to reduce site specific impacts caused by the mine dewatering. Potential impacts include inflow from the Weeli Wolli Creek system into the cone of depression caused by mining, as well as the potential movement of saline water from below the Fortescue Marsh, towards the cone of depression. Both of these impacts could be reduced, by discharging water into the impacted zones (i.e. downstream of where the East fault intersects the Creek and between the saline water and the mine site).

6.2.2 On site use and storage

As discussed in the Water Balance section, water will be used on site for dust suppression, to top up losses from the beneficiation plant, and for domestic use in the offices and at the mine camp.

There is limited potential for any storage of water on site, with the exception of “dirty” surface water runoff after rainfall events. The mine plan does not allow any of the open pits to be used as storage dams, with waste rock backfilling of mined out open pits proposed.

6.2.3 Offsite use by others

All of the existing adjacent mines have a similar excess water disposal problem, with approximately 19 GL/annum of excess water being discharged into the Weeli Wolli Creek, upstream of the Iron Valley mine site. This disposal, started in October 2007 and has raised water levels in the alluvium downstream of the two disposal areas, with permanent stream flow now occurring for a distance of between 23 km downstream from the disposal sites (which is opposite the southern-most extents Iron Valley mine site). At this stage, there do not appear to be any adjacent users who might want to utilise the excess from the Iron Valley mine.

6.2.4 Reinjection

Reinjection into aquifer systems requires suitable aquifer conditions, namely:

- Suitable aquifer permeability to be able to accept the injected flow rate necessary.
- Suitable available storage to accept the volumes that need to be disposed of.
- Acceptable water quality (both in terms of compatibility between the injected water and the receiving aquifer, and in terms of potential chemical and physical clogging of the injection bores/aquifer system).

6.2.4.1 On site

Injection within the BC Iron tenement is not seen as viable, as the shallow water levels mean that limited space exists for injection, while the limited size of the tenement, means that any injection will result in recycling of water back to the open pits being dewatered. This poses unacceptable operational problems.

6.2.4.2 Off Site

Away from BC Iron, there are areas where suitable aquifer conditions may exist. The closest of these are the Tertiary deposits making up the alluvial fan at the mouth of the Weeli Wolli Creek, where it exits into the Fortescue River basin. Dogramaci et al (2015) have suggested that the area has a very high aquifer transmissivity. As this area falls outside of the BC Iron tenement, access to the land will have to be negotiated with current landowners. Further the distances required to pump the water would make the option economically infeasible.

6.2.5 Irrigation.

The irrigation of pastures by Rio Tinto, using their excess water from the Marandoo mine is well documented. However, BC Iron does not have access to tenements in the vicinity of the mine, where irrigation could be contemplated. Discussions with DoW staff involved in the Water for Food programme (Alastair Hoare, pers com, 2015) has indicated that there are no other organisations considering irrigation in this area either.

6.2.6 Discharge to Weeli Wolli Creek system

It has been common practice in the past to dispose of this abstracted groundwater by discharging it to surface water systems. This often creates environmental issues, because the quality of the groundwater can be significantly different to that of the receiving surface water, or it can change the flow regime of the surface water system (Dow, 2011). In the case of the Weeli Wolli Creek, disposal of excess water into the Creek since 2007, has changed part of the Creek from non-perennial, to perennial with stream flow noted during a site inspection adjacent to the southern extent of BC Iron's tenement in November 2015.

Dewatering of the Iron Valley open pits will induce some flow (via the fault) from the Weeli Wolli alluvium. Discharge of excess water back into the creek system would help to reduce any impacts caused by the dewatering. To minimise the development of new ecosystems related to the discharge locations, it is possible to vary the scheduling of the discharge. For example:

- Discharge from the dewatering of the South pit could be at the tenement boundary adjacent to the Weeli Wolli Creek (Figure 5.1)
- Discharge from the Eastern pit could be to the Creek bed, at the tenement boundary, with flow to the adjacent Weeli Wolli Creek.
- Discharge from the Central and Northern pits could be rotated between a location to the north of the mine site into the Weeli Wolli Creek and the East pit discharge point.

In essence, this excess water discharge would be returning water lost out of the Creek due to the mine dewatering. During the mine life, initial dewatering removes water stored in the orebody aquifer, but once this storage is removed, further pumping removes inflow from the surrounding aquifers, mostly from the Weeli Wolli system, due to the connections via the East Fault and northern extension of the orebody. Over the life of the mine, the total dewatering, is 145 M kL, while the total inflow from the Weeli Wolli (via the East Fault) is 105 M kL. After mine use and evaporation losses, the discharge put back into the Creek is 90 M kL.

6.2.7 Discharge to fluvial fan environments

Off the BC Iron tenement, the non-perennial creek courses on the alluvial fan to the north-east of the mine site could be utilised as discharge points, with a rotation between different creeks undertaken, to limit the development of new ecosystems. The Tertiary sediment underlying these creeks is believed to be highly transmissive (Dogramaci et al, 2015), with water level depths in excess of 20 m below surface, providing some unsaturated storage potential.

6.3 Best Option

Comparison between these different options has been tabulated, to allow selection of the most suitable option. Water use on site and discharge to the Weeli Wolli Creek system are seen as the two best options, based on the factors addressed.

Table 6:1: Comparison Between Excess Water Discharge Options

Option	Pro's	Con's	Operational and cost suitability	Environmental suitability	Overall Rating
On site use	• No need to develop separate water supply • Helps to decrease excess for disposal	• Usage below total supply	• High	• High	• High
Off-site use	• Removes any discharge impacts if all water used	• No users identified	• Low	• High	• Mod
Re-injection on site	• On tenement • Low capital cots	• No available aquifer storage • Recirculating of discharge to dewatering bores	• Low	• High	• Mod
Re-injection off site	• Hydrogeology appears suitable	• Off BC Iron tenement • High development and operating cost	• Low	• Mod	• Mod
Crop irrigation	• Food/fodder generation	• No on-tenement land available • High development and operating costs	• Low	• Low	• Low
Discharge to Weeli Wolli Creeks	• Disposal sites available on tenement or miscellaneous licenses • Greatest versatility in disposal locations/scheduling • Low development and operating costs • Possibility to ameliorate dewatering impacts and saline intrusion risks	• Possibility of developing new ecological systems where long term creek disposal takes place	• Mod	• High	• Mod-High
Discharge to creeks on alluvial fan	• Lower operating costs compare to re-injection • Might assist with management of any ingress of the saline wedge	• Off BC Iron tenement • Possibility of developing new ecological systems if long term disposal takes place to one creek.	• High	• Mod	• Mod

7 Mine Water Supply

The modelling predictions indicate an excess water surplus throughout the mine life. As a result, assessment of alternative water supplies for the mine is not necessary.

The current mine camp location (Phil's Creek) is expected to be utilised as the future camp for the BWT mining. The camp has its own licensed water supply bore, so no additional supplies will be required.

8 Dewatering and Excess Water Disposal Impacts

The numerical modelling has indicated that a cone of depression in the regional groundwater levels will occur due to the dewatering which is required to keep the open pits dry during mining. Excess water disposal, together with seepage out of the TSFs, will result in a mounding of water levels in some areas (see Figure 4.38 for water levels at the end of mining in 2025).

8.1 Impacts on current stream flow

The upstream disposal of excess water is resulting in surface water flow in the Weeli Wolli Creek adjacent to the southern end of the BC Iron tenement. The mine dewatering, and the inflow of water from the Weeli Wolli Creek, along the East Fault to the mine site, will result in the lowering of water levels in the Weeli Wolli Creek, such that surface water flow will cease. However, should the disposal from the Pocket and Billiard mine take place, this surface water flow will be re-instated.

8.2 Impacts on GDEs due to dewatering

The drawdown/mounding details from the numerical modelling have been assessed by:

- Wetland Research Management (WRM, 2016) – evaluation of impacts on the Creek ecology
- Astron Environmental (2016) - assessing potential impacts on groundwater dependent vegetation (GDV).
- Bennelongia (2012) - an assessment on the stygofauna/troglofauna.

WRM (2016) reported that the dewatering discharge entering within the Creek, will alter the current surface water flow regime, from isolated permanent and semi-permanent pools and episodic surface flows, to permanent surface and sub-surface (alluvial / hyporheic zone) flows. As a result, the diversity and abundance of micro-invertebrate assemblages may be reduced in the zone where surface flow is generated. The saturation of the coarse alluvium will increase the extent of available habitat for hyporheic fauna, which in turn lead to the increased presence of short range endemic (SRE)[1] species, such as stygal[2] amphipods, isopods and syncarids (crustaceans) of high conservation value in the hyporheic zone downstream of the discharge outlet. The development of permanent surface flows due to the dewatering discharge, would likely cause an increase in habitat heterogeneity, and diversity of macroinvertebrate and fish fauna along the area of permanent stream flow. This increase in diversity is likely to come at the expense of those that were occurring naturally. At the cessation of pumping, any ecological values enhanced by the provision of permanent flows will be lost.

[1] Short range endemic as defined by Harvey (2002): a species occupying an area of less than 10, 000 km^2.

[2] Taxa which are obligate inhabitants of aquatic subterranean environments, such as aquifers or the hyporheic zone. Common morphological adaptations to subterranean environments include loss of eyes and pigmentation, reduction in body size, and the lengthening of appendages (e.g. antennae).

Astron's study (2016) found that groundwater dependent vegetation was found along the entire inspected length of the Marillana/Weeli Wolli Creek system, mostly along creek banks and in creek beds but also within floodplain areas up to 1.5 km wide. They found that the southern portion of the Marillana/Weeli Wolli Creek system, where excess water disposal has been ongoing for over 15 years, was clearly wetter and more highly productive than the drier northern portion of Weeli Wolli Creek. This excess water disposal was noted to be a major confounding influence with regard to assessing the groundwater dependence of existing vegetation.

Astron (2016) defined a large area of vegetation at moderate to high risk from either drawdown or discharge (a total of 1,561 ha). Moderate to high drawdown risk was confined to the southern portion of the Weeli Wolli Creek and the central drainage line within the tenement, while moderate to high discharge risk was confined to the northern portion of the Creek.

Impacts identified due to drawdown in the southern portion, are removed should Rio Tinto's disposal from Pocket and Billiard mine take place. However, it is likely that additional discharge from the Iron Valley Project would have a cumulative effect on mounding that would likely increase the discharge risk and expand the moderate to high risk zones across a larger area than presented in the Base Case scenario.

Bennelongia (2012, page i) reported that "twenty-two of the 23 stygofauna species recorded at Iron Valley were recorded from within the proposed drawdown cone, importantly all but two of these species are known from elsewhere. The remaining two species potentially have more localised ranges. These species, the ostracod Meridiescandona sp. BOS 171 and, to a lesser extent, the syncarid Bathynella sp. may be potentially threatened by drawdown. Meridiescandona sp. BOS 171 was collected from five drill holes within the Iron Valley Project, while Bathynella sp. was collected from a single hole. However, it is likely that both species exploit the habitat connectivity between the Project and surrounding areas in the same way as demonstrated by most of the stygofauna species at Iron Valley".

8.3 Impacts on aquatic systems/vegetation due to Excess Water Disposal

The Astron (2016) work covered above, has indicated that certain communities in the southern Weeli Wolli Creek area appear to have flourished as a result of the ongoing excess water disposal, while others (in areas where there may have been periods of excess water disposal in the past), are not in as good a healthy condition. The mounding presents a moderate to high discharge risk to GDVs along the norther section (Astron, 2016).

8.4 Impacts on Water quality in Weeli Wolli Creek due to excess water disposal

The mine dewatering and excess water disposal, will result in groundwater being disposed of to the Creek that has a marginally different water chemistry to that in the shallow Creek alluvium, or surface water flows events. As discussed in Section 2.3.5.1 the groundwater from the Iron Valley mine site is very similar to the surface water flow sampled in the Weeli Wolli Creek and better than groundwater samples collected from the shallow alluvium in the Creek system.

The disposal of the excess water to the Creek system, is not therefore expected to have a material impact on the water quality of the system.

8.4.1 Acid Mine drainage

The geochemical assessment of the mine waste rock material and material that will be encountered in the open pits (Soil Water Group, 2015b) has not identified any acid mine drainage (AMD) or metalliferous drainage (MD) concerns. Shales of the Mount McRae Formation (which can cause AMD issues), will not be encountered during the mining.

8.5 Cumulative Impacts

The impact that the Iron Valley mine would have on the adjacent environment, especially the Weeli Wolli Creek system, need to take cognizance of other existing or proposed external impacts on the creek.

The history of water discharge to the Weeli Wolli Creek system is summarized as follows (Rio Tinto, 2012):

- May 1992 - discharge of surplus water from the BHPBIO Yandicoogina mine operation into Marillana Creek.
- 1998 - RTIO releasing surplus water into Marillana Creek.
- December 2006 - average discharge rate from BHPBIO and Rio Tinto of 34 ML/day.
- 2007 - surplus water discharged to the Weeli Wolli Creek from JSE / Hope Downs 1 operations.
- December 2009 to present - the combined average discharge rate to the Marillana and Weeli Wolli Creeks from all three operations was 116 ML/day.
- Permanent streamflow extends 6 - 9 km downstream of the Marillana / Weeli Wolli Creek confluence, depending on discharge/rainfall conditions (Dogramaci, 2014) – the 9 km distance is adjacent to the location where disposal from open pits S1/S2 would take place (disposal location DL1 shown in Figure 4.22)

There are a number of proposed new mines (other than the Iron Valley mine) which could also impact on the surface and groundwater conditions linked to the Weeli Wolli Creek, namely:

- Rio Tinto - proposed Pocket and Billiard mine, with a 2017 start (~30 GL/a of additional surplus water added to the Marillana Creek, pushing permanent streamflow in the Weeli Wolli Creek to a location 16 km downstream of the Marillana / Weeli Wolli Creek confluence (Rio Tinto, 2014a)).
- BHPBIO - proposed Jinidi mine.
- Brockman Resources - proposed Marillana mine.
- Fortescue Metals Group – proposed Nyidinghu mine.

