10 ASSESSMENT OF KEY ENVIRONMENTAL FACTORS

10.1 Overview

The environmental assessment for the Sandy Ridge Proposal has:

(i) Completed a robust environmental impact assessment was carried out in accordance with applicable environmental laws, standards and guidelines.

(ii) Identified a number of potential benefits which include:

  a. Creating long-term job opportunities (25 plus years) for local and regional communities.

  b. Providing a solution to the inappropriate management and storage of Class V intractable wastes.

  c. Opportunities for future recovery and re-use of certain waste streams, e.g. spent pot line residues can be recycled in the aluminium industry.

(iii) Not identified any significant adverse environmental, social or economic impacts arising from the Proposal.

(iv) Outlined, at a high level, necessary environmental mitigation measures which the proponent proposes to implement in order to either avoid or reduce any identified potential negative impacts to an acceptable and manageable level.

A summary of the potental enviornmental impacts and precidcted outcomes of the environmental assessment is presented in Table 10-1.

Table 10-1 Summary of potential environmental impacts and predicted outcomes

Environmental factor	EPA objective	Existing environment	Potential sources of impacts	Environmental management	Predicted outcome
Biophysical					
Flora and Vegetation	To maintain representation, diversity, viability and ecological function at the species, population and community level.	• Coolgardie IBRA Bioregion which covers the interzone between mulga and spinifex country and eucalypt environments over an area of 12,912,204 ha. • Southern Cross IBRA subregion of which approximately 5,773,838 ha of the current extent of pre-European vegetation remains. • Four vegetation associations were identified in the proposed development envelope: o (437) Shrublands; mixed acacia thicket on sandplain. o (141) Medium woodland York gum, salmon gum and gimlet. o (538) *Eucalyptus* open woodland/*Triodia* open hummock grassland. o (435) *Acacia* sparse shrubland/*Cryptandra* mixed sparse heath. • No Threatened, or Endangered, or Priority Ecological Communities were identified in the proposed development envelope. • No Threatened, or Endangered flora was identified in the proposed development envelope. • Priority species were identified in the proposed development envelope; *Calytrix creswellii* (Priority 3), *Lepidosperma lyonsii* (Priority 3) and an undescribed Lepidosperma sp.	• Clearing of 276.05 ha of native vegetation. • Potential for fire and loss of vegetation. • Changed hydrology (quality and quantity of surface water) and effects on downstream vegetation. • Indirect impacts from dust. • Indirect impacts from uptake of saline water from dust suppression. • Introduction and spread of weeds that compete with native vegetation. • Indirect impacts from radiation exposure.	• The proponent would develop and implement a Construction Environmental Management Plan (CEMP) which outlines management and mitigation measures to address potential impacts to flora and vegetation values. A list of measures to be included is provided in Section 10.2.4. • Implement fire prevention and management measures to be included in a site specific Emergency Response Management Plan (ERMP). The conceptual ERMP (flowchart) is contained in Appendix A.22. • Rehabilitation of disturbed areas in accordance with the Mine Closure Plan (Appendix A.19) and Waste Facility Closure and Decommissioning Plan (Appendix A.18).	• The Proposal would clear a maximum (worst case) of 276.05 ha of native vegetation. The actual area of clearing however is likely to be less than this area once exploration drilling has been completed to confirm the actual locations of the pits/cells and associated stockpiles, V drains and sumps. • Clearing for the Proposal does not significantly reduce the extent of any regional vegetation association, with <1 % of the pre-European extent and <1 % of the current area remaining for all vegetation associations present within the proposed development envelope. • No vegetation associations would be cleared below the 'threshold level' of 30 % of its pre-clearing extent. • No Threatened, Endangered or Priority Ecological Community would be impacted by the Proposal. • No direct impacts to the Mount Manning Nature Reserve, Mount Manning—Helena–Aurora Range Conservation Park or the Die Hardy Class A Reserve would occur. These sensitive receptors are greater than 9 km from the proposed development envelope and all works associated with the Proposal are confined to a defined development envelope. • The Proposal would result in clearing <1 % of the vegetation within the former Jaurdi Pastoral Lease and <1 % of the vegetation within the Proposed Conservation and Mining Reserve, which is not considered to significantly alter the high biodiversity conservation values of these DPAW managed lands. • Populations of the Priority flora *Calytrix creswellii* (P3) and *Lepidosperma lyonsii* (P3) would not be reduced as a result of implementing the Proposal. • No significant impacts to the potentially conservation significant species, *Lepidosperma* sp. would occur as a result of the Proposal. The implementation of the proposed management measures would achieve the EPA's objective to maintain the conservation status, diversity and productivity of flora and vegetation across the wider Sandy Ridge site.
Terrestrial Fauna	To maintain representation, diversity, viability and ecological function at the species, population and assemblage level.	• Two fauna habitats were mapped within the proposed development envelope; open woodland and shrublands: o Open woodlands: Open eucalypt woodland with an open understorey of shrubs over ephemeral grasses or	• Vegetation clearing would directly remove or possibly fragment fauna habitat. • Gamma radiation exposure to fauna. • Indirect impacts associated with increased light, noise and vibration.	• Pre–clearing surveys would be conducted prior to any ground disturbance to determine if there are any signs of conservation significant fauna activity within the area proposed for clearing.	• Regionally, clearing for the Proposal does not represent a significant impact to fauna habitat, as clearing accounts for less than 1 % of the woodland dominated Beard vegetation associations (141 and 538) and less than 1 % of the shrubland dominated Beard vegetation associations (435 and 437). • A worst case total of 14.60 ha of woodland habitat and 261.45 ha of shrubland habitat (total of 276.05 ha) would be directly disturbed by the Proposal which is considered to be of some value to the conservation significance malleefowl and rainbow bee–eater.

Environmental factor	EPA objective	Existing environment	Potential sources of impacts	Environmental management	Predicted outcome
		scattered spinifex on red sandy clay soils. o Shrubland: Moderately dense to dense sand plain shrubland varying in height from 0.5–1.8m on yellow sandy soils. • Evidence of two conservation significant species was observed in the proposed development envelope; Malleefowl (*Leipoa ocellata*) and Rainbow Bee-eater (*Merops ornatus*). • No Malleefowl or active mounds were observed during the targeted survey. Old mounds were evident, with 63 identified during the survey of various ages and in varying states of degradation. Most were little more than circular raised areas of gravel, potentially unused for decades or centuries. • Two Rainbow Bee–eaters were observed during the survey; however, as the nesting period had finished for the season it was assumed the birds were just passing through.	• Indirect impacts associated with fauna displacement, increased predation and competition for resources. • Potential for fire. • Potential increase in feral fauna. • Potential injury or death from fauna ingress into a cell or from vehicle collisions. • Indirect impacts from radiation exposure (unlikely). • Possible generation of voide space and subsequent collapse / instability of the cell (unlikely).	• The CEMP would include fauna management measures to minimise, manage and monitor potential impacts on fauna from the Proposal. A list of measures to be included is provided in Section 10.4.4. • Implement fire prevention and management measures as outlined in the Emergency Response and Management Plan. • Rehabilitation of disturbed areas in accordance with the Mine Closure Plan and Waste Facility Closure and Decommissioning Plan (Appendix A.18).	• Fauna habitat within approximately 1,000 m from a blast may be indirectly affected by moderate noise emissions (60–85 dBA). Emissions are temporarily (a few seconds per year) and unlikely to cause permanent damage to any species. • No fauna of conservation significance (listed under the Wildlife Conservation Act 1950 or the EPBC Act) would cease to exist or have its conservation status affected as a result of the Proposal. • No Priority species as listed by DPAW would cease to exist or have its priority status affected as a result of the Proposal. The EPA's objective to maintain representation, diversity, viability and ecological function at the species, population and community level would be met by limiting the amount of ground disturbance and land clearing. In addition, all vehicles will only use defined access tracks.
Inland Waters Environmental Quality	To maintain the quality of groundwater and surface water, sediment and biota so that the environmental values, both ecological and social, are protected.	No evidence of a groundwater aquifer present in the proposed pit / cell area. No surface water receptors in the proposed development envelope.	• Leak/spill from a waste package which may contaminate surface water runoff and groundwater. • Generation of leachate from a stored waste package which may contaminate surface water runoff and groundwater. • Adverse effects on water quality at the Carina pit from abstraction of water.	• Implement the Surface Water Assessment and Management Plan. • Surface water management measures (e.g. roof canopy, operational bunding, V drains and sumps) would be implemented to protect surface water quality by ensuring it is diverted from operational areas. • Spill response operational procedures would be implemented. • Undertake annual groundwater monitoring. • Undertake weather monitoring. • Undertaken subsidence monitoring in accordance	The Proposal was specifically cited in this location because there is little to no evidence of groundwater and surface water receptors. Therefore, proposed operations would not significantly impact these environmental aspects. Based on the scientific evidence and the ongoing commitment to environmental monitoring across the development envelope, the EPA objective for inland waters environmental quality would be achieved.

Environmental factor	EPA objective	Existing environment	Potential sources of impacts	Environmental management	Predicted outcome
				with the Waste Facility Decommissioning and Closure Plan. • Hydrogeological modelling with be verified by collecting soil moisture data and temperatures at various depths above the silcrete to establish soil moisture profiles during rain events and subsequent dry periods.	
Heritage	To ensure that historical and cultural associations, and natural heritage, are not adversely affected.	There are no known records of heritage items (Aboriginal or European) within or in close proximity to the proposed development envelope as confirmed via online database searches (WA Department of Aboriginal Affairs Site Register, State Heritage Register [inHerit], World Heritage Register, National Heritage Register, Commonwealth Heritage Register and the Australian Heritage Database). In addition, a search of the Land, Approvals and Native Title Unit indicated there are no registered native title claims over the proposed development envelope (Government of Western Australia, 2015). Field surveys did not record any heritage items (registered or previously unrecorded) or ethnographic values within the proposed development envelope. The field surveys were conducted in consultation with representatives of the Kapam Native Title Group, Kelamaia Kabu(d)n and Widji Group.	The Proposal would not disturb any known Aboriginal or European heritage sites or interfere with any known cultural associations within the proposed development envelope.	As no heritage sites (registered or previously unrecorded) occur within the proposed development envelope, no additional mitigation measures would be required. In the event that items of potential European historical significance are encountered, work in their immediate vicinity (defined as a 10 metre radius) would stop and the Heritage Council and State Heritage Office would be contacted. Similarly, if items of Aboriginal heritage significance are identified during construction, work in their immediate vicinity would stop and the the Department of Aboriginal Affairs in addition to the Kaparn Native Group, Kelamaia Kabu(d)n and Widji Group would be contacted for further advice. If suspected skeletal remains are discovered during construction, work in their immediate vicinity would stop and the local police and the Department of Aboriginal Affairs would be notified as soon as possible to determine a course of action. Construction works in the area of the remains would not resume until the proponent receives written approval from either the police or from the Department of Aboriginal Affairs, as appropriate.	The Proposal would not result in an adverse impact on cultural heritage values in the region. The EPA objective for this key environmental factor would be achieved.
Human Health	To ensure that human health is not adversely affected.	There are no sensitive receptors located within 5 km of the development envelope. The people (receptors) who may be exposed to chemicals/agents during the waste	The hazards considered to pose the greatest potential risk of adverse human health effects (i.e. injury, illness or death) include:	The primary mechanism to protect human health would be achieved through implementing and adhering to a number of management plans including the	The proponent recognise that risks to human health have extreme to high consequences. However, the provision of multiple barriers of containment around waste, knowledge of waste content, training and supervision of all employees, appropriate personal protective equipment, monitoring of health and continue improvement of waste handling and storage procedures would either avoid or greatly

Environmental factor	EPA objective	Existing environment	Potential sources of impacts	Environmental management	Predicted outcome
		acceptance process are considered to be limited to: • Truck drivers/transporters. • Onsite workers or visitors. Given the remote nature of the facility, there is no credible scenario in which a member of the public could be exposed to a hazard from a material once it has been accepted at the facility.	• exposure to chemicals/agents in waste materials which are released from their packaging (i.e. a leak or a spill). • bushfire emergency. These hazards are considered to pose a moderate risk to human health, where unmanaged. Stringent planning to prevent these situations (and others with lower risks to human health) occurring to the extent practicable and to manage the potential risks if they do inadvertently happen would be implemented.	Operational Strategy, waste acceptance criteria and a detailed Safety Case. The proponent' Safety Case considers risks that may occur whilst operating the proposed Facility and human safety during: • The design, construction and operation of the facility. • Movement and placements of hazardous materials within the site during operations. • The safety of the facility in the very long term after it has been sealed and closed. In addition to a fundamental analysis of the site characteristics and management practices, the safety case draws on best practice examples developed around the world for the safe storage and isolation of various types of wastes based on strict acceptance criteria, and for the construction in geological settings that are internationally recognised as suitable. The outline Safety Case (Appendix A.15) is a living document which would be updated at each step of the development of the facility – during construction, operation and after closure. Human health management measures are also outlined in the following management plans which are provided as appendices to this PER: • Operating Strategy (Appendix A.16). • Radioactive Waste Management Plan (Appendix A.14). • Mine Closure Plan (Appendix A.19). • Waste Facility Decommissioning and Closure Plan (Appendix A.18).	minimise risk to human health. By adopting the proposed engineering designs and adhering to proposed human health management measures, the EPA objective for this factor would be met.

Environmental factor	EPA objective	Existing environment	Potential sources of impacts	Environmental management	Predicted outcome
				• Developing the outline ERMP in Appendix A.22 into a detailed ERMP following the completion of detailed design. • Drinking Water Quality Management Plan (Appendix A.20).	
Rehabilitation and decommissioning	To ensure that premises are decommissioning and rehabilitated in an ecologically sustainable manner.	The development envelope is currently undisturbed with the exception of exploration activities (temporary campsite, drill pads and access tracks).	• A qualitative risk assessment has been undertaken for all aspects of mine and waste facility closure. The outcome of the risk assessment included the identification of 6 planned and 14 unplanned credible risks. The highest residual ranking risks were: • Major earthquake with surface displacement and cracking of the domed caps over the cells. This could lead to subsidence/slumping of the cell and further erosion of the cap (rills and gullies). The loss of cell stability could potentially allow water to infiltrate into the cells, potentially generating leachate from waste packages into the surrounding clay. • Bushfire which may cause injury or death of Threatened / Priority fauna and damage revegetation. • Terrorist attack from a plane crashing into, or bombing of, the cells. This may cause an expulsion of chemical and radioactive waste from the cell to the surface and into the atmosphere. • Failure of revegetation due to degraded topsoil, compacted soils, erosion, fauna predation, lack of seed pre–treatment, no tubestock available, and weed invasion. • Unauthorised access to the Facility and / or accidental deep excavation into a pit (i.e. mineral exploration). This could impact upon human health and potentially lead to injury or death of fauna by falling into the cell.	The proponent would rehabilitate all disturbed areas in accordance with the Mine Closure Plan and Waste Facility Decommissioning and Closure Plan. Rehabilitation would primarily include respreading of topsoil, ripping of surface, revegetation using local species, irrigation in the initial months of establishment and the application of appropriate fertiliser (where appropriate). Decommissioning of infrastructure would occur in phases, depending if it's used for mining/processing or ore, or for the waste facility. Decommissioning schedules are provided in both the Mine Closure Plan (Appendix A.19) and the Waste Facility Decommissioning and Closure Plan (Appendix A.18).	The EPA's objective, to ensure that premises are decommissioning and rehabilitated in an ecologically sustainable manner, would be met. The proponent is committed to continual improvement through the three–yearly revisions of the MCP and WFDCP to ensure that rehabilitation and decommissioning is conducted in an ecologically sustainable manner at closure time.

Environmental factor	EPA objective	Existing environment	Potential sources of impacts	Environmental management	Predicted outcome
			The pit may become unstable and collapse.		
Offsets	To counterbalance any significant residual environmental impacts or uncertainty through the application of offsets.	The proponent has assessed the residual impacts to the Environmental Factors 'flora and vegetation' and 'terrestrial fauna' as a result of clearing (a maximum) 276.05 ha of native vegetation in accordance with the Residual Impact Significance Model (Government of Western Australia, 2014). The only issue which potentially triggers a requirement for an offset relates to the clearing required within the former Jaurdi Pastoral Lease of which 6.44 ha is within the proposed Conservation and Mining Reserve. As this area is only a proposed reserve at this stage, and vegetation is sparse with no Threatened or Priority flora or TECs/PECs in the 6.44 ha area, the potential impact is not considered to be significant enough to warrant an offset. Therefore, the proponent considers that the residual impacts are not significant and the EPA's objective for flora and vegetation and terrestrial fauna can be achieved without the requirement for an offset.			
Pollution management					
Terrestrial Environmental Quality	To maintain the quality of land and soils so that the environment values, both ecological and social, are protected.	The Sandy Ridge Project is located in the centre of a 160 km long and 20 km wide north–northwest trending granitic body (CRM, 2016) covering 3,200 km^2. At Sandy Ridge, the weathered granite is typical 6 m BGL and unweathered/fresh granite is greater than 27 m BGL. The proposed development envelope is located within the Norseman (266) soil landscape mapping zone, within the Kalgoorlie Province as defined by Tille (2006). The soils of the Norseman zone are described as calcareous loamy earths, yellow sandy and loamy earths, red loamy earths, red deep sands and salt-lake soils. The field assessment identified two soil types within the proposed development envelope; Deep Yellow Sand and Red Sandy Duplexes.	• Sterilisation of minerals beneath the cells. • Degradation of stockpiled soils over time. • Gamma radiation exposure on surrounding soils. • Radon emanating from waste cells. • Soil contamination from leaks/spills. • Subsidence and instability of waste cell allowing infiltration of water and generation of leachate. • Change in landform to surrounding landscape.	• Prior to ground disturbance the proponent would conduct detailed baseline soil sampling in accordance with Department of Health and Department of Lands requirements. • Spill response operational procedures would be implemented. The proponent would ensure all operators are trained and familiar with operational procedures and are educated regularly at toolbox meetings. There would be onsite traffic management, including speed limits and two–way communication between all vehicles, to mitigate potential spills.	With the implementation of management and mitigation measures, the EPA objective with respect to terrestrial environmental quality can be met.
Social surroundings					
Amenity	To ensure that impacts to amenity are reduced as low as reasonably practicable.	There are no sensitive receptors located within 5 km of the development envelope. The nearest permanent sensitive receptor to the proposed development envelope is the Carina Iron Ore Village (approximately 52 km away), tourists residing at the Jaurdi Homestead (approximately 51 km away) and Koolyanobbing (approximately 75 km away).	• Diminished quality of life to nearby receptors due to noise emissions. • Decreased amenity to nearby receptors due to increased dust emissions. • Impacts to visual amenity of people utilising the 'Reserve System' (including the Mount Manning Range Nature Reserve, Mount Manning-Helena and Aurora Ranges Conservation Park and the former Jaurdi Pastoral Lease) specifically in terms of:	• Best practice noise management would be implemented during operation of the mine to ensure compliance is achieved with the Environmental Protection (Noise) Regulations 1997. • Dust suppression and management measures would be implemented to minimise dust impacts where possible. This would include: o Application of dust suppression methods along internal access	Impacts on amenity are limited to a small footprint within a vast landscape of similar landscape character. The Proposal would have a very low impact on amenity values. These impacts would be even further reduced through the implementation of mitigation and management measures such as active vegetation rehabilitation once pits have been infilled and capped.

Environmental factor	EPA objective	Existing environment	Potential sources of impacts	Environmental management	Predicted outcome
			• Impacts to nature based tourism that is travel routes and the use of public viewpoints in the existing and proposed Reserve System. • Impacts to scientific study in the existing and proposed Reserve System.	roads and hard stand areas using watercarts during dry, dusty periods. o Weather conditions would be monitored prior to mining activities most likely to generate dust (i.e. vegetation removal, topsoil and subsoil stripping, and blasting). o Dust deposition gauges would be installed on the proposed development envelope boundaries nearest to the IWDF and the former Jaurdi Pastoral Lease and monitored quarterly for the initial 12 months. The final locations of dust deposition gauges would be identified in consultation with the DER. • Disposal cells would be rehabilitated on completion of subsidence monitoring with the objective of producing a surface slightly mounded above the existing nature surface that is vegetated. • Following closure of the mine, all mining related infrastructure would be removed and disturbed areas would be rehabilitated.	

10.2 Flora and vegetation

10.2.1 Introduction

This section provides assesses the potential impacts on flora and vegetation during both construction and operation of the Proposal. Mitigation and management measures are identified to avoid or reduce potential impacts with the objective *to 'maintain representation, diversity, viability and ecological function at the species, population and community level'* in accordance with the EPA's Environmental Assessment Guideline No. 8 (2015a).

This section draws on a number of comprehensive studies including:

- *Sandy Ridge Project Exploration Tenement E16/440 Level 1 Flora and Vegetation Survey* (PGV Environmental, 2015; see Appendix A.3).
- *Sandy Ridge Project Exploration Tenement E16/440 Level 2 Flora and Vegetation Survey* (PGV Environmental, 2016; see Appendix A.3).
- *Environmental Risk from Ionising Contaminants Assessment (ERICA) Modelling* (Hygiea Consulting, 2016; see Appendix A.14).

The assessment has also been prepared with reference to the applicable standards, guidelines and procedures listed in Chapter 4, Table 4-3 and in accordance with the requirements set out in the ESD which is presented in Appendix A.1. A copy of the EPA's checklist for documents submitted for environmental assessment on terrestrial biodiversity is provided in Appendix A.9.

10.2.2 Methodology

A Level 1 Flora and Vegetation Survey was undertaken to assess the flora and vegetation values of the proposed development envelope and to identify the potential presence of flora species or vegetation communities of conservation significance. The Level 1 Flora and Vegetation Survey included the following:

- A review of previous flora and vegetation surveys in the region.
- A review of relevant biodiversity databases for threatened and priority flora species and threatened and priority flora communities that may be affected by the Proposal.
- Examination of recent aerial photography and contour maps to provisionally identify vegetation types and condition.

Based on the results of the Level 1 Flora and Vegetation Survey, a Level 2 Flora and Vegetation Survey was undertaken in accordance with *Guidance Statement 51: Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia* (EPA, 2004a). The Level 2 Flora and Vegetation Survey included the following:

- Desktop search and review of DPAW's Declared Rare and Priority Flora database and Threatened Ecological Communities database.

- Examination of recent aerial photography and contour maps to provisionally identify vegetation types and condition.
- Field survey in spring using quadrats (25, 20 m by 20 m quadrats) and several traverses of the access roads and water pipeline route to record native and introduced species, as well as a site walkover of any areas of native vegetation.
- Recording of any significant plant species using a hand–held GPS.
- Description and mapping of vegetation types and vegetation condition.
- Compilation of a flora list.

10.2.3 Assessment of potential impacts and risks

Direct impacts on terrestrial flora and vegetation during construction and operation of the Proposal include the removal of vegetation and impacts on land managed by DPAW. Indirect impacts may include the increased incidence of fire; altered hydrology; dust; the uptake of saline water from dust suppression or from potential water pipeline leaks; and the introduction and spread of weeds. These impacts are discussed below. The potential impacts associated with radiation exposure and the transpiration of leachate are also discussed, although are highly unlikely to occur.

Mitigation and management measures to avoid or reduce impacts on terrestrial flora and vegetation are outlined in Section 10.2.4.

Direct impacts (removal of vegetation)

A total of approximately 276.05 ha of native vegetation would be removed for the construction and operation of the Proposal. This would include the removal of approximately 202.3 ha for the cells, 17.2 ha for the mine infrastructure, 2.5 ha for the accommodation camp, 0.25 ha for the putrescible landfill, 4 ha for the technology park area, 22.2 ha for the access roads and 27.6 ha for the water pipeline.[25]

The clearing of vegetation would initially be undertaken for all disturbance areas except for the cells. This area would be cleared progressively over 25 years (e.g. one cell per year).

Impacts on regional vegetation associations

As discussed in Section 9.1.1, four regional vegetation associations occur within the proposed development envelope, as defined by Beard (1972). An assessment of the impact from the direct clearing of these four vegetation associations is presented in Table 10-2 using data provided in *2014 Statewide Vegetation Statistics Incorporating the CAR Reserve Analysis* (DPAW, 2014).

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[25] *Not all of the 202.3 ha footprint of the cells would be used for mining and subsequent waste disposal. Even though the amount of vegetation clearing within this area would be less than 202.3 ha, for the purpose of this assessment it has been assumed that the entire 202.3 ha would be cleared.*

Each of the four regional vegetation associations that occur within the proposed development envelope have greater than 97% of their pre-European extent remaining in the Southern Cross IBRA Subregion. Direct clearing of each vegetation association represents clearing less than 1% of their current remaining extent. All vegetation associations that would be impacted by the Proposal are well represented across the Southern Cross IBRA Subregion. The area proposed to be cleared would not result in any changes to the conservation status of these vegetation associations and, therefore, the overall regional impact on vegetation would not be significant.

Table 10-2 Impacts on regional vegetation associations

Beard vegetation association	Pre-European extent (ha)[26]	Current area remaining (ha)*	Total area within proposed development envelope	Total clearing for Proposal (ha)	Percentage of area remaining directly affected by Proposal (%)
141 – Medium woodland: York gum, salmon gum and gimlet	883,085.69	858,525.04	224.61	18.89	<1%
437 – Shrublands: mixed acacia thicket on sandplain	312,850.92	312,825.96	773.57	254.16	<1%
538 – Eucalyptus open woodland/Triodia open hummock grassland	127,866.58	124,866.81	5.23	2.61	<1%
435 – Acacia sparse shrubland/Cryptandra mixed sparse heath	732,096.18	726,352.32	0.79	0.39	<1%

Impacts on local vegetation types

As discussed in Section 9.1.2, a range of different local vegetation types occur within the proposed development envelope. An assessment of the impact from the direct clearing of each vegetation type is presented in Table 10-3 and is shown graphically in Figure 9-2a and Figure 9-2b.

Table 10-3 Impacts on local vegetation types

Vegetation type (code)	Total area in proposed development envelope (ha)	Total area of clearing (ha)	Clearing as a percentage of total area within proposed development envelope (%)
Ab	0.98	0.49	50.00
Ar	434.18	139.51	32.13
ArAa	0.04	0.04	100
ArEpTs	295.57	92.97	31.45
ArMu	10.91	5.45	49.95
CpAr	2.19	0.08	3.65
EcAt	60.44	4.72	7.81
Eg	150.86	18.22	12.08
EgAaEo	0.91	0.46	50.55

[26] *Source: 2014 Statewide Vegetation Statistics incorporating the CAR Reserve Analysis (DPAW, 2014).*

Vegetation type (code)	Total area in proposed development envelope (ha)	Total area of clearing (ha)	Clearing as a percentage of total area within proposed development envelope (%)
EpMuTs	15.59	2.06	13.21
ErMuAa	2.22	1.11	50.00
EsalMu	1.62	0.81	50.00
EsAt	4.42	1.82	41.18
EsEo	16.11	8.06	50.03
Lr	8.16	0.25	3.06
Total	1004.2	276.05	-

Direct impacts (impacts on vegetation of conservation significance)

No Priority Ecological Communities listed by DPAW, Threatened or Endangered Ecological Communities listed under the WC Act or Threatened or Endangered Ecological Communities listed under the EPBC Act were recorded within the proposed development envelope. Therefore, no Priority Ecological Communities listed by DPAW, Threatened or Endangered Ecological Communities listed under the WC Act or Threatened or Endangered Ecological Communities listed under the EPBC Act would be impacted by the Proposal.

Direct impacts (impacts on flora species of conservation significance)

Two species of conservation significance, *Calytrix creswellii* and *Lepidosperma lyonsii* (both listed as Priority 3 by DPAW), were recorded within the proposed development envelope. An undescribed sedge species was also recorded within the proposed development envelope – *Lepidosperma* sp. This species is currently undescribed and may have some conservation value. The potential impacts on these species are discussed below.

