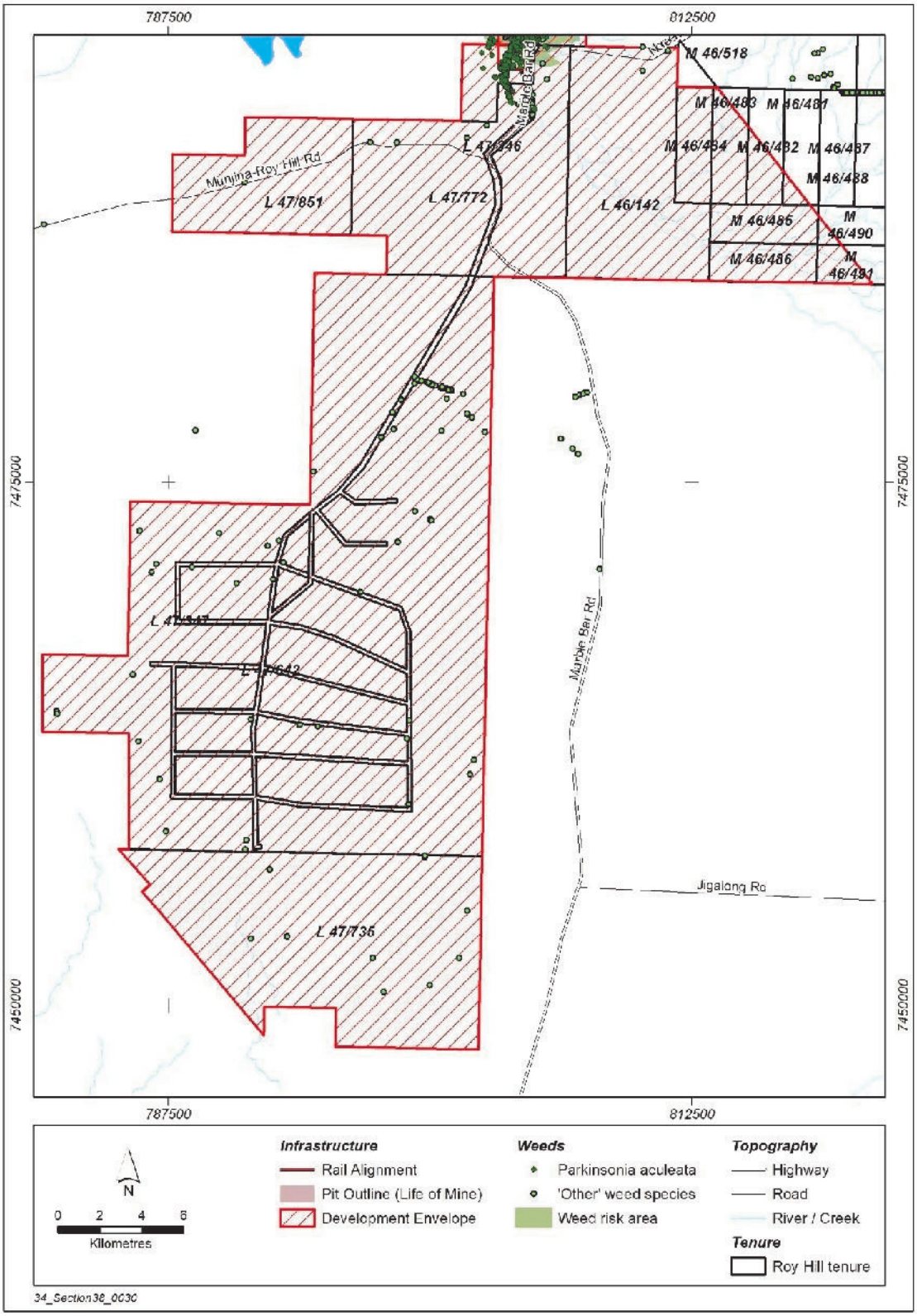


Figure 29: Weed locations in the Remote MAR and Southern Borefield area

4.3.3.6 Ecosystems

4.3.3.6.1 Priority and Threatened Ecological Communities

Priority Ecological Communities (PECs) are naturally occurring biological assemblages that occur in a particular habitat type which is either possibly threatened, rare but not threatened or near threatened (DPaW, 2017a). They are deemed Priority by DBCA and require regular monitoring.

The Priority 3 Fortescue Valley PEC ("Vegetation of sand dunes of the Hamersley Range/Fortescue Valley" - previously 'Fortescue Valley Sand Dunes') (DPaW, 2017) is located to the south west of the Southern Borefield Area, approximately 2km from RHIO's L47/735 tenement boundary at its closest point (Figure 30) (Biologic, 2018). A small number of dunes are vegetated with *Acacia dictyophleba* scattered tall shrubs over *Crotalaria cunninghamii*, *Trichodesma zeylanicum* var. *grandiflorum* open shrubland (DBCA, 2017b). These vegetated sand dunes are regionally rare, small and fragile, and highly susceptible to threatening processes (DBCA, 2017b).

The Priority 1 Marsh Land System is located immediately to the west of the mine area (Figure 30). The Fortescue Marsh is further discussed in section 4.3.3.6.2.

The Priority 3 Narbung Land System PEC occurs within the Remote MAR Borefield area (RHIO's L47/851, L47/642, L46/142 and L47/772 tenement boundaries; Figure 30). It comprises alluvial wash plains with prominent internal drainage foci supporting snakewood (*Acacia xiphophylla*) and mulga (*Acacia aneura* and its close relatives) shrublands with halophytic low shrubs (Biologic, 2018). Approximately 37% (5,850 ha) of the Narbung Land System PEC occurs within Revised Development Envelope (Figure 30).

The Priority 3 Stony saline plains of the Mosquito Land System occur approximately 23km to the east of RHIO's M46/518 tenement tenure boundary (Biologic, 2018).

No Threatened Ecological Communities occur in the Revised Development Envelope.

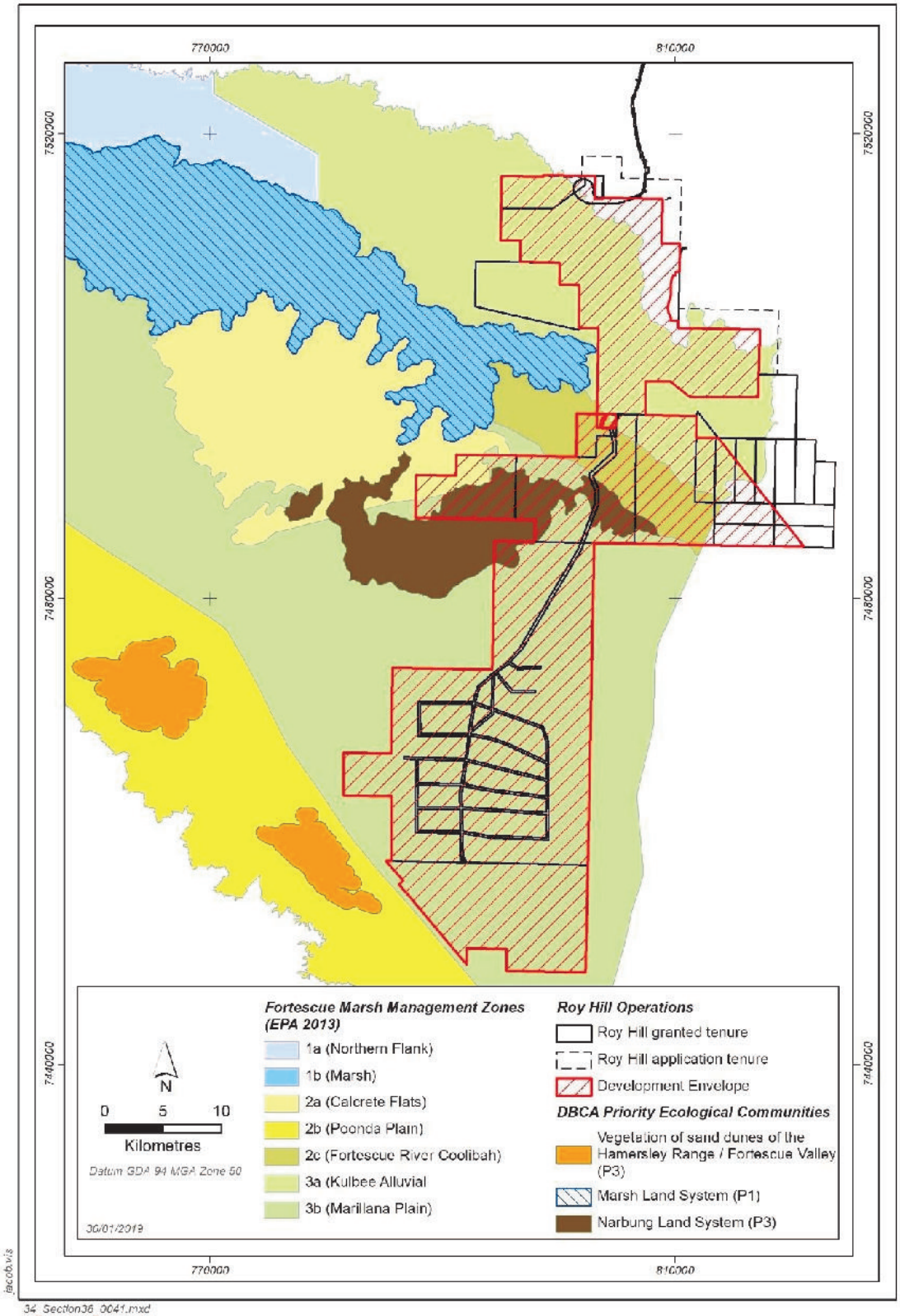


Figure 30: PECs within the Revised Development Envelope

4.3.3.6.2 Fortescue Marsh

The Fortescue Marsh (the Marsh) is the largest ephemeral wetland in the Pilbara region (EPA, 2013). It is listed on the Australian Heritage Commission Register of the National Estate as an "Indicative Place", and in the Directory of the Important Wetlands in Australia (Environment Australia, 2001). The Fortescue Marsh is listed as a wetland of national significance and a Priority 1 Ecological Community. The Fortescue Marsh supports a rich diversity of migratory birds and is recognised by the Commonwealth under the Japan-Australia Migratory Bird Agreement and the China-Australia Migratory Bird Agreement.

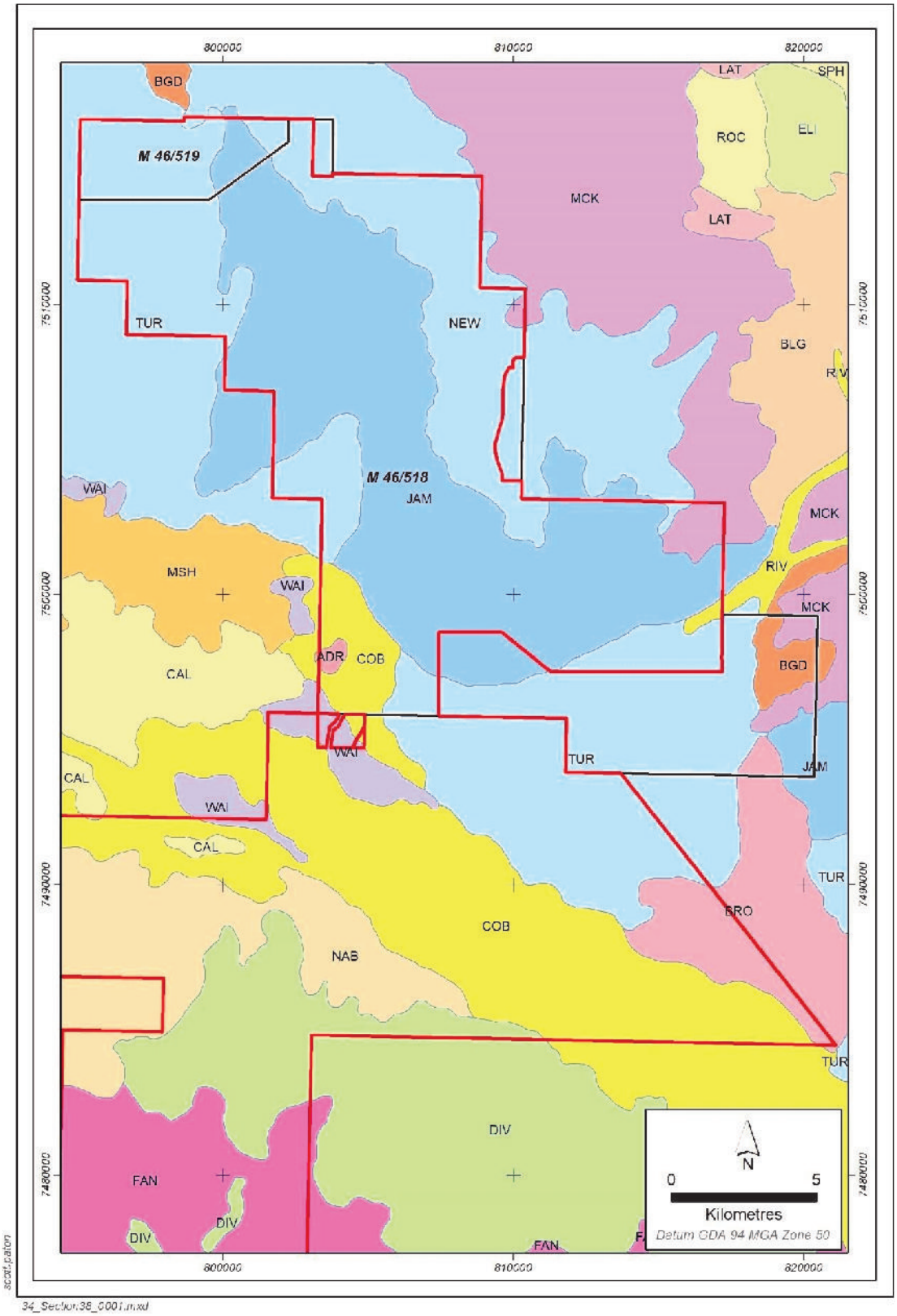
The Fortescue Marsh extends over approximately 1,050km^2 within a management area of 5,836km^2 and the broader catchment of the upper Fortescue River of 29,791km^2 (EPA, 2013).

The Marsh is described as an extensive, episodically inundated samphire marsh at the upper terminus of the Fortescue River and the western end of Goodiadarrie Hills. It is a highly diverse ecosystem with fringing mulga woodlands (on the northern side), samphire shrublands and groundwater dependant riparian ecosystems (DBCA, 2017a). It harbours several endemic species of plants and supports a rich diversity of restricted aquatic and terrestrial invertebrates (DBCA, 2017a). The area has high conservation value with an ancient and complex array of alluvial aquifers and groundwater systems. It is also at the heart of an important mining province and long-standing pastoral industry and has high cultural and heritage importance to the Indigenous peoples of the region (EPA, 2013).

The Fortescue Marsh Management Area (FMMA) is an area identified as having primary importance to the direct management of the Marsh, particularly in relation to the natural water regime and ecological perspectives. The EPA (2013) divides the FMMA into three zones: highest, medium and lowest environmental significance. Zones within the FMMA are assigned in relation to key environmental values and management / decision-making priorities assigned by the EPA (EPA, 2013).

4.3.3.7 Land Systems

Van Vreeswyck et al (2004) described 102 land systems for the Pilbara. These were grouped into 20 land types according to a combination of landforms, soils, vegetation and drainage patterns (Payne, 2004). The land systems that occur within the Revised Development Envelope are illustrated in Figure 31 (Mine area) and Figure 32 (Remote MAR and Southern Borefield).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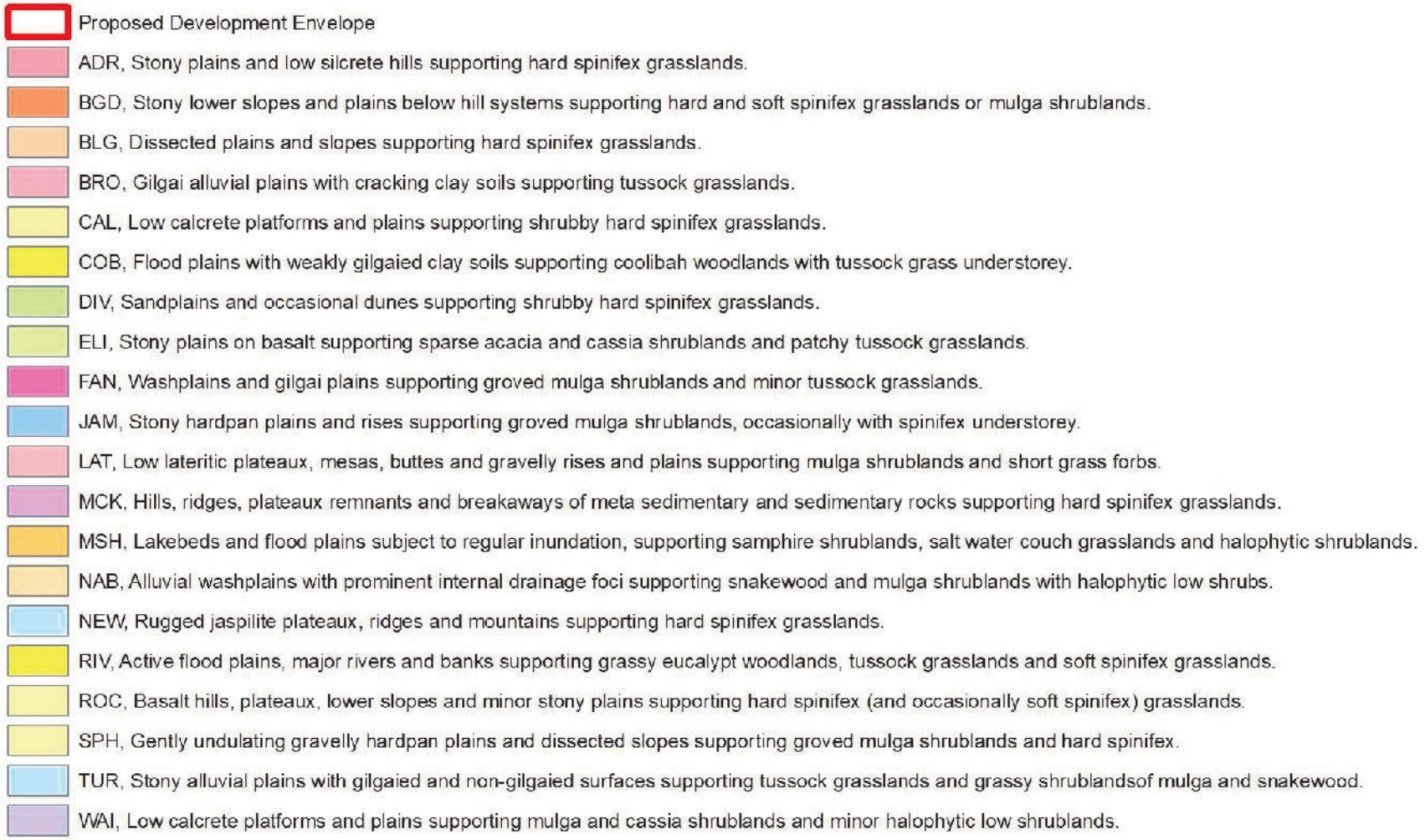

Figure 31: Land systems occurring within RHIO Mine area

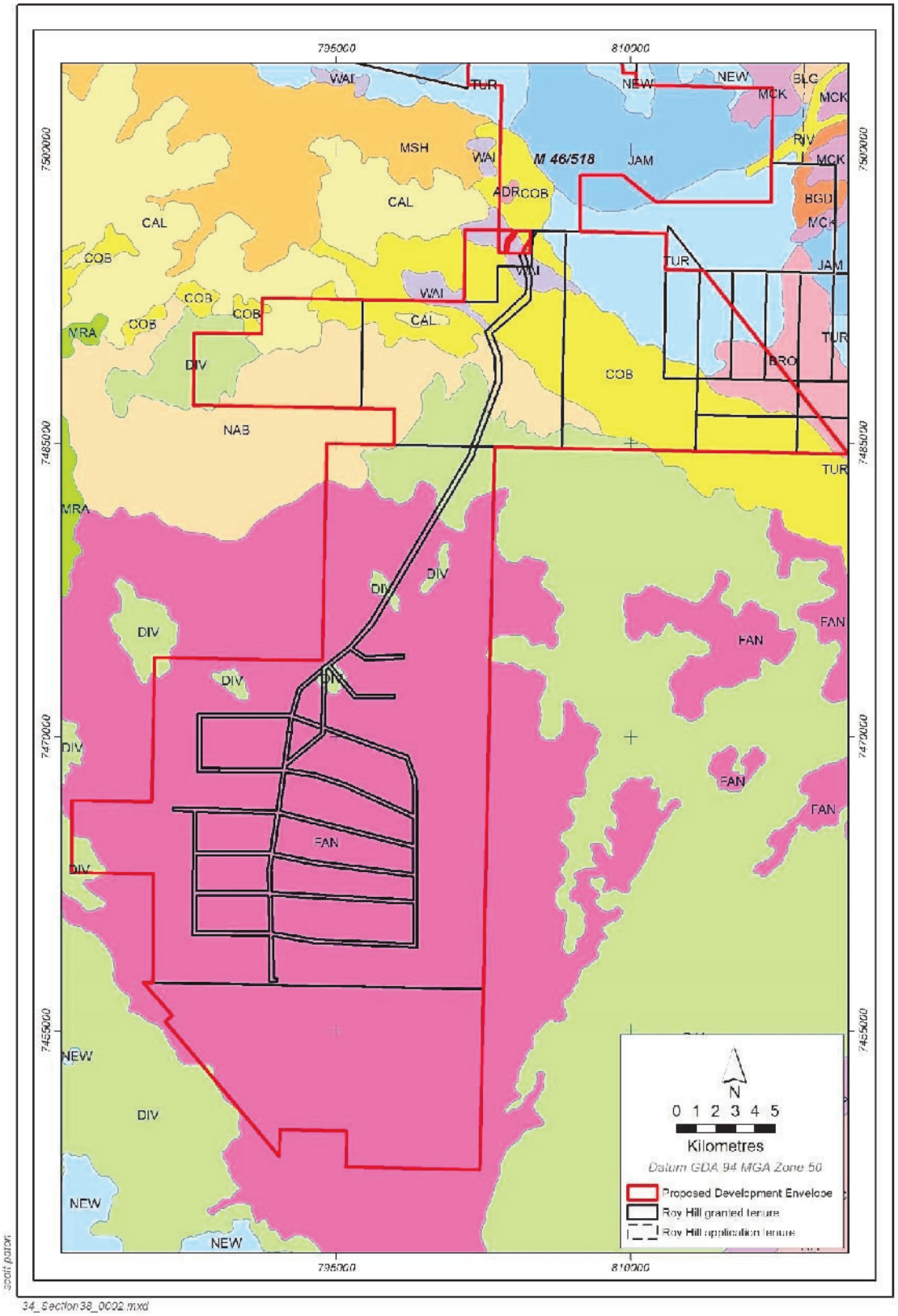

Figure 32: Land systems occurring within RHIO Borefield Area

4.3.4 Potential impacts

The following potential impacts to Flora and Vegetation from the implementation of the Revised Proposal have been identified:

- Direct loss of flora and vegetation from clearing and ground disturbance activities has the potential to affect the regional representation of species and communities;
- Indirect impacts, including a decline in health and/or change in vegetation composition, due to saline water or decant water disposal for dust suppression or disposal via MAR;
- Indirect impacts, including a decline in health and/or change in vegetation composition, from reduction in groundwater levels due to groundwater abstraction or dewatering;
- Indirect impacts, including a decline in health and/or change in vegetation composition, from increase in groundwater levels due to groundwater re-injection;
- Indirect impacts, including a decline in health and/or change in vegetation composition, from a change in the groundwater quality due to re-injection of groundwater of a different quality to that naturally existing;
- Indirect impacts, including a decline in health and/or change in vegetation composition from alteration of surface water flows;
- Indirect impacts, including a decline in health and/or change in vegetation composition, from introduction and spread of weeds; and
- Indirect impacts, including a decline in health and/or change in vegetation composition, from dust deposition.

The proposed impact of the indicative footprint of the overall Revised Proposal on Flora and Vegetation, is identified in Table 4-6 and discussed in Section 4.3.5.1. Proposed impacts on Flora and Vegetation identified as having significant environmental value and requiring protection, are identified in Table 4-6 and discussed in Sections 4.3.5.2 to 4.3.5.7. Proposed impacts to Priority flora is outlined in Table 4-7 and described in Section 4.3.5.1.2. The assessment of potential impacts outlined in Section 4.3.4 considers impacts from the Revised Proposal that have increased, changed to that of the Original Proposal, or have not previously been assessed.

Table 4-8 summarises the cumulative changes that are expected to occur in the Revised Development Envelope as a result of the Original and Revised Proposals. Cumulative impacts in the mine area are high due to the nature of mining, however cumulative impacts are much lower in the Remote MAR Borefield and Southern Borefield due to the ability to avoid sensitive areas such a Priority flora and drainage foci.

Ecosystems within the Revised Development Envelope that have regional significance include the Priority 3 Narbung Land System and the Fortescue Mars. Impacts to these Ecosystems are outlined in Table 4-9 and discussed in Section 4.3.5.8. The proposed impacts to Land systems of the Pilbara Region are outlined in Table 4-10 and discussed in Section 4.3.5.8. The impacts proposed in Table 4-9 and Table 4-10 and discussed in Sections 4.3.5.8 and 4.3.5.9 are not additional to those described in Table 4-6 and discussed in Sections 4.3.5.2 to 4.3.5.7; rather this represents another way of assessing the impacts of the Revised Proposal using regionally significant Ecosystems and Land systems.

Table 4-6: Vegetation Impacts in the Revised Development Envelope based on Indicative Footprint

Environmental Value	Level of significance	Cause	Revised Proposal Direct Impact ha	Revised Proposal Potential Indirect Impact ha
General Flora and Vegetation	Total 5,995 ha of vegetation within Revised Development Envelope	Direct impacts resulting from clearing or ground disturbance	5,995	N/A
		Direct impacts to priority flora	See Table 4-7	
		Indirect impacts resulting from changes in groundwater levels and quality	N/A	6,678.7
		Indirect impacts resulting from changes in, alterations in surface water flows	N/A	85.92
		Indirect impacts resulting from the introduction and spread of weeds	N/A	N/A
		Indirect vegetation health impacts caused by disposal of saline water/decant water for dust suppression	N/A	N/A
		Indirect vegetation health impacts caused by dust deposition	N/A	N/A
Mulga woodland incorporating six vegetation types (AaArTl, ApAa, AaAtSahAc, AaArEffSahElf, AaSglEc, AaPs)	Significant environmental value in the Fortescue Plains sub region as it is near the northern most extent of mulga in the Pilbara Bioregion. 11,333.7 ha mapped in Revised Development Envelope	Direct impacts resulting from clearing and ground disturbance	2273.4	N/A
		Indirect vegetation health impacts caused by a reduction in groundwater levels from water abstraction or dewatering	N/A	4.65
		Indirect vegetation health impacts caused by an increase of groundwater levels causing waterlogging or change in water quality (salinization)	N/A	1,223.72
Riparian Vegetation (including potential GDV species) incorporating six vegetation types (EcEvCh,	551.4 ha surveyed in Revised Development Envelope	Direct impacts resulting from clearing and ground disturbance	158.6	N/A
		Indirect vegetation health impacts caused by a reduction in groundwater levels from water abstraction or dewatering	N/A	0.02

Environmental Value	Level of significance	Cause	Revised Proposal Direct Impact ha	Revised Proposal Potential Indirect Impact ha
EvAaAcpAh, AsppGwh, EvAtAsVf, EvAs, ApAaPl)		Indirect vegetation health impacts caused by an increase of groundwater levels causing waterlogging or change in water quality (salinization)	N/A	62.65
		Indirect vegetation health impacts caused by alteration of surface water flow pathways	N/A	85.92
Open hummock grassland (TaTpTsMOHG, TbTsHG (THG))	High local significance due to presence of priority species 82.6 ha surveyed in Revised Development Envelope	Direct impacts resulting from clearing and ground disturbance	82.2	N/A
		Indirect vegetation health impacts caused by an increase of groundwater levels causing waterlogging or change in water quality (salinization)	N/A	36.25
Tall Open Shrubland (AxTOS, AxAapSL (ASL-4))	Moderate local significance as it most closely resembles the Narbung land system description and occurs within the land system mapping.	Direct impacts resulting from clearing and ground disturbance	59.7	N/A
		Indirect vegetation health impacts caused by an increase of groundwater levels causing waterlogging or change in water quality (salinization)	N/A	190.23
Groundwater Dependent Ecosystem associated with Fortescue River (EcoMIT, EvAaLIT)	Moderate local significance due to presence of phreatophytic and potentially phreatophytic vegetation.	Direct impacts resulting from clearing and ground disturbance	10.5	N/A
		Indirect vegetation health impacts caused by an increase of groundwater levels causing waterlogging or change in water quality (salinisation)	N/A	41.66
Drainage foci in vegetation unit ASL1 / AmAtAaSL	Moderate local significance due to Potential GDV in drainage foci	Direct impacts resulting from clearing and ground disturbance	0	N/A
		Indirect vegetation health impacts caused by a reduction in groundwater levels from water abstraction	N/A	0

Table 4-7: Impact to Priority flora species

Species	Priority	No. identified in indicative disturbance area	No. identified in Revised Development Envelope	*% impacted	No. of other known locations regionally
Acacia glaucocaesia	Priority 3	3	6	50	27
Eremophila youngii subsp. *Lepidota*	Priority 4	20	110	18	155
Goodenia nuda	Priority 4	12	28	43	363
Rhagodia sp. Hamersley (M. Trudgen 17794)	Priority 3	290	715	41	793
Rostellularia adscendens var. *latifolia*	Priority 3	98	198	49	323
Polymeria distigma	Priority 3	0	0	0	1
Aristida jerichoensis subsp. *Subspinulifera*	Priority 3	0	0	0	3
Eremophila pilosa	Priority 1	0	0	0	369
Triodia veniciae	Under review	0	7	0	46
Stemodia sp Battle Hill	Priority 1	0	58	0	118
Eremophila spongiocarpa	Priority 1	0	1	0	71

*Percentage indicates impact based on that mapped as remaining within the Revised Development Envelope. It does not consider distribution outside of the Revised Development Envelope

Table 4-8: Cumulative Direct Impacts of the Original Proposal and the Revised Proposal.