Presuming a late 2016 start to excess water disposal, it is anticipated that the discharge from the Iron Valley dewatering will extend the zones of permanent stream flow to 6 km downstream of the tenement boundary (Figure 8.1). Within a year, this zone will be further extended by the Pocket and Billiard disposal. The Iron Valley mine life is approximately 10 years, while the Pocket and Billiard mine is expected to last approximately 16 years. During this 16-year period, the disposal of water from Hope

Downs 1 is expected to stop (closure expected in 2025) and other mines may also be developed and could influence the stream flow. As the Weeli Wolli Creek flow is only anticipated to contribute to less than 5% of the total inflow to the Fortescue Valley (Aquaterra, 2001), the overall impact of these changes on the whole valley are expected to be limited, although impacts on the Weeli Wolli Creek ecology are anticipated.

The modelling has shown that dewatering of the Iron Valley mine will result in both the lowering of water levels and the raising of water levels, in different areas of the Weeli Wolli Creek. Further, the scenario prediction for the development of the Pocket and Billiard mine, shows that their excess water discharge will dominate the Iron Valley impact, resulting in elevated water levels and stream flow to a location 17 km downstream of the Weeli Wolli / Marillana Creek confluence – beyond the expected stream flow wetting front predicted for the Iron Valley mine. With both mines generating excess water disposal, the wetting front could be pushed even further downstream, possibly as far as 23 km from the confluence.

9 Saline Intrusion from Fortescue Marsh

9.1 Background

The Fortescue Marsh has a catchment area of approximately 30,000 km^2, but has a restricted outflow, resulting in most of the surface water evaporating from the main marsh zone. This results in the accumulation of salts within the marsh area and the development of a hypersaline groundwater mound below the marsh (EPA, 2013). Density driven flow has extended the movement of saline water into the bedrock, away from the marsh area, towards the boundaries of the Fortescue Valley (see Figure 9.1).

9.2 Groundwater Quality to the north-east of the Iron Valley mine

Available data (DoW, and FMG) as well as data collected during the fieldwork phase of this study (see Appendix A) has allow the contouring of water quality in the upper detritals (fresher water) and the bedrock (more saline). The fresher water in the upper detritals (<1000 mg/L TDS) extends out a distance of approximately 10 km from the tenement boundary, while the equivalent bedrock water quality is approximately 3 km downstream (Figure 9.2).

9.3 Dewatering Impacts

Mine dewatering develops a cone of depression. At the Iron Valley mine, this cone could draw in saline water from the Fortescue Valley. However, to help reduce potential impacts of saline water from the bedrock aquifers being drawn into any cone of depression formed by the mine dewatering, the excess water disposal plan proposes to discharge some of the excess water along the Weeli Wolli Creek between the mine and the more saline bedrock water. As a result, a mound in the groundwater occurs between the mine and the more saline bedrock water (Figure 4.38). This mound will remove the risk of saline bedrock groundwater moving towards the mine.

10 Mine Water Balance

The water balance assessment covers the estimation of what the excess/shortfall might be over the mine life. The water balance takes into account:

- The volume of groundwater that needs to be pumped to allow dry mining to take place.
- The volume of “dirty” surface water that is generated on site and needs to be stored on site and is therefore available for site use.
- Seepage from the TSF.
- The mine’s water demand for domestic use and processing.

10.1 Mine dewatering

The predicted dewatering necessary to keep the open pits dry during mining, varies over the life of the mine between 22,263 - 63,175 kL/d (Table 4.8).

10.2 Surface water storage

During rainstorm events “dirty” water can be generated, when rainfall from the area within the mining area generates runoff. Where this water has a high sediment content, it is treated in containment dams, where the sediment is allowed to precipitate, before the clean water is discharged from site. Table 2.5 provides an indication of the volumes of water that would end up in the pit for different rainfall recurrence events. For a 1:1 yr event, a volume of 272,700 kL of stormwater would enter the pits, making up a potential water supply. Normally this water would be pumped out of the pits into settling dams to allow sediment to settle and then disposed of off-site.

10.3 Tailings return flow

It is proposed that the tailings facility be developed with the rock waste dump, as two cells with a co-disposal integrated waste landform (IWL). Over a 10-year mine life, approximately 32 Mt of tailings would be stored in the IWL. Golder (2015) have estimated that seepage out of the base of the IWL would be between 1 - 5 L/s over the mine life, if the decant pond is underlain by fine tailings. Under the normal operating conditions expected, seepage out of the base of the northern cell of the IWL is expected at 39,800 kL/annum (1.3 L/s), while the southern cell seepage would be 54,900 kL/annum (1.7 L/s).

On top of the seepage out of the base of the IWL, there would also be return flow captured from the decant pond, of approximately 1.3 GL/annum (41 L/s).

10.4 Mine Site Water Demand

Water is required on the mine site for domestic use (at the offices and the accommodation village) and for use during mine operations (dust suppression and use in the beneficiation plant). Generally, domestic consumption ranges from 250-350 L/person per day, while mine use is generally between 50-100 L of water per tonne of ore processed. The beneficiation plant usage depends on the material feed (Table 10.1).

Table 10:1: Mine Operations Water Requirements

	Coarse Feed	Medium Feed	Fine Feed
Beneficiation Plant make up water m^3/hr	460	702	764
Hours per year	6120	6120	6120
GL/pa consumed in plant	2.8	4.3	4.7
Other usage (dust suppression) (GL pa)	1.0	1.0	1.0
Total usage (GL/pa)	3.8	5.3	5.7
Total Usage (kL/d)	10,410	14,520	15,616

At Iron Valley the Coarse/Fine feed conditions may persist for up to a year as the mine progresses through different levels, with a long term water demand (including domestic consumption) in the range of 15,700 kL/d.

10.5 Water Balance

The mine will generate more water than the demand, necessitating the disposal of excess water throughout the mine life. Excess water disposal rates are anticipated to vary between 6,563 - 47,475 kL/d (Table 4.8). The average water balance for the mine site is shown diagrammatically in Figure 10.1 and summarized in Table 10.2 below.

Table 10:2: Mine Site Water Balance – Annual Average (GL/a)

Inputs		Outputs	
Seepage out of base of TSF to groundwater	0.05	Mine Use (beneficiation top-up, dust suppression, domestic)	5.7
Groundwater pumping	16.06	Excess Water disposal	10.33
Surface water capture	0.01		
Surface water inflow	0.27	Surface Water disposal	0.27
TSF Decant Recycling	1.3	Losses / Evaporation	1.39
Total	17.69	Total	17.69

11 Mine Closure Impacts

The mine plan has backfilling taking place during the mining. At the end of mining, all the open pits have been backfilled to some degree, to levels as detailed in Table 11.1 below. As discussed in the modelling section, the northern most pits (C1, C3, C5, N1, N2 and N3) are not backfilled to above the water table.

Table 11:1: Levels of Backfilling for Pit Areas

Backfill Zone	Backfill Level (m RL)			
	2019	**2020**	**2024**	**2025**
Pits C2 & C4	490	500		
Pits S1 & S2		500		
Pits C1, C3 & C5			430	440
Pits N1, N2 & N3				440
Pits E1 & E2				490

Once mining stops, water levels will rise back to a new post-mining equilibrium. The water level recovery is relativley rapid, mostly as a result of the connection between the open pits and the Weeli Wolli Creek in the south, via the Eastern Fault. In the areas of the Southern and Central pits, water levels recovery back to a new equilibrium level (5-25 m below pre-mining water levels) within 10 years of the end of mining (Figures 4.44-4.45). The decrease in water levels is due in part to evaporation losses out of the pit lakes and in part to the lack of the pre-mining "daming effect", as a result of the removal of parts of the dyke barrier during mining. For the northern most pits, water levels rise to ~5 m above pre-ming water levels (Figure 4.46 – 4.47), due to the mining out of parts of the dyke, thus allowing greater water flow to the north. For the eastern pits, water levels recover to pre-mining water levels (Figure 4.45 – 4.46).

It should be borne in mind that all of the groundwater levels prior to mining starting are artificial, having been influenced by wetter than normal conditons over the last 10 years and current excess water disposal practise by BHPBIO and Rio Tinto, to the Weeli Wolli Creek. Water levels in the Creek (as indicated in the graph for bore YM119, located at the confluence of the Marillana and Weeli Wolli Creeks (Figure 11.1, from Rio Tinto, 2012), have risen from 463 mRL to 476 mRL since late 1994.

The numerical model utilised during this project was run with a water level at the upstream end of the catchment set 15 m lower than current levels (i.e. 470 m AHD), to assess how a lower water level in the Creek would influence groundwater levels at the mine site. The model predicted that water levels at the Iron Valley mine site would have been approximately 12 m lower than they currently are, if water levels in the Creek were the same now as in 1994.

11.1 Post Closure Impacts

After mining has stopped, there will still be some post-closure impacts on the site hydrogeology.

- It will take 15 - 30 years for groundwater levels to recover to a new equilibrium level. Some of these equilibrium levels will be different to pre-mining levels.
- Groundwater levels will not dam up behind the dyke as the dyke will be removed in places. Similarly, the lack of a dyke barrier will allow through flow to the north of the dyke, which will raise water levels in this area.
- Evaporation out of the pit lakes will lower water levels marginally. However, as the main pit lake (central and northern pits), will be a throughflow lake, salinisation of the pit lakes is expected to be very limited.
- Water levels in the Weeli Wolli Creek (raised due to the excess water disposal) will drop off after excess water discharge stops, returning to just below pre-mining levels within 2 years.
- Changes to downstream water quality in the Weeli Wolli Creek bed alluvium (due to the excess water discharge), will be very limited (as the Weeli Wolli Creek water quality and the Iron Valley groundwater quality are similar). Any alteration in quality will be regularly diluted after every major streamflow event.

12 Conclusions

The development of the below water table mine at the Iron Valley site will encounter a permeable orebody aquifer, which will require dewatering to allow dry mining to take place. The orebody aquifer extends to the north to the Weeli Wolli Creek and is also connected, via a permeable fault system (East Fault), to the Weeli Wolli Creek to the south of the proposed mine. As a result, high dewatering rates have been predicted, varying from approximately 22,000 - 63,000 kL/d, depending on the stage of mining. As the mine water demand is 15,700 kL/d, there will be a water surplus that will need to be disposed. Review of all possible disposal options, has identified the disposal to the adjacent Weeli Wolli Creek as the most suitable option. Disposal to the Creek is the most practical option from a mining perspective, but also has environmental benefits. By disposing of water in an area between the mine site and the saline bedrock water of the Fortescue Valley, a groundwater mound is developed, which stops saline bedrock water being drawn in towards the areas of pumping. Over the life of the mine, the majority of the water pumped from the dewatering system, is derived from the Weeli Wolli system. As a result, disposal back to the Creek is returning water back to the original source.

The elongated north south trending aquifer and the associated fault, together with low permeability material to the east and west of the aquifer, results in a cone of depression that is elongated north-south. Similarly, the aquifer strike also required the siting of ex-pit dewatering bores at the north and south ends of the open pits, together with a number of in-pit bores. Dewatering bore locations will have to be changed throughout the mine life, to accommodate the different pits and the proposed backfilling programme.

Once mining stops (10 year mine life), the water levels in the pits will recover relatively quickly (generally within 10 years), due to the East Fault connection to the Weelli Wolli Creek. Even though pit-infilling is planned, not all of the pits will be infilled to above the groundwater levels. As a result, pit lakes will develop for the C1, C3, C5, N1, N2 and N3 pits. The pit void lakes are predicted to form throughflow lakes. As a result saline lake conditions will not develop.

During the mine life, dewatering will lower groundwater levels around the mine site and in parts of the Weeli Wolli Creek (in the south where the fault enters the Creek), which could influence the existing GDE populations. Similarly, there are areas where the disposal will raise water levels in the Creek to surface, resulting in surface water flow taking place over a distance of 6 km from the discharge locations. Should Rio Tinto proceed with the development of their Pocket and Billiard Mine, their excess water disposal with override the drawdown in the Weeli Wolli Creek, resulting in surface water flow that would extend to approximately 23 km downstream from the Weeli Wolli / Marillana Creek confluence.

After the Iron Valley mining ends, water levels will recovery relatively quickly at the mine site to the equilibrium level (within 10 years), but will not recover to the same pre-mining water levels. The removal of the dyke barrier during mining, together with evaporation from the pit lakes that develop post-mining, results in water levels to the south of the dyke being deeper than before mining, while water levels to the north of the dyke recover to shallower levels than before mining started. Water levels in the Creek system recover within 2 years, without Rio Tinto's discharge. Should the Pocket and Billiard mine process, the disposal will last for a further 6 years post the end of the Iron Valley mine, continuing to generate surface flow along the Weeli Wolli Creek.