Calytrix creswellii

One population (with more than 100 individuals) of *Calytrix creswellii* was recorded within the proposed development envelope (refer to Figure 9-2a). This population would not be cleared during either construction or operation of the Proposal. This species also occurs outside of the proposed development envelope within the Coolgardie and Murchison Bioregions of the Eremaean Province (Florabase, cited in PGV Environmental, 2016). It has been recorded on nearby sites including the IWDF (Ecologia, 1997), the IWDF Access Road (Mattiske Consulting, 2012) and at the site of the Carina Iron Ore Project (Recon Environmental, 2010).

Mattiske Consulting (2012) recorded many separate populations of the species with population sizes greater than 50, which is considered to be typical for this species. Further surveys outside of the proposed development envelope would likely identify additional populations of this species as it is likely to be more common in the local area/region (PGV Environmental, 2016).

Lepidosperma lyonsii

One population (five individuals) of *Lepidosperma lyonsii* was recorded within the proposed development envelope (refer to Figure 9-2b). This population would not be cleared during construction or operation of the Proposal. This species is known from populations outside of the proposed development envelope and occurs in several locations around Mount Finnerty, Mount Walter and Erayinia Hill near Karonie in the Coolgardie Botanical District.

Regionally, 254 individuals were recorded by Western Botanical (2008), with 37 to 70 individuals recorded by Mattiske Consulting (2009) and one population (number not determined) recorded by Recon Environmental (2010) at the site of the Carina Iron Ore Project. A population (number not determined) was also identified along the IWDF Access Road (Mattiske Consulting, 2012). Barrett (2007) noted that while *Lepidosperma lyonsii* was a poorly known species, it may be more widespread than the current herbarium collections suggest. Further surveys outside of the proposed development envelope would likely identify additional populations of this species as it is likely to be more common in the local area/region.

Lepidosperma sp.

An undescribed sedge species was recorded within the proposed development envelope – *Lepidosperma* sp. Five populations of this species were recorded in vegetation dominated by *Acacia resinimarginea* (refer to refer to Figure 9-2a and Figure 9-2b). Based on the results of current and previous field surveys, the species is likely to be more widespread within the proposed development envelope than the populations recorded. It is also highly likely to occur in numerous locations which would not be impacted by the Proposal. As discussed in Section 9.1.5, the taxonomy of the *Lepidosperma* sp. is currently being reviewed by the WA Herbarium. Its conservation status is currently unknown.

Until the taxonomy and conservation status of this species is known, it is difficult to predict impacts to this species during construction and operation of the Proposal. If the species is deemed to have conservation significance, surveys would be undertaken prior to construction to confirm the presence/absence of the species within the proposed development envelope. If the species is found to be present, significant impacts would be avoided through changes to the location of the proposed infrastructure, if possible. Alternatively, a translocation program developed in consultation with DPAW would be implemented to avoid significant impacts to this species. If significant impacts could not be avoided, the need to calculate and deliver biodiversity offsets would be assessed in accordance with the *Environment Protection and Biodiversity Conservation Act 1999 Environmental Offsets Policy* and in consultation with the DoEE and/or DPAW, as appropriate.

Direct impacts (impacts on lands managed by DPAW)

The Proposal is approximately 9.8 km south-east of the Mount Manning Nature Reserve and 19.8 km northeast of the Mount Manning – Helena and Aurora Ranges Conservation Park (refer to Figure 9-7). The Die Hardy Class A Reserve is 79 km to the west. Due to the location of the proposed development envelope, no direct impacts on these conservation areas would occur during construction or operation of the Proposal. The implementation of the Proposal potentially increases the risks associated with fire which could impact upon the conservation values of these areas. However, fire risk is recognised as an operational issue and would be managed through the implementation of a Bushfire Management Plan. Details relating to fire management are discussed further below.

Table 10-4 lists the total area of vegetation to be cleared for the Proposal. The proposed water pipeline would disturb approximately 13.32 ha of vegetation within the former Jaurdi Pastoral Lease, which includes 6.44 ha of vegetation within the proposed Conservation and Mining Reserve. This represents less than 1% of vegetation within the former Jaurdi Pastoral Lease and less than 1% of vegetation within the proposed Conservation and Mining Reserve.

Table 10-4 Impacts on DPAW managed lands

DPAW managed land	Total area (ha)	Area within proposed development envelope (ha)	Total area of clearing (ha)	Percentage of DPAW managed land directly affected by Proposal (%)
Former Jaurdi Pastoral Lease (excludes area of Proposed conservation and mining reserve)	221,355.02	13.76	6.88	<1%
Proposed Conservation and Mining Reserve	68,945.98	13.28	6.44	<1%
TOTAL DPAW MANAGED LAND	**221,355.02**	**27.04**	**13.32**	**<1%**

No flora species of conservation significance or vegetation of conservation significance were identified along the water pipeline route within the former Jaurdi Pastoral Lease and proposed Conservation and Mining Reserve during the field surveys.

As such, there would be no impact on conservation significant flora or vegetation within these DPAW managed areas. In addition, no significant impacts on the values of these areas would occur as the highest concentration of biodiversity conservation values in the region are predominantly associated with banded iron formation (BIF) ranges (EPA, 2007), which are not present within the water pipeline corridor.

Indirect impacts

Indirect impacts on flora and vegetation may include an increased incidence of fire, altered hydrology, increased dust, the uptake of saline water, and the introduction and spread of weeds. These impacts are discussed below. The potential for radiation exposure and the transpiration of leachate from the waste cells are discussed but would not likely occur.

Fire

The proposed development envelope is located within the Goldfields Bushfire Region, which experiences long periods of extreme fire weather in the dry summer months (NRM Rangelands, 2015). Bushfires in this region are mostly started by lightning and while infrequent, under extreme weather conditions they can be large in scale, intense and burn all vegetation types (NRM Rangelands, 2015).

Vegetation in the region (including within the proposed development envelope) comprises a rich mosaic of eucalypt woodlands and dense shrublands, which have contrasting fuel properties and hence fire regime potentials and responses to fire. Fuel in the eucalypt woodlands comprises sparse, usually discontinuous leaf litter and a low understorey of small shrubs, making these fuels of low flammability. In contrast, the often dense shrublands become highly flammable fuel, especially under dry windy conditions (NRM Rangelands, 2015). Fire intervals in the woodlands can be many decades, even centuries, whereas much shorter fire intervals are possible in the more flammable shrublands.

Alteration of the natural fire regime may occur due to improved access and increased human activity associated primarily with flammable liquids, combustible materials and hot machinery used within the proposed development envelope during construction and operation of the Proposal. The risk of causing fire during construction or operation has the potential to increase the frequency of fires in the proposed development envelope.

The potential consequences of an altered fire regime would affect approximately 80.97 ha of woodland vegetation within the proposed development envelope as it is considered to be fire sensitive and is most likely fire independent (i.e. it does not require fire for its persistence) (NRM Rangelands, 2015). Woodland species are obligate seeders which once killed by fire, recruit thereafter from banks of seed buried in soil or encapsulated in woody fruits. The approximately 923.23 ha of shrubland vegetation within the proposed development envelope is well adapted to fire at intervals of a few decades and generally recovers more quickly than woodlands (NRM Rangelands, 2015).

Following a fire, many species are stimulated to reproduce. Plant responses post fire may include:

- Increased productivity.
- Increased flowering.
- Fire stimulated seed release and dispersal.
- Improved seedling germination and establishment through physical and chemical cues such as rupturing of seed coat/smoke and ash.

Fire prevention and management measures would be implemented to minimise bushfires and, therefore, protect native flora species.

Altered hydrology

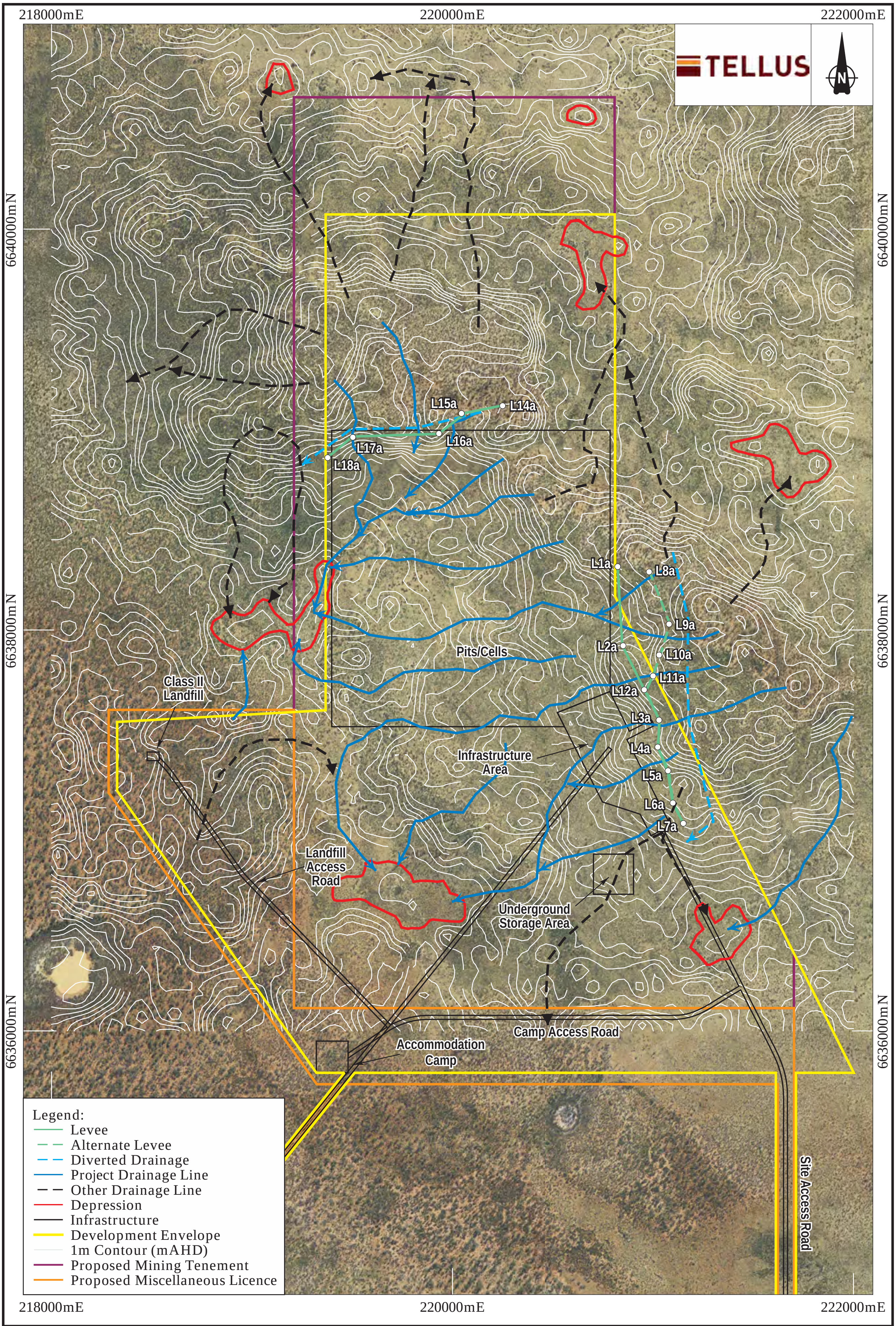
The probability for surface water flows occurring in the development envelope is considered to be very low due to the semi-arid climate of the region. Any surface water flows generated would be restricted to infrequent, but significant storm events.

Typically, rainfall would be intercepted by vegetation or infiltrated within the sandy surficial soils before being lost to evaporation (noting that annual evaporation is approximately eight times more than annual rainfall). However, any residual surface runoff (after infiltration losses) would flow overland following surface topography to lower-lying depressions where it would pool and then evaporate (refer to Figure 10-1).

The potential for indirect impacts on vegetation from the alteration of surface water runoff are considered to be negligible as the likely occurrence of large storm events generating runoff is rare given the semi-arid nature of the region.

To protect the proposed cells, drainage levees would be constructed to divert residual surface water flows around the cells (refer to Figure 10-1). These surface water flows would discharge down gradient of the cells following the natural topography across the landscape eventually infiltrating the soil profile or accumulating temporarily in the same low-lying depressions that would currently receive runoff.

Vegetation within the development envelope, however, is not reliant on surface water runoff for survival due to its location within the ‘semi desert Mediterranean’ bioclimatic category (Beard, 1990) and the risk of reduced surface water availability for vegetation is considered to be low.



0 400m Scale 1:25,000 MGA94 (Zone 51) CAD Ref: g2294_PER_09_01.dgn Date: November 2016 Rev: B A4	Aurora environmental Author: C. Dorrington AE Ref: THO2014-003 Drawn: CAD Resources ~ www.cadresources.com.au Tel: (08) 9246 3242 ~ Fax: (08) 9246 3202	**Sandy Ridge Facility** **Surface water drainage lines, depressions and levees** **Public Environmental Review**

Figure:

10-1

Dust

Impacts on flora and vegetation in the proposed development envelope resulting from dust generating activities would be localised. The main activities likely to create suspended dust particles in the air would be associated with vegetation removal, topsoil and subsoil stripping, blasting, excavation of overburden and ore, backfilling, truck movements and processing of ore. The extent of the dust dispersion would be determined by the intensity of the specific activity and the direction of the prevailing wind conditions.

Dust is more likely to be a hazard close to the cell (i.e. less than 1,000 m), with the hazard decreasing with distance until background dust levels are reached. However, under adverse weather conditions dust can travel considerable distances. Dust accumulation on leaf surfaces can reduce essential plant processes including photosynthesis, respiration and transpiration.

Dust can also produce physical effects on plants such as blockage and damage to stomata, shading, and abrasion of leaf surface or cuticle. This can result in cumulative effects such as drought, stress on already stressed species or lead to decreased plant health and even death in extreme circumstances. Decreased growth and vigour of plants may mean that they are more susceptible to pathogens and other disturbance, and these plants are more likely to be subject to increased mortality. Such impacts on individual plants generally result in decreased productivity and can result in changes in vegetation and community structure (Farmer, 1993).

Although the generation of dust from mining activities is unavoidable, the impacts on flora and vegetation are considered low due to the frequency and extent of each activity. These include the following:

- Vegetation removal and topsoil and subsoil stripping for cells and associated stockpiles would be undertaken annually, over a period of several days only, reducing the extent and volume of dust generated.
- Blasting would likely occur at a frequency of one event per year and would last for a matter of seconds.
- Excavation of overburden and ore, as well as backfilling with overburden, would be undertaken at one cell location per year, primarily below the ground surface, restricting the volume of dust released.
- Truck movements would be limited to four days per week (Monday to Thursday) at an average frequency of nine movements per week.
- The processing plant would be fully enclosed to contain dust emissions. A dust extraction system would be operational during ore processing.

Uptake of saline water from dust suppression

Saline groundwater with concentrations close to seawater would be used for dust suppression activities on hardstand work areas and internal access roads within the proposed development envelope. The consequences of vegetation utilising saline water would include reduced plant regrowth and damage to individual plants, due to either salt impacts on foliage or increased soil salinity.

The water cart spray drift would be designed to spray water across the width of the road, approximately 40 m wide. Some overspray could occur in the prevailing wind direction, which could affect roadside vegetation. The extent of vegetation indirectly affected would be limited to those plants within approximately 2 m of the road verge (a total area of 3.53 ha or less than 1% of vegetation within the proposed development envelope). Death of vegetation is considered unlikely on the basis that water would be applied sparingly to prevent runoff and water would likely evaporate in the semi-arid climate given the high energy and solar evaporation within the proposed development envelope which drives moisture from the soil.

Impacts from saline water used for dust suppression on vegetation within the proposed development envelope is not considered to be significant as less than1 % of vegetation within the proposed development envelope would be indirectly affected.

Uptake of saline water from potential water leaks within the former Jaurdi Pastoral Lease

A rupture or slow leak of saline water along the proposed pipeline route has the potential to impact upon vegetation within the former Jaurdi Pastoral Lease, including the proposed Conservation and Mining Reserve. The impacts on vegetation from utilising saline water include reduced plant growth and damage to individual plants due to either salt impacts on foliage or increased soil salinity.

Although impacts are possible, the risk of saline water significantly impacting vegetation within these DPAW managed areas are considered low, as the pipeline (approximately 110 mm external diameter) would be located with a 10 m wide corridor which would be cleared and kept free of vegetation. The pipeline would be subjected to weekly checks for leaks. However, any water leaking from the pipeline would likely evaporate quickly due to the high rates of evaporation experienced in the region. In addition, as the surficial soils within the proposed development envelope are a mix of predominately coarse (50-70%) and fine (20-30%) grained sands containing minimal clay content (i.e. 3-8%), saline water is likely to infiltrate rapidly rather than runoff.

Introduction and spread of weeds

Environmental weeds are described by DEC (1999) as ‘plants that establish themselves in natural ecosystems and proceed to modify natural processes, usually adversely, resulting in the decline of communities they invade’. Environments affected by mining activities are highly susceptible to invasion by weeds, as disturbances to soils caused by mining operations (i.e. creating bare ground) provide an ideal habitat where weeds can readily colonise and quickly become the dominant vegetation. Weeds pose a key risk, not only during the operational phase of mining, but also during rehabilitation or care and maintenance phases. Weed infestations can compete directly (as well as indirectly) with native or selected revegetation species and can also increase the risk of fires (and fire intensity) that may damage revegetated areas. Weeds have the potential to substantially change the dynamics of natural ecosystems by:

- Competing with or displacing native plant species.
- Affecting natural processes such as fire intensity, stream flows and water quality.
- Changing habitats and therefore impacting on ecosystem health.
- Diminishing natural aesthetic values (DLRM 2012 and Smith 2002).

The proposed development envelope currently contains no environmental weed species, however, it is possible that weeds could be introduced from vehicles movements, mainly from off-site vehicles entering the proposed development envelope. Weeds could then be spread through mining activities such as vegetation removal, topsoil and subsoil stripping, blasting, excavation of overburden and ore, backfilling, truck movements and processing.

Radiation exposure (flora and vegetation)

An assessment was undertaken using the ERICA software tool (refer Appendix A.14). In ERICA, the reference organisms are characterised by their dimensions, the concentration of radionuclides that they exhibit relative to the environmental media with which they are associated and the fraction of the time (occupancy) that they are present within, or at the surface of, the various environmental media.

With this information, dose conversion factors can be used to convert concentrations in organisms into whole-body dose rates, which are then compared to threshold dose rates (dose constrains) (e.g. 10 µGy/h) for various broad categories of organisms to which there are not expected to be significant population effects.

Four exposure scenarios were modelled using ERICA Tier 2 assessments:

- Scenario 1 – exposure of fauna and flora present in the area surrounding the radioactive waste warehouse.
- Scenario 2 – exposure to windblown material originating from operational (kaolin) stockpiles e.g. plant tails; ore, sand, laterite and silcrete stockpiles.
- Scenario 3 – exposure to windblown material originating from ad hoc (waste) stockpiles e.g. low level NORM received as bulk or from emergency clean-up operations.
- Scenario 4 – exposure post closure, with capping material and rehabilitation during the institutional control period.

The above scenarios are highly unlikely to occur because upon closure, with a minimum capping of 7 m, and for the duration of the institutional control period, no risk to non-human biota is foreseen.

The modelled dose rates for all organisms are below the threshold dose rate of 10 µGy/h. External gamma dose rate on surface post closure (minimum cover of 7 m) would be negligible, even if all radioactive waste (2,500,000 tonnes) would be high activity concentration radium scales at an activity concentration of 17,800 Bq/g radium (Ra-226 and Ra-228 combined).

Transpiration of leachate from waste cell

The death of vegetation via transpiration of leachate from the waste cells is not likely to occur. The reasons for this include:

- There would be a separation distance between shallow plant roots and the stored waste. Approximately 7 m of compacted backfill would separate stored waste from the surface. Vegetation would be planted on the topsoil on the domed cap, which is elevated between approximately 1.7 m to 5 m above the ground surface. It is highly unlikely that plant roots would penetrate to the stored waste.
- Leachate would be highly unlikely to be generated from the stored waste, given the lack of groundwater and surface water infiltration into a cell. Engineered controls outlined in the Safety Case specifically exclude water from entering the cell cap.
- In order for planted vegetation to survive, groundwater-dependent species would not be planted. The vegetation planted would be adapted for semi-arid environments and, therefore, would be shallow rooted with a fibrous root system rather than a tap root system which may penetrate deeper.

Vegetation association cumulative impacts

Regional vegetation associations mapping has been used to assess cumulative impacts from the Carina Iron Ore Mine, the IWDF and the Jackson 4 Iron Ore Mine and Haul Road in combination with the Proposal. Regional level mapping has been used rather than local scale mapping, due to the difficulties in comparing vegetation types, which differs substantially between botanists depending on their preferred naming conventions.

Table 10-5 lists the area cleared/proposed to be cleared from each project, and lists the cumulative impacts on the vegetation association. For all affected vegetation associations, less than 1% of their current extent is affected by clearing for all projects combined. Therefore, the cumulative impacts would be negligible and insignificant.

Table 10-5 Cumulative impacts on vegetation

Vegetation association	Current Extent (ha)	Total clearing for Carina Iron Ore Project (ha)	Total clearing for IWDF (ha)	Total clearing for J4 satellite cell (ha)	Total clearing for Sandy Ridge Project (ha)	Cumulative impact (ha)	Impact on current remaining vegetation[27] (%)
141 – Medium woodland; York gum, salmon gum and gimlet	858,525.04	379.10	3.61	536.82	18.89	938.42	0.11
437 – Shrublands; mixed acacia thicket on sandplain	312,825.96	-	71.25	-	254.16	325.41	0.10
538 – Eucalyptus open woodland/Triodia open hummock grassland	124,866.81	39.56	-	10.38	2.61	52.55	0.04
435 – Acacia sparse shrubland/Cryptandra mixed sparse heath	732,470.23	149.33	21.77	162.57	0.39	334.06	0.05
128 – Bare areas; rock outcrops	34,228.77	2.20	1.48	-	-	3.68	0.01
142 – Medium woodland; York gum and salmon gum	11,118.41	3.48	5.03	-	-	8.50	0.08
520 – Shrublands; *Acacia quadrimarginea* thicket	21,214.46	-	-	95.29	-	95.29	0.45
936 – Medium woodland; salmon gum	5,501.81	-	-	10.04	-	10.04	0.18

[27] *Based on current extent remaining in the Coolgardie IBRA Bioregion as per DPAW (2014).*

Evidence of the presence of Rainbow Bee-eater in the region has been documented:

- Two birds were recorded during the field surveys within the proposed development envelope at Sandy Ridge.
- Three records of the bird from two sites (Polaris Metals NL, 2010).
- Approximately 21 records within 50 km of the J4 study area (Polaris Metals Pty Ltd, 2013).

This suggests the migratory bird may frequent the region. The global distribution of the Rainbow Bee-eater is listed by DoE (2016b) as:

The Rainbow Bee-eater is widely distributed throughout Australia and eastern Indonesia, including Bali, the Lesser Sundas and Sulawesi, and east to Papua New Guinea, the Bismarck Archipelago and, rarely, the Solomon Islands. It is a vagrant visitor to locations further north including Palau, south-western Micronesia, Saipan, the northern Mariana Islands, and Miyako Island and the southern Ryuku Islands in Japan.

Given the bird's ability to fly away from disturbance before being affected, and its large distribution and likely low densities in the region, it is unlikely that significant impacts on the Rainbow Bee-eater would occur on a species, population or assemblage level.

10.2.4 Proposed mitigation and management measures

Although impacts on flora and vegetation are not considered to be significant, the following mitigation and management measures would be implemented to further reduce impacts to flora and vegetation during construction and operation of the Proposal.

Construction Environment Management Plan

A Construction Environment Management Plan (CEMP) would be developed which would address potential impacts on flora and vegetation. The CEMP would include the following key mitigation and management measures with respect to flora and vegetation:

- If the *Lepidosperma* sp. is deemed to have conservation significance, surveys would be undertaken prior to construction to confirm the presence/absence of the species within the proposed development envelope. If the species is found to be present, significant impacts would be avoided through changes to the location of the proposed infrastructure, if possible. Alternatively, a translocation program developed in consultation with DPAW would be implemented to avoid significant impacts to this species. If significant impacts could not be avoided, the need to calculate and deliver biodiversity offsets would be assessed in accordance with the *Environment Protection and Biodiversity Conservation Act 1999 Environmental Offsets Policy* and in consultation with the DoEE and/or DPAW, as approprite.
- Educate contractors during inductions and regular toolbox meetings regarding the presence of *Calytrix creswellii* and *Lepidosperma lyonsii* within the proposed development envelope.
- Ensure that clearing is kept to a minimum and undertaken progressively, where possible.

- Develop and implement specific clearing procedures, including:
  - Delineation of clearing boundaries with high visibility flagging tape.
  - Clearing authorisation requirements.
  - Supervision of all clearing activities by environmental staff.
- Ensure that the populations of *Calytrix creswellii* and *Lepidosperma lyonsii* are incorporated into mine planning, marked with flagging tape and avoided.
- Implement dust suppression and management measures to mitigate any adverse effects on vegetation including the following:
  - Stabilisation of topsoil stockpiles.
  - Application of dust suppression methods along internal access roads and hard stand areas using watercarts during dry, dusty periods.
  - Monitoring of weather conditions prior to mining activities most likely to generate dust (i.e. vegetation removal, topsoil and subsoil stripping and blasting).
  - Installation of dust deposition gauges in close proximity to the population of *Calytrix creswellii* within the proposed development envelope and at control locations and ensure monitoring is conducted quarterly for 12 months. The final locations of dust deposition gauges would be identified in consultation with DER.
- Monitor vegetation health either side of the surface water diversion levees to determine if water ponding or water starvation is occurring and adversely affecting vegetation.
- Incorporate weed management measures into the CEMP.
- Conduct weekly inspections of the water pipeline to identify leaks and conduct any necessary repairs.

Outcomes/objectives, trigger and contingency actions to ensure impacts on flora and vegetation are not greater than predicted would be included in a Flora and Vegetation Management Plan that would be included as part of the CEMP.

Emergency Response and Management Plan

Fire prevention and management measures would be implemented and outlined in an Emergency Response and Management Plan. These measures would include:

- Hot work permits would be required prior to commencing any activity that may create an ignition source.
- Ensure that fire extinguishers are available in all hot work areas and personnel are trained in their use.

- If necessary, undertake controlled burning of shrubland vegetation under cool mild conditions in consultation with DPAW to reduce the size and intensity of bushfires by burning fuel loads and to reduce the likelihood of fire spreading to fire sensitive woodlands.
- Ensure that emergency response procedures for bushfires and for controlled burning activities are understood and adhered to within and around the proposed development envelope.

Rehabilitation of disturbed areas

All disturbed areas would be rehabilitated in accordance with the Waste Facility Decommissioning Closure Plan (refer Appendix A.18) and MCP (refer Appendix A.19). Rehabilitation would primarily include respreading of topsoil, ripping of surface, revegetation using local indigenous species, irrigation in the initial months of establishment and the application of fertiliser (where appropriate). Further details on rehabilitation are provided in detail in Appendices A.17 and A.19.

10.2.5 Predicted environmental outcome

After implementing the mitigation and management measures described above, the following environmental outcomes are expected in regard to flora and vegetation:

- No more than 276.05 ha of native vegetation would be cleared for the Proposal. The actual area of clearing is likely to be less than this area once exploration drilling has been completed to confirm the planned locations of the cells and associated stockpiles, V drains and sumps.
- Clearing of native vegetation would not significantly reduce the extent of any regional vegetation association, with less than 1% of the pre-European extent and less than 1% of the current area remaining for all vegetation associations present within the proposed development envelope.
- No regional vegetation associations would be cleared below the ‘threshold level’ of 30% of its pre-clearing extent.
- No Priority Ecological Communities listed by DPAW, Threatened or Endangered Ecological Communities listed under the WC Act or Threatened or Endangered Ecological Communities listed under the EPBC Act would be impacted by the Proposal.
- No direct impacts on the Mount Manning Nature Reserve, Mount Manning – Helena and Aurora Ranges Conservation Park or the Die Hardy Class A Reserve would occur given these areas are greater than 9 km from the Proposal.
- Less than 1% of the vegetation within the former Jaurdi Pastoral Lease and less than 1% of the vegetation within the Proposed Conservation and Mining Reserve would be cleared for the Proposal, which is not considered to significantly alter the high biodiversity conservation values of these DPAW managed lands.

