APPENDIX L  MINERAL CONCENTRATE AND PROCESS WASTE MATERIALS ASSESSMENT
ATLAS-CAMPASPE MINERAL SANDS PROJECT

MINERAL CONCENTRATE AND PROCESS WASTE MATERIALS ASSESSMENT

Radiation Advice & Solutions

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1 Introduction

1.1 Background

The Atlas-Campaspe Mineral Sands Project (the Project) includes the development of a mineral sands mining operation (herein referred to as the Atlas-Campaspe Mine), together with the construction and operation of a rail loadout facility located near the township of Ivanhoe (herein referred to as the Ivanhoe Rail Facility). Cristal Mining Australia Limited (Cristal Mining) is the proponent of the Project.

The proposed Atlas-Campaspe Mine is located approximately 80 kilometres (km) north of Balranald, New South Wales (NSW) and 270 km south-east of Broken Hill, NSW. The proposed Ivanhoe Rail Facility is located approximately 135 km north-east of the Atlas-Campaspe Mine.

Product (mineral concentrate) generated as a result of operations at the proposed Atlas-Campaspe Mine would be trucked to the Ivanhoe Rail Facility for transfer to train wagons, which would then be railed to the existing Broken Hill Mineral Separation Plant (the MSP).

The Project would integrate with currently existing/approved Cristal Mining operations in western NSW, including (Figure 1):

- **MSP** – located approximately 270 km north-west of the proposed Atlas-Campaspe Mine;
- **Snapper Mine** – located approximately 105 km to the west of the proposed Atlas-Campaspe Mine; and
- **Ginkgo Mine** – located approximately 100 km to the west of the proposed Atlas-Campaspe Mine.

1.2 Purpose of this Report

An Environmental Impact Statement (EIS) has been prepared to accompany a Development Application made for the Project, in accordance with Division 4.1 of Part 4 of the NSW Environmental Planning and Assessment Act, 1979. This mineral concentrate and process waste assessment has been prepared to form part of this EIS.

The Project like all other mineral sands operations, including Cristal Mining’s existing/approved Gingko and Snapper Mines, would include handling materials which contain low levels of radioactive materials, and thus it is incumbent on Cristal Mining to assess the potential radiation impacts associated with these materials containing naturally occurring radionuclides.
This report characterizes and classifies (under relevant regulations and guidelines) the various material streams, being:

- **Ore** mined at the Atlas-Campaspe Mine.
- **Heavy Mineral Concentrate (HMC)** produced from the primary gravity concentration unit at the Atlas-Campaspe Mine.
- **Mineral concentrates** produced from the HMC treatment facility at the Atlas-Campaspe Mine.
- **MSP process waste** produced at the MSP from the processing of Project mineral concentrates that would be returned to the Atlas-Campaspe Mine for disposal.
- **Blended process waste** (combined sand residues, coarse rejects and MSP process waste) that would be placed in the active mining area (behind the advancing ore extraction area) at the Atlas-Campaspe Mine.

This report assesses the potential occupational and environmental impacts associated with the handling, storage, transport and disposal of the abovementioned materials.
2 Background to Mineral Sands, Radiation and Radiation Management

2.1 Mineral Sands

Mineral sands comprise an assemblage of minerals generally including zircon, rutile, ilmenite, leucoxene, and monazite in varying proportions and concentrations. Zircon is used in ceramic glazes and as the prime source of zirconium; rutile and ilmenite (and leucoxene) are the sources for titanium, used in autoclaves and other high temperature, acid-resistant vessels; and monazite is a potential source of rare earths, which have a variety of ‘hi-tech’ uses including dopants for high strength magnets, semiconductor, flat-screen, and solid state lasers, etc. Monazite is not presently commercially viable as a rare earths source, and is thus generally discarded as waste.

Mineral sand deposits are invariably strand-lines, being fossil beach deposits, resulting from deposition of heavy mineral grains and their repeated reworking and concentration by wave action, with subsequent immobilization following marine regression (i.e. sea level retreat).

Being the subject of repeated seawater action, it follows that all mineral sands are extremely insoluble in saline water (otherwise they would not have survived), and in fact they are leachable only under the most extreme chemical and/or thermal conditions. This means that mineral sands are inherently not a risk to groundwater by leaching.