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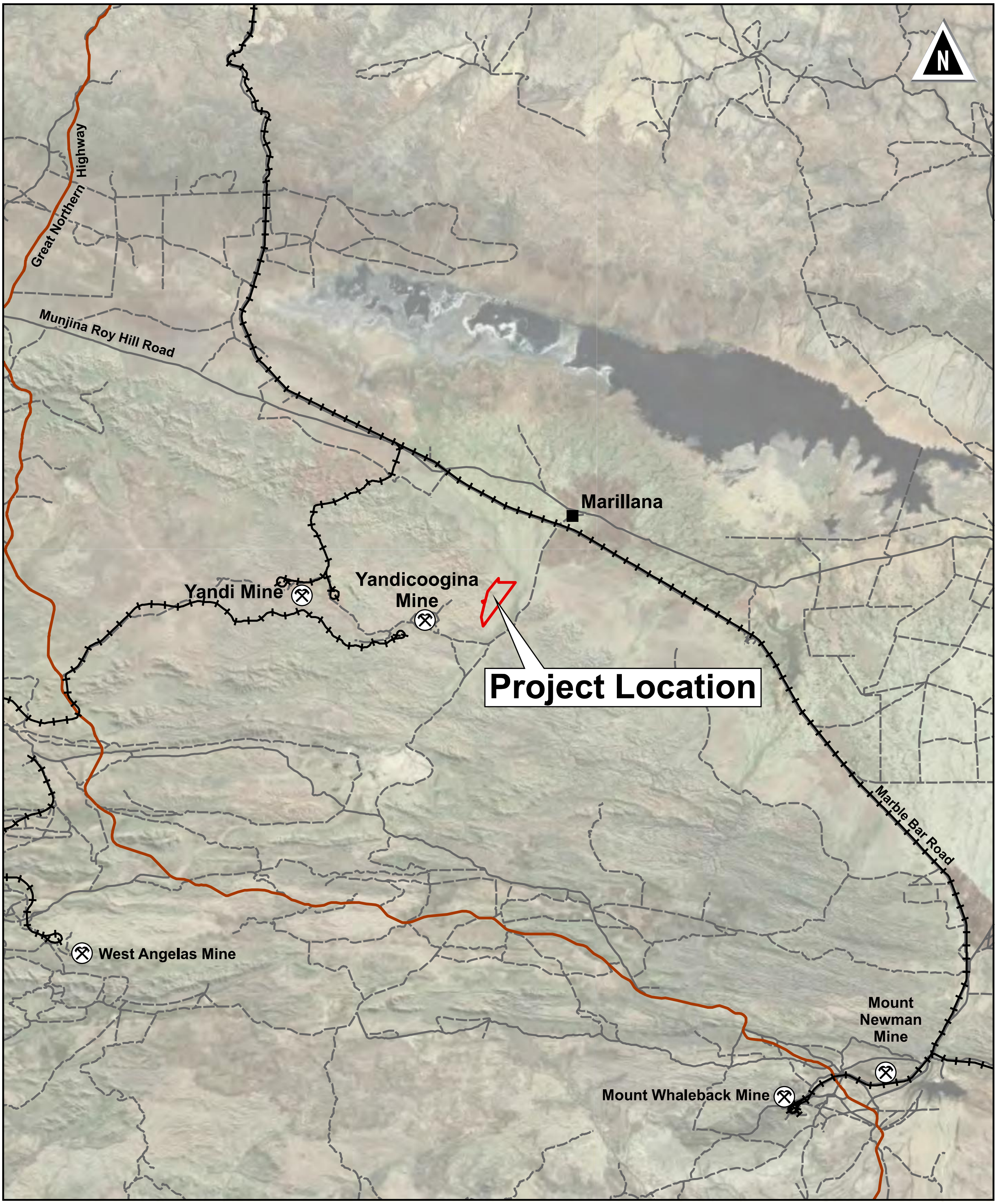
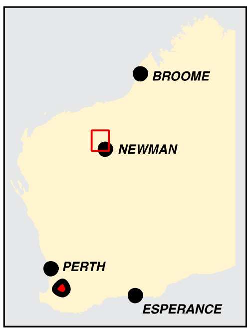
FIGURES





LEGEND

Mine Locations
Homesteads
Project Location
Railways
Major Road
Minor Road
Track

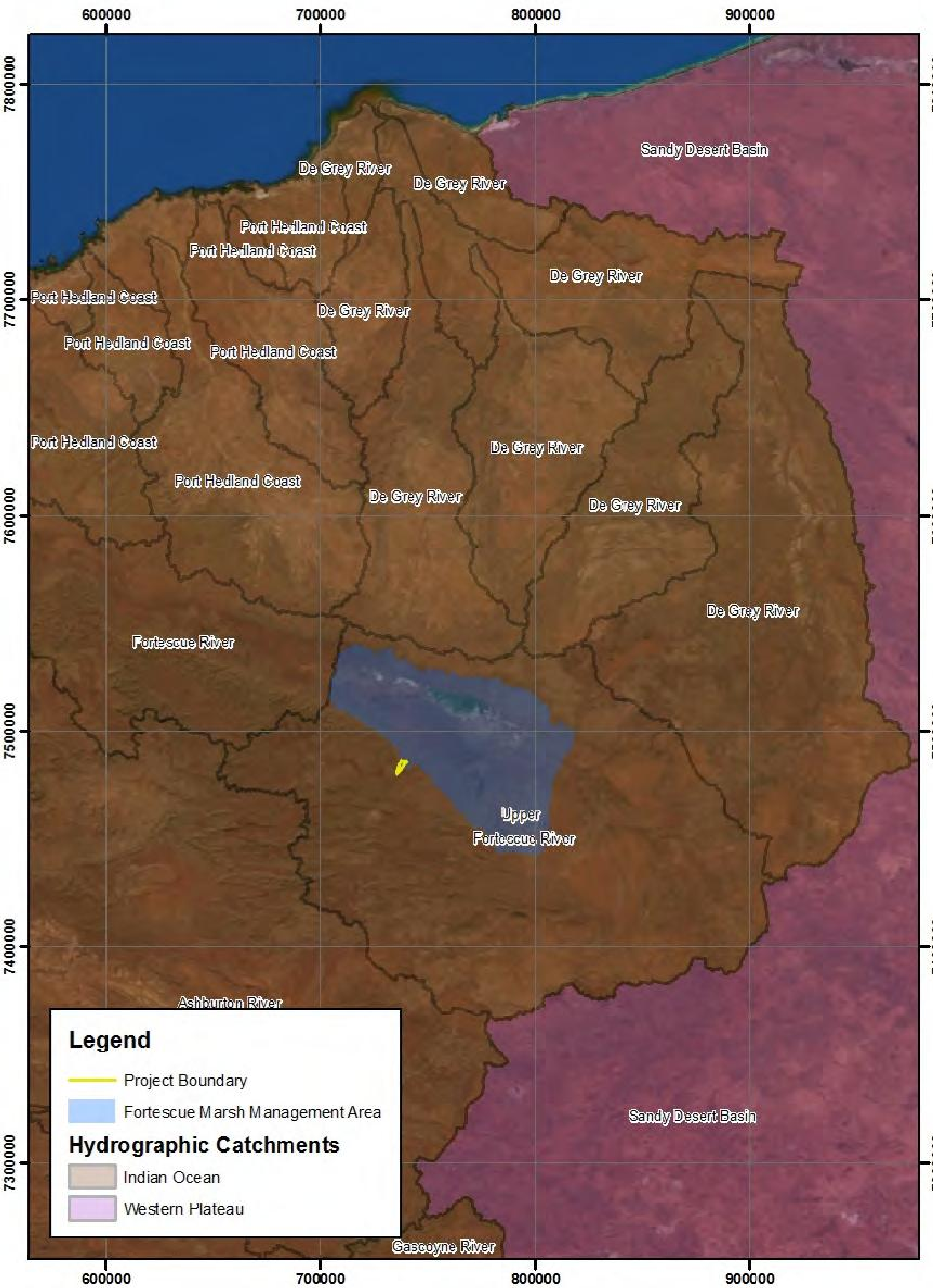
0 5 10 20
kilometres

AUTHOR: JJ
DRAWN: RC
DATE: 06/01/2015

REPORT NO: 013b
REVISION: a
JOB NO: 030b

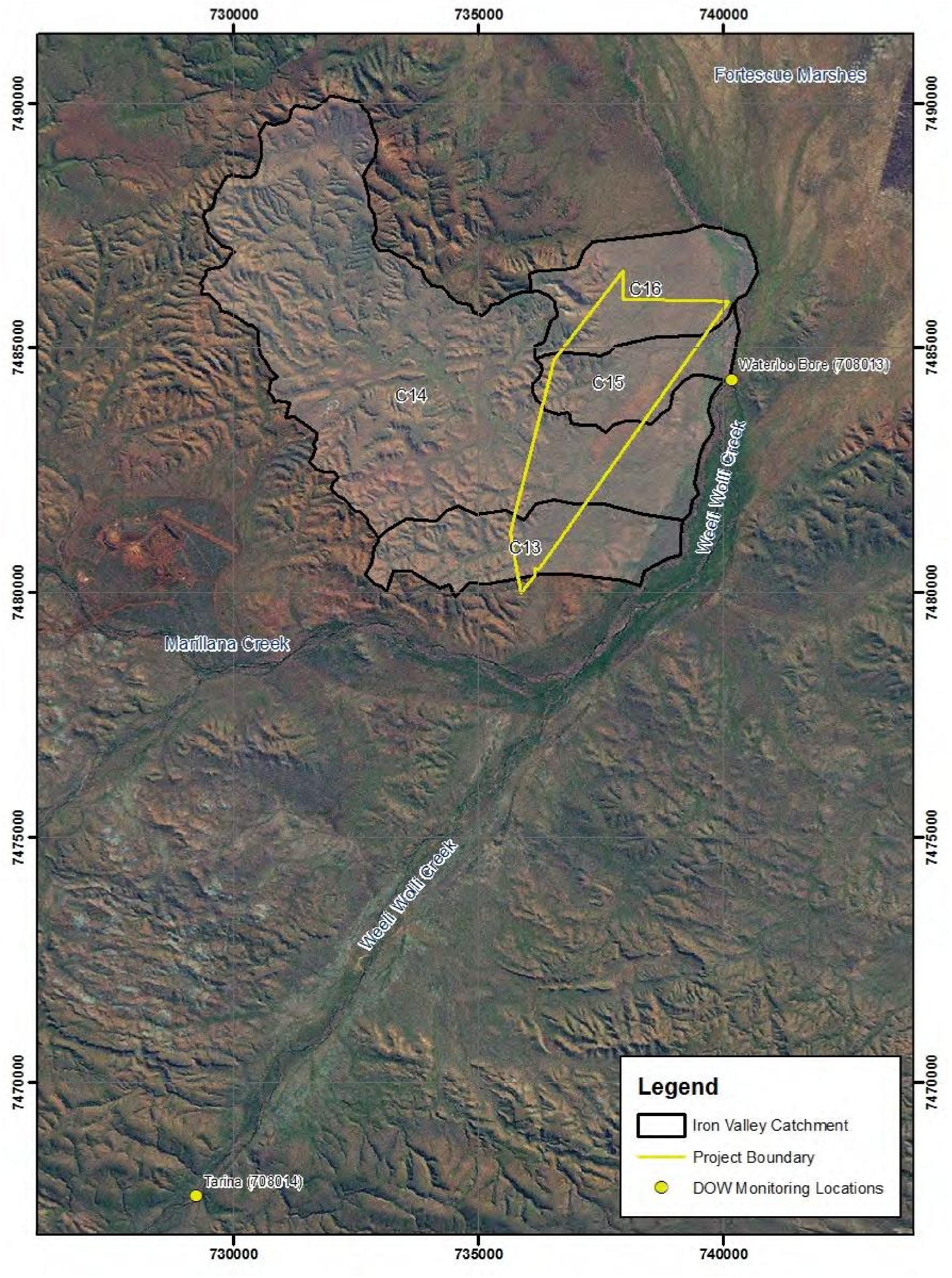
NOTES & DATA SOURCES:
MGA Zone 50 (GDA94)