- Populations of *Calytrix creswellii* and *Lepidosperma lyonsii* (both listed as Priority 3 under the WC Act) would not be reduced as a result of the Proposal.

With the implementation of the proposed mitigation and management measures listed above, the EPA's objective to maintain representation, diversity, viability and ecological function at the species, population and community level would be achieved.

10.3 Terrestrial environmental quality

10.3.1 Introduction

This section assesses the potential impacts on terrestrial environmental quality during both construction and operation of the Proposal. Mitigation and management measures are identified to avoid or reduce potential impacts with the objective *to 'maintain the quality of land and soils so that the environment values, both ecological and social, are protected'* in accordance with the EPA's Environmental Assessment Guideline No. 8 (2015a).

This section draws on several comprehensive studies including:

- *Sandy Ridge Project Soils Assessment* (Landloch, 2015; see Appendix A.5).
- *Mine Closure Plan* (See Appendix A.19).
- *Sandy Ridge Landform Evolution Modelling* (Landloch, 2016; see Appendix A.7).
- *Sandy Ridge Project Western Australia Regional Geology and Geological Evolution* (CRM, 2016; Appendix A.4).
- ERICA modelling (Hygiea Consulting, 2016; see Appendix A.14).
- *Radioactive Waste Management Plan* (see Appendix A.14).
- *Safety Case Summary Report* (see Appendix A.15).
- *Waste Facility Decommissioning and Closure Management Plan* (see Appendix 18).

The assessment has also been prepared with reference to the applicable standards, guidelines and procedures listed in Chapter 4, Table 4-3 and in accordance with the requirements set out in the ESD which is presented in Appendix A.1.

10.3.2 Methodology

Land use and topography within and in the vicinity of the proposed development envelope was determined based on a desktop review of publicly available information, a review of aerial photography and via a field reconnaissance survey.

A regional geology and geological evolution report was prepared in order to understand and describe the geology within and in the vicinity of the proposed development envelope. This included a desktop review of publicly available information, a review of geological mapping and a field reconnaissance survey.

A baseline soils assessment was undertaken to characterise and quantify the soil resource within the proposed development envelope. The baseline soils assessment included:

- Desktop review of publicly available information including: Geoscience Australia and Geological Survey of WA mapping, Western Australian Department of Agriculture technical bulletins and online journal articles
- Field assessment, including excavation of four soil cells to 1.5 m below ground level (BGL), for collection of soil samples and logging of soil profiles
- Physical and chemical analysis of collected soil samples, and interpretation of results
- Soil mapping of the proposed development envelope.

Climate data (rainfall, temperature, humidity, wind speed and direction) for the area was obtained from the BoM weather station at Menzies, located approximately 110 km to the north-east of the proposed development envelope. Climate data was also obtained from an Automated Weather Station (AWS) set up within the proposed development envelope in May 2015.

10.3.3 Assessment of potential impacts and risks

Impacts on terrestrial environmental quality during construction and operation of the Proposal include the removal degradation of stockpiled soils; soil contamination from leaks/spills; potential subsidence and instability of a waste cell allowing infiltration of water and generation of leachate; sterilisation of minerals beneath the cells; and a change in landform. These impacts are discussed below. The potential impacts associated with radiation exposure are also discussed, although are highly unlikely to occur.

Mitigation and management measures to avoid or reduce impacts on terrestrial environmental quality are outlined in Section 10.3.5.

Direct impact of soil removal

The mining pit and surface infrastructure would disturb the Deep Yellow Sands, while the accommodation camp and Class II waste storage facility would disturb the Red Sandy Duplex soils (see Table 10-6). GIS software was used to calculate the disturbance area of the roads and racks to the two soil types.

Road corridor disturbance width is assumed to be 20 m and the extent is from the Mt Dimer access road turn off to the Class II waste facility and the entrance to the mining infrastructure.

Table 10-6 Disturbance areas by soil type for the Proposal

Disturbance type	Area (ha)	
	Deep Yellow Sands	Red Sandy Duplex
Mine pit and waste disposal and permanent isolation	37.2 ha	
Mine surface infrastructure	11.8 ha	
Accommodation camp		2.5 ha
Class II waste facility		0.26 ha
Underground storage area	4.0 ha	
Roads and tracks (average 20 m wide)	12.8 ha	5.5 ha
TOTALS	**65.8 ha**	**8.26 ha**

The soil extents within the proposed development envelope are:

- Red Sandy Duplex – 8.26 ha.
- Deep Yellow Sands – 65.8 ha

Recoverable topsoil volumes based on a strip of 10 cm are:

- 8,260 m^3 of Red Sandy Duplex.
- 65,800 m^3 of Deep Yellow Sand.

Recoverable subsoil volumes based on a strip of 20 cm are:

- 16,520 m^3 of Red Sandy Duplex.
- 131,600 m^3 of Deep Yellow Sand.

Both soil types are poorly structured and have a high presence of sand. This means they are likely to be susceptible to erosion, particularly if they are placed on a sloping land surface.

Degradation of stockpiled soils

The creation of cells would require stockpiling of topsoil and subsurface soil for the first 10 years of operations. From years 11 to 25, direct stripping topsoil/subsoil from one cell, could be directly respread on the recently completed cell (i.e. material stripped from cell 11 is placed on cell 1) rather than stockpiled. An identified risk of rehabilitation is the degradation of topsoil and subsoil stockpiles. Stockpiling of soils can lead to compaction, nutrient depletion and loss of seed stock and soil microfauna.

Implementing these principles would mean the risk of stockpile degradation would be low. Topsoil and subsurface soils would be respread with a seed bank of target species and adequate nutrient levels to ensure germination and growth of vegetation.

At mine closure, there would be no residual stockpiles, as these would be incorporated into the final cell landform as per the MCP (see Appendix A.19). Therefore, the soils are expected to maintain their quality and are unlikely to be significantly impacted by the Proposal.

Soil contamination from leaks/spills

Direct contamination of surficial soils could occur from:

- Leak or spill from a solid waste package.
- Leak or spill of dangerous goods stored or used onsite (e.g. diesel).
- Overflow of a contaminated water pond or pad (i.e. when washing down containers), from a leak/crack in a pond liner or from a very low pressure system event which overflows contaminated water from ponds.
- Waste spill during transfer to the cells.
- Bushfire and use of fire-fighting foams and chemical extinguishers.

The consequence of a solid spill from a waste package on soils would be minor as the spill would likely be isolated within the immediate vicinity of the spill site. If the spill were to occur in any of the operational areas (warehouse or receivables pad), these areas would be concreted and bunded and the spill would be unlikely to contact the underlying soil. An identified hazard is a vehicle collision with an ADT which is carrying waste along the road between the infrastructure area and the open cell. If loss of containment occurred, solid waste material could spill onto the surrounding road and cause localised soil contamination, may damage vegetation and toxic dust may disperse from the spill site.

To avoid this, all operators would be trained and familiar with operational procedures and educated regularly at toolbox meetings. There would be onsite traffic management, including speed limits and two-way communication between all vehicles. Visual assessments and rapid clean-up of the spill would ensure the extent of the spill is small, and efficient and effective clean-up would minimise dust generation. With these measures in place, the likelihood of soil contamination would be unlikely and the residual risk would be low.

The refuelling station would consist of a diesel storage tank, pipelines and a bowser. Diesel would be contained in a double walled (self bunded) above ground tank. The refuelling point for plant would have a spill containment unit installed in the ground to capture leaks during refuelling. The bowser would be contained within a self bunded skid unit. Spill kits would be available and the operators working in the area would be trained in operating procedures on how to manage a spill incident, and regular toolbox meetings would be held to continually educate operators. These measures would reduce the likelihood of spilt material affecting the underlying soils to unlikely and the residual risk would be low.

The consequence of a contaminated water overflow from a pond or a waste spill may be moderate as water would likely infiltrate and, therefore, soils at depth could be impacted by a spill, which could take longer to clean-up than a surface spill. It is considered unlikely that contaminated overflow water would impact on soil quality following the implementation of management measures such as:

- Quality assurance/quality control testing on liners.
- Engineering design (which includes 500 mm of freeboard in ponds, and that the ponds are of sufficient capacity to hold washdown and contaminated water).
- Containment of overflow in a secondary sump.
- Implementation of operational procedures including visual inspections of pond/sumps and washdown procedures.

In the event of a cyclone, water could be pumped from the cell into tankers and removed from site prior to heavy rainfalls occurring to ensure the pond would not overflow. To avoid a waste spill contaminating water, wastes would not be transferred into the cells whilst surface water flows are occurring in the infrastructure area, on the internal access road to the cells or in the vicinity of the open cell.

Fire-fighting foam and extinguishers contain chemicals to douse a fire, leaving residual chemicals in the soil following evaporation of water. The consequence of this could be moderate, in the case of a large fire where the use of foams or extinguishers could be extensive. The use of fire extinguishers would be minimised as far as possible, and the soil contamination assessed and remediated in accordance with DER (2014) guidance.

Subsidence and instability of waste cell allowing infiltration of water and generation of leachate

Subsidence and instability of a waste cell could occur if backfilling and compaction activities are not undertaken in accordance with specified procedures. This may lead to the generation of a void space(s) within the cell, which could then cause slumping of the cell backfill, changes to the integrity of the cap, and may generate pathways with greater permeability for water to enter the cell. Water entering the cell could potentially generate leachate from the waste packages.

Impacts on soil quality would be associated with:

- Degradation of the physical structure of soils at the surface (i.e. those that have caved in or collapsed inwards to the cell).
- Soil contamination at the base of the mine void.

Hazards which may contribute to subsidence are primarily related to the backfill and compaction requirements of the engineering design. This would be managed through briefings to the operators from the project engineer, measurements of compaction density undertaken in accordance with *AS1289.5.8.1*, visual inspection following placement of waste and backfill of each layer, and topographical survey at the completion of each layer to confirm engineering specifications have been met and monitoring of the clay dome following cell completion.

Sterilisation of minerals beneath the cells

The proposed development envelope is located in the centre of a 160 km long and 20 km wide north-north-west trending granitic body covering approximately 3,200 km^2 (CRM, 2016). Within the proposed development envelope, the weathered granite is typically 6 m BGL and unweathered/fresh granite is greater than 27 m BGL. The result of disposing of waste within a mine void hosted by weathered granite would permanently prevent access to geological materials located below the cells. This would effectively sterilise materials below the subsurface from any surface soils.

The footprint of an individual cell would be approximately 7,200 m^2 (0.0072 km^2). Assuming 25 cells are constructed over the life of the Proposal, this represents a loss of access to 0.18 km^2 or less than 1% of the land (subsurface). The consequence of this is minor, as subsurface soils are not of social or economic benefit or heritage, hydrological or hydrogeological value (in that they are not part of an aquifer or connected to surface water receptors). The impact of this loss or 'sterilisation' of minerals below the cells is not considered significant, as abundant granite and kaolin are available in the north-north-west trending granitic body. Therefore, the impact on the land quality from sterilisation would be negligible.

Graphical conceptual representation of the final landform

Landform evolution modelling was undertaken by Landloch (Appendix A.7). The modelling was used to predict changes to the landform once mine closure and rehabilitation has been completed. The model incorporated potential changes to the landform over a period of 10,000 years. It included an assessment of:

- Rainfall.
- Average minimum and maximum temperatures.
- Dew point temperature.
- Slope.
- Solar radiation.
- Wind speed and direction.

The model calculates potential erosion rates and sediment loads during different rainfall events/intensities to predict whether the landform would change over time i.e. up to and including 10,000 years. The modelling predicted that there would be relatively little change to the clay domes and the landform is likely to be erosionally stable over the very long term.

A graphical representation of the current view from the west of the proposed development envelope is provided in Figure 10-2. The graphic shows the cells area as vacant, sparsely vegetated land. Figure 10-2 also shows a graphical representation of the final landform with the domed caps of the cells approximately 5 m higher than the surrounding land. The surrounding landscape is mapped by Tille (2006) as Norseman (266); consisting of very low relief, undulating plains and low rises. It is considered that the increased height of the waste cell landforms would likely blend in with the natural topography of the surrounding landscape.

Radiation exposure (land and soils)

An assessment was undertaken using the ERICA software tool (refer Appendix A.14).

Four exposure scenarios were modelled using ERICA Tier 2 assessments:

- Scenario 1 – exposure of fauna and flora present in the area surrounding the radioactive waste warehouse.
- Scenario 2 – exposure to windblown material originating from operational (kaolin) stockpiles e.g. plant tails; ore, sand, laterite and silcrete stockpiles.
- Scenario 3 – exposure to windblown material originating from ad hoc (waste) stockpiles e.g. low level NORM received as bulk or from emergency clean-up operations.
- Scenario 4 – exposure post closure, with capping material and rehabilitation duration the institutional control period.

The above scenarios are highly unlikely to occur because upon closure, with a minimum capping of 7 m, and for the duration of the institutional control period, no risk to non-human biota is foreseen (refer to Section 10.2.3).

The modelled dose rates for all organisms are below the threshold dose rate of 10 μGy/h. External gamma dose rate on surface post closure (minimum cover of 7 m) would be negligible, even if all radioactive waste (2,500,000 tonnes) would be high activity concentration radium scales at an activity concentration of 17,800 Bq/g radium (Ra-226 and Ra-228 combined).

10.3.4 Consistency with the National Waste Policy and Western Australian Waste Strategy

The Proposal would be consistent with the *National Waste Policy: Less Waste, More Resources* or NWP (DoE, 2015a) and the *Western Australian Waste Strategy: 'Creating the Right Environment'* (Western Australian Waste Authority, 2012), as discussed below and in Section 4.6.

The Proposal would not result in an increased production of hazardous waste in WA or within Australia. As discussed in Section 2.4.2, waste volumes in the hazardous waste market between 2014 and 2034 have been estimated by Blue Environment Pty Ltd (2015) (refer to Figure 2-2). The estimates predict that Australia would produce approximately six million tonnes of hazardous waste in 2016. By 2034, the volume of hazardous waste produced is predicted to rise to 10 million tonnes. Of the total volume produced per annum in Australia, the proponent proposes to manage a very small portion of the total volume, as shown in Figure 2-2.

The orange line in Figure 2-2 shows that despite a predicted increase of hazardous waste over the next 20 years, the Proposal is seeking approval for a steady state of 100,000 tonnes (capacity) of hazardous waste per annum. Approval of the Sandy Ridge Facility would not increase the production of hazardous waste in Australia but go a long way to assisting in the legacy waste management issue within WA and Australia.

The benefits of receiving hazardous wastes interstate are that it would also help reduce legacy hazardous waste management issues at those locations. Risks associated with receiving wastes from all over Australia are excluded from this assessment (refer to Section 5.1 for more information).

National Waste Policy

The *National Waste Policy: Less Waste, More Resources* or NWP (DoE, 2015a), agreed by all Australian Environment Ministers in 2009, provides for a coherent, efficient and environmentally responsible approach to waste management in Australia. The policy provides waste management and resource recovery direction to 2020. The aims of the NWP are to:

- Avoid the generation of waste, reduce the amount of waste (including hazardous waste) for disposal.
- Manage waste as a resource.
- Ensure that waste treatment, disposal, recovery and re-use is undertaken in a safe, scientific and environmentally sound manner.
- Contribute to the reduction in greenhouse gas emissions, energy conservation and production, water efficiency and the productivity of the land.

The NWP includes hazardous wastes and substances in the municipal, commercial and industrial, construction and demolition waste streams and covers gaseous, liquid and solid wastes. Radioactive waste is excluded. The policy sets directions in six key areas and identifies 16 priority strategies that would benefit from a national or coordinated approach. The strategies focus on (but are not limited to) sustainability, collaboration, reducing health and safety risks, better packaging management and classification of wastes, reduction in biodegradable wastes sent to landfill, services to remote and regional communities and responsibility to international obligations.

The Proposal would be developed with consideration of the NWP. If implemented, the Proposal would support the following key areas of the policy:

- **Improving the market** – efficient and effective Australian markets operate for waste and recovered resources, with local technology and innovation being sought after internationally.
- **Reducing hazard and risk** – reduction of potentially hazardous content of wastes with consistent, safe and accountable waste recovery, handling and disposal.
- **Tailoring solutions** – increased capacity in regional, remote and Indigenous communities to manage waste and recover and re-use resources.

Western Australian Waste Strategy

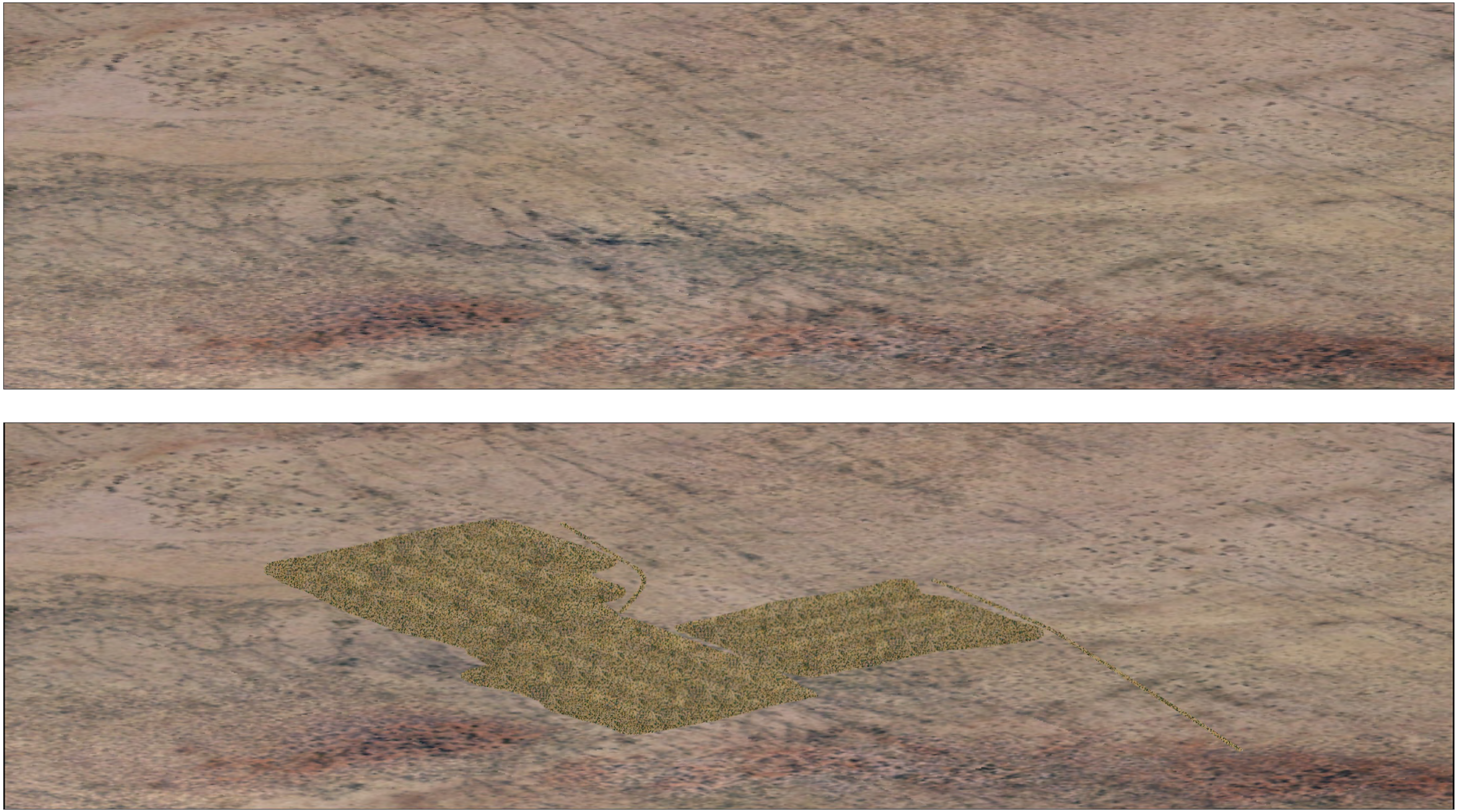
The *Western Australian Waste Strategy: 'Creating the Right Environment'* (Western Australian Waste Authority, 2012) is the primary strategy for waste management and resource recovery in WA. The five objectives of the strategy are as follows:

- **Strategy objective 1** – initiate and maintain long-term planning for waste and recycling processing, and enable access to suitably located land with buffers sufficient to cater for the State's waste management needs.
- **Strategy objective 2** - enhance regulatory services to ensure consistent performance is achieved at landfills, transfer stations and processing facilities.
- **Strategy objective 3** - develop best practice guidelines, measures and reporting frameworks and promote their adoption.
- **Strategy objective 4** - use existing economic instruments to support the financial viability of actions that divert waste from landfill and recover it as a resource.
- **Strategy objective 5** - communicate messages for behaviour change and promote its adoption, and acknowledge the success of individuals and organisations that act in accordance with the aims and principles in the strategy and assist in its implementation.

If implemented, the Proposal would support the objectives of the WA Waste Strategy (particularly Strategy objective 1) by planning for the long-term storage and isolation of hazardous, intractable and LLW that cannot be recycled or recovered, to cater for WA's waste management needs.

Waste disposal cumulative impacts

Situating the Proposal adjacent to an existing Class V landfill (the IWDF) may affect the future use of the land in this locality, but this impact is negated by the fact that the environment is ideal, and potentially the best possible location for the long-term storage of hazardous wastes in WA. By co-locating Class V landfills, this avoids land use conflicts from locating the Facility elsewhere in WA which is a benefit to the State. As there are no pastoral, economic or social values associated with the locality of the IWDF or the Proposal, the cumulative impacts on terrestrial environmental quality is considered insignificant.



TELLUS

Aurora environmental

CAD Ref: g2294_PER_09_02.dgn

Date: Nov 2016 | Rev: B | A4

Author: C. Dorrington | AE Ref: THO2014-003

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Tel: (08) 9246 3242 ~ Fax: (08) 9246 3202

Sandy Ridge Facility

Current and final landform

Public Environmental Review

Figure:

10-2

10.3.5 Proposed mitigation and management measures

The following mitigation and management measures would be implemented with respect to terrestrial environmental quality (following the mitigation hierarchy of avoidance and minimisation):

- Prior to ground disturbance, detailed baseline soil sampling would be undertaken in accordance with the requirements of the Department of Health and Department of Lands to avoid sensitive soils such as highly erodible soils. This management measure would be linked to an overall Construction Environmental Management Plan (CEMP) to ensure soil erosion is avoided and/or minimised in areas characterised as being potentially highly erodible. Contingency measures would include a combination of minimal vegetation removal; silt traps, catch-drains etc. The following principles would be implemented when stockpiling soils:
    - Combined use of a front-end loader, truck and bulldozer would be used to stockpile soils to reduce compaction, not a scraper.
    - Topsoil stockpiles would not exceed 1 m in height and would be flat-topped or slightly domed to maximise water entry. Encouraging water entry would make more water available to plants and minimise the risk of erosion and sediment movement from the stockpile.
    - Subsurface soils (deep yellow sands) would be stockpiled up to 4 m tall and would be flat-topped or slightly domed to maximise water entry.
    - Stockpiles would be monitored for changes in physical and chemical condition. Monitoring should occur at a minimum of every 12 months and should record:
        - Surface condition and erosion.
        - Nutrient status, pH and electroconductivity.
        - Seed germination.
    - If soils are stockpiled for longer than 12 months, they would be fertilised and seeded to reduce erosion, maintain and accumulate soil organic matter and increase soil seed banks.
    - Monitoring of stockpiles for erosion (wind and water) and weed infestation would occur.
- Tree debris including shrubs, brush with trunk diameters greater than 10 cm should be used as erosion protection for stockpiled soil material. In addition, the debris from trees, shrubs, brushes and grasses would add seed, nutrients and organic carbon to the soil.
- Soil striping to the recommend depth of 30 cm should be performed at a time of year when the soil seed bank is highest.
- To avoid compaction of soils, handling of topsoils should not be undertaken when it is wet.

- Spill response operational procedures would be implemented. Visual assessments and rapid clean-up of any spill would ensure the extent of the spill is small, and efficient and effective clean-up would minimise dust generation. This management measure would be linked to a detailed Emergency Response Management Plan (ERMP). The PER currently provides and outline ERMP in Appendix A.22 which would be updated to a detailed management plan once detailed engineering design has been completed for the Proposal.
- All operators would be trained and familiar with operational procedures and are educated regularly at toolbox meetings. There would be onsite traffic management, including speed limits and two-way communication between all vehicles to mitigate potential spills. The proposed CEMP and Operation Environment Management Plan (OEMP) would include provisions for on-site traffic management and internal communications.

In addition, a Mine Closure Plan (AppendixA.19), a Waste Facility Decommissioning and Closure Management Plan (Appendix A.18) and a Radioactive Waste Management Plan (Appendix A.14) have prepared for the Facility. The management objectives for mine closure, rehabilitation and decommissioning are discussed in Section 10.9.4 and summarised in Table 10-7.

Table 10-7 Indicative completion criteria

Trigger	Closure objective	Indicative completion criteria[28]	Management tools
Landform stability	Each excavated pit is structurally stable.	At closure of the pit, walls do not collapse inwards.	Geotechnical assessment.
Safety and security	Each excavated pit is free of ponded water (i.e. not a pit lake).	At closure the mine void does not pose a safety hazard, that persons or vehicles could accidently fall into. The mine void would not contain water of sufficient volume that could create a potential drowning hazard.	Visual inspection. Safety bunding around all open pits.
Vegetation development	Vegetation in rehabilitated areas is comparable as reasonably practicable to the analogue site.	At the completion of the 10 year rehabilitation monitoring period vegetation composition is comparable to the species diversity/richness and structure of the analogue site. All plants used in rehabilitation to be of local provenance. No declared pests[29] to be introduced into the area.	Re-vegetation monitoring
Decommissioning	Mining related infrastructure (except for that infrastructure to be closed under the WFDCP) removed from site during the Decommissioning Phase.	At mine closure, no mining related infrastructure is left on the tenement.	Visual inspection.

10.3.6 Predicted environmental outcome

The site for the Proposal was specifically chosen in this location because of the lack of groundwater aquifer and surface water receptors, so that the Proposal operations would not significantly impact these environmental aspects.

Therefore, the land and soils of the proposed development envelope would be maintained and would be very unlikely to be significantly affected by the Proposal. With the management and mitigation and contingency measures outlined in Section 10.3.5, the EPA objective to maintain the quality of land and soils so that the environmental values, both ecological and social, are protected would be achieved.

[28] *As described in Appendix K of the MCP guidelines (DMP & EPA, 2015), indicative completion criteria is used in the early stages of closure planning, and may be qualitative or semi–quantitative. As the closure planning progresses the completion criteria would become quantitative.*

[29] *Declared pests are defined under the Biosecurity and Agriculture Management Act 2007 and have the meaning (a) a prohibited organism; or (b) an organism for which a declaration under section 22(2) is in force.*

10.4 Terrestrial fauna

10.4.1 Introduction

This section assesses the impacts on terrestrial fauna during both construction and operation of the Proposal. Mitigation and management measures are identified to avoid or reduce potential impacts with the objective *to 'maintain representation, diversity, viability and ecological function at the species, population and assemblage level'* in accordance with the EPA's Environmental Assessment Guideline No. 8 (2015a).

This section draws on a number of comprehensive studies including:

- *Level 1 Vertebrate Fauna Assessment for the Sandy Ridge Project* (Terrestrial Ecosystems, 2015; see Appendix A.8).
- *Sandy Ridge Project Malleefowl Assessment* (Bamford Consulting Ecologists [BCE], 2016; see Appendix A.8).
- ERICA modelling (Hygiea Consulting, 2016; see Appendix A.14).

