8. ENVIRONMENTAL IMPACT ASSESSMENT - KEY ENVIRONMENTAL FACTORS - MINE SITE DEVELOPMENT ENVELOPE

Key environmental factors for the Mine Site Development Envelope comprise the following:

- Flora and Vegetation.
- Terrestrial Fauna.
- Hydrological Processes.
- Inland Waters Environmental Quality.
- Heritage.
- Rehabilitation and Decommissioning (Integrating Factor).
- Offsets (Integrating Factor).

Potential impacts for the key environmental factors are detailed in Sections 8.1 to 12. Offsets are addressed separately in Section 14.

8.1 FLORA AND VEGETATION

The EPA's objective in relation to flora and vegetation is "*to maintain representation, diversity, viability and ecological function at the species, population and community level*".

8.1.1 Key Statutory Requirements, Environmental Policy and Guidance

Vegetation and flora are protected under Commonwealth and State legislation, primarily governed by three Acts:

- *Environment Protection and Biodiversity Conservation Act 1999* (Cth).
- *Wildlife Conservation Act 1950* (WA).
- *Environmental Protection Act 1986* (WA).

In addition to Commonwealth and State legislation, the following policy and guidance statements were considered in the impact assessment for flora and vegetation:

- EPA Position Statement No. 2, Environmental Protection of Native Vegetation in Western Australia (EPA 2000).
- EPA Position Statement No. 3, Terrestrial Biological Surveys as an Element of Biodiversity Protection (EPA 2002).
- EPA Guidance Statement No. 51, Terrestrial Vegetation and Flora Surveys for Environmental Impact Assessment in Western Australia (EPA 2004c).
- EPA and DPaW Technical Guide – Flora and Vegetation Surveys for Environmental Impact Assessment (EPA and DPaW 2015).
- Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) Guide G-1, Radiation Protection of the Environment (ARPANSA 2015).

8.1.2 Assessment of Potential Impact

Clearing for the project in the Mine Site Development Envelope will directly impact flora and vegetation, resulting in:

- **Loss of native vegetation communities**.
- **Loss of conservation significant flora**.

Potential indirect impacts to flora and vegetation resulting from the project within the Mine Site Development Envelope include:

- **Dust generated from construction and mining activities resulting in reduced vegetation health and condition** – construction and mining activities and use of the Site Access Road may generate dust that impacts vegetation health.
- **Increased presence of weeds resulting in reduced native vegetation cover and diversity** – weeds may be introduced to the area or spread by movement of equipment and nutrient loading from land irrigation of treated wastewater may favour weed growth.
- **Modification of surface water flows resulting in loss or reduced health and condition of native vegetation** – surface water flows may be modified due to pipelines or other landscape modifications, and vegetation may be inundated or receive reduced amounts of water.
- **Groundwater abstraction resulting in loss or reduced health and condition of groundwater dependent ecosystems (GDEs).**
- **Altered fire regimes resulting in loss or reduced health and condition of native vegetation**.

Other potential impacts were screened out from further assessment (Section 7.4) as they were either assessed as not likely to occur or were unlikely to have any discernible consequence on any factor different to background levels:

Stressor	Justification for Exclusion
Radiation exposure to native vegetation resulting in loss or reduced health and condition of native vegetation	The vast majority (98%) of all process waste streams is from ilmenite processing or initially rejected sand/slimes material with low activity (0.39 Bq/g, see Appendix 21). Material with activity less than 1 Bq/g based on composition of Sheffield waste materials does not trigger the Tier 1 Environmental screening criteria of 10 µGy/h using the ERICA software assessment (ARPANSA 2015) for terrestrial flora. Sheffield commit to mixing and co-disposal of wastes to <1 Bq/g (combined activity of reject material from processing c.a. 0.74 Bq/g). Backfill areas will be monitored to ensure radiation levels are within environmental screening criteria (10 µGy/h) or established pre-mining background levels. The inherent use of wet slurries for transport of mine waste back to the void minimises potential for dust emissions of higher activity material.

The assessed likelihood, consequence and residual impact (as per Section 7.3), is provided below for each potential impact.

8.1.2.1 Clearing Resulting in Loss of Vegetation Communities or Conservation Significant Species

A total of 2,215.3 ha are required to be cleared during the project life, with a further 57.3 ha already having been cleared (Mt Jowlaenga Road). Clearing for permanent infrastructure is 593.3 ha, with the remainder of the clearing to be undertaken progressively as the mining excavation advances. At any given time, the clearing footprint for the mineral deposit area will be about 200 ha.

Clearing Resulting in Loss of Vegetation Communities

A total of 15 vegetation communities occur within the wider survey area of the Mine Site (Table 54 and Figure 28). There are no TECs or PECs within or adjacent to the Mine Site Development Envelope, with the nearest approximately 50 km away.

Two vegetation communities, W6 and W8 (including W8a), were considered to be most representative of the Mine Site Development Envelope, and accounted for the majority (86%) of the surveyed area (Figure 28). These communities consist of Pindan vegetation (low sparse Eucalypt woodlands over *Acacia tumida* shrubland over *Triodia/Chrysopogon* grasslands), which are common and widespread throughout the broader Kimberley region (Mattiske 2016). As shown in Table 54, seven of the 15 identified communities will not be impacted by the project and all communities proposed to be cleared are represented outside the Mine Site Development Envelope. The largest proposed impact is to vegetation community W8 at 15.6% (Table 54).

It is anticipated that clearing will 'Almost Certainly' result in a localised and medium term decrease in abundance and structure of vegetation communities. The potential residual impact from clearing on vegetation communities, after implementation of management measures, is assessed as 'Medium'.

Impact	Consequence	Likelihood	Residual Impact
Clearing resulting in loss of vegetation communities	Minor	Almost Certain	Medium

Table 54: Proposed Disturbance at the Mine Site Development Envelope for Each Defined Vegetation Community

Code	Vegetation Community Description	Mapped Area (ha)[1]	Proposed Clearing Area (ha)	Proposed Clearing Area (%)
Woodlands				
W1	*Melaleuca viridiflora*, *Melaleuca alsophila* and *Eucalyptus tectifica* low sparse woodland over *Bauhinia cunninghamii*, *Carissa lanceolata* and *Atalaya hemiglauca* tall sparse shrubland over *Ectrosia schultzii*, *Eriachne sulcata* and *Cyperus conicus* low sparse grassland on grey-white to light brown sandy soils in drainage channels and low lying drainage areas.	127.5	1.9	1.5%
W2	*Eucalyptus tectifica* mid open woodland over *Acacia plectocarpa* subsp. *plectocarpa* and *Grevillea pyramidalis* subsp. *pyramidalis* tall sparse shrubland over *Aristida holathera* subsp. *latifolia*, *Eriachne obtusa* and *Xerochloa laniflora* mid sparse grassland on light brown clayey sands in low lying drainage areas.	3.1	0.0	0.0%
W3	*Corymbia dendromerinx, Eucalyptus tectifica* and *Corymbia greeniana* mid open woodland over *Dolichandrone heterophylla*, *Dodonaea hispidula* var. *arida* and *Grevillea pyramidalis* subsp. *pyramidalis* mid sparse shrubland over *Triodia caelestialis* (P3), *Triodia schinzii* and *Eriachne obtusa* mid sparse hummock grassland on orange-brown clayey sands on flats and drainage areas.	35.7	0.0	0.0%
W4	*Corymbia dendromerinx* mid open woodland over *Terminalia canescens*, *Calytrix exstipulata* and *Wrightia saligna* tall sparse shrubland over *Triodia caelestialis* (P3), *Triumfetta albida* and *Polycarpaea longiflora* mid open tussock grassland on brown sandy clay soils on mid-slopes to ridges of hills with sandstone outcropping.	272.0	0.0	0.0%
W5	*Corymbia dendromerinx* mid open woodland over *Grevillea pyramidalis* subsp. *pyramidalis*, *Terminalia canescens* and *Waltheria indica* mid sparse shrubland over *Triodia caelestialis* (P3), *Sorghum plumosum* and *Hybanthus enneaspermus* subsp. *enneaspermus* low sparse tussock grassland on pale brown to orange-brown sandy clay loam soils on slopes and broad flat hill tops with sandstone outcropping.	234.5	0.1	0.1%
W6	*Eucalyptus tectifica*, *Bauhinia cunninghamii* and *Brachychiton diversifolius* subsp. *diversifolius* mid open woodland over *Carissa lanceolata* and *Dolichandrone heterophylla* mid sparse shrubland over *Triodia caelestialis* (P3), *Triodia schinzii* and *Eriachne obtusa* mid sparse tussock grassland on pale brown to grey brown sandy clay loams on flats.	3,432.0	89.9	2.6%
W7	*Brachychiton diversifolius* subsp. *diversifolius* and *Eucalyptus tectifica* low open woodland over *Bauhinia cunninghamii, Acacia plectocarpa subsp. plectocarpa* and *Melaleuca viridiflora* tall sparse shrubland over *Triodia caelestialis* (P3), *Triodia schinzii* and *Aristida holathera var. holathera* mid sparse hummock grassland on pale orange-grey clayey sands on flats.	101.6	3.7	3.6%
W8	*Erythrophleum chlorostachys*, *Brachychiton diversifolius* subsp. *diversifolius* and *Corymbia greeniana* mid open woodland over *Acacia tumida* var. *tumida*, *Bauhinia cunninghamii* and *Dodonaea hispidula* var. *arida* tall sparse shrubland over *Triodia caelestialis* (P3), *Triodia schinzii* and *Eriachne obtusa* mid sparse tussock grassland on orange brown to red fine sandy soils on flats.	12,834.5	2001.2	15.6%

Code	Vegetation Community Description	Mapped Area (ha)[1]	Proposed Clearing Area (ha)	Proposed Clearing Area (%)
W8a	*Erythrophleum chlorostachys, Brachychiton diversifolius* subsp. *diversifolius* and *Corymbia greeniana* mid open woodland over *Acacia tumida* var. *tumida, Bauhinia cunninghamii* and *Dodonaea hispidula* var. *arida* tall sparse shrubland over *Triodia caelestialis (P3), Triodia schinzii* and *Eriachne obtusa* mid sparse tussock grassland on orange-brown to red fine sandy soils in swale area subject to seasonal inundation.	36.9	0.7	1.9%
W9	*Corymbia dendromerinx* low open woodland over *Grevillea pyramidalis* subsp. *pyramidalis*, *Microstachys chamaelea* and *Terminalia canescens* mid sparse shrubland over *Chrysopogon sp.* (*C. fallax* or *C. pallidus*), *Glycine tomentella* and *Sorghum plumosum* mid sparse grassland on orange-brown sandy clay with sandstone rocks and outcropping on hills.	67.9	0.0	0.0%
W10	*Corymbia greeniana, Corymbia dendromerinx* and *Brachychiton diversifolius subsp. diversifolius* low open woodland over *Grevillea pyramidalis* subsp. *pyramidalis*, *Grevillea refracta* subsp. *refracta* and *Terminalia canescens* tall sparse shrubland over *Triodia caelestialis* (P3), *Solanum cunninghamii* and *Aristida hygrometrica* mid open tussock grassland on orange-brown clayey sands with occasional sandstone or ironstone rocks on flats and slopes associated with drainage areas.	964.3	88.4	9.2%
W11	*Corymbia zygophylla* low open woodland over *Acacia tumida* var. *tumida* and *Erythrophleum chlorostachys* tall sparse shrubland over *Triodia schinzii* and *Microstachys chamaelea* low sparse grassland on orange-brown clayey sands on flats and slopes.	40.9	0.0	0.0%
W12	*Corymbia greeniana*, *Eucalyptus tectifica* and *Corymbia dendromerinx* mid open woodland over *Dolichandrone heterophylla*, *Bauhinia cunninghamii* and *Acacia tumida* var. *tumida* tall sparse shrubland over *Triodia caelestialis* (P3), *Triodia schinzii* and *Eriachne obtusa* mid sparse tussock grassland, on brown clayey sands on flats and drainage channels.	519.8	29.0	5.6%
W13	*Brachychiton diversifolius* subsp. *diversifolius, Erythrophleum chlorostachys* and *Corymbia dendromerinx* mid open woodland over *Grevillea refract* subsp. *refracta*, *Acacia monticola* and *Microstachys chamaelea* tall sparse shrubland over *Corchorus sidoides*, *Goodenia sepalosa* subsp. *sepalosa* and *Pterocaulon paradoxum* low sparse forbland on orange-brown clayey sands on flats.	25.1	0.0	0.0%
W14	*Eucalyptus camaldulensis* mid open woodland over *Melaleuca viridiflora, Melaleuca alsophila* and *Bauhinia cunninghamii* mid sparse shrubland over *Ectrosia schultzii, Eriachne sulcata* and *Fimbristylis littoralis* low sparse grassland on grey to light brown sandy clay soils in drainage channels.	13.6	0.0	0.0
Shrubland				
S1	*Acacia tumida* var. *tumida* low sparse shrubland over *Waltheria indica* and *Bauhinia cunninghamii* low isolated shrubs over *Ectrosia schultzii*, *Eriachne obtusa* and *Corchorus pumilio* low sparse grassland on pale grey sandy clay loam soils on flats and slopes.	58.9	0.4	0.7%

Notes: 1 – Source Mattiske 2016

Clearing Resulting in Loss of Conservation Significant Flora

A total of five Priority flora taxa have been recorded in the Mine Site Development Envelope (Mattiske 2016) and Ecologia (2012a, 2014b, 2015) (Table 55). Two Priority taxa were recorded by Mattiske (2016); *Triodia caelestialis* (P3) was recorded widely as a groundcover and *Pterocaulon intermedium* (P3) was recorded infrequently and not associated with any specific landform, soil type or vegetation community. Proposed impacts to these species based on the Development Envelope are 8% and 17% respectively based on records in the survey area of Ecologia (2012a, 2014b, 2015) and Mattiske (2016). Given the widespread distribution of both taxa within the survey area and the scarcity of surveys in the less-accessible parts of the Dampier Peninsula, there is a reasonable expectation that more of these taxa would be found outside the Mine Site Development Envelope beyond known records (Mattiske 2016).

Three other priority taxa have been recorded infrequently in the Mine Site Development Envelope (Ecologia 2012a, 2014b, 2015); *Fuirena incrassata* (P3), *Fuirena nudiflora* (P1), and *Tephrosia valleculata* (P3). None of these taxa were recorded during the Mattiske (2016) survey, and their recording is uncertain as no specialist taxonomic identification was undertaken by Ecologia (2012a, 2014b, 2015). It is considered highly unlikely that *Fuirena nudiflora* is present as the project is located far outside its known distribution. In addition, none of these taxa are proposed to be cleared (Table 55). One record of *Tephrosia valleculata* (P3) is located within the Development Envelope; however it is outside of proposed disturbance areas.