All mineral sands contain some levels of Naturally Occurring Radioactive Materials because of minor amounts of uranium and thorium bound within their crystalline structure. The main mineral carrier of this radioactive content is monazite (rare earths and thorium phosphate), and zircon and leucoxene sometimes also have lower levels of uranium and thorium.

Monazite generally contains about 5 percent (%) thorium and about 0.3% uranium by weight. In mineral sands separation circuits, monazite concentrates in the MSP process waste streams along with other minerals that have similar specific gravities, magnetic and conductivity properties.

2.2 Radiation Theory

Uranium and thorium and their decay products (‘daughters’) are naturally occurring radioactive elements, meaning that atoms of these elements emit alpha (α), beta (β), or gamma (γ) radiation when they decay or transmute from one element to the next in the decay chain (see Tables 1 and 2).
### Table 1
Thorium-232 Decay Chain

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Radiation</th>
<th>Energy (MeV)</th>
<th>Half-life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thorium 232</td>
<td>α</td>
<td>4.0</td>
<td>14 billion years</td>
</tr>
<tr>
<td>Radium 228</td>
<td>β</td>
<td>0.06</td>
<td>5.7 years</td>
</tr>
<tr>
<td>Actininium 228</td>
<td>β</td>
<td>1.2, 1.7, 2.1</td>
<td>6.1 hours</td>
</tr>
<tr>
<td></td>
<td>γ</td>
<td>0.91, 0.96</td>
<td></td>
</tr>
<tr>
<td>Thorium 228</td>
<td>α</td>
<td>5.4</td>
<td>1.9 years</td>
</tr>
<tr>
<td></td>
<td>γ</td>
<td>0.08, 0.21 (weak)</td>
<td></td>
</tr>
<tr>
<td>Radium 224</td>
<td>α</td>
<td>5.7</td>
<td>3.6 days</td>
</tr>
<tr>
<td></td>
<td>γ</td>
<td>0.24 (weak)</td>
<td></td>
</tr>
<tr>
<td>Radon 220 (Thoron)</td>
<td>α</td>
<td>6.3</td>
<td>55 seconds</td>
</tr>
<tr>
<td>Polonium 216</td>
<td>α</td>
<td>6.8</td>
<td>0.15 seconds</td>
</tr>
<tr>
<td>Lead 212</td>
<td>β</td>
<td>0.35, 0.59</td>
<td>10.6 hours</td>
</tr>
<tr>
<td></td>
<td>γ</td>
<td>0.24, 0.3</td>
<td></td>
</tr>
<tr>
<td>Bismuth 212</td>
<td>β (64%)</td>
<td>2.3</td>
<td>61 minutes</td>
</tr>
<tr>
<td></td>
<td>α (36%)</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>γ (weak)</td>
<td>0.73</td>
<td></td>
</tr>
<tr>
<td>Polonium 212 (64%)</td>
<td>α</td>
<td>8.8</td>
<td>300 nanoseconds</td>
</tr>
<tr>
<td>Thallium 208 (36%)</td>
<td>β</td>
<td>1.3, 1.5, 1.8</td>
<td>3.1 minutes</td>
</tr>
<tr>
<td></td>
<td>γ</td>
<td>2.6, 0.51, 0.58, 0.86</td>
<td></td>
</tr>
<tr>
<td>Lead 208</td>
<td>nil, stable</td>
<td></td>
<td>infinite</td>
</tr>
</tbody>
</table>

MeV = million electron volt.