The assessment has also been prepared with reference to the applicable standards, guidelines and procedures listed in Chapter 4, Table 4-3 and in accordance with the requirements set out in the ESD which is presented in Appendix A.1. A copy of the EPA's checklist for documents submitted for environmental assessment on terrestrial biodiversity is provided in Appendix A.9.

10.4.2 Methodology

A Level 1 Vertebrate Fauna Assessment was undertaken to assess the fauna values of the proposed development envelope and to identify the potential presence of fauna species of conservation significance. The fauna assessment included:

- A review of previous fauna surveys in the region to determine the potential fauna assemblage for the general area.
- A review of relevant biodiversity databases for Threatened and Priority fauna that may be affected by the Proposal.
- A field reconnaissance survey that included a fauna habitat assessment.
- Targeted threatened fauna searches for Malleefowl (*Leipoa ocellata*).

Based on the results of the Level 1 Vertebrate Fauna Assessment, a Level 2 Vertebrate Fauna Assessment was not required. More information is provided in Appendix A.8.

10.4.3 Assessment of potential impacts and risks

The direct impact on terrestrial fauna during construction and operation of the Proposal would be the loss of habitat (through the removal of vegetation within the proposed development envelope). Indirect impacts may include those associated with increased light, noise and vibration; fauna displacement, increased predation and competition for resources; fire; increased feral fauna attracted to water and food resources; and injury or death from fauna ingress into a cell or from collisions. These impacts are discussed below.

The potential impacts associated with radiation exposure and the generation of void space and subsequent collapse/instability of the waste cell are also discussed, although are highly unlikely to occur. Mitigation and management measures to avoid or reduce impacts on terrestrial flora and vegetation are outlined in Section 10.2.4.

Direct impacts (loss of habitat - regional impacts)

The removal of approximately 276.05 ha of native vegetation would result in the loss of fauna foraging, breeding, roosting, sheltering and/or dispersal habitat. Four regional vegetation associations occur within the proposed development envelope, as defined by Beard (1972). Each of the four regional vegetation associations that occur within the proposed development envelope have greater than 97% of their pre-European extent remaining in the Southern Cross IBRA Subregion. Direct clearing of each vegetation association would represent clearing less than 1% of their current remaining extent. These impacts would not have a significant impact on fauna habitat at a regional level.

The Great Western Woodlands covers an area of almost 16 million ha. Clearing of less than less than 1% of the Woodland Beard vegetation associations (141 and 538) would have a negligible and insignificant impact on the values of the Great Western Woodlands.

Direct impacts (loss of habitat - local impacts)

Almost all native fauna relies on native vegetation to provide food, shelter and breeding sites. The removal of vegetation reduces the capacity of habitat to support fauna, potentially leading to the displacement of fauna. Linear clearing for tracks can fragment habitats by partitioning existing activity areas, isolating sections of established communities and altering long and medium-term patterns of movement within established home ranges, particularly for small mammals and reptiles.

Two fauna habitats were identified within the proposed development envelope: open woodlands and shrublands. The area and percentage of each habitat type that would be directly impacted during construction and operation of the Proposal is presented inTable 10-8.

Table 10-8 Fauna habitats to be cleared within the proposed development envelope

Habitat type	Total area within proposed development envelope (ha)	Area to be cleared for the Proposal (ha)	Percentage of habitat in the proposed development envelope to be cleared (%)
Woodland	80.97	14.60	18.03
Shrubland	923.23	261.45	28.32
TOTAL	**1,004.20**	**276.05**	**27.49**

A total of approximately 276.05 ha of fauna habitat would be removed for the Proposal. This includes about 14.60 ha of open woodland habitat and 261.45 ha of shrubland habitat which accounts for only 18.03% and 28.32% of these habitat types within the proposed development envelope, respectively. Most fauna species are not confined to a specific habitat type and given the presence of large areas of suitable adjoining habitat, the proposed clearing would not have a significant impact on fauna habitats, nor would it act to fragment fauna habitat.

Clearing of fauna habitat would occur progressively over a 25-year period during the implementation phase of the Proposal. It is also anticipated that the actual area cleared would be less than the estimated 276.05 ha.

The fauna habitat types in the proposed development envelope are abundant and in very good condition within adjacent areas, indicating that the fauna assemblage present in the proposed development envelope would also be abundant in adjacent areas. This is supported by fauna survey data from the:

- Jackson-Kalgoorlie and the Boorabbin-Southern Cross sections of the Eastern Goldfields Biological Surveys (Dell and How, 1985 and McKenzie and Rolfe, 1995).
- Fauna surveys conducted for nearby mining proposals (Ecologia Environmental Consultants, 2001; 2003 and Ninox Wildlife Consulting 2008, 2009a, and 2009b).
- Research of Dickman *et al.* (1991) and Lyons and Chapman (1997).

The above surveys provide an adequate indication of the fauna assemblages likely to be encountered in the proposed development envelope.

Impacts on fauna species of conservation significance

Evidence of two species, Malleefowl (*Leipoa ocellata*) (listed as Vulnerable under the WC Act and the EPBC Act) and Rainbow Bee-eater (*Merops ornatus*) (listed as Migratory under the WC Act and the EPBC Act), were recorded within the proposed development envelope. The potential impacts on these species are discussed below.

An additional four species may possibly occur within the proposed development envelope. These species include sp. 1 Central Long-eared Bat (*Nyctophilus [timoriensis]*), Western Rosella (Mallee) (*Platycercus icterotis xanthogenys*), Fork-tailed Swift (*Apus pacificus*) and Peregrine Falcon (*Falco peregrinus*). Clearing of vegetation from within the proposed development envelope would unlikely have a significant impact on these species. Everything would readily move to adjacent undisturbed vegetation once vegetation clearing commences.

Malleefowl (*Leipoa ocellata*)

No Malleefowl tracks, active mounds or individuals were recorded within the proposed development envelope during the targeted surveys. Densities of Malleefowl are generally greatest in areas with higher rainfall and on more fertile soils where habitats tend to be thicker and there is an abundance of food plants (Benshemesh, 2007). The proposed development envelope may contain suitable habitat for Malleefowl (i.e. Eucalypt woodlands, *Acacia* shrublands, Broombrush), however, the low rainfall received at the site has limited food availability for the species. Given that the available habitat is likely to be marginal for the Malleefowl, and that the species has a wide distribution (all states of Australia except Queensland), the number of individuals frequenting the proposed development envelope is expected to be low.

Malleefowl have previously occurred within the proposed development envelope but now appear to be absent as a breeding species, at least from the areas surveyed. This may be a consequence of the extensive recent fires (within approximately the last 10 years) which would have reduced the supply of leaf-litter that is essential for the species' breeding mounds. While the breeding distribution of the species would have been limited to areas of gravelly-loam soils, the birds probably foraged widely through all vegetation types within the proposed development envelope. Malleefowl would presumably return to the area when the vegetation is sufficiently mature to support breeding, and a few birds may occasionally pass through the proposed development envelope.

The potential impact on Malleefowl during construction and operation of the Proposal is considered to be very low as there would be no direct impacts on current breeding sites. The species is likely to occur in the proposed development envelope, but only as an occasional visitor. Therefore, the risk of impacts (e.g. injury or mortality) is expected to be very low. Over time, Malleefowl may return to the proposed development envelope and its surrounds as the quality of the habitat improves. However, the species generally favours gravelly soils for mound construction and these soils are found mostly outside of the proposed development envelope.

Rainbow Bee-eater (*Merops ornatus*)

The sandy soils within the proposed development envelope potentially provides suitable breeding habitat for the Rainbow Bee-eater. However, no recently used burrows were observed within the proposed development envelope. Two individuals were observed opportunistically during the field survey. As the nesting period for the Rainbow Bee-eater had finished for the season, it was assumed that the birds were passing through the area. Therefore, it is considered that Rainbow Bee-eaters may be present when transiting across the proposed development envelope only. Impacts on this species during construction and operation of the Proposal would not be significant as there is no evidence of breeding within the proposed development envelope, the species would readily move out of the area if disturbed and there are large areas of suitable adjoining habitat.

Indirect impacts

Indirect impacts may include those associated with increased light, noise and vibration; fauna displacement, increased predation and competition for resources; fire; increased feral fauna attracted to water and food resources; and injury or death from fauna ingress into a cell or from collisions. These impacts are discussed below. The potential impacts associated with radiation exposure and the generation of void space and subsequent collapse/instability of the waste cell are also discussed, although are highly unlikely to occur.

Increased light, noise and vibration

An increase in light within the proposed development envelope from vehicles and machinery could affect nocturnal fauna, potentially disrupting movement and behaviour. Construction activities would also result in an increase in noise levels within the proposed development envelope, which may affect fauna species. Some fauna species would likely tolerate an increase in noise, while others may not, causing them to leave the affected area or making the area less desirable for foraging, nesting and breeding.

Noise associated with blasting during construction is not expected to have a significant impact on fauna (it would not likely result in temporary or permanent hearing loss of fauna in the vicinity of the blasting activities nor would it likely result in fauna injury or death). Blasting is scheduled to occur once per year and would last a matter of seconds. In addition, the area likely to experience the highest disturbance effects from blasting noise would be cleared of fauna and fauna habitat and fenced prior to blasting. Therefore, the probability of fauna being present in close proximity to the blasting area would be low.

Vibration from construction activities such as heavy vehicle movements and from blasting during construction and operation may deter native fauna from using the area near the vibration sources. This may potentially interrupt dispersal within the area if an individual is unwilling to travel through the area where the vibration is detectable, or may cause some species to abandon an area in search of areas where vibration is not detectable.

Fauna displacement, increased predation and competition for resources

The displacement of fauna would occur as a result of the removal of vegetation that would be required to facilitate the construction and operation of the Proposal. Two separate perimeter fences would be erected around the infrastructure area and the Class II landfill to exclude fauna from these operational areas. The clearing for fence installation may contribute to 'edge effects'. Edge effects can result in the disruption to ecological processes such as predation and dispersal, animal movements and can also change assemblage structure (Terrestrial Ecosystems, 2015). If the fauna species were moving into different habitats as a result of the displacement, this could have an adverse impact upon native fauna through predation and an increase in competition for resources.

Some mammal species are very sensitive to introduced predators and the decline of many mammals in Australia has been linked to predation by the Fox (*Vulpes vulpes*), and to a lesser extent the Feral Cat (*Felis catus*) (Burbidge and McKenzie, 1989). Introduced grazing species such as the Rabbit (*Oryctolagus cuniculus*), Goat (*Capra hircus*), Camel (*Camelus dromedaries*) and domestic livestock can degrade habitats as well as alter the structure and diversity of vegetation that may be a food source for other species and outcompete native species. However, given that displaced fauna would reside within similar habitat outside the perimeter fencing, the disruption to ecological processes is considered to be minor, and unlikely to affect fauna species at a population level.

Fire

Alteration of the natural fire regime as a result of improved access and increased human activity associated primarily with flammable liquids, combustible materials and hot machinery may pose a risk of fire within the proposed development envelope. Fire can result in the loss of fauna habitat and death to some individuals. Similarly, increased fire frequency can lead to alterations to native ecosystems by impacting species regeneration. Fire prevention and management measures would be implemented to minimise bushfires and, therefore, protect native fauna species and their habitat surrounding the proposed development envelope.

Increase in feral fauna attracted to water and food resources

An increase in development and human activity is often associated with an increase in the abundance of introduced species such as the house Mouse (*Mus musculus*), Cat (*Felis catus*), Wild Dog (*Canis lumpus*), Fox (*Vulpes vulpes*) and Rabbit (*Oryctolagus cuniculus*). Increased opportunities for sourcing food and water could lead to an increase in the presence of feral fauna numbers in operational areas (e.g. water storage ponds and Class II landfill) and in areas adjacent to other infrastructure such as the campsite. Increased numbers of feral fauna species may have an adverse impact upon native species (e.g. injury, illness, death or displacement) through predation and competition.

Injury or death from fauna ingress into cell

During or following the excavation of a cell, there is the potential for ground dwelling fauna and birds to ingress into the open excavation resulting in injury or death. In general, each mine cell would be nominally 120 m long, 60 m wide and 23 m deep (depending on local stratigraphy). The profile of an average mine cell is shown in Figure 5-6. The cell would be covered with a roof canopy which may deter birds from entering the cell. The cells area would be fenced and bunds constructed around each cell to prevent fauna ingress. If fauna do enter the cell, ramps for egress would be available. Therefore, the number of individuals that are likely to enter the open cell is limited, and deaths or injury as a result is considered a low residual risk.

Injury or death of fauna from collisions

Vehicle strike can pose a significant risk to some wildlife, particularly but not exclusively to ground dwelling species, including the conservation significant Malleefowl. While some mobile species such as birds have the potential to move away from machinery or vehicles, other species that are less mobile, or those that are nocturnal and restricted to tree hollows, may have difficulty moving. A collision with an individual animal may result in minor injury or death for the animal.

The Proposal involves road construction and the operation of vehicles. Native fauna would need to cross these roads and negotiate moving vehicles, increasing the risk of fauna mortality from vehicle strikes. Although some mortality may occur as a result of vehicle strikes, this is likely to be limited to individuals and it is not expected that collisions from fauna would affect a species at a population level.

Radiation exposure (terrestrial fauna)

An assessment was undertaken using the ERICA software tool (refer Appendix A.14).

Four exposure scenarios were modelled using ERICA Tier 2 assessments:

- Scenario 1 – exposure of fauna and flora present in the area surrounding the radioactive waste warehouse.
- Scenario 2 – exposure to windblown material originating from operational (kaolin) stockpiles e.g. plant tails; ore, sand, laterite and silcrete stockpiles.
- Scenario 3 – exposure to windblown material originating from ad hoc (waste) stockpiles e.g. low level NORM received as bulk or from emergency clean-up operations.
- Scenario 4 – exposure post closure, with capping material and rehabilitation during the institutional control period.

The above scenarios are highly unlikely to occur because upon closure, with a minimum capping of 7 m, and for the duration of the institutional control period, no risk to non-human biota is foreseen.

The modelled dose rates for all organisms are below the threshold dose rate of 10 µGy/h. External gamma dose rate on surface post closure (minimum cover of 7 m) would be negligible, even if all radioactive waste (2,500,000 tonnes) would be high activity concentration radium scales at an activity concentration of 17,800 Bq/g radium (Ra-226 and Ra-228 combined).

Generation of void space and subsequent collapse/instability of the waste cell (terrestrial fauna)

The encapsulation of wastes within each cell is subject to rigorous engineering design and compaction testing to ensure the properties of the constructed cell are a close analogue of the existing geological and hydrogeological conditions at the site.

A feature survey of the cell would be conducted to confirm the cell is constructed in accordance with the engineering design. Therefore, the generation of void space and collapse of cells is considered an extremely unlikely event. If an animal happened to be on the cell and a collapse occurred, the consequence would be slight slumping (if any) of the cap, and potential displacement of the animal. It is highly unlikely that the animal would be injured or killed.

Terrestrial fauna cumulative impacts

Evidence of the presence of Malleefowl in the region has been documented within the proposed development envelope at Sandy Ridge, at the Carina Iron Ore Mine and at the site of the Jackson 4 Iron Ore Mine and Haul Road. Specifically:

- A disused nest mound of the Malleefowl was recorded near the Carina Iron Ore Mine, but outside the exploration tenement (Polaris Metals NL, 2010).
- Secondary evidence of Malleefowl was also found in the form of fresh tracks as well as three mounds (two recently used and moderately old, and one old mound) within the broader

proposal development envelope. The recently used and moderately old mounds were estimated to be between 5 and 25 years old. The fresh tracks were recorded in the south of the disturbance area (Polaris Metals Pty Ltd, 2013).

This suggests Malleefowl are present in the region, but no active mounds have been identified in any of the proposed development envelopes. Only old, disused mounds were identified. Given the lack of active mounds, it is unlikely an important breeding population is supported in the vicinity of the three projects, and it is unlikely cumulative impacts would affect an important breeding population.

While Malleefowl have not been sighted in any of the fauna surveys undertaken for the three projects, its likely occurrence is supported by the evidence of tracks and old mounds. Given the widespread habitat for this species and their large range of occurrence, the densities of the birds in the vicinity of these projects are expected to be low. Therefore, significant cumulative impacts at a species, population and assemblage level are very unlikely.

10.4.4 Proposed mitigation and management measures

Although impacts on terrestrial fauna are not considered to be significant, the following mitigation and management measures would be implemented to further reduce impacts on fauna during construction and operation of the Proposal.

Pre-clearing surveys

Pre-clearing surveys would be conducted prior to any ground disturbance to determine if there are any signs of conservation significant fauna activity within the area proposed for clearing. Fauna present in the clearing area would be encouraged to move to nearby vegetation, or captured and relocated to adjacent habitat away from the clearing area. The capture/relocation would be undertaken by an experienced fauna handler with the appropriate licences in place. If a Malleefowl mound is encountered, the area containing the mound would be demarcated and an assessment would be undertaken to determine if the mound is active or not.

In addition to the above pre-clearing surveys, areas subject to blasting during construction would be cleared of fauna and fauna habitat and fenced prior to blasting.

Construction Environment Management Plan

The CEMP would include the following key mitigation and management measures with respect to terrestrial fauna:

- Educate contractors during inductions and regular toolbox meetings regarding the potential presence of Malleefowl and Rainbow Bee-eater within the proposed development envelope.
- Develop and implement clearing procedures to minimise impacts on fauna (including conservation significant fauna and their habitats). This would include demarcation of areas to be cleared, pre–clearing checks (see above) and authorisation requirements.

- Ensure that clearing is minimised and conducted in stages, where practical. For example, proposed access routes would be aligned with existing roads and tracks, where possible, to reduce the overall clearing footprint and reduce the impacts on fauna habitat.
- Ensure that an experienced fauna spotter/handler is present on-site during clearing activities to conduct daily checks of vegetation to be cleared and to retrieve fauna, if necessary. The fauna spotter would operate under the relevant licence requirements and would be responsible for all activities related to the protection and welfare of individual fauna.
- Ensure that there is no unauthorised driving off designated access roads. Night driving would be limited and vehicle speeds would be restricted around the operational areas.
- Restrict speed limits on internal access roads to minimise the risk of vehicle strike.
- Implement the following vehicle strike procedures:
    a. Report any collisions with Malleefowl or Rainbow Bee-eaters to the DoEE and DPAW.
    b. If regular collisions are occurring, reduce speed limits, and discuss further management measures with DoEE and DPAW, as appropriate.
- Monitor the integrity of the fences regularly to reduce the likelihood of fauna accessing operational areas.
- Design water storage ponds to reduce fauna accessibility and incorporate deterrent devices such as high visibility material flapping.
- Construct artificial water bodies and drains with non-slippery sides and install egress points so that animals that enter a water body can escape.
- Limit the time that a mine waste cell is open (where practicable), to reduce the likelihood of fauna ingress.
- Pets would not be permitted on site.
- Implement control measures (i.e. physical or chemical) if feral fauna numbers increase in operational areas.
- Manage all waste and rubbish appropriately to ensure fauna have no access to scraps or rubbish. This would include placing all rubbish and scraps in closed containers and/or being placed in the site Class II Landfill and covered with soil to prevent fauna access.
- No feeding of native fauna would be permitted.
- Report sightings or mortalities of conservation significant species to DPAW.

Outcomes/objectives, trigger and contingency actions to ensure impacts on fauna are not greater than predicted would be included in a Fauna Management Plan that would be included as part of the CEMP.

Emergency Response Management Plan

Fire prevention and management measures would be implemented and outlined in an Emergency Response and Management Plan. These measures would include:

- Hot work permits would be required prior to commencing any activity that may create an ignition source.
- Ensure that fire extinguishers are available in all hot work areas and personnel are appropriately trained in their use.
- If necessary, undertake controlled burning of shrubland vegetation under cool mild conditions in consultation with DPAW to reduce the size and intensity of bushfires by burning fuel loads and to reduce the likelihood of fire spreading to the fire sensitive woodlands.
- Ensure that emergency response procedures for bushfires and for controlled burning activities are understood and adhered to within and around the proposed development envelope.

Rehabilitation of disturbed areas

All disturbed areas would be rehabilitated in accordance with the MCP and WFDCP. Rehabilitation would primarily include respreading of topsoil, ripping of surface, revegetation using local indigenous species, irrigation in the initial months of establishment and the application of appropriate fertiliser (where appropriate). Further details on rehabilitation are provided in detail in Appendix A.18 and Appendix A.19.

10.4.5 Predicted environmental outcome

After implementing the mitigation and management measures described above, the following environmental outcomes are expected in regard to terrestrial fauna and their habitats:

- No more than 276.05 ha of native vegetation would be cleared for the Facility. Direct clearing of each vegetation association present within the proposed development envelope would represent clearing less than 1% of their current remaining extent within the Southern Cross IBRA Subregion. These impacts would not have a significant impact on fauna habitat at a regional level.
- A total of 14.60 ha of woodland habitat and 261.45 ha of shrubland habitat (total of 276.05 ha) would be directly disturbed by the Proposal which is considered to be of some value to Malleefowl (*Leipoa ocellata*) (listed as Vulnerable under the WA Act and the EPBC Act) and Rainbow Bee-eater (*Merops ornatus*) (listed as Migratory under the WA Act and the EPBC Act).
- No fauna of conservation significance (listed under the WC Act or the EPBC Act) would cease to exist or have its conservation status affected as a result of the Proposal.

- No Priority species as listed by DPAW would cease to exist or have its priority status affected as a result of the Proposal.

With the implementation of the proposed mitigation and management measures listed above, the EPA's objective to maintain representation, diversity, viability and ecological function at the species, population and assemblage level would be achieved. There would be no residual impacts on terrestrial fauna as a result of the Proposal.

10.5 Inland waters environmental quality

10.5.1 Introduction

This section assesses the potential impacts on inland waters during both construction and operation of the Proposal. Mitigation and management measures are identified to avoid or reduce potential impacts with the objective *to 'maintain the quality of groundwater and surface water, sediment and biota so that the environmental values, both ecological and social, are protected'* in accordance with the EPA's Environmental Assessment Guideline No. 8 (2015a).

This section draws on a number of comprehensive studies including:

- *Radioactive Waste Management Plan* (see Appendix A.14).
- *Sandy Ridge Landform Evolution Modelling* (Landloch, 2016; see Appendix A.7).
- *Sandy Ridge Kaolinite Project Surface Water Assessment and Management Plan* (Rockwater, 2016a; see Appendix A.10).
- *Sandy Ridge Kaolinite Project Surface Water Assessment and Management Plan: Addendum* (Rockwater, 2016b; see Appendix A.10).
- *Hydrogeological Studies for the Sandy Ridge Project* (Rockwater, 2015; see Appendix A.11).
- *The Assessment of Long-term Recharge to Encapsulated Waste Isolation Cells – Sandy Ridge Project* (CyMod, 2016; see Appendix A.12).
- *Waste Facility Decommissioning and Closure Management Plan* (see Appendix A.18).
- *Mine Closure Plan* (see Appendix A.19).

The assessment has also been prepared with reference to the applicable standards, guidelines and procedures listed in Chapter 4, Table 4-3 and in accordance with the requirements set out in the ESD which is presented in Appendix A.1.

10.5.2 Methodology

A hydrological study of the proposed development envelope was undertaken. The hydrological study included:

- Demarcation of the catchment areas and waterways likely to impact on the cell area, infrastructure area and access road.

- Hydrological analysis of relevant catchment areas in order to estimate peak run-off for rainfall events ranging from 1 in every 2 years and 1 in every 100 years' average recurrence intervals (ARI), and the extreme probable maximum precipitation (which is a 1 in 2000 year) event.
- Examination of historical rainfall records for nearby weather stations in order to assess the maximum total rainfall and ARI.
- Preparation of intensity frequency duration rainfall curves using the polynomials as recommended by *Australian Rainfall and Runoff* (Institution of Engineers, Australia, 1987).
- Examination of recorded total losses due to evaporation and infiltration in the Mount Walton area in order to estimate realistic peak flows.
- Completion of a surface water hydraulic analysis in order to assess the extent, depths and velocities of natural flow paths likely to impact the cell area, infrastructure area and access road.
- Design and recommendations for preliminary concept flood protection levees for the cell area, infrastructure area and waterway crossings along the access road.

A hydrogeological study of the proposed development envelope was undertaken. The hydrogeological study included:

- Desktop review of regional hydrogeology which included examination of the:
  - Kalgoorlie 1:250 000 Hydrogeological Series Sheet SH51-9 (Kern, 1994).
  - WA Department of Water's Water Information Reporting database.
  - Previous hydrogeological and geotechnical drilling results from other investigations in the vicinity of the proposed development envelope.
- Field investigation of seven bores to depths in the range of 21-49 m BGL.

A conceptual and numerical hydrogeological model of the existing natural system was developed to aid in understanding the hydrogeological processes and water balance that exists within the proposed development envelope (refer to Appendix A.12).

10.5.3 Assessment of potential impacts and risks

Impacts on inland waters during construction and operation of the Facility may include leaks/spills from a waste package which may contaminate surface water runoff and groundwater, the generation of leachate from a stored waste package which may contaminate surface water runoff and groundwater, and adverse effects on water quality at the Carina Pit from the abstraction of water. These impacts are discussed below.

Assessment of peak surface water flows

If unmanaged, flow from catchment E could directly impact the mining area. The 100 year ARI peak flow of 3.93 m^3/s at corss section one, would be slow moving, 88 m wide and 90 mm deep. The results for cross section one suggest that even with an allowance of 500 mm and the overly conservative peak flow, the minimum flood mitigation levee requirements at the eastern boundary of the proposed mining area is lower than the typical nomincal 1.0 m safety bund area around a pit. Therefore, it is recommended that the safety bund be strategically located and sonctructed to act as both a safety bund and a flood mitigation levee.

Cross sections two and three assessed potential durface water flow impacts from the northern perimeter of the proposed mining site. Model results for cross section two show that 1.63 m^3/s discharge would flow at a depth of to 230 mm over a 27 m width. The natural topography of the site, surface water flows would travel against the northern perimeter of the plant site until it reaches a ground level of 473 AHD where it would spread over approximately 375 m width, pond and infiltrate. Residual water, under this modelled scenario, would flow towards lower ground to the west of south-west and away from the proposed mine area.

Cross section three modelling results show surface water flowing to the southern perimeter of the proposed mine area. Here, peak flows would be approximately 3.25 m^3/s at a depth of 110 mm. Similar to the modelled scenario for cross section two, flows are expected to drain away to the west, southwest and away from the mine area.

Leaks/spills and potential generation of leachate

A leak or spill of solid waste material on the ground surface may result in the release of hazardous contaminants into any ponded surface water. If the leak/spill coincided with an extreme rainfall event, it may contaminate surface water runoff, which may then contaminate low lying depressions (shown in Figure 10-1) to which the runoff flows and ponds before evaporating. The consequence of such an event would be degradation of surface water quality and potentially the soils across which the contaminated water flows.

This consequence is considered to be minor, as individual waste packages would be solid, not liquid and therefore not easily leached, and the volume of a spill is likely to be small as one drum holds approximately 200 L and one bulka bag holds a maximum of approximately 2 m^3.

The likelihood of a leak or spill occurring is considered to be very low due to:

- The minimal volumes of surface water that would be present at the time of a spill/leak.
- The various barriers around, and integrity of, the waste package itself.
- Management measures to be implemented as described in Section 10.5.4.

Rockwater's (2016a) rainfall analysis suggests a 1 in 100 year event would see 176 mm of rainfall over a 72 hour period. A 1 in 2000 year event (probable maximum precipitation) would produce 285 mm of rainfall over the same period. Infiltration rates into the sandy soils of the development envelope are estimated to be 500 mm per day (Rockwater, 2016a), while the infiltration rates in the small clay pans present around the proposed development envelope are slightly less, at between 24 mm and 120 mm per day.

Rockwater predicts that ponded surface water from even the highest rainfall events should infiltrate the surface soils within around 12 hours. Any surface water is prevented from migrating vertically more than a few metres due to the presence of the natural silcrete layer in undisturbed areas of the proposed development envelope or the compacted clay cap in the footprint of the cells. During subsequent dry periods, evaporation and evapotranspiration acts to remove this rainfall infiltration from the top few metres of soil. Unless a leak/spill occurs during or up to 12 hours after a large rainfall event, it is unlikely that any surface water would be present at the site of a spill.