Table 55: Numbers of Priority Flora Recorded Within the Survey Areas

Species	CC	Plants Within Development Envelope	Plants Within Disturbance Area	Total Population (Ecologia and Mattiske)	Percentage Impact (%) Within Development Envelope**	Percentage Impact (%) Within Disturbance Areas
Pterocaulon intermedium	P3	16	5	94	17	5
Triodia caelestialis	P3	10,665	770	135,363	8	6
Tephrosia valleculata	P3	1	0	3	33	0
Fuirena incrassata	P3	0	0	1	0	0
*Fuirena nudiflora**	P1	0	0	1	0	0

*Notes: CC = Conservation Code. * Unlikely to be correct identification.*

*** Based on assumption all records within Development Envelope will be removed.*

Some Ecologia data lacked population information. Where no data was provided, a count of one was assumed. Impacts are only based on site specific surveys, not regional population numbers, so percentage impacts are far higher than a total population count.

Clearing is 'Likely' to result in minor, localised loss of two conservation significant flora species, both of which are P3 species. These species were found to be widely distributed within the survey area. The potential residual impact from clearing on conservation significant flora, after implementation of management measures, is assessed as 'Medium'.

Impact	Consequence	Likelihood	Residual Impact
Clearing resulting in loss of conservation significant flora	Minor	Almost Certain	Medium

8.1.2.2 Dust Generated from Construction and Mining Activities Resulting in Reduced Vegetation Health and Condition

Accumulation of dust particulates on leaf surfaces can occur as a result of exposure to dust, resulting in a reduced ability for plants to photosynthesise and transpire, causing decline in health and eventual plant death if not alleviated.

Dust is likely to be generated during construction as a result of clearing for support infrastructure such as the Site Access Road, accommodation village and mining infrastructure. During the operational phase, dust will be generated from clearing of topsoil and vegetation ahead of the progressing mining excavation, driving of vehicles on roads and tracks, mining of overburden and ore, screening of ore within MUPS and rehabilitation activities such as spreading of overburden, topsoil and vegetation. There will be an average of 10 return road train trips (20 individual road train movements) in each 24 hour period along the unsealed Site Access Road during the operational phase of the project.

Impacts from dust generation are likely to be limited to within 50 m of the generation point, and there are no listed Threatened species or communities located within the Mine Site Development Envelope or the immediate surrounding area. Several Priority species are located within and adjacent to the Mine Site Development Envelope, however these species are well represented locally and regionally.

Incidental impacts to vegetation health and condition would be 'Likely' to occur. The potential residual impact of dust generation on vegetation health and condition, after implementation of management measures, is assessed as 'Low'.

Potential impact	Consequence	Likelihood	Residual Impact
Dust resulting in reduced vegetation health and condition	Incidental	Likely	Low

8.1.2.3 Increased Presence of Weeds Resulting in Reduced Native Vegetation Health and Condition

Vegetation condition in the Mine Site Development Envelope ranged from Excellent to Poor, with the majority assessed as being Excellent to Very Good, despite grazing within the Mt Jowlaenga pastoral lease. Weeds have the potential to outcompete and displace native vegetation if introduced or conditions are altered to favour their growth. Additionally, weeds can displace palatable feed for stock, reducing carrying capacity of pastoral areas.

Weeds may be spread and/or introduced by poor hygiene practices on vehicles and equipment, resulting in soil and weed vegetative material being transported around site and being present on equipment entering and exiting site. Additionally, favourable conditions for weed growth may be encouraged by watering and nutrient loading from land irrigation of treated wastewater. Weed species are known to occur within the Mine Site Development Envelope and surrounds (Ecologia 2012a, 2014b, 2015; Mattiske 2016).

Given the existing presence of weeds it is considered 'Unlikely' that project activities will result in an increased presence of weeds or any increased competition with native species given the proposed management measures. The potential residual impact of weeds on terrestrial flora, after implementation of management measures, is assessed as 'Low'.

Impact	Consequence	Likelihood	Residual Impact
Increased presence and health of weeds resulting in reduced native vegetation health and condition	Minor	Unlikely	Low

8.1.2.4 Modification of Surface Water Flows Resulting in Loss, or Reduced Health and Condition, of Native Vegetation

Small-scale, localised changes to surface water flows as a result of construction of infrastructure and the progressive excavation of the mineral deposit area are likely to occur during the wet season (December to April) following rainfall events. Changes in surface water flows may impact on established vegetation that is no longer receiving adequate resources to support growth, or vegetation may become inundated through extended ponding of stormwater, or failure of pipelines or other water infrastructure. Inundation causes stress and plant death when prolonged in those species not adapted to flooded conditions by decreasing oxygen levels within soils and impeding root respiration.

The volumes of runoff generated from the catchment upstream of infrastructure and the progressive mining excavation will be relatively small as they are adjacent to the major drainage divide between the Fraser River Catchment and Fraser River South Catchment, and therefore there is low flow accumulation. Additionally, runoff from the Mine Site area is inherently low due to low surface relief and high soil infiltration rates, with rainfall readily infiltrating through the soil to be utilised by vegetation in situ. This is evident by the absence of any defined drainage channels within the mine deposit area. In those areas outside of the mine deposit area where there are defined channels associated with runoff, such as across the proposed Site Access Road, infrastructure will be constructed with culverts and other drainage features to allow water to move through unimpeded.

It is considered 'Unlikely' that project activities will result in a decrease in health or abundance of native vegetation as a result of modifications to surface water flows. The potential residual impact of modifications to surface water flows on native vegetation, after implementation of management measures, is assessed as 'Low'.

Impact	Consequence	Likelihood	Residual Impact
Modification of surface water flows resulting in loss or reduced health and condition of native vegetation	Incidental	Unlikely	Low

8.1.2.5 Groundwater Abstraction Resulting in Loss, or Reduced Health or Condition, of Groundwater Dependent Ecosystems

Discussion on the impacts to potential GDEs is provided in Section 8.3.2.1.

8.1.2.6 Altered Fire Regime Resulting in Loss or Reduced Health and Condition of Native Vegetation

Bushfires are often caused by lightning and are considered a natural part of the environment as they can assist with regeneration of some species and ecosystems. Mining activities have the potential to ignite bushfires through hot work and other activities. Increased fire intensity and frequency can impact local flora and vegetation (Environs Kimberley 2013; EPA 2006b).

The presence of the project will reduce prescribed or intentional burning within the Mine Site Development Envelope and its surrounds, however mining activities will provide additional potential ignition sources. In order to reduce the likelihood of accidental ignition as a result of the project, fire and emergency management procedures will be developed for the project.

Vehicles will not be permitted to leave access tracks or cleared areas. Firefighting equipment will be maintained within light vehicles, earth moving equipment and buildings. Larger scale firefighting response will be provided as part of the projects Emergency Response Plan. Fire Breaks will be installed at key locations to minimise risk to people and infrastructure. Lightning protection will be installed within the processing plant to minimise risk of damage to key infrastructure. Implementation of a Hot Work permit system will minimise the risk of accidental fire due to project activities. The result of these changes is likely to be a reduction in widespread cool, controlled burns across the Mine Site Development Envelope and an increase risk of uncontrolled, hot burns for small areas within the Mine Site Development Envelope.

Fires may 'Possibly' cause 'Incidental' damage to native vegetation. The potential residual impact of increased fire risk on native vegetation, after implementation of management measures, is assessed as 'Low'.

Impact	Consequence	Likelihood	Residual Impact
Altered Fire regime resulting in loss or reduced health and condition of native vegetation	Incidental	Possible	Low

8.1.3 Management Measures

A summary of key measures to address potential impacts on flora and vegetation are listed in Table 56.

Table 56: Proposed Management Measures for Flora and Vegetation for the Mine Site Development Envelope

Potential Impact Requiring Management	Measure
Clearing resulting in loss of vegetation communities or significant species	• Land disturbance will be kept to the minimum necessary for development of the project. • Existing disturbed areas will be used wherever possible to minimise total ground disturbance. • Land clearing will be undertaking progressively with the amount of active disturbance minimised. • Ground disturbance procedures and a permitting system will be implemented. • Progressive rehabilitation will be undertaken on disturbed areas as they become available. • Monitoring of analogue and rehabilitated areas will be undertaken to ensure short, medium and long-term rehabilitation objectives are achieved. Monitoring will be carried out on a regular basis to assess the success of revegetation in rehabilitated areas. • Ongoing development of monitoring methodology and rehabilitation techniques will occur during the life of the project. Further assessments over time will plot the development of rehabilitated areas against analogue sites and progression towards completion targets. • Topsoil and vegetation (including woody debris) will be respread over rehabilitated areas to act as a seed source and to protect the soil from erosion. • Local provenance seed and propagated material will be used, if required, to rehabilitate disturbed areas • The site induction program will provide information on protection of vegetation and ground disturbance authorisation procedures.
Dust generated from mining activities resulting in reduced vegetation health and condition or loss of significant flora	• Vehicles and mining equipment will keep to designated roads. • Dust suppression will be carried out during construction, operation and closure.

Potential Impact Requiring Management	Measure
Increased presence and health of weeds resulting in reduced vegetation health and condition	• A weed hygiene system will be developed and implemented in consultation with the pastoralist. • Weed inspections will be conducted following significant rainfall, and depending on results, appropriate management actions will be implemented if required.
Modification of surface water flows resulting in loss or reduced health and condition of native vegetation	See Section 8.3.3 – Hydrological Processes Management Measures, Infrastructure causing localised reduction in surface water volumes and Infrastructure changing local drainage patterns and increasing flood risk.
Altered fire regime resulting in loss or reduced health and condition of native vegetation	• Firefighting equipment will be located on site and emergency personnel will be trained in fire response • Lightning protection equipment will be installed as part of project design where necessary. • Vehicles will not be permitted to leave access tracks or cleared areas. • A Hot Work Permit system will be developed and implemented. • All machinery and vehicles undertaking clearing activities will be fitted with firefighting equipment. • Sheffield will work with the pastoralist, Traditional Owners and DFES to undertake prescribed burns and install and maintain firebreaks if required so that potential environmental damage from extreme and out of control wildfires is minimised and infrastructure and the community are protected throughout the life of the project. • The project site induction will include information on the prevention and management of fires.
Radiation exposure resulting in loss or reduced health and condition of native vegetation	• Rehabilitated areas will be monitored to ensure radiation levels are within environmental screening criteria (10 µGy/h) or established pre-mining background levels.

8.1.4 Predicted Outcome

Clearing will result in the loss of vegetation however the majority of clearing (86%) is of communities that are common and widespread and all vegetation communities are represented outside the clearing footprint. Furthermore, the main clearing area is for the Mine Site Area, which will be progressively cleared and rehabilitated, therefore maintaining representation and diversity in the wider area as impacts will be short to medium term.

It is recognised that individuals of Priority listed species *Triodia caelestialis* (P3) and *Pterocaulon intermedium* (P3) will be impacted as a result of the proposal, however these taxa are considered to be widespread within the wider environment and are not restricted to the Mine Site Development Envelope. Whilst the Priority flora that Ecologia have recorded could not be substantiated by Mattiske (2016), impacts are not expected to be significant.

Dust, increased presence of weeds, modification of surface water flows, fire regimes and radiation exposure may affect flora and vegetation; however these impacts will result in localised and incidental effects on the health, abundance and structure of vegetation communities, all of which are well represented in the region.

Sheffield considers that the potential impacts to flora and vegetation will be able to be adequately managed such that the environmental objective for flora and vegetation (Section 8.1) will be met.

8.2 TERRESTRIAL FAUNA

The EPA's objective in relation to terrestrial fauna is "*to maintain representation, diversity, viability and ecological function at the species, population and assemblage level*".

8.2.1 Key Statutory Requirements, Environmental Policy and Guidance

Terrestrial fauna are protected under Commonwealth and State legislation, primarily governed by three Acts:

- *Wildlife Conservation Act 1950* (WA).
- *Environmental Protection Act 1986* (WA).
- *Environment Protection and Biodiversity Conservation Act 1999* (Cth).

In addition to Commonwealth and State legislation, the following policy and guidance statements were considered in undertaking fauna surveys and in the impact assessment for terrestrial fauna:

- EPA Position Statement No. 3, Terrestrial Biological Surveys as an Element of Biodiversity Protection (EPA 2002).
- EPA Guidance Statement No. 56, Terrestrial Fauna Surveys for Environmental Impact Assessment (EPA 2004d).
- EPA Guidance Statement No. 20, Short Range Endemic Invertebrate Fauna (EPA 2009a).
- EPA and DEC Technical Guide – Terrestrial Vertebrate Fauna Surveys for Environmental Impact Assessment (EPA and DEC 2010).
- Survey Guidelines for Australia's Threatened Mammals (DSEWPC 2011).
- Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) Guide G-1, Radiation Protection of the Environment (ARPANSA 2015).

8.2.2 Assessment of Potential Impact

Studies were carried out to provide baseline information to assist with assessing potential impacts to terrestrial fauna; these are detailed in Section 4.2.9. A description of the terrestrial vertebrate fauna found in the vicinity of the project is provided in Section 4.2.9, and a description of Short Range Endemic (SRE) species in Section 4.2.9.

Vertebrate fauna surveys recorded a total of 20 mammals, 118 birds, 44 reptiles and 8 amphibians occurring within the Mine Site Development Envelope or surrounding areas. Of these, nine were of conservation significance; however, only three were recorded within the Mine Site Development Envelope as shown in Figure 31 and Table 22. These were the Lakelands Downs Short-tailed Mouse, Greater Bilby and Rainbow Bee-eater.

Potential impact on the Greater Bilby (*Macrotis lagotis*), management measures and predicted outcomes are addressed in Section 13– Matters of National Environmental Significance.

SRE species surveys conducted in 2014 yielded a total of 200 invertebrate specimens with a total of 6 orders, 11 families and 31 taxa. Of these species, 22 were identified as being potential SRE, with one species (the land snail *Rhagada bulgana*) confirmed as a SRE (Section 4.2.9.5).

Potential impacts to terrestrial fauna in the Mine Site Development Envelope may occur as a result of:

- **Fragmentation of vertebrate fauna habitat resulting in displacement of fauna**.
- **Habitat clearing causing disturbance of conservation significant fauna species.**
- **Loss of SRE fauna habitat resulting in loss of SRE.**

- **Vehicle strike causing injury or death of native fauna.**
- **Increase in pest species impacting native fauna** – potential increase in populations and number of species of pests due to establishment of domestic waste disposal and permanent water storage facilities.
- **Altered fire regime impacting native fauna** – fire regimes may be altered due to implementation of the project.
- **Light and noise pollution disrupting native fauna.**
- **Fauna entrapment leading to injury or death**.