Environmental Value	Original Proposal Total		Revised Proposal Total		Total Impacts		Remaining within Revised Development Envelope	
	ha	%	ha	%	ha	%	ha	%
Note: % indicates the percentage of vegetation type within the Revised Development Envelope								
Mulga woodland incorporating six vegetation types (AaArTl, ApAa, AaAtSahAc, AaArEffSahElf, AaSglEc, AaPs)	9,060.3	34.02	2273.4	8.54	11,333.7	42.56	15,298.3	57.44
Riparian Vegetation (including potential GDV species) incorporating six vegetation types (EcEvCh, EvAaAcpAh, AsppGwh, EvAtAsVf, EvAs, ApAaPl)	392.8	16.00	158.6	6.51	551.4	22.62	1,886.1	77.38
Open hummock grassland (TaTpTsMOHG)	0.4	0.02	82.2	4.17	82.6	4.19	1,888.2	95.81
Vegetation unit AxTOS	0	0	59.7	3.55	59.7	3.55	1617.9	96.44
Groundwater Dependent Ecosystem associated with Fortescue River (EcoMIT)	0.03	0.01	10.5	4.47	10.53	4.48	224.3	95.52
Drainage foci in vegetation unit ASL1 / AmAtAaSL	0	0	0	0	0	0	6.52	100
Fan land system	47.9	0.09	1,448.9	2.91	1496.8	3.01	48,181.8	96.98

Table 4-9: Ecosystems - Narbung Land System PEC and Fortescue Marsh Management Area Zones overlapping the Revised Development Envelope

Zone	Relative Priority	Key Environmental Values	Activity with Potential Impact	Ha to be cleared in Revised Development Envelope (Original & Revised Proposal)	Potential Indirect Impacts from LOM WMS in Revised Development Envelope	Total Impacts in the Revised Development Envelope	Total area of Land system or FMMA in Revised Development Envelope	Potential Indirect Impacts from LOM WMS Outside Revised Development Envelope
Narbung Land System								
Narbung Land System PEC	Medium environmental significance	• Drainage foci • Halophytic low shrubs	Surface water, Clearing and ground disturbance, Remote MAR	252.51	1,060.79	1313.3	5,850	722.90
Fortescue Marsh Management Area								
1b Marsh	High environmental significance	• Pools and springs • Wetland • Water quality gradient • Species of conservation significance • Samphire vegetation community • Aquatic invertebrates • Waterbirds	Surface water, Mine dewatering and MAR	0	0	0	0	1,933.20
2a Calcrete Flats	Medium environmental significance	• Natural water regimes • Subterranean fauna • Aquatic invertebrates • Riparian vegetation • Species of conservation significance	Surface water, Clearing and ground disturbance, Remote MAR	86.47	11.79	98.26	1,376.73	43.93
2c Fortescue	Medium environmental significance	• Natural water regimes • Subterranean fauna • Greater Bilby	Surface water, Clearing and	245.55	343.49	589.04	6,505.75	46.93

River Coolibah		• Riparian vegetation	ground disturbance, Remote MAR					
3a Kulbee Alluvial Flank	Lowest environmental significance	• Natural water regimes • Natural springs and pools • Mulga woodlands • Species of conservation significance • Subterranean Fauna	Surface water, Clearing and ground disturbance Mine dewatering, MAR	12,339.94	950.56	13,290.5	22,128.66	3,120.61*
3b Marillana Plain	Lowest environmental significance	• Natural water regimes • Land systems • Mulga woodlands • Species of conservation significance • Subterranean Fauna • Aquatic invertebrates	Surface water, Clearing and ground disturbance, Remote MAR, Southern Borefield abstraction	2,030.06	1,803.85	3,833.91	60,569.34	2,402.37
		FMMA Total (Ha)		**14,702.02**	**3,109.39**	**17,811.71**	**90,580.48**	**7,547.04**

*included indirect impacts on L46/141 owned by RHIO but outside the Development envelope

Table 4-10: Land Systems of the Revised Development Envelope

Land type	Land System and description	Total proposed clearing within Revised Development Envelope (ha) (Original and Revised Proposal)	Total Area of Land System within Revised Development Envelope (ha)	Total Area of Land System (Ha)*	Percentage (%) of Land System within Revised Development Envelope
Land type 1: Hills and ranges with spinifex grasslands	**Newman (NEW)**: Rugged jaspilite plateaux ridges and mountains supporting hard spinifex grasslands.	2,995.18	4004.15	1,458,000	0.27
	McKay (MCK): Hills, ridges, plateaux remnants and breakaways of meta sedimentary and sedimentary rocks supporting hard spinifex grasslands.	208.20	389.51	4,202,000	0.01
Land type 6: Stony plains and hills with spinifex grasslands	**Adrian (ADR)**: Stony plains with low silcrete hills supporting hard spinifex grasslands.	0	82.81	23,500	0.35
Land Type 11: Sandplains with spinifex grasslands	**Divide (DIV)**: Sandplains and occasional dunes supporting shrubby hard spinifex grasslands.	209.87	5,630.66	529,300	1.06
Land Type 12: Wash plains on hardpan with groved Mulga shrublands (sometimes with spinifex understorey)	**Jamindie (JAM)**: Stony hardpan plains and rises with groved Mulga shrublands, occasionally with spinifex understorey.	9,059.02	11,539.96	207,400	5.56
	Fan (FAN): Wash plains and gilgai plains supporting groved mulga shrublands and minor tussock grasslands	1,496.81	48,181.80	148,200	32.51
Land type 14: Alluvial plains with tussock grasslands or grassy shrublands	**Brockman (BRO)**: Alluvial plains with cracking clay soils supporting tussock grasslands and grassy shrublands.	0	1,312.72	73,500	1.78
	Turee (TUR): Stony alluvial plains with gilgaied and non-gilgaied surfaces supporting tussock grasslands and grassy shrublands.	3,197.68	9,282.47	58,100	15.98

Land type	Land System and description	Total proposed clearing within Revised Development Envelope (ha) (Original and Revised Proposal)	Total Area of Land System within Revised Development Envelope (ha)	Total Area of Land System (Ha)*	Percentage (%) of Land System within Revised Development Envelope
Land Type 15: Alluvial plains with snakewood shrublands	**Narbung (NAB)**: Alluvial washplains with prominent internal drainage foci supporting snakewood and mulga shrublands with halophytic low shrubs	252.51	5850	15,954	36.7
Land type 17: River plains with grassy woodlands and shrublands and tussock grasslands	**Coolibah (COB)**: Flood plains with weakly gilgaied clay soils supporting coolibah (*E. victrix*) woodlands with tussock grass understorey.	421.44	9,935.91	1,014,000	0.98
	River (RIV): Comprises active floodplains and major rivers supporting grassy eucalypt woodlands, tussock grasslands and soft spinifex grasslands.	70.04	72.28	408,800	0.02
Land type 18: Calcrete drainage plains with shrublands or spinifex grasslands	**Warri (WAI)**: Low calcrete platforms and plains supporting Mulga and *Senna* shrublands.	20.26	739.37	30,500	2.42
	Calcrete (CAL): Low calcrete platforms and plains supporting shrubby hard spinifex grasslands	55.11	923.64	144,400	0.63

*Data from Van Vreeswyck et al (2004)

4.3.5 Assessment of Impacts

4.3.5.1 Overall Revised Proposal

4.3.5.1.1 Direct impacts resulting from clearing and ground disturbance

Direct loss of flora and vegetation from clearing and ground disturbance activities has the potential to affect the regional representation of species and communities. Direct clearing and ground disturbance is the biggest cause of impact to native vegetation expected from the implementation of the Revised Proposal.

The Revised Proposal will result in the direct impact of a maximum of 5,995ha of vegetation.

4.3.5.1.1 Direct impacts to Priority flora

Clearing and ground disturbance is considered the only potential cause of impacts to Priority flora species. Due to the inherent flexibility in the location of bore pads and tracks in the Remote MAR Borefield and Southern Borefield, identified Priority flora species will be avoided where possible. Impacts to Priority 1 species *Stemodia* sp. Battle Hill, *Eremophila spongiocarpa* and *Eremophila pilosa* will be avoided. Eight Priority species have been identified as occurring in the Revised Development Envelope (Table 4-7) of which five have individual plants which are likely to be impacted by clearing and ground disturbance of the Revised Proposal. These species have rankings of either Priority 3 or Priority 4 and have several records that extend beyond the Revised Development Envelope.

Only two-point records of Priority flora were assigned a low or medium risk of decline or mortality due to groundwater mounding or salinization. The LOM WMS management measures of limiting groundwater mounding to >5mbgl will ensure minimal impacts to Priority flora (Astron, 2019).

Impacts to the Priority 3 and 4 species are not considered to be of significance, due to the number of these species both remaining within the Revised Development Envelope and located outside of the Revised Development Envelope. Priority species identified in the indicative borefield pipeline route and bore locations will be avoided where possible, as infrastructure locations have a degree of flexibility.

4.3.5.1.1 Indirect impacts resulting from changes in ground water level and quality

RHIO commissioned Astron (2019;Appendix 9) to conduct a risk assessment of the potential indirect impacts from changes in groundwater level and quality associated with RHIO's proposed LOM WMS (GHD, 2018). Astron (2019) considered the following risk scenarios:

- Groundwater drawdown (decoupling of roots from a reliable water source);
- Groundwater mounding (water logging);
- Unbalanced growth (canopy growth which is not matched by root growth); and
- Groundwater mounding and salinisation (osmotic or toxic stress due to saline groundwater).

The risk was determined based on a likelihood and consequence matrix consistent with Department of Environmental Regulation (2017) as shown in Table 4-11.

Table 4-11: Risk Treatment Table

Risk Rating	Acceptability	Treatment
Extreme	Unacceptable	Risk event will not be tolerated
High	May be acceptable. Subject to multiple regulatory controls	Risk event will be tolerated and may be subject to multiple regulatory controls.
Medium	Acceptable, generally subject to regulatory controls.	Risk event is tolerable and is likely to be subject to some regulatory controls.
Low	Acceptable, generally not controlled.	Risk event is acceptable and will generally not be subject to regulatory controls.

The likelihood was conceptualised as the probability of a negative impact occurring, while consequence was conceptualised as the magnitude of the impact and was determined based on established sensitivities of specific vegetation types. Vegetation types considered to offer considerable conservation values were those in which mulga, samphire*, E. victrix* or *E. camaldulensis* were detected. The vegetation types comprising these key species were assigned an elevated consequence level in the risk matrix (Astron, 2019).

The hydrological modelling undertaken in the LOM WMS (GHD, 2018) was utilised for the risk assessment. The LOM WMS considers six dewatering and injection scenarios, with injection occurring in the SWIB, Stage 1 Borefield, Remote MAR and Southern Borefield (either individually or a combination of these). Astron's (2019) risk assessment considers scenario 2B outlined in the LOM WMS (GHD, 2018), in which all four injection fields are used at the same time (GHD, 2018). This scenario was selected because it represents the largest spatial extent of groundwater mounding, which is considered to pose the greatest threat to vegetation. Temporally, the model output for 2026 was selected to represent a period of high risk of decline or mortality because it represents a phase of the LOM WMS when groundwater drawdown approaches the maximum depth and groundwater mounding has occurred over a sustained period.

The risk assessment identified that groundwater drawdown, mounding and unbalanced growth would result in only a medium or low risk to vegetation, which is considered acceptable risk and manageable with appropriate controls. Groundwater mounding where salinisation would also occur resulted in the highest risk to vegetation.

Astron's (2019) risk assessment assigned only 12.5ha of vegetation near the SWIB and within the RHIO tenure, as being at high risk of decline or mortality due to groundwater mounding and salinisation (Figure 33).

The areas at low to medium risk of decline or mortality due to groundwater mounding or salinisation were focussed within the north-west of the Revised Proposal area, near the current mining area, the proposed clearing footprint and re-injection fields (Figure 33). Probability levels were low or negligible in all areas, particularly when the 5mbgl water level limit was considered, however vegetation at the SWIB and Remote MAR Borefield areas received a predominantly moderate risk of mounding and salinisation due to the shallow depths to groundwater and presence of Priority flora (Section 4.3.5) which increased the consequence level. Aside from a medium risk rating for several samphire populations on the fringe of the Fortescue Marsh, there was a low or negligible risk of impact of decline or mortality due to any scenario in the nearby PECs (Astron, 2019).

Re-injection of water through MAR in the Stage 1 Borefield and Southern Borefield will be limited to 5,000mg/L TDS. Modelling suggests this may cause groundwater quality changes in these areas up to 5,000mg/L. In the SWIB and Remote MAR Borefields where natural groundwater up to 100,000mg/L is found, re-injection water

up to 50,000mg/L will be used, and re-injection will occur at depth into the hypersaline body of groundwater. Mixing will likely reduce the overall salinity and associated concentrations of the hypersaline body in the zone of influence. The saline injected water is likely to partly migrate vertically, however vertical migration is expected to be minor due to physical and density controls on upward migration and mixing (Astron, 2018).

Impacts to vegetation resulting from changes in ground water level and quality are not considered to be of significance, due to the number of these species both remaining within, and located outside of, the Revised Development Envelope, as well as the short-term extent of the expected mounding and salinisation.

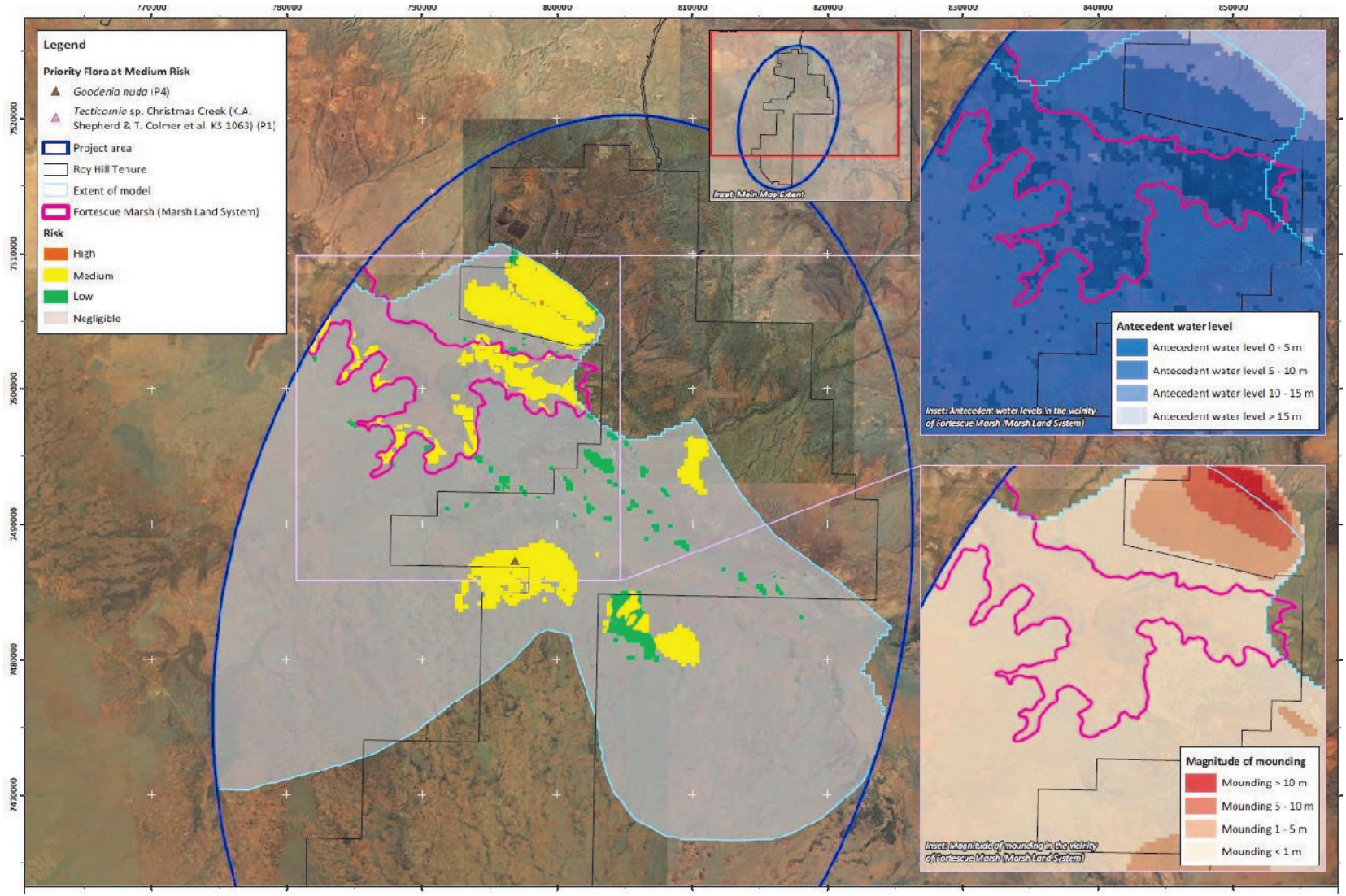

Figure 33: Risk of decline or mortality due to groundwater mounding and salinisation

4.3.5.1.4 Indirect impacts resulting from alterations in surface water flow

Alterations in surface water flow have the potential to impact on mulga and riparian vegetation species that are dependent on surface water flow to recharge soil moisture and shallow aquifers. Impacts will be greatest in the Mine area where several creeks are diverted around open pits. This Revised Proposal proposes to make these diversions a permanent feature at mine closure. GHD (2018a; Appendix 3) undertook a study to support the proposed changes (Section 2.3.5).

In accordance with current approval conditions, hydraulic structures need to be designed and managed to minimise impacts to mulga and riparian vegetation. Where possible water diversions divert water back into the original water way down stream of the open pit, and where this is not possible the diverted water is diverted into other water ways. GHD (2018a) assessed the downstream flows at eleven locations downstream of the mine representing the main water ways impacted by the Revised Proposal (Table 4-12 and Figure 34).

Table 4-12: Waterway flow rates in 50% AEP flood (GHD, 2018a)

Reporting Location	Pre-Mine (m^3/s)	Mine Closure (m^3/s)	Percent of original
1	4.5	2.4	52%
2 (No Name Creek)	10.1	10.0	99%
3 (West Kulbee Creek)	7.1	6.7	93%
4	1.0	6.7	670%
5*	1.1	0.1	9%
6*(Kulbee Creek)	27.3	9.4	34%
7	5.4	0.1	1%
8	3.6	3.2	90%
9	0.3	8.5	3054%
10	5.6	0.4	7%
11 (Kulkinbah Creek)	14.6	14.3	98%

*Impacts at Locations 5 and 6 were previously assessed and are therefore not addressed in this document.

The reduction of flows at location 7 is due to the Golf 201 diversion (Figure 13 and Figure 14), affecting approximately 3.7km of riparian vegetation (Figure 34). Flow rates at location 8 are reduced by the Sierra 104 diversion (Figure 14, but largely replaced by the Golf 201 diversion. Flow rates at reporting location 10 are substantially lower than pre-mine conditions due to mining activities proposed to the north of the Ginbata Aerodrome runway that necessitate the Sierra 401 and 204 diversion structures (Figure 14). Due to topographic limitations, it is not possible to return these diverted flows to the original waterway.

Flows are increased at location 4 due to the Kulbee Creek Diversion. Although the substantial increase of flow rates at location 9 will provide sufficient water supply to the riparian vegetation, they potentially increase the scour risk.

The Fortescue Marsh is located downstream of the Mine area. Whilst the catchment of the mine is just 0.15% of the catchment of the Fortescue Marsh (Gilbert and Associates, 2009), changes to runoff quality may affect

the Marsh. GHD (2018a) found that in the locations where stream power has increased, it is still lower than published values (Alluvium, 2014) for both supply limited and transport limited streams, therefore is unlikely to increase scour risk, and therefore impact the water quality.

Impacts to Flora and Vegetation from alteration in surface water flows are considered minor and localised to small areas around open pits. Impacts to the Fortescue Marsh from alteration in surface water flows are not considered to be of significance.

4.3.5.1.5 Indirect impacts resulting from introduction and spread of weeds

Thirty species of introduced flora were recorded from the surveyed areas, including *Parkinsonia aculeata,* which is a Weed of National Significance and a listed Declared Plant. Construction and operation of the Revised Proposal has the potential to spread existing weeds and to introduce new weed species into previously weed free areas. Weeds can have a significant impact on natural values by:

- Successfully out-competing native species for available nutrients, water, space and sunlight;
- Reducing the natural diversity by smothering native plants or preventing them from growing back after clearing, fire or other disturbance; and
- Replacing the native plants that animals use for shelter, food and nesting (DoEE, 2019).

Weeds can be spread a number of ways including transfer of seeds on vehicles (and in some cases on clothing, such as *Bidens bipinnata*), transfer of topsoil, transfer of seeds in surface water flow, animals grazing (spread in faeces or by being carried on animal bodies) and wind dispersion. Spread of weeds has been assessed as a part of the Original Proposal. Works associated with this Revised Proposal do not alter the risk of introduction and spread of weeds to that previously assessed. RHIO will continue to implement weed management and control measures that have been well established and undertaken during the operation of the Original Proposal.

4.3.5.1.5 Indirect vegetation health impacts caused by use of saline water/decant water for dust suppression

Use of saline water for dust suppression to RHIOs unsealed road network was previously assessed and approved by EPA under s45C of the EPA Act through Attachment 4 to MS 824.

Astron (2015) conducted a desktop study and risk assessment of saline dewater used for dust suppression. This indicated that the areas of highest risk to impact of saline dewater disposal are associated with high density patches of vegetation within 10m of the road, vegetation associated with major drainage lines that intersected roads, and patches of vegetation on the downslope sides of roads. The use of saline dewater for dust suppression will continue to be undertaken in accordance with the RHIO Saline Water Use Management Procedure (OP-PRO-01073).

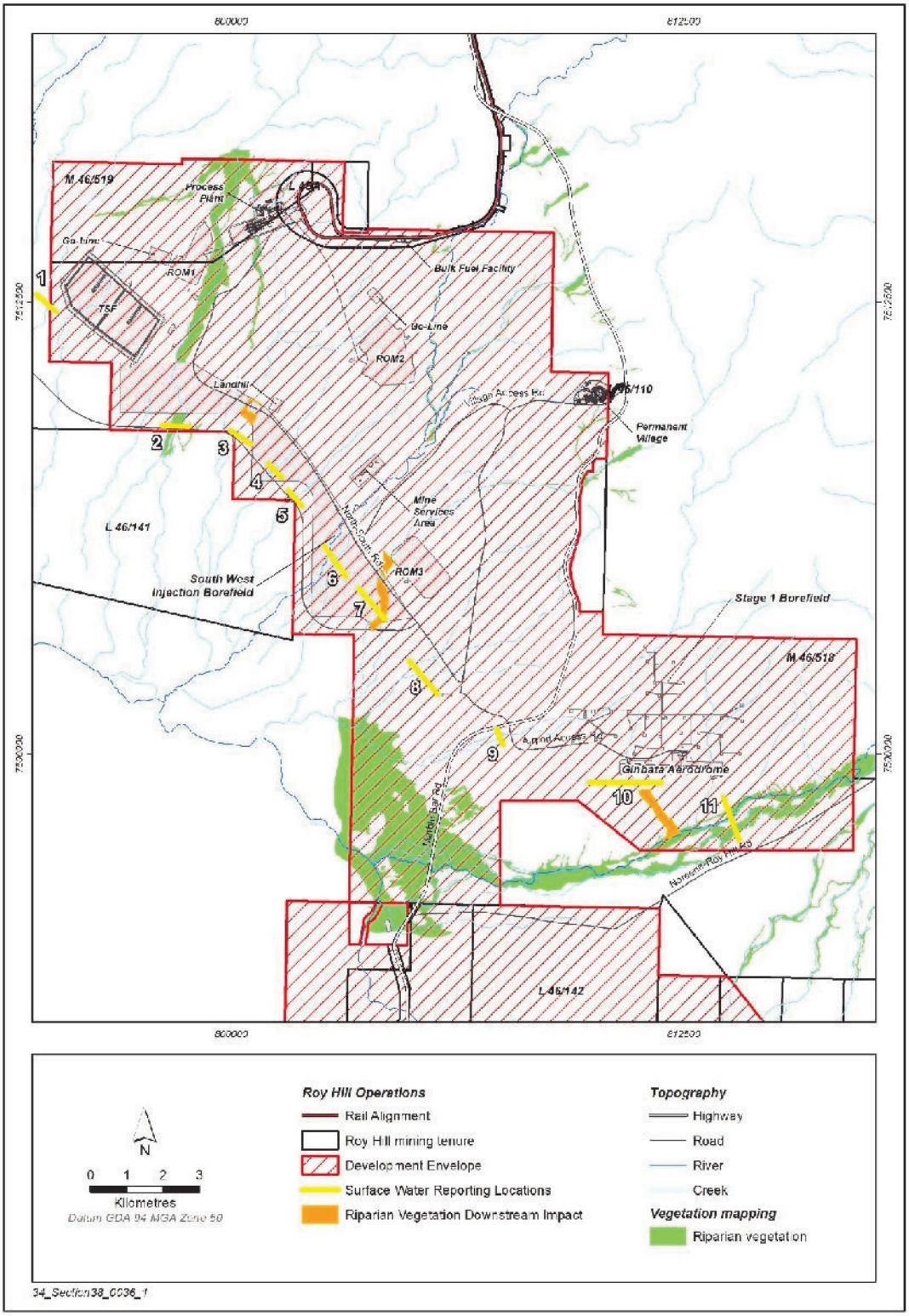

Figure 34: Location of downstream waterway assessment sites and riparian vegetation impacts

GHD (2019) conducted a risk assessment of utilising TSF decant water for dust suppression on the unsealed roads network around the mine. The impact area is expected to be similar to that of the saline dewater i.e. the

areas of highest risk to impact of TSF decant water disposal via dust suppression are associated with high density patches of vegetation within 10m of the road, vegetation associated with major drainage lines that intersected roads, and patches of vegetation on the downslope sides of roads. GHD (2019) concluded that nutrients and metals within the TSF decant water are expected to pose a low risk to native vegetation, fauna and human health. If approved, the TSF decant water for use in dust suppression, will be managed in accordance with RHIO Saline Water Use Management Procedure (OP-PRO-01073).

Impacts to vegetation from nuisance and fugitive dust or use of saline water or TSF decant water for dust suppression is not expected to have a significant impact. The use of saline water or TSF decant water for dust suppression under this Revised Proposal does not change the impacts from that previously assessed.

4.3.5.1.7 Indirect vegetation health impacts caused by dust deposition

The RHIO mine is an operational mine and dust is generated through mining activities. RHIO have processes and procedures in place to manage and reduce dust emissions. RHIO consider that implementation of the Revised Proposal is unlikely to have any additional impacts to vegetation health caused by dust deposition, that has not already been assessed as part of the Original Proposal.

4.3.5.2 Mulga Woodland

Mulga Woodlands occur throughout the Revised Development Envelope and are identified as a Key Environmental Value in the FMMA particularly 3a Kulbee Alluvial Flank, which covers the Mine area and the eastern part of the Remote MAR Borefields, and 3b Marillana Plain, which covers the western part of the Remote MAR and Southern Borefields. The greatest impacts to Mulga Woodlands will be in the Mine area due to the clearing and ground disturbance resulting from mining operations. Impacts in Remote MAR borefield and Southern Borefield are likely to be lower due to the reduced amount of clearing required for borefields. Sections 4.3.5.2.1 to 4.3.5.2.3 outline the activities that will impact Mulga Woodland and the extent of those impacts. In total, 2,273.4ha of Mulga Woodland is expected to be directly impacted by the Revised Proposal. It is not considered that this extent of impact is significant at a regional level.

4.3.5.1.7 Clearing and ground disturbance

Within the Revised Development Envelope, 20% of the Mulga Woodland is likely to be impacted by clearing and ground disturbance. The biggest impact is to Mulga is in the Mine area which is dominated by the Mulga Vegetation (Figure 20). Impacts to Mulga Vegetation are lower in Borefields due to the flexibility of the clearing and infrastructure placement allowing the avoidance of mature trees.

4.3.5.2.2 Reduction in groundwater levels from dewatering/abstraction

It is likely that mulga root systems in the Revised Development Envelope are predominantly shallow and almost fully contained within the top 3m of the profile. Although the maximum rooting depth of many mulga species is unknown, root biomass beyond 3m depth is likely to be very small. The increased productivity of mulga growing in the riparian zone suggests that this vegetation type is supplemented by surface water flows, and in these locations may be classified as Surface Flow Dependent Vegetation. Similarly, the higher productivity of banded mulga formations that occur outside of the riparian zone may be classified as Sheet Flow Dependent Vegetation (Astron, 2019).

Pre-mining groundwater levels in the vicinity of mulga vegetation are >10mbgl. Based on the risk assessment, it is unlikely the changes to groundwater levels will impact mulga communities within the Revised Development Envelope.

4.3.5.2.2 Increase of groundwater levels causing waterlogging or change in water quality (salinisation)

Mulga species are shallow rooted (with the majority of the root system within 3m of the surface, with some roots potentially extending to around 4m). Mulga vegetation has been identified as vulnerable to secondary impacts arising from altered hydrological regimes as a result of MAR from:

- Waterlogging - Impacts occur when unsaturated soil within the root zone is greatly diminished and a substantial portion of the root system is inundated; and
- Salinisation within the root zone – A rise in the water table may mobilise salts stored in the soil profile (analogous to secondary salinisation that has occurred in agricultural areas of southern Australia) or if there is connectivity between aquifers around the injection point, groundwater within the root zone may become saline.

Astron (2019, Appendix 9) conducted a risk assessment of potential negative impact (biologically significant decline in condition or death) on the types of mulga in response to groundwater mounding and groundwater salinisation. The risk assessment was based on mounding to within 5mbgl and salinisation of groundwater to a concentration of 50,000mg/L TDS. RHIO will manage MAR activities so that the >5mbgl limit on groundwater rise in the SWIB and Remote MAR Borefield areas is maintained.

Due to the medium to low risk of impact on mulga species, it is not considered that groundwater level or quality changes will have a significant impact on Mulga woodlands.

4.3.5.3 Riparian Vegetation (including Mulga Riparian and GDV)

Riparian vegetation occurs throughout the Revised Development Envelope mainly along creek lines and also in areas of drainage foci. Riparian Vegetation is identified as a Key Environmental Value in the FMMA, in particular, 2a Calcrete Flats around the Fortescue River, which runs through the Remote MAR Borefield. The greatest impacts to Riparian Vegetation will be in the Mine area due to clearing and ground disturbance required for pits and surface water diversion structures. Impacts to Riparian Vegetation in the Remote MAR Borefield and Southern Borefield are likely to be minimal due to the reduced clearing required for borefields and the flexibility in siting of infrastructure to avoid sensitive areas.

Sections 4.3.5.3.1 to 4.3.5.3.4 outline the activities that will impact Riparian Vegetation and the extent of those impacts. In total, 158.6ha direct impacts from clearing and 65.65ha of indirect impacts from implementation of the WMS on Riparian Vegetation is expected to be impacted by the Revised Proposal. It is not considered that this extent of impact is significant at a regional level.

4.3.5.3.1 Clearing and Ground Disturbance

Clearing and ground disturbance is expected to impact up to 158.6ha of riparian vegetation, of which 551.4ha has been mapped in the Revised Development Envelope. Only 28.9% of the riparian vegetation within the Development Envelope will be cleared, thus it is not considered that clearing will have a significant impact on riparian vegetation.

4.3.5.3.1 Reduction in Groundwater levels from dewatering/abstraction

Astron (2019) risk assessment found that areas at risk of decline or mortality due to groundwater drawdown are confined to small areas within the northern third of the project area, on the periphery of the RHIO tenure and associated clearing footprint. These areas (equating to 4.7ha) which received a risk rating of medium or low, include linear drainage features (Kulkinbah Creek and tributaries of the Fortescue River) that comprised of *E. camaldulensis* and/or *E. victrix*.

4.3.5.3.1 Increase of Groundwater levels causing waterlogging or change in water quality (salinisation)

Astron assessed the risk of impact to vegetation owing to groundwater mounding was confined to 65.65ha of Riparian Vegetation, with the high and medium risk levels restricted to an area north of the Fortescue Marsh (SWIB and Stage 1 Borefield). This area is dominated by banded mulga and riparian mulga, the latter associated with drainage lines, including Kulbee Creek, which join the Fortescue River or terminate directly at the boundary of the Fortescue Marsh. While not identified as at risk, parts of the Fortescue Marsh which were classified as samphire fringe were adjacent to the area of low risk of decline or mortality owing to groundwater mounding. A second area at low risk of mounding lies east of the Fortescue Marsh, at the junction of the Kulkinbah Creek and the Fortescue River (Stage 1 Borefield Area). This area includes phreatophytes (*E. camaldulensis* and/or *E. victrix*).

4.3.5.3.1 Alteration of Surface Water Flows

The establishment of permanent surface water diversion structures around pits and infrastructure will alter water movements downstream. Diversions that collect and convey runoff from one waterway to another waterway will reduce flow rates in the downstream segment of the original waterway, and therefore potentially impact the associated riparian vegetation. Furthermore, the additional flows arriving at the second waterway may increase the risk of scour (GHD, 2018a).

GHD (2018a, Appendix 3) conducted an assessment on the changes in flood waters from pre-mining to post development of the proposed permanent surface water structures, at key locations, for a 50% AEP flood (representing a runoff event occurring every 1 -2 years on average). The base case is defined as a theoretical pre-mine scenario, based on topographic data obtained prior to mining activities. The closure scenario represents the proposed mine arrangement at mine closure.

Although permanent surface water structures will be designed to direct flows immediately back into the natural creek line where possible, there are some diversions where topography limits the possibility to return water flows back to the original creek lines. A future low flow channel has been incorporated into the Kulbee Creek diversion design to reduce impacts to downstream waterways. With this addition, there remains three potential impact areas, containing riparian vegetation, where post mining flow rates are substantially lower than pre-mine conditions Table 4-13. At all other locations, the closure flow rates are not considered to be significantly changed for the purpose of protection of riparian protection (GHD, 2018a).

Changes in surface water flows is expected to indirectly impact up to 85.92ha of riparian vegetation. Figure 34 indicates riparian vegetation that has potential to be permanently impacted by alterations of surface water flows as a result of the Revised Proposal. Permanent diversion structures would ultimately result in permanent downstream impacts of the areas outlined in Table 4-13, however this is considered preferable to the alternative options of:

- rediverting over backfilled pits, with potential to cause significant increases in downstream sedimentation; or
- discharging the surface water into open pits and consequently recharging the aquifer and reducing overland flow.