The predicted flow paths for surface water are shown on Figure 10-1, with any residual flow, not lost through infiltration, ponding in minor surface depressions prior to evaporating. If a spill occurred during a large rainfall event or within 12 hours of the event, and resulted in contaminated runoff, the impacted water would eventually pond in a depression and the water would evaporate off, potentially leaving some minor residual contaminants on the soil. In this unlikely event, the soil would be treated and managed in accordance with the *Contaminated Sites Act 2003* (WA). All except one of these depressions is located outside of operational areas where waste packages would be handled or stored. The only depression within the operational area is located adjacent to the internal site access road. This depression is approximately 5.72 ha and could be affected if a spill occurred on the internal access road.

V drains constructed on each side of the road would be designed to contain stormwater from the road preventing any contaminated water generated from a spill directly entering the depression and affecting ponded surface water before it evaporates. Due to the semi-arid nature of the environment in which the proposal is located, whilst it is possible that some localised contamination of surface water may occur, the final fate for virtually any rainfall onsite during an incident would ultimately be discharge to atmosphere by evaporation.

Unloading, handling or temporary storage of waste packages prior to disposal and permanent isolaiton in a cell would be undertaken under cover with bunded concrete floors. This effectively precludes the contamination of surface waters or egress of split materials in those circumstances. Handling of waste packages prior to placement in the cell is unlikely to adversely affect surface water quality or affect the environment values of the development envelope.

Management measures, as described further in Section10.5.4, would be implemented to ensure correct handling and storage of waste packages to minimise the likelihood of leaks or spills. Engineered controls would modify surface water flows to avoid surface water entering operational areas where spill or leaks may occur.

Given the lack of surface water receptors within the proposed development envelope, that surface water flows are generated only under extreme rainfall events, the high rainfall infiltration rate into sandy soils, and the small volume of a potential spill/leak, the risk to the quality of surface water is considered very low. Degradation of water quality is further minimised by diversion levees, operational bunding and operational procedures which serve to divert uncontaminated surface water flows away from operational areas. Additional management procedures would ensure that any spills/leaks would be rapidly detected and cleaned up. The ecological and social values of the development envelope are expected to be maintained and protected.

Assessment of direct and indirect impacts on groundwater from waste in disposal cells after capping

Due to site characteristics, there are few credible mechanisms whereby waste disposal operations can realistically impact on groundwater quality.

Although still posing a very low risk of contamination, the only credible mechanism for the deposited waste to contribute to impacts on groundwater quality is a failure of cell containment allowing water to enter the cell and contact stored waste. As all waste to be deposited would be in a solid form, no liquids could leak within the cell.

Although almost all waste would be securely packaged before placement in the cell, it is assumed such packaging would degrade over time and so the packaging itself only provides safeguard during the period of placement, backfilling and capping of the cell. If water enters the cell (e.g. from infiltration of rainfall through the cap) it may enter the pores of the granular material which surrounds the waste packages (either compacted backfill or the natural material in the wall and base of the cell.

If present in sufficient quantity, this water could leach contaminants from the solid waste at a rate determined by the quantity of water and the characteristics of the waste. The resulting contaminated leachate could then migrate vertically through the saprolite until it reached the surface of the underlying granite. The saprolite profile at the site is a very dry material that has a very large capacity to store and retain any leachate.

Contamination can only occur where there is a source, a receptor and a complete pathway connecting the two. To determine if a complete pathways exist for leachate to reach receptors, hydrogeological modelling (CyMod, 2016) was undertaken of four scenarios:

- ***Scenario 1 – Existing conditions***: the objective was to establish that the model can replicate known conditions, thereby confirming that the model correctly simulated the conceptual hydrogeology, which reduces uncertainty in Scenarios 2, 3 and 4. Two cases were simulated: A) using estimated material properties based on soil characteristics, and B) material properties were adjusted based on no runoff of rainfall from a 50 mm event over 12 hours and vegetation being present on the cap.
- ***Scenario 2 – Backfilled and capped cell: lower boundary sensitivity:*** the objective was to simulate a backfilled and capped cell and quantitatively assess the sensitivity of infiltration and seepage to changes in the model's lower boundary condition. The lower boundary represented the top of the unweathered/fresh granite.
- ***Scenario 3 – Backfilled and capped cell: estimate of infiltration and seepage:*** the objective was to simulate a backfilled and capped cell and estimate the infiltration through the compacted clay cap and seepage through the compacted kaolin layer 7 m below the surface

(referred to in the modelling report as the 'kaolinised granite seal') into the granular material that surrounds waste packages.

- ***Scenario 4 – Backfilled and capped cell: high conductivity topsoil and waste rock:*** the objective was to simulate a backfilled and capped cell and estimate the infiltration through the compacted clay cap and seepage through the kaolinised granite seal into the granular material that surrounds waste packages, using a hydraulic conductivity of 5×10^{-5} m/s for the topsoil, yellow clayey sand and laterite layer that sits on the clay cap.

Daily rainfall inputs for the modelling were:

- Scenario 1 used 20 years of historic climate data starting in 1995 (as shown in Figure 4 of Cymod, 2016).
- Scenarios 2 to 4 used repeated cycles of the 10 wettest years since 1890 (refer to Table 10- 9). This climate sequence was used as it may result in a conservative (i.e. larger than would actually occur) estimate of infiltration and seepage under high rainfall conditions.

Table 10-9 Ten wettest years since 1890

Year	Rainfall (mm/annum)
1992	553.8
1999	521.2
1995	499.6
1963	476.6
1974	443.2
1975	412.9
2011	411.6
1915	405.6
2000	399.8
2006	386.9

The Scenario 1 Case A and B results suggest in the existing natural environment all geological materials remain unsaturated.[30] These modelling results correlate well with the results of the exploration drilling and Hydrogeological Assessment (Rockwater, 2015) which suggests the absence of a groundwater aquifer in the saprolite.

Scenario 1 Case A (properties estimated from soil characteristics)

Based on a 100-year simulation using repeated cycles of the last 20 years of historical rainfall data (1995–2015), the soil moisture (as the volumetric fraction of water in a unit volume of soil) is predicted to be 2% to 8% after 100 years in the topsoil, yellow clayey sand and laterite layer. Silcrete is expected to have a soil moisture content of 2% after 100 years. Based on the water balance, most rainfall is evaporated with infiltration into the topsoil/subsoil layer estimated at 0.05 mm/year.

The infiltration below the silcrete layer, which is indicative of rainfall recharge, is modelled on average to be 0.017 mm/year. This modelling result was consistent with the average rainfall recharge, estimated based on a chloride mass balance, which indicated a range from 0.0036 mm/year to 0.10 mm/year. The predicted vertical flux of water under Case A is illustrated in Figure 10-3.

[30] A region of the subsurface where pores are completely filled with water (i.e. 100 %) is known as the saturated zone. It is important to keep this in mind, as it means for the saprolite to be saturated 40 – 50 % of the pores must be filled with water.

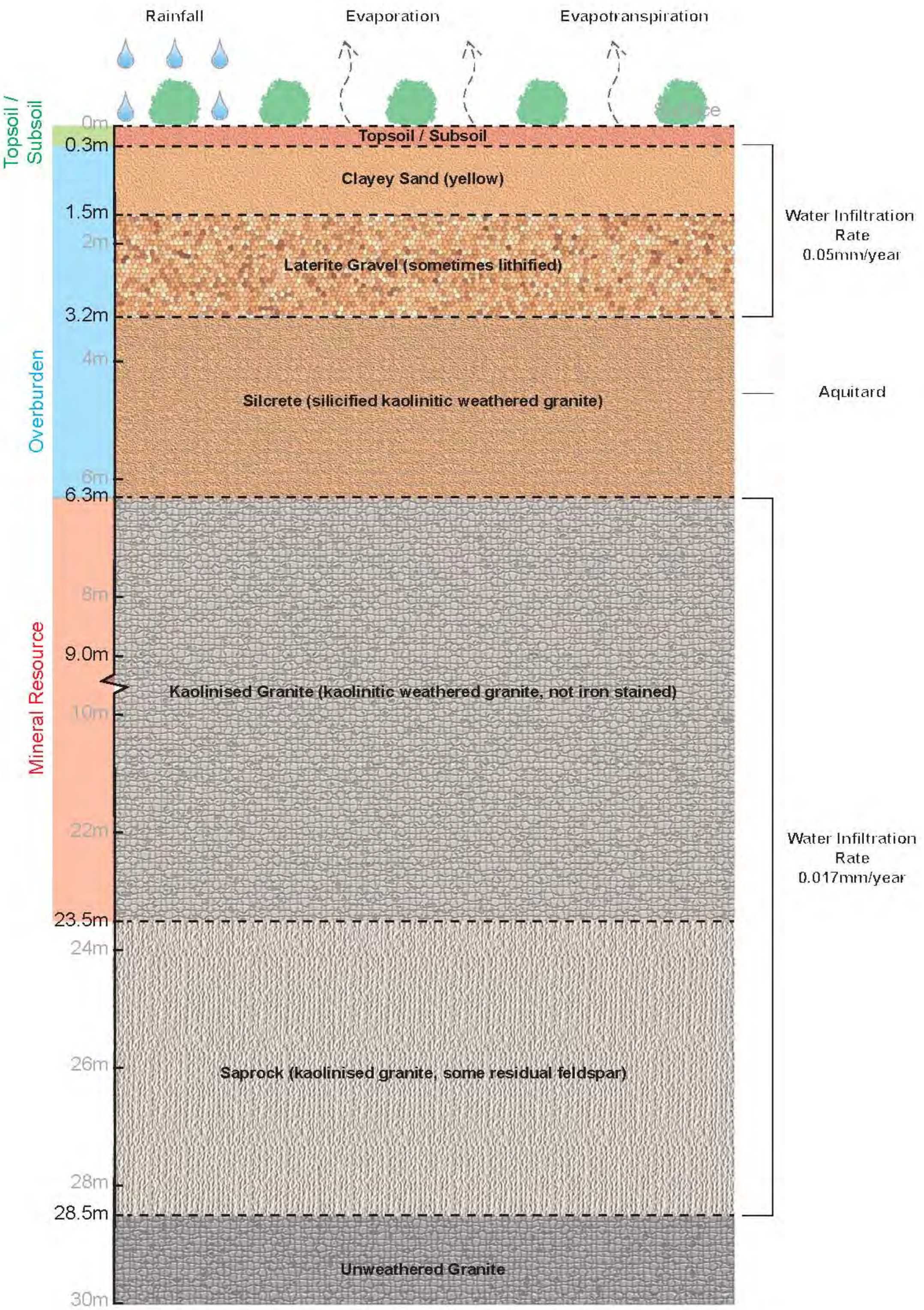

Figure 10-3 Predicted vertical flux of water through the existing natural weathered profile

There is increased saturation at the top of the silcrete, due to the low hydraulic conductivity of this material. The saturation profile confirms that for the climatic conditions simulated and the characteristics of the soil column, it is unlikely that a saturated aquifer would occur either perched above the silcrete or at the interface between weathered and unweathered granite (refer to Figure 10-3).

The modelling predicts that only 2% to 26% of the pore space of the topsoil, yellow clayey sand and laterite layer would be saturated after 100 years. This means the existing geological materials would remain unsaturated.

The low moisture content of soils at Sandy Ridge results in very low unsaturated hydraulic conductivity (i.e. due to very large suction pressures > 10,000 kilopascals [kPa])), which reduces water flow in these soils.

Scenario 1 Case B (soil properties adjusted to reflect no run-off from a 50 mm rainfall event over 12 hours)

Based on a 100-year simulation, the soil moisture and the existing silcrete is predicted to be 2% after 100 years in the topsoil, yellow clayey sand and laterite layer. Based on the water balance, most rainfall is evaporated, with infiltration into the topsoil of 0.175 mm/year. The infiltration below the silcrete layer, which is indicative of rainfall recharge, is on average 0.125 mm/year. The higher recharge in this scenario results from greater surface infiltration.

There is increased saturation at the top of the silcrete, due to it having low hydraulic conductivity. The saturation profile confirms the modelled climatic conditions would not result in groundwater occurring either above the silcrete or at the interface between weathered and fresh granite. The low moisture content of the soils results in very low unsaturated hydraulic conductivity (i.e. due to very large suction pressures greater than 10000 kPa), which reduces water flow in these soils.

The modelling predicts that only 2% to 28% of the pore space of the geological materials would be saturated after 100 years, indicating these geological materials would remain unsaturated.

Discussion – Scenario 1 Case A and Case B

The results of Scenario 1 Cases A and B are consistent with measured water content of sampled soils from exploration holes drilled across the proposed development area, which showed a soil moisture content ranging from 10% to 12% below 6 m BGL. These percentages indicate the soils at Sandy Ridge are very dry.

The reason the geological materials are unsaturated is attributed to the semi-arid environment in which they are located. Sporadic rainfall events (which may be intense) currently result in local runoff, and some infiltration of rainfall into the thin aeolian surface sand. However, during subsequent dry periods, evaporation and evapotranspiration acts to remove this rainfall infiltration from the top few metres of soil, which results in little if any net recharge into the soil profile below the silcrete layer (silcrete acts as an aquitard). Therefore, the natural rainfall/evaporation cycle is:

- Rainfall infiltrates and migrates vertically to the silcrete layer where its velocity is slowed due to the silcrete being relatively impermeable.
- The silcrete is typically within 3 m of the surface, which ensures that any infiltrated water in the soil above the silcrete remains close to the surface where it is subject to evaporation and evapotranspiration.

The Scenario 1 results are consistent with the conceptual hydrogeology and confirm that the model is a reasonable analogue of the existing conditions at the site. Following this confirmation CyMod (2016) then continued simulations with Scenarios 2 to 4 to examine how water would infiltrate the constructed cell, that is, a backfilled and capped cell, and estimated seepage rates.

Water balance

Based on the water balance, most rainfall is evaporated, with infiltration into the topsoil/subsoil layer of 0.21 mm/annum. The infiltration below the silcrete layer, which is indicative of rainfall recharge, is on average 0.0.20 mm/annum.

This scenario shows the sensitivity of recharge to changes in the hydraulic conductivity of the top soil, and how quickly rainfall can infiltrate the soil column. From the results, it is suggested recharge is not sensitive to top soil saturated hydraulic conductivity when it is greater than $1x10^{-6}$ m/sec. This is consistent with the conceptual hydrogeological model, where the low hydraulic conductivity of the silcrete layer acts to impede downward flow, and allow evaporation and evaporation to occur over a longer time.

Scenario 2 – how sensitive is water infiltration and seepage to a change in condition of the unweathered/fresh granite?

This scenario was run using three different conditions:

1. No flow at the lower boundary, which represents impervious unweathered/fresh granite.
2. A specified pore pressure at the lower boundary, which represents elevated saturation at the base of the model (water sitting atop or emanating from unweathered/fresh granite).
3. Unit gradient at the lower boundary, which represents low topographical gradient (e.g. slope or low point) of the unweathered/fresh granite for drainage to depth.

The Scenario 2 results indicate that under all conditions all geological materials remain unsaturated. The water balance shows that the lower boundary condition has no significant impact on the surface boundary change in flows, but does affect the change in storage:

- For the no flow lower boundary (condition 1 above), the change in storage is associated with evapotranspiration of water from shallow soils.

- For the specified pressure boundary (condition 2 above), the saturation in the weathered granite has increased from 12% to 22% due to the lower suction pressure at the boundary over the 20 years compared to the initial condition.
- For the unit gradient (condition 3 above), storage has decreased due to drainage and evapotranspiration.

In effect the model predicts that all of the geological materials remain unsaturated. In general, the lower boundary condition has limited effect on the vertical fluxes, other than for the unit gradient, which tends to increase the vertical flux below the compacted kaolinised granite seal due to the lower saturation in this region and deep drainage.

Scenario 3 –what is the water infiltration and seepage rate into and out of a cell?

In assessing potential impacts on groundwater, it is important to consider whether the climate is likely to remain the same as current day, or whether changes are likely to occur. It is possible that the semi-arid climate of Sandy Ridge could become wetter in future years, and this may affect the infiltration and seepage rates of water into and out of the constructed cell. As described earlier, to account for a worst case wetter climate, the modelling assumed repeated sequences of the 10 wettest years since 1890 to estimate the movement of water that passes through the cell (i.e. vertical flux) (Table 10-9).

Scenario 3 results indicate that all geological materials remain unsaturated after 100 years. Based on the water balance, 69% of rainfall runs off the cell cap and is evaporated, with 31% recharging the shallow surface soils. Infiltration, net recharge to the topsoil/subsoil, is 1.4 mm/year. Vertical flow below the clay cap is 0.8 mm/year, which flows vertically via the compacted silcrete and laterite backfill to the compacted kaolinised granite seal. The vertical flux below the compacted kaolinised granite seal is 0.008 mm/year. This seepage is larger than that estimated for the natural system (0.0017 mm/year), due to the higher hydraulic conductivity of the clay cap and kaolinised granite seal compared to the silcrete.

Based on a seepage rate of 0.008 mm/annum into the waste storage area, over the surface area of a cell (7200 m^2), model results predict about 0.058 m^3/year (58 L/year) of seepage (in a worst case wetter climate) may enter the environment as vertical leakage. This vertical leakage could:

- Be stored within the unsaturated weathered or fresh granite and form a groundwater mound.
- Flow laterally to the north-west following the topography of the fresh granite.

It would be assumed that most of the seepage is retained in the unsaturated weathered granite (i.e. the saprock) directly beneath the cell. The characteristics of the saprock are:

- It is on average about 10 m thick across the cell area.
- Has a porosity of 0.35.
- Initial saturation of 0.1.

This suggests that this material would become fully saturated in about 400,000 years given the estimated seepage rate.

Conversely, if this seepage flows in a thin saturated layer:

- Horizontally to the north-west.
- Under a prevailing gradient of 0.001.
- Through fractures having 1% porosity.
- With an average hydraulic conductivity of 4×10^{-6} m/s.

This equates to a groundwater velocity of 4×10^{-7} m/s, indicating a travel time of about 6,000 years to the most likely exposure point (75 km to the north). In the absence of connected fractures, and flow in the porous weathered granite, the travel time would increase to more than 200,000 years. In either case, the model results suggest the magnitude of seepage potentially emanating from the cell (under wetter climate conditions) is unlikely to mound or move far from the site for a long period of time (centuries).

In reality, these predictions are based on highly conservative assumptions (use of the rainfall data from the 10 wettest years since 1890) and it is considered highly unlikely that a saturated aquifer would ever be created. In the absence of saturation and due to the dry nature of the saprolite overlying the fresh granite, there would be no ability for water to migrate away from the base or sides of the waste cells.

Scenario 4 – what if the topsoil/subsoil is more permeable than we expect?

CyMod (2016) simulated the topsoil/subsoil layer with a hydraulic conductivity of 5×10^{-5} m/s, using the same parameters as Scenario 3 and repeated sequences of the 10 wettest years of climate data (Table 10-9).

The results indicate that with a more permeable soil layer, the geological materials still remain unsaturated after 100 years. There is increased saturation at the top of the clay cap and the compacted clay layer 7 m below the cap due to the low hydraulic conductivities of these materials.

Given that the materials are unsaturated the simulated pressure head is negative, meaning water is not being pushed down through the clay materials, it is unlikely that a saturated aquifer would develop either perched atop the compacted clay layers or at the interface between weathered and unweathered/fresh granite.

Summary of pathways

There are several hydrogeological aspects that would influence the flow of water through a waste cell:

1. Amount of recharge on the cell surface which is directly affected by rainfall, runoff and evapotranspiration.

2. Infiltration rate of water through the compacted clay cap.
3. Infiltration rate of water through the kaolinised granite seal located approximately 7 m below the ground surface.
4. Seepage rate of water at the base of the cell.

A saturated zone would be required in order to induce a plume of contamination. As shown in the four scenarios described above, the geological materials are not predicted to reach saturation even under a wetter climate than currently experienced.

In the worst-case scenario if leachate was generated, Scenario 3 predicts there is:

- Sufficient storage capacity in the saprock directly beneath the cell, to hold seepage for 400,000 years (assuming it moves at a rate of approximately 0.058 m^3/year).
- If water moves to the northwest it would take at least 6000 years to travel to the most likely exposure point (75 km to the north). In the absence of connected fractures, and flow in the porous weathered granite, the travel time would increase to more than 200,000 years.

The model results suggest the magnitude of seepage potentially emanating from the cell (under wetter climate conditions) is unlikely to mound or move far from the site for a long (centuries) period of time.

There are no groundwater bores in the region, with the exception of bores for monitoring purposes at the IWDF (5.5 km east of the proposed development envelope) and water supply bores at the Mount Dimer gold mine, greater than 23 km from the proposed development envelope. This suggests there are no other registered users of groundwater in the vicinity of the Proposal.

The stored waste is a potential source of contamination, if a sufficient quantity of water infiltrates the cell and leaches contaminants from the waste packages. The stimulations indicate the natural soil materials used to construct the cell remain unsaturated even using very conservative climate conditions modelled (i.e. using the wettest 10 years on record to model a 100 year period). Infiltration and seepages rates of water are very low. Assuming a 7,200 m^2 surface area of a cell, this flux equates to 58 L/year of seepage averaged across the cell area under rainfall conditions of continuous wettest years recorded for 100 years.

The saprock beneath the cell has sufficient capacity to hold this volume of water for 400,000 years. If the storage capacity is exceeded, then contaminated water would take between 6000 and 200,000 years, depending on connectivity of fractures to migrate 75 km (note that for much of this distance, the water would be in contact with extremely dry unsaturated clay which would tend to act like a sponge and take up any free water). No receptors have been identified 75 km north of the proposed development envelope. The site selection criteria and engineering design of the cells would ensure ecological and social values of the development envelope are maintained and protected.

Assessment of direct and indirect impacts on wetlands and salt lakes

There are no wetlands or salt lakes within the proposed development envelope.

Surface water flow which is only generated in an extreme rainfall event is likely to follow the natural topography and evaporate or infiltrate within 12 hours (Rockwater, 2016a). The flow trajectory of the natural topography is generally to the north to north-west. There are salt lakes within the vicinity (i.e. 50 km) of the development envelope.

A paleo channel (old or ancient channel) exists approximately 16.5 km east of the cells which joins to Lake Ballard, a salt lake, approximately 112 km north-west from the development envelope. However, the paleo channel is on the opposite side of a hill (approximately 515 m AHD) to the development envelope (approximately 460–490 m AHD). Surface water flow is unlikely to move up gradient and over a hill, and would ultimately in this scenario infiltrate into surficial sands (at a rate of 500 mm/day) or evaporate. As described previously the arid nature and high evaporation and evapotranspiration regime in the region means that little if any water would infiltrate beneath the silcrete. Therefore, it is highly unlikely contaminated or uncontaminated surface water would reach the paleo channel or Lake Ballard, and therefore neither would be affected by the Proposal.

Assessment of potential surface water ingress into mined waste cells

The proponent would implement the proposed Surface Water Assessment and Management Plan (Appendix A.10). Management controls would be in place to prevent water ingress into the mined cell during operation. The cell would be surrounded by operational bunding and V drains that would drain collected surface water to a sump. The water in the sump would evaporate. When waste is being deposited, a roof canopy would be rolled into place to prevent rainfall entering the open cell.

Surface water that could flow into the cells during an extreme rainfall event would be diverted by 0.5 m high bunding/levees as illustrated in Figure 10-1. One levee would be located on the northern boundary of the cells area and one on the eastern boundary to divert water away from the cells area. Diverted water would infiltrate or pond in low-lying depressions where it would evaporate. Details on the proposed levees are provided in the Sandy Ridge Surface Water Assessment and Management Plan (Rockwater 2016a) and its Addendum (Rockwater, 2016b; Appendix A.10). Operational bunding approximately 0.5 m high would be in place around open cells to prevent surface water flowing into the cell from the sides.

The natural characteristics of the site are the main mechanism for groundwater protection. The proposal location was selected largely due to the lack of surface and ground water. As described in Section 2, the position of the development envelope in the regional landscape, the topography, low rainfall, high evaporation rate, high average temperatures and the site stratigraphy and soil types mitigate against the establishment of a groundwater table and anything but the most ephemeral surface water flows or water bodies.

When individual cell locations are drilled prior to blasting, the proponent would ensure that at least 5 m of kaolinised material remains in situ between the bottom of the cells and above the top of the unweathered/fresh granite. This would be achieved through mine planning and grade control drilling. The location of each drill-hole would be surveyed so that any hole penetrations within the cell base are known, and any locations where 'over-drilling' below the cell floor elevation has taken place can be carefully backfilled with compacted kaolinitic material. This process would ensure that the drilling activities do not provide pathways of low permeability soil in the unlikely event that water entered a cell and generated leachate.

Engineering design of the cell and procedural controls around the handling and storage of hazardous and intractable waste would minimise spills and leaks. Spill response operational procedures would be implemented to guide operators on the actions to be taken to contain, clean-up and dispose of spilt material to ensure it does not contaminate surface water flow.

10.5.4 Mitigation and monitoring measures

Runoff observed following high rainfall events should be recorded and used later in the detailed deisgn stage to reassess flood protection requirements.

Monitoring

Annual monitoring of seven bores (listed in Table 10-10) would be conducted for the life of the Proposal.

Table 10-10 Monitoring bores

Bore ID	Location (Zone 51J) Easting	Northing	Depth (m AHD)	(mbtoc[31])	Screened interval (m AHD)	(mbtoc)	Lithology of screened interval
srmb146	219,888	6,637,794	458	30.5	434.38–428.38	24.5–30.5	Kaolinite and deeply weathered granite
srmb147	219,890	6,638,007	458	20.6	444.28–438.28	14.6–20.6	Kaolinite (saprock)
srmb148	219,702	6,637,808	457	24.3	439.7–433.7	18.3–24.3	Kaolinite (weathered granite)
srmb149	220,238	6,637,886	463	22.9	447.25–441.25	16.9–22.9	Weathered granite
srmb150	219,372	6,638,392	455	49	416.07–407.07	40–49	Weathered and fresh granite
srmb151	219,681	6,638,402	457	44.7	418.88–412.88	38.7–44.7	Moderately to slightly weathered granite
srmb152	219,499	6,637,606	455	38.4	423.14–417.14	32.4–38.4	Weathered granite

Shallow monitoring bores would be installed around contaminated water ponds, to assess to monitor any leaks in the liner.

[31] *Methyl Bromide Technical Options Committee*

Weather monitoring would continue for over the course of the Proposal. This involves collecting daily data of the following parameters:

- Maximum wind speed.
- Average wind speed.
- Average wind direction.
- Maximum peak wind gust.
- Maximum relative humidity.
- Minimum relative humidity.
- Average relative humidity.
- Minimum air temperature.
- Maximum air temperature.
- Average air temperature.
- Maximum rain and total rain.

Subsidence monitoring of the capping systems of completed cells would be undertaken on an annual basis in accordance with the WFDCP (Appendix A.18).

Mitigation

In the initial years of operation, the proponent would monitor the success of the diversion levees, operational bunding, V drains and sumps, and would correlate measured peak flow rates with weather data obtained from the onsite weather station to corroborate the hydrological modelling. Data would be used to verify adequacy of surface water flow predictions (i.e. that Lake Ballard would be unaffected even during extreme rainfall events).

Hydrogeological modelling would be verified by collecting soil moisture data and temperatures at various depths above the silcrete to establish soil moisture profiles during rain events and subsequent dry periods. This data would be used to calibrate future unsaturated flow modelling. Future modelling would also incorporate the unsaturated hydraulic conductivity properties of silcrete (once a stockpile of silcrete is available for sampling at the commencement of mining) and backfill material.

Flood flows

It is recommended that the safety bund be strategically located and sonctructed to act as both a safety bund and a flood mitigation levee. The levee length is recommendedto be approximately 545 m long with the highest point been 0.60 m high. On average, the levee would be 0.50 m high.