Other potential impacts were screened out from further assessment (Section 7.4) as they were either assessed as not likely to occur or were unlikely to have any discernible consequence on any factor different to background levels:

Stressor	Justification for Exclusion
Radiation exposure to native fauna	The vast majority of (98%) of process waste streams is from ilmenite processing or initially rejected sand/slimes material with low activity (0.39 Bq/g Appendix 21). Material with activity less than 1 Bq/g based on composition of Sheffield waste materials was not found to trigger Tier 1 Environmental screening criteria of 10 µGy/h using ERICA software assessment (ARPANSA 2015) for terrestrial fauna. Sheffield commit to mixing and co-disposal of wastes to <1 Bq/g (combined activity c.a. 0.74 Bq/g). Backfill areas will be monitored to ensure radiation levels are within environmental screening criteria (10 µGy/h) or established pre-mining background levels. The inherent use of wet slurries for transport of mine waste back to the void minimises potential for dust emissions of higher activity material.

Additionally the following species were screened out from further assessment as they were assessed as not likely to be either directly or indirectly impacted by the project (Section 4.2.9.3):

- Gouldian Finch.
- Oriental Pratincole
- Dampierland Plain Slider.
- Dampierland Burrowing Snake.
- Dampierland Peninsula Goanna.
- Wood Sandpiper.
- Eastern Yellow Wagtail.
- Grey Wagtail.

The assessed likelihood, consequence and residual impact (as per Section 7.3), is provided below for each potential impact.

8.2.2.1 Fragmentation of Vertebrate Fauna Habitat Resulting in the Displacement of Fauna

Clearing of vegetation can lead to fragmentation of fauna habitat and increased resource competition with species already using adjacent uncleared habitat. The proposed percentage impact from construction of the project to fauna habitats compared to known distributions by Ecologia mapping is shown in Table 57. The conceptual site layout over habitat type is shown in Figure 30.

Table 57: Proposed Impacts to Fauna Habitats of the Mine Site Development Envelope and Surrounding Area

Habitat	Vegetation Description	Geology, Soil, Landform Description	Total Mapped Area (ha)	Proposed Disturbance Within Survey Area (ha)
Pindan Shrubland	*Corymbia greeniana*, over a moderately open to dense shrub layer consisting primarily of *Acacia tumida var tumida*, *Acacia platycarpa* and *Grevillea refracta*. Ground vegetation layers consists of a mix of grasses including *Triodia caelestialis*, *Aristida holathera var holathera*, *Crysopogon* sp., *Eriachne obtusa* and *Sorghum plumosum*	Flat plains, with weak orange to red sandy-loam soils	9,908.1	2,036
Sandstone Range and Footslopes	*Corymbia dendromerinx* over moderately dense *Acacia drepanocarpa* subsp. latifolia over a ground vegetation layer of dense *Triodia caelestialis* hummock grassland and *Sorghum plumosum* tussock grassland.	Undulating hills, slopes and gullies of orange sandy soils with Sandstone residuals ranging from moderately dense pebbles to dense rocks	3,835.5	102.2
Savannah Woodland	Scattered *Eucalyptus tectifica* and *Brachychiton diversifolius*, with open to moderately dense shrubs of mainly *Acacia platycarpa*	Firm brown-white sandy clay soils	1,950.3	134.4
		Total	**15,693.9**	**2,272.6**

A total of 2,036 ha of Pindan Shrubland, 102.2 ha of Sandstone Range and Footslopes, and 134.4 ha of Savannah Woodland will be impacted over time by the project (Table 57). However, due to the nature of mineral sands mining, rehabilitation will be progressive as areas become available after mining, creating additional new habitat which can be colonised throughout the project life. Clearing activities will also be managed to ensure clearing is strictly limited to that necessary for the operations.

Clearing is 'Likely' to result in some displacement of fauna, however the overall habitat in the area will remain intact and is not anticipated to have lasting effects on population viability or abundance. The potential residual impact from the fragmentation of habitat on vertebrate fauna, after implementation of management measures, is assessed as 'Low'.

Impact	Consequence	Likelihood	Residual Impact
Fragmentation of vertebrate fauna habitat resulting in displacement of fauna	Incidental	Likely	Low

8.2.2.2 Habitat Clearing Causing Disturbance of Conservation Significant Fauna Species

The Lakelands Downs Short-tailed Mouse occupies a diverse range of habitats across northern Australia, from Cape York to the Pilbara in WA, with populations also occurring on Thevenard and Serrurier Island. Home ranges average around 5.3 ha and are larger during the non-breeding season. Habitat preferences are sandy soils and

cracking clays within WA (DPaW 2016d), which corresponds to the Pindan Shrubland and Savannah Woodland habitat types in the surveyed areas. The single specimen collected was found on the border of these two habitat types.

Based on project design, 2,036 ha (21%) of the Pindan Shrubland and 134.4 ha (7%) of the Savannah Woodland habitats within the survey area will be impacted by the project. This leaves 9,688 ha (82%) of potential habitat available for colonisation, and affected individuals are expected to move to suitable habitats outside the impact area.

Clearing associated with the project represents a localised loss of habitat for the conservation significant Short-tailed Mouse and minimal fragmentation of its habitat. Surveys have recorded that suitable habitat (Spinifex and tussock grasslands on cracking clays and acacia shrubland, samphire, woodlands and stony ranges) occur throughout most of the studied areas (Ecologia 2014a).

The Rainbow Bee-eater is found throughout mainland Australia except in desert areas and breeds throughout most of this range, although southern birds move north to over winter. Its habitat preference is most often open forest, woodlands, shrublands and cleared areas, usually near water. As detailed above 9,688 ha (82%) of mapped Pindan Shrubland and Savannah Woodland habitat will not be impacted by the project and sufficient habitat remains for the protection of this species in the area.

Forked-tailed Swifts are nomadic in response to broad scale weather pattern changes and are attracted to thunderstorms. They rarely land, living almost exclusively in the air. The species is considered a transient visitor to the Mine Site Development Envelope and may at times be found in varying numbers foraging in the air above the project area however this species does not rely on the area for its survival and will move to suitable habitats within the region.

Significant trees (especially those with hollows) for bird, bat and reptile habitat will be retained where practicable.

Project clearing will 'Almost Certainly' cause a localised, medium term loss of habitat for the conservation significant Short-tailed Mouse and Rainbow Bee-eater, however the habitats of both species are well represented in the region. The residual impact of habitat clearing on the Short-tailed Mouse and the Rainbow Bee-eater, after implementation of management measures, is assessed as 'Medium'.

Impact	Consequence	Likelihood	Residual Impact
Habitat clearing causing disturbance of conservation significant fauna species	Minor	Almost Certain	Medium

8.2.2.3 Loss of SRE Fauna Habitat and Loss of SRE

Potential impacts that could affect SRE fauna as a result of the project include:

- Clearing of vegetation or habitats with known potential to support SRE fauna.
- Directly removing known populations of SRE fauna.

The status of SRE invertebrate fauna recorded at Mine Site Development Envelope and surrounding area was based on categories developed by the Western Australian Museum and modified by Ecologia (2014a) in order to describe the status of taxa using current knowledge of distribution and biology of each species.

A vulnerability rating has been included in Table 58 in order to inform the assessment of the likelihood of SRE species being lost as a result of clearing in the Mine Site Development Envelope. This vulnerability rating is based on the number of locations where specimens were collected and the prevalence outside the Mine Site Development Envelope of the habitat types at these locations. Species collected from multiple locations within a common habitat type are considered to have a low vulnerability rating, whilst those collected from either multiple

locations or a common habitat type (but not both) are considered to have a medium vulnerability rating. Species which were collected in only one location in a rare habitat type are considered to have a high vulnerability rating.

Most SRE species recorded in the Mine Site Development Envelope are considered to have a low vulnerability rating, and no SRE species are considered to have a high vulnerability rating (Table 58). Of the six species with a medium vulnerability rating, five (*Aname* 'MYG387?', *Aname* 'sp. indet.', *Aname* 'sp. juv.', *Urodacus sp.* indet. and *Olpiidae* 'genus indet. (juvenile)') were either juvenile or female and thus identification to species level could not be confirmed.

Lychas 'JPP2' (a morphospecies of *Lychas* 'JPP') has a medium vulnerability rating due to only being collected once, and as such will be impacted by clearing in the Mine Site Development Envelope. However based on species surrogates (*Lychas* 'JPP', *Lychas* 'JPP1' and *Lychas* 'JPP3', which are found several kilometres from *Lychas* 'JPP2') it can be inferred that *Lychas* 'JPP2' has a high probability of occurring outside the Mine Site Development Envelope. In addition and taking into consideration habitat surrogates, *Lychas* 'JPP2' was recorded from the extensive Pindan Shrubland and Savannah Woodland habitats which extend well beyond the impact area, increasing the probability of the species occurring outside the Mine Site Development Envelope.

In order to protect SRE habitat clearing activities will be managed to ensure clearing is strictly limited to that necessary for operations and disturbed areas will be rehabilitated as they become available.

It is 'Almost Certain' that the project will result in localised loss of SRE habitat (Figure 32), however the habitat types that most species were found in are well represented in the region. It is 'Almost Certain' that the project will cause a loss of SRE individuals, although it is not expected that this will affect population viability or abundance. The potential residual impact from loss of SRE habitat on SRE, after implementation of management measures, is assessed as 'Medium'.

Impact	Consequence	Likelihood	Residual Impact
Loss of SRE fauna habitat and loss of SRE	Incidental	Almost Certain	Medium

Table 58: Relative Vulnerability of the Mine Site Development Envelope on SREs

Order	Family	Species	SRE Status	Collected From Multiple Locations	Collected From Common Habitat	Relative Vulnerability
Mygalomorphae (Spiders)	Nemesiidae	*Aname* 'MYG284'	Potential	X	X	Low
		Aname 'MYG285'	Potential	X	X	Low
		Aname 'MYG387'	Potential	X	X	Low
		Aname 'MYG387?'	Note 1		X	Medium
		Aname 'MYG388'	Potential	X	X	Low
		Aname 'sp. indet.'	Note 2 and 3		X	Medium
		Aname 'sp. juv.'	Note 2 and 3		X	Medium
Arachnida (Opiliones)	Assamiidae	*Dampetrus* sp.	Potential	X	X	Low
Scorpiones (Scorpions)	Buthidae	Lychas 'annulatus'	No	X	X	Low
		Lychas 'broome'	Potential	X	X	Low
		Lychas 'JPP'	Potential	X	X	Low
		Lychas 'JPP1'	Potential	X	X	Low
		Lychas 'JPP2'	Potential		X	Medium
		Lychas 'JPP3'	Potential	X	X	Low
		Lychas 'multipunctatus'	No	X	X	Low
	Urodacidae	*Urodacus 'kraepelini'*	Potential	X	X	Low
		Urodacus sp. indet.	Note 2		X	Medium
Pseudoscorpiones	Sternophoridae	*Afrosternophorus* sp. indet.	No	X	X	Low
	Chernetidae	*Haplochernes* sp. Indet.	No	X	X	Low
	Olpiidae	*Beierolpium* 'sp. 8/4'	No	X	X	Low
		Olpiidae 'genus indet. (juvenile)'	Note 2 and 3		X	Medium
		Indolpium'sp. Indet.'	No	X	X	Low
Isopoda (Slaters)	Armadillidae	*Armadillidae* 'EE1501C'	Potential	X	X	Low
		Buddelundiinae 'genus indet. NE Broome'	Potential	X	X	Low
		Buddelundiinae sp. 74	Potential	X	X	Low
		Buddelundia sp. '90'	Potential	X	X	Low
		Buddelundia sp. '91'	Potential	X	X	Low

Order	Family	Species	SRE Status	Collected From Multiple Locations	Collected From Common Habitat	Relative Vulnerability
Gastropoda (Snails)	Subulinidae	*Eremopeas interioris*	No	X	X	Low
	Pupillidae	*Pupoides pacificus*	No	X	X	Low
	Camaenidae	*Quistrachia leptogramma*	Potential	X	X	Low
		Rhagada bulgana	Confirmed	X	X	Low

Note 1: Single female specimen captured. Could be conspecific with Aname 'MYG387'.

Note 2: Specimen was unable to be identified to species level.

Note 3: Only juveniles collected.

8.2.2.4 Vehicle Strike Causing Injury or Death of Native Fauna

Injury or death of fauna from vehicle strike is most likely to occur along the Site Access Road and village access roads due to relatively high volumes of traffic. The implementation of lower traveling speeds (particularly at night) will reduce this likelihood of vehicle strikes. Additionally, the width of the Site Access Road corridor (up to 62 m including other services) will allow drivers to identify fauna well in advance allowing them to slow down or stop. All fauna injuries and/or deaths will be reported as required and the site induction program will provide information of fauna of conservation significance, their appearance and habitats.

It is 'Likely' that infrequent vehicle strikes will occur within the Mine Site Development Envelope, but this will not affect fauna population viability or species diversity. The potential residual impact from vehicle strikes on native fauna, after implementation of management measures, is assessed as 'Low".

Impact	Consequence	Likelihood	Residual Impact
Vehicle strike causing injury or death of native fauna	Incidental	Likely	Low

8.2.2.5 Increase in Pest Species Impacting Native Fauna

The establishment of both domestic waste disposal areas and new water sources can result in an increase in pest species attracted to the area. This can result not only in an increase in predation of native fauna but also result in an increase in competition for food resources. Fencing of waste disposal and water sources will limit the increase of these species within the Mine Site Development Envelope. Additional management measures such as the regular covering of wastes as well as trapping of feral predators will further reduce the impact to native fauna.

It is 'Unlikely' that pest species will impact upon the population viability and abundance of native fauna populations. Any increase in pest species numbers will be localised, and it is anticipated that controls will be effective and will limit pest species populations from becoming established. The potential impact of an increase in pest species on native fauna, after implementation of management measures, is assessed as 'Low'.

Impact	Consequence	Likelihood	Residual Impact
Increase in pest species impacting native fauna	Incidental	Unlikely	Low

8.2.2.6 Altered Fire Regimes Impacting Native Fauna

The Kimberley region is subject to frequent burning, which has increased in intensity in recent years; either as a result of natural or deliberate events (Section 4.2.11). Controlled burning conducted as part of pastoral activities will not be conducted on the same frequency or extent within the Mine Site Development Envelope as a result of implementation of the project. Due to the increased presence of people and machinery in the area there is however an increased risk of accidental fires, which could affect fauna and habitat on a local and regional scale. The project site induction will include information on the prevention and management of accidental fires. Should a fire occur, fauna are likely to move away from the fire.