### Table 2
Uranium-238 Decay Chain

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Radiation</th>
<th>Energy (MeV)</th>
<th>Half-life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uranium 238</td>
<td>α</td>
<td>4.2</td>
<td>4.5 billion years</td>
</tr>
<tr>
<td>Thorium 234</td>
<td>β</td>
<td>0.2</td>
<td>24 days</td>
</tr>
<tr>
<td></td>
<td>γ</td>
<td>0.06, 0.09 (weak)</td>
<td></td>
</tr>
<tr>
<td>Protactinium 234</td>
<td>β</td>
<td>2.3</td>
<td>1.2 minutes</td>
</tr>
<tr>
<td>Uranium 234</td>
<td>α</td>
<td>4.7</td>
<td>250,000 years</td>
</tr>
<tr>
<td>Thorium 230</td>
<td>α</td>
<td>4.7</td>
<td>80,000 years</td>
</tr>
<tr>
<td>Radium 226</td>
<td>α</td>
<td>4.8</td>
<td>1,600 years</td>
</tr>
<tr>
<td></td>
<td>γ</td>
<td>0.186 (weak)</td>
<td></td>
</tr>
<tr>
<td>Radon 222 (gas)</td>
<td>α</td>
<td>5.5</td>
<td>3.8 days</td>
</tr>
<tr>
<td>Polonium 218</td>
<td>α</td>
<td>6.0</td>
<td>3 minutes</td>
</tr>
<tr>
<td>Lead 214</td>
<td>β</td>
<td>0.7</td>
<td>27 minutes</td>
</tr>
<tr>
<td></td>
<td>γ</td>
<td>0.3, 0.35</td>
<td></td>
</tr>
<tr>
<td>Bismuth 214</td>
<td>β</td>
<td>1.0, 1.5, 3.3</td>
<td>20 minutes</td>
</tr>
<tr>
<td></td>
<td>γ</td>
<td>0.6, 1.1, 1.8</td>
<td></td>
</tr>
<tr>
<td>Polonium 214</td>
<td>α</td>
<td>7.7</td>
<td>160 microseconds</td>
</tr>
<tr>
<td>Lead 210</td>
<td>β</td>
<td>0.016</td>
<td>22 years</td>
</tr>
<tr>
<td></td>
<td>γ</td>
<td>0.047 (weak)</td>
<td></td>
</tr>
<tr>
<td>Bismuth 210</td>
<td>β</td>
<td>1.16</td>
<td>5 days</td>
</tr>
<tr>
<td>Polonium 210</td>
<td>α</td>
<td>5.3</td>
<td>140 days</td>
</tr>
<tr>
<td>Lead 206</td>
<td>nil, stable</td>
<td></td>
<td>infinite</td>
</tr>
</tbody>
</table>
**Alpha** (α) radiation comprises particles (actually helium nuclei) emitted with very high energy from the nucleus of a decaying atom. Alpha particles have a very short range (in air, about 5 centimetres; in liquids or solids, about 50 micrometres). Alpha radiation can therefore be easily shielded.

**Beta** (β) radiation comprises particles (actually electrons) emitted at just under the speed of light from the nucleus of a decay atom. Beta particles have a range in air depending on their initial energy of one to several metres (m), and in water or solids, of a fraction to a few millimetres (mm). Beta radiation can therefore be easily shielded.

**Gamma** (γ) radiation is electromagnetic radiation (like light), and is essentially identical to x-rays, except that x-rays are (generally) produced by artificial means and gamma rays are emitted from the nucleus of atoms. Gamma rays, like x-rays, are penetrating, and have a range which is limited only by inverse square law effects and attenuation by absorption and scattering.

**Activity** of a sample of radioactive material describes the number of decay transitions per second in that sample, and is expressed in Becquerels. One Becquerel is equal to one decay event per second, in the sample. Activity concentration, or specific activity, equals the number of Becquerels per gram (Bq/g) in the sample. Specific activity has units of Bq/g.

As examples, the specific activity of the uranium-238 in pure uranium metal is 12,500 Bq/g, and the specific activity of the thorium-232 in pure thorium metal is 4,000 Bq/g. Garden soil (with world-average uranium content of 2 parts per million [ppm] and thorium content of 10 ppm) has a specific activity of its uranium-238 content of 0.025 Bq/g, and specific activity of its thorium-232 content of 0.04 Bq/g.

When we talk (as above) about the activity of the uranium-238 or thorium-232 in a mineral sample, we are referring to the ‘head of chain’ activity. Noting however, the other elements in the decay chain are also radioactive, and unless chemical separation has been ongoing in the original orebody and are all of the same activity as the parent; then the ‘total decay chain’ or ‘all nuclides’ activity will be, from the uranium chain, 14 times the uranium-238 head of chain activity, and from the thorium chain, 10 times the thorium-232 head of chain activity. It is important to know which activity is being discussed, because in some contexts (e.g. NSW Radiation Control Act, 1990 [RC Act] and NSW Radiation Control Regulation, 2003 [RC Regulation]) the ‘all nuclides’ activity is relevant, but in other contexts (e.g. Code of Practice for the Safe Transport of Radioactive Material [the Transport Code] [Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), 2008]) the head of chain activity is relevant.