Table 4-13: Potential Impacts of Riparian Vegetation

Reporting Location (Figure 34)	Length of riparian waterway impacted (km)	Area of riparian vegetation impacted (ha)
7	4.9	44.16
10	2.0	41.76

4.3.5.4 Open Hummock Grasslands

Open Hummock Grasslands (TaTpTsMOHG (Biologic, 2018); TbTsHG (THG; Maia, 2018)) is found in the Remote MAR Borefields and Southern Borefield. This vegetation unit is considered to have locally high significance due to presence of Priority flora species. Direct impacts to this vegetation unit is not expected to not exceed 82.2ha and impacts to Priority species in this vegetation unit are expected to be minimal due to the low level of disturbance proposed in the borefield areas. Due to the vast extent of remaining vegetation of this unit, it is not considered that the Revised Proposal will have significant impacts on this vegetation type.

4.3.5.4.1 **Clearing and Ground Disturbance**

Some tracks, bores and borefield pipeline routes are proposed to require some clearing of this vegetation unit. Clearing of this vegetation unit is expected to not exceed 82.2ha, however species with a Priority listing of 3 or 4 will be avoided where possible during development of the final borefield locations and pipeline routes. Impacts to species with a Priority 1 listing will be avoided. With the small amount of clearing required across this vegetation unit, and the inherent flexibility in locating infrastructure to avoid Priority flora species suggests it is not considered to result in significant impacts to this vegetation unit and associated priority species.

4.3.5.4.2 Increase of Groundwater levels causing waterlogging or change in water quality (salinisation)

This vegetation unit not considered to contain species that may be groundwater dependent as groundwater systems are deep (>10mbgl) and not accessible to vegetation (Astron, 2019). Hummock grasslands represent vegetation types dominated by xerophytes. There is however, the potential for these shallow rooted species to access groundwater where water is redistributed by co-occurring phreatophytic trees, a process known as hydraulic lift (Dawson and Pate, 1996; cited in Astron, 2019).

Modelling indicates that in the areas of this vegetation unit, 36.25ha is located in the area of groundwater rise, however groundwater mounding is expected to remain at greater than 5mbgl. The groundwater increases are not expected to reach the root zone; therefore, any mounding or water quality changes will not impact this vegetation unit.

4.3.5.5 Tall Open Shrubland

Tall Open Shrubland (TxTOS (Biologic, 2018); AxAapSL (ASL-4; Maia, 2018)) is found in the Remote MAR Borefield and Southern Borefield. This vegetation unit is considered to have locally high significance due to presence of Priority flora species and its close resemblance to the Narbung Land System. Direct impacts to this vegetation unit is expected to not exceed 59.7ha and impacts to Priority flora species in this vegetation unit are expected to be minimal due to the low level of disturbance proposed in the borefields. Due to the vast extent of remaining vegetation of this unit, it is not considered that the Revised Proposal will have significant impacts on this vegetation type.

4.3.5.4.2 Clearing and Ground Disturbance

Some tracks, bores and borefield pipeline routes are proposed to require some clearing of this vegetation unit. Clearing of this vegetation unit is expected to be 59.7ha, however Priority species with a 3 or 4 listing will be avoided where possible during development of the final borefield locations and pipeline routes. Priority 1 listed species will be avoided. With the small amount of clearing required in this vegetation unit, and the inherent flexibility in locating infrastructure to avoid Priority flora species it is not considered there will be significant impacts to this vegetation unit.

The Narbung Land System is a Priority 3 PEC with a total area of 15,954ha, of which 5,847ha occurs in the Revised Development Envelope. Of this, a maximum of only 252.51ha of clearing is proposed.

4.3.5.4.2 Increase of Groundwater levels causing waterlogging or change in water quality (salinisation)

This vegetation unit is not considered to contain species that may be groundwater dependent. Modelling indicates that in the areas of this vegetation unit, 190.23ha is located in the area of groundwater rise, however groundwater mounding is expected to remain at greater than 5mbgl. The groundwater increases are not expected to reach the root zone; therefore, any mounding or water quality changes will not impact this vegetation unit.

4.3.5.6 Groundwater Dependent Ecosystem associated with Fortescue River

This vegetation unit (EcoMIT, EvAaLIT) is found mainly in the Remote MAR Borefield with some feeder creek lines extending into the Mine area. This vegetation unit is considered to have locally high significance due to the presence of *Eucalyptus victrix* and *E. camaldulensis*. Astron described this vegetation unit as phreatophytes associated with the Fortescue River and associated tributaries. Impacts to this vegetation unit is expected to not exceed 10.5ha. Due to the vast extent of remaining vegetation of this unit, it is not considered that the Revised Proposal will have significant impacts on this vegetation type

4.3.5.6.1 Clearing and Ground Disturbance

Clearing of this vegetation unit will be minimal, as existing tracks can be utilised where traversing of this vegetation unit is required. The clearing of this vegetation unit in the Remote MAR is expected to be limited to 10.5ha. With the small amount of clearing required, it is not considered to result in significant impacts to this vegetation unit.

4.3.5.6.1 Recharge of Groundwater levels causing waterlogging or change in water quality (salinisation)

Re-injection in the Remote MAR Borefield will consist of water to a maximum 50,000mg/L TDS. Background water quality indicates the water in the area is around 100,000mg/L TDS. Re-injection bores are located away from sensitive vegetation types associated with the Fortescue Marsh and Fortescue River (EcoMIT, EvAaLIT). As the re-injection water quality is expected to remain similar to that of the existing aquifer and unlikely to mix vertically due to physical and density controls on upward migration and mixing (GHD, 2018) it is not considered that re-injection of water in the Remote MAR borefield will impact upon this environmental value.

4.3.5.7 Drainage foci in vegetation unit ASL1 / AmAtAaSL

4.3.5.6.1 Clearing and Ground Disturbance

The drainage foci area of the vegetation type ASL-1 with potential GDV (Figure 27) is located within the borefield area. As such bore locations and infrastructure will be located to avoid this area.

4.3.5.6.1 Reduction in Groundwater levels from dewatering/abstraction

A reduction in groundwater levels of up to approximately 5m is expected to occur in the Southern Borefield area due to water abstraction (GHD, 2018). It is not expected however, that this water level change will occur in the vicinity of the drainage foci, and therefore will not impact the drainage foci areas.

Abstraction in the Southern Borefield is not expected to differ to that assessed in the Original Proposal.

4.3.5.6.1 Recharge of Groundwater levels causing waterlogging or change in water quality (salinisation)

As *Eucalyptus victrix is a* phreatophytic flora (Astron, 2019), it may be at risk if groundwater levels rise or become more saline. GHD (2018) assessed the risk of groundwater mounding and salinisation in the areas of drainage foci in the Southern borefield and found that groundwater levels were >20mbgl. Groundwater rise due to MAR in the area would be less than 2m which is consistent with natural fluctuations. Any change in TDS of groundwater will remain less than 5,000mg/L TDS. It is therefore highly unlikely the drainage foci areas will be impacted by waterlogging or salinisation as a result of the implementation of this Revised Proposal.

4.3.5.8 Ecosystems

4.3.5.8.1 Narbung Land System

Approximately 37% (5850ha) of the Narbung Land System PEC occurs within Revised Development Envelope (Figure 30). Direct impact from clearing of the Remote MAR Borefield will impact 252.51ha of the Narbung Land System, priority flora and drainage foci will be avoided were possible. Potential indirect impacts to the Narbung Land System may occur as a result of MAR 1060.79ha within the Development envelope and 722.90ha outside the Revised Development Envelope. However, the LOM WMS limits groundwater rises to >5mbgl and ground water mounding in the land system area is expected to be within natural fluctuations (i.e. <2m) minimising the potential for indirect impacts to occur.

Potential indirect impacts to the Narbung Land System (which occurs both within and outside the RHIO tenure) arose primarily from an elevated consequence level for this area due to presence of Priority flora species and a modest likelihood level owing to groundwater mounding and antecedent groundwater levels.

Disturbance to the Narbung Land System will be from clearing and construction of borefield infrastructure, due to the inherent nature of borefield infrastructure Priority flora will be avoided and clearing kept to minimum required for operation, rehabilitation of borefield tracks and infrastructure will occur. Impact to the Narbung Land System are not expected to compromise the value of the PEC due to the low intensity nature of borefields and ability to avoid Priority flora and vegetation.

4.3.5.8.1 Fortescue Marsh Management Areas

Approximately 95,061ha (86.19%) of the Revised Development Envelope overlaps with the FMMA (Figure 35; Table 4-9). The Revised Development Envelope intersects four FMMAs whilst the proposed water footprint as a result of MAR has the potential to extend across one additional FMMAs (Table 4-9 and Figure 35). Impact to the Fortescue Marsh are mentioned in sections above.

Clearing in the Mine area is restricted to the FMMA 3a Kulbee Alluvial Flats (low environmental significance) and will result in a total of 12,339.94ha being cleared for mine infrastructure. Impact to the FMMA 3a are not expected to be significantly different to that assessed in the Original Proposal. FMMA 3b Marilina Plain (low environmental significance) covers parts of the Remote MAR Borefield and Southern Borefield and will result in maximum of 2,030.06ha of low intensity clearing for borefields. Impacts to the FMMA 3b are not expected to be significantly different to that assessed in the Original Proposal. The Remote MAR Borefield includes portions of FMMA 2a Calcrete Flats and FMMA 2c Fortescue River Coolibah (both of medium environmental significance) and will result in 332.02ha (2a, 86.47ha; 2c 245.55ha) of low intensity clearing for borefields. Impact to the FMMA 2a and 2c are not expected to compromise the value of the FMMA due to the low intensity nature of borefields.

Indirect impacts to the FMMA from LOM WMP include 3,120.61Ha of predominantly Low risk to FFMA 3a the Kulbee Alluvial Flank largely as a result of Reinjection in the SWIB, the majority of this potential impact is contained within L46/141 tenement owned by RHIO but not included in the Revised Development Envelope, the purpose of this tenement is to monitor impacts form SWIB. Indirect Impacts to the FMMA 1b Marsh are classified as low risk due to the naturally shallow groundwater (within 10m of surface) and the presence of several Samphire populations on the fringe of the Fortescue Marsh (1,818ha) which increases the consequence but not

the likelihood of impacts to the Marsh and therefore results in risk (Astron, 2019). GHD (2018) modelling indicates the likelihood of mounding or salinisation reaching the FMMA 1b is Rare due to the influence of the Mine dewatering drawdown causing the flow of groundwater back toward the mine. Impact to the FMMA 3b Marilina Plain are largely the Result of the Narbung Land System which overlaps with this FMMA.

4.3.5.9 Land System

Of the thirteen Land Systems found in the Revised Development Envelope (Table 4-10) nine of these are well represented outside the Revised Development Envelope and clearing will impact less than 2% of each of these Land Systems. In contrast the Jamindie (JAM), Fan (FAN), Turee (TUR), and Narbung (NAB) are locally restricted Land Systems. 5.56% of JAM Land System and 15.98% of TUR Land System occur within the Revised Development Envelope. The NAB (36.80%) and FAN (32.51%) are restricted to the areas around the Fortescue River. JAM and TUR occur in the Mine area (Figure 31), NAB and TUR occur in the Remote MAR Borefield (Figure 35) and FAN occurs in the Southern Borefield (Figure 32). The NUB land system is discussed in Section 4.3.5.8.1 above, the JAM, FAN and TUR Land Systems are discussed below.

The JAM Land System is located within the Mining area and complete avoidance of clearing of this Land System is not possible during implementation of this Revised Proposal. 9,059.02ha of clearing will be undertaken in the is land system which represents 5.56% of the land system. In addition, it may be potentially at risk from indirect impacts resulting from mounding and salinisation due to MAR, these risks have previously been assessed under the original Proposal.

The Southern Borefield is dominated by the FAN Land System (Figure 32) which also extends in to the southern most section of the Remote MAR Borefield. It is expected that a maximum of 1,448.9 ha (<1%) of the land system will be cleared for the development of the Southern and Remote MAR Borefields. Up to 10.49ha of indirect impact due to groundwater mounding has the potential to occur however the risk of this is low and located along the norther margin of the land system.

The TUR Land System is associated with the JAM Land System in the Mine area and the northern part of the Remote MAR Borefield. It that a maximum of 3,197.68ha (<5.5%) of the Land System will be cleared for the development of the Mine Area and Remote MAR Borefield. Up to 627.4ha of indirect impact due to groundwater mounding has the potential to occur however the risk of this is predominantly low.

Disturbance in the Mine area has been previously assessed in the Original Proposal. Disturbance in the Borefield areas as a result of this Revised Proposal will be mainly limited to low intensity clearing thus impacts are expected to be minimal. Impacts on Land Systems due to the direct loss of flora and vegetation from clearing and ground disturbance activities are not considered to be of significance, due to the majority of the Land Systems being located outside the Revised Development Envelope.

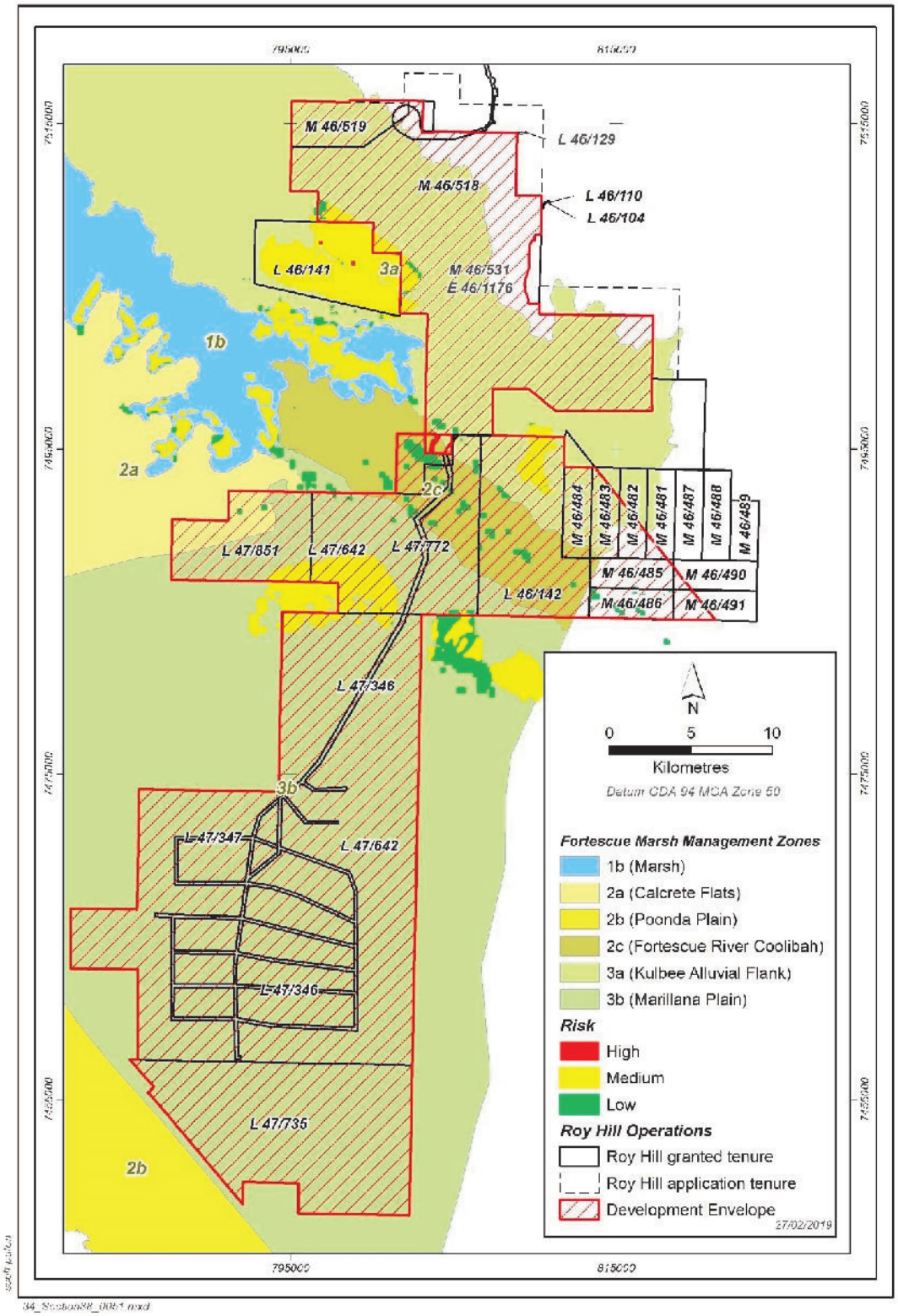

Figure 35: Direct and Potential Indirect impacts on the FMMA

4.3.6 Mitigation Measures

The objective of the mitigation measures is to reduce the impact to Flora and Vegetation within the Revised Development Envelope resulting from the implementation of the Revised Proposal. Flora and Vegetation mitigation measures are outlined in Table 4-14.

Table 4-14: Flora and Vegetation Mitigation and Management Measures

Activity	Potential Impact	Type	Mitigation Measure
Clearing of Vegetation and Ground Disturbance	Loss of vegetation and species	Avoid	Utilise areas of existing disturbance before clearing of new ground, where possible
			Avoid identified Priority 1 species, *Stemodia* sp. Battle Hill, *Eremophila spongiocarpa* and *Eremophila pilosa*
			Avoid clearing of drainage foci area of vegetation unit ASL1 / AmAtAaSL in Southern Borefield
			Avoid clearing of GDV and GDE where possible
			Borefield pipeline route and bore locations to be sited to avoid Priority flora species where possible
		Minimise	Clearing of no more than an additional 5,995ha to that already approved (totalling 17,988ha) within the Revised Development Envelope of 97,747ha
			Revised Development Envelope excludes portions of Kulkinbah Creek to minimise impacts to potential GDV and riparian vegetation
			Implement the RHIO Ground Disturbance Permit (GDP) system
			Clearing boundaries are to be surveyed, pegged and flagged prior to commencement of clearing activities in accordance with the RHIO GDP Procedure
			Backfilling of pits to occur where possible to reduce above ground waste rock dumps
			Minimise the clearing disturbance footprint during the mine planning and design phase, sufficient to enable safe construction and operation of the mining operation
			Clearing and ground disturbance activities will only occur in accordance with the current Mining Proposal approved by DMIRS
			Minimise impacts to Priority 3 and Priority 4 species where possible
		Rehabilitate	Rehabilitate land as soon as possible after completion of activities to meet closure criteria in accordance with RHIO Mine Closure Plan (prepared in accordance with the DMIRS Guidelines for Preparing Mine Closure Plans) and approved by DMIRS

Activity	Potential Impact	Type	Mitigation Measure
		Monitor	Record areas cleared and report to regulatory agencies where required
	Introduction and Spread of Weeds	Avoid	High risk areas (with high weed cover) are mapped in Geographical Information System (GIS) databases for topsoil segregation during implementation of the GDP process
			New tracked and ground engaging vehicles entering the Revised Proposal area must be inspected in accordance with the Vehicle and Mobile Equipment Weed Hygiene Inspection Form (OP-FRM-00006)
			Material (ballast, borrow, fill, gravel etc) brought to site must be inspected and certified by the supplier as being weed free upon arrival on site
			Borefield pipeline route and bore locations to be sited to avoid heavily infested weed areas, where possible
		Minimise	Existing periodic weed spraying/eradication campaigns will continue
			Weed eradication programs are to be implemented where declared weeds, or weeds in rehabilitation areas, are recorded
		Rehabilitate	Manage rehabilitation and weeds in accordance with the RHIO Mine Closure Plan, approved by DMIRS
			Topsoil from weed risk areas is treated as waste and buried.
			Rehabilitation of areas occurs as soon as possible to prevent weed proliferation on bare soil
			Use of seeds of native provenance and supplied from a reputable source to ensure no possibility of weed contamination or species that are not found within the Revised Proposal area
		Monitor	Weed areas are mapped prior to mining disturbance by third party specialist
		Monitor	Weed locations are recorded in the RHIO GIS database.
		Monitor	Record and monitor any new declared weed infestations.
Groundwater mounding and changes to groundwater quality resulting from managed aquifer recharge.	Groundwater mounding resulting in waterlogging and a decline in health or loss of vegetation	Monitor	Monitor groundwater levels against trigger criteria and implement management actions should the trigger levels be reached/exceeded, in accordance with Mine Operating Licence L8621/2011/1, approved two-year trial MAR s45C to MS 824 and MS 829 and RHIO Mine Water Management Plan
		Monitor	Monitor permanent monitoring sites within MAR Vegetation Monitoring Zones to capture on ground measurements of vegetation composition, structure and plant health, consistent with existing approved RHIO's Vegetation Health Monitoring Plan

Activity	Potential Impact	Type	Mitigation Measure
	Increase in groundwater salinity resulting in a decline in health or loss of vegetation	Minimise	Limit re-injection water quality to: • 50,000mg/L TDS into SWIB and Remote MAR • 5,000 mg/L TDS into Stage 1 Borefield and Southern Borefield • Mine Borefield determined on case by case basis and approved under Part V of EP Act
		Monitor	Monitor groundwater quality against trigger criteria and implement management actions should the trigger levels be reached/exceeded, in accordance with Mine Operating Licence L8621/2011/1 and RHIO Mine Water Management Plan
Groundwater drawdown resulting from dewatering or abstraction	Groundwater drawdown resulting in a decline in health or loss of GDV or riparian vegetation	Minimise	Dewatering to only occur in areas where required to maintain dry mining or ground conditions
		Monitor	Monitor vegetation condition and plant health via remote sensing
Construction and operation of Surface water diversions impacting riparian vegetation	Loss or degradation of vegetation as a result of altered hydrological regimes	Avoid	A 500m buffer zone is implemented inside the western boundary of tenement M46/518 to minimise shadow effects to Mulga vegetation beyond the boundary of the project area.
		Minimise	Surface water management structures have been designed to maintain natural patterns of surface water flows downstream of mine pits where possible.
		Minimise	No more than 85.92ha of riparian vegetation will be indirectly impacted by creek diversions.
		Minimise	Construct and manage surface water structures to meet requirements of RHIO Mine Closure Plan, as approved by DMIRS.
		Monitor	Monitor health of vegetation in identified surface water impact zones as per the approved Vegetation Condition Environmental Management Plan
Saline and decant water disposal	Indirect impacts, including a decline in health and/or change in vegetation composition.	Minimise	The use of surplus saline or decant water for dust suppression will be undertaken in accordance with the RHIO Saline Water Use Management Procedure (OP-PRO-01073) as approved by S45C to MS 824.
		Monitor	Monitor health of vegetation in identified impact zones as per the approved Vegetation Condition Environmental Management Plan
Dust from general mining activities	Indirect impacts,	Avoid	Avoid vegetation clearing and earthworks in wind conditions of >50 km/hr, where possible.

Activity	Potential Impact	Type	Mitigation Measure
	including a decline in vegetation health	Minimise	Use dust suppression techniques, such as water trucks, in areas of high dust-off risk.
		Minimise	Utilise existing tracks and adhere to vehicle speed limits.

4.3.7 Predicted Outcome

Vegetation units within the Revised Development Envelope are considered widespread in the region and the direct and indirect impacts to vegetation units resulting from the Revised Proposal are not expected to result in outcomes which would be inconsistent with EPA guidance.

When the mitigation and management measures have been implemented, it is expected that the Revised Proposal will result in the following residual impacts and outcomes in relation to Flora and Vegetation:

- No more than an additional 5,995ha of vegetation will be directly impacted by the Revised Proposal. The vegetation associations are well represented in the region and impacts to vegetation is unlikely to result in a significant reduction in the occurrence of these associations.
- No more than 10.5ha of GDV lost or degraded as a result of the implementation of the Revised Proposal.
- No more than 158.6ha of riparian vegetation lost or degraded as a result of the implementation of the Revised Proposal.
- Up to 423 identified Priority flora individuals, as listed by DPaW, will be impacted by the Revised Proposal. The conservation status of these species is unlikely to be affected by the implementation of the Revised Proposal.
- Impacts to Priority 1 species, *Stemodia* sp. Battle Hill, *Eremophila spongiocarpa* and *Eremophila pilosa* will be avoided.
- No increase in the cover of weeds or new weeds are expected to be identified within the Revised Development Envelope as a result of implementation of the Revised Proposal.

4.4 Key Environmental Factor – Terrestrial Fauna

4.4.1 EPA Objective

The EPA's environmental objective for the factor *Terrestrial Fauna* is "To protect terrestrial fauna so that biological diversity and ecological integrity are maintained".

4.4.2 Policy and Guidance

The relevant policy and guidance for Terrestrial Fauna is summarised in Table 4-15.

Table 4-15: Terrestrial Fauna Policy and Guidance

Author	Title	Year of Publication
EPA	Environmental Factor Guideline – Terrestrial Fauna	2016
EPA	Technical Guidance Terrestrial Fauna Surveys	2016
EPA	Technical Guidance Sampling Methods for Terrestrial Vertebrate Fauna	2016
DBCA	Pilbara Conservation Strategy	2017

4.4.3 Receiving Environment

4.4.3.1 Studies and Investigations

The Mine area was surveyed in detail between 2006 to 2010 with additional monitoring surveys having also been conducted during the implementation of the Original Proposal. These surveys and assessments were undertaken at various levels as required; being Desktop, Targeted, Level 1 and Level 2 (Table 4-16).

Additional surveys (Table 4-16) were conducted during 2017 and 2018 to cover areas not previously surveyed, and to collect information on the possible occurrence of the Night Parrot within the Revised Development Envelope.

Where recommendations suggested additional works were required to meet current guidelines, these works have either been undertaken, or are proposed to be undertaken. Additional works proposed to be undertaken are summarised in Table 4-17.

Table 4-16: Completed Baseline Terrestrial Fauna Surveys and Studies

Consultant	Title	Description	Location	Guidance/Methodology*
ecologia Environment (2006)	Roy Hill Iron Ore Project Short-range Endemic Survey 2006	Targeted SRE survey undertaken comprising of a desktop survey and a site visit that included a habitat assessment, pitfall traps, leaf litter and soil collection and hand foraging. The Field survey was undertaken in June 2006.	Mine	Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia, Guidance Statement No. 56 (EPA, 2004a).
ecologia Environment (2008)	Roy Hill Iron Ore Project Proposed Infrastructure Supplementary	Level 1 Fauna Survey for terrestrial vertebrate fauna involving desktop assessment and three reconnaissance surveys. Field surveys were	Mine	Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia, Guidance Statement No. 56 (EPA, 2004a).

Consultant	Title	Description	Location	Guidance/Methodology*
	Level 1 Terrestrial Vertebrate Fauna Survey 2008	undertaken in September and November 2008.		Terrestrial Biological Surveys as an Element of Biodiversity Protection. Position Statement No. 3 (EPA 2002).
ecologia Environment (2008a)	Roy Hill Additional SRE Survey Report 2008	Targeted SRE survey undertaken comprising of transect mapping within designated areas and opportunistic sampling targeting prospective SRE habitats. The field survey was conducted in October 2008.	Mine	Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia, Guidance Statement No. 56 (EPA, 2004a).
Env Australia (2009)	Roy Hill Borefield Vertebrate Fauna Assessment 2009	Level 2 Detailed survey comprising of a desktop survey and a site visit that included a habitat assessment, trapping program, and opportunistic observations. Field survey was undertaken in July 2009.	Southern Borefield	Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia, Guidance Statement No. 56 (EPA, 2004a). Terrestrial Biological Surveys as an Element of Biodiversity Protection. Position Statement No. 3 (EPA 2002).
ecologia Environment (2009d)	Roy Hill Iron Ore Project Vertebrate Fauna Assessment 2009	Level 2 Detailed survey comprising of a desktop survey and a site visit that included a habitat assessment, trapping program, and opportunistic observations. Field surveys were undertaken in November 2005 and May 2006.	Mine	Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia, Guidance Statement No. 56 (EPA, 2004a). Terrestrial Biological Surveys as an Element of Biodiversity Protection. Position Statement No. 3 (EPA 2002).
ecologia Environment (2009e)	Roy Hill Iron Ore Project Borefield Desktop Survey 2009	Desktop review of published and unpublished fauna reports, database searches and liaison with regulatory agencies.	Southern Borefield	Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia, Guidance Statement No. 56 (EPA, 2004a). Terrestrial Biological Surveys as an Element of Biodiversity Protection. Position Statement No. 3 (EPA 2002).
ecologia Environment (2009f)	Roy Hill Short Range Endemic Desktop Survey 2009	Desktop review of databases of the Western Australia Museum for SRE species.	Mine	Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia, Guidance Statement No. 56 (EPA, 2004a). Terrestrial Biological Surveys as an Element of Biodiversity Protection. Position Statement No. 3 (EPA 2002).

Consultant	Title	Description	Location	Guidance/Methodology*
Western Australian Museum (WAM) (2009)	The Short-Range Endemic Invertebrate Fauna of Roy Hill (*Ecologia* Project 1106) (Western Australia) 2009	Taxonomic identification of the invertebrate specimens collected in July 2009.	N/A	
Animal Plant Mineral (2010)	Fauna Habitat Survey of the Proposed Bore-fields Pipeline Route from Adjacent Roy Hill Station to Eaton Bore	Level 1 Survey of proposed borefields pipeline route. The Field survey was undertaken in December 2010	Southern Borefield	EPA Guidance Statement No. 56 on terrestrial fauna surveys for environmental impact assessment (Environmental Protection Authority, 2004a).
ecologia Environment (2010)	Remote Borefield and Pipeline Short Range Endemic Survey, March 2010	Targeted SRE survey of the Remote Borefield and Pipeline corridor comprising a site visit that included dry pitfall traps, litter sifting, leaf litter collection and hand foraging. The Field survey was undertaken in November 2009.	Southern Borefield Remote MAR Borefield (pipeline corridor only)	EPA Guidance Statement No. 20: Sampling of Short Range Endemic Invertebrate Fauna for Environmental Impact Assessment in Western Australia (Environmental Protection Authority, 2006a).
Bennelongia (2011)	Monitoring short range endemic invertebrates at the Roy Hill 1 Mine. Report 2011/115	Monitoring of SRE with the intent to show wider distribution of certain species.	Mine Remote MAR Borefield (two sites only)	Proposed Monitoring Plan for Short Range Endemic Invertebrate Species at the Roy Hill 1 Mine (Bennelongia, undated) approved by the Environmental Protection Authority (EPA) in December 2010.
Bennelongia (2012)	Monitoring short range endemic invertebrates at the Roy Hill 1 Mine Feb 2012. Report 2012/155, April 2012	Monitoring of SRE with the intent to show wider distribution of certain species.	Mine Remote MAR Borefield (four sites only)	Proposed Monitoring Plan for Short Range Endemic Invertebrate Species at the Roy Hill 1 Mine (Bennelongia, undated) approved by the Environmental Protection Authority (EPA) in December 2010.
Bennelongia (2013)	Monitoring Short Range Endemic Invertebrates at the Roy Hill 1 Mine April to July 2013, November 2013.	Formal monitoring to meet Condition 9 of Ministerial Statement 902 incorporating three field trips monitoring SRE habitat at 16 sites.	Mine Remote MAR Borefield (one site only)	Proposed Monitoring Plan for Short Range Endemic Invertebrate Species at the Roy Hill 1 Mine (Bennelongia, undated) approved by the Environmental Protection Authority (EPA) in December 2010.
Bennelongia (2015)	Requirement for monitoring of SRE habitat	Review of conservation benefit of habitat monitoring for the	N/A	

Consultant	Title	Description	Location	Guidance/Methodology*
	under Ministerial Statement 902	identified SRE species under Condition 9 of MS 902.		
Strategen (2018)	Roy Hill Night Parrot Survey	Targeted survey for Night Parrot using 10 Song Meter 4 acoustic units, recording 1088.65 hours of acoustic data across 20 locations.	Mine Remote MAR Borefield Southern Borefield	Interim guideline for preliminary surveys of Night Parrot (*Pezoporus occidentalis*) in Western Australia (DPaW, 2017).
Biologic (2018a)	Roy Hill Level 1 Targeted Vertebrate Fauna Assessment Updated	Level 1 Targeted Fauna Survey of M46/518, M46/519, L47/346, L47/347, L47/342 and L47/735 as well as E47/1326, E46/586 and L47/642 undertaken in August 2017 and July 2018	Mine Remote MAR Borefield Southern Borefield	EPA (2016b) Technical Guidance: Terrestrial Fauna Surveys. EPA (2016a) Technical Guidance: Survey Methods for Terrestrial Vertebrate Fauna (developed in collaboration with DBCA).