Vehicles will not be permitted to leave access tracks or cleared areas. Firefighting equipment will be maintained within light vehicles, earth moving equipment and buildings. Larger scale firefighting response will be provided as part of the projects Emergency Response Plan. Fire breaks will be installed at key locations to minimise risk to people and infrastructure. Lightning protection will be installed within the processing plant to minimise risk of damage to key infrastructure. Implementation of a Hot Work permit system will minimise the risk of accidental fire due to project activities. The result of these changes is likely to be a reduction in widespread cool, controlled burns across the Mine Site Development Envelope and an increase risk of uncontrolled, hot burns for small areas within the Mine Site Development Envelope.

It is 'Unlikely' that an accidental fire will occur, and any loss of habitat from fire is likely to be localised and short-term. The potential residual impact of altered fire regime on native fauna, after implementation of management measures, is assessed as 'Low'.

Impact	Consequence	Likelihood	Residual Impact
Altered fire regime impacting native fauna	Incidental	Unlikely	Low

8.2.2.7 Light and Noise Pollution Disrupting Native Fauna

Light and noise pollution can result in a disruption to the natural behaviours of fauna, in particular those that are nocturnal by interfering with the timing of necessary biological activities. Artificial light sources and noise pollution at night seriously constrain their lives, exposing them to predators and reducing the time available to find food, shelter, or mates with which to reproduce.

The amount of natural habitat surrounding the project means that impacts are likely to be minimal, and susceptible affected fauna are likely to move away from noise or light sources. Management measures to limit the impact of noise and light on fauna will be considered during the design, construction and operational phases of the project and engineering controls implemented where possible.

Light and noise may 'Rarely' impact local fauna, causing some displacement of fauna with no lasting effects; however no mortality of individuals is expected. The potential residual impact of light and noise on fauna, after implementation of management measures, is assessed as 'Low'.

Impact	Consequence	Likelihood	Residual Impact
Light and noise pollution disrupting native fauna	Incidental	Rare	Low

8.2.2.8 Fauna Entrapment Leading to Injury or Death

Trenches, excavations, and water storage structures often have steep, slippery sides which prevent fauna that fall into them from escaping. Fauna may also be attracted to waste storage bins or domestic waste facilities, and become trapped. Entrapment may lead to fauna injury or death from starvation, dehydration, drowning, or injury. Artificial water sources will have fauna egress points so that fauna will be able to escape over and above being fenced. Open holes, trenches (if applicable) and the refuse impoundment will be fenced and visual inspections will be implemented to reduce the potential impact to fauna

Fauna mortalities are considered 'Unlikely' to occur, and will not result in effects on population viability or species diversity. The potential residual impact of entrapment on fauna, after implementation of management measures, is assessed as 'Low'.

Impact	Consequence	Likelihood	Residual Impact
Fauna entrapment leading to injury or death	Incidental	Rare	Low

8.2.3 Management Measures

A summary of key measures to address potential impacts on terrestrial fauna is shown in Table 59.

Table 59: Proposed General Management Measures for Terrestrial Fauna for the Mine Site Development Envelope

Potential Impact Requiring Management	Measure
Fragmentation of vertebrate fauna habitat resulting in displacement of fauna Loss of SRE fauna habitat resulting in loss of SRE	• Clearing activities will be managed to ensure clearing is strictly limited to that necessary for operations. • Land clearing will be undertaking progressively with the amount of active disturbance minimised. • Disturbed areas will be rehabilitated as they become available. • Topsoil and vegetation will be respread over rehabilitated areas to act as a seed source and mulch to protect the soil from erosion and provide habitat for fauna.
Habitat clearing causing disturbance of conservation significant fauna species	• Significant trees (especially those with hollows) will be retained where practicable.
Vehicle strikes causing injury or death of native fauna	• Speed limits will be implemented for operational areas and the Site Access Road in order to minimise the risk of fauna injury or mortality from vehicle strike. • Personnel will be required to adhere to speed limits and drive to road/weather conditions to minimise risks of fauna injuries or death due to vehicle traffic • The Site Access Road will be constructed with a 5 m buffer of cleared area on each side with topsoil stockpiles located up to 20 m away from the trafficable surface. • Travel between dusk and dawn on the Site Access Road and village access road will be limited to essential travel with driving speed limits set to reduce the potential for road strikes. • The site induction program will provide information on fauna of conservation significance, including their appearance and habitats.
Increase in pest species impacting native fauna	• Sheffield will undertake pest animal control in co-operation with regional control programs. • Domestic waste facilities will be fenced and putrescible wastes will be regularly covered. • Borrow pits will be designed and constructed to minimise surface water ponding after rehabilitation.
Changes to fire regimes impacting native fauna	• Firefighting equipment will be located on site and emergency personnel will be trained in fire response. • Lightning protection equipment will be installed as part of project design where necessary. • Vehicles will not be permitted to leave access tracks or cleared areas. • A Hot Work Permit system will be developed and implemented. • All machinery and vehicles undertaking clearing activities will be fitted with firefighting equipment. • Sheffield will work with the pastoralist, Traditional Owners and DFES to undertake prescribed burns and install and maintain firebreaks if required so that potential environmental damage from extreme and out of control wildfires is minimised and infrastructure and the community are protected throughout the life of the project. • The project site induction will include information on the prevention and management of fires.

Potential Impact Requiring Management	Measure
Light and noise emissions disrupting native fauna	• Lights will be strategically placed and designed to shine towards plant operations and minimise light spill to the environment. • Equipment design will be specified to be within Australian standard noise limits.
Fauna entrapment leading to injury or death	• Artificial water sources will have egress points installed. • Open holes, trenches, the refuse impoundment, and any water holding facilities will be inspected regularly for fauna. • Domestic waste facilities will be fenced and putrescible wastes will be regularly covered.

8.2.4 Predicted Outcome

It is likely that clearing associated with the project will result in some habitat fragmentation, but the impacts on terrestrial vertebrate fauna (including conservation significant species) and SREs are likely to be incidental due to availability of habitat outside the Mine Site Development Envelope and the progressive nature of the majority of land clearing.

The presence of pest species, light, noise, and radiation may affect fauna, however these impacts are not considered likely to cause fauna injury or mortality. Fauna injury or mortality due to vehicle strikes, fire, or entrapment may occur, however are not considered likely to impact native fauna population viability or diversity. These impacts are able to be adequately managed by mitigation and management measures.

Sheffield considers that the potential impacts to terrestrial fauna will be able to be adequately managed such that the environmental objective for terrestrial fauna (Section 8.2) will be met, and that the residual impacts are therefore acceptable.

8.3 HYDROLOGICAL PROCESSES

The EPA's objective in relation to hydrological processes is "*to maintain the hydrological regimes of groundwater and surface water so that existing and potential uses, including ecosystem maintenance, are protected*".

8.3.1 Key Statutory Requirements, Environmental Policy and Guidance

Groundwater and surface water is protected by the following State legislation:

- *Rights in Water and Irrigation Act 1914 (WA).*
- *Country Areas Water Supply Act 1947 (WA).*
- *Environmental Protection Act 1986 (WA).*

In addition to State legislation, the following policy and guidance statements were considered in the impact assessment for hydrological processes:

- EPA Position Statement No. 4, Environmental Protection of Wetlands (EPA 2004a).
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 (Commonwealth) (ANZECC and ARMCANZ 2000).
- State Water Quality Management Strategy Document No. 6 (DoW 2004).

- Operational Policy No. 5.12, Hydrogeological Reporting Associated with a Groundwater Well Licence (DoW 2009).
- Water Quality Protection Guidelines No. 11, Mining and Mineral Processing, Mine Dewatering (WRC 2000).
- DoW Report No. 12, Western Australian Water in Mining Guideline. Water licensing delivery report series (DoW 2013).
- Water Quality Protection Guidelines for Mining and Mineral Processing (WRC 2000).
- State Water Quality Management Strategy Document No. 6 (DoW 2004).
- National Water Quality Management Strategy (ARMCANZ and ANZECC 1995).
- Kimberley Regional Water Plan (DoW 2010).

The following documents were also considered:

- Kimberley Regional Planning and Infrastructure Framework (DoP and WAPC 2015).

8.3.2 Assessment of Potential Impact

8.3.2.1 Groundwater

Mine and mineral separation activities require water to be supplied at certain volumes during the project's life; Table 9 and Table 10 summarise the anticipated sources and extent of project water supply. During the early years of project life, overall water demand for the project is met entirely from a project-specific borefield targeting the Broome Sandstone Aquifer. In order to maintain safe mining conditions during later mining years, water is required to be abstracted from the mine deposit area, also within the Broome Sandstone Aquifer. The dewatering volume will exceed project demand, so it is proposed to artificially recharge the excess back into the Broome Sandstone Aquifer downstream of the mining operations. There is no other suitable management alternative (e.g. use or disposal).

Groundwater within the Broome Sandstone Aquifer underlying the Mine Site Development Envelope is deep (in excess of 20m below ground level). Several areas of perched groundwater exist within the Mine Site Development Envelope (Section 4.2.5.5); these are not connected with the deeper Broome Sandstone Aquifer to be targeted by abstraction and will not be affected by dewatering (Rockwater 2016; Appendix 8).

A three-dimensional groundwater model was prepared to enable predictions of the extent and magnitude of groundwater drawdown and mounding associated with life of mine water demand (Rockwater 2016; Appendix 8). The model was calibrated against a number of data sets and is considered appropriate for prediction of cumulative impacts associated with the borefield and with tailings storage of mine waste backfill. The model was prepared to enable a range of climate change scenarios to be considered, with variations to outcomes identified.

Modelling has indicated that abstraction within the water supply and dewatering borefields will cause drawdown of existing groundwater levels (Table 60). A 1 m drawdown contour is shown in Figure 44 for Year 15; Figure 45 for Year 32; and Figure 46 for Year 47 in mine life for a variety of climate scenarios (annual rainfall 10, 50 and 90 percentile from predicted). Modelled differences between the three climate scenarios are small, as would be expected given that most of the dewatering comes from aquifer storage rather than recharge. Drawdown extent is maximal under the high rainfall scenario which requires extra dewatering effort, and conversely under the dry rainfall scenario, less dewatering effort is required. A gradual increase in the area impacted by the 1 m drawdown contour occurs during the period of dewatering, from Year 15 to Year 47. Post-mining aquifer recovery was simulated via the transient response of aquifer recovery from Year 47 onwards, and did not include borefield extraction or reinjection. At two years post-mining, the magnitude of drawdown has declined markedly from greater than 40 m to less than 7.5 m. After 10 years post-mining the residual drawdown is confined to an area close to the mining deposit area and the magnitude is less than 2 m (Figure 47).

Groundwater mounding of up to about 12 m is predicted as a result of reinjection at the end of mine life (Table 60). However, as the unsaturated zone is more than 30 m deep in this region, groundwater mounding is not predicted to result in surface-waterlogging or other mounding impacts (Rockwater 2016). Mounding due to seepage from tailings disposal is likely to occur (especially in the first 15 years of mining) with modelling suggesting that it may be up to about 24 m (Table 60). However, as for reinjection, tailings mounding occurs in regions where the unsaturated zone is relatively deep (about 40 m), therefore it is not predicted to result in surface-waterlogging or other mounding impacts (Rockwater 2016). Post-mining aquifer recovery was simulated via the transient response of aquifer recovery from Year 47 onwards, and did not include borefield extraction or reinjection. Mounding rapidly reduces upon cessation of mining, with mounding negligible after two years. Predicted mounding contours at 10 years post-mining (Figure 47) show that residual groundwater mounding is negligible.

Table 60: Summary of Modelled Drawdown and Mounding from Project Activities

Assessment Area	Mining Year		
	Year 15	Year 32	Year 47
Borefield Drawdown	≤ 11 m	≤ 20 m	≤ 43 m
Reinjection Borefield Mounding	N/A	N/A	≤ 12 m
Tailings Seepage Mounding	≤ 20 m	≤ 11 m	≤ 3 m

Impacts to groundwater quality are discussed in Section 8.4.

Potential impact pathways for groundwater regimes are:

- **Groundwater abstraction and dewatering causing localised lowering of groundwater levels** causing vegetation decline in groundwater dependent ecosystems.

Other potential impacts to groundwater were screened out from further assessment (Section 7.4) as they were either assessed as not likely to occur or were unlikely to have any discernible consequence on any factor different to background levels:

Stressor	Justification for Exclusion
Abstraction causing a reduction in groundwater availability to other users	Groundwater availability in the Canning-Pender Groundwater sub-area is currently estimated to be 47.7 GL/yr (DoW, 2010), significantly more than the proposed project-related net abstraction of approximately 10.7 GL/yr or 12.2 GL/yr in the first year (net abstraction is the water supply and dewatering volume minus aquifer reinjection of excess dewatering volumes). Additionally, the groundwater resources of the Broome Sandstone Aquifer for the Canning-Pender sub-area of the Canning-Kimberley Groundwater Area have 95.4% of its 50 GL/yr available allocation unused. Licence entitlements within the sub-area total 2.3 GL/yr, with one major user (Kilto Station, 2 GL/yr) located about 40 km southwest of the Mine Site Development Envelope. The nearest licensed users and nearest registered Indigenous heritage sites are at least 30 km from the Mine Site Development Envelope, outside the modelled drawdown. It is not thought that drawdown will impact on the Water Corporation's Broome Borefield located in the Broome Groundwater Area about 12 km northeast of Broome (about 80 km southwest of the Mine Site Development Envelope) (Figure 24).

Stressor	Justification for Exclusion
Localised lowering of groundwater levels reducing subterranean fauna habitat	Given the wide extent of the Broome Sandstone Aquifer across the Canning Basin, together with the lack of any significant obligate stygofauna identified within the study area and the relatively localised impact on aquifer saturated thickness, groundwater drawdown will have incidental impacts on subterranean fauna (See Section 10.2.2). No specific management actions are proposed for subterranean fauna.
Process waste disposal and water reinjection causing localised increase in groundwater levels	Groundwater mounding of up to about 13 m is predicted as a result of reinjection at the end of mine life. However, as the unsaturated zone is more than 30 m deep in this region, groundwater mounding is not predicted to result in surface-waterlogging or other mounding impacts (Rockwater 2016). Mounding due to seepage from tailings disposal is likely to occur (especially in the first 15 years of mining) with modelling suggesting that mounding may be up to about 24 m. However, as for reinjection, tailings mounding occurs in regions where the unsaturated zone is relatively deep (about 40 m), therefore groundwater mounding is not predicted to result in surface-waterlogging or other mounding impacts (Rockwater 2016).