**Dose** refers to when radiation impinges on a solid object and it delivers energy to it. The energy deposited to a kilogram (kg) of matter is described as the **Absorbed Dose** (D) and the unit (joules of energy per kg) is a Gray. In environmental measurements, gamma radiation dose rate is sometimes reported in micrograys per hour.
Effective Dose (E) is the absorbed dose, corrected for biological damage effectiveness of different radiation types, weighted for the cancer-induction radiosensitivity of different human organs and tissues, and is described in Sieverts. Effective dose is the summation, over all organs of the body, of the absorbed dose delivered to each organ of the exposed person, weighted to account for radiation type and for tissue cancer induction sensitivity (refer to page 68 of International Commission on Radiological Protection [ICRP], 2007).

Doses to workers and to members of the public can in principle arise from being in a gamma radiation field, due to proximity to large masses of gamma emitting material for an extended period of time (an external radiation hazard); and/or from inhaling radioactive dusts which contain alpha emitting radionuclides (an internal radiation hazard). It is thus appropriate to monitor and control both these ‘dose delivery pathways’.

Control of the gamma dose delivery pathway is achieved by use of ‘Time, Distance, and Shielding’ to limit workers’ doses when working with gamma emitting materials. Monitoring is by means of workplace gamma instrumental surveys and by issue of personal dosimeters (Thermoluminescent Dosimeters [TLD] badges), which are normally worn for a three month period then sent to a service supplier for readout and assessment against relevant criteria (Section 2.3).

Control of the alpha-emitting radionuclide inhalation pathway is achieved by designing for enclosure of all dusty equipment (such as electrostatic separators and cross-belt magnet separators), and by wetting down or vacuuming to control workplace dusts. In some circumstances, dusty work may require use of personal protection (e.g. P1 or P2 dust masks). Monitoring is by means of personal and area workplace dust monitoring, with alpha-counting performed to assess against the Derived Air Concentration as set by the Code of Practice and Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing (the Mining and Processing Code) (ARPANSA, 2005).

2.3 Radiation Management

Radiation Protection Framework

Radiation management in NSW is guided by the requirements of the following:

- RC Act and RC Regulation; and
- National Standard for Limiting Occupational Exposure to Ionizing Radiation (ARPANSA, 2002).

These documents are based on the ICRP’s (1990 and 2007) 1990 Recommendations of the International Commission on Radiological Protection and 2007 Recommendations of the International Commission on Radiological Protection.

The ICRP provides a framework for radiation regulation and management, applicable across all industries and operations, focusing on licensing of activities using or handling ‘controllable’ sources of radiation, and requiring the operational entity and the regulatory agency comply with the ‘system of dose limitation’. This requires that all controllable doses be subject to (i) justification, (ii) optimization, and (iii) limitation.
Justification requires that any imposed doses be assessed as being of net benefit. A benefit cost analysis for the Project has been undertaken by Gillespie Economics (2012) (Appendix I of the EIS). Optimization means that doses must be kept to the minimum consistent with achievement of the required outcomes i.e. doses must be kept ‘As Low As Reasonably Achievable’ (the ALARA concept). Limitation means that the doses to workers and to members of the public, from the licensed operation (e.g. the Project), must be kept within limits. The limits set by the ICRP, the ARPANSA, and NSW legislation, are 20 milliSieverts per year (mSv/yr) for workers, and 1 mSv/yr for members of the public.

In both cases the doses to be counted exclude natural background radiation (which is ubiquitous, and variable from place to place, and averages worldwide about 2.5 mSv/yr, but can be above 10 mSv/yr in high background regions). Also excluded from that which must be counted against the limit, is any medical dose, this being (a) separately justified by personal medical need, and (b) outside the control of the regulated entity.

**Radiation Management for Mining and Processing Mineral Sands**

The Mining and Processing Code and the Transport Code are relevant to the mining, processing and transport of ores, products or wastes containing radioactive material. The Mining and Processing Code requires specific management measures, focusing on the following areas:

i. design, monitoring, and management to control workers’ radiation doses;

ii. design, monitoring, and management to control any potential impact on the environment, including prevention of unintended releases and proper control over disposal of wastes containing radionuclides; and

iii. need to ensure any transport of materials containing radionuclides will be in conformity with the regulations for safe transport of radioactive materials.

The main requirement of the Mining and Processing Code is that a Radiation Management Plan and a Radioactive Waste Management Plan be prepared and implemented.

3 Proposed Project

This section provides an overview of the Project and a summary of the management of materials containing radioactive elements during the mining and processing at the Atlas-Campaspe Mine, transport to and from the MSP, and disposal at the Atlas-Campaspe Mine.