*EPA guidelines were updated December 2016

Table 4-17: Additional Environmental Surveys and Studies related to the Revised Proposal – Future / In Progress

Description	Survey / Study	Guidance
Targeted fauna survey of borefield pipeline routes	Borefield pipeline route and bore locations are yet to be finalised. A Targeted fauna survey is to occur prior to final borefield alignment to ensure that conservation significant fauna and/or habitats can be avoided	EPA Technical Guidance: Terrestrial Fauna Surveys (2016d); EPA Technical Guidance: Survey Methods for Terrestrial Vertebrate Fauna (2016e)

4.4.3.2 Habitats

A total of 13 broad fauna habitat types were recorded and mapped across the Revised Development Envelope. This comprised, in decreasing order of extent, Mulga Woodland, Open Tussock Grassland, Spinifex Stony Plain, Spinifex Sandplain, Eucalypt Woodland, Mulga Drainage Line, Major Drainage Line, Mulga Spinifex, Low Rocky Hills, Minor Drainage Line, Snakewood Shrubland, Chenopod Shrubland and Claypans (Figure 36 to Figure 38). An additional area was also mapped as Cleared Area, which comprised areas completely cleared of all native vegetation (Biologic, 2018a; Table 4-18). Spinifex Sandplain was considered to have a high significance and Mulga Woodlands a moderate significance due to the occurrence of fauna of conservation significance, specifically the Greater Bilby. Three habitats, Low Rocky Hills, Major Drainage Line and Claypan, were considered to have a moderate significance as fauna of conservation significance were recorded in instances of these habitats and they may support small and sparse populations of such species, specifically the Northern Quoll, Pilbara Olive Python and Ghost Bat. The remaining ten habitats were deemed to have a low significance as they either do not support species of high conservation value and/or such species are not dependent on these habitats at the broad-scale (Biologic, 2018a).

Descriptions of the distinguishing characteristics and the occurrence inside and outside of the Revised Development Envelope, of the high and moderate significant habitat types, are presented in Table 4-18 (Biologic, 2018a).

The condition of habitats within the Revised Development Envelope ranged from completely degraded to pristine. Areas considered completely degraded comprised only Cleared Areas. The largest disturbance to the remaining fauna habitats were the impacts of Cattle (*Bos taurus*). The impacts caused by Cattle include overgrazing, trampling, and spreading weeds. The occurrence of weeds, particularly Buffel Grass (*Cenchrus ciliaris*) was apparent in many areas, particularly low-lying habitats such as Major Drainage Line, Minor Drainage Line, Mulga Drainage Line and Eucalypt Woodland habitats. Areas with high weed infestation were considered unlikely to ever recover back to a native/ pristine state should they be left untouched. In most cases, weed free areas were assessed as having a high likelihood of recovery from other impacting factors such as clearing. This consisted mainly of habitats within rocky terrain, away from primary grazing areas (Biologic, 2018a).

Table 4-18: High and Moderately Significant Habitat of the Revised Development Envelope

Habitat	Habitat Significance	Characteristics	Occurrence within Revised Development Envelope	Occurrence outside Revised Development Envelope	Potential Conservation Significant Species Present
Spinifex Sandplain	High	Spinifex Sandplains are characterised by sandy soils supporting dense spinifex grasslands often with sparse shrubs. The shrub layer varied from dense thickets to scattered shrubs often dominated by Acacia. Mallee were also common within instances of this habitat type. Sandy soils for burrowing were a key feature of the habitat type.	This habitat is largely common in the southern section of the Revised Development Envelope and within the corridor through the centre. Within the Revised Development Envelope, the depth of soil within the Spinifex Sandplain varied between deep sands to shallow relatively compact areas. Areas of deeper softer soils are likely to of importance to species of conservation significance such as the Greater Bilby.	The Spinifex Sandplain habitat is a moderately uncommon habitat in the Pilbara region. It is more common within the northern Chichester subregion where it is often associated with large drainage systems and granite outcrops.	Greater Bilby Spectacled Hare-wallaby Brush-tailed Mulgara
Mulga Woodland	Moderate	This habitat includes woodlands in which Mulga is the dominant strata, either as the principal Acacia species or mixed with others. It consists of disintegrating groves on stony and alluvial soils. Small hollows, leaf litter and woody debris are components of this habitat.	The Mulga Woodlands is the dominant habitat type located throughout much of the Revised Development Envelope. Located everywhere except the far northeast. The condition of the Mulga Woodland is generally Very Good with instances of over grazing and weed infestation.	A common habitat throughout the Fortescue and Hamersley subregions. The Fortescue subregion represents the northern limit of Mulga in Western Australia's north-west (Kendrick, 2001). The Pilbara Mulga Woodlands are a common and widespread habitat type, occupying ~20% of the Australian continent and as a result are well represented within Western Australian conservation estates.	Greater Bilby Lakeland Downs Mouse

Habitat	Habitat Significance	Characteristics	Occurrence within Revised Development Envelope	Occurrence outside Revised Development Envelope	Potential Conservation Significant Species Present
Major Drainage Lines	Moderate	The Major Drainage Line habitat is defined by large drainage channels lined with large Eucalyptus trees. The main drainage channel is often devoid of vegetation or dense Buffel Grasslands. Within the Revised Development Envelope this habitat is often lined with Mulga. The major feature influencing species composition is the extensive number of large hollows as well as the high vegetation cover, woody debris and leaf litter.	This habitat is located throughout the central and northern sections of the Revised Development Envelope of the Mine area and is associated with drainage from the Low Rocky Hills and ranges to the north. The largest Major Drainage Lines within the Revised Development Envelope are Kulkinbah Creek which occurs to the South of the mine area and feeds into the Fortescue River, which occurs in the Remote MAR Borefield.	Major Drainage Lines are common throughout the Pilbara due to the topography of the region. This habitat is also well represented within the regions conservation estates. Major Drainage Lines within the Pilbara are somewhat unique to similar systems found in surrounding regions, attributed mainly to the amount and frequency of water that they are exposed to and the habitats in which they intersect. As with most drainage systems, this habitat is well connected within the landscape.	Pilbara Olive Python Northern Brushtail Possum Peregrine Falcon *Anilios ganei* Grey Falcon Osprey
Low Rocky Hills	Moderate	Low Rocky Hills comprises spinifex hummock grasslands occurring on hills with major ironstone outcropping. Vegetation also includes scattered shrubs including Acacia and Grevillea species and occasional *Eucalyptus leucophloia*. The substrate exists as skeletal red soils with exposed bedrock. The primary feature of the habitat is the rocky outcrops, cracks and crevices.	This habitat type was confined to the north-west margins of the Revised Development Envelope as a transition into the Chichester subregion.	The Low Rocky Hills are characteristic features of the greater Chichester subregion and are therefore common through this subregion and throughout the Pilbara bioregion. As a result, this habitat and other habitats which contain similar features to fauna, are well represented outside the Revised Development Envelope and within the Western Australian conservation estates.	Northern Quoll Pilbara Olive Python Ghost Bat Peregrine Falcon *Anilios ganei* (blind snake) Western Pebble-mound Mouse Long-tailed Dunnart

Habitat	Habitat Significance	Characteristics	Occurrence within Revised Development Envelope	Occurrence outside Revised Development Envelope	Potential Conservation Significant Species Present
Claypans	Moderate	Bare, open claypans, with occasional tussock grasses and shrubs, dominated by *Eragrostis australasica, Diplachne fusca* subsp. *fusca* and *Sesbania cannabina*. Ephemeral and semi-permanent Claypans occur where sheet runoff may collect after rains.	This habitat type is scattered mainly across the centre of the Revised Development Envelope where it approaches the Fortescue Marsh.	Within the Pilbara bioregion Claypans are most common in the area surrounding the Fortescue Marsh, however they are distributed throughout the region and in most neighbouring regions.	Various migratory waterbirds

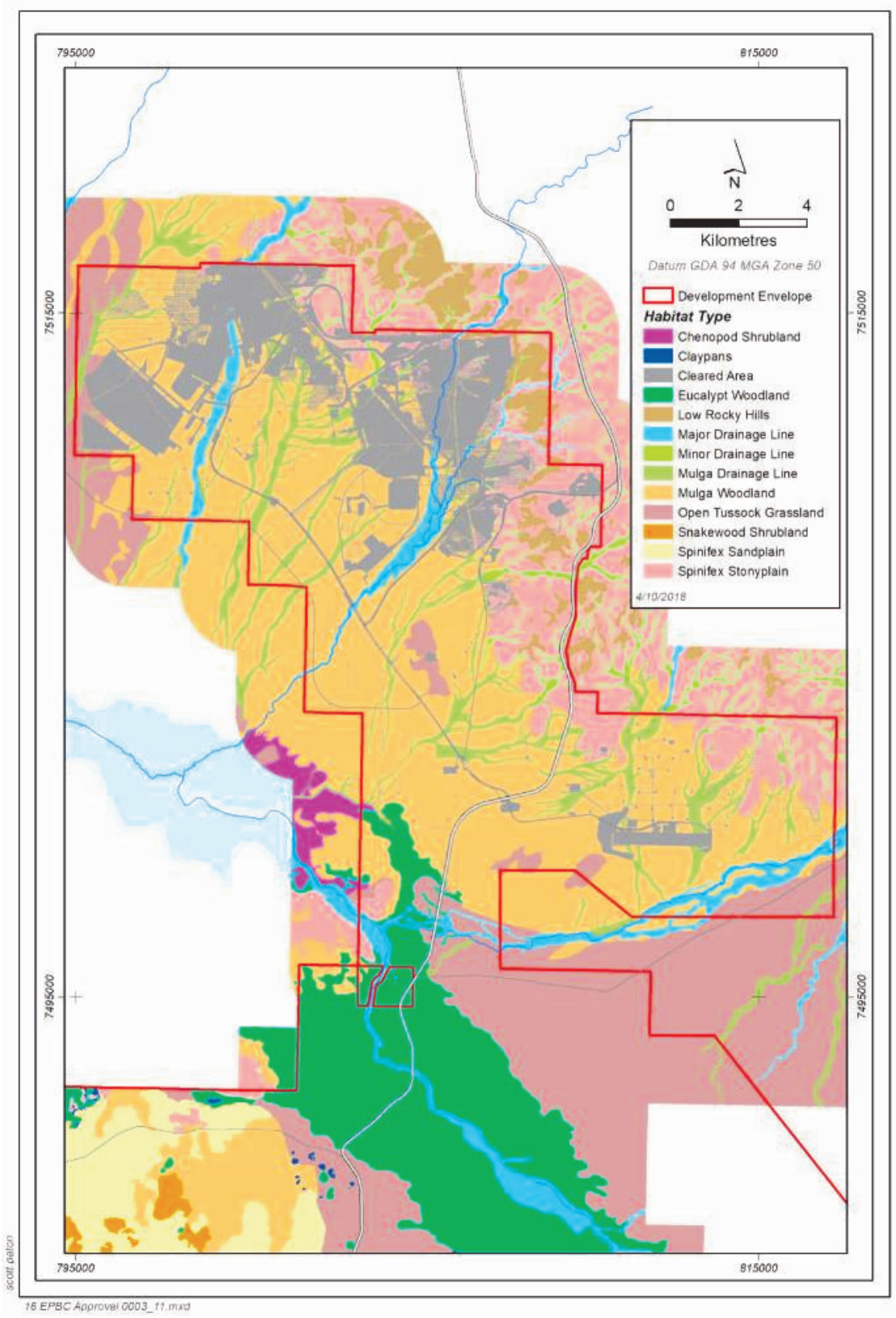

Figure 36: Fauna Habitats within the Revised Development Envelope – Mine

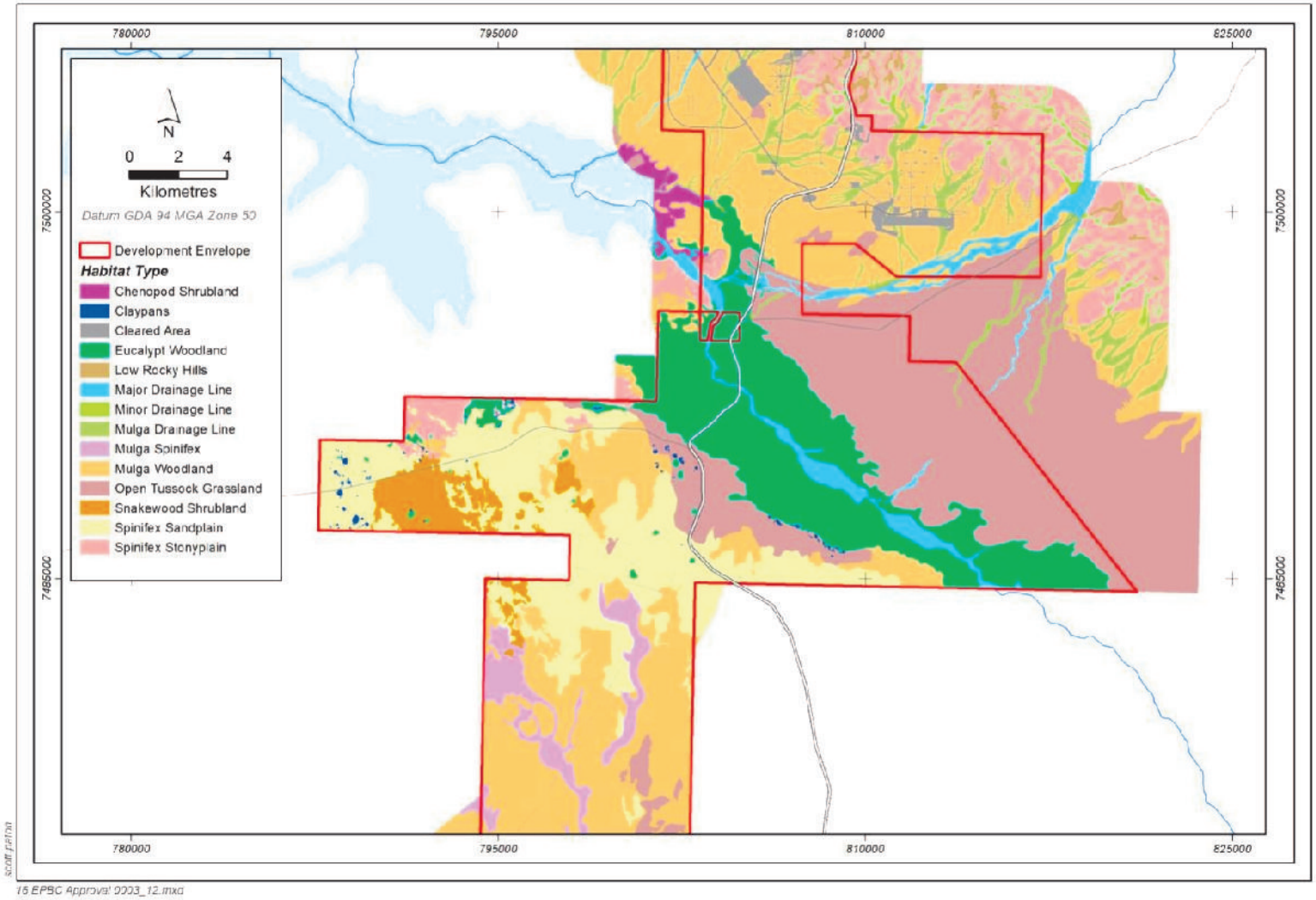

Figure 37: Fauna Habitats within the Revised Development Envelope – Remote MAR Borefield

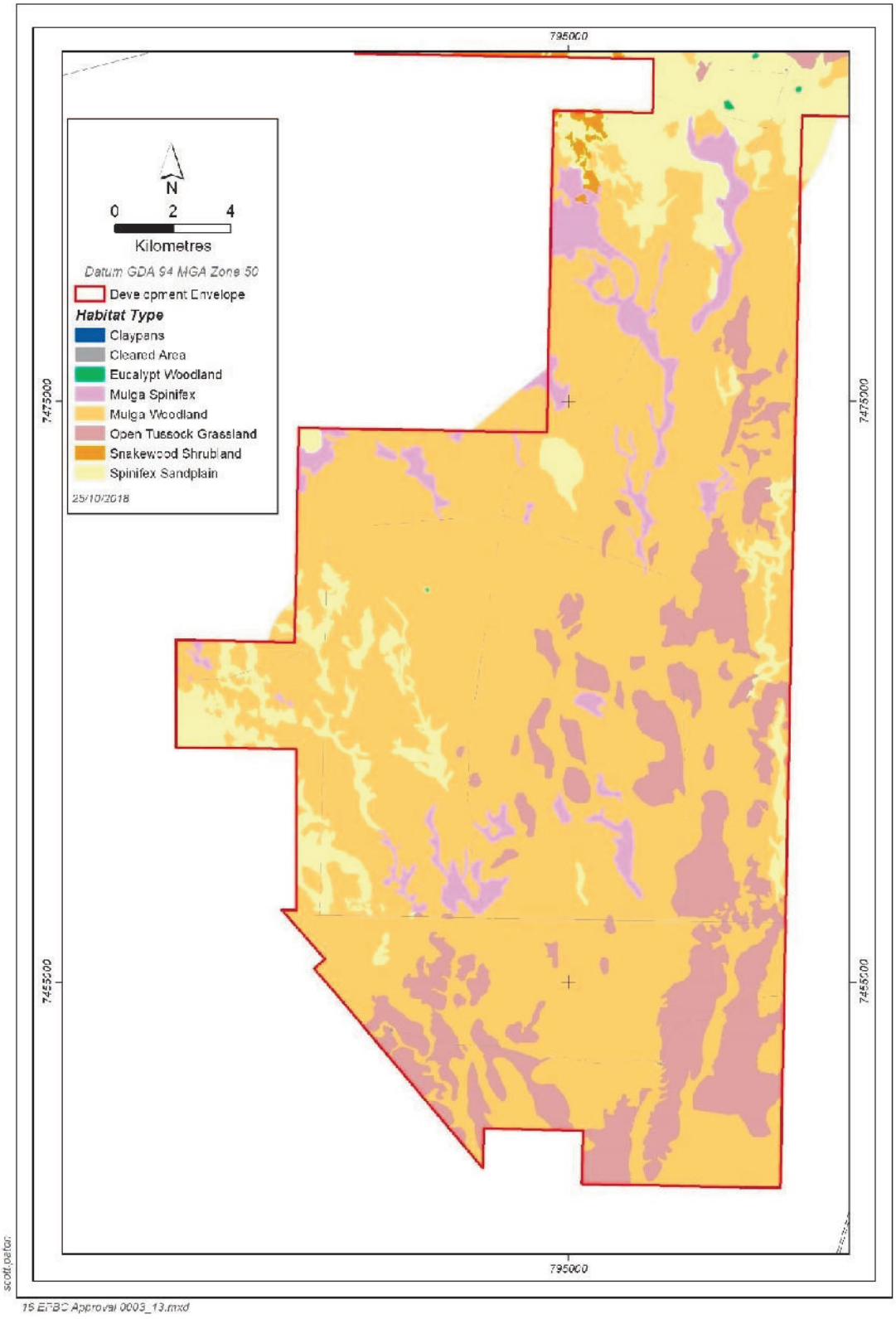

Figure 38: Fauna Habitats within the Revised Development Envelope – Southern Borefield

4.4.3.3 Habitat Features

4.4.3.3.1 Caves

One cave was recorded within the Revised Development Envelope. The cave was recorded within the Low Rocky Hills habitat. It measured approximately 15m in depth, 12m in width and 2m in height, with an entrance measuring 12m in width by 4m in height. A Ghost Bat midden consisting of approximately 300-400 scats (ranging in age from fresh to old), was recorded within the cave. A motion camera deployed within the cave also recorded an individual Ghost Bat visiting the cave on two nights, indicating regular visitation by the species. Due to the lack of similar features within the Revised Development Envelope, this cave should be considered an important feature (Biologic, 2018). The location of the cave is shown in Figure 39.

4.4.3.3.1 Water Pools

Water sources are a limiting factor (James et al., 1995) and important habitat feature within the Pilbara region, and more broadly within arid-zone ecosystems (Burbidge et al., 2010; Doughty et al., 2011a). While temporary water sources may be abundant during and following the wet season, key features are those which can provide a resource for ecosystems for the majority of the year. Generally, areas containing semi-permanent water sources are comparatively more productive ecosystems due to the direct and indirect benefit to fauna and flora (Murray et al., 2003).

Within the Revised Development Envelope, five waterbodies were recorded, consisting of one semi-permanent pool and four claypans, in addition to numerous temporary pools recorded along the Fortescue River. One semi-permanent waterbody was recorded within an isolated patch of *Eucalyptus* sp. upon an alluvial plain supporting Mulga and represented a unique and isolated feature of the Fortescue Valley (EPA, 2013a).

The remaining four claypans were recorded throughout the southern portion of the Revised Development Envelope, usually within Mulga Woodland habitat. Most features recorded contained little to no water at the time of survey but showed signs that they regularly collect and pool surface water, and therefore can be regarded as key features within the broader landscape. Numerous large pools were also recorded along the Fortescue River, which intersects the central portion of the Revised Development Envelope. Such pools were large in extent and their occurrence likely to prevail for long periods after flooding (Biologic, 2018). Significant water pools within the Revised Development Envelope are shown in Figure 39.

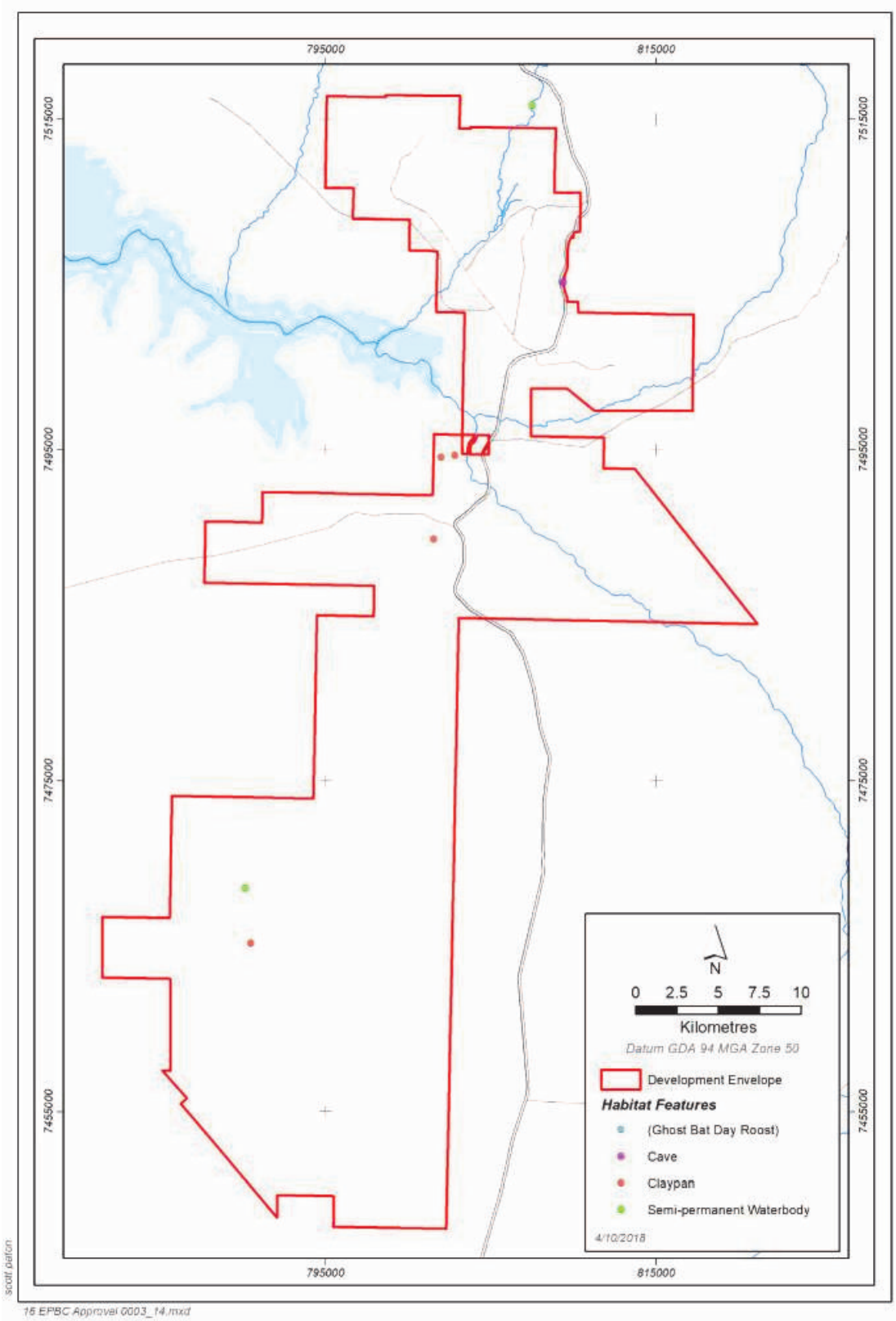

Figure 39: Caves and Water Pools within the Revised Development Envelope

4.4.3.4 Vertebrate Fauna

Database searches and a literature review (Biologic, 2018) identified 335 species of vertebrate fauna, which have previously been recorded and/or have the potential to occur within the Revised Development Envelope. This comprised 35 native mammals, eight non-native mammals, 184 birds, 99 reptiles and nine amphibians. Some of those species are unlikely to occur in the Revised Development Envelope as the database searches were undertaken over a larger area than the Revised Development Envelope itself.

Biologic completed a field Level 1 targeted vertebrate fauna assessment in 2017 and 2018 to identify the potential occurrence of conservation significant species and their supporting habitats within the Revised Development Envelope (Appendix 10). Field survey methods included habitat assessment, targeted searches, remotely piloted searches, acoustic recordings (for bats and Night Parrots) and the use of motion-activated cameras.

Of the 335 species of vertebrate fauna identified as being previously recorded and/or having the potential to occur, 33 are considered to be of conservation significance, comprising eleven mammals, 19 birds and three reptiles (Biologic, 2018a). Of these 33 species, 11 have been confirmed as occurring in the Revised Development Envelope (Table 4-19).

Table 4-19: Fauna species of conservation significance identified as potentially present in the Revised Development Envelope

Species	Scientific Name	Likelihood of Occurrence in the Revised Development Envelope	Current Conservation Status	
			EPBC Act	WC Act
Mammals				
Greater Bilby	*Macrotis lagotis*	Confirmed	VU	S3
Ghost Bat	*Macroderma gigas*	Confirmed	VU	S3
Northern Brushtail Possum	*Trichosurus vulpecula arnhemensis*	Confirmed	-	S3
Spectacled Hare-wallaby	*Lagorchestes conspicillatus leichardti*	Confirmed	-	P3
Brush-tailed Mulgara	*Dasycercus blythi*	Confirmed	-	P4
Lakeland Downs Mouse	*Leggadina lakedownensis*	Confirmed	-	P4
Western Pebble-mound Mouse	*Pseudomys chapmani*	Confirmed	-	P4
Northern Quoll	*Dasyurus hallucatus*	Possible (Confirmed adjacent to Revised Development Envelope)	EN	S2
Pilbara Leaf-Nosed Bat	*Rhinonicteris aurantia*	Possible	VU	S3
Long-tailed Dunnart	*Sminthopsis longicaudata*	Possible	-	P4
Black-flanked Rock Wallaby	*Petrogale lateralis lateralis*	Unlikely	EN	S2

Species	Scientific Name	Likelihood of Occurrence in the Revised Development Envelope	Current Conservation Status	
			EPBC Act	WC Act
Birds				
Grey Falcon	*Falco hypoleucos*	Confirmed	-	S3
Peregrine Falcon	*Falco peregrinus*	Confirmed	-	S7
Night Parrot	*Pezoporus occidentalis*	Possible	EN	S1
Fork-tailed Swift	*Apus pacificus*	Possible	MI	S5
Osprey	*Pandion haliaetus*	Possible	MI	S5
Australian Painted Snipe	*Rostratula australis*	Unlikely	EN	S2
Princess Parrot	*Polytelis alexandrae*	Unlikely	VU	P4
Grey Wagtail	*Motacilla cinerea*	Unlikely	MI	S5
Oriental Plover	*Charadrius veredus*	Unlikely	MI	S5
Yellow Wagtail	*Motacilla flava*	Unlikely	MI	S5
Curlew Sandpiper	*Calidris ferruginea*	Rare	CR/MI	S5
Barn Swallow	*Hirundo rustica*	Rare	MI	S5
Common Greenshank	*Tringa nebularia*	Rare	MI	S5
Common Sandpiper	*Actitis hypoleucos*	Rare	MI	S5
Caspian Tern	*Hydroprogne caspia*	Rare	MI	S5
Gull-billed Tern	*Gelochelidon nilotica*	Rare	MI	S5
Pectoral Sandpiper	*Calidris melanotos*	Rare	MI	S5
Sharp-tailed Sandpiper	*Calidris acuminata*	Rare	MI	S5
Wood Sandpiper	*Tringa glareola*	Rare	MI	S5
Reptiles				
Pilbara Olive Python	*Liasis olivaceus barroni*	Confirmed	VU	S3
-	*Anilios ganei*	Confirmed	-	P1
-	*Ctenotus nigrilineatus*	Unlikely	-	P1

Note: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; MI = Migratory, S*x* = Schedule *x*; P*x* = Priority *x*; EPBC Act = *Environment Protection and Biodiversity Conservation Act 1999*; WC Act = *Wildlife Conservation Act 1950*.

The following species were also recorded, or assessed as possible to occur, during previous surveys of the Roy Hill tenements and, at the time of the previous surveys, were considered to be of conservation significance but have since been delisted:

- Australian Bustard (*Ardeotis australis*) – Priority 4;
- Bush Stone-curlew (*Burhinus grallarius*) – Priority 4;
- Star Finch (*Neochmia ruficauda*) – Priority 4;
- Woma (*Aspidites ramsayi*) – Priority 1;
- Cattle Egret (*Bubulcus ibis*) – WC Act, Schedule 5;
- Great Egret (*Ardea modesta*) – WC Act, Schedule 5; and
- Rainbow Bee-eater (*Merops ornatus*) – WC Act, Schedule 5.

Species of conservation significance that have been confirmed within the Revised Development Envelope and those that may possibly occur, are further outlined in the subsections below. They consist of ten mammals, five birds and two reptiles. These species have been assessed against their known locations within the proposed footprint, extent of denning and foraging habitat and the extent of proposed disturbance areas of each habitat to determine the significance of potential impact to each species.

4.4.3.4.1.1 Conservation Significant Species – Confirmed Within Revised Development Envelope

4.4.3.4.1.1.1 Greater Bilby (*Macrotis lagotis*)

The Greater Bilby (Bilby) is listed as Vulnerable under the EPBC Act and Schedule 2 under the WC Act (Biologic, 2018). The Bilby was formerly associated with a variety of inland habitats, including desert sandplains, dune fields with hummock grasslands, and massive red earths and *Acacia* shrublands (Woinarski *et al.*, 2014), but populations underwent a sudden and widespread collapse in the early 1900s (van Dyck & Strahan, 2008). The species is now restricted to approximately 20% of its former range, with wild populations restricted predominantly to the Tanami Desert in the Northern Territory, the Great Sandy and Gibson Deserts and Pilbara region in Western Australia (Woinarski *et al.*, 2014).

RHIO received an initial report of a Bilby sighting in July 2018 close to existing Mine infrastructure. RHIO staff located a potential active Bilby burrow and positioned five camera traps in the area. A Bilby was successfully recorded on the cameras on multiple occasions (Figure 38). The Bilby's burrow and active area was in proximity to the main access road into the RHIO mine and within 1km of the RHIO mine offices. Two burrows were active (utilising old Varanus burrow systems), with a total of 23 dig locations (some with multiple digs), two sets of fresh tracks and 10 scat locations recorded (additional scats were found within the multiple dig locations) (Biologic, 2018a). The fresh tracks were recorded in two areas which had recently been cleared of vegetation, located approximately 200m from the active burrow area (where the soil was softer to enable tracks to be easily seen), with one of the areas being on a freshly cleared track and pipeline corridor.

The Bilby was recorded in Mulga Woodland which is not considered to be the preferable habitat of Bilbies in the Pilbara, but they utilise these areas if there are enough resources available. Southgate (1990) found that Bilbies utilise a range of different habitats which includes Mulga Woodlands. It is considered likely that the Bilby activity found at the RHIO mine would most probably be by an individual male Bilby, given that males tend to range

more widely than females, overlapping with multiple female's home ranges. Male Bilbies can travel long distances looking for potential mates or finding new resources (Biologic, 2018a).