FIGURE 1.1
IRON VALLEY PROJECT
REGIONAL LOCATION

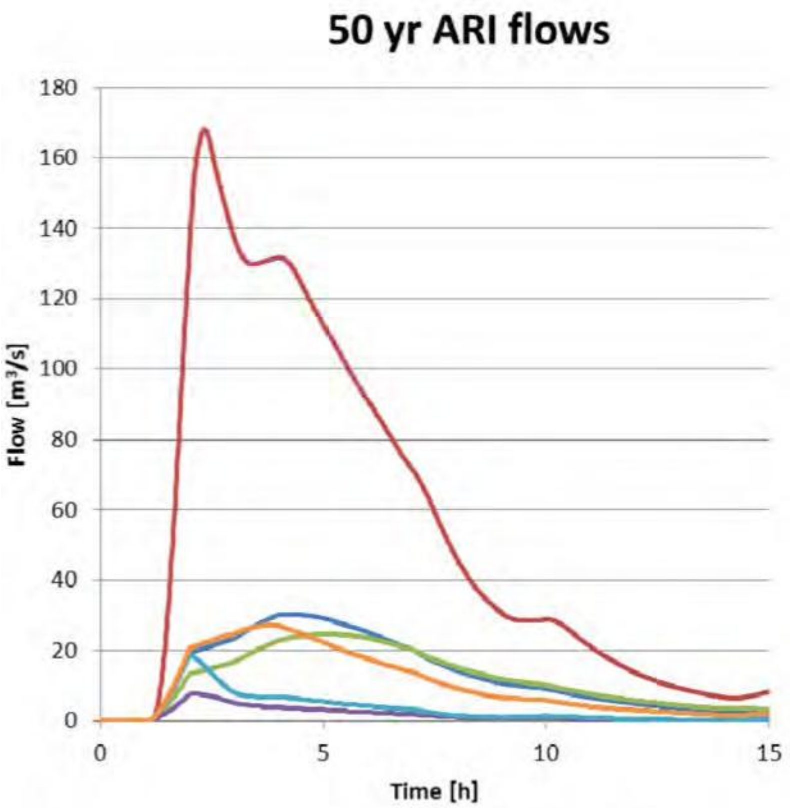


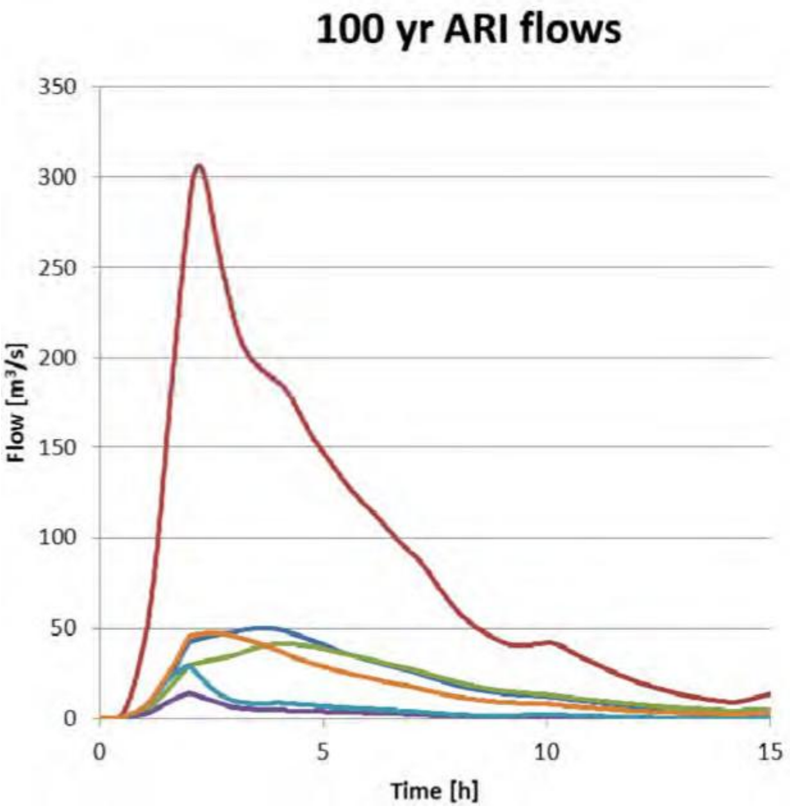
Regional Hydrology Setting

FIGURE 2.1



Local Hydrological Setting
FIGURE 2.2



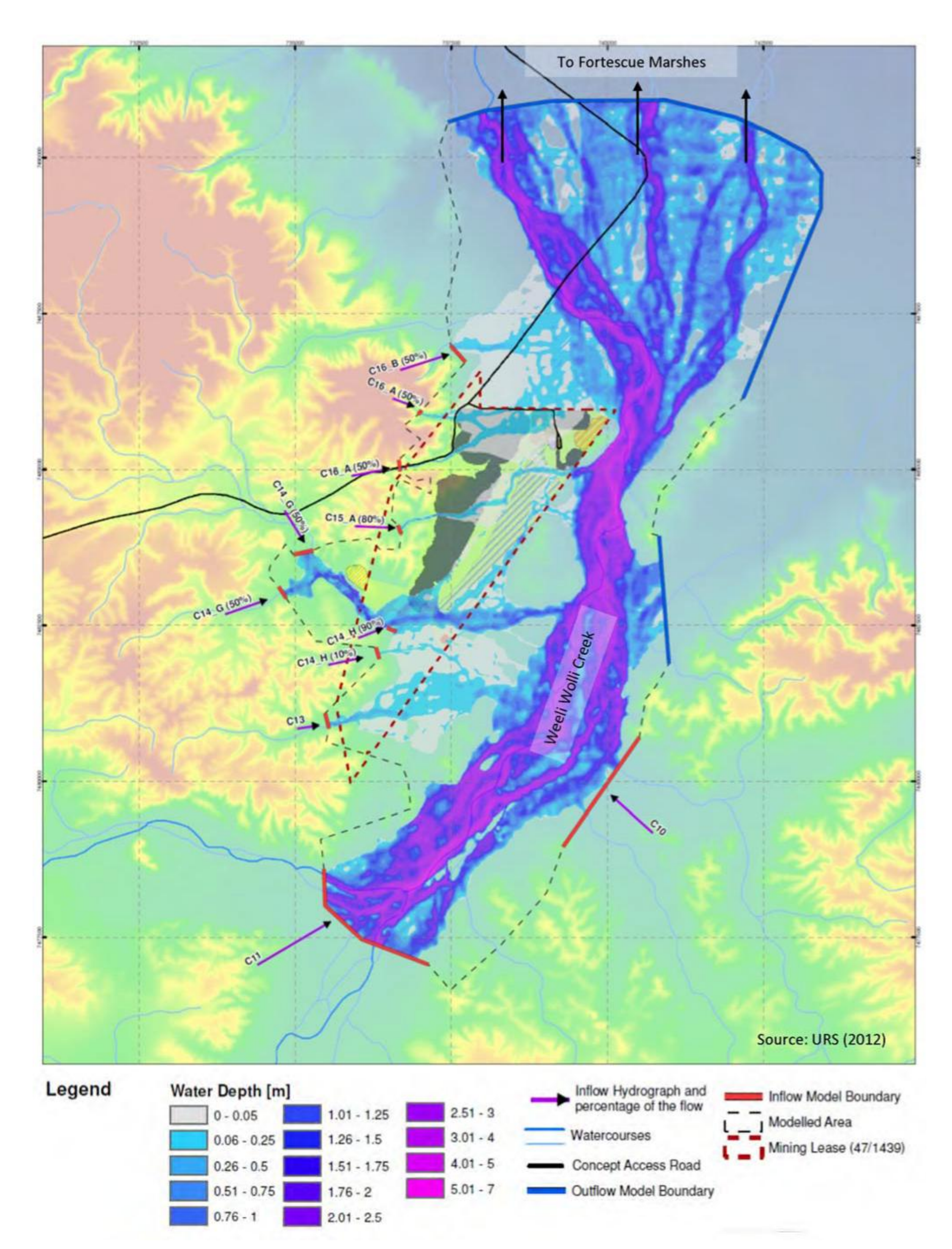


Legend

- C13
- C14_G
- C14_H
- C15_A
- C16_A
- C16_B

Note: See Figure 2.2 for sub-catchment locations

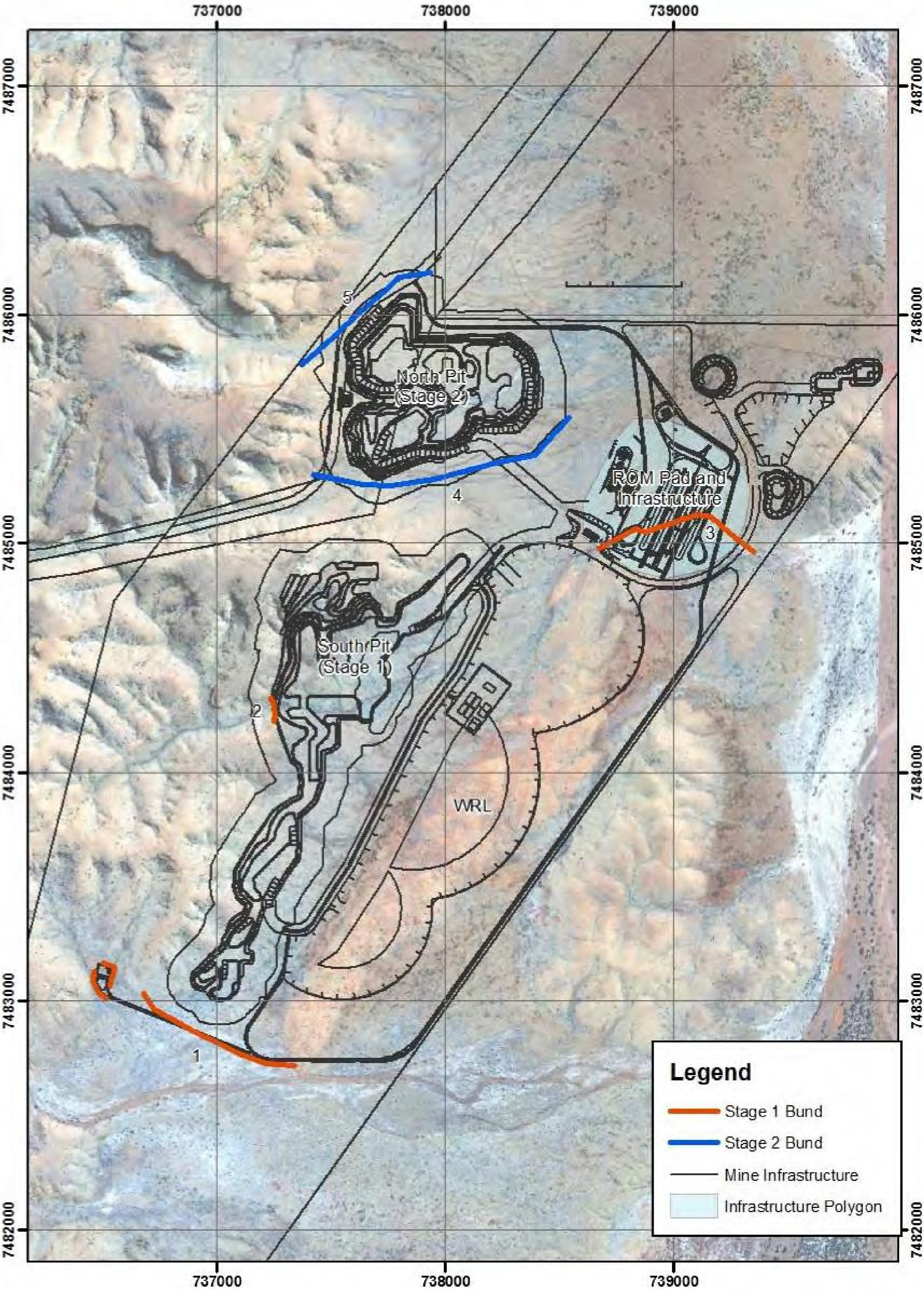
Source: (URS, 2012)