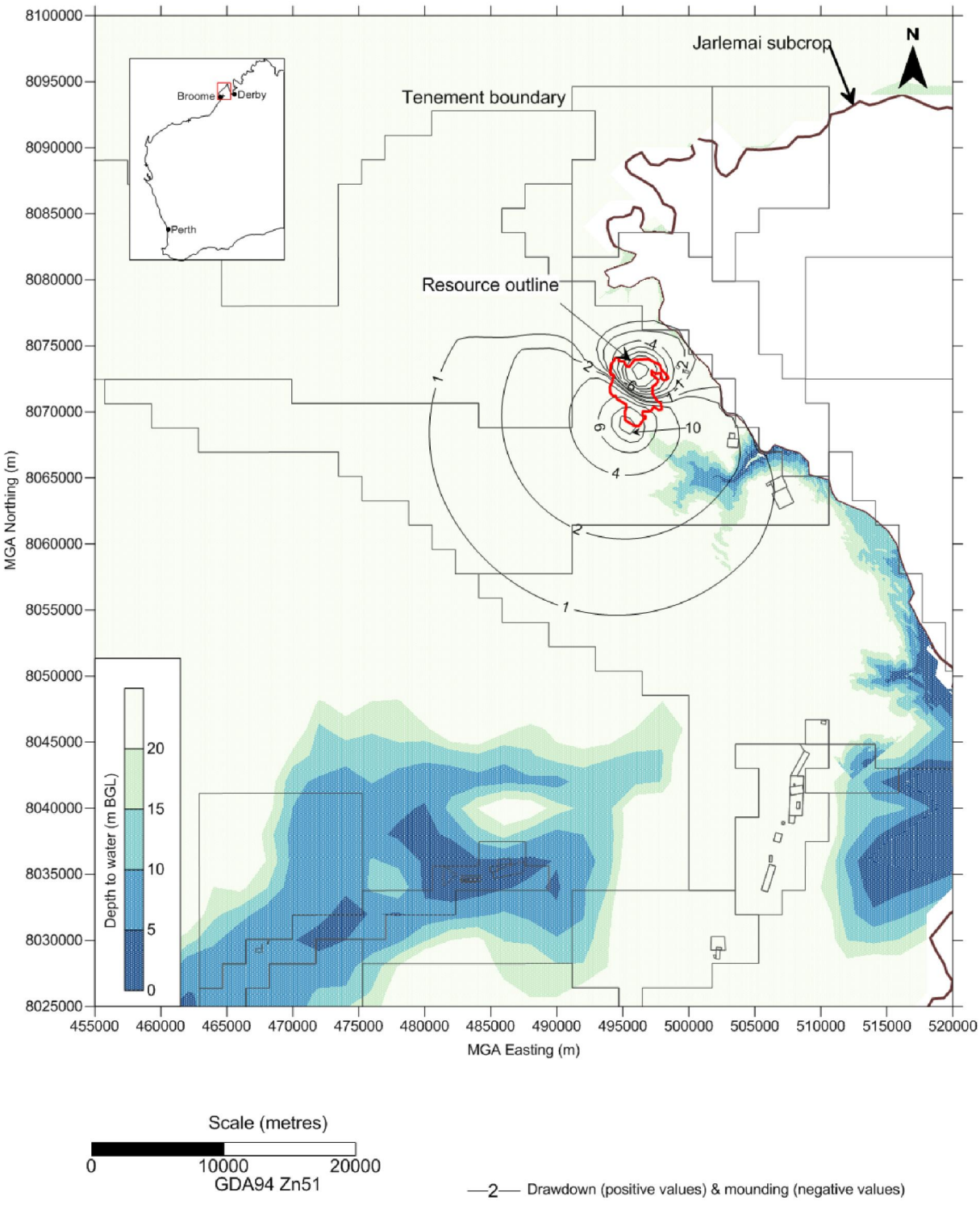


Figure 44: Modelled Groundwater Drawdown and Mounding Year 15 of Mine Life

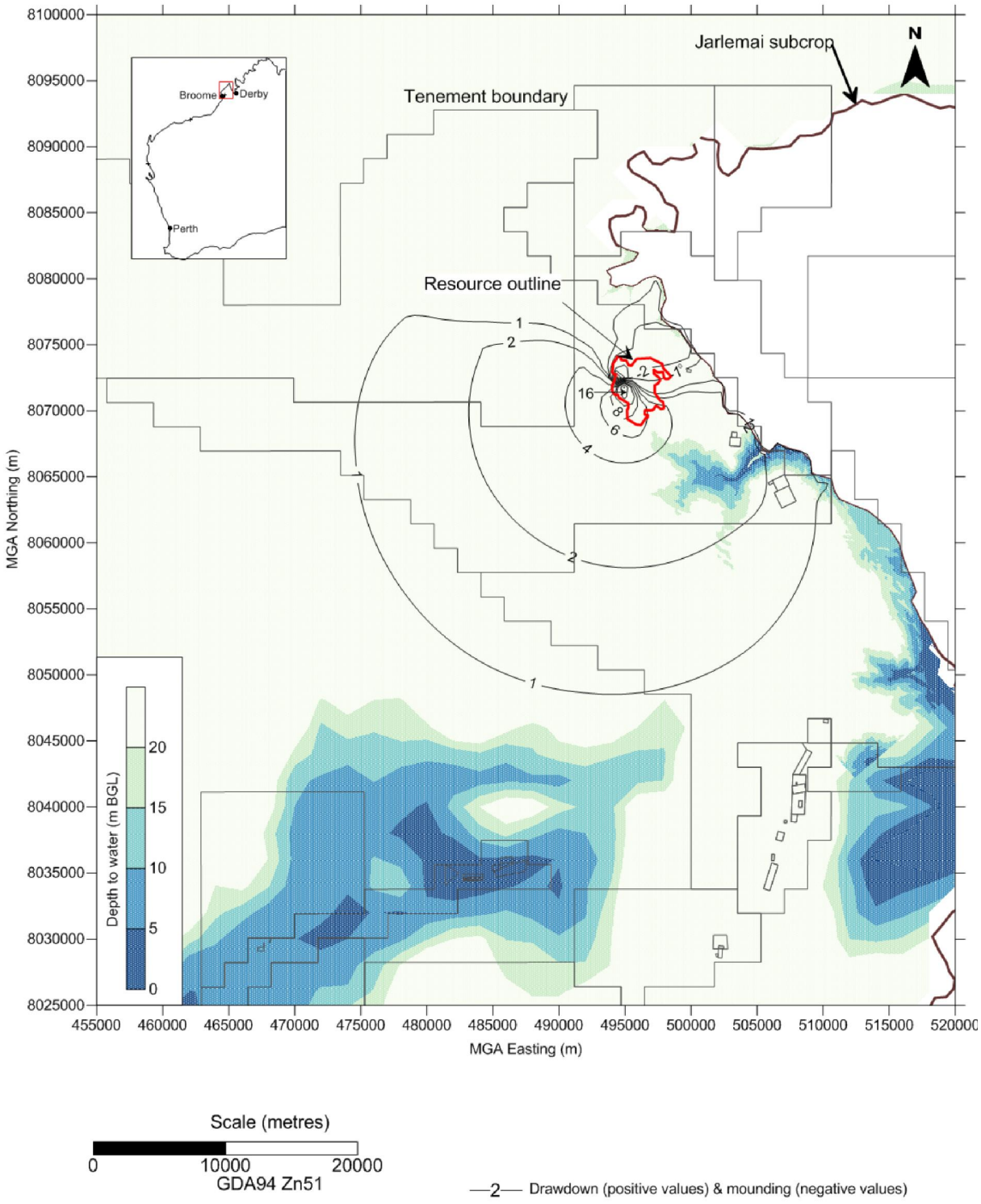


Figure 45: Modelled Groundwater Drawdown and Mounding Year 32 of Mine Life

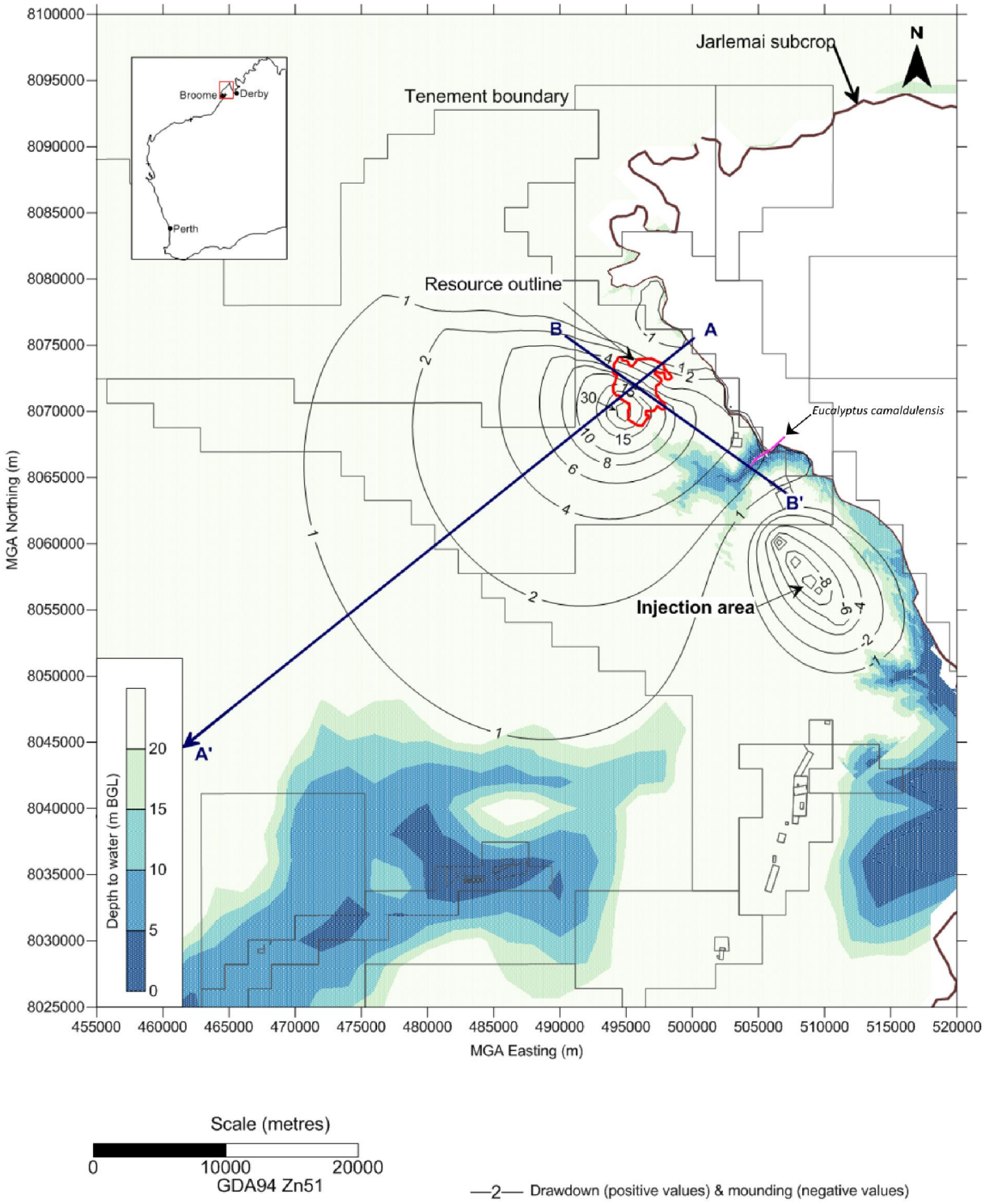


Figure 46: Modelled Groundwater Drawdown and Mounding Year 47 of Mine Life

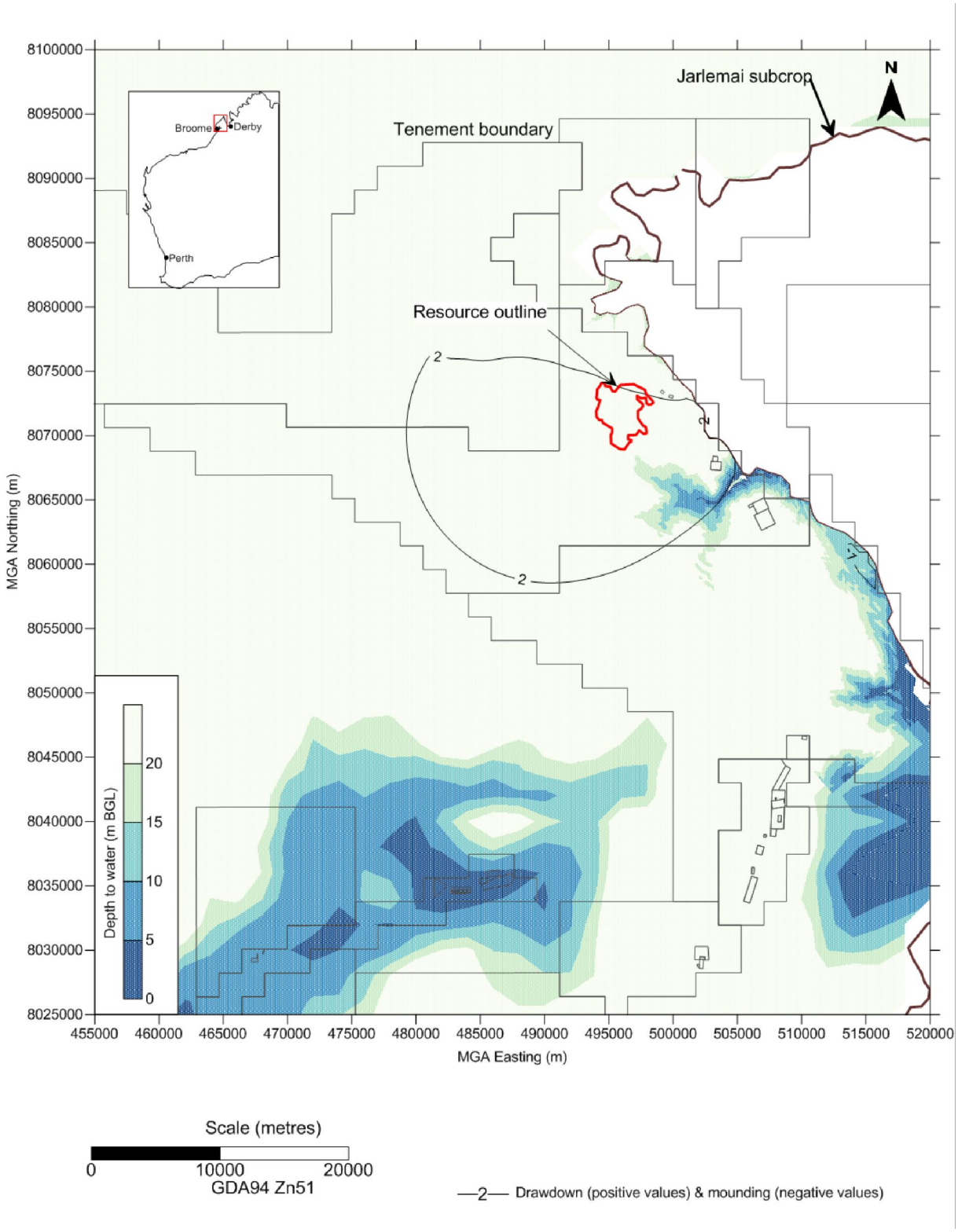


Figure 47: Modelled Groundwater Drawdown and Mounding 10 Years Post Cessation of Groundwater Abstraction and Reinjection