Within the local area of the Bilby record, Mulga Woodlands should be considered of High significance, although the remainder of this habitat should be considered as Moderate significance.

Previously the species has been confirmed (2017) at Christmas Creek, ~15km west of the Revised Development Envelope (T. Edwards pers. comm. cited in Biologic, 2017) and 15km east of the Revised Development Envelope by DBCA (Biologic, 2017). Evidence of the species was recorded elsewhere in the Revised Development Envelope during the July survey, from seven old burrow systems and five (probable) old diggings, however no scats were recorded. Each of these records was from within the Spinifex Sandplain, specifically within a vegetation community on softer deeper sands.

Figure 40: Bilby recorded on camera traps in July 2018, on a trail (left), and coming out of burrow (right)

4.4.3.4.1.1.2 Ghost Bat (*Macroderma gigas*)

The Ghost Bat is listed as Vulnerable by DoEE and Schedule 3 by DBCA. The Ghost Bat formerly occurred over a wide area of central, northern and southern Australia but has declined significantly in the southern parts of its' range in the last 200 years (Armstrong & Anstee, 2000). The species now occurs in only a few highly disjunct sites across northern Australia, confined to the Kimberley and Pilbara regions in Western Australia (van Dyck & Strahan, 2008). In the Pilbara region, the species roosts in deep, complex caves beneath bluffs of low rounded hills, often composed of Marra Mamba or banded iron formation, granite rock piles and abandoned mines (Armstrong & Anstee, 2000). They roost either individually or in colonies of up to 1,500 individuals (Churchill, 2008) and move between a number of caves, both seasonally and as dictated by weather changes (van Dyck & Strahan, 2008).

Populations are potentially distinct at local and regional scales (Worthington-Wilmer *et al.*, 1994). It is conceivable that low gene flow is occurring between the northern and southern Pilbara due to the partial barrier of the Fortescue Marsh. However, a Ghost Bat was captured (mist net) during surveys within the Fortescue Marsh (J. Turpin, *pers. comm.;* cited in Biologic 2018) many kilometres from suitable roosting habitat suggesting the flat expanse of the Fortescue Marsh is not a total barrier.

The Ghost Bat was previously recorded acoustically by ecologia (2009d) from within Mulga Woodlands and <1km east of the Revised Development Envelope in Low Rocky Hills as recorded by DBCA (Biologic, 2018). The species was recorded on eight occasions by Biologic (2018), including directly via motion camera (*n* = 2), by call (*n* = 1), a deceased individual on a barbed-wire pastoral fence (*n* = 1), and via scat from one cave and two small overhangs (*n* = 4). Additionally, the species was recorded via secondary evidence, i.e. via scats on three occasions. The motion camera records and one of the scat records were located at a cave in the Revised Development Envelope. The deceased individual recorded on the barbed-wire fence was located <100m from the entrance of this cave, although confirmed as a different individual to that recorded using the cave during the survey (via motion camera) as the dead individual was observed prior to the camera capture date (Biologic, 2018a).

Given the high amount of survey effort expended searching for caves in the Low Rocky Hills habitat, it is unlikely that many, if any, similar cave features exist within the Revised Development Envelope. Although similar cave features may be present outside the Revised Development Envelope, the species is believed to forage on wooded plains (Tidemann *et al.*, 1985) that occur in much of the Revised Development Envelope. The cave recorded within the Revised Development Envelope is potentially one of the closest roost sites to the Fortescue Marsh and therefore should be considered of significance to the species. The cave is highly likely to represent a diurnal roost for the species and may possibly represent a maternity roost.

The species was also recorded via scat from two other small overhangs within the Revised Development Envelope. However, only a small number of new scats (1-2) were recorded in each feature suggesting they provide a temporary nocturnal feeding site only, of which there are many in the surrounding habitat (Biologic, 2018a).

4.4.3.4.1.1.3 Northern Brushtail Possum (*Trichosurus vulpecula* subsp. *arnhemensis*)

The Northern Brushtail Possum was listed as Schedule 3 (Vulnerable) under the WC Act in 2016. This subspecies occurs from the north-west Pilbara, through the Kimberley into the Northern Territory (van Dyck & Strahan, 2008). Little ecological information is known about the Pilbara population, although it is most often recorded from major drainage lines that contain large hollow-bearing Eucalypts (Biologic, 2018). Within the Northern Territory, the species is omnivorous often feeding on flowers and insects (Cruz *et al.*, 2012; Cruz *et al.*, 2012a).

Multiple scratching, possibly belonging to the species, were recorded in 2017 and 2018 on the trunks of large hollow-bearing Eucalypts. The scratching's were deemed as possible evidence of the species only, as no other evidence of the species could be located. The scratching's were characteristic of the species, being laterally positioned from one-another, of suitable size and with extended lateral thumb (Biologic, 2018). The isolated Eucalypt Woodland and instances of the Major Drainage Line habitat, such as the Fortescue River, both contain a high density of suitable denning hollows and provide potential habitat for the species (Biologic, 2018a).

The nearest record of the species is located approximately 60 km west of the Revised Development Envelope, north of the Cloudbreak mine site. The species is infrequently recorded within the Pilbara, with less than 20 records existing on DBCA's NatureMap (Biologic, 2018a).

4.4.3.4.1.1.4 Spectacled Hare-wallaby (*Lagorchestes conspicillatus leichardti*)

The Spectacled Hare-wallaby is currently listed as Priority 3 by DBCA. The Spectacled Hare-wallaby is sparsely distributed and generally uncommon across northern Australia, occurring from northern Queensland to the Pilbara, where the species is considered relatively rare (van Dyck & Strahan, 2008). The species shelters within grass tussocks and spinifex hummocks and low shrubs (Ingleby & Westoby, 1992).

The species was not recorded during the Biologic 2017 and 2018 surveys, however scats of the species were recorded (Animal Plant Mineral, 2010) from tall long unburnt spinifex in the southern section of the Revised Development Envelope within the Spinifex Sandplain habitat. The species is patchily distributed throughout the Pilbara region and is considered likely to occur within Spinifex Sandplain habitat within the Revised Development Envelope (Biologic, 2018a).

4.4.3.4.1.1.5 Brush-tailed Mulgara (*Dasycercus blythi*)

The Brush-tailed Mulgara is listed as Priority 4 by DBCA (Biologic, 2018a). This species is closely associated with Spinifex Sandplain habitat, distributed from south-western Queensland across the Simpson, Tanami, and Great Sandy Deserts of southern and central Northern Territory and central Western Australia, including parts of the Pilbara (Pavey *et al.*, 2012).

The species was recorded by Biologic (2017) on one occasion (by scat and burrow) and has been recorded immediately west of the Revised Development Envelope (~4.5km) in Spinifex Sandplain habitat, as well as ~50km west of the Revised Development Envelope at Yandi in 2014 as noted in DBCA's NatureMap (Biologic, 2018). The species is moderately common in suitable habitat and is likely to occur throughout the Spinifex Sandplain habitat in the Revised Development Envelope (Biologic, 2017).

4.4.3.4.1.1.6 Lakeland Downs Mouse (*Leggadina lakedownensis*)

The Lakeland Downs Mouse is listed as Priority 4 by DBCA. Populations of this small, elusive rodent are distributed across northern Australia, but records are sporadic (van Dyck & Strahan, 2008). The species occupies a diverse range of habitats from the monsoon tropical coast to semiarid climates, including spinifex and tussock grasslands, samphire and sedge lands, *Acacia* shrublands, tropical eucalypt and *Melaleuca* woodlands and stony ranges; however, in the Pilbara, the species is usually found in seasonally inundated habitats on red or white sandy-clay soils (Moro & Morris, 2000).

The species was not recorded by during the Biologic 2017 and 2018 surveys but has previously been recorded in the central-eastern margins of the Revised Development Envelope in 2004 and areas ~4.5 km outside the Revised Development Envelope to the east, and to the west near Christmas Creek as shown in DBCA's NatureMap (Biologic, 2018). The species is relatively common in suitable habitat and is likely to occur in the Open Tussock Grasslands and Mulga Woodlands (Biologic, 2018a).

4.4.3.4.1.1.7 Western Pebble-mound Mouse (*Pseudomys chapmani*)

The Western Pebble-mound Mouse is currently listed as Priority 4 by DBCA. This species has experienced a significant decline in its range through the Gascoyne and Murchison, and is now considered endemic to the Pilbara (van Dyck & Strahan, 2008). This species almost exclusively occurs on the gentler slopes of rocky ranges

where the ground is covered with a stony mantle and vegetated by hard spinifex, often with a sparse over storey of eucalypts and scattered shrubs (van Dyck & Strahan, 2008).

One active and one inactive mound was recorded by Biologic (2017). Two inactive mounds were recorded in the Revised Development Envelope by ecologia Environment (2009d) and a number of inactive and active mounds were recorded by ecologia Environment (2008). It is likely that the Western Pebble-mound Mouse occurs throughout the Low Rocky Hills and Spinifex Stony plain habitats located within the Revised Development Envelope (Biologic, 2017).

4.4.3.4.1.1.8 Grey Falcon (*Falco hypoleucos*)

The Grey Falcon is classified as Schedule 3 under the WC Act. This species appears to have a distribution centred on ephemeral or permanent creek lines (Garnett & Crowley, 2000), with numerous records on DBCA's NatureMap from the Fortescue Marsh region. Grey Falcons prefer sparsely-treed, open plains and creek lines for hunting (Olsen & Olsen, 1986). They typically nest in the abandoned nest of a raptor or corvid (Olsen & Olsen, 1986) in trees or man-made structures, most notably repeater towers (Biologic, 2018a).

The species was recorded within the northern section of the Revised Development Envelope by ecologia Environment (2009d) and was previously recorded within the eastern section of the Revised Development Envelope in 2001. Additionally, DBCA's NatureMap shows three records of the species <20km from the Revised Development Envelope within the last 20 years (Biologic, 2018a). The species may nest within the major drainage systems that intersect the Revised Development Envelope and may also forage through most of the surrounding habitats, if present (Biologic, 2018a).

4.4.3.4.1.1.9 Peregrine Falcon (*Falco peregrinus*)

The Peregrine Falcon is listed under the WC Act as Schedule 7 "other specially protected fauna" (Biologic, 2018a) and is considered rare over much of its range (Johnstone & Storr, 1998). In arid areas, it is most often encountered along cliffs above rivers, ranges and wooded watercourses where it hunts birds (Johnstone & Storr, 1998). It typically nests on rocky ledges occurring on tall, vertical cliff faces between 25m and 50m high (Olsen & Olsen 1989). It also appears to prefer nesting on large ledges a reasonable distance (average of 13m) from the top of the cliff (Olsen & Olsen, 1989), possibly to avoid ground dwelling predators.

An individual Peregrine Falcon was recorded at a bore by Biologic (2017). The species was also recorded hunting waterbirds along a creek line tributary of Kulkinbah Creek by ecologia Environment (2009d), in 'rocky areas' by ecologia Environment (2008) and in the east of the Revised Development Envelope as recorded by DBCA in 2013. An additional six records are scattered within 30km of the Revised Development Envelope (Biologic, 2018a). Potential nesting habitat may be present within the Low Rocky Hills and along the Major Drainage Line habitat, either within the Revised Development Envelope or nearby. The Major Drainage Line habitat is likely to provide suitable foraging habitat for the species, although the species may occur throughout the majority of the Revised Development Envelope.

4.4.3.4.1.1.10 Pilbara Olive Python (*Liasis olivaceus barroni*)

The Pilbara Olive Python is listed as Vulnerable under the EPBC Act and Schedule 3 under the WC Act (Biologic, 2018a). It commonly occurs in the ranges, water courses and pools in rocky gorges and gullies of the Pilbara

region (Pearson, 1993). This species is primarily nocturnal and tends to shelter in small caves or under vegetation during the day, although it is occasionally active after sunrise, particularly in the warmer summer months (Pearson, 2003).

The species was not recorded during the Biologic (2018) survey, however, three records from RHIO staff are located within the Revised Development Envelope. A further two records are located <2km from the margins of the Revised Development Envelope, one to the north from Christmas Creek in 2011 and two to the east from 2013 (DBCA, 2017a). The Low Rocky Hills and Major Drainage Line provide suitable habitats for the species (Biologic, 2018a).

4.4.3.4.1.1.11 *Anilios ganei* (Blind Snake)

Anilios ganei is a DBCA Priority 1 blind-snake endemic to the Pilbara region (Wilson & Swan, 2014). Given its cryptic fossorial habit, there are few records of the species. Little is known of the species' ecology but, like most other blind-snakes, it is insectivorous and feeds on termites and their eggs, as well as the larvae and pupae of ants (Wilson & Swan, 2014). This species is often associated with moist soils and leaf litter within gorges and gullies (Doughty *et al*., 2011), and potentially within a wide range of other stony habitats.

The species has previously been recorded within the within the Low Rocky Hills habitat as noted in DBCA's NatureMap (Biologic, 2018). The species has been recorded from numerous habitats within the region but is most likely to be present in Low Rocky Hills and along Major Drainage Lines. The species was recorded in 2009 (Animal Plant Mineral, 2010), 25km west of the Revised Development Envelope in what appears to be drainage line habitat.

4.4.3.4.1.2 Conservation Significant Species – May Possibly Occur

4.4.3.4.1.2.1 Northern Quoll (*Dasyurus hallucatus*)

The Northern Quoll is listed as Endangered under the EPBC Act and Schedule 2 under the WC Act. At present Northern Quolls are relatively common in the northern Pilbara region (generally within 150km of the coast) but are much less common in southern and south-eastern parts of the region (Cramer *et al.*, 2016).

The species has previously been recorded in the vicinity of, but outside of the RHIO mine tenure by DPaW in 2016. The record was of a scat from an isolated hill within the Low Rocky Hill habitat. This record was located <1,500m from a scat found in a 2018 survey. Both scat records were collected <1,200m from a semi-permanent waterbody located to the north and outside of RHIO mine tenure (Biologic, 2018).

Northern Quolls are known to occur in rocky habitats associated with water sources (Oakwood, 2002), believed to be attributed to the higher productivity of such habitats. The species is known to occur within the region, having been recorded north, south, east and west of the Revised Development Envelope (DBCA, 2017a). The Low Rocky Hills, which is the most suitable habitat in the Revised Development Envelope for the species, is considered only a moderately suitable habitat for the species. While the habitat is rocky relative to other habitats within the Revised Development Envelope, it was noticed that these Low Rocky Hills possessed few deep cracks, crevices and few large boulder piles that are considered suitable for denning. The suitability of habitat, paucity of records and the lack of direct records (i.e. observations of individuals), suggests that the

species is likely to occur in low numbers if permanent, or that the records to date have been made by individuals dispersing from nearby populations (Biologic, 2017).

Pre-clearance surveys were undertaken for Northern Quoll (*Dasyurus hallucatus*) within potential habitat areas in 2014, in accordance with the Vertebrate Fauna Management Plan for the Roy Hill Rail Corridor (100RH-3000-EN-REP-2009) and Fauna Trapping and Translocation Program Guideline (100RH-0000-EN-GUI-2010). The surveys targeted potential habitat for the species in a small area within the RHIO mine tenements near the rail loop. No individuals or suitable denning habitat for Northern Quoll was identified during the surveys.

4.4.3.4.1.2.2 Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*)

The Pilbara Leaf-nosed Bat is listed as Vulnerable under the EPBC Act and Schedule 2 under the WC Act. The species is restricted to the Pilbara region and is thought to have been separated from populations of the Orange Leaf-nosed Bat in the Kimberley, Northern Territory and western Queensland for at least 30,000 years (Churchill, 1991). The species is heavily reliant on warm (28-32°C), humid (85 to 100%) sites for roosting (Armstrong, 2001), which enable individuals to reduce water loss and energy expenditure (Baudinette *et al.*, 2000). The distribution of the species is therefore limited by the scarcity of caves that possess the required microclimates (Armstrong, 2001; Churchill, 1991).

The nearest record of the species is located approximately 17km south of the Revised Development Envelope at Kalgan River in the Hamersley ranges. The average flight distance is believed to be approximately 20km per night (Bullen & McKenzie, 2011), and therefore it is possible that the species may forage in the Revised Development Envelope. No roosting locations have been recorded within the Revised Development Envelope and none are likely to occur. The Revised Development Envelope may provide foraging habitat for the species on an irregular basis (Biologic, 2018).

4.4.3.4.1.2.3 Long-tailed Dunnart (*Sminthopsis longicauda*)

The Long-tailed Dunnart (DBCA Priority 4) is a nocturnal and agile species distributed through the Pilbara, north eastern goldfields and Gibson desert, south to the Nullarbor Plain, to central Northern Territory and western South Australia (McKenzie *et al.*, 2008). Its core habitat includes rocky scree slopes with hummock grass and shrubs, and tall open *Acacia* shrubland and woodlands (McKenzie *et al.*, 2008), which are well represented within the Revised Development Envelope.

The Long-tailed Dunnart has been recorded twice within 40km east and north of the Revised Development Envelope (Biologic, 2018). Owing to the occurrence of suitable habitats on Low Rocky Hills in the north-west margins of the Revised Development Envelope, it is regarded as possible that the species occurs within the Revised Development Envelope (Biologic, 2018).

4.4.3.4.1.2.4 Night Parrot (*Pezoporus occidentalis*)

The Night Parrot is listed as Endangered under the EPBC Act and Schedule 1 (Critically Endangered) under the WC Act. The Night Parrot is one of Australia's rarest birds, with very few confirmed sightings in recent years (Pyke & Ehrlich, 2014). Night Parrots reportedly occur in spinifex grasslands in stony or sandy areas on floodplains or near creeks, shrubby samphire and chenopod vegetation on claypans or at the edges of salt lakes, and in dense, low vegetation around watercourses (Murphy et al., 2017; Night Parrot Recovery Team, 2017;

Pyke & Ehrlich, 2014). There are only two contemporary records of the species within Western Australia, one located approximately 65km west of the Revised Development Envelope at Minga Qwirriawirie Well, (Davis & Metcalf, 2008) and the other from an unnamed location in early 2017 (Night Parrot Recovery Team, 2017). It is understood that there have been additional sightings in recent years, however the locations have remained confidential.

Seven acoustic SM2 recorders were deployed by Biologic in 2017 within the Revised Development Envelope. The recorders were placed in long unburnt *Triodia longiceps* hummock grasslands associated with a paleo-drainage system or healthy stands of samphire, similar to habitats where the species was recorded in Queensland (Night Parrot Recovery Team, 2017) and as recommended by DPaW (2017a) (Biologic 2018a). An additional targeted Night Parrot survey was conducted by Strategen (2018) between 24 April 2018 to 3 May 2018 within the Revised Development Envelope (Appendix 11). Acoustic data covering an extensive 1,088 hours, was collected using ten SM4 acoustic recorders placed across 20 different locations, capturing a survey effort of 89 nights. Sites were selected based on preferred nesting habitat of large Spinifex hummocks and was undertaken in accordance with "Interim guideline for preliminary surveys of Night Parrot (*Pezoporus occidentalis*) in Western Australia" (DPaW, 2017a).

Despite the species not being recorded during either survey, it is possible that the species may still occur due to the inability for acoustic recorders to completely survey the expansive amount of potentially suitable habitat. However, the likelihood of this species occurring in the Revised Development Envelope is considered to be low.

4.4.3.4.1.2.5 Fork-tailed Swift (*Apus pacificus*)

This species is listed as Migratory under the EPBC Act and Schedule 5 under the WC Act. The species breeds in north-east and east Asia and winters in Australia and southern New Guinea (Johnstone & Storr, 1998). This species is entirely aerial within the Pilbara and does not utilise the terrestrial surface. The nearest record is located ~2km east of the Revised Development Envelope from 2013 in DBCA's NatureMap. This species is expected to utilise the skies above the Revised Development Envelope sporadically in the summer months, being attracted to thunderstorms and cyclonic systems (Johnstone & Storr, 1998). Due to the sporadic nature of its occurrence (as a visitor or temporary resident), it is considered that this species may possibly occur (Biologic, 2018a).

4.4.3.4.1.2.6 Osprey (*Pandion haliaetus*)

The Osprey is listed as Migratory under the EPBC Act and WC Act (as Schedule 5). The Osprey is a large (50-60cm), highly visible and water-dependent bird of prey with a world-wide distribution (Johnstone & Storr, 1998). It occurs around most of the Australian coastline, inhabiting coastal areas and favouring mangroves, rivers and estuaries, inshore seas as well as coastal islands (Johnstone & Storr, 1998).

The nearest record is located approximately 45km west of the Revised Development Envelope, from 2011. The Major Drainage Line habitat, particularly the Fortescue Marsh, provides potential nesting and foraging habitat for the species (Biologic, 2018a).

4.4.3.5 Short Range Endemic Species

Short Range Endemic (SRE) species refers to an endemic species with restricted range, which is currently defined in Western Australia as less than 10,000km^2 (100km x 100km). SRE taxa are usually invertebrates, as they are

more likely to display poor dispersal abilities and a more defined or restrictive biology that promotes their isolation and eventual speciation. The groups of organisms which display short-range endemism include (but are not limited to) molluscs (e.g. Camaenid land snails), onychophorans (velvet worms), millipedes, arachnids (e.g. scorpions, pseudoscorpions, mygalomorph spiders) and some crustaceans (isopods) (ecologia Environment, 2006).

The Pilbara Biological Survey, including SRE surveys, undertaken by the then Department of Environment and Conservation (DEC) between 2002 to 2007, identified 76 invertebrate species from two sites outside of the RHIO mine tenement boundary. The invertebrate species comprised 23 spiders, 2 scorpions, 31 ants and 20 beetles (van Leeuwen, pers. comm., 2008; cited in RHIO Stage 1 PER, 2009).

SRE surveys were conducted in and around the Revised Development Envelope prior to the initial referral of the Original Proposal. A baseline SRE survey was undertaken in 2006, covering approximately 4,160ha of the Mine and surrounding areas. Three major habitat assemblages were found to occur in the Revised Development Envelope, namely Mulga woodland, major drainage lines and southern facing ridge slopes, all of which were not locally restricted and therefore unlikely to provide the processes which promote short-range endemism (ecologia Environment, 2006).

Ten invertebrate species from recognised SRE taxa were found by ecologia Environment (2006) five of which were not formally described. These included two possibly new species of scorpion (i.e. *Urodacus* sp. and *Lychas* sp.), two new centipede species (i.e. a species from the order Geophilomorpha and *Asanda* sp.) and one undescribed, but known, isopod species (i.e. *Laevophiloscia wahrberg* 1922 sp.). It was concluded that the undescribed scorpion and isopod species were unlikely to be SRE or highly restricted species, as the habitat that is normally suitable for harbouring such SRE taxa was relatively widespread both within and outside the survey area. It was therefore determined that it was unlikely for this habitat to facilitate allopatric speciation (speciation triggered by geographic isolation), that would give rise to SRE invertebrate species (ecologia Environment, 2006).

An additional survey for SRE species was undertaken in 2008, as a result of very few potential SRE species and total absence of mygalomorph spiders being found in the 2006 survey. The survey used transect mapping within designated areas and opportunistic sampling that targeted prospective SRE habitats, however it was conducted at the end of a dry season (October), when most invertebrate SRE species were considered to be inactive. Much of the land surveyed within the RHIO tenements was considered to be degraded and therefore largely unsuitable for ground dwelling SRE species such as mygalomorph spiders. The two main causes of the land degradation were cattle grazing and a bushfire that appeared to have swept through large areas of the tenement (ecologia Environment, 2008a).

In one of the 17 sites surveyed, a single female specimen of a mygalomorph spider from the genus *Conothele* was found. The specimen was collected from a small creek line in the south-eastern corner of the RHIO mine tenements and it belonged to a new and/or undescribed species. However, in order to confirm taxonomic resemblance with other undescribed species of *Conothele* in the Pilbara, the collection of adult males was required. Two additional burrows of the same species were found in the same creek line; however, both were old and abandoned (ecologia Environment, 2008a).

Further sampling of invertebrates was undertaken at 16 locations within the RHIO tenements in July 2009, using systematic pitfall trapping. The specimens were subsequently identified by the Western Australian Museum and included mygalomorph spiders in the families Actinopodidae (*Missulena*), Barychelidae (*Synothele*) and Idiopidae (*Aganippe*), pseudoscorpions in the families Atemnidae (*Oratemnus*) and Olpiidae (*Austrohorus, Beierolpium, Indolpium*), and some unidentifiable fragments of a millipede (Western Australian Museum, 2009).

In November 2009, a survey was carried out (ecologia Environment, 2010) within the Southern Borefield area and a proposed pipeline corridor. A total of 154 specimens were collected including snails, pseudoscorpions, scorpions and centipedes from six families and eight genera. All specimens were lodged with the Western Australian Museum for taxonomic identification and recommendations concerning SRE status. None of the specimens identified from this survey are known to be SRE species. The SRE status of a single specimen (a cryptopid centipede) was unable to be commented on due to poor taxonomy of the group, however all other species were either widespread or known from other localities.

Condition 9 of MS 824 defined eight of the survey sites within the Mine area as requiring protection (i.e. the avoidance of disturbance) and monitoring of the SRE species located at them. The species identified as requiring further monitoring were *Missulena sp*., *Synothele* 'MYG127', *Aganippe* 'MYG126', *Idiommata* 'MYG128' and *Beierolpium* sp. Further survey work conducted from 2010 to 2012 found all but one species, *Idiommata* 'MYG128', occurring outside of the Mine area (ecologia Environment, 2010; Bennelogia, 2011; Bennelogia, 2012). It was determined that further pit-trap sampling be undertaken to determine occurrences of *Idiommata* 'MYG128'.

The requirement for monitoring within the Mine area under Condition 9 of MS 824 was subsequently replaced in July 2012 by new MS 902 requirements. The new Condition 9 required that suitable habitat monitoring sites (a minimum of three) were required to be found outside the RHIO mine tenement boundaries for each of the five species and monitored triennially until authorised to cease.

In accordance with MS 902, monitoring of SRE habitat was undertaken between April and July 2013. Habitat condition was monitored at ten sites outside of RHIO mine tenure, where the spider species *Missulena* `MYG252-DNA`, *Synothele* `MYG127`, *Aganippe* `MYG126` and the pseudoscorpion *Beierolpium* sp. had been recorded. The purpose of monitoring was to compare habitat condition against a set of habitat targets to examine whether environmental conditions had remained suitable for the SRE species identified in Condition 9 of Ministerial Statement 902 (Bennelogia, 2013).

Ten sites were also sampled for *Idiommata* `MYG128`, focussing on wet-pit trapping methods and foraging. While 13 non-target mygalomorph spiders were collected, no specimens of *Idiommata* `MYG128` were trapped and no potential burrows of the species were found. It was concluded that the failure to re-collect *Idiommata* `MYG128` at the original site (1106_13 in 2009) despite significant trapping efforts, was likely to be due to it no longer being present there. It was also concluded that the species occurs at a low abundance, and that it has cryptic burrows which are difficult to detect by foraging. The level of sampling required to collect *Idiommata* `MYG128` at three locations outside of RHIO mine tenure was therefore determined to be outside the expectations of a monitoring program. It was subsequently recommended that no habitat monitoring sites be required for *Idiommata* `MYG128` (Bennelongia, 2013).

In July 2015, RHIO commissioned a review of current information regarding the five SRE species identified within the mine area (Bennelongia, 2015). The review found that:

- *Missulena* 'MYG252-DNA' currently appears to be a tightly restricted species, with a linear range of 17km and an areal range of 60km^2. It is known from 16 specimens and burrows from outside the Revised Development Envelope, and specimens have been recorded within the Pilbara region associated with similar habitat (mulga dominated drainage lines) found within the current range. Therefore, it is likely that *Missulena* 'MYG252-DNA' is more prevalent within similar habitats outside of the current known extent (Bennelongia, 2015).
- *Synothele* 'MYG127' distribution extends along the northern side of the Fortescue Marsh, with a linear range of 218km and an areal range of 2,000km^2. Surveys have found over 20 burrows in nine locations outside the Revised Development Envelope, and 25 specimens (Bennelongia, 2015). *Synothele* 'MYG127' was also discovered within the Serenity Valley by Phoenix Environmental Sciences Pty Ltd (Phoenix) in 2010, approximately 250km to the east of the RHIO mine. Phoenix did not consider *Synothele* 'MYG127' to be a SRE (Phoenix, 2010).
- *Aganippe* 'MYG126' is abundant outside the mine site, with a linear range of 105km and an aerial range of 1,000km^2. 750 burrows have been recorded at 21 sites, with 78 specimens within the northern edge of the Fortescue Marsh. It has also been recorded up to 60km west of the Revised Development Envelope at four other sites. This species has a distribution extending along the northern edge of the Fortescue Marsh and is not restricted to the RHIO mine site (Bennelongia, 2015).
- *Idiommata* 'MYG128' has been identified at two locations outside of the Revised Development Envelope in the Pilbara since 2009 (Western Australian Museum, 2014). These sites were located 70km north of Tom Price and 35km east of Newman respectively. Whilst *Idiommata* 'MYG128' has not been located from other sites, the current known identified specimens suggest it has a linear range of 296km and an aerial range of >15,000km^2 (Bennelongia, 2015). As a result, the Western Australian Museum does not consider *Idiommata* 'MYG128' to be a SRE species.
- *Beieroplium* sp. '8/2' has been found at eight sites outside the Revised Development Envelope with 22 individuals in 2010 and two individuals in 2013 (Bennelongia, 2015). Phoenix identified *Beierolpium* sp. '8/2' at Anketell Point, 30km east of Karratha, during a 2010 survey. *Beierolpium* sp. '8/2' has also been recorded near Cape Preston 80km west of Karratha, and Davidson Creek, 80km east of Newman (Bennelongia, 2015). The Western Australian Museum deemed it to be widespread, and Phoenix considered that it was unlikely for *Beierolpium* sp. '8/2' to be a SRE (Phoenix, 2010a).

Given the wide distribution of habitat that currently exists across the Fortescue Marsh area, the increased number of specimens recorded outside of the Revised Development Envelope, and the distribution of these species based on current known collections, RHIO in August 2015 requested authorisation for the SRE habitat monitoring to cease in accordance with Condition 9-2 of MS 902, and for Condition 9 to be removed. The then OEPA authorised the cessation of SRE habitat monitoring in September 2015.

All five SRE species have now been found in widespread areas outside of the Revised Development Envelope through the numerous surveys undertaken.

4.4.3.6 Ecosystems

The Fortescue Marsh is considered a significant habitat for fauna being the community with the second largest recorded population of wetland birds in Western Australia (after Lake Gregory at Kumarina (DBCA, 2017a)). It is also a recorded locality for Night Parrot, Greater Bilby and several other threatened vertebrate fauna (DBCA, 2017a).

The Fortescue Marsh and its associated FMMAs are discussed in detail in section 4.3.3.6.2.

4.4.4 Potential Impacts

The following potential impacts on Terrestrial Fauna from the implementation of the Revised Proposal have been identified:

- Direct loss of fauna individuals through impacts resulting from ground disturbance machinery or vehicle movements;
- Direct impact on habitat resulting from clearing activities;
- Indirect impacts, including a decline in health and/or change in habitat composition, arising from:
    - dust deposition;
    - saline water disposal for dust suppression;
    - groundwater abstraction or re-injection;
    - alteration of surface water flows;
    - introduction and spread of weeds; and
    - altered fire regimes.
- Direct loss or injury of individual fauna due to presence of water storage facilities and trenching for burial of pipelines;
- Indirect loss of fauna as a result of increased feral cat activity, which can arise from:
    - the permanent presence of infrastructure (providing shade and water);
    - an increase in vermin prey (which accesses food waste) for feral cats; and
    - easier access to remote areas such as the mine via linear infrastructure (provides easier travel corridors);

The proposed impact of the indicative footprint of the Revised Proposal on fauna habitats and conservation significant fauna regarded as having significant environmental value and requiring protection is provided in Table 4-20.