AQ2 soilwater GROUP

Modelled 1:100-year Peak Flood Levels within Iron Valley Project Area

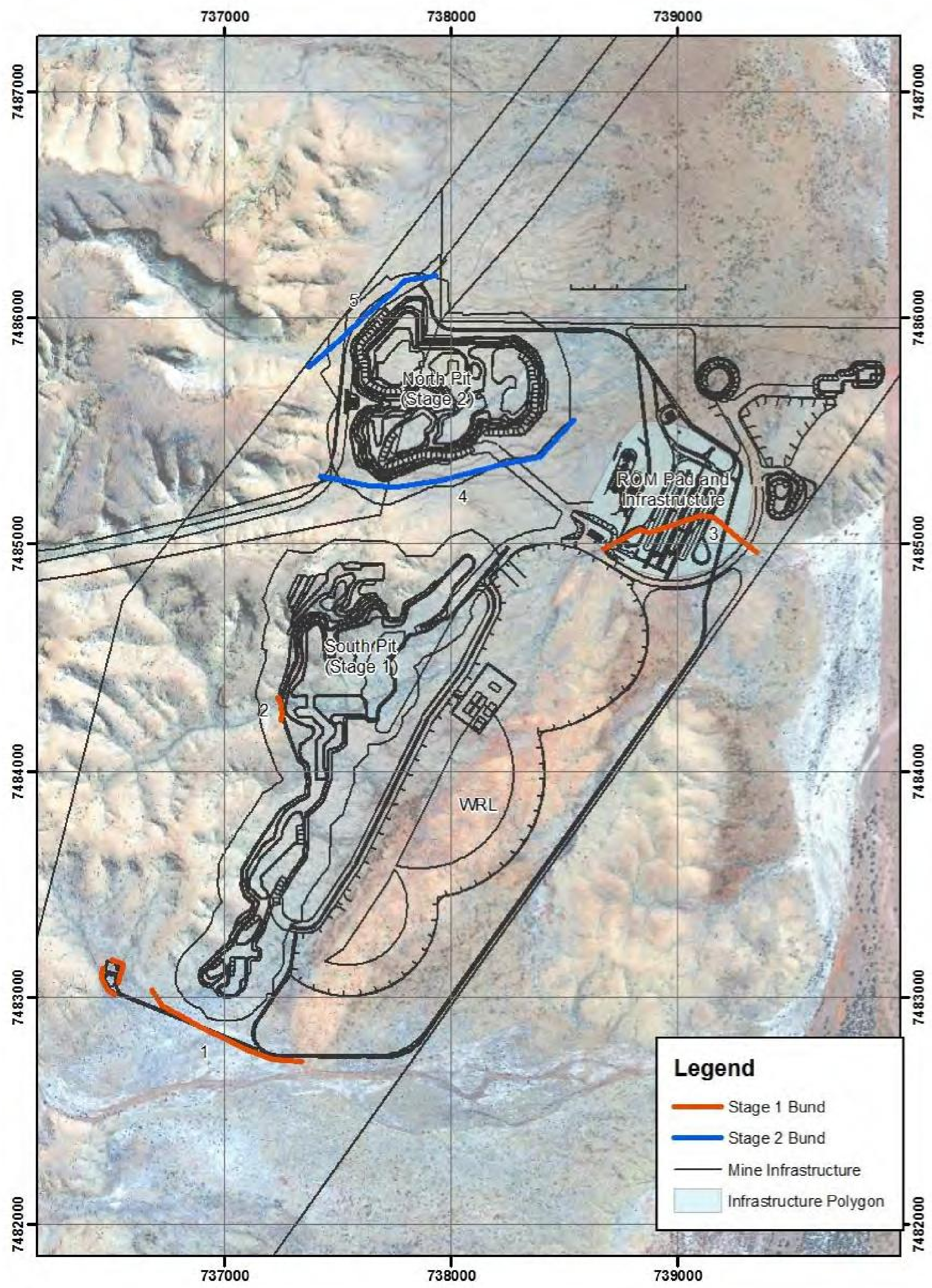
FIGURE 2.4



AQ2 soilwater GROUP

AWT Mine Site Layout

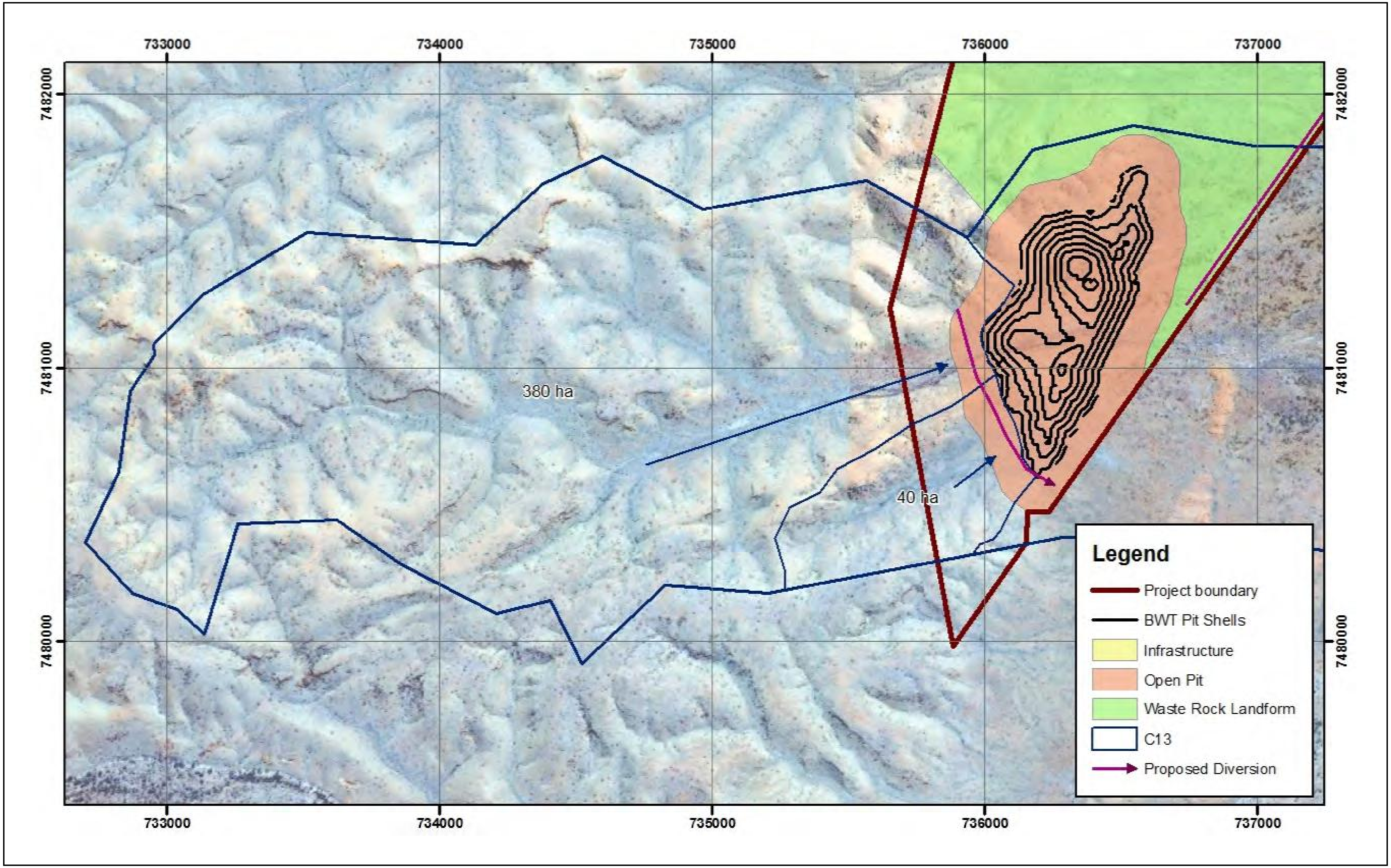
FIGURE 2.5



AQ2 soilwater GROUP

BWT Mine Site Layout

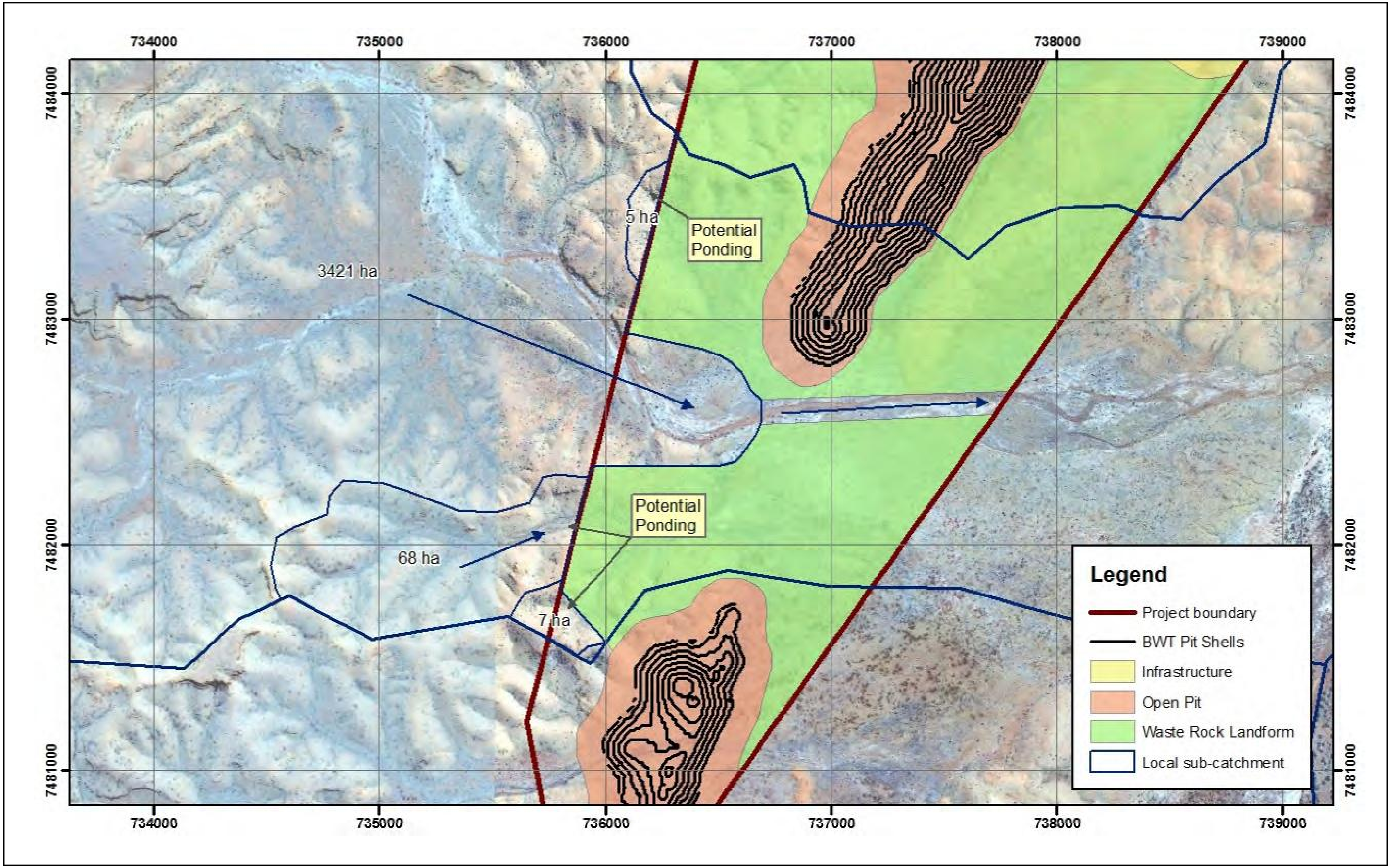
FIGURE 2.6



AQ2 soilwater GROUP

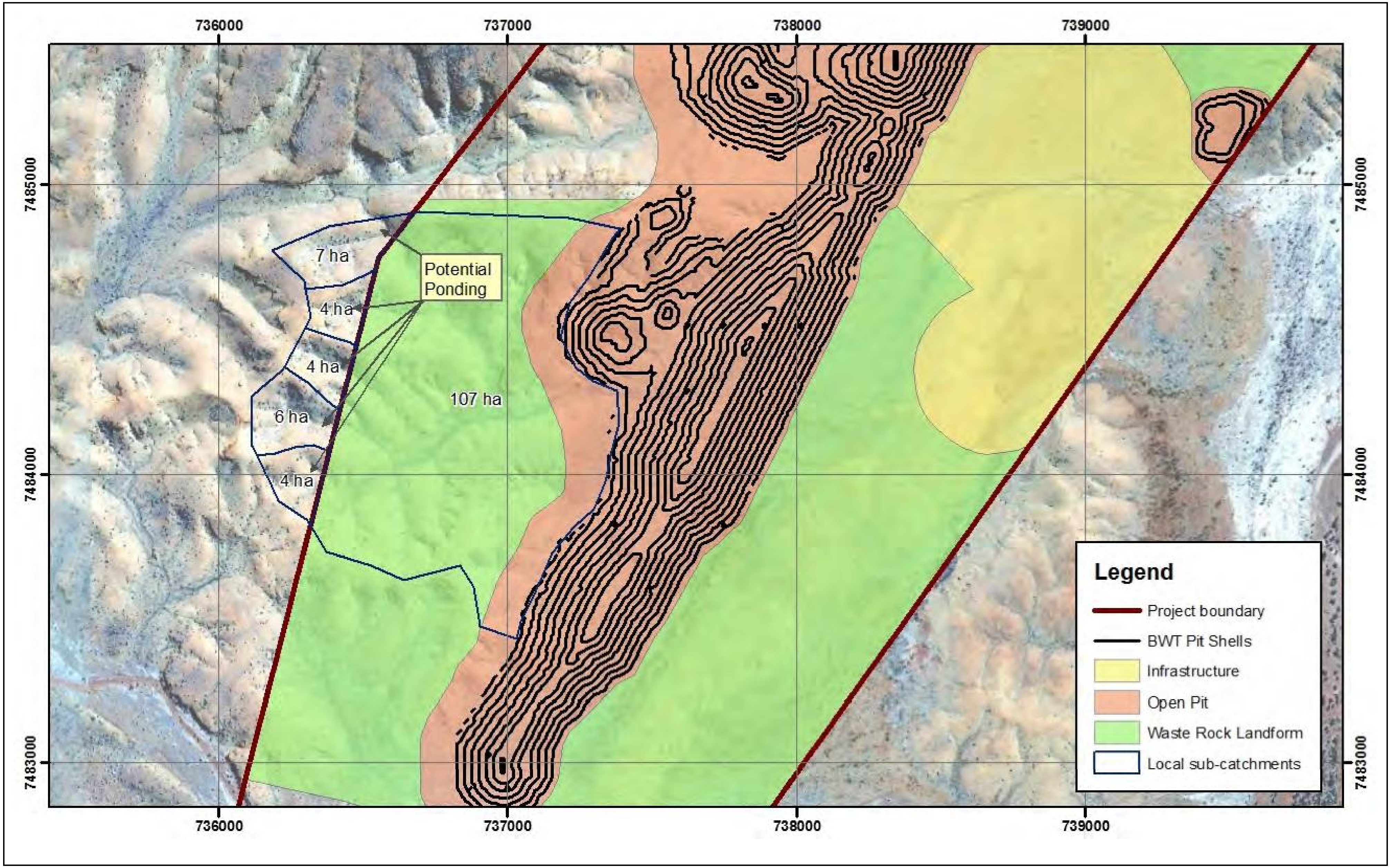
Catchment C13 Interaction with Site Infrastructure