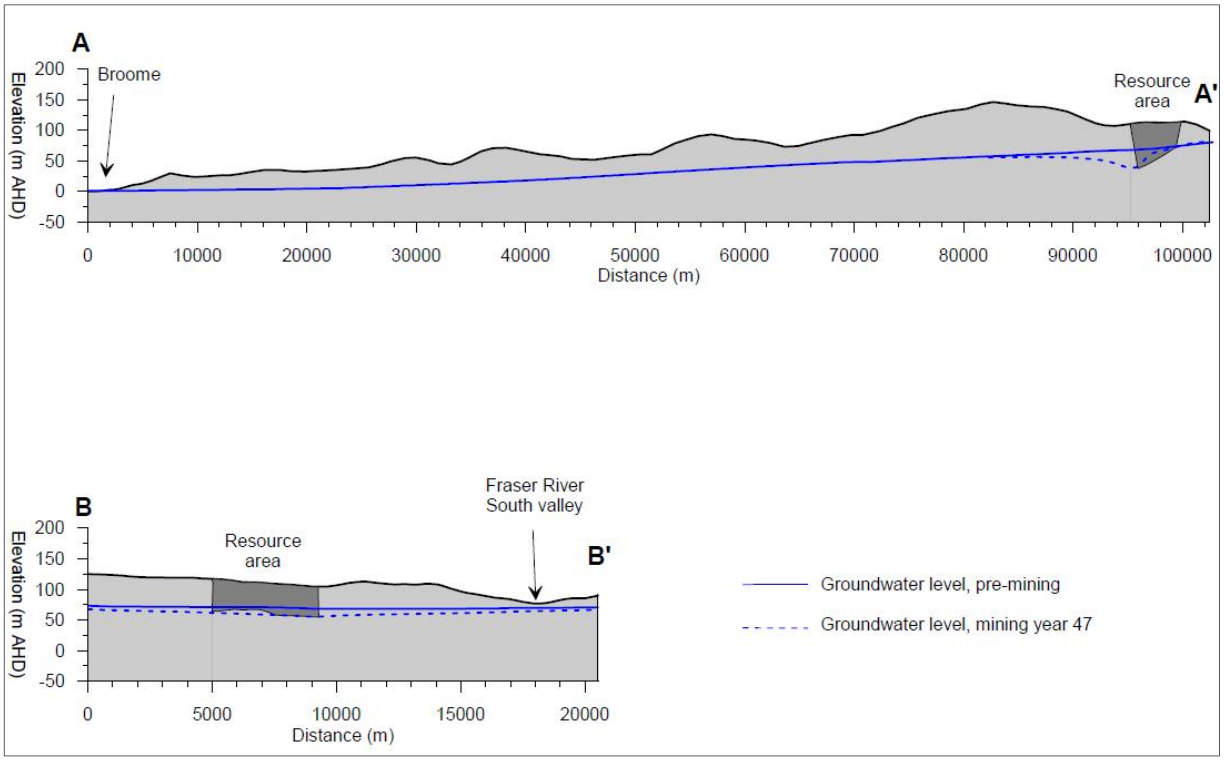
Localised Lowering or Rise of Groundwater Levels Causing Vegetation Decline in Groundwater Dependant Ecosystems

Drawdown of the groundwater table resulting from mine dewatering and abstraction is predicted to be contained largely within the mining lease and it is anticipated that any impact to nearby ecosystems, if this occurs, will be gradual and minimal. Several areas of vegetation associated with ephemeral waterlogging were noted during early investigations of the project area as potential GDEs, including intermittent 'soaks' to the southeast and northeast of the Mine Site Development Envelope. These areas are considered to be disconnected from or have limited connection to the aquifer to be targeted for abstraction (Section 4.2.5.5; Appendix 8), so will not be impacted by modelled drawdown (Table 61).

Vegetation community W14 in the Fraser River South valley to the south east of the mine area, is the only community identified as groundwater dependent due to the presence of *Eucalyptus camaldulensis* (Section 4.2.8.4; Appendix 8). The existing depth to groundwater in this area was interpolated to range from approximately 5 to 20 m below ground level (Appendix 8), and has a gradual modelled drawdown of approximately 2.7 m over the 32 year abstraction period (Table 61, Figure 46 and Figure 47).

Table 61: Summary of Modelled Drawdown and Mounding in the Vicinity of Interpreted Perched Groundwater Ecosystems

Assessment Area	Mining Year		
	Year 15	Year 32	Year 47
'Nearby Soak'	≤ 3.7 m	≤ 3.8 m	≤ 6 m
Fraser River South	~ 2 m	≤ 2.6 m	≤ 2.7 m



Section locations shown on Figure 46. Source: Rockwater 2016.

Figure 48: Hydrological Cross Sections Mining Year 47

As the area has a lower transmissivity basal transition unit (Rockwater 2016), the extent to which drawdown would affect vegetation is not certain. Given that modelled drawdown is not predicted to reduce groundwater levels below 10 to 12 m, the threshold at which a decline in health of *Eucalyptus camaldulensis* would be expected (after Colloff 2014), it is considered unlikely that adverse impacts to trees within the vegetation community would occur. Additionally, any adverse impacts are highly unlikely to impact on the distribution of the species as *Eucalyptus camaldulensis* occurs widely outside of the project area, across most of the Australian mainland (Chippendale 1988, DPaW 2016b).

Notwithstanding, a precautionary adaptive management approach is proposed to monitor vegetation and associated groundwater levels. Monitoring bores will be installed near Fraser River South and baseline groundwater monitoring will be conducted prior to the commencement of dewatering to provide further clarity around vegetation reliance on groundwater and any impacts of dewatering, should they occur. During abstraction, monitoring will continue, with trigger levels and mitigation measures implemented to maintain water levels should this area be shown to be impacted by groundwater drawdown. Part of the reinjection borefield could be relocated to maintain water levels in this area if required. These management measures are outlined in the Groundwater Management Plan (Appendix 24).

All groundwater abstraction, monitoring and reporting activities will be conducted in accordance with relevant regulatory permits and licences, and the volume of water abstracted will only be that required for safe mining operations. Flow meters will be fitted to groundwater extraction bores to enable monitoring of abstraction volumes.

The likelihood of groundwater level changes as a result of Project activities impacting on potential GDEs present in Fraser River South is 'Possible', however the consequence is considered as 'Minor' as modelled drawdown over the 32 year abstraction period is gradual. The potential residual impact on this community from changes in groundwater levels, after implementation of the management measures outlined in the Groundwater Management Plan, is assessed as 'Medium'.

Impact	Consequence	Likelihood	Residual Impact
Localised Lowering or Rise of Groundwater Levels Causing Vegetation Decline in Groundwater Dependant Ecosystems	Minor	Possible	Medium

8.3.2.2 Surface Water

Surface water flow volume within the Mine Site Development Envelope is inherently low due to high soil infiltration rates and low surface relief, with rainfall readily infiltrating through the soil, evident by the absence of any well-defined drainage channels within the mineral deposit area. The proposed location of all mine deposit and mineral separation plant infrastructure is within 5 km of the major drainage divide between the Fraser River South and Fraser River catchments and (other than the southernmost 500 m of the mineral deposit area) will only receive surface runoff from small local catchments.

While there are no visually discernible drainage lines requiring diversion, some of the project infrastructure lies over broad depressions which may be subject to waterlogging in wet conditions. The southernmost 500 m of the mineral deposit area extends across a broad valley receiving runoff from a catchment area of 108 km^2 which will require temporary diversion while that portion is being mined. The Site Access Road transverses an area of undulating terrain with drainage channels of the Fraser River South and Little Logue River catchments. During mining operations all surface runoff within the active mining area of up to 200 ha will be captured and used for process water.

Potential impact pathways for surface water regimes are:

- **Infrastructure causing localised reduction in surface water volumes.**
- **Infrastructure changing local drainage patterns and increasing flood risk.**
- **Surface water management structures causing localised erosion and sedimentation** - inappropriately engineered and constructed water management structures causing localised erosion and sedimentation surface of creek lines and drainage channels during rainfall events.

Impacts to surface water quality are discussed in Section 8.4. The assessed likelihood, consequence and residual impact (as per Section 7.3), is provided below for each potential impact.

Infrastructure Causing Localised Reduction in Surface Water Volumes

The only significant reduction in surface water volumes will be due to the capture of incident rainfall in the active mining area. This water will be captured in sumps and used as process water. The reduction in volume will be small as the mining area will be limited to approximately 200 ha (2 km^2) at any time. Surface flow from upstream of the active area will be diverted around the active mining area so only direct rainfall will be captured. The valley immediately south of the mineral deposit area has a catchment area of 108 km^2 so the impact of loss of runoff from 2 km^2 during mining operations will be incidental (<1%). The Fraser River South catchment at the Site Access Road is 369 km^2 so the impact of reduced volumes is likely to be undetectable at that point.

Surface water flows are inherently low due to high soil infiltration rates and low surface relief, with rainfall readily infiltrating through the soil. Due to diversion of upstream flows around the active mining area the impact is very small compared to the catchment area immediately downstream.

The local 'soak' 3 km southeast of the mineral deposit area will not be directly affected by surface runoff from operational areas and will not receive reduced surface water volumes. Further discussion on the impacts of surface water alteration on vegetation are discussed in Section 8.1.

Although some reduction in surface water volumes as a result of the mine excavation is considered 'Likely', this is expected to be localised and 'Incidental' in nature as it will affect any beneficial uses. The impact of infrastructure causing localised reduction in surface water volumes, after implementation of management measures, is assessed as 'Low'.

Impact	Consequence	Likelihood	Residual Impact
Infrastructure causing localised reduction in surface water volumes	Incidental	Likely	Low

Infrastructure Changing Local Drainage Patterns and Increasing Flood Risk

Other than the Site Access Road, proposed infrastructure areas are generally not subject to flood risk from large upstream catchments. Diversion drains or bunds will be put in place upstream of the active mining and process plant areas. The greatest flood risk is to the southernmost extent of the mineral deposit area, which encroaches on a broad ephemeral drainage line in the upper Fraser River South catchment with a catchment area of 108 km^2 which will require substantially larger diversion structures than the rest of the operations. No distinct channel can be seen; rather it is a wide valley exhibiting variation in vegetation associated with ephemeral drainage.

With regards to the Site Access Road, existing tracks have no engineered floodways or bridges/culverts at the crossing points with watercourses. Surface flow is able to pass over the track, but it is impassable during wet conditions. The Site Access Road will be upgraded to an all-weather road, with engineered drainage structures designed to allow natural flows to pass the road while maintaining all season access. The water pipeline to the reinjection borefield will be buried where it crosses tributaries of Fraser River South to ensure it does not impeded flow.

Very local changes to drainage patterns are considered 'Likely' at the location of infrastructure, but the construction of appropriate drainage measures will ensure the impacts are 'Incidental'.

Increased flood risk from construction of infrastructure is considered 'Possible' in at the southernmost extent of the mineral deposit area during large rainfall events. However, as flows would not be increased and suitable diversions and drainage measures in place, impacts would then be considered 'Incidental'. The potential impact on local drainage patterns and increased flood risk as a result of construction of infrastructure, after implementation of management measures, is 'Low'.

Impact	Consequence	Likelihood	Residual Impact
Infrastructure changing local drainage patterns	Incidental	Likely	Low
Infrastructure increasing flood risk	Incidental	Possible	Low

Surface Water Management Structures Causing Localised Erosion and Sedimentation

Increased sediment runoff and scouring may occur during clearing and through the incorrect installation of culverts and floodways. Concentrating flow and energy through culverts or over floodways can lead to erosion of both the upstream side of the culvert/floodway and of the downstream environment. Culverts and floodways will be installed in accordance with approved engineered design. Given the low flow volumes and high evaporation, any sediment runoff and scour is likely to be localised and managed through standard environmental management practices.

Localised erosion and sedimentation of creek lines and drainage channels caused by inappropriately engineered and constructed surface water management structures is considered 'Unlikely', with only minor and short term changes to surface water quality expected within the Mine Site Development Envelope that do not affect other surface water users. The potential residual impact of surface water management structures on localised erosion and sedimentation of creek lines and drainage channels, after implementation of management measures, is assessed as 'Low'.

Impact	Consequence	Likelihood	Residual Impact
Surface water management structures causing localised erosion and sedimentation	Incidental	Unlikely	Low

8.3.3 Management Measures

A summary of key measures to address potential impacts on surface water and groundwater is shown in Table 62. No other specific management measures are considered necessary.

Table 62: Proposed Management Measures for Hydrological Processes for the Mine Site Development Envelope

Potential Impact Requiring Management	Measures
Groundwater abstraction and dewatering causing localised changes in groundwater levels	• Recycling of water within the process water circuit will be implemented to minimise abstraction needs and water waste. • Monitoring bores will be established to assess potential groundwater drawdown and mounding impacts. This will included monitoring bores in the shallow strata of Fraser River South and Soak areas. • All groundwater abstraction, monitoring and reporting activities will be conducted in accordance with relevant permits and licences. • Only the volume of water required for ore processing and safe mining operations will be abstracted. • Flow meters will be fitted to groundwater abstraction bores to enable monitoring of abstraction volumes. • Process water storage facilities will be designed to minimise seepage.
Infrastructure causing localised reduction in surface water volumes. Infrastructure changing local drainage patterns and increasing flood risk.	• Roads and access tracks will be constructed with appropriate surface water drainage structures to minimise impacts on surface water flows. • Diversion bunds will be constructed around active mine pit areas to prevent surface water runoff from entering active mining areas. • Where necessary, suitable floodways, drains and culverts will be installed to transfer flow past infrastructure and return it to its natural flow path. • Pipelines will be buried when crossing watercourses to prevent impediment of flow.
Surface water management structures cause localised erosion and sedimentation	• Appropriately engineered surface water management structures will be constructed to redistribute flow downstream where no suitable natural channels are present.

8.3.4 Predicted Outcome

Drawdown of the groundwater table resulting from mine dewatering and abstraction from a water supply borefield is predicted to be contained largely within the mining lease and it is anticipated that any impact to nearby ecosystems, if this occurs, will be gradual and minimal. Drawdown impacts are not predicted to begin until after mining below the water table commences i.e. post Year 15. Monitoring bores are proposed as a precautionary measure, with trigger levels and mitigation measures implemented to maintain water levels should potentially groundwater dependant ecosystems associated with tributaries of Fraser River South be shown to be impacted by groundwater drawdown. Part of the reinjection borefield could be relocated to maintain water levels in this area if monitoring shows it is required.