3.1 Project Overview

The Project would include the development of the Atlas-Campaspe Mine (Figure 2), together with the construction and operation of the Ivanhoe Rail Facility (Figure 3). The Project would integrate with currently existing/approved Cristal Mining operations, the MSP, Ginkgo Mine and the Snapper Mine (Figure 1).

Conventional (non-dredge) mining methods would be utilised at the Atlas-Campaspe Mine, both for overburden removal and for ore extraction. Product (mineral concentrates) generated as a result of operations at the proposed Atlas-Campaspe Mine would be trucked to the Ivanhoe Rail Facility for transfer to train wagons, which would then be railed to the MSP.

At the MSP, the mineral concentrates from the Atlas-Campaspe Mine would be separated and treated to produce valuable minerals. Process wastes generated as a result of processing mineral concentrates at the MSP (MSP process waste) would continue to be backloaded to the Snapper and Ginkgo Mines until the Development Consents at the existing operations expire (approximately Year 12 of Project).

At that time, the MSP process waste generated as a result of processing mineral concentrates from the Atlas-Campaspe Mine would be transported via the Orange – Broken Hill Railway to the Ivanhoe Rail Facility for subsequent road transport to the Atlas-Campaspe Mine for unloading, stockpiling and placement behind the advancing ore extraction areas.

The proposed life of the Project is approximately 20 years, commencing approximately 1 July 2013 or upon the grant of all required approvals.

A detailed description of the Project is provided in Section 2 in the Main Report of the EIS.

3.2 Management of Radioactive Materials

This section provides a summary of the proposed management of materials containing radioactive elements during the mining and processing at the Atlas-Campaspe Mine, transport to and from the MSP, and disposal at the Atlas-Campaspe Mine. The proposed management is based on the measures successfully implemented at Cristal Mining’s existing/approved operations.
**Mining and Mineral Processing – Atlas-Campaspe Mine**

**Mining**

Mining would involve dozers and loaders placing mineral sands ore in a dry mining unit (DMU) located in the ore extraction area. At the DMU, the mineral sands ore would be slurried, screened and pumped to the primary gravity concentration unit for on-site processing (Figure 4). Approximately 109 million tonnes of mineral sands ore would be mined from the Atlas and Campaspe deposits during the life of the Project.

**Primary Gravity Concentration Unit**

The ore slurry would be pumped from the DMU in the active mining area to the primary gravity concentration unit (Figure 4). The ore slurry feed material would be approximately 45% solids and comprise unconsolidated sands with 2 to 3% very fine particle content (e.g. clays) and minor amounts of coarse reject material.

The ore would initially report to a surge bin so that a consistent feed rate and pulp density can be maintained to the subsequent concentration circuits. A screen above the surge bin would separate coarse reject material (greater than 3 mm) to a reject bin.

The ore slurry would then be pumped from the surge bin to gravity separation circuits within the primary gravity concentration unit to separate valuable minerals from sand residues (including clays). The gravity separation circuits would consist of a series of spiral separators.

The gravity separation circuits would produce HMC comprising approximately 94% valuable heavy minerals (principally ilmenite, leucoxene, rutile and zircon). The radioactive components of the ore would concentrate in the HMC. The HMC recovered by the primary gravity concentration unit would be pumped as a slurry to the HMC treatment facility for further processing (Figure 4).

Sand residues (including clays) separated by the gravity separation circuits would be deposited to the reject bin. Sand residues and coarse reject materials would be pumped directly from the primary gravity concentration unit to either the active mining area (behind the advancing ore extraction area) or in sand residue dams (Figure 4).

**HMC Treatment Facility**

Due to the saline nature of groundwater from the borefield used for the slurrying of ore from the Atlas and Campaspe deposits, HMC pumped from the primary gravity concentration unit would have a high salt content.

The residual salt in the HMC would inhibit the efficiency of the separation process in the wet high intensity magnetic separation (WHIMS) circuit which, in part, involves electrostatic separation. The HMC would therefore be washed with desalinated water prior to processing in the WHIMS. The salt washing facility would source desalinated water from the proposed on-site reverse osmosis (RO) plant. Following salt washing, the HMC would be pumped to the WHIMS circuit (Figure 4).
The WHIMS circuit is a preliminary treatment stage which separates the HMC into ilmenite-rich, leucoxene-rich and non-magnetic (containing rutile-rich and zircon-rich) mineral concentrates. The WHIMS circuit relies on magnetic separation and requires no chemical reagents. The WHIMS circuit consists of primary and secondary magnetic separators to separate the magnetic and non-magnetic mineral concentrates and product de-watering cyclones. The radioactive components of the HMC collect in all three mineral concentrates streams.