FIGURE 2.7



Catchment C14 Interaction with Site Infrastructure

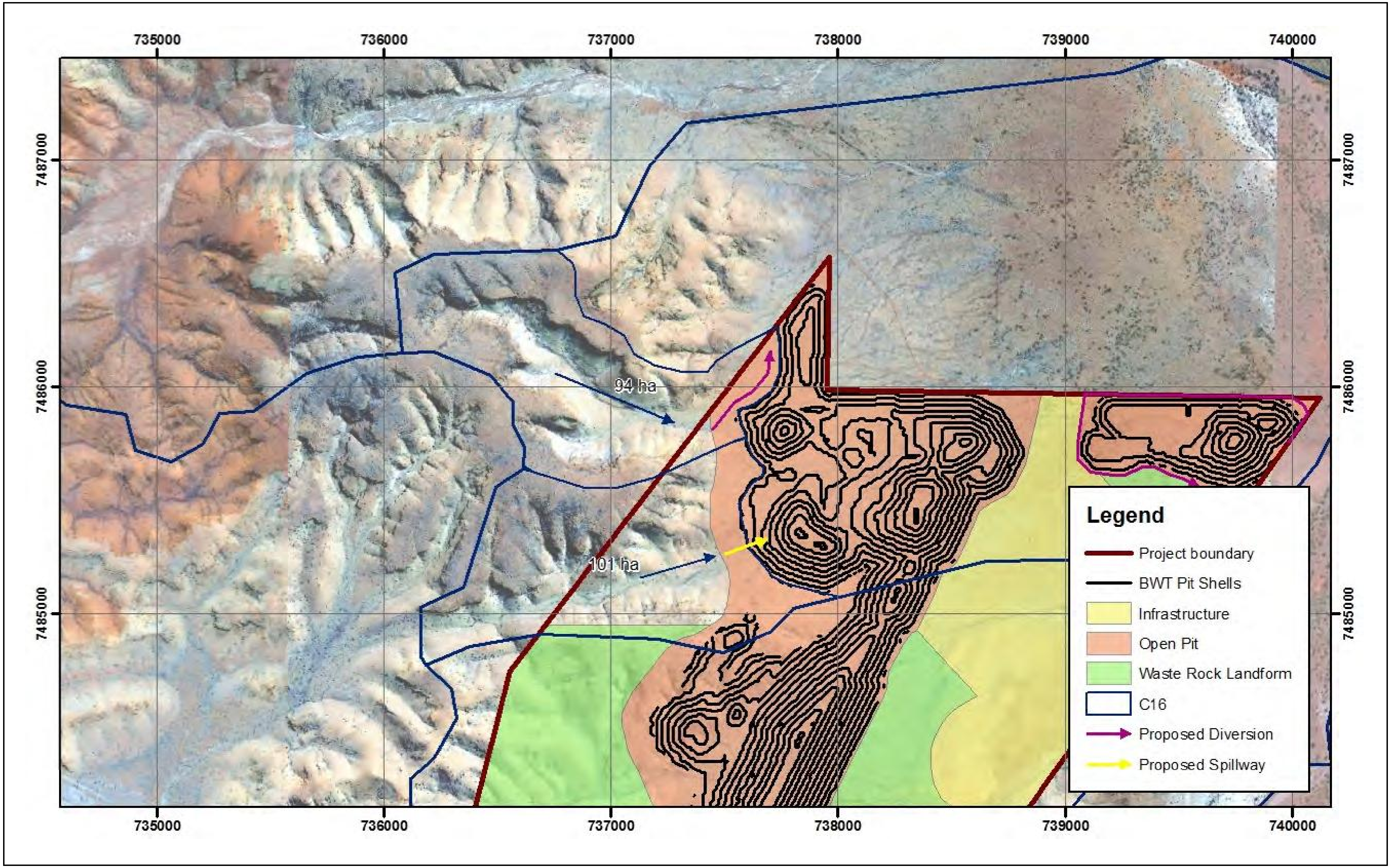
FIGURE 2.8



AQ2 soilwater GROUP

Catchment C15 Interaction with Site Infrastructure

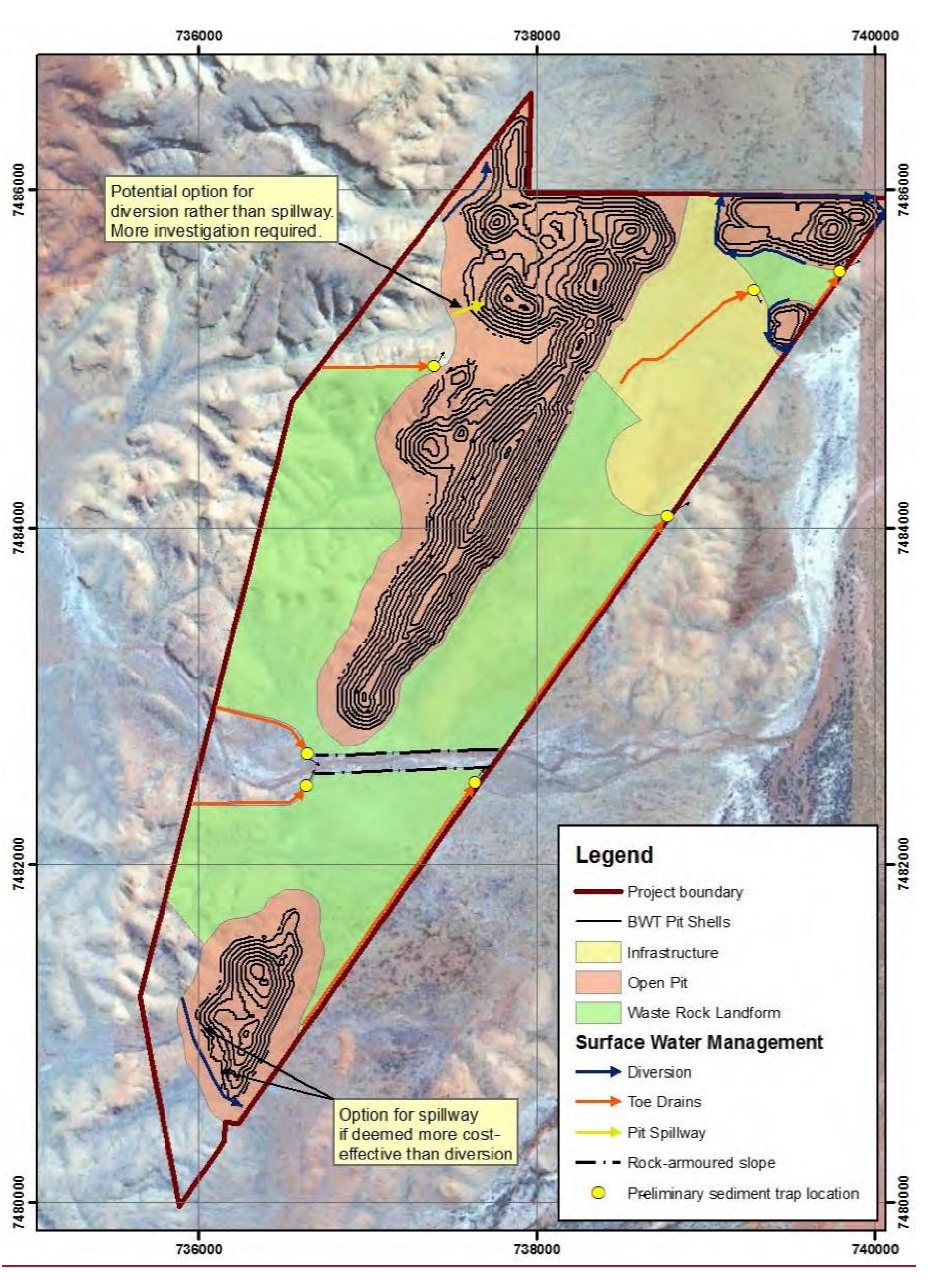
FIGURE 2.9



AQ2 soilwater GROUP

Catchment C16 Interaction with Site Infrastructure

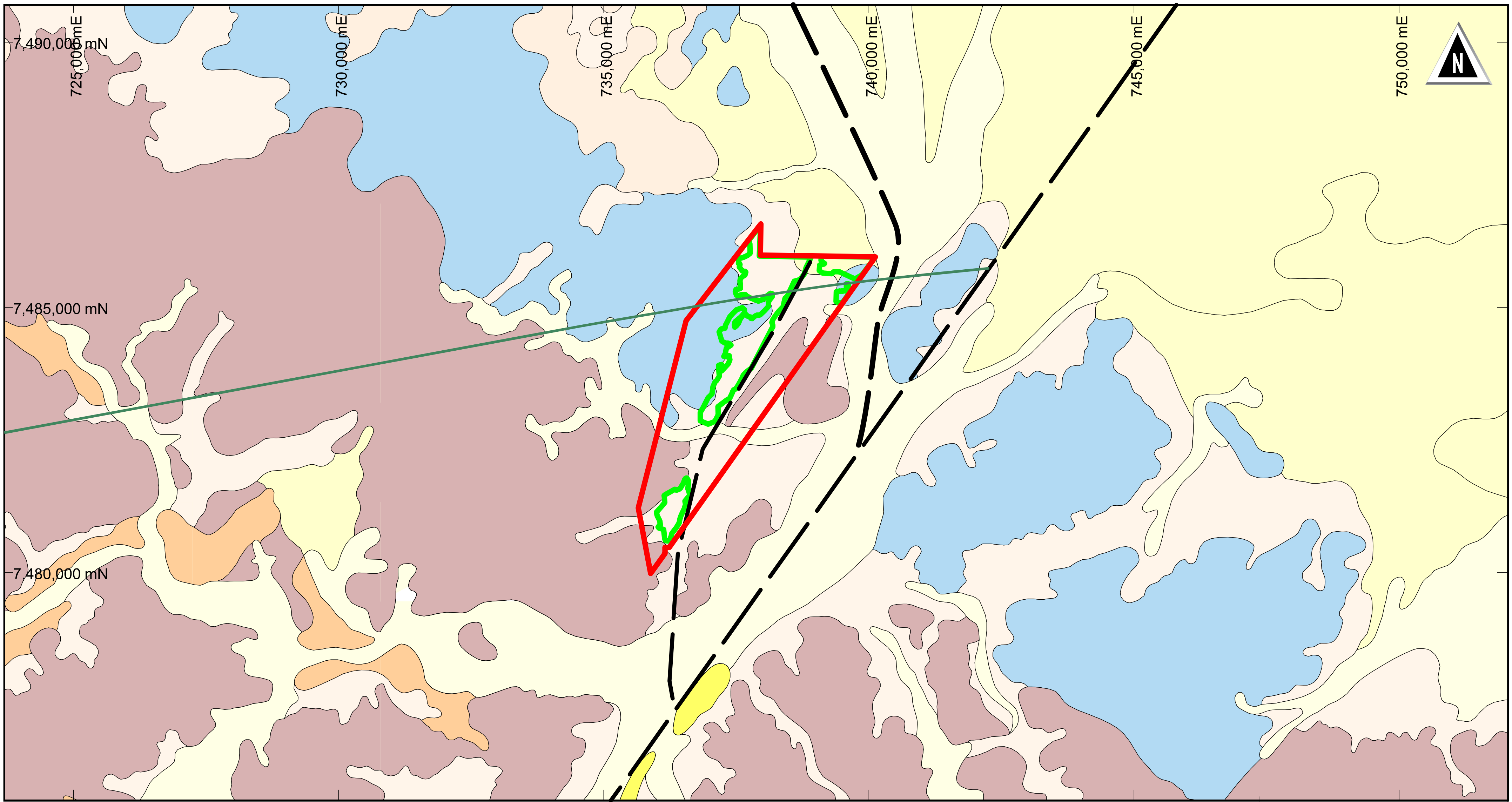
FIGURE 2.10



AQ2 soilwater GROUP

Overview of Proposed Surface Water Management

FIGURE 2.11



LOCATION MAP

DERBY
NEWMAN
KALGOORLIE
PERTH
ALBANY

LEGEND

- Weeli Wolli Creek Alluvium
- Weeli Wolli Creek Outwash
- Scree
- Scree
- Channel Iron Deposit
- **Weeli Wolli Formation**
- **Brockman Iron Formation**
- Interpreted Faults
- Dyke
- Project Area
- Pit Outline

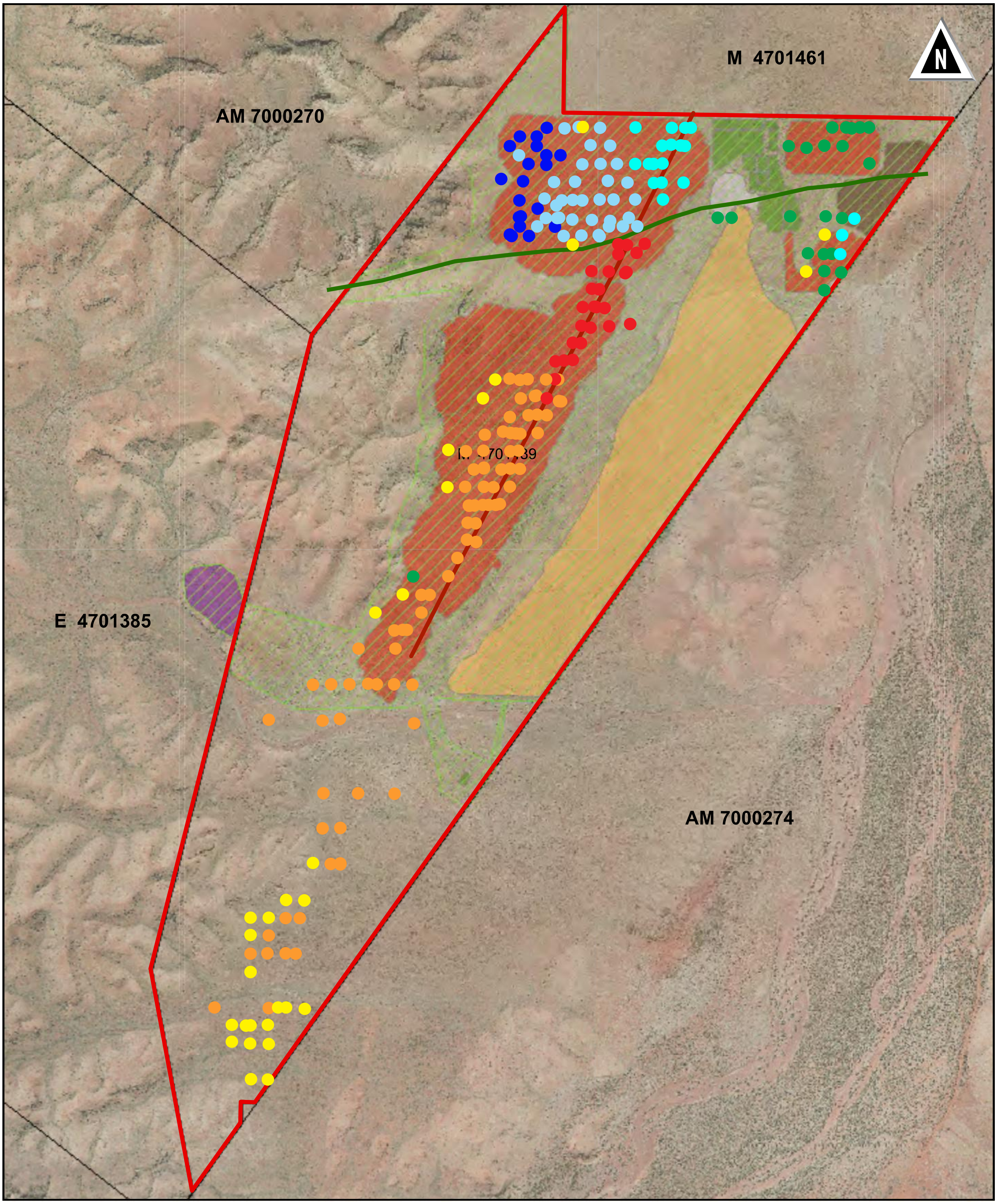
AQ2

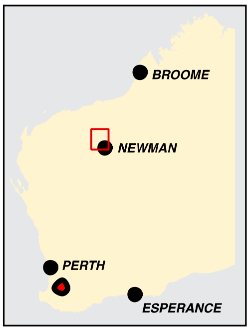
AUTHOR:	JJ
DRAWN:	RC
DATE:	7/1/2016
REPORT NO:	013B
REVISION:	...
JOB NO:	...

NOTES & DATA SOURCES:
MGA Zone 50 (GDA94)

0 2.5 5
kilometres

FIGURE 3.1
GEOLOGY
IRON VALLEY PROJECT





LEGEND

- Project Location
- Mining Tenements
- Dolerite Dyke (approx.)
- Orebody Fault (approx.)