The nearest licensed users and nearest registered Aboriginal heritage sites are unlikely to be affected as they are at least 30 km from the project, outside the modelled drawdown. There are no other major developments taking place surrounding the project and there will be no cumulative impacts on hydrological processes.

Given the paucity of watercourses within and near to the Mine Site Development Envelope, impacts to surface water flows from project infrastructure are likely to be minor and localised, and any associated erosion or sedimentation is expected to be highly localised.

Sheffield considers that the potential impacts of the project to hydrological processes will be able to be adequately managed such that the environmental objective for hydrological processes (Section 8.3) will be met, and that the residual impacts are therefore acceptable.

8.4 INLAND WATER QUALITY

The EPA's objective in relation to inland waters environmental quality is "*to maintain the quality of groundwater and surface water, sediment and biota so that the environmental values, both ecological and social, are protected*."

8.4.1 Key Statutory Requirements, Environmental Policy and Guidance

Groundwater and surface water is protected by the following State legislation:

- *Rights in Water and Irrigation Act 1914 (WA).*
- *Country Areas Water Supply Act 1947 (WA).*
- *Environmental Protection Act 1986 (WA).*

In addition to State legislation, the following policy and guidance statements were considered in the impact assessment for inland water quality:

- EPA Position Statement No. 4, Environmental Protection of Wetlands (EPA 2004a).
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 (Commonwealth) (ANZECC and ARMCANZ 2000).
- State Water Quality Management Strategy Document No. 6 (DoW 2004).
- Operational Policy No. 5.12, Hydrogeological Reporting Associated with a Groundwater Well Licence (DoW 2009).
- Water Quality Protection Guidelines No. 11, Mining and Mineral Processing, Mine Dewatering (DoW 2000).
- DoW Report No. 12, Western Australian Water in Mining Guideline. Water licensing delivery report series (DoW 2013).
- Water Quality Protection Guidelines for Mining and Mineral Processing (WRC 2000).
- National Water Quality Management Strategy (ARMCANZ and ANZECC 1995).
- Kimberley Regional Water Plan (DoW 2010).
- Guide to Departmental Requirements for the Management and Closure of Tailings Storage Facilities (DMP 2015).

The following documents were also considered:

- Kimberley Regional Planning and Infrastructure Framework (DoP and WAPC 2015)

8.4.2 Assessment of Potential Impact

Potential impacts of the Thunderbird Mineral Sands Project (the project) on inland water environmental quality are:

- **Exposure of contaminating materials causing contamination of surface water and groundwater** - Potentially Acid Forming (PAF) materials or other contaminating materials.
- **Accidental spills causing contamination of surface water and groundwater –** spills of chemical reagents and hydrocarbons may lead to contamination of surface water and groundwater.
- **Poor waste management causing contamination of surface water and groundwater** - at the wastewater treatment plant (WWTP) or landfill facilities.
- **Release of poor quality water causing contamination of surface water and groundwater** – release of poor quality water from the Tailings Storage Facility (TSF), water ponds and pipelines to natural drainage lines, particularly during periods of high rainfall.

Other potential impacts were screened out from further assessment (Section 7.4) as they were either assessed as not likely to occur or were unlikely to have any discernible consequence on any factor different to background levels:

Stressor	Justification for Exclusion
Erosion and sedimentation	Given the low gradient of the Mine Site, erosion is not considered to be a significant impact from the mineral deposit area. Although increased sediment runoff and scouring may occur during clearing and through the installation of incorrectly constructed culverts and floodways within the Mine Site Development Envelope, there are no defined surface water courses that will be impacted. Culverts and floodways will be installed in accordance with the approved engineered design.
Contamination of subterranean fauna habitat resulting in a loss of species diversity	Given the wide extent of the Broome Sandstone Aquifer across the Canning Basin, together with the lack of any significant obligate stygofauna identified within the study area and the relatively localised impact on aquifer saturated thickness, localised, minor contamination of groundwater will have incidental impacts on subterranean fauna (See Section 10.2.2).

The assessed likelihood, consequence and residual impact (as per Section 7.3), is provided below for each potential impact.

8.4.2.1 Exposure of Contaminating Materials Causing Contamination of Surface Water and Groundwater

Assessments of mine wastes and process residues (Appendix 19 and Appendix 20) was conducted to determine any risk of environmental contamination from excavation, backfilling and tailings storage of process materials, as well as exposure of acid forming materials as a part of the mining process. These assessments indicated that the significant majority of mine waste, including process residues, will be Non Acid Forming (NAF) and Barren with essentially no capacity for acid generation or acid neutralisation. Levels of soluble salts, metals and metalloids in any seepage from these materials will be extremely low, even under mildly acidic conditions.

Generation of potentially harmful acidic runoff through excavation or dewatering of acid sulfate soils (ASS) is therefore not considered a risk for the majority of the project materials. However, an apparent demarcation of sulfidic, Potentially Acid Forming (PAF) material was found to occur at a depth between 48.5 m (non-sulfidic) and 53.5 m (sulfidic) below the natural water table (approximately 85 m from ground surface), which will be approached in the final years of the proposed 47 year mine life. Consistent with a staged approach to soil investigations (DER 2015a), well ahead of planned mining and dewatering at depths which could disturb any of this material, further confirmation of the exact depth and extent of sulfidic material by additional more intensive regolith sampling and analysis will be conducted. Subsequent development of an appropriate mining strategy and

sulfide soil management plan (DER 2015a and 2015b), including groundwater monitoring, will be implemented before any possible disturbance of material at this depth occurs. This includes consideration of the cone of depression resulting from mine dewatering.

Concentrations of water soluble elements of environmental significance in mine wastes and process residues were generally very low to non-detectable and below ANZECC livestock drinking water guidelines (only current beneficial use of groundwater), indicating that there is an extremely low risk of mine waste leachates from circum-neutral waters adversely impacting the surrounding environment by rainfall or groundwater interaction (TSF seepage).

Results from major ion analysis suggests that seepage from mine wastes and process residues will have extremely low levels of salinity, however the clay sized fraction (i.e. slimes from ore body processing) have the potential to be dispersive in nature, that when placed back into the initial TSF or mining excavation may result in supernatant water remaining highly turbid with suspended clay, limiting options for discharge of any excess mine water during high rainfall events.

For the majority of mine waste samples, dilute acid leach testing mobilised low levels of aluminium and iron, consistent with a natural presence of hydrated aluminium and iron oxides from weathering and groundwater interactions. Concentrations of all other environmentally significant metals and metalloids (including geochemically enriched thorium and selenium in various samples of mine waste and process residues) were extremely low in all samples and below corresponding ANZECC livestock drinking water guidelines. This is consistent with these metals and metalloids being held in highly insoluble and environmentally unavailable forms (particularly monazite). Such acidic conditions in any event are not expected to be possible in the significant majority of mine life and will be avoided by appropriate management at extreme depth towards the end of mine life.

As well as the leachate from the mined areas and wastes being, relatively environmentally benign, there will be no planned discharge of surface water from mining areas into the environment, either through surface water discharge or reinjection into groundwater. All drainage from the mine excavation will be directed into holding sumps and used for dust suppression, or used within ore processing.

Although the majority of leached solutions from mined wastes are thought to be chemically benign, to develop more robust understanding of site hydrology and hydrogeochemistry and the potential for potentially contaminating solutions to be transferred away from the Mine Site during later stages of mining, it is proposed that additional groundwater monitoring be conducted, including relevant chemical parameters within the Mine Site Development Envelope.

It is considered 'Unlikely' that even minor changes to surface water and groundwater quality in the project area watercourses would occur as a result of exposure of contaminating materials. Any changes that do occur with management and mitigation as above would not prevent the water from being used by livestock or fauna given the absence of harmful soluble contaminants in the waste materials. The potential residual impact of exposure of contaminating materials on surface water and groundwater quality, after implementation of management measures, is assessed as 'Low'.

Impact	Consequence	Likelihood	Residual Impact
Exposure of contaminating materials causing contamination of surface water and groundwater	Minor	Unlikely	Low

8.4.2.2 Accidental Spills Causing Contamination of Surface Water and Groundwater

Hydrocarbons and process reagents (acids, caustic and lime) will be used on site during the mining process and during ore processing. Diesel will be used as fuel for the mining fleet and will be refuelled from a purpose built fuel facility. Failure of material containment or equipment malfunction may potentially discharge these environmentally

hazardous materials into the wider environment. Contamination of the wider environment through accidental mishandling or inadequate storage of materials will be avoided as far as practicable. Chemicals, hydrocarbons and other environmentally hazardous materials will be stored and handled in accordance with *Dangerous Goods Safety Act 2004* and associated regulations, including use of a bunded and sealed assembly area for hazardous chemicals (containerised) prior to offsite treatment/disposal, with leachates (if any) being collected in lined sumps and treated or containerised for disposal off site by a licenced and authorised waste contractor. Infrastructure will be periodically inspected and maintained to prevent failures into the wider environment.

Spills will be cleaned up and contaminated soils will either be remediated or removed from site by a licensed third party. Incident investigation will be undertaken as required to determine the cause of environmentally harmful spills/leaks and control measures identified to prevent future incidents. As required, spills will be reported to the relevant authorities.

Monitoring and assessment programs for surface and groundwater will be implemented as required and will include environmental quality analysis for parameters agreed with by regulatory authorities. Any deviations from agreed parameters will be investigated and control measures put in place.

It is considered 'Unlikely' that even minor changes to surface water and groundwater quality in the project area watercourses would occur as a result of accidental spills. Any 'Incidental' changes that may occur would not be expected to prevent the water from being used by livestock or fauna. The potential impact of exposure of accidental spills on surface water and groundwater quality, after implementation of management measures, is assessed as 'Low'.

Impact	Consequence	Likelihood	Residual Impact
Accidental spills causing contamination of surface water and groundwater	Incidental	Unlikely	Low

8.4.2.3 Poor Waste Management Causing Contamination of Surface Water and Groundwater

During normal operation of the WWTP, treated wastewater will be irrigated to an assigned area to infiltrate or evaporate, with no surface ponding or runoff. However, abnormal operation may cause excess nutrients and other contaminants within inadequately treated effluent outflow to enter the wider environment. Raised nutrient levels may favour the growth of introduced invasive weed species, as well as discourage the growth of native species not adapted to high nutrient loads. There are no defined drainage channels within the vicinity of the WWTP, mitigating any impacts to surface waters. Low levels of nutrients may infiltrate through the deep unsaturated profile to reach groundwater during rainfall events, however are not anticipated to be of a sufficient concentrations to be of concern.

The WWTPs will be constructed, operated and maintained in accordance with the Department of Environment Regulation (DER) Works Approval, Environmental Licence and local government and Department of Health regulations and permitting requirements as issued by the Shire of Broome. Effluent outflow produced by the WWTPs will either be irrigated to the environment or reused for dust suppression, and managed to allow effluent to infiltrate or evaporate and prevent surface ponding or runoff from the irrigation area. The WWTPs will be fitted with alarms and able to be shut down remotely should a failure occur. They will be regularly inspected, and discharge suspended if it is discovered they are operating below the required standard, with contingency storage capacity to be made available for up to two days of normal flow.

If allowed, access to food waste and other edible wastes within the onsite landfill may encourage and support populations of feral cats, dogs, and rodents who have the potential to transport litter into the wider environment. Additionally, inadequate fencing or containment of waste may lead to litter being blown outside the landfill boundaries. The landfill will be constructed and operated in accordance with the *Environmental Protection (Rural Landfill) Regulations 2002* under Prescribed Category 89 for a threshold of 'More than 20, but less than 5,000 t/a'.

A boundary fence will be erected to ensure an effective barrier is in place to prevent fauna access (specifically feral animals) and to create a wind barrier, with an entrance/exit gate incorporated, to be kept closed other than when waste is being deposited.

It is considered 'Unlikely' that even minor changes to surface water and groundwater quality in the project area watercourses would occur as a result of poor waste management. Any 'Incidental' changes that may occur would not be expected to prevent the water from being used by livestock or fauna. The potential residual impact of exposure of poor waste management on surface water and groundwater quality, after implementation of management measures, is assessed as 'Low'.

Impact	Consequence	Likelihood	Residual Impact
Poor waste management causing contamination of surface water and groundwater	Incidental	Unlikely	Low

8.4.2.4 Release of Poor Quality Water Causing Contamination of Surface Water and Groundwater

Water used in processing will be abstracted from the borefield to the south of the Thunderbird deposit and is not saline, however after use in processing, may contain low concentrations of environmentally hazardous materials. Failure of water infrastructure, such as pipelines or tailings storage facility, or overtopping during high rainfall events, may cause this water to be released into the wider environment. However, any streamflow leaving the Mine Site Development Envelope will be rapidly diluted by inflow from other catchments, effectively ameliorating impacts on some water quality parameters. There are no well-defined drainage channels within the area of the Thunderbird deposit and ore processing areas, where environmentally hazardous materials will be predominantly stored and used. Groundwater within the underlying strata is deep (greater than 20m), and localised surface contamination is unlikely to seep to groundwater in any significant concentrations.

A lined Process Water Dam will be constructed in order to store water from mine dewatering operations and process water from the borefield. Water in this dam will be used for either dust suppression on the roads within the mineral deposit area, or reused within the WCP. All HDPE-lined ponds shall be designed to have a controlled release point to prevent over topping and sufficient freeboard will be maintained in water storages to allow capture of rainfall from a one in one hundred year 72 hour ARI (average recurrence interval) event.

As discussed under Section 10.3.2.3, mine waste materials, including process residues, are environmentally benign. Should an ore delivery pipe from the MUP to the WCP or a tailings pipe burst between the processing plant and initial TSF or mine void, automatic shutoff valves will minimise loss to the environment. Any spilt process residue material will be collected and placed in the initial TSF or as backfill within the mined areas.

Likelihood of failure of the TSF and release of its contained supernatant and slurries into the wider environment will be reduced by a detailed design compliant with the *Code of Practice for Tailings Storage Facilities in Western Australia* (DMP 2013) and *ANCOLD Guidelines on Tailings Dam Planning, Design, Construction, Operation and Closure* (2012). The proposed materials for construction of the TSF have undergone geotechnical assessment, and have been deemed suitable for TSF construction.

Characterisation of mine wastes and process residues identified that tailings supernatant is likely to be highly turbid due to potentially dispersive material within the tailings. Biodegradable flocculant will be used to manage turbidity within process water and tailings supernatant to assist in settling of suspended clay/silt material to allow for re-use in the processing plant.
It is considered 'Unlikely' that even minor changes to surface water and groundwater quality in the project area watercourses would occur as a result of accidental release of poor quality water. Any 'Incidental' changes that may occur would not be expected to prevent the water from being used by livestock or fauna. The potential residual impact of exposure of accidental spills on surface water and groundwater quality, after implementation of management measures, is assessed as 'Low'.