Table 4-20: Potential Fauna Impacts in the Revised Development Envelope based on Indicative Footprint

Environmental Value and Extent in Revised Development Envelope(ha)	Level of significance	Cause	Revised Proposal Direct Impact (ha)		Revised Proposal Indirect Impact (ha)		Revised Proposal Impact Total	
			Ha	%*	Ha	%*	Ha	%*
Fauna Species								
Fauna individuals (all species)	N/A	Direct loss of fauna individuals through impacts resulting from ground disturbance machinery or vehicle movements	See section 4.4.5.1					
Habitat								
Spinifex Sandplain 9,793.76	A moderately uncommon habitat in the Pilbara region providing denning and foraging habitat for: Greater Bilby Spectacled Hare-wallaby Brush-tailed Mulgara Habitat occurs to the south of Fortescue River, in the Remote MAR and Southern Borefields	Direct impact on Spinifex Sandplain habitat resulting from clearing activities	324.51	3.31	N/A	N/A	546.11	5.58
		Indirect impact on Spinifex Sandplain habitat resulting from alteration of groundwater quality and water table depths from groundwater abstraction or re-injection	N/A	N/A	221.60	2.26		
Mulga Woodland 47,980.2	A common habitat throughout the Fortescue and Hamersley subregion providing denning and foraging habitat for: Greater Bilby Lakeland Downs Mouse Habitat occurs within the Mine area, and Southern Borefield with pockets in the Remote MAR Borefield	Direct impact on Mulga Woodland habitat resulting from clearing activities	7,669.86	15.99	N/A	N/A	12,463.24	28.69
		Indirect impact on Mulga Woodland habitat resulting from alteration of groundwater quality and water table depths from groundwater abstraction or re-injection	N/A	N/A	4,793.38	9.99		

Environmental Value and Extent in Revised Development Envelope(ha)	Level of significance	Cause	Revised Proposal Direct Impact (ha)		Revised Proposal Indirect Impact (ha)		Revised Proposal Impact Total	
			Ha	%*	Ha	%*	Ha	%*
Major Drainage Lines 11,548.24	Common habitat and well represented within conservation estates providing denning and foraging habitat for: Pilbara Olive Python Northern Brushtail Possum Peregrine Falcon *Anilios ganei* Grey Falcon Osprey Habitat occurs within Remote MAR Borefield and Mine area	Direct impact on Major Drainage Line habitat resulting from clearing activities	402.97	25.03	N/A	N/A	540.57	4.68
		Indirect impact on Major Drainage Line habitat resulting from alteration of groundwater quality and water table depths from groundwater abstraction or re-injection	N/A	N/A	51.68	3.74		
		Alteration of surface water flows indirectly impacting Major Drainage Line habitat	N/A	N/A	85.92	0.74		
Low Rocky Hills 454.85	Common habitat throughout the Pilbara bioregion providing habitat for: Northern Quoll Pilbara Olive Python Ghost Bat Peregrine Falcon *Anilios ganei* (blind snake) Western Pebble-mound Mouse Long-tailed Dunnart Habitat occurs in the north east of the Mine area	Direct impact on Low Rocky Hills habitat resulting from clearing activities	340.76	62.27	N/A	N/A	340.76	62.27
		Indirect impact on Low Rocky Hills habitat resulting from alteration of groundwater quality and water table depths from groundwater abstraction or re-injection	N/A	N/A	0	0		
Claypans	Within the Pilbara bioregion Claypans are most common in the	Direct impact on Claypans habitat resulting from clearing activities	8.67	7.73	N/A	N/A	8.67	7.73

Environmental Value and Extent in Revised Development Envelope(ha)	Level of significance	Cause	Revised Proposal Direct Impact (ha)		Revised Proposal Indirect Impact (ha)		Revised Proposal Impact Total	
			Ha	%*	Ha	%*	Ha	%*
112.16	area surrounding the Fortescue Marsh providing habitat for Migratory birds	Indirect impact on Claypans habitat resulting from alteration of groundwater quality and water table depths from groundwater abstraction or re-injection	N/A	N/A	0	0		
Habitat Features								
Caves	Denning habitat for Ghost Bat	Direct impact resulting from clearing activities	0	0	0	0	0	0
Water Pools / Drainage Foci	Important features within the broader landscape and a water source for fauna	Direct impact resulting from clearing activities	0	0	N/A	N/A	0	0
		Indirect impact resulting from changes in groundwater levels	N/A	N/A	0	0	0	0

* % of affected habitat within the Revised Development Envelope resulting from the Revised Proposal

4.4.5 Assessment of Impacts

The potential impacts to terrestrial fauna from general operational mining activities, the disposal of saline water for dust suppression, groundwater abstraction and re-injection (short term) and alteration of surface water flows were assessed during the impact assessment for MS 824, MS 829 and subsequent s45 and s46 applications.

The assessment in this section considers impacts from the Revised Proposal that have increased, changed or have not previously been assessed, as well as considering the cumulative impact within the Revised Development Envelope.

4.4.5.1 Fauna Individuals

4.4.5.1.1 **Impacts from ground disturbance machinery or vehicle movements**

The clearing of 5,995ha of additional areas within the Revised Development Envelope has the potential to result in fatalities to, or injury of fauna individuals. Deaths or injury of individual fauna are not expected to affect the conservation status and distribution of any fauna species.

RHIO have existing and demonstrated procedures to manage potential impacts to fauna during clearing and ground disturbance. It is not considered that the activities resulting from the Revised Proposal would result in significant additional impacts to the Original Proposal.

4.4.5.2 Fauna Habitats

4.4.5.1.1 **Spinifex Sandplain**

4.4.5.2.1.1 Clearing and ground disturbance

The clearing of up to 324.51ha of Spinifex Sandplain habitat is expected to occur as a result of development of the Remote MAR and Southern Borefields. Due to the nature of clearing occurring to develop borefields, being relatively small areas for drill pads and tracks, and with the ability to avoid identified significant fauna locations (i.e. identified Greater Bilby burrows), it is not considered that clearing or ground disturbance would have significant impacts to any species of conservation significance in this habitat.

4.4.5.2.1.2 Alteration of water table depths

The impacts of the LOM WMS in the Remote MAR and Southern Borefields are discussed in Section 4.6.5.2.2 and 4.6.5.3.2. Water abstraction from the Southern Borefield is not expected to differ to that assessed in the Original Proposal. As a result of MAR:

- the depth to water table in the Remote MAR Borefield will be managed to remain below 5mbgl and in the Southern Borefield will be managed to remain below 10mbgl GHD (2018);
- groundwater mounding is expected to be less than 2m which is close to seasonal variations; and
- re-injection water will be similar or lower salinity than the existing groundwater.

Therefore, impacts to fauna species, resulting from impacts to the Spinifex Sandplains Habitat due to variations in groundwater levels or quality from MAR above those experienced due to seasonal variations are considered unlikely.

4.4.5.2.2 Mulga Woodland

4.4.5.2.2.1 Clearing and ground disturbance

Mulga habitat clearing may impact on Greater Bilby and Lakeland Downs Mouse. However, this is generally not considered the usual habitat for Greater Bilby. Due to the common occurrence of this habitat within the region it is not considered that the clearing of up to 7,669.86ha would impact on the conservation significance of these species.

4.4.5.2.2.2 Alteration of groundwater quality and water table depths

The impacts of LOM WMS on Mulga Woodland vegetation unit in the Revised Development Envelope is provided in section 4.3.5.2. Based on the risk assessment conducted by Astron (2019) it is unlikely the variations in groundwater levels or quality will impact mulga communities, and therefore the Mulga Woodland habitat within the Revised Development Envelope.

4.4.5.2.2 Major Drainage Lines

4.4.5.2.3.1 Clearing and ground disturbance

Clearing of Major Drainage Lines habitat including the Fortescue River and feeder streams may impact Pilbara Olive Python, Northern Brushtail Possum, Peregrine Falcon, *Anilios ganei*, Grey Falcon and Osprey. The Northern Brushtail Possum preferers Eucalypts with large hollows as nesting sites. Where these occur in the Remote MAR Borefield disturbance area, large trees will be avoided where possible, with clearing diverted around the trees. Although clearing may impact on fauna individuals, due to the widespread nature of the habitat outside the Revised Development Envelope it is unlikely that clearing in Major Drainage Lines habitat will impact the conservation significance of any of these species.

4.4.5.2.3.2 Alteration of groundwater quality and water table depths

The impacts of LOM WMS on Riparian Vegetation in the Revised Development Envelope is provided in section 4.3.5.3. Based on the risk assessment conducted by Astron (2019), there is a low to medium risk of some areas of Major Drainage Line habitat being impacted by the LOM WMS. Considering the small extent of these potential impacts, and the management and mitigation measures proposed, it is unlikely the variations in groundwater levels or quality will affect the Major Drainage Line habitat within the Revised Development Envelope.

4.4.5.2.2 Low Rocky Hills

4.4.5.2.4.1 Clearing and ground disturbance

Although it is expected that up to 75% of the Low Rocky Hills habitat within the Revised Development Envelope may be impacted, this area was previously assessed and approved for clearing under the Original Proposal. The Low Rocky Hills habitat is common throughout the Pilbara Bioregion, and occurs outside of the Revised Development Envelope. The area of this habitat within the Revised Development Envelope has few deep cracks or crevices and few large boulder piles that are considered suitable for denning for species such as Northern Quoll (Biologic, 2018).

It is therefore considered that there will be no significant impact to this habitat resulting from clearing and ground disturbance associated with the Revised Proposal.

4.4.5.2.4.2 Alteration of groundwater quality and water table depths

The Low Rocky Hills habitat will not be impacted from alteration of groundwater quality and water table depths.

4.4.5.2.5 **Claypans**

4.4.5.2.5.1 Clearing and ground disturbance

Claypan habitat areas are dotted within the Remote MAR Borefield. Due to the inherent flexibility in the location of bore pads and tracks and resultant bores, pipelines and roads in the Remote MAR Borefield, the Clayplan habitat areas will be avoided, where possible.

4.4.5.2.5.2 Alteration of groundwater quality and water table depths

In the Remote MAR Borefield groundwater mounding will be maintained to be <5mbgl and therefore not impact on claypan habitat. Re-injected water will be similar or lower salinity than the existing groundwater. It is therefore considered that impacts to Claypans habitat due to variations in groundwater levels or quality resulting from the LOM WMS are considered unlikely.

4.4.5.3 Fauna Habitat Features

4.4.5.2.5 **Caves**

Although it is located within the Revised Development Envelope, the significant habitat feature (cave) is located outside of the proposed disturbance footprint. RHIO will commit to not impacting this cave as part of the Revised Proposal.

4.4.5.2.5 **Water Pools / Drainage foci**

Water management is not expected to result in a change to the water availability to any semi-permanent pools or drainage foci. No semi-permanent pools or drainage foci will be impacted directly via clearing or ground disturbance.

4.4.5.4 Fauna of Conservation Significance

Based on the proposed impacts to habitats, it is expected that the Revised Proposal may impact individuals of fauna of conservation significance, and affect minor areas of habitat for some species, however will not have a significant impact to species of conservation significance or their habitats.

The ground disturbance footprint in the Remote MAR and Southern Borefield areas can be adjusted to preserve identified burrows or nests of fauna of conservation significance, or preferred species habitat areas, where appropriate.

4.4.6 Mitigation Measures

The objective of the mitigation measure is to reduce the impact to Terrestrial Fauna within the Revised Development Envelope resulting from the implementation of the Revised Proposal. Mitigation measures for Terrestrial Fauna are outlined in Table 4-21.

RHIO has applied the mitigation hierarchy to reduce the potential impacts to significant terrestrial fauna located within the Revised Development Envelope. An overarching Fauna Management Plan will be developed to reduce potential impacts to significant terrestrial fauna, which will incorporate the mitigation hierarchy of Avoid, Minimise and Rehabilitate.

Table 4-21: Terrestrial Fauna Mitigation and Management Measures

Activity	Potential Impact	Type	Mitigation Measure
Clearing and ground disturbance	Direct loss of fauna individuals	Avoid	Utilise areas of existing disturbance before clearing of new ground where possible
		Minimise	Implement programs for induction and education of the workforce with respect to fauna protection and management
			Minimise the clearing disturbance footprint during the mine planning and design phase, sufficient to enable safe construction and operation of the mining operation
	Direct loss of conservation significant fauna individuals	Avoid	Utilise areas of existing disturbance before clearing of new ground where possible
			Avoid disturbance to the cave habitat feature
			Borefield pipeline route and bore locations to be sited to avoid Priority fauna locations where possible (Targeted fauna surveys of pipeline and borefield route will be used to identify and avoid locations of priority fauna where possible)
		Minimise	Conduct trapping and translocation where conservation significant species (northern quoll and bilby) have been identified as occurring within the areas to be cleared in borefield and borefield pipeline route if the habitat area cannot be avoided
			Implement the RHIO Ground Disturbance Permit system
			Implement programs for induction and education of the workforce with respect to fauna protection and management
			Locate infrastructure and transport routes to preferentially avoid areas of importance to significant species
			Incorporate fauna crossing areas within linear infrastructure to ensure Potentially Significant Fauna Habitat is not segregated
			Implement traffic management to reduce speed limits in areas where known Greater Bilby burrows are located close to, or near to, mine site roads
		Monitor	Record any injury or death to fauna as an incident
	Direct loss of habitat for species of conservation significance	Avoid	Utilise areas of existing disturbance before clearing of new ground where possible
			Manage all disturbance using the RHIO Ground Disturbance Permit system to avoid unauthorised clearing
			Avoid disturbance to the cave habitat feature
			Avoid disturbance to semi-permanent water bodies
			Avoid disturbance to claypan habitat features, where possible, in borefield areas
		Minimise	Implement the RHIO Ground Disturbance Permit system

Activity	Potential Impact	Type	Mitigation Measure
			Implement programs for induction and education of the workforce with respect to fauna protection and management
			Minimise the clearing disturbance footprint during the mine planning and design phase, sufficient to enable safe construction and operation of the mining operation
			Locate infrastructure and transport routes to preferentially avoid areas of importance to significant species
		Rehabilitate	Rehabilitate land as soon as possible after completion of activities to meet closure criteria in accordance with RHIO Mine Closure Plan (prepared in accordance with the DMIRS Guidelines for Preparing Mine Closure Plans) and approved by DMIRS
Groundwater mounding and changes to groundwater quality resulting from managed aquifer recharge	Groundwater mounding resulting in waterlogging and / or increase in salinity of groundwater resulting a decline in health or loss of fauna habitat	Monitor	As per mitigation measures for Flora and Vegetation (Table 4-14)
Groundwater drawdown resulting from dewatering or abstraction	Groundwater drawdown resulting in a decline in health or loss of fauna habitat	Monitor	As per mitigation measures for Flora and Vegetation (Table 4-14)
Construction and operation of Surface water diversions	Loss or degradation of fauna habitat as a result of altered hydrological regimes	Avoid	Semi-permanent pools and claypan habitat features will not be impacted by surface water diversions
		Minimise	A 500m buffer zone is implemented inside the western boundary of tenement M46/518 to minimise shadow effects to Mulga vegetation beyond the boundary of the project area
			Surface water management structures have been designed to maintain natural patterns of surface water flows downstream of mine pits where possible
			No more than 85.92ha of riparian vegetation will be indirectly impacted by permanent creek diversions
		Monitor	As per mitigation measures for Flora and Vegetation (Table 4-14)
Saline and decant water disposal	Indirect impacts, including a decline in health and/or change in habitat composition, from saline water disposal		As per mitigation measures for Flora and Vegetation (Table 4-14)

Activity	Potential Impact	Type	Mitigation Measure
Trenching for burial of pipework associated with Remote MAR Borefield and Southern Borefield	Loss or injury to fauna individuals	Minimise	Implement the requirements of the existing 'Fauna Management Procedure' (OP-PRO-00134) which incorporates the following management measures: • Check open trenches for the presence of trapped fauna at least twice a day; no later than 3.5 hours after sunrise, between the hours of 3:00pm and 6:00pm and no more than one hour prior to backfilling trenches • Report any trapped fauna to licenced fauna-rescue personnel as soon as the fauna are found to enable prompt rescue and relocation • Ensure that only licenced fauna-rescue personnel clear trenches of trapped fauna and entrapped fauna are released at a suitable location nearby to where they were trapped but far enough away to prevent re-entrapment • Ensure that open trenches (e.g. for mine borefield water supply pipeline) do not exceed a length of 2.5km at any one time • Construct open excavations / trenches with a permanent means of fauna egress (e.g. ramps) and refuges (e.g. shade cloth shelter covers) at intervals not exceeding 50m • Cap pipe ends prior to and during pipe-laying works to prevent fauna entrapment • Cover, fence or bund open excavations, wherever practicable, to prevent injury to fauna Pump out pooled water in open trenches and discharge to adjacent vegetated areas via mesh (or similar) that dissipates flow energy which could cause erosion

4.4.7 Predicted Outcomes

When the mitigation measures have been implemented, it is expected that the Revised Proposal will result in the following residual impacts and outcomes in relation to Terrestrial Fauna:

- No more than an additional 5,995ha will be directly impacted by the Revised Proposal. The habitat types are well represented in the region and impacts to habitats are unlikely to result in a significant reduction in, or impact to, conservation significant species.
- Clearing limited to no more than 324.51ha within the Spinifex Sandplain habitat of 9,793.76ha within the Revised Development Envelope. The habitat is well represented in the region.
- Clearing limited to no more than 7,669.86ha within the Mulga Woodland habitat of 47,980.22ha within the Revised Development Envelope. The habitat is well represented in the region.
- Clearing limited to no more than 402.97ha within the Major Drainage Line habitat of 1,548.24ha within the Revised Development Envelope. The habitat is well represented in the region.
- Clearing limited to no more than 340.76ha within the Low Rocky Hills habitat of 454.85ha within the Revised Development Envelope. The habitat is well represented in the region.
- Clearing limited to no more than 8.67ha within the Claypan habitat of 112.16ha within the Revised Development Envelope. The habitat is well represented in the region.
- Clearing of habitat minimised to that which is required for operational activities.
- Areas that have been cleared are rehabilitated in accordance with the DMIRS approved Mine Closure Plan once operational activities have been ceased.
- No measurable reduction in the populations of conservation significant fauna.
- Minimal direct loss or injury of individual fauna due to operational activities.

Due to the wide distribution of SRE habitat that currently exists across the Fortescue Marsh area outside of the Revised Development Envelope, it is not considered that the additional clearing required for the proposal would have significant impact to Short Range Endemic Species. Clearing for the Remote MAR Borefield and Southern Borefield is not expected to have impacts to SRE species. Habitats in these areas are widespread and the clearing associated with bore pads, pipelines and tracks is not expected to impact any locally restricted habitats which provide the processes promoting short-range endemism.

It is expected that the EPA's Management Objective for Terrestrial Fauna will be achieved as it is not expected that the abundance, diversity, geographic distribution or productivity of any terrestrial fauna species will be significantly impacted by the activities of the Revised Proposal.

4.5 Key Environmental Factor – Subterranean Fauna

4.5.1 EPA Objective

The EPA's environmental objective for the factor *Subterranean Fauna* is "To protect subterranean fauna so that biological diversity and ecological integrity are maintained".

4.5.2 Policy and Guidance

The relevant policy and guidance for Subterranean Fauna is summarised in Table 4-22.

Table 4-22: Inland Water Environmental Quality Policy and Guidance

Author	Title	Year of Publication
EPA	Environmental Factor Guideline – Subterranean Fauna	2016
EPA	Technical Guidance - Subterranean Fauna Survey	2016
EPA	Technical Guidance - Sampling Methods for Subterranean Fauna	2016

4.5.3 Receiving Environment

4.5.3.1 Studies and Investigations

Baseline surveys and studies were undertaken in 2009 within and adjacent to the Revised Development Envelope to inform the Original Proposal. Additional work was conducted in 2018 to evaluate the potential impacts of the LOM WMS. Surveys conducted are listed in Table 4-23. Investigations which are proposed to further inform the Revised Proposal are listed in Table 4-24. RHIO will complete these surveys prior to works commencing.

Table 4-23 Completed Baseline Subterranean Fauna Surveys and Studies

Consultant	Title	Description	Guidance/Methodology*
SMEC, 2009	Roy Hill Iron Ore: Subterranean Fauna Assessment September 2009	Targeted surveys for stygofauna and troglofauna were undertaken and comprised of leaf letter traps for troglofauna and modified plankton nets for stygofauna. Three phases of sampling were undertaken in March-May 2008, August-October 2009 and March-April 2009	EPA's Draft Technical Appendix No. 54a (EPA, 2007).
SMEC, 2009a	Roy Hill Iron Ore: Subterranean Fauna Assessment Stage 2 Addendum October 2009	Assesses potential impacts to subterranean fauna from Stage 2 mine dewatering	EPA (2007) Sampling methods and survey considerations for subterranean fauna in Western Australia Technical Appendix No. 54a

Consultant	Title	Description	Guidance/Methodology*
Bennelongia, 2009	Roy Hill Remote Borefield Stygofauna Assessment 2009	Targeted surveys for stygofauna were undertaken for the Remote Borefield. Field surveys comprised utilised weighted plankton nets and sampling was conducted in July and September 2009	EPA (2007) Sampling methods and survey considerations for subterranean fauna in Western Australia (Technical Appendix to Guidance Statement No. 54). Guidance Statement 54A. and outlined in Eberhard *et al*. (2005b) Assessment and conservation of aquatic life in the subsurface of the Pilbara region, Western Australia. In: *World Subterranean Biodiversity.*
Bennelongia (2018)	Managed Aquifer Recharge and Stage 2 Borefield Subterranean Fauna Desktop Assessment, July 2018	Desktop evaluation on the potential impacts of MAR on subterranean fauna species	

*EPA guidelines were updated December 2016

Table 4-24 Proposed Subterranean Fauna Surveys and Studies

Proposed Survey	Dependencies
Troglofauna survey of SWIB	Water modelling conducted by GHD (2018) indicate potential groundwater mounding and salinisation in the SWIB. RHIO is proposing to complete a troglofauna survey of the SWIB due to expected groundwater mounding and the presence of suitable habitat for troglofauna

4.5.3.2 Environmental Values

The two commonly recognized groups of subterranean fauna, being stygofauna and troglofauna are differentiated according to whether they live above (troglofauna) or below (stygofauna) the water table. Troglofauna live deeper below the surface than the soil invertebrates that are encountered when digging shallow holes.

A review of impacts of mining and mine dewatering on subterranean fauna was conducted during the initial referral of the Original Proposal (RHIO, 2009 and Environ Australia Pty Ltd, 2009). EPA (2009 and 2009a) considered that the mine project, mine dewatering and borefield abstraction would be unlikely to significantly affect subterranean fauna.

Subterranean fauna assessments were originally undertaken across the Mine area and surrounding areas (SMEC, 2009 and 2009a). The most abundant, diverse and potentially significant specimens from stygofauna surveys were located outside the Mine area and it was therefore concluded that no significant impacts to stygofauna were expected as a result of implementation of the Original Proposal (SMEC, 2009). Habitat assessments suggested that specimens recorded were not expected to be restricted to the project area due to the connectivity between aquifers and the presence of similar geology and hydrogeology to that occurring throughout the Fortescue region.

A stygofauna assessment was conducted in the Southern Borefield (Bennelongia, 2009) to support the referral of the Original Proposal, which comprised of water abstraction for use in mining activities from the Southern Borefield. At least 11 species of stygofauna were collected from within the Southern Borefield area that was subject to drawdown of >1m. All of these species were known to have ranges extending well beyond the Southern Borefield area.

Sampling efforts for stygofauna in the wider regional area, in geological units contiguous with that of the RHIO mine, has been substantial, with at least 68 species of stygofauna being recorded. These sampling results are considered indicative of the potential suite of stygofauna in the Revised Development Envelope (Bennelongia, 2018). A total of 22 species of stygofauna have been found within the Revised Development Envelope, with all the recorded species known to occur outside the Revised Development Envelope (Bennelongia, 2018).

Three phases of troglofauna sampling indicated that the environmental conditions and geology of the immediate vicinity of the Mine are unlikely to support troglobitic communities; therefore, no significant impacts were considered likely to occur from the development of the Original Proposal. This was reflected by the fact that no true troglofauna specimens were collected during sampling at the Mine (SMEC, 2009). Troglofauna were not sampled in the Southern Borefield for the Original Proposal as the likely impacts of groundwater drawdown on troglofauna species in the Southern Borefield were considered to be negligible (Bennelongia, 2009).

To further clarify the occurrence of subterranean fauna, previous records in a 100km x 100km search area surrounding the Revised Development Envelope were reviewed by Bennelongia (2018). The search included many areas that are geologically and hydrologically analogous to, or in some cases such as the Chichester Hub, contiguous with the Revised Development Envelope. At least 119 stygofauna species have been collected in the search area. A moderate number of stygofauna species has previously been recorded in RHIO tenements. At Christmas Creek, an area with comparable/contiguous geology to the Revised Proposal, substantial sampling effort has revealed a diverse stygofauna community (Bennelongia, 2018).

At least 66 species of troglofauna have been recorded in the search area. Two species, a cockroach and an isopod, have been recorded in stygofauna samples in RHIO tenements. At Kutayi to the east-northeast of the Revised Development Envelope, 14 species have been recorded from mineralised iron formations including the Marra Mamba Formation (MMF), while 29 species have been recorded from Christmas Creek. Although a number of species have been recorded through numerous surveys within areas of analogous geology and hydrogeology, it is considered unlikely that previous surveys have recorded all subterranean fauna species that occur in the Revised Development Envelope (Bennelongia, 2018).

4.5.4 Potential Impacts

The following potential impacts to Subterranean Fauna from the implementation of the Revised Proposal have been identified:

- Direct loss of stygofauna through:
  - removal of habitat as a result of dewatering during operations; and
  - changes in salinity of the existing groundwater aquifers as a result of MAR.
- Direct loss of troglofauna habitat via flooding due to rising groundwater levels resulting from MAR.

Dewatering of mine pits, and water abstraction from the Mine area and Southern Borefield were assessed in the Original Proposal. The additional 28GL/a of dewatering proposed as part of this Revised Proposal is considered to not result in additional significant impacts to stygofauna. The additional dewatering will result in a slightly larger drawdown footprint than outlined in the Original Proposal (see section 4.6.3.5.1), however the Revised Proposal will maintain the drawdown for a longer period of time.

The Original Proposal incorporated impacts on subterranean fauna species due to direct loss of habitat via excavation from mine pits and indirect loss due to groundwater drawdown and potential uprising of saline water within the Mine area and Southern Borefield. The Revised Proposal does not change the extent of pit footprint to that previously approved.

The Revised Proposal has the potential to indirectly impact on subterranean fauna species through additional activity of MAR (Remote MAR Borefield, Southern Borefield and SWIB) as well as the increase in abstraction/dewatering to that assessed under the Original Proposal (Table 4-25).

Table 4-25: Summary of Activities and Locations with Potential Subterranean Fauna Impact

Location	Activity	Environmental Value potentially impacted	Level of Habitat Significance	Revised Proposal Potential Impact
Mine	Mining Pits Dewatering	N/A - Assessed in Original Proposal		
Mine Borefield	In- Pit Tailing and disposal of excess water in mine voids	Mine pits and dewatering assessed in Original Proposal		
Stage 1 Borefield	Mining Pits Dewatering Re-injection	N/A - Assessed in Original Proposal MAR activities in the Stage 1 borefield will not have additional impacts to those already assessed through pit and borefield development		
SWIB	Re-injection resulting in habitat loss due to rising water levels	Troglofauna	Low - Alluvials provide moderately prospective habitat	Water level rise results in a localised loss of habitat however the habitat is not restricted to the SWIB impact area
	Re-injection resulting in changes to salinity of aquifer	Stygofauna	High - Alluvial and detrital hydrogeological units provide potentially highly prospective habitat	Negligible loss of habitat due to reinjected water being of similar or lower TDS to background levels
Remote MAR Borefield	Re-injection resulting in habitat loss due to rising water levels	Troglofauna	Moderate - Calcrete and surficial alluvium provide moderately prospective habitat	Based on preliminary modelling, water level rise is not expected to cause a significant loss of habitat
	Re-injection resulting in changes to salinity of aquifer	Stygofauna	High - Alluvials and Detritals and Weathered Wittenoom hydrogeological units provide potentially highly prospective habitat	Negligible loss of habitat due to re-injected water being of similar or lower TDS to background levels
Southern Borefield	Groundwater abstraction	N/A - Assessed in Original Proposal		
	Re-injection resulting in habitat loss due to rising water levels	Troglofauna	Moderate - Calcrete and surficial alluvium provide moderately prospective habitat	Water level rise is expected to remain less than 5m therefore resulting in negligible loss of habitat

Location	Activity	Environmental Value potentially impacted	Level of Habitat Significance	Revised Proposal Potential Impact
	Re-injection resulting in changes to salinity of aquifer	Stygofauna	High - Weathered Wittenoom hydrogeological unit provides highly prospective habitat	Negligible loss of habitat due to re-injected water being of similar or lower TDS to background levels

4.5.5 Assessment of Impacts

A recent review of the LOM WMS included an update to the groundwater impact assessment (GHD, 2018). Modelling of LOM WMS groundwater change suggests that, under the worst-case scenario, the impacts are predicted to be:

- For stygofauna:
  - the changes in salinity levels are expected to be minor at the SWIB, Remote MAR Borefield and Southern Borefield; and
  - increased timeframe of water drawdown in the Mine area is not expected to change the level of impact to stygofauna.
- For troglofauna:
  - the increase in water levels suggested in the preliminary modelling, at the SWIB is expected to result in only minor loss of habitat when compared with the total potential habitat available in the region; and
  - water level rise in the Remote MAR Borefield and Southern Borefield results in negligible habitat loss at these locations.

Impacts on troglofauna in the Mine area will not change to that assessed in the Original Proposal.

4.5.5.1 Stygofauna

Bennelongia (2018) completed a desktop assessment of the potential impact of MAR to dispose of excess water, on subterranean fauna that may occur in the area of groundwater influence (Appendix 12). This desktop assessment focussed on the re-injection proposed in the SWIB, Stage 1 Borefield, Remote MAR Borefield and Southern Borefield with disposal water to be injected at depth into the MMF.

The assessment outlined that the most prospective hydrogeological units for stygofauna in proposed MAR areas are (Figure 41):

- Alluvials – potentially highly prospective depending on local transmissivity. Salinity levels are suitable for stygofauna throughout this unit. This unit potentially provides highly prospective habitat in the SWIB and Stage 1 Borefield.
- Detritals – potentially highly prospective depending on local transmissivity and groundwater salinity. Calcrete deposits in this unit may provide highly prospective habitat. This unit potentially provides highly prospective habitat in the SWIB, Stage 1 Borefield and the Southern Borefield.
- Hard cap and Semi-Hard cap (Nammuldi Member) in the MMF – especially areas with well-developed vughs and cavities but also, depending on groundwater salinities and depth, deeper, more saline MMF units may provide habitat for a reduced suite of stygofauna. This unit potentially provides highly prospective habitat in the SWIB and Stage 1 Borefield.

- Weathered Wittenoom – a widespread, relatively transmissive brackish aquifer comprising weathered and karstic dolomite over depths of 10–35m potentially provides highly prospective habitat in the Southern Borefield and Remote MAR Borefield.

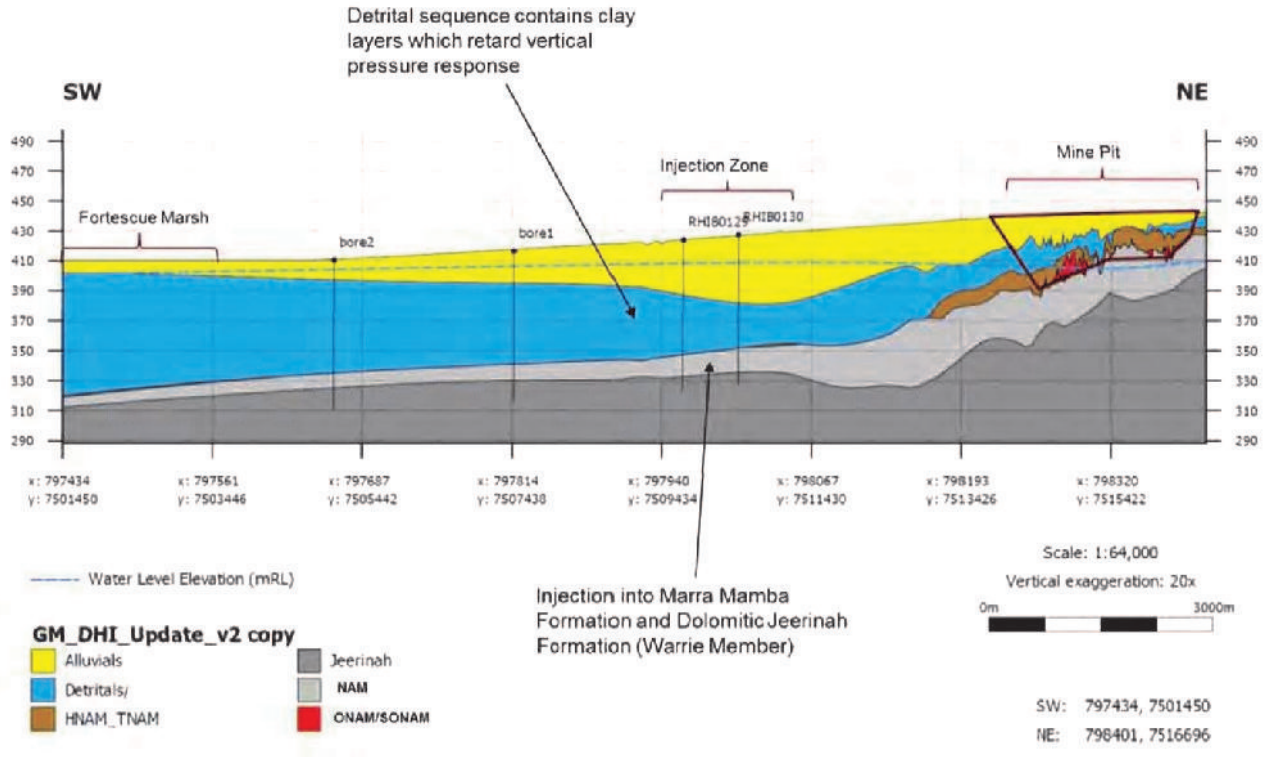

Figure 41: Geological units of prospective stygofauna habitat in the project area and beyond

Injection water is generally less saline than receiving aquifers and RHIO predicts that vertical mixing will not occur (Roy Hill, 2018). MAR water quality parameters are provided in Table 4-26, against background water quality data. Salinisation of existing groundwater aquifers (including potential stygofauna habitat) could occur if reinjected disposal water is more saline than background levels. The impact of salinisation would be greatest in the immediate vicinity of the injection location and would attenuate over distance and time through dilution.