Depth To Groundwater (mbgl)

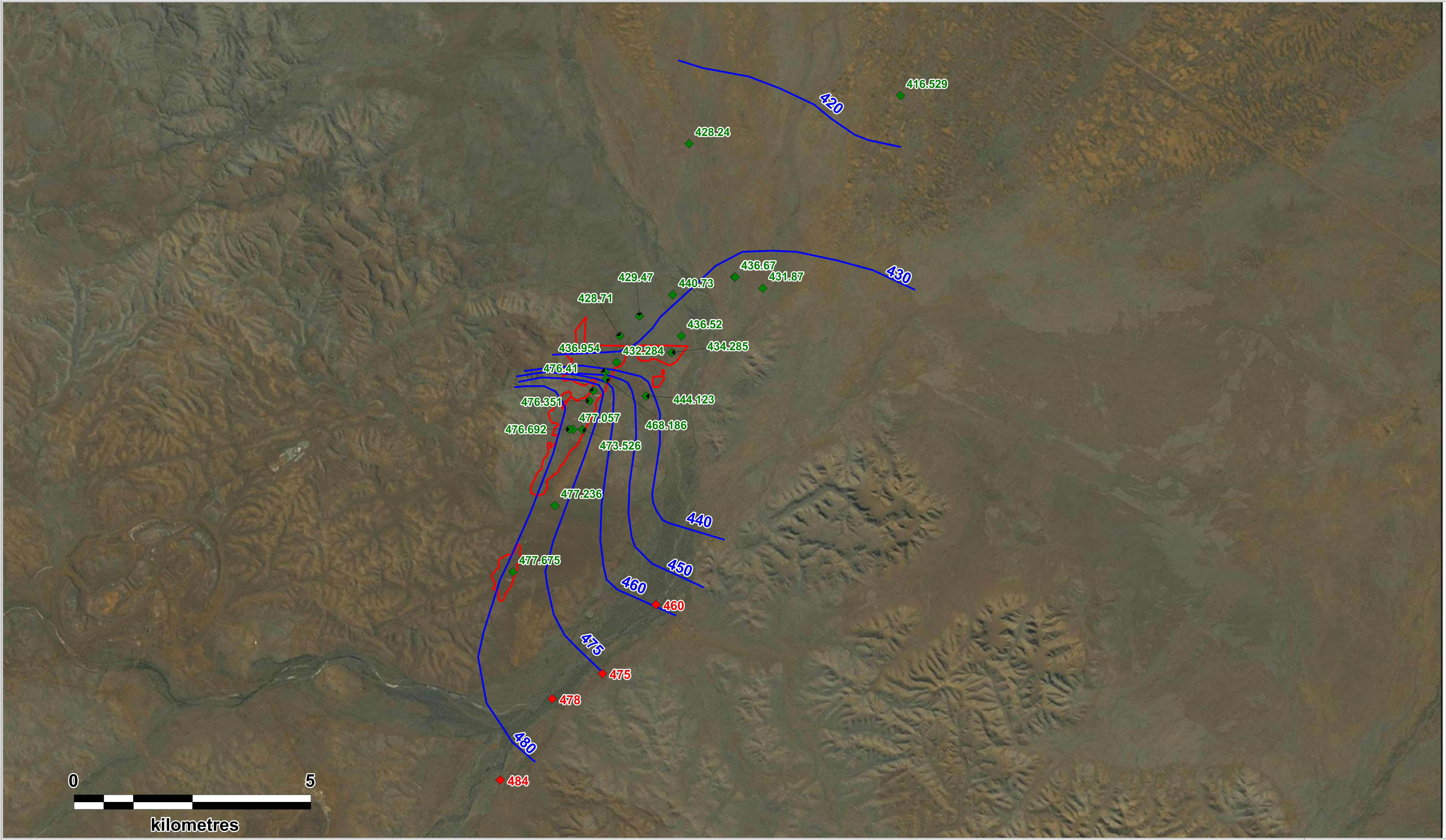
- 1 - 10
- 11 - 20
- 21 - 30
- 31 - 40
- 41 - 50
- 51 - 60
- 61 - 70

- Accommodation Village
- Infrastructure Areas
- Pit Areas
- ROM Pad
- Topsoil Storage
- Waste Rock Landform
- Total Disturbance Footprint

0 5 10 20
kilometres

AUTHOR: JJ	REPORT NO: 013b	NOTES & DATA SOURCES:
DRAWN: RC	REVISION: a	MGA Zone 50 (GDA94)
DATE: 06/01/2015	JOB NO: 030b	

FIGURE 3.2
PRE-GROUNDWATER ABOVE WATER TABLE LEVEL DATA REGIONAL LOCATION



LOCATION MAP

Location: Pilbara

KEY

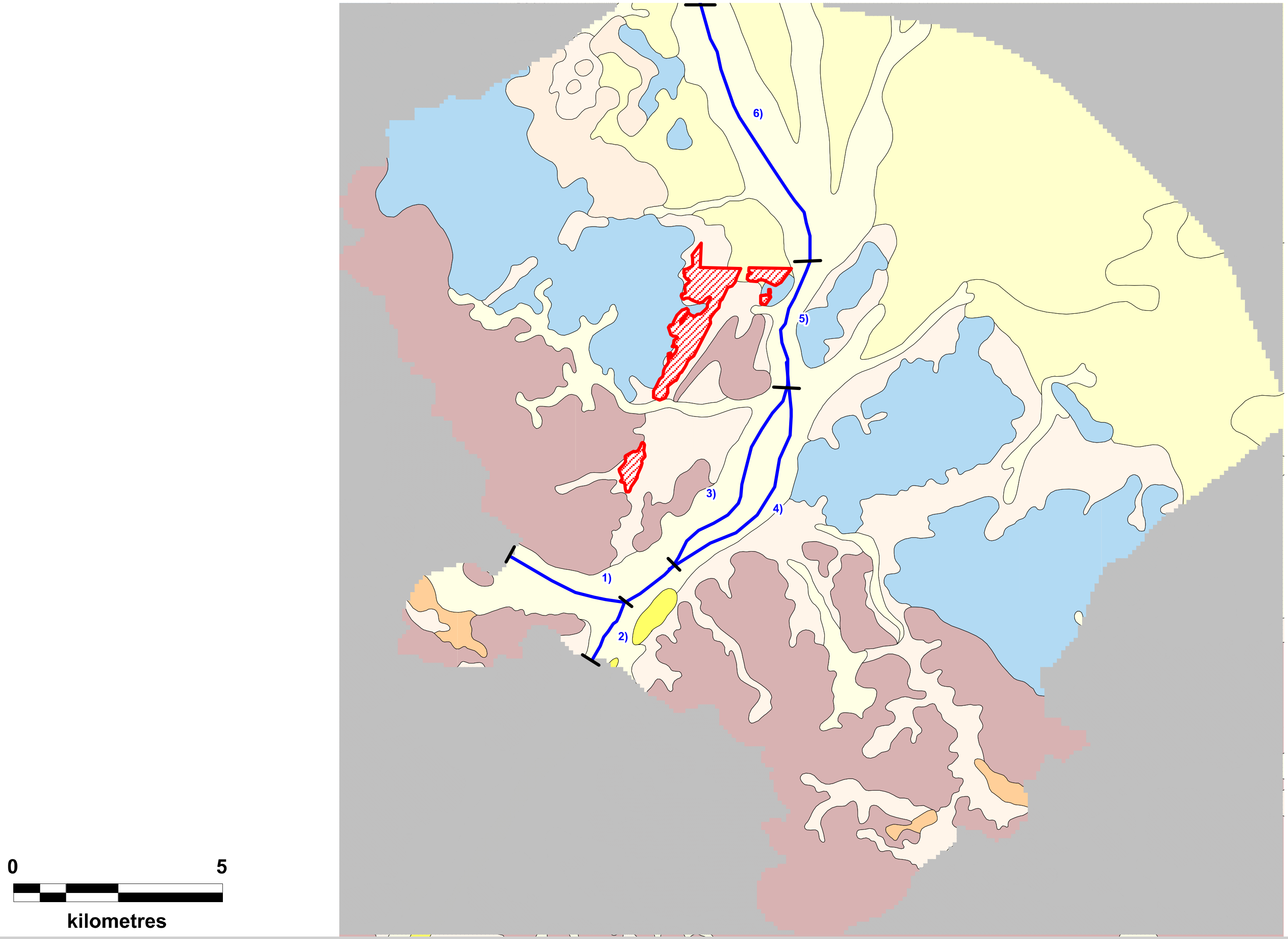
- Rio Tinto Water Levels (from Dogramaci et al 2014)
- Iron Valley Water Levels
- GW Contours (mAHD)
- Pit Outline

AUTHOR: ATS
DRAWN: ATS
DATE: 14/01/2016

REPORT NO: 083B
REVISION: B
JOB NO: 13B

NOTES & DATA SOURCES:
Catagraphic Scale= 1:75000

FIGURE 3.3
GROUND WATER LEVELS- 2015 IRON VALLEY PROJECT



LOCATION MAP

Location: XXXX

KEY

Reaches of Weeli Wolli Creek used for Catchment Water Balance

Pit Outline

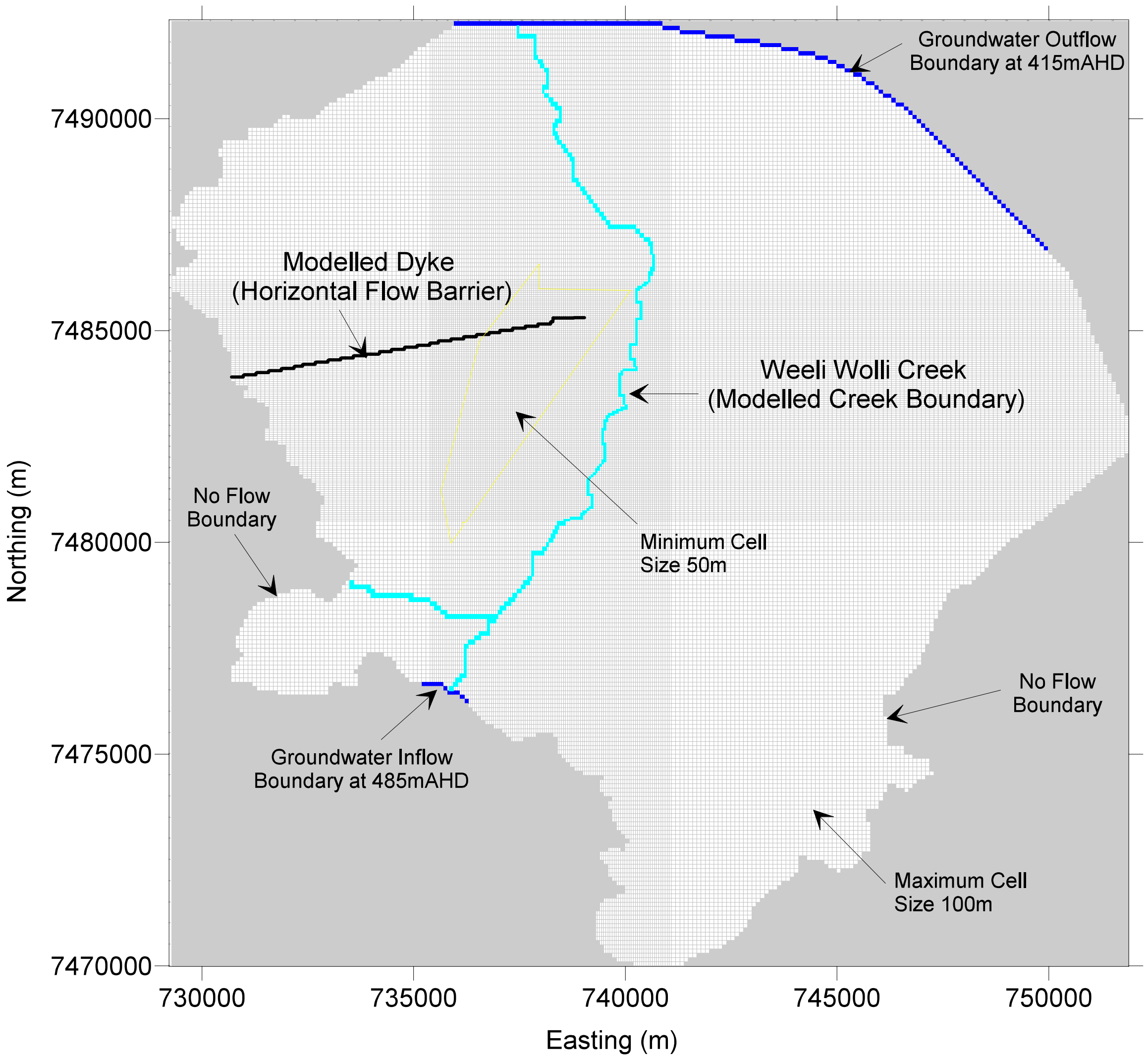
AQ2

AUTHOR: ATS
DRAWN: ATS
DATE: 08/01/2015

REPORT NO: 083A
REVISION: A
JOB NO: 13B

NOTES & DATA SOURCES:

FIGURE 3.4
CATCHMENT FOR WATER BALANCE



LOCATION MAP

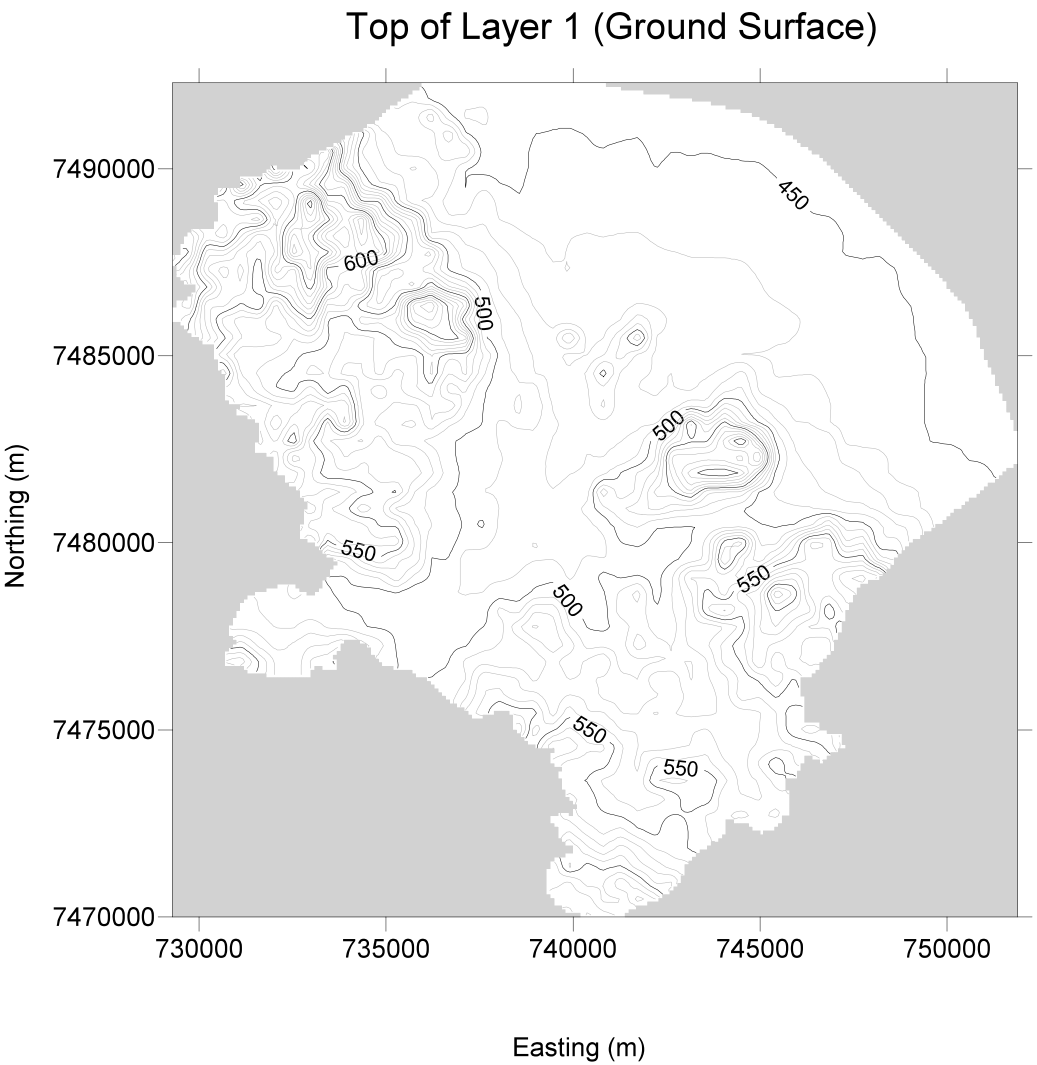
LEGEND

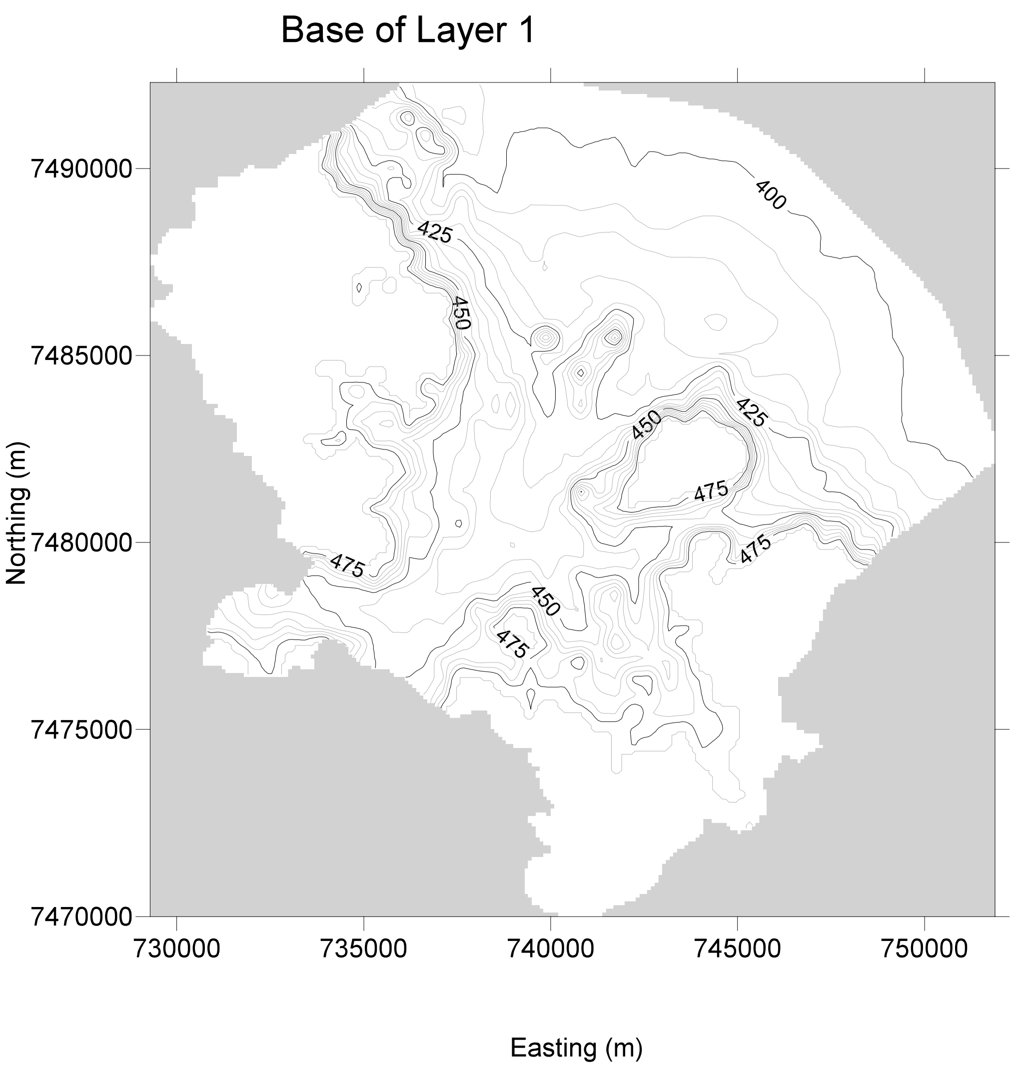
- Constant Head Boundary
- Horizontal Flow Barrier (Dyke)
- Modelled Creek Boundary (Weeli Wolli Creek)
- Project Area Boundary

AQ2

AUTHOR: KR DRAWN: KR DATE: 3 Nov 2015	REPORT NO: 062a REVISION: A JOB NO: 013B	GDA94 Zone 50 SCALE: 1:175,000 (at A4) f:/013b/GIS/Modelling Figures/062a Figure 4.1.srf

FIGURE 4.1
MODEL EXTENT AND BOUNDARY CONDITIONS





LOCATION MAP

LEGEND

Minor Elevation Contour (mAHD), shown at 10m interval

Major Elevation Contour (mAHD)m shown at 50m interval

AUTHOR: KR
DRAWN: KR
DATE: 3 Nov 2015

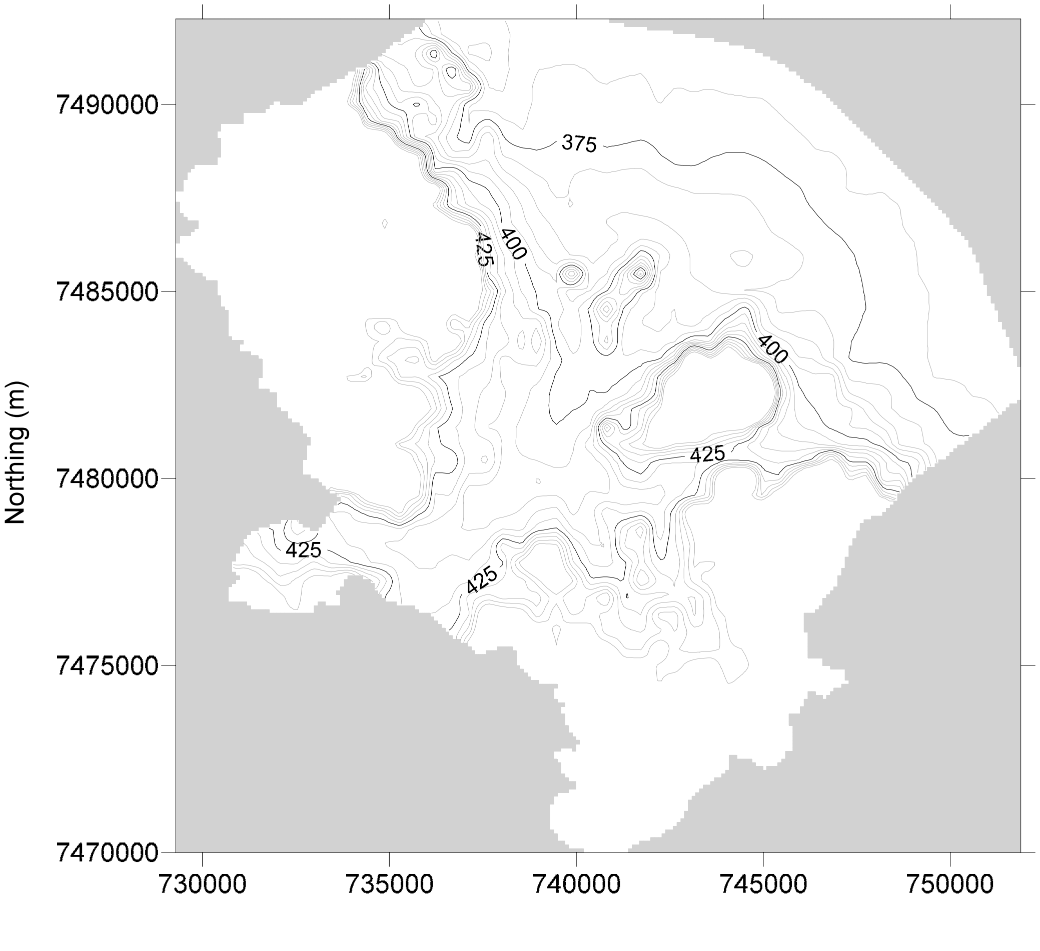
REPORT NO: 062a
REVISION: A
JOB NO: 013B

GDA94 Zone 50
SCALE: 1:200,000 (at A4)

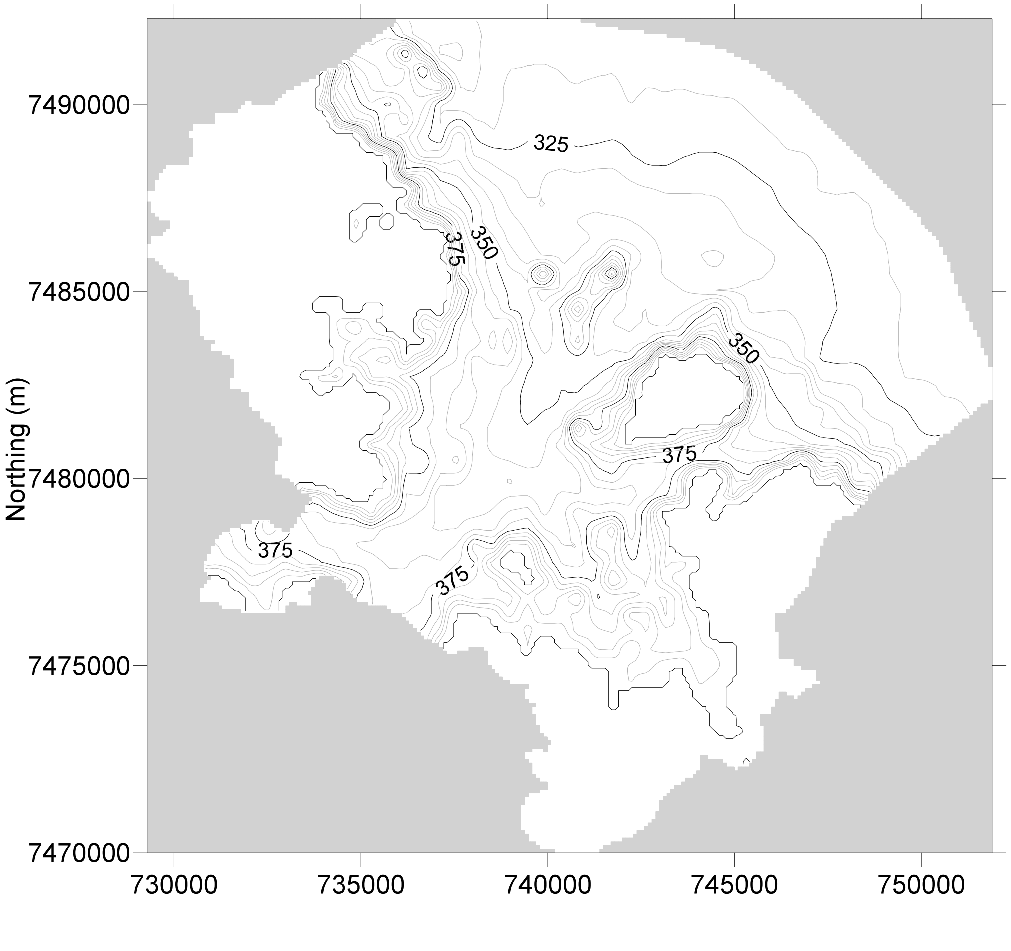
f:/013b/GIS/Modelling Figures/Figures/062a Figure 4.2.srf

FIGURE 4.2
CONTOURS OF TOP AND BASE ELEVATION LAYER 1

Base of Layer 2



Base of Layer 3



LOCATION MAP

LEGEND

Minor Elevation Contour (mAHD), shown at 5m interval

Major Elevation Contour (mAHD)m shown at 25m interval

AUTHOR: KR DRAWN: KR DATE: 3 Nov 2015	REPORT NO: 062a REVISION: A JOB NO: 013B	GDA94 Zone 50 SCALE: 1:200,000 (at A4) f:/013b/GIS/Modelling Figures/Figures/062a Figure 4.3.srf

AQ2

FIGURE 4.3
CONTOURS OF BASE ELEVATION LAYER 2 AND LAYER 3