The mineral concentrates from the WHIMS circuit would be stockpiled in the mineral concentrate stockpile areas at the Atlas-Campaspe Mine by product stackers. Prior to loading and transport to the MSP, the mineral concentrate stockpiles would be dewatered to approximately 6% water content. Once dewatered, front end loaders would be used to load mineral concentrates from the stockpiles direct to haulage vehicles.

Haulage vehicles would be fitted with side tipping trays to minimise the potential for spillage during loading. Once loaded, the haulage vehicle load would be covered to minimise the potential loss of mineral concentrates during transport.

**Mineral Concentrate Transport**

**Road Transport**

Mineral concentrate would be hauled via road approximately 175 km from the Atlas-Campaspe Mine to the Ivanhoe Rail Facility (Figure 1). The mineral concentrate would be transported in road trains¹.

The proposed mineral concentrate transport route to the Ivanhoe Rail Facility is shown on Figure 1. The proposed mineral concentrate transport route would not pass through the township of Ivanhoe (Figure 3).

The maximum mineral concentrate transport rate would be approximately 450,000 tonnes per annum (tpa). Up to a maximum 24 haulage vehicle trips (i.e. 48 haulage vehicle movements) per day would be required, with approximately 19 haulage vehicle trips (i.e. 38 haulage vehicle movements) per day on average over the life of the Project. Road transport of mineral concentrate would be undertaken 24 hours per day, seven days per week.

**Rail Transport**

Mineral concentrates would be railed from the Ivanhoe Rail Facility to the MSP via the Orange – Broken Hill Railway.

The Project would require a maximum of three trains per week over the life of the Project. No more than one train load of mineral concentrate from the Atlas-Campaspe Mine would be railed to the MSP in any 24 hour period. Rail transport movements would be scheduled to occur at any time once loading is completed (i.e. 24 hours per day, seven days per week).

¹ Type 1 road train as defined by NSW Roads and Maritime Services, 2012.
**Ivanhoe Rail Facility**

Haulage vehicles would enter the Ivanhoe Rail Facility via the access road off the Balranald-Ivanhoe Road (Figure 3). A turn-around loop at the Ivanhoe Rail Facility would enable the haulage vehicles to turn-around, unload and exit using the same access road.

Mineral concentrate emptied from the haulage vehicles would be dumped directly onto mineral concentrate stockpiles within the hardstand area.

A front end loader would be used to reclaim mineral concentrate from the stockpiles at the Ivanhoe Rail Facility and load directly into containers on train wagons. A forklift would be used to remove and replace covers on the train wagons.

**Mineral Separation Plant**

At the MSP, mineral concentrates from the Project would be processed to produce mineral products (i.e. leucoxene, non-magnetic concentrate, rutile, zircon, unroasted and roasted ilmenite). The Atlas and Campaspe deposits contain very low levels of monazite which are insufficient to warrant its commercial recovery.

MSP process waste from the processing of Project mineral concentrates would be directed to a process sump where it would be wetted. The MSP process waste would then be temporarily stored in a concrete storage bay and wetted as required to minimise generation of wind blown material. Up to approximately 50,000 tpa of MSP process waste would be produced at the MSP from the processing of Project mineral concentrates.

The additional MSP process wastes produced by the Project would be combined with the existing/approved MSP process waste produced from the Ginkgo and Snapper Mines and then be transported to the Ginkgo and Snapper Mines in accordance with existing/approved operations up until cessation of those operations (approximately Year 12 of the Project).

Following the cessation of operations at the Snapper and Ginkgo Mines (i.e. Year 12 of the Project), MSP process waste would be transported to the Atlas-Campaspe Mine.

**MSP Process Waste Transport**

**Rail Transport**

Following the cessation of operations at the Snapper and Ginkgo Mines (i.e. Year 12 of the Project), MSP process waste in sealed containers would be railed from the MSP to the Ivanhoe Rail Facility for further transport via road to the Atlas-Campaspe Mine. No additional rail movements for the transport of MSP process waste would be required for the Project as it would be transported in trains returning to the Ivanhoe Rail Facility to collect mineral concentrates.