At crossing points on the proposed access road, it is recommended that a standard floodway and culvert system by construction to manage potential sheet flows.

Once detailed design has been completed, mapping of potental surface water flooding based on the Rockwater report (2015) would be prepared. This information would form part of the proposed CEMP for the Proposal.

Potential infiltration of surface waters

Retaining water near the surface is important so it is allowed to evaporate/evapotranspired. By doing this, it would reduce potential recharge to less than 0.1 mm/year below the proposed clay cap area.

Groundwater and climate monitoring should continue through the development of the Proposal. The monitoring of soil moisture probes to establish soil moisture profiles during rain events and dry periods, and at various depths, was installed in April 2016. The proponent would run analysis of both winter and summer soil moisture data in April 2017 to validate soil moisture profiles at the proposed Sandy Ridge site.

Trigger and contingency actions

If a 1 in 100 ARI event (approximately 136 mm over 24 hours) or larger is forecast, a review would be conducted of the incoming waste to be accepted during that period, and of the scheduled movement of waste into the cell for disposal and permanent isolation. A risk assessment would be undertaken to eliminate potential for spills and, where appropriate, scheduled activities may be postponed. Shipping containers delivered during this period would remain unopened until the rainfall event passes.

In the unlikely event groundwater is detected in the weathered granite profile, this would trigger a review of the hydrogeological modelling to ascertain the groundwater source. Mining and the permanent isolation of waste would be temporarily deferred until the groundwater source is identified and can be protected or until it is confirmed that activities would not significantly affect the groundwater or that the presence of the groundwater does not compromise operational safety.

Assessment of impacts on water quality from sourcing water from the Carina Iron Ore Mine over 25 years

The Facility requires potable water for the accommodation village and administration building and amenities, for use in the laboratory, for use in kaolin processing, for vehicle washdown and for firefighting. Non-potable water (RO reject and raw saline water) would be used for dust suppression and compacting of waste cell backfill and capping.

The proponent would apply for a Licence to Take Water from the Department of Water following completion of the environmental impact assessment (i.e. Part IV) process. It is anticipated that an agreement would be made with Mineral Resources for access to the Carina Pit water via overlapping tenure following the Part IV environmental impact assessment process. The operations at the Carina Pit would be nearing their end around the time that construction of Sandy Ridge would commence. It is unlikely that the two operations would conflict, and discussions held with Mineral Resources representatives indicated that the mine cell is proposed to be left as a mine cell ‘lake’ at mine closure.

The water within the pit is held within fractured rock and Mineral Resources' licence (GWL 169652) allows for abstraction of 1.6 GL per annum. Significantly less water is proposed to be extracted (estimated at 0.18 GL per annum) than Mineral Resources is currently abstracting.

10.5.5 Predicted environmental outcome

The Sandy Ridge Proposal was specifically cited in this location because the site is void of a groundwater aquifer as well as surface water systems. Owing to a lack of these sensitive environmental values, the proposal's operations would not significantly impact these environmental aspects.

In addition to site selection, the proponent has commissioned modelling using very conservative rainfall/climate assumptions of the hydrogeological regime of both the existing natural environment, and long-term performance of the constructed cells under a range of scenarios. The unsaturated soils provide storage capacity for any minor amounts of water or leachate that may migrate vertically or horizontally from the cells. Without a saturated aquifer, lateral movement of contaminated water from the immediate vicinity of the cells is highly unlikely.

Surface water management measures (e.g. roof canopy, operational bunding, V drains and sumps) would be implemented to protect surface water quality by ensuring it is diverted from operational areas. Due to the high energy environment of the site, surface water evaporates or infiltrates relatively quickly. Confined to extreme rainfall events, if surface water flows are ever generated, they are likely to pond in low-lying depressions and evaporate.

Following closure of the cells, completion of subsidence and revegetation monitoring, cells are expected to be stable, with no water ingress. Landform evolution modelling (Landloch, 2016; Appendix A.7) predicts that after 10,000 years there would be relatively little change to the clay domes and the landform is likely to be erosionally stable over the very long term. Therefore, the groundwater and surface water environment of the development envelope would be maintained both during operations and for geological time following closure.

With the implementation of the proposed mitigation and management measures listed above and those applicable to Section 10.3.5 and Section 10.4.4 that deal with sediment and fauna, the EPA's objective to maintain the quality of groundwater and surface water, sediment and bioata so that the environmental values, both ecological and social would be achieved. Due to the fact, the site is void of groundwater and surface water features, there would be no residual impact on these environmental values as a result of the Proposal.

10.6Human health

10.6.1 Introduction

This section assesses the potential impacts on human health during both construction and operation of the Proposal. Mitigation and management measures are identified to avoid or reduce potential impacts with the objective *to 'ensure that human health is not adversely affected'* in accordance with the EPA's Environmental Assessment Guideline No. 8 (2015a).

This section draws on a number of comprehensive studies including:

- *Baseline Radiation and Metals Report* (Terra Search, 2016; see Appendix A.6).
- *Worker Dose Assessment* (Hygiea Consulting, 2016; see Appendix A.14).
- *Radioactive Waste Management Plan* (see Appendix A.14).
- *Sandy Ridge Project Operating Strategy* (see Appendix A.16).
- *Outline Safety Case* (see Appendix A.15).
- *Drinking Water Quality Management Plan* (see Appendix A.20).
- *Waste Facility Decommissioning and Closure Management Plan* (Appendix A.18).
- *Mine Closure Plan* (Appendix A.19).

The assessment has also been prepared with reference to the applicable standards, guidelines and procedures listed in Chapter 4, Table 4-3 and in accordance with the requirements set out in the ESD which is presented in Appendix A.1.

10.6.2 Methodology

To determine potential risks on human health, modelling was undertaken. The methodology followed the guidance given in the following documents:

- *Managing naturally occurring radioactive material (NORM) in mining and mineral processing – Guideline, DMP* (2010) NORM 5 Dose Assessment (currently under review at the time of submitting this PER)
- *Environmental Health Risk Assessment-Guidelines for assessing human health risks from environmental Hazards* (enHealth Council 2012)
- *Assessing Dose of the Representative Person for the Purpose of the Radiation Protection of the Public. ICRP Publication 101a. Ann. ICRP 36 (3)* (ICRP, 2006)
- *Approved Procedure for Dose Assessment Guideline RSG05* (Department of Industry and Resources, 1997).

The key stages of the assessment below, involved the following:

- Issue identification
- Hazard identification
- Dose–response assessment
- Exposure assessment
- Risk characterisation.

10.6.3 Assessment of potential impacts and risks

Engineering design of the waste cells have been detailed in Section 5.5.4 and illustrated in Figure 5- 12. The conceptual engineering design of the proposed Facility was independently reviewed (refer to Appendix A.21) and concluded "*the design is likely to perform well during the longer term and it appears from the assessments performed that radiation doses will be very low during operations*".

In addition, the independent peer review although recognising there is not yet a clear link between the design and the safety case, which is considered best practice but not considered necessary at this stage, concluded that the design of the waste cells at Sandy Ridge is excellent and that the proposed multibarrier system offers very good prospects of excellent long-term performance that would be comparable or in excess of that for many other LLW disposal facilities in other countries. This is facilitated by the favourable hydrological and hydrogeological environment. Therefore, it can be concluded that risk of human exposure is low.

The independent review identified a number of areas for future work by the proponent which the proponent is aware of, and would be addressing in the next iteration of the Safety Case (Pre-Construction Safety Case), which is to be produced to support licencing activities. Some examples of the items highlighted in the independent review which would be addressed during the development of the PCSR are;

- Radionuclide specific activity limits for the sources that are suitable for disposal in the facility would be set out clearly with consideration of design and site-specific issues. This would be addressed by the production of an assumed inventory which would be used for planning and design purposes.
- Design of the waste store and mechanical handling involving the placing of ILW within the storage shafts would be given particular attention.
- Detailed argument and supporting engineering calculations to demonstrate that the design would perform appropriately.

The waste management plan would be further developed using the principles of optimisation to provide assurance that all aspects of waste storage, handling and emplacement would be appropriately managed.

Impacts on human health during construction and operation of the Proposal may arise from leaks or spills, radiation exposure, radon from waste cells, dust emissions, and the threat of fire. These potential impacts are discussed below.

Leak and spills

The potential for leaks and spills and the assessment of potential associated risks has been assessed in Sections 10.2.3 and 10.3.3.

Radiological exposure during operation

Pathways of radiation exposure giving rise to potential risks on human health during operation were considered and assessed. They included:

- External radiation exposure (ϒ-radiation).
- Inhalation of suspended dust (α radiation).
- Inhalation of radon and decay products.

Exposure to radiation during operation of the proposed Facility is unlikely due to low baseline radiation levels (Appendix A.6) and the very low levels of radioactive material that would be delivered to Sandy Ridge.

However, exposure was considered for activities including:

- Radiation waste and storage.
- Waste placement and burial.
- Earthmoving and contouring.

Based on the *Approved Procedure for Dose Assessment Guideline RSG05* (Department of Industry and Resources, 1997), the following doses were calculated for each workgroup (Table 10-11).

Table 10-11 Dose calculations for work activity per year

Workforce	Gamma dose (mSv/a)	Individual internal dose (mSv/a)	Inhalation of RnDP (mSv/a)	Total dose (mSv/a)
Rad waste receipt and storage	0.400	0.014	0.004	0.418
Waste packaging	0.096	0.002	0.004	0.102
Waste placement/burial	0.004	0.001	0.004	0.009
Chemical waste placement	0.096	0.000	0.000	0.096
Earthmoving and contouring	0.044	0.000	0.000	0.044
Admin and other staff	0.000	0.000	0.000	0.000

Based on current market expectations and uncertainty as to how much LLW would be sent to the Facility, the following exposure hours were assumed (Table 10-12).

Table 10-12 Worker exposure hours

Workforce	Assumed hours per year	Logic of assumed hours
Radiation waste receipt and storage	1000	Unknown. Assume 1000 hours.
Waste Packaging	160	Four packing campaigns a year of five days each.
Waste placement/burial	80	Actual radioactive waste handling component to take 20 hours maximum per campaign. Assuming four campaigns a year.
Chemical waste placement	1920	Full shift assumed.
Earthmoving and contouring	882	Three months.
Admin and other staff	2000	Assuming maximum.

The following exposure levels were assumed based on similar facilities exposure records (Table 10-13).

Table 10-13 Potenital exposure dose levels

Workforce SEG's	µSv/hr expected dose
Radiation waste receipt and storage	0.40
Waste Packaging	0.60
Waste placement/burial	0.05
Chemical waste placement	0.05
Earthmoving and contouring	0.05
Admin and other staff	0

Based on the *Approved Procedure for Dose Assessment Guideline RSG05* (Department of Industry and Resources, 1997) the following doses were calculated for each workgroup (see Table 10-14).

Table 10-14 Dose calculations for each workgroup per year

Workforce	Gamma dose (mSv/a)	Individual internal dose (mSv/a)	Inhalation of RnDP (mSv/a)	Total dose (mSv/a)
Radioactive waste receipt and storage	0.400	0.014	0.004	0.418
Waste packaging	0.096	0.002	0.004	0.102
Waste placement/burial	0.004	0.001	0.004	0.009
Chemical waste placement	0.096	0.000	0.000	0.096
Earthmoving and contouring	0.044	0.000	0.000	0.044
Admin and other staff	0.000	0.000	0.000	0.000

Table 10-14 show that all of the workforce exposure levels would be below the occupational exposure limit of 10 mSv/a, the dose constrain level of 5 mSv and, are highly unlikely to be exposed above the public dose limit of 1 msv/a.

Investigation into exposure levels from similar international facilities indicate that approximately 95% of the staff receive a dose less than 0.1 mSv/a, and 80% less than 0.01 mSv/a. The exposure times at the international facility would be longer that those assumed as Sandy Ridge due to the amount of waste disposed. These levels are within similar range of those calculated above.

Workers involved in the unloading and burial of radioactive waste may be exposed to low levels of external gamma radiation from the waste package, inhalation of suspended dust (α- radiation) and inhalation of radon and decay products. The waste at this stage is packaged and would be lowered into the shafts by mobile equipment. Worker protection includes shielding (provided by the waste packaging and mobile equipment), increased in distance from sources by using mobile equipment and scheduling of waste placement to ensure minimum time is spent near radioactive waste. Exposure is expected to be below 0.01msv/a.

All radiation exposure hazards identified during the baseline qualitative risk assessment were assessed against likelihood of exposure above the exposure limits (20 mSv/a) and above a dose constrain limit of 5 mSv.

Even with an increase of 100% higher than those assumed in the baseline calculations, no dose was above 1 mSv/a. Investigation into exposure levels from similar international facilities indicate that the most exposed worker was around 1.2 mSv/a (individual in charge of traveling crane operations above the disposal vaults). It is therefore unlikely that any person would be exposed to doses above 1.2 mSv/a.

On the basis of the characteristics described above, the initial dose assessments and sensitivity analysis concludes that it is highly unlikely that workers would be exposed to levels above the dose constrain limit of 5 mSv/a. Risks from exposure would be further reduced by following standard guidelines and procedures for the transport and handling of dangerous and hazardous goods. In addition, the separation of LLW from other wastes, in appropriately designed cells, would further reduce the risks of exposure at the proposed Sandy Ridge Facility.

Radiological exposure during post closure

A design objective for the proposed Facility is to provide for the protection of human health and the environment during operation of the Facility, after the facility is closed and, until the time when the associated radiological hazard would reach an insignificant level through natural decay.

A post closure radiological risk assessment was carried out (refer to Appendix A.14) that deals with the post-closure period of the facility, and in particular, the human intrusion scenarios during the period of passive safety and the findings are summarised below.

The dose limit for members of the public from all sources during operations is 1 mSv in a year. During the period of passive safety, a risk target approach is used. This should be considered as the target criteria not to be exceeded in the future. To comply with the risk target during the passive safety period, the waste disposal facility and management systems are designed so that the estimated average dose or risk to members of the public, who, if in the unlikely event, are exposed to radiation at some point in the longer term, shall not exceed a dose constraint of 0.3 mSv in year[32]. To comply with this limit, the proposed Facility has been designed so that the estimated average dose or risk to members of the public, who may be exposed as a result of the disposal facility in the future, shall not exceed the above dose limit but would target 0.3 mSv in a year.

As well as considering passive safety where the disposal system evolves and performs as expected, consideration has been given to human intrusion, this report looks in particular at this. As human intrusion bypasses the designed barriers a dose constraint on 0.3 mSv per year is not felt to be appropriate. ARPANSA[33] advise where it is calculated that human intrusion could result in doses of between 10 and 100 mSv for any human associated with the intrusion, there needs to be further evaluation of the scenario producing this result. The proponent has used a dose of 10 mSv/yr in a number of the human intrusion scenarios analysed.

The post closure risk assessment took into consideration all relevant pathway of exposure, to demonstrate that potential radiological impacts are at acceptable level of risk (as per set dose constrain level) and manageable to adequately safeguard humans.

The post closure risk assessment was undertaken using both first principle calculations and RESRAD modelling software. Five post-closure exposure scenarios were investigated:

- Scenario 1 – First Principle evaluation of human intrusion next to the shaft containing (Category B) sealed radioactive sources that is in accordance to the WAC (refer to Appendix A.24).
- Scenario 2 – RESRAD evaluation of human intrusion - living on exposed bulk waste at activity concentration levels of Category A.

[32] *IAEA-TECDOC-1380 Section 3.3.2*
[33] *Australian Radiation Protection and Nuclear Safety Agency – Licencing of Radioactive Waste Storage and Disposal facilities Section 3.3.5*

- Scenario 3 – RESRAD evaluation of human intrusion - living on exposed bulk waste at activity concentration levels of Category C.
- Scenario 4 – RESRAD evaluation of a recreational visitor to the site post closure.
- Scenario 5 – A reverse calculation using RESRAD evaluation to determine radionuclide activity concentration levels in bulk NORM wastes which would give rise to tolerable exposure conditions for post closure and intrusion scenarios.

The shielding provided from concrete inside a drum, with steel around the drums (refer to Figure 10-4) and concrete in the shafts, is sufficient to shield the radiation from all sources assessed except high activity Caesium-137 sources. By adding 0.0255 m lead shielding (as found in standard source casings) the dose rate is further reduced from 0.16 mSv/hr to 0.02 mSv/hr. With the assumed 40 hours exposure, the dose was calculated as being 0.63 mSV.

This result is below the public dose limit of 1mSv/year. Given the conservative nature of the assessment and, the low probability of event occurring it can be concluded that the risk of human exposure is sufficiently controlled through the proposed design.

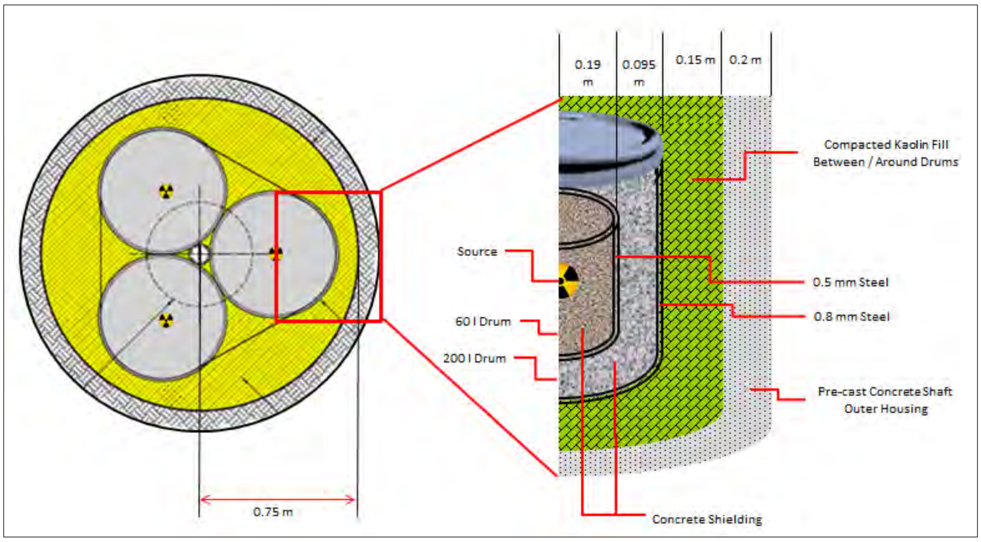

Figure 10-4 Source shielding prior to placement in a concrete shaft

As demonstrated by the results from Scenarios 2 and 3, in the unlikely case where humans would reside on top of exposed bulk waste of category A, an exposure of 587 hours/year would result in total maximum dose of 10 mSv/y. If the exposure would occur on uncapped Category C waste, 6.5 hours occupancy would result in total maximum dose of 10 mSv/y.

In reality, it is implausible that someone would spend this duration in the bulk waste due to site selection of the facility, the cap design and the public notice mitigation illustrated in Figure 10-7.

In the unlikely case where humans would reside on top of exposed bulk waste of category A, a total dose of 112 mSv/y is incurred from occupancies considered being residential (RESRAD default). The dose received is directly proportional to the duration of exposure. Occupancy of 5,870 hours/year would reduce the total maximum dose to 100 mSv/y and 5,87 hours / year would reduce total maximum dose to 10 mSv/y.

From Scenario 3 it was shown that a maximum total dose of 10,170 mSv/y is incurred at 0.6 years after intrusion at occupancies considered being residential (RESRAD default). Occupancy of 65 hours/year would reduce the total maximum dose to 100 mSv/y and 6.5 hours/year would reduce total maximum dose to 10 mSv/y.

External gamma exposure was shown to be the highest contributor to total dose, followed by radon.

From the analysis of Scenario 4 it was shown that a maximum total dose of 6.2 x 10^{-7} mSv/y is incurred only at 100,000 years after closure, indicating that for the expected land-use post institutional control, no risk to human receptors are foreseen, given that the possibility of intrusion is mitigated through engineering controls.

In Scenario 5, the RESRAD (onsite) code was also used, to determine radionuclide activity concentration levels in bulk NORM wastes which would give rise to conditions as specified above for post closure and intrusion scenarios. These values were adopted in the WAC for NORM waste and are detailed in Table 8 of the post closure risk assessment contained in Appendix 424A.14.

Radon from waste cells

Similar facilities around the world (e.g. France and Spain) indicate very low risk of inhalation of radon products due to the nature of waste disposed, the containment thereof and the half-life of radon. For the purpose of this assessment, it has been assumed the dose due to inhalation of radon gas would be less than 0.004mSv/a. This level is well below the occupational exposure limit of 10 mSv/a.

Generation of void space and subsequent collapse/instability of the waste cell

Section 5.5.4 provide detailed information on the generation of void space and how it would be managed. The information below is an overview of how each cell would be managed to safeguard it against potential collapse and future instability.

Waste packages would be contained within the kaolin mine void. The base and walls of the void would comprise kaolin clays which are naturally impermeable to water. The natural kaolin clay would effectively act as a liner as this material is present in a significant thickness and is more impermeable in the long-term than a synthetic liner (e.g. HDPE, geomembrane or concrete), which would break down and disintegrate over geological time (i.e. 10,000 years).

The waste cells would be filled in layers with multiple sections in each layer containing wastes of similar characteristics. All space between waste packages would be backfilled and compacted to minimise air or void space. If this approach is not taken it may result in settlement. Each layer would be compacted, until approximately 7 m below the ground surface, where a thick capping layer of low permeability clay (referred to as a ‘seal’) would be installed to prevent water ingress into the cell. Following this, more compacted backfill and a clay domed cap would be situated on the top of the cell, to shed any landing rainfall. Figure 5-20 illustrates how co-disposed chemical and radioactive wastes would be contained within the cells.

The encapsulation of wastes within each cell is subject to rigorous engineering design and compaction testing to ensure the properties of the constructed cell is a close analogue of the existing geological and hydrogeological conditions at the site, which naturally excludes water from the kaolinitic soils located beneath the silcrete layer. A feature survey of the cell would be conducted to confirm the cell is constructed in accordance with the engineering design

Dust emission from kaolin mining and subsequently the handling and processing of water material on site

Dust would be generated by all earthmoving operations where vehicles are driving over on-sealed surfaces and excavating or dumping any earthen material. This dust would be controlled by spraying working areas with water from a water-truck equipped with both a dribble bar (for roads) and side-sprays (stockpiles and working surfaces). Fortunately, kaolin clay is an excellent absorber of water and forms a durable crust once wetted and subsequently dried on stockpiles.

The white colour of kaolin also reduces rates of evaporation (when compared to typical Western Australian red dusts) and hence requires less frequent water application to achieve the same level of dust control.

Dust from blasting of the silcrete during mining is not expected to be a significant problem as it would only occur once or twice per year.

The kaolin processing operations would not be dust generating as almost all of the process is conducted as a slurry in water. Only the very final stage of the process involves drying of the kaolin to a damp lump form containing 12% moisture, and some dust may be generated in the dryer which is captured in the exhaust air stream by a dust collector and returned to the process.

The kaolin dust within the drying process is contained within the equipment and might only become a nuisance dust to maintenance workers attending to the dryer and dust collector system. Kaolin is not a classified as a hazardous dust and normal PPE in areas where dust might be present would be a dust mask.

The potential human health hazards from exposure to waste materials during the handling, loading, treatment and re-locating of packaged waste materials into shipping containers or directly into the cells are generally similar to those described above for the acceptance and handling of wastes. These activities increase the likelihood of waste materials being released to the environment, and so overall increase the possibility of exposure to waste materials.

Measures to reduce the likelihood of events occurring where waste materials may be released through these activities would be stringent as outlined in the Sandy Ridge Operating Procedure *SROP-11 Unpacking of Shipping Container and Placement of Waste Package in Cell*. The residual risk from transferring wastes to storage areas following implementation of appropriate management measures is considered low.

The long-term containment of waste materials refers to when the cells are completed to final design specifications. As waste cells would be created and completed in campaigns, people would be working in the cell and in the vicinity of completed cells. The cells would be designed and constructed to meet geotechnical engineering criteria.

Ongoing management and monitoring would also be implemented with the overall objective to ensure adequate long-term stability so that it is extremely unlikely that waste materials would be exposed even over very long time periods. Landform evolution modelling of the completed containment cells has been undertaken over a period of 10,000 years suggesting minimal erosion, with contingency measures to rectify any post-completion settlement planned (Appendix A.7).

The likelihood of people being exposed to waste materials once they are stored/contained is rare. Radioactive waste materials would continue to decay and may emit gamma radiation. Given the thickness (a minimum of 7 m) of the proposed capping layer and the inclusion of compacted clay layers with a nominal permeability of 10^{-9}m/s for the containment cells, the transmission of decay products would not result in exposure risks to humans on the ground surface. This has been modelled and is presented in Appendix A.14.

In terms of chemical wastes, only solid, non-reactive, non-flammable, non-explosive materials and non-biodegradable materials would be placed in the cells. All wastes would be placed in layers with progressive backfilling to avoid the creation of voids. As a result, the waste would be stable and inert in nature and would not produce gases or liquids that are likely to migrate either vertically or horizontally from the cells.

Detailed modelling shows that there would be minimal ingress of moisture into the cells as a result of rainfall events even using extreme rainfall assumptions (Appendix A.12). As a result, there is not a completed exposure pathway for these types of wastes and as a consequence the risk to human health is insignificant even following closure of the Facility.

A complete source-pathway-receptor link is not considered credible for the storage and containment of wastes. While a source of hazard exists (that is, buried chemical and radioactive waste), a pathway to people (receptors) on the ground surface is not considered credible. Once buried under 7 m of compacted clay, laterite and silcrete, it is highly unlikely that the waste could be exposed to humans, directly or indirectly. On this basis, the residual risk to human health is considered to be low.

The acceptance and handling of waste has the potential to expose workers (through either direct or indirect contact) to waste during their work activities. Exposure resulting in adverse human health effects is considered rare when the following is taken into account:

- Waste accepted would be of a known composition and the magnitude of potential doses could be calculated with an aim to minimise exposure to be as low as reasonably practicable.
- All workers would wear appropriate PPE and would follow applicable operating procedures and safety management plans.

- Workers who load and package waste, truck drivers/transporters and emergency responders would have received training and would have experience in conducting their designated work activities including managing incidents where waste materials may be released.
- The release of waste from appropriate containment or packaging would be a very infrequently occurring incident.

On this basis, the residual risk to human health is considered to be low.

Potential for fire and loss of life

The proposed development envelope is located within the Goldfields Bushfire Region, which experiences long periods of extreme fire weather in the dry summer months (NRM Rangelands, 2015). Bushfires in this region are mostly started by lightning and while infrequent, under extreme weather conditions they can be large in scale, intense and burn all vegetation types (NRM Rangelands, 2015).

Fire and its associated smoke can affect the health or lives of people working at the Facility and may cause injury, illness or death. If a bushfire was to affect the Facility and particularly areas of temporarily stored waste (i.e. the hardstand), the potential for subsequent exposure to waste materials may increase where fire may compromise the safe packaging or integrity of the shipping containers or if an explosion occurred.

The likelihood of a bushfire affecting stored waste would be minimised by clearing vegetation surrounding the operational areas. The Radioactive Waste Warehouse and Waste Inspection Area which may temporarily store wastes would be fire rated. Fuel storage facilities and systems would be designed to meet relevant codes and access would be restricted to the Explosives Store, which would also be fire rated.

Given the management measures that would be implemented to prevent bushfires, and the additional mitigation in areas of stored waste, the risk of adverse effects to human health would be as low as reasonably practicable.

Graphical conceptual representation of the final landform

Waste material would be backfilled into cells below the land surface. A graphical conceptual representation of the final landform within the cell area once all cells have been filled and capped is provided in Figure 10-2. Post operations, the land surface would be rehabilitated. A cap of soil providing surface runoff would alter the surface profile by up to 0.5 metres higher than the current profile at the centre of the mined and backfilled cell. Surface vegetation is expected to eventually grow on the cap after a revegetation program has been implemented.

The overall change in landform is not considered significant and, therefore, would not directly impact on human health. A graphical conceptual representation of the final steps of returning the landform to near original condition after they have been backfilled are shown in Figure 10-5 and Figure 10-6.