Table 4-26: Water quality parameters for disposal water in the MAR system and background conditions

Parameter	SWIB	Mine Borefield	Stage 1 Borefield	Remote MAR Borefield	Southern Borefield
Total Dissolved Solids (TDS, mg/l)					
Background	>100,000	<3,000	<3,000	50,000-100,000	960–96,000
Disposal water	50,000	<5,000	<5,000	50,000	<5,000
Conductivity (EC, µS/cm)					
Background	>156,00	>4,000	4,690	1,500–150,000	1700-5650
Disposal water	46,900	7,810	7,810	46,900	7,810

As stated in the hydrogeological assessment for MAR (Roy Hill, 2018) disposal water to be injected into the MMF in the SWIB is less saline than the deep receiving aquifer, which is hypersaline. Modelling outlined by Roy Hill (2018) predicts that as the vertical pressure gradient increases, injection water will migrate vertically within the zone of re-injection. Injection water is not expected to mix vertically through the full stratigraphic column owing to presence of confining layers and the difference in water density in shallower alluvial aquifers (Roy Hill, 2018). Therefore, salinity is not expected to increase in the vicinity of the SWIB as a result of MAR.

Background salinities in the Remote MAR Borefield are variable with salinity appearing to increase east-to-west (Managed Recharge, 2018). Two bores in the west and north western portion of the Remote MAR Borefield have salinities of 140,000–150,000µS/cm and the areas around these have been identified as potentially suitable for saline re-injection (Managed Recharge, 2018). Background salinities throughout the Southern Borefield are brackish (<10,000mg/L) and this area has been deemed suitable for brackish re-injection (Managed Recharge, 2018).

For stygofauna, species-specific salinity tolerances are unknown but are likely to reflect natural environmental conditions. Salinisation as a result of MAR is not expected to occur due to the similar water qualities being reinjected to that of background water quality, therefore impacts to stygofauna are not expected to be significant. The connectivity of groundwater extending outside the Revised Development Envelope would allow for stygofauna dispersal between the project and other areas. Local geology suggests there are unlikely to be barriers to stygofauna migration. Additionally, the potential reduction in stygofauna habitat within the Revised Development Envelope is minor and almost negligible if the wider areas outside of the Revised Development Envelope are considered.

All geological units within the borefield areas cover larger areas than the likely zones of influence and suggest that species in these habitats may have ranges larger than potential impacts. Figure 41 shows the geological units of moderate and highly prospective habitat in the Revised Development Envelope and how these extend outside the Revised Development Envelope.

4.5.5.2 Troglofauna

Additional disturbance proposed within the Mine area is for above ground infrastructure which is not expected to impact troglofauna.

The primary threat to troglofauna from the MAR programme is the potential for habitat loss via flooding. Some degree of troglofauna habitat loss is likely to occur in MAR areas (SWIB, Remote MAR Borefield and Southern Borefield) following re-injection at depth and an increase in vertical pressure.

The same geological units identified as prospective for stygofauna, where they occur above the water table, may be prospective for troglofauna. Depth to groundwater is spatially variable and generally decreases towards the Fortescue Marsh, so that prospectivity for troglofauna decreases with proximity to the Fortescue Marsh.

4.5.5.2.1 **SWIB**

Depth to groundwater across the SWIB ranges approximately 5–20mbgl from the south-west to the north-east. Prospectivity for troglofauna in the SWIB is considered moderate, with potential habitat occurring entirely in upper alluvials, whose prospectivity will depend on local transmissivity. Nevertheless, previous sampling conducted at the SWIB and surrounding areas found no species of troglofauna (SMEC, 2009a).

Injection in SWIB is predicted to form a groundwater mound in an area of up to 10km long and 6km wide. The mound will be noticable in monitoring bores during mining but will disappear after closure and will be absorbed by the drawdown area of dewatering before it rebounds completely. Injection of groundwater in the SWIB will be carefully managed to keep water levels >5mbgl, however groundwater rises of between 5 and 10m are likley. Outside the immediate vicinity of the MAR area (but within the zone of influence) the water table will generally be more than 10mbgl.

It is clear that MAR will result in some loss of potential troglofauna habitat in the vicinity of the SWIB, although no true troglofauna species have been found to date. Considering the extent and connectivity of alluvial habitat throughout the Fortescue Valley, species occuring in alluvials within the Revised Proposal impact area could reasonably be expected to have moderately large distributions relative to the extent of proposed impacts. However, a net increase in groundwater levels is likely to result in loss of potential troglofauna habitat in the vicinity of the SWIB that may possibly affect some troglofauna species.

4.5.5.2.1 **Stage 1 Borefield and Mine Borefield**

The Stage 1 Borefield occurs in an area already approved in the Original Proposal for mine pits. Mining is expected to commence in this area around 2023. At the time of mining, this area will be dewatered as required to ensure dry mining can occur consistent with the Original Proposal. It is expected that re-injection into the Stage 1 Mine Borefield will occur up until commencement of mining.

Re-injection into mined out areas within the larger Mine Borefield may be utilised as suitable opportunities arise. As these areas have previously been dewatered and mined, and the re-injection will offset the dewatering footprint, additional impacts to troglofauna area not expected to occur as a result of the Revised Proposal.

4.5.5.2.3 Remote MAR Borefield and Southern Borefield

In the Remote MAR Borefield, the water table is variable and sits 5-10mbgl with depth decreasing toward the Fortescue Marsh (GHD, 2018). Thus, there is limited habitat for troglofauna. In the Southern Borefield, the water table is variable and sits at approximately 11–30mbgl. Weathered and karstic dolomite of the Weathered Wittenoom Formation occurs below this level and is therefore not prospective for troglofauna. Water level change in the Remote MAR Borefield and Southern Borefield is expected to be minor (generally less than 2m). There may be small areas at the western end of the Remote MAR Borefield and southern end of the Southern Borefield where water levels change more than 2m, however the depth to groundwater in these areas remains >5mbgl (GHD, 2018).

Habitat prospectivity for troglofauna in the Remote MAR Borefield and Southern Borefield is considered moderate and is predominantly within alluvials and calcrete above the water table. Mapped surficial geology suggests that these units are moderately extensive and there is the potential for habitat connectivity, so the effect of minor fluctuations in groundwater levels on troglofauna species in the Remote MAR Borefield and Southern Borefield is expected to be minimal. In addition, impacts may be mitigated by the spatial extent of habitat and associated species ranges.

All geological units within Borefield areas cover larger areas than the likely zones of influence and species in these habitats are likely to have ranges larger than potential impact area.

4.5.6 Mitigation Measures

The objective of the mitigation measures is to minimise the impact to Subterranean Fauna resulting from implementation of the Revised Proposal. Subterranean Fauna mitigation measures are outlined in Table 4-27.

Table 4-27 Subterranean Fauna Mitigation and Management Measures

Activity	Potential Impact	Type	Mitigation Measure
MAR	Groundwater mounding resulting in reduced habitat for troglofauna	Minimise	Potential impacts to subterranean fauna will be managed via the LOM WMS
		Monitor	Targeted Troglofauna survey to occur in the SWIB re-injection borefield
		Monitor	Should significant subterranean fauna species be identified, further sampling will be conducted outside of the impact area to confirm the identified species is not confined to the impact area
		Monitor	Water level monitoring will occur to determine the extent of groundwater mounding
	Changes to groundwater quality resulting in	Minimise	Potential impacts to subterranean fauna will be managed via the Water Management Plan
		Minimise	Water quality reinjected into each borefield will be consistent with the background water quality of the area

Activity	Potential Impact	Type	Mitigation Measure
	alteration of habitat for stygofauna	Monitor	Water quality monitoring will occur to ensure that water reinjected within each area remains within the quality range of background water quality.
Dewatering of mine pits / abstraction of groundwater for operational purposes	Groundwater drawdown resulting in reduced stygofauna habitat.	Minimise	Potential impacts to subterranean fauna will be managed via the LOM WMS
		Minimise	Dewatering to only occur in areas where required to maintain dry mining or ground conditions
		Monitor	Water level monitoring will occur to determine the extent of groundwater drawdown.
Mine pit excavation	Direct loss of troglofauna habitat from ground disturbance activities	Avoid	No additional pits will be developed, other than those already approved under the Original Proposal. Additional disturbance proposed within the mine area is for above ground infrastructure.

4.5.7 Predicted Outcome

Overall, under the current modelled outcomes of the MAR, for the SWIB, Stage 1 Borefield, Remote MAR Borefield and Southern Borefield areas, habitat loss through either change in groundwater levels or salinisation is not considered a significant threat to stygofauna or troglofauna species that may occur in and around the Revised Proposal area (Bennelongia, 2018).

The potential loss of habitat and individuals resulting from the Revised Proposal will not significantly affect stygofauna and troglofauna as the distribution of the habitat is considerably larger than the potential impact area.

It is expected that the EPA's Management Objective for Subterranean Fauna will be achieved as it is not expected that the abundance, diversity, geographic distribution or productivity of any subterranean fauna species will be significantly impacted by the activities of the Revised Proposal.

4.6 Key Environmental Factor – Inland Waters

4.6.1 EPA Objective

The EPA's environmental objective for the factor *Inland Waters* is "To maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected"

4.6.2 Policy and Guidance

The relevant policy and guidance for Inland Waters is summarised in Table 4-28.

Table 4-28: Inland Water Environmental Quality Policy and Guidance

Author	Title	Year of Publication
EPA	Environmental Factor Guideline – Inland Waters	2018
EPA	Environmental and Water assessments relating to mining and mining related activities in the Fortescue Marsh	2013
DoW	*Western Australian Water in Mining Guideline*	2013
DoW	*Pilbara - Regional Water Plan 2010 - 2030*	2010
ANZECC/ARMCANZ	*National Water Quality Management Strategy*	2000
State Government	*State Water Quality Management Strategy*	2001

4.6.3 Receiving Environment

4.6.3.1 Surveys and Investigations

Baseline surveys and studies were undertaken within and adjacent to the Revised Development Envelope to inform the Original Proposal. Additional studies have been conducted during the implementation of the Original Proposal. These are listed in Table 4-29. In addition, water quality sampling has been undertaken within the Revised Development Envelope since 2007.

Table 4-29: Completed Baseline Inland Waters Surveys and Studies

Consultant	Title	Description	Guidance/Methodology*
MWH, 2007	Roy Hill Hydrogeological Assessment Part A 2007	The assessment comprised drilling, bore construction, test pumping and hydro chemical sampling. The program has derived baseline information on the hydrogeological characteristics of the area	Licence to Construct CAW161545
MWH, 2009	Roy Hill Stage 1 Dewatering and Water Supply Strategy 2009	Development of a numerical model of the Stage 1 area and to assessing the potential impact of groundwater abstraction for water supply and mine dewatering	Visual MODFLOW Version 4.3 (Schlumberger Water Services, 2008)
MWH, 2009a	Roy Hill Stage 2 Dewatering Strategy 2009	Review of the numerical model to include Stage 2 area and to assessing the potential impact of groundwater abstraction for water supply and mine dewatering	Visual MODFLOW Version 4.3 (Schlumberger Water Services, 2008)

Consultant	Title	Description	Guidance/Methodology*
MWH 2009b	Hydrogeological Assessment of the Roy Hill Remote Borefield. Unpublished report prepared for Hancock Prospecting Pty Ltd, October 2009.	Hydrogeological investigation of the Southern Borefield to supplement mine water supply	
Gilberts and Associates, 2009	Roy Hill Iron Ore Project Surface Water Assessment 2009	Assessment of the potential impacts from surface water diversions and mine activities. A site reconnaissance was conducted to characterise the main creek lines and catchments	
SMEC, 2009b	Roy Hill 1 Acid Mine Drainage Investigation 2009	Waste characterisation focused primarily on the metal contents of the waste materials and the potential for metalliferous drainage	Managing Acid and Metalliferous Drainage – Department of Industry and Tourism (DITR) Commonwealth of Australia February 2007 Environmental Notes on Mining – Acid Mine Drainage. Department of Industry and Resources November 2006.
MWH 2010	Roy Hill Iron Ore Mining Project - Bankable Feasibility Study. Mine site water supply, hydrology and dewatering. Unpublished report prepared for Roy Hill Iron Ore Pty Ltd, November 2010.	Bankable feasibility study covering all aspects of water management of the project.	
MWH, 2011	Roy Hill - Dewatering & Water Supply, Years 1 to 5 2011	Evaluate the dewatering requirements for a revised mine plan for the first 5 years of mining	
MWH, 2014	Roy Hill Iron Ore Mine - Dewatering Update 2014	Review of the model formulation and concepts against revised mining activities	MODFLOW NW MDBC-Groundwater Flow Modelling Guideline (2000)
GHD, 2012	Roy Hill Iron Ore: Hydrologic Investigation and Drainage Design Report. Unpublished report prepared for Roy Hill Iron Ore Pty Ltd, May 2012.	Drainage assessment and design of diversion structures for first 5 years	CatchmentSIM GIS terrain software and XP-Rafts hydrologic model
SRK Consulting, 2015	Roy Hill Review of Geochemical Database	Review of Roy Hill Geochemical Database to identify knowledge gaps and inform testing strategy	Acid Mine Drainage Test Handbook AMIRA International 2002

Consultant	Title	Description	Guidance/Methodology*
SRK Consulting, 2016	Roy Hill - Geochemical Characterisation of Waste Rock Samples, September 2016	Geochemical characterisation of waste rock to determine management of acid generation and metalliferous drainage	Acid Mine Drainage Test Handbook AMIRA International 2002
Alluvium, 2016	Roy Hill Mine – Kulbee Creek East (3A) Diversion Review. Unpublished report prepared for Roy Hill Iron Ore Pty Ltd, May 2016.		
GHD, 2017	Roy Hill Iron Ore Pty Ltd Zulu 5 Conceptual In-Pit Tailings Facility Groundwater Impact Assessment	Groundwater impact assessment of the proposed Zulu 5 In-Pit Tailings disposal facility (TSF)	
SRK, 2017	Roy Hill – Geochemical Characterisation of Iron Ore Tailings, August 2017	Geochemical characterisation of tailings.	Acid Mine Drainage Test Handbook AMIRA International 2002
Roy Hill, 2018	Hydrogeological assessment for Roy Hill Managed Aquifer Recharge system (unpublished report, January 2018)	Hydrogeological assessment for 2yr MAR proposal	Australian groundwater modelling guidelines, 2012
GHD, 2018	Roy Hill Holdings Pty Ltd Roy Hill Life of Mine Water Management Strategy – Groundwater Impact Assessment	Groundwater impact assessment for LOM WMS incorporating dewatering, abstraction and managed aquifer re-injection for remaining life of mine	Australian groundwater modelling guidelines, 2012
GHD, 2018a	Section 38 Referral, Hydraulic structures, Unpublished report prepared for Roy Hill Iron Ore, August 2018	Present a strategy for location and configuration of future hydraulic structures for mining operations and mine closure	The Leading Practice Sustainable Development Program (LPSDP) for the Mining Industry – Water Management Handbook (Department of Resources, Energy and Tourism, 2008) Guideline: Works that interfere with water in a watercourse – watercourse diversions (Department of Natural Resources and Mines, 2014) Mine site watercourse diversions – a balance of competing objectives (Markham, Atkinson, & Pearson, 2018)
SRK, 2018	Saturated leach column test work - Test Status and	Results of saturated leach columns	Acid Mine Drainage Test Handbook AMIRA International 2002

Consultant	Title	Description	Guidance/Methodology*
	Recommendations, May 2018		
SRK, 2018a	Operating of Seven AMIRA free draining columns – test status and recommendations	Results of AMIRA free draining columns	Acid Mine Drainage Test Handbook AMIRA International 2002

4.6.3.2 Climate

The climate of the Mine area is semi-arid, characterised by seasonal periodic rainfall and high evaporation rates. Maximum average temperatures generally occur from November to March, during the season of peak rainfall, with maximum temperatures ranging between 34°C and 39°C (BoM, 2015). Coolest months occur between June and August, when temperatures reach an average maximum of 22°C to 26°C, and an average minimum between 6°C and 8°C (Figure 42).

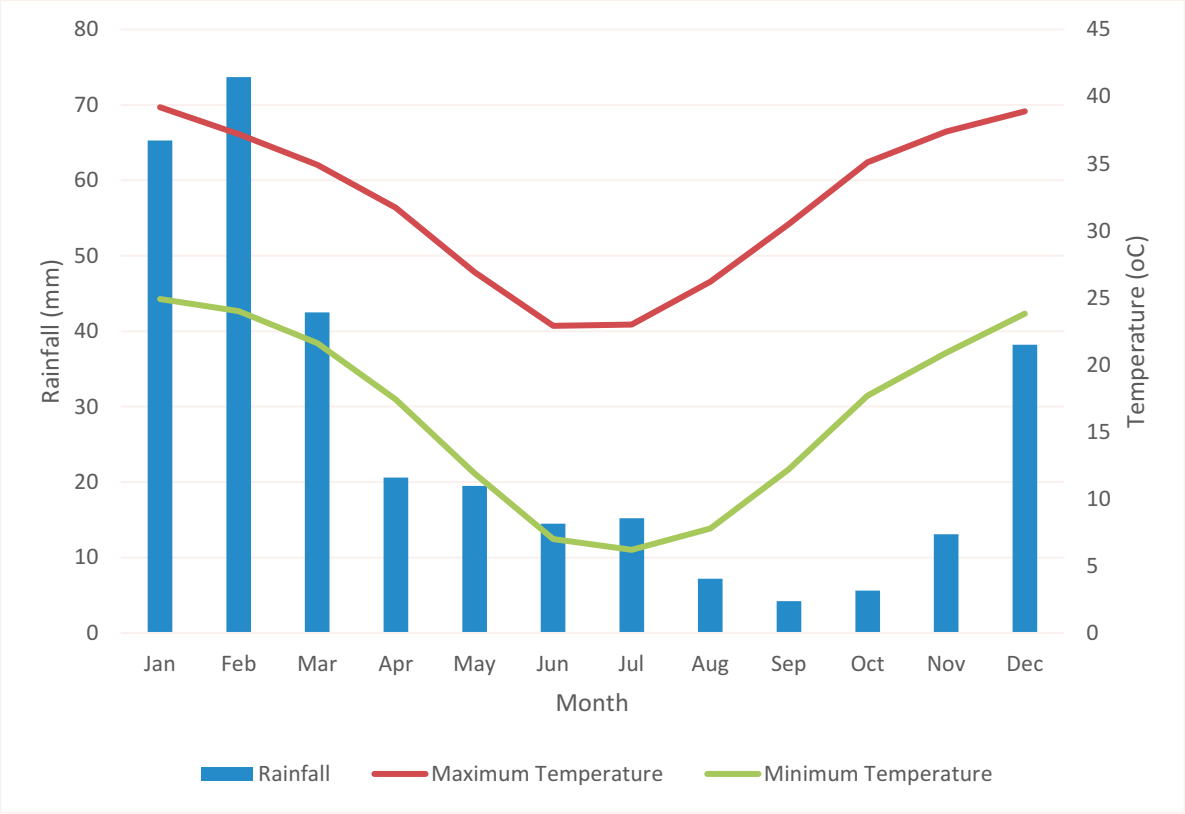

Figure 42: Monthly Mean Climate Data for Newman Airport (Station 007176) (BoM, 2015)

Rainfall occurs predominantly in summer months; the largest events being associated with tropical cyclones bringing heavy rain to the inland parts of the Pilbara. Frequent summer thunderstorm activity and occasionally protracted rainfall, when a low-pressure trough descends into the region, are characteristic. The long-term annual average rainfall for Newman (1971 to 2015) is 326.8mm per year (Table 4-30). Rainfall during December to February ranges from 38-78mm per month, whilst the months of September to November ranges between 4-13mm per month.

Rainfall data analysis was conducted in 2012 comparing rainfall data from on-site pluviometers and data from nearby Pastoral Stations with rainfall data from the Newman Airport (BOM certified station 007176). The results of this analysis confirmed the correlation to the Newman Airport weather station was considered appropriate for use in determining design parameters of infrastructure for the Mine (MWH, 2012).

Table 4-30: Monthly and Annual Rainfall (in mm) for Newman Airport Years 1971 to 2015 (Station 007176) (BoM, 2015)

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean	65.3	73.7	42.5	20.6	19.5	14.5	15.2	7.2	4.2	5.6	13.1	38.2	326.8
Median	40.1	42.2	30.8	8.9	5.2	4.1	4.2	0	0	1.2	8.1	25.3	-
Highest	239.8	305.6	214.2	89.6	113	77.8	139.8	79.6	44.6	34.8	79.2	236	-

Due to cyclonic activity, rainfall intensity in the region is high. Design storms were prepared based on rainfall intensity and temporal patterns in accordance with Australian Rainfall and Runoff (Engineers Australia, 2007). A range of average rainfall intensity events for the region and that are predicted to occur at the Mine is presented in Table 4-31.

Table 4-31: Rainfall Intensity Frequency Duration Data

Duration (Hours)	Average Rainfall Intensity (mm per hour)		
	10 Year ARI	100 Year ARI	1,000 Year ARI
1	45.0	74.8	130.5
3	21.4	37.3	70.63
6	13.0	23.3	46.17

Source: GHD 2012

The annual evaporation rate is approximately 3400mm (BOM, 2016) vastly exceeding annual average rainfall (Figure 43). Maximum evaporation rates generally occur in January with approximately 400mm anticipated in the seasonal peak. These rates can reduce to approximately 125mm in June.

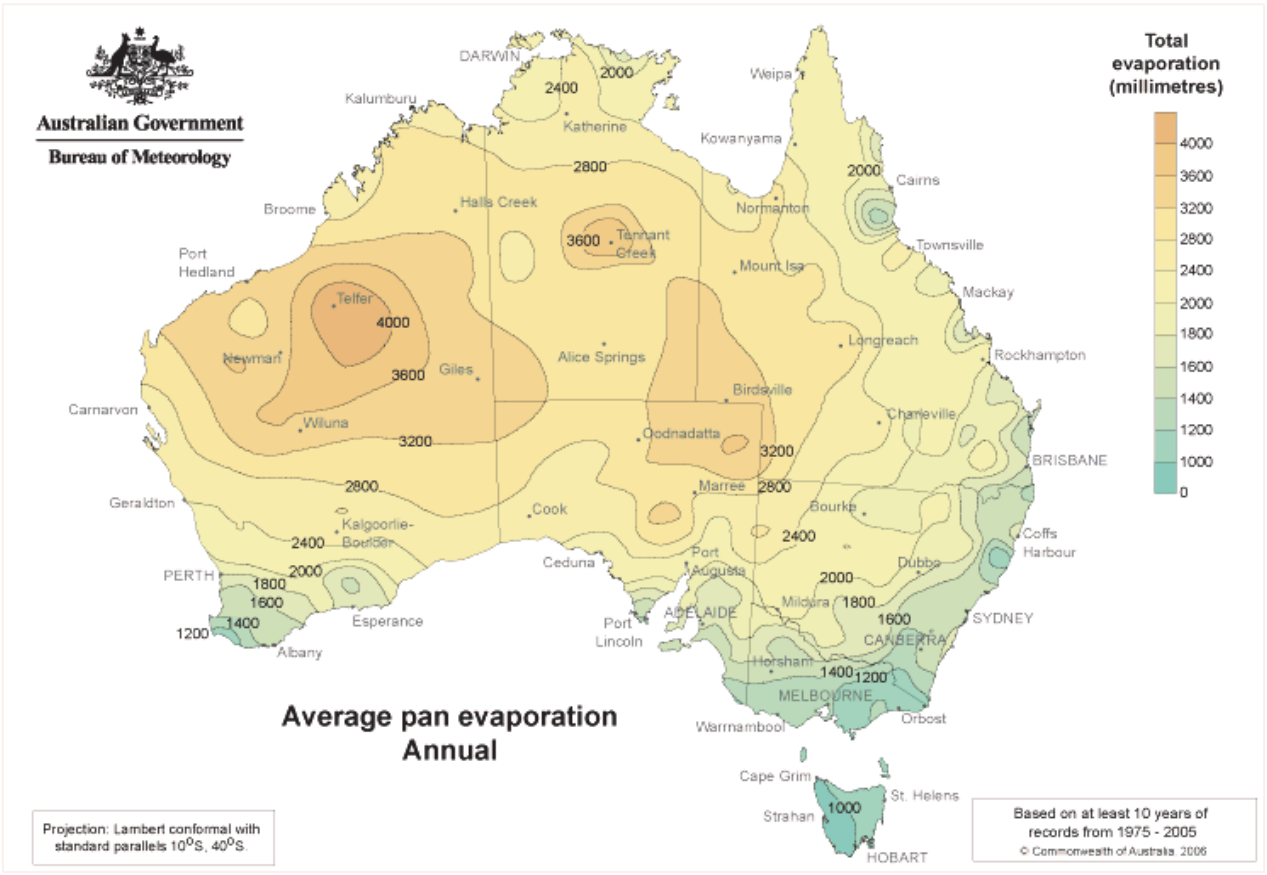

Figure 43: Annual Evaporation Rate (Source: BoM 2016)

RHIO undertook meteorological modelling utilising CALMET (a diagnostic meteorological model) which included a wind field generator. The annual wind rose extracted from the model for the Mine indicated a dominance of south-easterly to easterly winds (Figure 44).

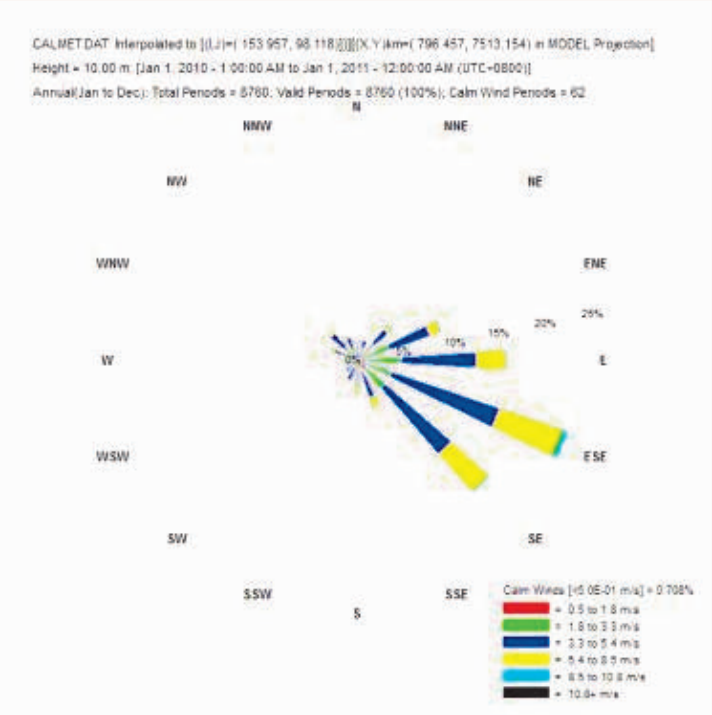

Figure 44: CALMET Wind Rose for the RHIO Mine (Source PEL 2015)

4.6.3.3 Ecosystems

The Fortescue Marsh is discussed in in detail in section 4.3.3.6.2.

4.6.3.4 Surface Water Hydrology

The topography of the Mine area reflects a very old landscape with low weathered hills and flat plains areas with typically ephemeral creeks and drainage lines. The Mine and associated infrastructure is located in the upper Fortescue River catchment that covers an area of 30,700km^2.

The Fortescue River Valley is an east-west trending internal-drainage system lying between the Hamersley Range to the south and the Chichester Range to the north. Drainage is ephemeral, with surface flows occurring for periods of several weeks to months following significant rainfall events (MWH, 2015a). Runoff can persist for periods of weeks to months (GHD, 2018). Brackish to saline wetlands are formed within the Fortescue Valley at the terminus of the Upper Fortescue River (MWH, 2015a).

The Fortescue River is one of the largest river systems in the Pilbara region of Western Australia and is naturally separated into upper and lower sections by the Goodiadarrie Hills that form the Fortescue Marsh, a large intermittent wetland lying between the Chichester Ranges to the north and Hamersley Ranges to the south covering an area of approximately 1,000km^2. The Fortescue Marsh is an expression of sediment accumulation and evaporite formation within the broad, closed valley-basin.

The Fortescue River is the main source of surface water inflows into the Revised Development Envelope, running from south east to north west across the Remote MAR Borefield area. The Upper Fortescue River, with a total

catchment area of 16,281 km^2, contributes significant surface water flow volumes into the eastern end of the Marsh. These flows are largely derived from upland areas, and delivered through numerous tributaries such as Homestead Creek, Whaleback Creek and Jimblebar Creek (GHD, 2018). The Fortescue River flows are highly variable and while they are not gauged within the RHIO area, annual flows into the Marsh from the Fortescue River catchment have been estimated at 34GL/a (Simonic et al, 2015).

The Mine is located in the foothills and upper colluvial plains of the Chichester Ranges that are drained by several ephemeral creeks, which generally flow in a south-westerly direction towards the Fortescue River and the Marsh. Kulbee Creek passes through the centre of the Mine area, with Kulkinbah Creek located to the southeast and No Name Creek to the northwest. The surface water catchment areas of the Mine creek systems are summarised in Table 4-32. The Kulbee, Kulkinbah and No Name Creek catchments combined represent less than 0.5% of the Fortescue River Catchment. There are no permanent creeks, surface water pools or wetlands within the Mine area (Figure 45).

Table 4-32: Mine project area surface water catchments

Drainage Catchment	Catchment Area at Downstream Lease Boundary (km^2)
Kulkinbah Creek	703
Kulbee Creek	38
No-name Creek	88
Central Catchment	31
Eastern Catchment	81

Regional runoff is highly variable. Typically, little or no runoff is produced in years when rainfall is less than 150mm to 200mm. The creeks only flow intermittently and are generally dry for the majority of the year. Due to the infrequent nature of major rainfall events that have capacity to create flows, the creeks are subjected to long periods of no flow during the dry season, and flows are usually limited to short durations during summer months triggered by cyclonic activity. It is estimated that approximately 25 to 50mm of rainfall over a 24-hour period is necessary to produce flow within the creek systems (MWH, 2015). Baseline monitoring over the 2006/07 and 2007/08 wet seasons recorded runoff as a small proportion of rainfall; only 2 to 3%, when averaged over the wet season. Under these conditions flow response and subsequent recession is typically rapid.

Surface water systems that flow through operational areas at the Mine are currently diverted around major disturbance areas (i.e. pits) by surface drainage structures to facilitate surface flow and prevent upstream containment of flows.