Impact	Consequence	Likelihood	Residual Impact
Release of poor quality water causing contamination of surface water and groundwater	Incidental	Unlikely	Low

8.4.3 Management Measures

A summary of key measures to address potential impacts on inland water quality is shown in Table 63. No further specific management measures for inland water quality are considered necessary.

Table 63: Proposed Management Measures for Protection of Inland Water Quality for the Mine Site Development Envelope

Potential Impact Requiring Management	Measure
Exposure of contaminating materials causing contamination of surface water and groundwater	• Prior to commencement of mining below the water table, additional ASS sampling and analysis of potentially sulfidic material at depth within the mine deposit area will be undertaken. • If additional sampling indicates potential issues with ASS, a Management Plan will be developed and implemented. • Conduct groundwater monitoring for groundwater levels and quality within the Mine Site Development Envelope. • Water collecting in the mining excavation will be directed into holding sumps and used for dust suppression or ore processing.
Accidental spills causing contamination of surface water and groundwater	• Refuelling and fuel delivery inlets will be located on concrete or HDPE-lined pads to contain any drips and spills. The pads will drain to a sump to allow removal of collected material. • A bunded and sealed assembly area for hazardous chemicals (containerised) prior to offsite treatment/disposal will be established. • Transformer stations will be in bunded areas which meet the requirements of Australia Standards AS1940, AS 2067 and AS 3007. • The power station day tank, waste oil tank and lubricants will be located in a bund that complies with Australian Standards AS1940 and AS1692. • All hydrocarbon and chemical storages will be designed and constructed in accordance with Australian Standards AS1940 and AS1692 • Equipment and vehicles including surface mobile equipment shall be subject to a regular maintenance program to reduce the likelihood of spills and leakages occurring. • Heavy, light vehicle and maintenance workshop facilities will be located on concrete pads and hydrocarbon spillages and leakages captured and appropriately managed through the use of hydrocarbon absorbent materials • Spill kits will be located at strategic locations throughout the project area and employees trained in their use. • Hydrocarbon wastes will be segregated from other wastes and collected for offsite disposal by a licensed contractor. • The transport, storage or use of any designated Dangerous Good or substance will be conducted in accordance with Dangerous Goods permits as required and in accordance with Dangerous Goods Safety Act 2004, Dangerous Goods Safety (Road and Rail Transport of Non-Explosives) Regulations 2007 and Dangerous Goods Safety (Explosives) Regulations 2007.

Potential Impact Requiring Management	Measure
	• Monitoring and assessment program for surface and groundwater will be implemented as required and will include environmental quality analysis for parameters agreed with by regulatory authorities. • Spills will be contained, remediated, investigated and reported to the relevant authorities as required.
WWTP: poor waste management causing contamination of surface water and groundwater	• WWTP will be constructed, operated and maintained in accordance with the Department of Environment Regulation (DER) Works Approval, Environmental Licence and local government and Department of Health regulations and permitting requirements as issued by the Shire of Broome. • Effluent produced by the WWTPs will either be irrigated to the environment or reused for dust suppression. • The WWTP will be fitted with alarms and be able to be shut down the plant should a failure occur. • WWTPs will be regularly inspected and discharge suspended if it is discovered they are operating below the required standard. • The WWTP will have contingency storage capacity for up to two days of normal flow if discharge is suspended while any problems are addressed. • Effluent discharge from the WWTP will be managed to allow effluent to infiltrate or evaporate and prevent surface ponding or runoff from the irrigation area.
Landfill facilities: poor waste management causing contamination of surface water and groundwater	• Domestic wastes will be disposed of into a purpose built onsite landfill. • The landfill will have a boundary fence to prevent fauna access (specifically feral animals) and to create a wind barrier. • An entrance/exit gate within the boundary fence will be kept closed other than when waste is being deposited. • Recyclable wastes will be collected in a laydown area and transported offsite for recycling.
Release of poor quality water causing contamination of surface water and groundwater	**Water Storages:** • A lined Process Water Dam will be constructed in order to store water from mine dewatering operations and process water from the borefield. • All HDPE-lined ponds shall be designed to have a controlled release point to prevent over topping. • Sufficient freeboard will be maintained in water storages to allow capture of rainfall from a one in one hundred year 72 hour ARI event. • Water in the Process Water Dam will be reused within the WCP. **Initial TSF/Backfill** • Detailed TSF design compliant with the Code of Practice for Tailings Storage Facilities in Western Australia (DMP 2013) and ANCOLD Guidelines on Tailings Dam Planning, Design, Construction, Operation and Closure (ANCOLD 2012). • A biodegradable flocculent will be used to assist in settling of suspended clay/silt material from process water.

8.4.4 Predicted Outcome

The potential to generate environmentally harmful acidic runoff through excavation or dewatering of acid sulfate soils (ASS) is not considered a risk for the majority of the project materials. However, samples of material found at depth within the mine deposit area were considered PAF and may be reached in the final years of the proposed

47 year mine life. These materials will be further defined and managed through developed management plans at a suitable point in the life of the mine.

Any contaminated flow leaving the Mine Site Development Envelope will be rapidly diluted by inflow from other catchments, effectively ameliorating impacts on some water quality parameters. Additionally, there are no defined water course channels within the mine deposit and ore processing plant areas, where environmentally hazardous materials and processes will be predominantly stored and used. Groundwater within the underlying strata is deep (≥ 20m), and localised surface contamination is unlikely to seep to groundwater in any significant concentrations.

There are no other major developments taking place surrounding the project, hence there will be no cumulative impacts on inland water quality.

Sheffield considers that the potential impacts to inland water quality will be able to be adequately managed such that the environmental objective for inland environmental quality (Section 8.4) will be met, and that the residual impacts are therefore acceptable.

8.5 HERITAGE

The EPA's objective in relation to heritage is "*to ensure that historical and cultural associations, and natural heritage, are not adversely affected*".

8.5.1 Key Statutory Requirements, Environmental Policy and Guidance

Both Commonwealth and State legislation apply to the protection of Aboriginal heritage:

- *Aboriginal Heritage Act (1972) (WA).*
- *Aboriginal and Torres Strait Islander Heritage Protection Act 1984 (Cth).*
- *Native Title Act 1993 (Cth).*

In addition to Commonwealth and State legislation, the following policy and guidance statements were considered in the impact assessment for Aboriginal heritage:

- Department of Aboriginal Affairs and Department of Premier and Cabinet (DAA & DPC) 2013. *Aboriginal Heritage – Due Diligence Guidelines, Version 3.0.*
- EPA, 2004e. Assessment of Aboriginal Heritage. *Guidance for the Assessment of Environmental Factors No 41*.
- Department of Aboriginal Affairs guidelines regarding Section 18 and risk assessment (DAA 2013)

8.5.2 Assessment of Potential Impact

The potential impacts to Aboriginal heritage from the project are:

- **Ground disturbance causing impacts to known Aboriginal heritage sites and landscape cultural values.**
- **Ground disturbance causing impacts to unknown Aboriginal heritage sites.**
- **Project activities causing impacts to groundwater and groundwater dependent ecosystems.**

8.5.2.1 Ground Disturbance Causing Impacts to Known Aboriginal Heritage Sites and Landscape Cultural Values

Sheffield has worked closely with Traditional Owners since 2012 to survey the project area to ensure its activities have avoided Aboriginal sites and areas of Aboriginal cultural value. Prior to these surveys and work undertaken

by the previous tenement owner, no formal heritage surveys have been conducted for the project area or immediate surrounds.

Searches of relevant government databases identified that there are no registered Aboriginal sites or other heritage places of significance located within the Mine Site Development Envelope.

Aboriginal sites and areas of Aboriginal cultural value (not registered with the Government) have been identified and mapped within the mining operations area and surrounds (Section 4.2.13.1). Buffer zones have been determined by the Traditional owners to protect these places. Project design has considered these and land disturbance has been located outside these. The majority of the Mine Site Development Envelope is located on flat terrain away from rocky outcrops, water sources and areas of good ground surface visibility that are known to be associated with Aboriginal heritage sites in the region.

It is considered very 'Unlikely' that the project will adversely affect known historical and cultural associations, or natural landscape heritage values, and any potential impacts would be 'Minor'. The potential residual impact of ground disturbance on known Aboriginal heritage sites, after implementation of management measures, is assessed as 'Low'.

Impact	Consequence	Likelihood	Residual Impact
Ground disturbance causing impacts to known Aboriginal heritage sites and landscape cultural values	Minor	Unlikely	Low

8.5.2.2 Ground Disturbance Causing Impacts to Unknown Aboriginal Heritage Sites

Aboriginal heritage surveys have been systematic (covering the entire project footprint from the air and on-ground) and targeted in areas with the greatest potential for Aboriginal sites to occur, such as water sources and topographic features. All known sites and areas likely to contain sites were considered, however it is noted that parts of the mining operations area are densely vegetated, precluding intensive pedestrian survey from those areas.

Although the mine site layout and footprint will be designed such that it adheres to buffer zones and identified sites and areas of Aboriginal cultural value, there is potential that isolated archaeological material, or Aboriginal ancestral remains, could be found in these areas. Sheffield has therefore developed contingency measures in the way of procedures and protocols should discovery of new Aboriginal cultural material or ancestral remains be made at any time during construction or operation of the project. These contingency measures are outlined in the Aboriginal Heritage Management Operations Framework document (Appendix 26).

It is considered very 'Unlikely' that the project will adversely affect unknown historical and cultural associations. The consequence of any impacts to unknown sites is considered to be 'Minor'. The potential residual impact of ground disturbance on unknown Aboriginal heritage sites, after implementation of management measures, is assessed as 'Low'.

Impact	Consequence	Likelihood	Residual Impact
Ground disturbance causing impacts to unknown Aboriginal heritage sites	Minor	Unlikely	Low

8.5.2.3 Project Activities Causing Impacts to Groundwater and Groundwater Dependent Ecosystems

Consultation with Traditional Owners identified that impacts to groundwater and groundwater dependant ecosystems were of concern. The nearest potential groundwater dependent ecosystem is in the low-lying areas associated with Fraser River South, about 10.5 km southeast of the mine, intersecting the Site Access Road.

Potential impacts of the project on groundwater dependent ecosystems and management measures are detailed in Section 8.1.2.

8.5.3 Management Measures

Since 2012 Sheffield has consulted with Traditional Owners from all Native Title groups in the project area, and amassed comprehensive information regarding Aboriginal sites and cultural heritage values in the project area. This has enabled Sheffield to adhere to its general management approach of avoidance and minimisation of impacts to Aboriginal heritage.

The management approach undertaken by Sheffield for the project is to avoid where possible and minimise where practicable impacts to important Aboriginal heritage through engagement with Traditional Owners, project design and use of appropriate management measures. Proposed management measures for protection of Aboriginal heritage are provided in Table 64.

Table 64: Proposed Management Measures for Protection of Heritage in the Mine Site Development Envelope

Potential Impact Requiring Management	Measure
Ground disturbance causing impacts to known Aboriginal heritage sites and landscape cultural heritage values	• Development and implementation of Aboriginal Heritage Management Operations Framework and Cultural Heritage Management Plan (see below). • Maintain buffer zones around important Aboriginal sites and areas with Aboriginal heritage values in the Mine Site footprint and surrounds. • Maintain consultation with Traditional Owners. • Disturbance of Aboriginal heritage sites to be consistent with agreements with Native Title claimants and Aboriginal Heritage Act 1972.
Impacts to unknown Aboriginal heritage sites as a result of ground disturbance	• Develop and implement procedures for discovery of new Aboriginal heritage cultural materials (Aboriginal Heritage Management Operations Framework). • Conduct additional surveys in consultation with Traditional Owners where required.
Impacts to groundwater and groundwater dependent ecosystems	See Section 8.3.3 Hydrological Processes Management Measures for impacts to groundwater.
Native Title	• Sheffield is seeking a Mining Agreement with the Native Title claimant.

The project will be constructed and operated in accordance with an Aboriginal Heritage Management Operations Framework. This Framework provides an overview of measures and controls that will be implemented to ensure Aboriginal heritage is managed effectively through the life of the project. The Framework will provide a reference for Sheffield employees and contractors and will assist Sheffield and its contractors to operate within an environment where important sacred and cultural material places occur close to key construction and operational areas.

The Framework details standards and procedures in relation to the following:

- Discovery of cultural material.
- Discovery of Aboriginal ancestral remains.
- Operating in proximity to a buffer zone.
- Cultural monitoring during future works.
- Incident reporting.
- Compliance with the *Aboriginal Heritage Act 1972*.

The Framework measures are consistent with the provisions of agreements made, and that are under negotiation, with the Native Title party.

Sheffield will work closely with Traditional Owners to prepare a Cultural Heritage Management Plan (CHMP) for the project. The CHMP will detail long term management requirements for specific places and sites that are not limited to the mining operations area, identified through further consultation with Traditional Owners. It will detail Sheffield's contribution to longer term management of important and significant Aboriginal sites and places, through:

- Identification of management requirements for specific sites and places with important Aboriginal heritage vales, for example site stabilisation works, access rationalisation, erosion control.
- Protocols for Traditional Owners to access and care for sacred sites.
- Identification of management measures for Aboriginal cultural values associated with the environment, such as ground water health.
- Identification of opportunities for collaboration with Traditional Owners to promote and enrich Aboriginal culture and heritage, for example interpretive material, oral history recording and intergenerational site visits.
- Identification of opportunities for training and capacity building for Aboriginal people in the project area.

8.5.4 Predicted Outcome

Database searches found no Aboriginal heritage or other heritage places on the Register of Aboriginal sites (Section 4.2.13.1) within the Development Envelope. The Mine Site Development Envelope has been surveyed by Traditional Owners, and all (unregistered) culturally important areas have been identified and mapped. Buffer zones have been defined to protect known heritage sites or culturally important areas within the Mine Site Development Envelope.

There is a possibility that unknown archaeological heritage sites or ancestral remains within the Mine Site Development Envelope may be found, however, Sheffield are effectively managing this through implementation of the Heritage Management Framework (Appendix 26) and a Heritage Management Plan to be developed with Traditional Owners. It is anticipated that this will eliminate the prospect of any inadvertent damage to these findings.

Any impact to known Aboriginal heritage will only occur in accordance with agreements reached with the Native Title claimants and the *Aboriginal Heritage Act 1972*.

Sheffield considers that the potential impacts to heritage will be adequately managed such that the objective for heritage (Section 8.5) will be met, and that the residual impacts are therefore acceptable.