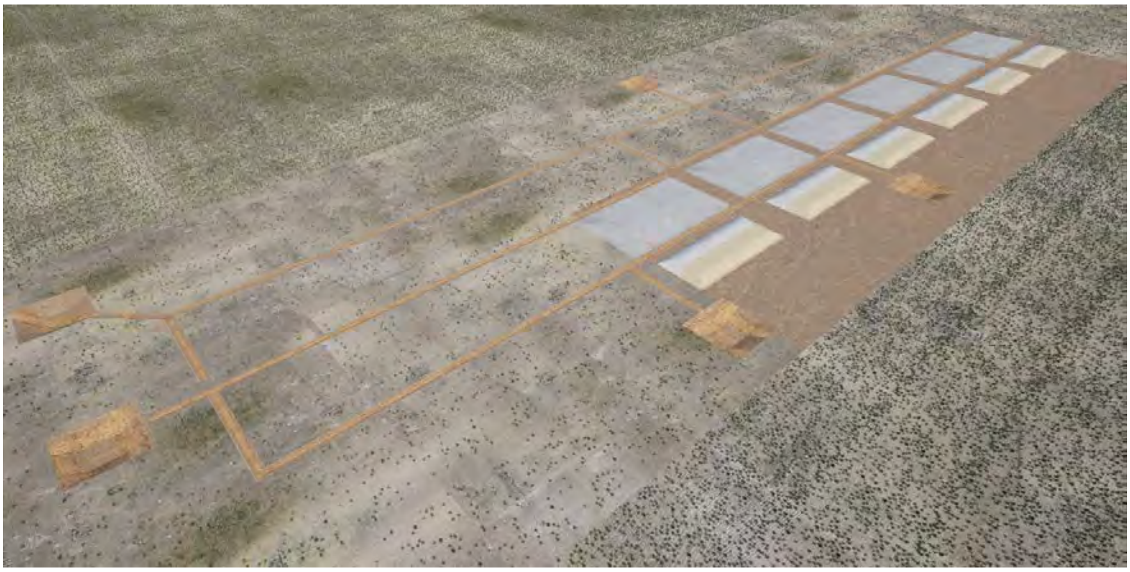

Figure 10-5 Backfilling complete capping of final cells in progress

Figure 10-6 What the landform would look like after it has been backfilled

The area would be marked by surface monuments such as those shown in Figure 10-7. Based on evolution modelling and the development of the Safety Case, the only plausible risks to human health post operations would occur in the unlikely event that a person knowingly or unknowingly disturbed the landform, for example, by digging a trench to a depth of 7 m. The effect of exposure to back filled materials on human health has been modelled at a very low risk. In addition, any potential impact would decrease with time.

Figure 10-7 Example of surface monument indicating a change in land use

Bush tucker consumption

Bush tucker foods (native plants and animals) potentially occurring within the proposed development envelope were identified through consultation with the local community and by comparison with the species list from the flora and vegetation survey and the species list of potential fauna in the development envelope identified during the fauna surveys. The bush tucker foods identified included:

- Malleefowl (*Leipoa ocellata*), considered a delicacy bush food.
- Emu (*Dromaius novaehollandiae*), used for bush food and the fat used for bush medicine.
- Echidna (*Tachyglossus aculeatus)*, considered a delicacy bush food.
- Sandalwood (*Santalum album*), used for cultural purposes (bush crafts and medicinal purposes).
- Bugadoo seeds used for bush food and medicinal purposes.
- Quandong (*Santalum acuminatum*), used for bush food.

Sandalwood and Quandong were not identified in the proposed development envelope during the flora and vegetation field survey. Malleefowl, Emu and Echidna would likely transit the proposed development envelope during the life of the Proposal. Whilst consultation did not specifically identify plants species found in the proposed development envelope, some of the plants used for bush tucker could potentially be present on the proposed development envelope.

The heritage survey did not identify sites of archaeological or ethnographic significance in the proposed development envelope. Generally, ethnographic sites of significance in the region are associated with prominent rocky outcrops or water sources, neither of which occurs in the proposed development envelope. In addition, the heritage survey made no reference to the use of the proposed development envelope for sourcing bush tucker.

Once the mine is constructed and waste accepted, the operational areas would be fenced to exclude the public, for safety reasons. The fencing would also exclude animals from the operational areas. In addition, vegetation would be cleared from the operational areas and, therefore, would not be available for consumption.

The likelihood of vegetation outside of the operational areas being affected by radiation is rare. Radioactive waste would be managed in accordance with a Radioactive Waste Management Plan which includes, storage within a restricted access building and handling procedures to minimise damage to the contents of drums (Appendix A.14). Radiation emissions modelling also predicts no impacts on vegetation (refer to the ERICA assessment in Appendix A.14). Therefore, the residual risk of bush tucker being affected by radiation is considered to be rare.

Following the completion of the cells and during the ICP, no access to the cells would be allowed. Therefore, no consumption of bush tucker would occur. Following the ICP, permanently isolated radioactive waste would have decayed to background levels and would no longer pose a human health risk, once the public are allowed to access the land.

Given that:

- There is an abundance of the same vegetation elsewhere in the region (5,773,838 ha), and therefore potentially bush tucker elsewhere in the region.
- The development envelope was/is unlikely to be used by Aboriginal people as it does not contain fresh water sources, or ethnographic sites.
- The proposed development envelope is remote from the nearest town (Koolyanobbing is 75 km away) and therefore unlikely to be frequented often by Aboriginal people specifically to consume bush tucker.
- Access to the operational areas of the Facility would be restricted during the construction and operation phase and the institutional control period.
- Accessible plants and animals (bush tucker) outside the fenced operational areas are highly unlikely to be affected by radioactivity from the waste stored on-site.
- Modelling of potential effects on plants from gamma radiation predicts no impacts would occur.

The risk to human health from bush tucker consumption would be rare.

Risks to workers at the accommodation village

The location of the proposed accommodation village has been selected against the requirements of the NHMRC guidelines. The accommodation area is in an of “zero” population density and, the projected population growth of the accommodation village will not change from what is reported in the PER. In addition, the prospects for future development at the Sandy Ridge site are also very low.

When constructed and in operation, the accommodation village is considered far enough away (3 km) from the operating site to have a neutral impact on human health. In addition, the operating management plans that are applicable to humans working at the site will maintain a neutral level of risk to the inhabitants at the accommodation village.

10.6.4 Proposed mitigation and management measures

The contents within the Outline Operating Strategy (Appendix A.16), the waste acceptance criteria documents (Appendix A.24) and the Outline safety case (Appendix A.15) aim to safeguard human health during operation of the proposed Facility. They include an assessment of construction and operational risks, safeguards around waste packaging; testing of the waste; acceptance of the waste for permanent isolation. These and other human health management measures are discussed below.

Outline Safety Case

An *Outline Safety Case* (Appendix A.15) has been prepared for the Proposal. The document is a collection of arguments and evidence in support of the safety of a facility or the activities to be undertaken at a facility. The Outline Safety Case includes the findings of the proponent's risk assessment and would include a safety assessment, a statement of risks and management measures, which is an ARPANSA regulatory requirement.

For a disposal facility, the safety case may relate to a given stage of development. The Proposal is at pre-development and as such, an *Outline Safety Case* presents potential risks and hazards and conceptually discusses their required management (refer to Chapters 6 and 7 in Appendix A.15). As the Proposal progresses into future development stages, the *Outline Safety Case* would be developed into a *Detailed Safety Case*, as required by ARPANSA.

The primary mechanism to protect human health during construction and operation is the identification of risks that may occur. These risks have been identified in the outline safety case and, subject to approval, would be developed during detailed design of the Proposal and supported by a *Detailed Safety Case*.

In addition to a fundamental analysis of the site characteristics and management practices, the Safety Case draws on best practice examples developed around the world for the safe storage and isolation of various types of hazardous wastes based on strict acceptance criteria, and for the construction in near surface geological settings that are internationally recognised as suitable.

The Safety Case is a living document which would be updated at each step of the development of the Facility – during detailed design, construction, operation and after closure.

The objective for the Safety Case is underpinned by the existing safety management system adopted by the proponent which is focused on its current business activities. These are mineral exploration, contract negotiation and approvals. Safety and management measures would be triggered following an incident under any one of the above business activities.

The safety management system described here would be revised as the proponent expands its business operations into construction and operation of the Sandy Ridge facility.

The proponent operates integrated quality, environmental management and health and safety management systems in accordance with the relevant standards:

- • ISO 9001 Quality management systems.
- • ISO 14001 Environmental management systems.
- • AS/NZS 4801 Occupational health and safety management systems.

Revisions of the safety management system would include the matters identified in Regulation 49 of the ARPANS Regulations and Regulation 558 and Schedule 17 of the WA WHS Regulations.

Outline Operating Strategy

The Outline Operating Strategy for the Proposal is provided in Appendix A.16. It provides details of how waste would be handled, stored, monitored and transported in accordance with the NEPM (as amended) and the Environmental Protection (Controlled waste) Regulations 2004 and Radiation Safety (Transport of Radioactive Substances) Regulations 2002 (WA).

The objective for the operating strategy is to control risks identified in this PER which includes some wastes that would not be acceptable for the Proposal. Solid and liquid chemical waste which would not be accepted are provided inTable 1-2 and Table 1-3 and in the WAC (Appendix A.24).

Low level radioactive waste must meet the following criteria in order to be accepted at the proposed Sandy Ridge Facility:

- Only LLW and some ILW that meet the waste acceptance criteria would be accepted for disposal. Refer to Radioactive Waste Acceptance Guide (Hygiea Consulting, 2016) for waste acceptance criteria.

If wastes in the list above can be treated and conditioned to remove the characteristics which make them unacceptable for storage in the geological repository, then they may be considered for acceptance on a case by case basis.

A range of management plans and procedures would be implemented to manage the potential impacts on human health during construction and operation of the Proposal. These management plans and operating procedures are listed in Table 10-15.

Table 10-15 Operating strategy management plans and operating procedures

Management plans	
SRMP-01	Radiation Waste Management Plan
SRMP-02	Mine Closure Plan
SRMP-03	Waste Facility Decommissioning and Closure Plan
SRMP-04	Emergency Management and Response Plan
SRMP-05	Project Management Plan
SRMP-06	Class II Landfill Post Closure Management Plan
SRMP-07	Drinking Water Quality Management Plan
SRMP-08	Radioactive Waste Acceptance Guide
SRMP-09	Construction Environmental Management Plan
SRMP-10	Operation Environmental Management Plan
Operating procedures	
SROP-01	Waste Acceptance Policy
SROP-02	Waste Acceptance Criteria
SROP-03	Waste Acceptance Procedure
SROP-04	Waste Zoning Guide
SROP-05	Assessment of Waste Pro forma
SROP-06	Review of Waste Documentation
SROP-07	External Shipping Container Audit
SROP-08	Gamma Radiation Monitoring
SROP-09	Transport Risk Assessment
SROP-10	Spill Clean-up
SROP-11	Internal Shipping Container Audit
SROP-12	Sampling of Wastes
SROP-13	Damaged and Leaking Waste Package
SROP-14	Issuing Waste Acceptance Certificate
SROP-15	Unpacking of Shipping Container and Placement of Waste Package in Cell
SROP-16	Backfilling
SROP-17	Subsidence Monitoring
SROP-18	Radon Monitoring
SROP-19	Occupational Radiation Monitoring

Waste Acceptance Criteria and supporting documents

The details and objectives of proposed WAC management measures are summarised in Section 5.5.4 and detailed in Appendix A.24.

Radioactive Waste Acceptance Guide

Acceptance criteria for radioactive waste developed for the Facility is described in the WAC (document reference THWACG170516 contained in Appendix A.14 of the PER).

The radionuclide concentration limits are set taking into account the actual siting, design and planning of the facility (e.g. Natural geological barrier, arid climate, remoteness, engineered multi-layered shielding and barriers, duration of institutional control, site specific management plans and operating procedures) and exposure dose constrains to ensure no person is exposed above the dose limit (as defined in Schedule I of the Radiation Safety (General) Regulations 1983).

Human health monitoring

Contingency measures would focus on monitoring human health. The purpose of human health monitoring would be to ensure that radiation exposure of workers remain below the statutory annual limit (1 mSv) and as low as reasonably acceptable. Triggers for exceeding the annual limit of 1 mSv may include having no radiation management controls in place, exposing works to low levels of radioactive waste for extremely long periods of time and without wearing appropriate personal protective equipment. To avoid such (unlikely) impacts on human health, the following contingency measure would be implemented through the Radiation Management Plan (RMP) provided in Appendix A.14.

Individuals working in a variety of roles would be fitted with personal monitoring devices to capture data on radiation doses received in the workplace. The monitoring would evaluate:

- Radioactive dust – personal dust samplers would collect dust particles. Samples would be analysed for gross alpha activity.
- Gamma rays – personal electronic dosimeters or Thermoluminescent Dosimeter (TLD) badges would record a worker's exposure to gamma radiation.
- Gamma radiation within specific work areas – portable TLD badges would be distributed in different works areas and used to demarcate areas based on exposure risk.

If an employee is pregnant, the employee would be issued with a personal electronic dosimeter and would be required to record her daily dose received. The employee's exposure would be calculated based on the dose received and the pregnancy time remaining. An employee's dose would be monitored throughout the pregnancy and she would be relocated to a less radioactive area if needed to ensure her dose received does not exceed 1 mSv over the pregnancy period.

Further information on human health monitoring is provided in the RMP (Appendix A.14).

Radiation Management Plan

The RMP for the Proposal is provided in Appendix A.14. The purpose of the RMP would be to ensure that radiation exposure of workers remain below the statutory annual limit (1 mSv) and as low as reasonably acceptable.

The proponent's outcome for the RMP is to eliminate and reduce, as far as possible, risks of exposure to radiation. To achieve this outcome, the proponent would take into account the following:

- Site (environmental) conditions.
- Current technological knowledge.
- Safe working conditions and whether these are being compromised by introducing a control method.
- Social and economic consequences.

The RMP would adopt the following hierarchy of control measures:

- Eliminate the hazard.
- Appropriate cell and warehouse design.
- Ventilation.
- Packaging.
- Substitute a work process for a process in which exposure levels are decreased.
- Implement engineering controls (specifically in the design and ventilation of the operational areas and the packaging of waste materials) which would prevent or reduce contact between the hazard and workers.
- Apply administrative controls such as placarding, time restrictions, work procedures and training.
- Require workers to use PPE such as respirators. Respiratory protective devices would be permanently available in the workplace. Instruction, training, proper maintenance and efficient use of the respirators would be carried out on an ongoing basis.

The radioactive disposal shaft has been designed and would be constructed in segments so that the placement of chemical waste and pre-fabricated shaft segments would progress to several metres of depth before radioactive waste placement occurs, so as to provide vertical physical separation between the radioactive waste and workers on the active surface.

The higher activity LLW would be placed at the bottom of the shaft to increase the distance between it and the surface and to reduce the exposure risk of those workers operating on the ground surface. This would reduce the exposure time, increase the distance between the radioactive waste and workers and would provide shielding between the waste and potential receptors.

Potential exposure to gamma radiation from radiation gauges would be minimised by setting those sources in concrete and then inside steel drums. This would provide shielding and would reduce the risk of exposure.

The radioactive waste warehouse would be designed and built to provide shielding and to reduce the risk of exposure. It would also be demarcated and access controlled to prevent unauthorised entry and exposure. If NORM are stored within the Radioactive Waste Warehouse, ventilation systems would be installed to minimise radon gas build-up to ensure the risk is reduced to as low as reasonable acceptable.

If there are stockpiles stored on site and material can be spread by wind the following practices would be implemented:

- Ad Hoc stockpile would be designed with a concrete slab and bunding. It can also be closed off with tarp or mesh material to ensure no generation of dust.
- Maintaining a minimum open air stock level to minimise drying and dust generation.

- A watering system and wind breaks to prevent the generation of dust.
- Shade cloth mesh barriers can be used in areas best suited to their application to prevent the generation of dust ad form wind breaks if needed.
- A dust suppression agent can be applied to non-active stockpiles to prevent dust emissions
- leaving the premises during periods of high winds; and
- A Comprehensive dust monitoring program, consisting of both personal and environmental dust monitoring, are in place to monitor and report on the efficiency of the existing control measures.

Contamination control would involve the following objectives and management measures:

- The site boundary is screened at least annually to confirm the efficiency of controls in place to prevent contamination of neighboring properties.
- All equipment that may be contaminated with radioactive material is screened to ensure they are within the release limits.
- Surface radiation contamination on plant and equipment must be less than 0.4 Bq/cm2 averaged over 300 cm^2, otherwise plant and equipment is not released from site.

To ensure ALARA principles are maintained, classification of areas is done based on the potential annual radiation exposure in excess of the natural background and the following work rules apply to those areas:

- “Radiation supervised area”: an area to which access by members of the public should be minimised and restricted. General awareness of elevated radiation levels in the area is required both for employees and for visitors. Visitors to the site must be accompanied at all times.
- “Radiation Controlled area”: an area to which access by employees should be limited or minimised:
- Only employees who have attended radiation safety training are allowed to work in these areas. Employees who have not attended this training are allowed to work only in exceptional circumstances.
- “Radiation restricted area” is an area where the potential for the radiation exposure of employees is above 75% of the annual dose limit. Only employees who have attended radiation safety training are allowed to work in these areas and wearing of a personal radiation monitor (a TLD badge or an electronic dosimeter) is mandatory.
- Visitors or employees who have not attended radiation safety training are not permitted to enter these areas under any circumstances except in emergency situations.

Emergency procedures would be developed to prepare for accidental spillage while transporting sources, fires and other relevant emergency situations.

Respiratory protective devices would be permanently available in the workplace. Instruction, training, proper maintenance and efficient use of the respirators would be carried out on an ongoing basis throughout the year so as to ensure the coverage of all new employees.

All employees are made aware during site induction of the risk of radiation exposure. They are made aware of the increased risk to radiation exposure if personal hygiene is not followed before eating, drinking or smoking.

Ablutions facilities are made available on site to enable employees to follow good personal hygiene practices. Designated employees dosage is monitored and calculated quarterly while pregnant employees dosage is calculated weekly. If an employee reaches 50 % of the annual exposure dose limitation, they would be removed to a non-designated area to ensure they are not being overexposed.

Monitoring of these employees would continue to ensure no overexposure to radiation. If 75 % of the annual dose limitation is reached the employee would be sent on leave or moved to activities where there are low radiation exposure levels to ensure they are not over exposed. The levels by which jobs would be rotated are given in Table 10-16:

Table 10-16 Job rotation levels

Exposure level	Pregnant employee (mSv)	Designated employee (MSv)	Contingency action
50% of dose limitation	0.5	10	Rotate employee to work in non0designated or lower radiation area.
75% of dose limitation	0.75	15	Employee to be sent on leave to prevent over exposure.

Wastewater management

The outcome objective for this management measure is to safeguard humans against the risk of contaminated waters which may result as a result of human or engineering error.

To safeguard human health, wastewater from the accommodation camp and infrastructure area (e.g. offices) would be pumped to a sewerage treatment system that would be located in the accommodation village and in the infrastructure area. Wastewater would be treated by BioMAX® systems, or equivalent. Treated effluent would be sprayed across a portion of the proposed development envelope dedicated for this purpose.

The wastewater treatment system would be designed to meet the wastewater requirements of the Shire of Coolgardie. Wastewater is not proposed to be reused.

Management of asbestiform materials

The outcome objective for this management measure is to safeguard humans against the risk of contamination from asbestiform materials.

Asbestos is not expected to be encountered within the surficial soils of the development envelope given it is relatively undisturbed (except for exploration activities), has limited access, is remote and is highly unlikely to have been used for other anthropogenic purposes. Further, metamorphic formations which may contain asbestos or asbestiform minerals were not encountered during exploratory drilling of the proposed development envelope.

Management of asbestiform materials would be focused on any incoming waste loads identified as asbestos through the waste acceptance process. The following contingencies would be adopted for the Proposal.

When carrying out licensed asbestos removal work at a waste producing site, a licensed asbestos remover must ensure that asbestos waste is contained and labelled before the waste is removed from the asbestos removal area. It must be disposed of as soon as is practicable at a site authorised to accept asbestos waste.

Asbestos-contaminated soil comprises non-attached pieces of asbestos cement products and other material containing asbestos uncovered in soil during other work activities. Contamination can be detected during building and road construction and excavation, waste disposal, damage following a severe weather event such as a hail storm, weathering over time, or when asbestos is poorly handled or damaged during removal jobs.

Individual components and wiping rags would be placed in plastic bags, tying each bag separately prior to placing them in a transport container. Disposal bags would to be heavy duty (200 µm), made of clear plastic and marked with the label 'Caution Asbestos – Do not open or damage bag. Do not inhale dust'. Asbestos waste awaiting disposal would be stored in closed containers (for example, 60 or 200 litre steel drums with removable lids or sealed skip).

A risk assessment by an independent licensed asbestos assessor or competent person, including contaminated site assessment practitioners, would determine the most appropriate control measures and remediation strategies. All asbestos and any contaminated soil removed would be disposed of as asbestos waste at a licensed waste disposal facility such as Sandy Ridge.

As a result of the pre-disposal management practices carried out at the site of waste arising, any asbestos waste arriving at Sandy Ridge would be appropriately prepared or packaged to ensure that asbestos fibres cannot become airborne at Sandy Ridge. These packaging requirements, which are the principle control mechanism to prevent airborne fibres being generated and inhaled, would be incorporated into site specific waste packaging acceptance criteria for asbestos containing wastes.

Following waste acceptance, asbestos containing material would be placed in the appropriate disposal zone and covered with a layer of kaolin during (or no later than the end of) the operating shift in which the material is emplaced. The kaolin layer provides a barrier against any further potential release of airborne fibres.

If asbestos is released and receptors are exposed, the potential dose is likely to be very low, that is below the occupational standard of 0.1 fibres/mL in air. Management of exposure to asbestos following an incident would, therefore, focus on:

- Limiting the potential for airborne asbestos fibres to be generated through stabilisation and dust control measures such as wetting.
- Limiting potential for airborne asbestos to be inhaled by ensuring only people who need be in the vicinity are, and they are protected with suitable PPE including respiratory protection.
- Appropriate decontamination and disposal of PPE which may have become contaminated during clean-up operations.

Food and water preparation

The outcome objective for this management measure is to safeguard humans against the risk of food contamination. To achieve this outcome, the following contingency measures would be adopted.

Food would primarily be prepared in the accommodation camp kitchen by experienced chefs familiar with the requirements of the *Food Act 2008* and the Food Regulations 2009. The kitchen would meet the requirements of the *Australia New Zealand Food Standards Code* (Food Standards Australia and New Zealand, 2015).

Potable water brought into the Facility or created from the reverse osmosis plant would be routinely tested to ensure compliance with the requirements for drinking water quality as outlined in the *Australian Drinking Water Guidelines* (NHMRC, 2011 as amended 2016) before it is available to workers for consumption. A Drinking Water Quality Management Plan is included in Appendix A.20 and includes a drinking water monitoring program as per the Small Community Sampling Grid and a system of compliance and reporting protocols as per the *Systems Compliance and Routine Reporting Requirements for Minesites and Exploration Camps* (Department of Health, 2011b).

Water management plan

The water quality monitoring plan is outlined in Table 4–1 of Appendix A.20. It has been prepared in accordance with the DoH's *Small Community Model Assessable Sampling Grid*. Disinfection would be through RO filtration and Chlorination.

Sample points are defined as follows:

- Source water – Carine Iron Ore Mine Pit.
- Treated water – A sample taken from the chlorination dosing system immediately after treatment.
- Distribution point – Samples taken from the pump following the storage tanks at each storage tank location (i.e. potable water tank and camp potable water tank).

- Consumer sample point – A sample would be taken at all distribution areas (i.e. the kitchen, accommodation camp and administration/production facilities).

All reporting (emergency and routine) would be conducted in accordance with Systems Compliance and Routine Reporting Requirements for Minesites And Exploration Camps (DoH, 2011). Appendix A.2 provides a risk model reporting format to be used for submission to the DoH.

Trigger and contingency actions

Human health incidents would be managed in accordance with the conceptual emergency response flow chart in Appendix A.22.

The potential impacts on human health discussed in Section 10.6.3 are considered to be low, the mitigation and management measures provided in the above documents would be implemented to further decrease risks on human health during construction and operation of the Proposal.

10.6.5 Predicted environmental outcome

Activities or situations considered to pose the greatest potential risk for adverse human health effects include kaolin mining, the acceptance and handling of hazardous and intractable waste, the storage and containment of hazardous and intractable waste, and bushfire.

Mitigation and management measures would be implemented to reduce human health impacts during both construction and operation of the Facility. The provision of multiple barriers of containment around waste, knowledge of waste content, training and supervision of all employees, appropriate PPE, monitoring of worker health and the continued improvement of waste handling and storage procedures would minimise the risk of adverse impacts on human health to as low as reasonably achievable.

With the implementation of the mitigation and management measures outlined above, the EPA's objective to ensure that human health is not adversely affected would be achieved.

10.7 Heritage

10.7.1 Introduction

This section assesses the potential impacts on heritage during both construction and operation of the Proposal. Mitigation and management measures are identified to avoid or reduce potential impacts with the objective *to 'ensure that historical and cultural associations, and natural heritage, are not adversely affected'* in accordance with the EPA's Environmental Assessment Guideline No. 8 (2015a).

This section draws on the *Report on an Aboriginal Heritage Survey of Tellus Sandy Ridge Project* (John Cecchi Heritage Management Consultancy, 2015 see Appendix A.13). The results of this study informed the assessment of the potential impacts on cultural heritage. The assessment has also been prepared with reference to the applicable standards, guidelines and procedures listed in

Chapter 4, Table 4-3 and in accordance with the requirements set out in the ESD which is presented in Appendix A.1.

10.7.2 Methodology

An Aboriginal cultural heritage assessment was undertaken with representatives of the Kapam Native Title Group, Kelamaia Kabu(d)n and Widji Group within the entire development envelope of the proposed Sandy Ridge site to assess the heritage values of the proposed development envelope and to identify the potential presence of cultural heritage items within the proposed development envelope. The cultural heritage investigation included:

- A desktop review of previous heritage surveys and relevant heritage databases to determine whether there are any listed heritage sites within or in close proximity of the proposed development envelope.
- A field survey consisting of pedestrian transects in consultation with representatives of the Kapam Native Title Group, Kelamaia Kabu(d)n and Widji Group.

The assessment of European heritage included a desktop review of publicly available information and a review of relevant heritage databases to determine whether there are any listed heritage sites within or in close proximity to the proposed development envelope.

The actual area surveyed was all the 'Development Envelope', walking north-south transects spaced 50 metres apart. Usually maps are drawn showing locations of transects if the area was sampled - i.e. survey of 10 ha in a 50 ha Proposal area, or when predictive sampling is undertaken in areas of high potential. This was not required at the Sandy Ridge site and full coverage of the development envelope area shown in Figure 1-3, meaning the whole area in question was surveyed.

As discussed in the specialist report (see Appendix A.13) *"the field survey was conducted via pedestrian transects aligned north-south, spaced fifty meters apart. Ground visibility was good, with an average of 50%. Given the survey methodology and ground visibility it is postulated that any sites with surface expressions would have been identified during the survey.' i.e. a theoretical complete ground coverage was achieved"*.

10.7.3 Assessment of potential impact and risk

There are no known records of heritage items (Aboriginal or European) within the proposed development envelope as confirmed via online database searches. In addition, the cultural heritage survey did not record any evidence of Aboriginal heritage sites (registered or previously unrecorded) within the proposed development envelope. There are also no relevant registered native title claimants and no determined native title holders.

The Aboriginal representatives from the Kaparn Native Group, Kelamaia Kabu(d)n and Widji Group (who assisted in the cultural heritage survey) provided no objection to the Proposal.

Based on the above information, there would be no impact on Aboriginal or European cultural heritage sites or on cultural associations within the proposed development envelope during construction or operation of the Proposal.