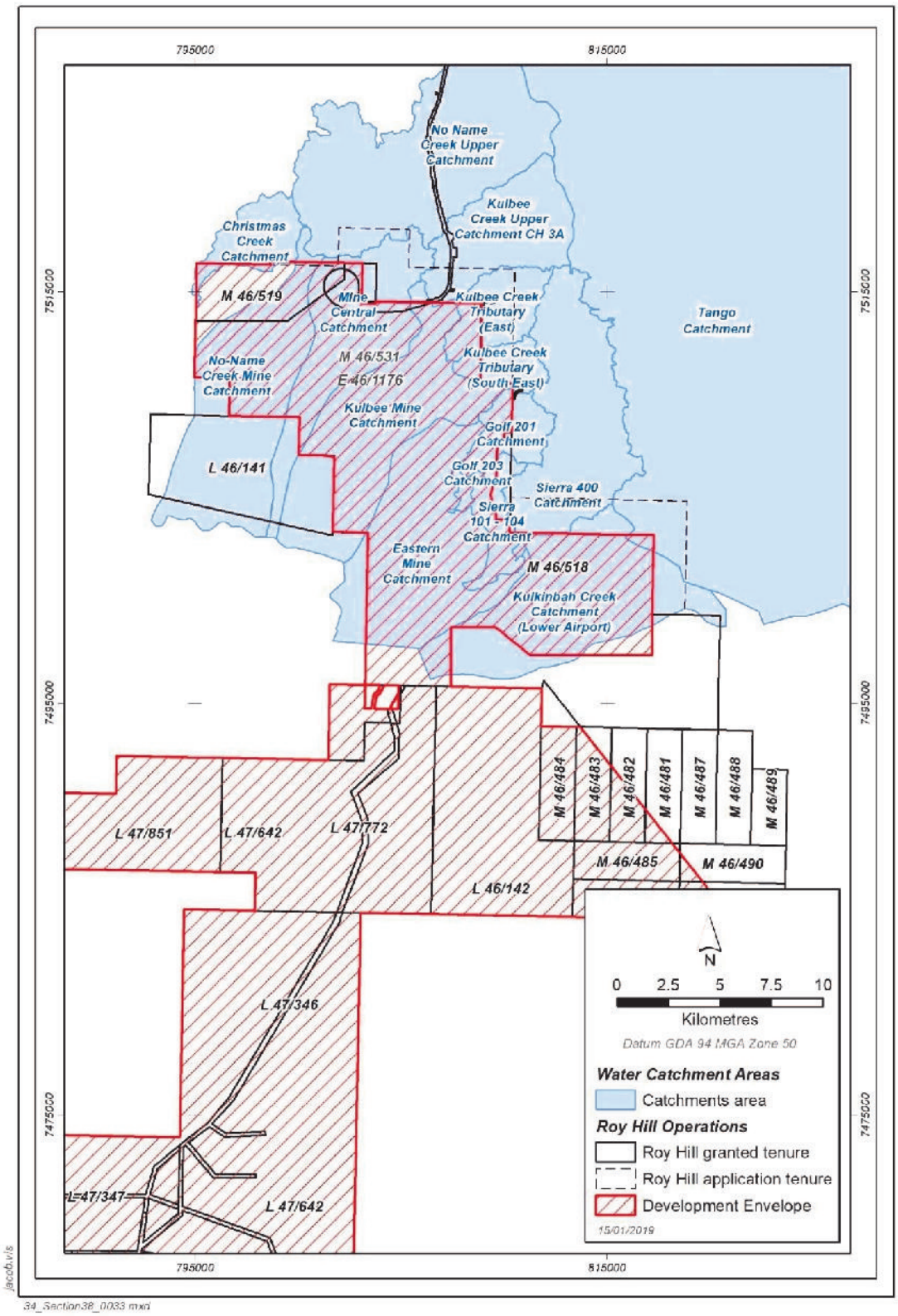

Figure 45: Surface water catchments at the Mine

RHIO has Rising Stage Samplers (RSS) and water level dataloggers (WLDL) installed in the main creek channels (Kulbee Creek, West Kulbee Creek, No Name Creek, Eastern Catchment and Fortescue River) to record surface water flows and water quality during rainfall events. In addition, four grab sample sites have been established as part of the ongoing water monitoring programme. Sample locations are summarised in Table 4-33 and shown on Figure 46. Data has been collected since 2010 and will continue throughout implementation of the Revised Proposal.

Table 4-33: Surface Water Monitoring Sites at RHIO

Station Name	Approximate Location		Monitoring Type	Date of Site Installation
	Easting	Northing		
Kulbee Creek				
KC1a	802513	7505068	WLDL	Nov-10
KC1b	802433	7504886	RSS	Nov-10
KC2b	807908	7511381	RSS/WLDL	Nov-10
West Kulbee Creek				
WKC4	800534	7509571	RSS	Dec-14
	800535	7509590	WLDL	May-16
GBS01	800194	7508704	Grab Sample	
No Name Creek				
NN1	800017	7516440	RSS/WLDL	Nov-10 (re-located Jun-15)
NN2	798523	7509072	RSS/WLDL	Nov-10
GBS02	798506	7509008	Grab Sample	
Eastern Catchment				
KC4	808527	7507379	RSS/WLDL	Nov-10
KB1 (Evaporation Pond)	803463	7500695	RSS/WLDL	Nov-10
Fortescue River				
FM01	804726	7492870	RSS	Dec-14
TSF Creek				
GBS03	795225	7509864	Grab Sample	
West Boundary				
GBS04	794130	7510967	Grab Sample	

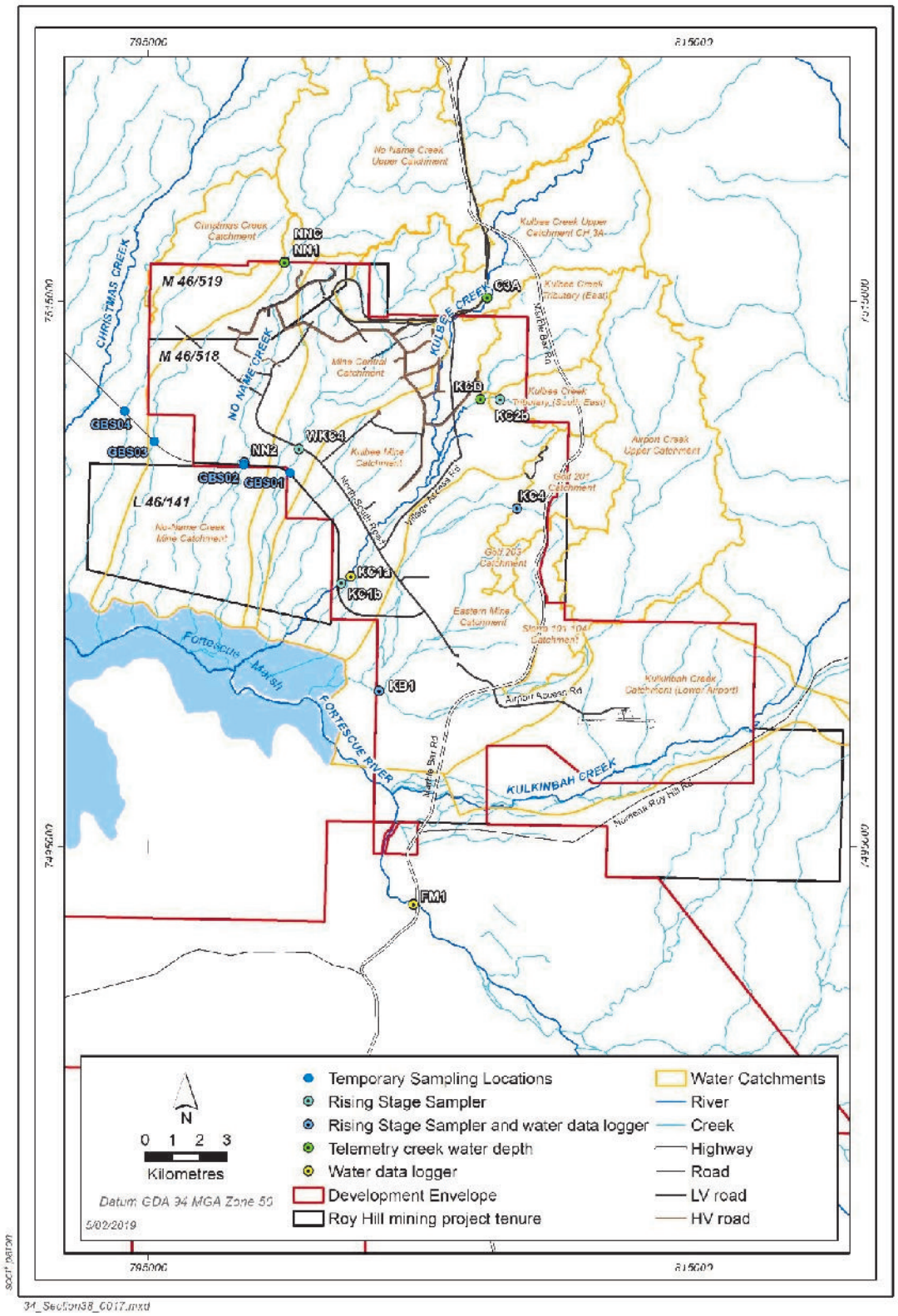

Figure 46: Surface water Features and Monitoring Locations

4.6.3.4.1 Hydrologic Modelling

Peak flow rates for catchments discharging to the Mine have been estimated using the Regional Flood Frequency Estimation (RFFE) technique (Ball, et al., 2016) for the 1% Annual Exceedance Probability (AEP) storm. Catchments for the Mine were delineated using CatchmentSIM terrain software interpreting the LIDAR generated DEM and satellite data (Geoscience Australia, 2010). Results of the catchment analysis are presented in Table 4-34.

To generate hydrographs for flood modelling purposes, catchments were subdivided into sub-catchments and analysed in the XP-Rafts hydrologic model. XP-Rafts is a non-linear runoff routing model used to generate hydrographs for both historic and design storms. The parameters applied in the model are included in Table 4-35. The application of these parameters was based on calibration of the model to the peak flow generated by the RFFE method. Results of the hydrologic modelling indicate the critical event duration for external catchments ranges 9 to 36 hours (Table 4-36).

Table 4-34: Peak flow estimates and catchment properties (GHD, 2017)

Catchment	Area (ha)	Length (km)	Slope (%)	100 Year ARI Peak flow (m^3/s)* (MWH 2011)
Kulbee Creek East at Channel 3A	2,999	8.3	0.67	84.3
Kulbee Creek at conveyor crossing	4,496	12.7	0.58	115
Ginbata Creek at lease boundary	4,203	17.7	0.36	97.5
No-name Creek at lease boundary	7,195	19.3	0.36	169
Kulkinbah Creek at lease boundary	61,904	58.8	0.15	472
Christmas Creek at lease boundary	25,189	26.9	0.30	370

Applying standard probability equations, the probability of certain AEP events occurring over the 20-year mine life is presented in Table 4-35.

Table 4-35: Hydrologic modelling parameters (GHD, 2017)

Parameter	Value
Initial Loss	20 mm
Continuing Loss	2 mm/hr
Temporal Pattern	Ensemble of 10 temporal patterns from Rangelands West region
Percentage Impervious	5%
Aerial Reduction Factors	Northern Coastal zone
Catchment Roughness (Manning's 'n')	0.035

Table 4-36: 1% AEP critical flows (m^3/s) (GHD, 2017)

Catchment and outlet	Critical duration (h)	XP-Rafts peak flow (m^3/s)
Kulbee Creek East at Channel 3A	9	86
Kulbee Creek at conveyor crossing	30	116
Ginbata Creek at lease boundary	12	93
No-name Creek at lease boundary	18	143
Kulkinbah Creek at lease boundary	36	507
Christmas Creek at lease boundary	18	379

Applying standard probability equations, the probability of certain AEP events occurring over a 20-year mine life is presented in Table 4-37.

Table 4-37: Likelihood of ARI event exceedance over 20 Years (GHD, 2017)

ARI of Event	Likelihood of Event Being Exceeded Over Operational Lifetime (20 years)
10%	88%
1%	18%
0.1%	2%
0.0001%	0.002%

A TUFLOW hydraulic model was prepared to simulate flooding at the Mine. The model was configured to accept the inflow hydrographs from the hydrologic model as upstream boundary conditions, together with a "rain-on-grid" arrangement to simulate rainfall across the Mine. This method allowed for the assessment of both channelised flow in the major waterways and sheet flow generated within the site.

Results of the analysis for the 1% AEP flood events illustrated the spatial distribution of flooding across the site prior to mining activities. Flows generally breach the small watercourses but are contained within the broader floodplain banks.

4.6.3.4.2 Surface Water Quality

Surface water quality sampling has indicated that pH during flow events is circum-neutral to slightly alkaline with pH ranging from 6.5 to 8.2. During surface water flow events EC is variable ranging from 18µS/cm to 500µS/cm. TDS concentrations are highly variable ranging from 54mg/L to 1300mg/L. TSS concentration in RSS surface water samples range from below <5mg/L to 1,400mg/L. In general, the concentration of TSS recorded in the RSS stations is highest during peak flow in the relatively high-volume flow events (>0.6mAGL).

Surface water sampling has shown an enrichment in Calcium (Ca), Sulphate (SO4), Sodium (Na) and Chloride (Cl) often occurring in the first flush of water through creek lines after an extended dry period. This is likely reflecting

the dissolution of surficial efflorescent minerals such as gypsum (CaSO4) and halite (NaCl). These minerals often form surficial crusts in the Pilbara region, especially in creek beds. Mobilisation, precipitation and re-mobilisation of these minerals is facilitated by the cyclic wetting and drying climatic pattern of the region.

Initial analysis of background surface water data indicated that ambient water quality values for some parameters (including iron, zinc, aluminium, total phosphorus) exceed the default ANZECC trigger values for a Slightly-Moderately Disturbed Ecosystem (MWH, 2011). It is therefore appropriate to apply site specific values from baseline data to assess changes to water quality or any potential impacts resulting from the Revised Proposal.

4.6.3.5 Groundwater Hydrology

4.6.3.5.1 Major Aquifer Systems

The Development envelope spans two major hydrogeologic sequences Fortescue Valley and the Chichester Range. Figure 47 shows the relationship between these unit. The Fortescue Valley sequence comprises Tertiary detritals (Calcrete and Pisolitic) and the underlying Wittenoom Formation (dominated by dolomite of the Paraburdoo Member). The Chichester Range comprises Cainozoic alluvial and detrital sediments over lying the Hamersley Group Marra Mamba Formation and Fortescue Group's youngest formation, the Jeerinah Formation.

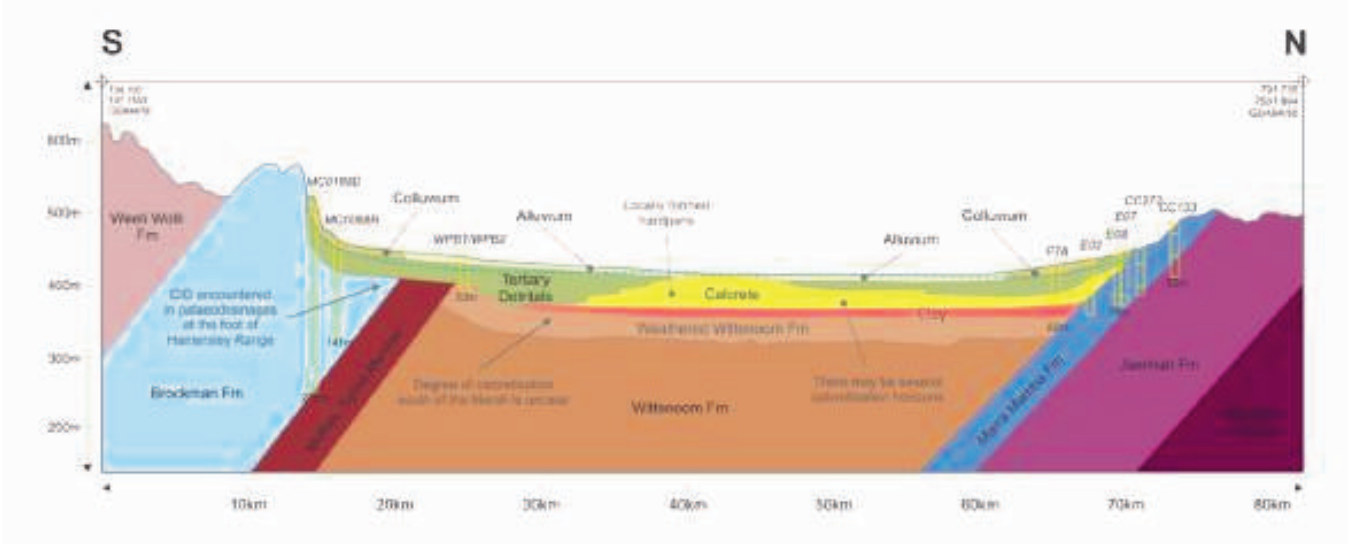

Figure 47: Conceptual geologic Section across the upper Fortescue River Catchment (adapted from Simonic et al., 2015, in GHD 2018)

4.6.3.5.1.1 Fortescue Valley sequence

The Fortescue Valley comprises a sequence of Quaternary and Tertiary sediments which generally overlie the weathered and fresh dolomite of the Wittenoom Formation. Tertiary calcrete or pisolitic limonite of the Fortescue Valley sequence formed as valley-fill sequences are both often highly permeable. The area also hosts large expressions of calcrete which is ascribed to Oakover Formation, however there can be several calcrete horizons within the sequence. The base elevation of the Tertiary calcrete is generally at 400m AHD, consistent with deeper parts of the Fortescue Marsh ground surface. Calcrete-described occurrences in the Fortescue

Marsh area also often form surficial or subcortically expressing hardpans or claypans which facilitate ponding of surface water or rainfall during major rainfall events (GHD, 2018).

Tertiary detritals that comprise silty and clayey playa deposits, with low permeability clay at the base. Their thickness increases towards the valley's central axis and may reach up to 70m. A rather homogeneous clay layer present at the base of detritals with thickness of 10 to 20m has likely confining effects on the underlying weathered dolomite aquifer and its base is generally at 380m AHD (GHD, 2018).

The upper section of the Wittenoom dolomite is weathered and karstified and sometimes erroneously described as 'calcrete'. Dolomite is often interbedded with chert and may contain manganese which weathers into black manganiferous clay. Depth of weathering is variable, but the available logs suggest that weathering ceases at an elevation of 350 to 360m AHD, suggesting an average thickness of the weathered dolomite being 20 to 30m.

The bedrock geology of the Fortescue Valley is offset against the basement rocks of the Hamersley Range to the south of the of the assessment area. This contact is a regional fault system, the part of which is known as the Poonda Fault System. The Wittenoom Formation in this part of the assessment area is offset against the upper members of the Hamersley Group sequence, including the low-permeability Mt McRae and Mt Sylvia Formations.

Drilling in the Southern Borefield identified three main hydrological units Table 4-38 and Figure 48.

Table 4-38: Hydrological Units of the Fortescue Valley (Managed Recharge, 2018)

Geological Unit	Groundwater Quality
Alluvial Deposits	The alluvial deposits are noted to be highly variable in nature, ranging from silty clays through to gravels and cobbles, and include older Tertiary pisolitic detritals. Chemical deposits of calcrete and silcrete are also present. The alluvial deposits are valley fill deposits and occur extensively on the lower ground in the modern-day drainage systems of the Fortescue River and tributaries reporting to the Fortescue Valley. They are generally >50 m thick, with thickness potentially increasing in depth to the west. The deposits form an unconfined to semi-confined, superficial aquifer.
Clay	The clay unit is generally between 10 and 20 m thick, forming the base of the alluvial deposits. It is typically reddish brown and/or brownish-yellow, stiff, and swelling in nature. The clay unit acts as a confining layer to the underlying dolomite aquifer.
Dolomite (Wittenoom Formation)	Underlying the clay and alluvial units is a typically white to blue-grey dolomite, the upper zone of which is usually weathered and karstic over a depth of 10 to 35 m. It forms a widespread, moderately high-yielding aquifer with a high storage capacity. The weathered dolomite is underlain by a thick sequence of fresh, crystalline dolomite, possibly thickened by a series of southerly-dipping, low-angle faults. The fresh dolomite is relatively impermeable, with groundwater flow restricted to limited fracture zones.

The Tertiary clays form a confining layer between 10 and 20 m thick, which apparently thins to the south where alluvial deposits directly overlie weathered dolomite (monitoring bore ECPZ0022; Managed Recharge, 2018; Figure 48). Ground water is deepest at the southern end of the Southern Borefield area (>30mbgl) shallowing to the north towards the Fortescue River and Marsh (14.5mbgl) at north end of Southern Borefield.

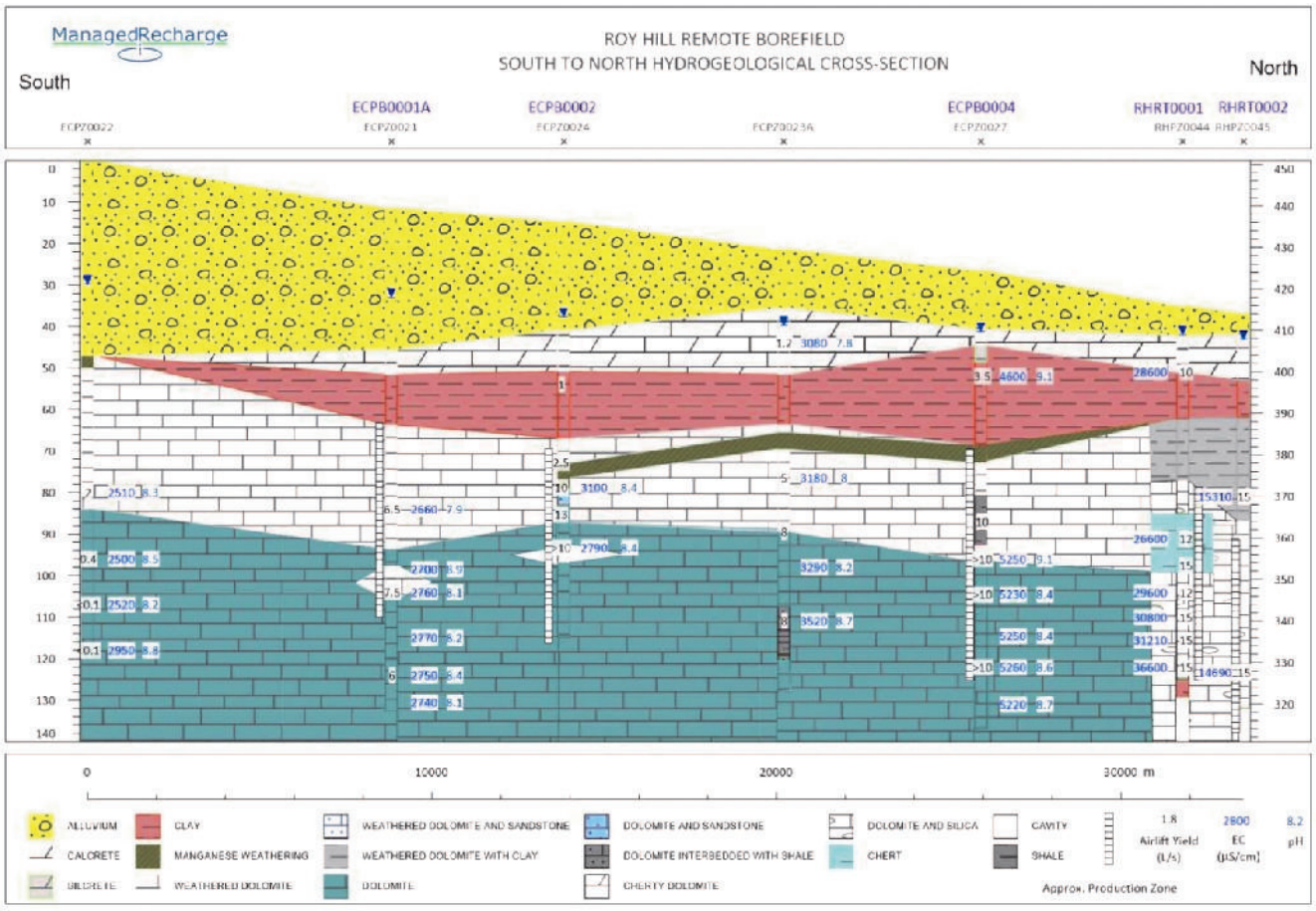

Figure 48: Hydrological cross section through Southern Borefield (Managed Recharge, 2018)

Two trial injection bores located north of the Southern Borefield in the Remote MAR Borefield intersected previously uncharacterised hydrogeological unit. It is hypothesised that the different stratigraphy beneath the Tertiary clays: saprolitic clay underlain by chert and/or cherty dolomite, represents a zone of faulting with possible Pinjian Chert Breccia shifted into the sequence via southwest - northeast trending slip strike faulting (Figure 49) or deposited in-situ as silicified Wittenoom Formation dolomite. Fractured Pinjian Chert Breccia forms a major aquifer in the Woodie Woodie region.

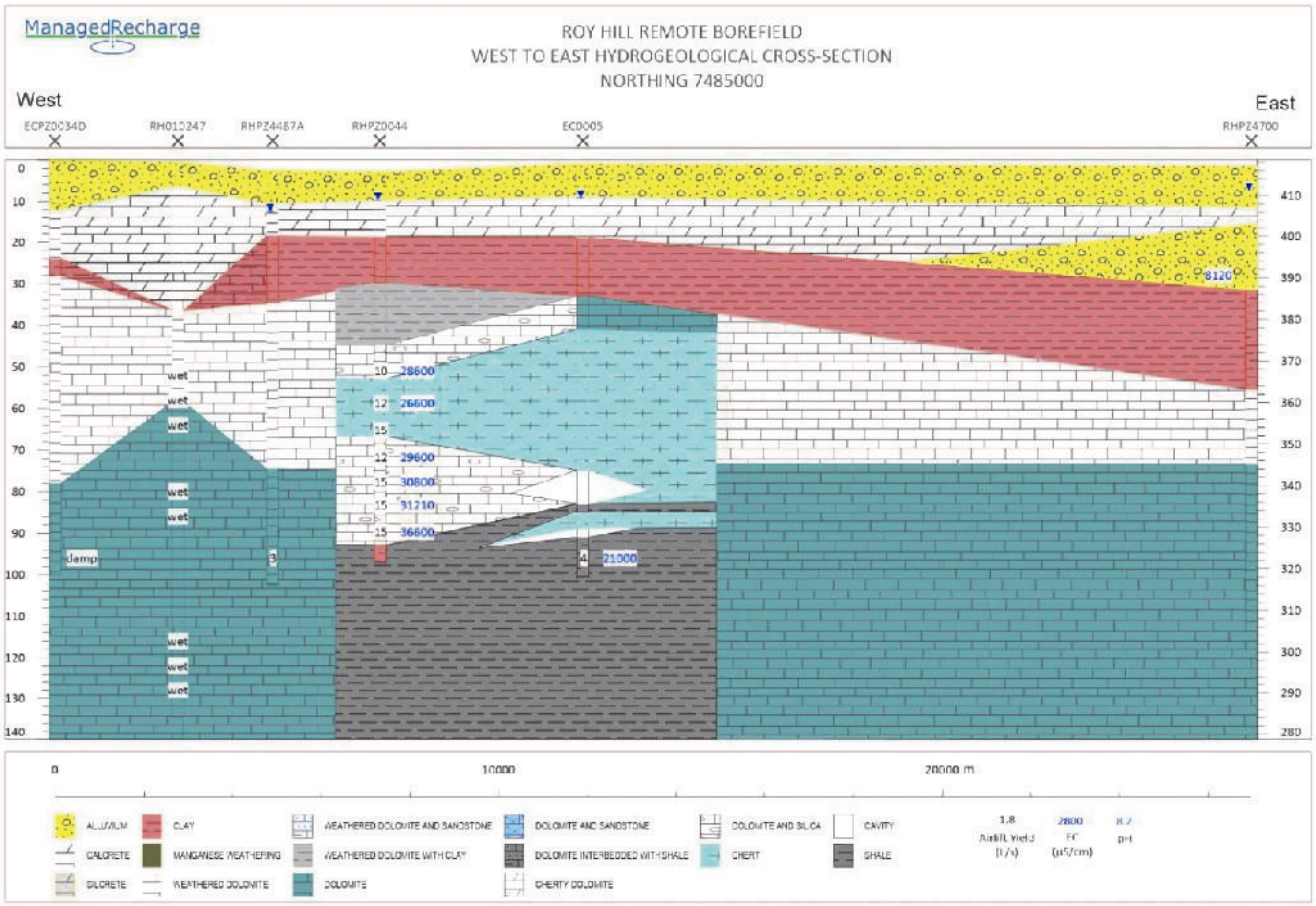

Figure 49: Hydrological cross section through Remote MAR Borefield (Managed Recharge, 2018)

4.6.3.5.1.2 Chichester Range (Mine Area)

The flanks of the valley rise into ranges comprising fractured-rock aquifers of low permeability and storage. In places, these basement rocks have more transmissive sections associated with orebodies and form localised aquifers. The extent of these orebody aquifers and their connectivity with larger groundwater flow systems may be enhanced by faulting or erosion or other structural features, and as such can vary widely and is site specific (GHD, 2018).

The Chichester Range comprises Cainozoic alluvial and detrital sediments overlying the Hamersley Group Marra Mamba Formation and Fortescue Group's youngest formation, the Jeerinah Formation (Table 4-39). Hydro geologically productive and transmissive Nammuldi Member is the basal unit of Marra Mamba Formation and is 10 to 60m thick. Its thickness is assumed to be progressively reduced on the southern flanks of the Chichester Range and may also thin out or erode in the drainage systems of creeks intersecting the Chichester Range. It overlies the Roy Hill Shale, the uppermost member of the Jeerinah Formation. The Nammuldi Member has high hydraulic permeability in supergene zones and forms a discontinuous aquifer. Unmineralised Marra Mamba Formation has generally low storage and permeability (GHD, 2018).

Alluvial fans are also a notable feature in the Cainozoic landscape and occur at the outflows of creeks from the Ranges (e.g. Coondiner Creek in the Hamersley Range and Christmas Creek in the Chichester Range) (GHD, 2018).

The pre-Cainozoic landscape is intersected by regional faults which may have influence on groundwater flows and salinity contrasts. The faults may be accompanied by dolerite dykes which could facilitate localised compartmentalisation.

The flanks of the valley rise into ranges comprising fractured-rock aquifers of low permeability and storage. In places, these basement rocks have more transmissive sections associated with orebodies and form localised aquifers. The extent of these orebody aquifers and their connectivity with larger groundwater flow systems may be enhanced by faulting or erosion or other structural features, and as such can vary widely and is site specific (GHD, 2018).

Table 4-39: Hydrological Units of the Chichester Range (Mine area; Managed Recharge, 2018)

Lithology/description	Hydrogeological Description
Alluvium (ALU) and Detrital (CL, GZM, GZO, GZW)	Groundwater is present in saturated horizons of alluvial/detrital sediments. The quantity and quality of the groundwater may vary depending on distance from Fortescue Marsh, and vertical and lateral extents of the system.
Nammuldi (BNAM, MNAo, ONAM)	Groundwater flow in this unit is charactered as fracture flow and is not considered a significant regional aquifer. Weathered and highly mineralised zones of the Nammuldi Member, however, locally contain significant groundwater, and are considered the primary aquifer system in parts of the project area.
Jeerinah (JER, JRS)	The Jeerinah Formation forms a relatively impermeable basement to the groundwater system and is present through the majority of the model area. The uppermost unit of the Jeerinah Formation (the Roy Hill Shale) has relatively low primary permeability with limited matrix storage. Permeability is enhanced in the unit where bedding planes and fractures have been weathered to form preferential groundwater flow paths. The contact zone between the Jeerinah Formation and the overlying Nammuldi Member was found to have increased groundwater inflows, which is likely the result of enhanced permeability from weathering of the contact zone.

4.6.3.5.2 Groundwater Recharge

Groundwater recharge is associated with major cyclonic events that are episodic and relatively short-lived. The major component of recharge during these events is lateral inflow from the ranges, with the majority of the valley sediments not recording any significant recharge during those times (GHD, 2018). Groundwater recharge is considered to occur via several processes:

- Recharge occurs along the Fortescue Valley margins, where overland flow infiltrates along the break of slope areas.
- Indirect runoff recharge also occurs along drainage lines, especially in creek channel beds, via surface water leakage from overlying alluvial deposits into the aquifer system.
- Infiltration into outcropping basement units.
- Natural groundwater discharge is mainly via through flow to the lowest point in the catchment, the Fortescue Marsh. Where the water table is shallow to the surface, groundwater can be removed by evapotranspiration.