10.7.4 Proposed mitigation and management measures

As no heritage sites (registered or previously unrecorded) occur within the proposed development envelope, no additional mitigation measures would be required. In the event that items of potential European historical significance are encountered, work in their immediate vicinity (defined as a 10 metre radius) would stop and the Heritage Council and State Heritage Office would be contacted. Similarly, if items of Aboriginal heritage significance are identified during construction, work in their immediate vicinity would stop and the Department of Aboriginal Affairs in addition to the Kaparn Native Group, Kelamaia Kabu(d)n and Widji Group would be contacted for further advice.

If suspected skeletal remains are discovered during construction, work in their immediate vicinity would stop and the local police and the Department of Aboriginal Affairs would be notified as soon as possible to determine a course of action. Construction works in the area of the remains would not resume until the proponent receives written approval from either the police or from the Department of Aboriginal Affairs, as appropriate.

10.7.5 Predicted environmental outcome

As no heritage sites (registered or previously unrecorded) occur within the proposed development envelope, there would be no impact on cultural heritage during construction or operation of the Facility. As such, the EPA's objective to ensure that historical and cultural associations, and natural heritage, are not adversely affected would be achieved.

10.8 Offsets

10.8.1 Introduction

This section assesses the need to offset significant residual environmental impacts associated with the construction and operation of the Facility.

The assessment has also been prepared with reference to the applicable standards, guidelines and procedures listed in Chapter 4, Table 4-3. Particular reference has been made to the following polices/guidelines:

- *Environmental Offsets Policy* (Government of Western Australia, 2011).
- *Environmental Offsets Guidelines* (Government of Western Australia, 2014).

The assessment has also been prepared in accordance with the requirements set out in the ESD which is presented in Appendix A.1.

10.8.2 Assessment of significant residual impacts

Environmental offsets are actions that provide environmental benefits which counterbalance the significant residual environmental impacts or risks of a Proposal or activity (Government of Western Australia, 2014). Environmental offsets are required where the residual impacts are determined to be significant after avoidance, mitigation and rehabilitation have been pursued (Government of Western Australia, 2014).

To ensure consistency and transparency of whether offsets are required for a Proposal, the significance of residual impacts are determined through the application of a residual impact significance model (Government of Western Australia, 2014).

Significant residual impacts include those that affect rare and endangered plants and animals, areas within the formal conservation reserve system, important environmental systems and species that are protected under international agreements and areas that are already defined as being critically impacted in a cumulative context. Impacts may also be significant if, for example, they could cause plants or animals to become rare or endangered, or they affect vegetation which provides important ecological functions (Government of Western Australia, 2014).

The residual impact significance model outlines how significance is determined and when an offset is likely to be required or may be required in relation to relevant EPA environmental factors. The model identifies four levels of significance for residual impacts:

- Unacceptable impacts (those impacts which are environmentally unacceptable or where no offset can be applied to reduce the impact).
- Significant impacts requiring an offset.
- Potentially significant impact which may require an offset (determined by the decision-maker based on information provided by the proponent and expert judgement).
- Impacts which are not significant (those impacts that do not trigger the above categories are not expected to have a significant impact on the environment and, therefore, do not require an offset) (Government of Western Australia, 2014).

An assessment of the significance of the Proposal's residual impacts has been undertaken in accordance with the Environmental Offsets Guidelines (Government of Western Australia, 2014). The assessment is provided in Table 11-1.

10.8.3 Predicted Environmental Outcome

An assessment of the residual impacts on flora and vegetation and terrestrial fauna has been undertaken in accordance with the Environmental Offsets Guidelines (Government of Western Australia, 2014).

The only issue which potentially triggers a requirement for an offset relates to the clearing required within the former Jaurdi Pastoral Lease, of which 6.44 ha is located within the proposed

Conservation and Mining Reserve. As this area is only a proposed reserve at this stage and vegetation is sparse with no Threatened or Priority flora or Threatened Ecological Communities (TEC)s/Priority Ecological Communities (PECs) in the 6.44 ha area, the potential impact is not considered to be significant enough to warrant an offset.

10.9 Rehabilitation and decommissioning

10.9.1 Introduction

This section addresses the rehabilitation and decommissioning of the Proposal. Mitigation and management measures are identified to avoid or reduce potential impacts on the environment during both rehabilitation and decommissioning activities in accordance with the objectives of the EPA and DMP. The EPA's objective for rehabilitation and decommissioning is to *'ensure that premises are decommissioned and rehabilitated in an ecologically sustainable manner'* Environmental Assessment Guideline No. 8 (EPA, 2015a).

10.9.2 Methodology

A qualitative risk assessment has been undertaken for all aspects of mine and waste facility closure, in accordance with the procedures outlined in the Australian and New Zealand Standards *AS/NZS ISO 31000:2009 Risk Management–Principles and Guidelines* and *HB 203:2012 (Managing Environment-Related Risk)*, using the proponent's Risk Assessment Matrix.

10.9.3 Assessment of potential impacts and risks

Potential impacts during rehabilitation and decommissioning include the subsidence of a waste cell allowing infiltration of water and the generation of leachate, topsoil degradation, erosion/gullies/deep rooted vegetation creating cracks in the clay capping allowing infiltration of water and the generation of leachate, vegetation not growing and unable to support a functioning ecosystem, fauna not returning and a functioning ecosystem is not achieved and long term impacts on terrestrial environmental quality, inland waters and human health. These potential impacts are discussed below.

Waste cell subsides allowing infiltration of water and generation of leachate

As discussed in Section 10.3.3, subsidence and instability of a waste cell could occur if backfilling and compaction activities are not undertaken in accordance with specified procedures. This may lead to the generation of a void space(s) within the cell, which could then cause slumping of the cell backfill, a change to the integrity of the cap, and may generate pathways with greater permeability for water to enter the cell. Water entering the cell could potentially generate leachate from the waste packages.

Hazards which may contribute to the subsidence are primarily related to achieving the backfill and compaction requirements of the engineering design. This would be managed through briefings to the operators from the project engineer, measurements of compaction density undertaken in accordance with *AS1289.5.8.1*, visual inspection following placement of waste and backfill of each layer, and topographical survey at the completion of each layer to confirm engineering specifications have been met and monitoring of the clay dome following cell completion.

Topsoil is degraded and unable to support a functioning ecosystem

Vegetation and topsoil would be stockpiled and later re-spread during rehabilitation and decommissioning. Topsoil would be preserved in a condition as near as possible to its pre-mining condition in order to allow for successful rehabilitation.

Procedures would be implemented to preserve topsoil during topsoil stripping and for the storage and appropriate use of topsoil during progressive cell closure and rehabilitation. Specifically, a topsoil stripping procedure would be implemented to maximise the volume of suitable topsoil removed, thereby maximising topsoil available for rehabilitation and decommissioning.

Stockpile design and maintenance procedures would be implemented as would erosion control techniques (for stockpiled topsoil and exposed subsoil following stripping and during rehabilitation). A topsoil application procedure (to be used during rehabilitation) would also be implemented. These procedures would be included in the CEMP, OEMP, WFDCP (refer Appendix A.18) and MCP (refer Appendix A.19).

Erosion/gullies/deep rooted vegetation create cracks in the clay capping which allows water to infiltrate and generate leachate from the stored waste

Current weathering and erosion in the area is extremely slow. The near horizontal sandy surface and lack of stream channels results in rain water being absorbed into this surface unit, rather than running off with resulting water erosion. Wind erosion is very limited, as the sandplain is well covered with native vegetation and average wind speeds are low for the majority of the year.

Following the placement of the final waste layer, capping layers would be used to fill the remaining void and cover the completed waste cell. This would occur at approximately 7 m below the ground surface. This capping layer serves to provide a barrier between the waste materials and the surface; to prevent water infiltration; and to prevent erosion. Landform evolution modelling predicts that after 10,000 years there is relatively little change to the clay domes and the landform is likely to be erosionally stable over the very long term (Landloch, 2016; Appendix A.7).

As discussed in Section 10.2.4, all disturbed areas would be rehabilitated in accordance with the WFDCP (refer Appendix A.18) and MCP (refer Appendix A.19). Rehabilitation would include revegetation using local indigenous species. Groundwater-dependent species would not be planted.

The vegetation planted would be adapted for semi-arid environments and, therefore, would be shallow rooted with a fibrous root system rather than a tap root system which may penetrate deeper. There would be a separation distance between the shallow plant roots and the stored waste. Approximately 7 m of compacted backfill would separate stored waste from the surface. Vegetation would be planted in the topsoil on the domed cap, which is elevated between approximately 1.7–5 m above the ground surface. It is highly unlikely plant roots would penetrate to the stored waste.

Given the above discussion, it is highly unlikely that erosion/gullies or deep rooted vegetation would create cracks in the clay capping. It is, therefore, unlikely that water would infiltrate the cells and generate leachate from the stored waste.

Vegetation does not grow and is unable to support a functioning ecosystem

As discussed in Section 10.2.4, all disturbed areas would be rehabilitated in accordance with the WFDCP (refer Appendix A.18) and MCP (refer Appendix A.19). Rehabilitation would primarily include respreading of topsoil, ripping of surface, revegetation using local indigenous species, irrigation in the initial months of establishment and the application of fertiliser (where appropriate). Further details on rehabilitation are provided in detail in Appendices A.17 and A.19.

In order for planted vegetation to survive in the rehabilitated areas, groundwater-dependent species would not be planted. The vegetation planted would be adapted for semi-arid environments and, therefore, would be shallow rooted with a fibrous root system rather than a tap root system which may penetrate deeper. There would be a separation distance between the shallow plant roots and the stored waste. Approximately 7 m of compacted backfill would separate stored waste from the surface. Vegetation would be planted in the topsoil on the domed cap, which is elevated between approximately 1.7 to 5 m above the ground surface. It is highly unlikely plant roots would penetrate to the stored waste.

No risk to flora and vegetation is foreseen with regards to radiation exposure, as demonstrated using ERICA (refer to Appendix A.14).

Based on the above, it is anticipated that all disturbed areas would be rehabilitated so as to achieve a functioning ecosystem.

Fauna does not return to the vegetation and therefore a functioning ecosystem is not achieved

As discussed above, all disturbed areas would be rehabilitated in accordance with the WFDCP (refer Appendix A.18) and MCP (refer Appendix A.19). Rehabilitation would primarily include respreading of topsoil, ripping of surface, revegetation using local indigenous species adapted for semi-arid environments (with shallow, fibrous root systems that would be highly unlikely to penetrate the stored waste), irrigation in the initial months of establishment and the application of fertiliser (where appropriate).

No risk to fauna is foreseen with regards to radiation exposure, as demonstrated using ERICA (refer to Section 10.4.3 and Appendix A.14).

It is anticipated that all disturbed areas would be rehabilitated so as to achieve a functioning ecosystem. Flora and vegetation would become established, creating habitat for local fauna.

Long-term impacts on terrestrial environmental quality, inland waters environmental quality and human health

There would no long-term impacts on terrestrial environmental quality, inland waters or to human health, as demonstrated in Section 10.3 and Section 10.5. In addition to the information presented in these sections, the outline RMP contained in Appendix A.14 provides safeguard measures to avoid, minimise and reduce any risks associated with radioactive waste.

Graphical conceptual representation of the final landform

Key findings of the landform evolution modelling report attached in Appendix A.7 are:

- The Facility design of 5 m high cells (i.e. landforms) with 3 degree batters covered with a deep layer of topsoil is predicted to be erosionally stable over the very long term. This is due to the permeability of the topsoil, arid climate, and a gently sloping design.
- There is predicted to be relatively little change to the Facility surface over the simulation period (10,000 years). Typically, less than 200 mm is eroded from the cell batter slopes and deposited in between cells with a maximum of 500 mm deposition predicted (Figure 10-8). This is based upon a simplistic model using peaked crests and flat batter slopes. In reality, crests and swales would all be broadly rounded or smoothed landforms.

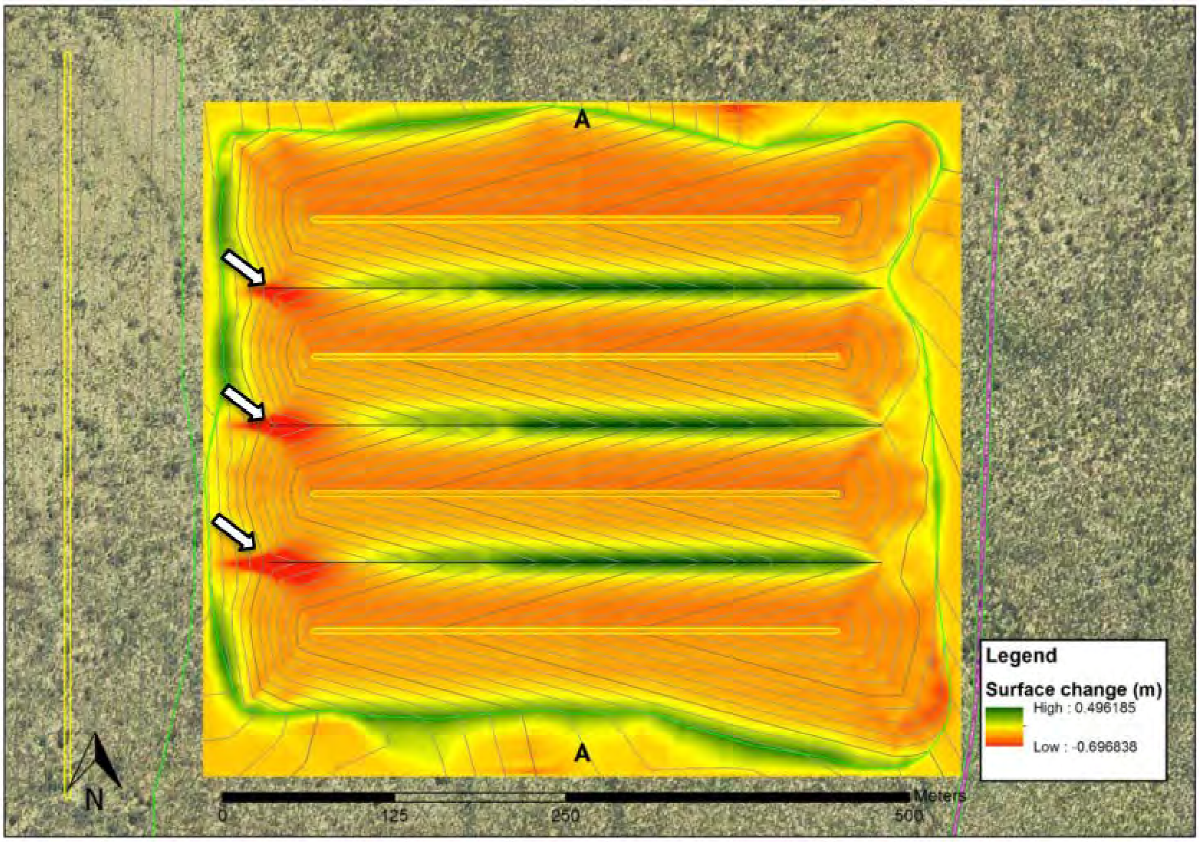

Figure 10-8 SIBERIA model 10,000 year results for long term landscape evolution of cells

The predicted original surface and the surface after 10,000 year simulation is shown in Figure 10-9 (not the axis in Figure 10-9 is shown in metres).

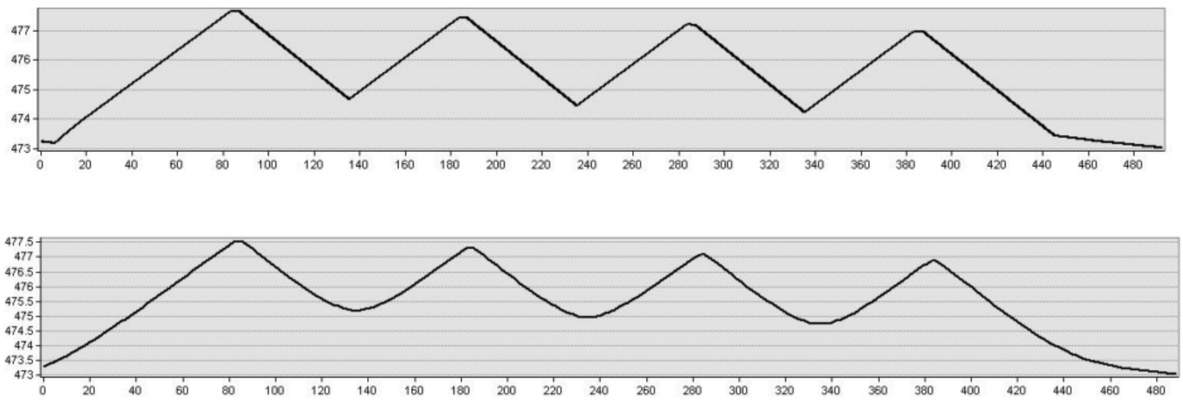

Figure 10-9 SIBERIA model results cross section for the original surface (top) and at 10,000 years (bottom)

Further discussion and graphical representation of long term landform evolution is provided in Section 10.3.3.

Other potential risks during rehabilitation and decommissioning (results of risk assessment)

The risk assessment identified six planned and 14 unplanned credible risks. The highest residual ranking risks were:

- Major earthquake with surface displacement and cracking of the domed caps over the cells. This could lead to subsidence/slumping of the cell and further erosion of the cap (rills and gullies). The loss of cell stability could potentially allow water to infiltrate into the cells, potentially generating leachate from waste packages into the surrounding clay
- Bushfire which may cause injury or death of Threatened/Priority fauna and damage revegetation
- Terrorist attack from a plane crashing into, or bombing of, the cells. This may cause an expulsion of chemical and radioactive waste from the cell to the surface and into the atmosphere
- Failure of revegetation due to degraded topsoil, compacted soils, erosion, fauna predation, lack of seed pre–treatment, no tubestock available, and weed invasion
- Unauthorised access to the Facility and/or accidental deep excavation into a cell (i.e. mineral exploration). This could impact upon human health and potentially lead to injury or death of fauna by falling into the cell. The cell may become unstable and collapse.

Additional risks have been identified and ranked as ‘low’ risk. The full risk assessment is provided in the WFDCP and MCP (see Appendix A.18 and A.19).

The stability of the cells is of paramount importance to the rehabilitation and decommissioning of the proposed development envelope. The potential sources of risk outlined above all have the potential to affect the stability of the cell. Any water infiltrating the cell has the potential to leach contaminants from the solid chemical and low LLW contained within the cell. The consequence may include emissions to the atmosphere which may have adverse effects on humans and flora and fauna, and may cause injury or death.

The likelihood of death of humans or flora or fauna would be reduced during the closure period as all cells would be capped and in varying states of subsidence monitoring and radiation monitoring. The risk would be further mitigated by the site continually being managed, through the ICP by the appropriate authority. The ICP, as defined by NHMRC (1992), is the period following closure of the disposal facility where public access to, or alternative use of, the site shall be restricted for a predetermined period of time (see Section 5.13).

10.9.4 Proposed mitigation and management measures

The proposed management for closure of the mining aspect and the waste disposal aspect have been segregated, primarily as the regulation of mining and waste disposal are managed under different legislation in WA. Therefore, two closure and decommissioning plans would be implemented specific to each aspect of the Proposal:

- Mining aspect – details relating to mine closure for tenement relinquishment are outlined in the MCP required under the *Mining Act 1978* (WA). See Appendix A.19.
- Waste disposal aspect – details relating to the cells and residual infrastructure needed to rehabilitate the Facility post closure of the cells, is set out in the WFDCP. See Appendix A.18.

The implementation of two closure and decommissioning plans also accounts for the differing timeline for closure and decommissioning of both aspects. The MCP would be implemented during the operational phase of the Facility (Year 0 to 25). Closure and decommissioning activities would extend further until the mining tenement is relinquished (currently expected to be Year 37). Once the mining tenement is relinquished, the MCP would no longer apply or be implemented at Sandy Ridge.

The WFDCP would be implemented during the operational phase (Years 0 to 25), during the post closure management period (Years 26 to 45) and for the agreed ICP.

Decommissioning of infrastructure would occur in phases, depending on if it is used for mining/processing of ore, or for the waste facility. Decommissioning schedules are provided in both the MCP and the WFDCP. The general closure stages are:

1. Collection of baseline data.
2. Research investigation and trials.
3. Materials handling and utilisation
4. Identification of potential contamination.
5. Progressive rehabilitation.

The applicable domains, the purpose and key activities of each strategy, and a description of the strategy to be implemented is described in A.19

Both plans are considered 'living' documents, and would be reviewed and revised every three years. They also include requirements to conduct consultation with stakeholders to continually discuss closure issues and management.

The closure objectives, indicative completion criteria and key measurement tools outlined in the MCP and WFDCP are presented below.

Mine Closure Plan

The closure objectives, indicative completion criteria and the key measurement tools outlined in the MCP for the Proposal are presented in Table 10-17. Further detail is provided in Appendix A.19.

Table 10-17 Closure objectives, indicative completion criteria and key measurement tools (Mine Closure Plan)

Closure objective	Indicative completion criteria	Measurement tools
Each excavated pit is structurally stable.	At closure, the pit walls do not collapse inwards.	Geotechnical assessment.
Each excavated pit is free of ponded water (i.e. not a pit lake).	At closure the mine void does not pose a safety hazard, that persons or vehicles could accidently fall into. The mine void would not contain water of sufficient volume that could create a potential drowning hazard.	Visual inspection. Safety bunding around all open pits.
Vegetation in rehabilitated areas is comparable as reasonably practicable to the analogue site.	At the completion of the 10 year rehabilitation monitoring period vegetation composition is comparable to the species diversity/richness and structure of the analogue site. All plants used in rehabilitation to be of local provenance. No declared pests to be introduced into the area.	Revegetation monitoring.
Mining related infrastructure (except for that infrastructure to be closed under the WFDCP) removed from site during the Decommissioning Phase.	At mine closure, no mining related infrastructure is left on the tenement.	Visual inspection.

Five domains have been developed for the purpose of mine closure planning:

1. Pits
2. Infrastructure area.
3. Accommodation camp.
4. Class II Putrescible Landfill.
5. Access roads

The water pipeline and associated infrastructure, the access roads into the mining lease, underground storage area and the cells would not be closed under the MCP; rather they would be closed under the WFDCP.

To estimate a timeline for closure, the proponent has assumed the following:

- A start date of 1 January 2018.
- That 25 mine pits would be created.
- That 10 years of vegetation monitoring of all domains would occur.
- Completion criteria would be met at year 37 of the Proposal. Based on these assumptions the timeline is shown in Table 10-18.

Table 10-18 Closure timeline

Year of the Proposal	Year 1 – 25	Year 26	Year 36	Year 37
Current estimated year	**2018 – 2042**	**2043**	**2052**	**2053**
Pits created, ore excavated				
Deep ripping/establishment of vegetation				
Vegetation monitoring				
Completion criteria met				
Mining tenement relinquished				

Vegetation monitoring during closure

The methodology appropriate for monitoring vegetation from year 26 to 36 would be based on the considered industry practice at the time. Currently the methodologies used by the industry include:

- **Point / Line intercept** — Uses a large number of observations to estimate cover values with high precision.
- **Quadrat monitoring** – Square or rectangle areas in the vegetation are examined and information regarding cover, frequency and diversity are collected.
- **Landscape Function Analysis** — measures the patchiness and quality of patch zones along a transect.

- **Plotless– vegetation monitoring** — the Point Centered Quarter method estimates density. A set of points (usually positioned along a transect to traverse the area) is initially selected. The area around each point is divided into four 90° quadrants, and the plant closest to the point in each quadrant is identified. The distance between the central point and selected plant in each quadrant is measured, and then averaged across the four to represent the distance at each sample point. At the conclusion of data collection, the average distance for all sample points is calculated (University of Arizona, 2016).
- **Photo–point monitoring** – photos are taken at fixed locations every monitoring event to visually see the change in vegetation.
- **Remote sensing** – a drone or similar may be used to look at the rehabilitation from a 'birds eye view'. GIS data can be collected and compared between monitoring events to see the change in vegetation cover.
- **Relevés method** – a list of plants in a delimited plot of vegetation, with information on species cover and a substrate and other abiotic features of the plot (Minnesota Department of Natural Resources, 2013).
- **Diameter at breast (DBH) height** – used as a measure of tree maturity, involves measuring the breast and height of a tree.

The method chosen would be part of an integrated approach designed for the specific climate of the site. The method or combination of methods would be repeatable (and auditable) and supported by studies and scientific literature. The methodology would also be discussed with the regulator prior to implementation.

An analogue site is an unmined feature against which a mined feature may be compared (DITR, 2006). Two analogue sites, one in Deep Yellow Sand and one in Red Sandy Duplex soil types would be setup and monitored, as per the same methodology as the rehabilitation sites. The purpose of the analogue sites would be to act as a control site, and used for comparison of monitored parameters.

Monitoring of all revegetated areas would be conducted on an annual basis for the first three to five years to determine initial establishment, then on a reduced frequency until completion criteria are achieved. Ideally, monitoring should be conducted at the same time each year following rains.

Results would be graphed against historical monitoring results. Graphs and raw data would be included in Annual Environmental Reports to the DMP. An assessment of the results of the monitoring in relation to achieving the completion criteria would be discussed in Annual Environmental Reports for each revegetated area.

Targeted remediation of poor–performing rehabilitation areas may be necessary. The proponent would consult a botanist to determine the appropriate remedial strategy for rehabilitation should the results of the monitoring not be trending towards the completion criteria. Remedial strategies may include; amendments to the soil, more seed broadcasting, weed management and feral animal controls.

Soil monitoring during closure

The *Mine rehabilitation* handbook (DTIR, 2006) confirms that a "combined use of a front-end loader, truck and bulldozer for the removal, transport, and spreading of topsoil is the best combination to reduce soil compaction.

Soils would be monitored for their physical and chemical condition to ensure any revegetation and/or rehabilitation programs undertaken are successful. Monitoring should occur at a minimum of every 12 months and should record:

- Surface condition and erosion.
- Nutrient status, pH and EC.
- Seed germination rates.

Waste Facility Decommissioning and Closure Plan

The closure objectives, indicative completion criteria and the key measurement tools outlined in the WFDCP for the Proposal are presented in Table 10-19. Further detail is provided in Appendix A.18.

Table 10-19 Closure objectives, indicative completion criteria and key measurement tools

Closure objective	Indicative completion criteria	Measurement tools
Structurally stable, non–eroding disposal cells.	No subsidence of pits over the subsidence monitoring period.	Subsidence monitoring.
No emissions or discharges from the cells following capping.	No significant erosion of the cell caps. No radiation (gamma and radon) emissions greater than the acceptable public health levels. No adverse effects on groundwater.	Erosion, radiation, and groundwater monitoring.
Establish vegetation on the cell caps.	At the completion of revegetation monitoring period vegetation composition is comparable to the species diversity/richness and structure of the analogue site. All plants used in rehabilitation to be of local provenance. No declared pests[2] to be introduced into the area.	Revegetation monitoring.

10.9.5 Predicted environmental outcome

The application of an MCP on a mining tenement is standard practice under the *Mining Act 1978*. Therefore, the kaolin mining aspect of the Proposal, with agreed closure objectives and completion criteria for rehabilitation, is fairly straightforward for this Proposal.

With the implementation of the MCP, the EPA's objective to ensure that premises are decommissioned and rehabilitated in an ecologically sustainable manner would be achieved. Three-yearly revisions of the MCP would be undertaken to ensure that rehabilitation and decommissioning is conducted in an ecologically sustainable manner at closure and that improvements in restoration and rehabilitation techniques are accommodated.

Given the closure of a Class V Waste Facility is a pioneer activity in WA (the IWDF Ministerial Statements does not include a requirement for a closure plan), the expectations for closure and decommissioning come from national guidance (ARPANSA, 2010 and NHMRC, 1992) and a review of publicly available international facilities' decommissioning and closure plans (LLW Repository Ltd, 2014 and ENRESA, 2007).

Given the three-yearly revision of the WFDCP, the discussions that would be held with stakeholders and the commitment to continual improvement and adherence to international best practice for closure of similar facilities, the EPA's objective would be achieved.