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1 Upgrades and extensions to the existing/approved MSP to enable receipt and processing of mineral concentrates from the Project would be subject to separate assessment and approval.
Ivanhoe Rail Facility

From approximately Year 12 of the Project, MSP process waste in sealed containers would be unloaded from trains at the Ivanhoe Rail Facility, and temporarily held in a designated area prior to loading onto haulage vehicles for the return trip to Atlas-Campaspe Mine.

Road Transport

Following the cessation of operations at the Snapper and Ginkgo Mines (i.e. Year 12 of the Project), MSP process waste in sealed containers would be unloaded from trains at the Ivanhoe Rail Facility, and temporarily held in a designated area prior to loading onto haulage vehicles for the return trip to Atlas-Campaspe Mine. No additional haulage movements for the MSP process waste, in addition to the mineral concentrate haulage vehicle movements, would be required for the Project.

MSP Process Waste Management – Atlas-Campaspe Mine

From approximately Year 12 of the Project, MSP process waste would be transported to the Atlas-Campaspe Mine for subsequent unloading, stockpiling, blending and placement behind the advancing ore extraction areas. The MSP process waste would be managed as per the existing management measures implemented at the Ginkgo and Snapper Mines.

At the Atlas-Campaspe Mine, MSP process waste would be removed from the designated stockpile and placed in a hopper (Monazite Return Tailings), mixed with brine from the RO plant, then transported to the primary gravity concentration unit via a slurry pipe, where it would be combined in the reject bin with sand residues and coarse rejects. The combined sand residues, coarse rejects and MSP process waste slurry would then be pumped and deposited in the process waste emplacement cells. Blended MSP process waste would be:

- placed above the groundwater table;
- placed no closer than 10 m from the natural ground surface; and
- covered under a minimum of 10 m of overburden and soil, such that the radiation level at the surface of the rehabilitated process waste emplacement cells would be equivalent to the natural background radiation level.

No MSP process wastes would be placed in off-path sand residue dams at the Atlas-Campaspe Mine.
4 Mineral Concentrate and Process Waste Characterisation and Classification

4.1 Characterisation

A summary of the uranium and thorium concentrations and the specific activities (head of chain and all nuclides) of the materials containing radioactive elements during the mining and processing at the Atlas-Campaspe Mine, transport to and from the MSP, and disposal at the Atlas-Campaspe Mine is provided in Table 3.

Table 3
Ore, HMC, Mineral Concentrates, MSP Process Waste and Blended Process Waste Characterisation

<table>
<thead>
<tr>
<th>Material</th>
<th>Uranium Concentration (ppm)</th>
<th>Thorium Concentration (ppm)</th>
<th>Specific Activity (All Nuclides) (Bq/g)</th>
<th>Specific Activity (Head of Chain) (Bq/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlas Deposit</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ore</td>
<td>5</td>
<td>25</td>
<td>1.87</td>
<td>0.16</td>
</tr>
<tr>
<td>HMC</td>
<td>61</td>
<td>337</td>
<td>24.16</td>
<td>2.11</td>
</tr>
<tr>
<td>Mineral Concentrate – Ilmenite</td>
<td>22</td>
<td>270</td>
<td>14.65</td>
<td>1.36</td>
</tr>
<tr>
<td>Mineral Concentrate – Leucoxene</td>
<td>51</td>
<td>897</td>
<td>44.81</td>
<td>4.23</td>
</tr>
<tr>
<td>Mineral Concentrate – Non-magnetics</td>
<td>102</td>
<td>179</td>
<td>25.01</td>
<td>1.99</td>
</tr>
<tr>
<td>MSP Process Waste</td>
<td>271</td>
<td>4,197</td>
<td>215.31</td>
<td>20.18</td>
</tr>
<tr>
<td>Blended Process Waste</td>
<td>3</td>
<td>48</td>
<td>2.45</td>
<td>0.23</td>
</tr>
<tr>
<td>Campaspe Deposit</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ore</td>
<td>4</td>
<td>22</td>
<td>1.58</td>
<td>0.14</td>
</tr>
<tr>
<td>HMC</td>
<td>94</td>
<td>647</td>
<td>42.33</td>
<td>3.76</td>
</tr>
<tr>
<td>Mineral Concentrate – Ilmenite</td>
<td>57</td>
<td>577</td>
<td>33.06</td>
<td>3.02</td>
</tr>
<tr>
<td>Mineral Concentrate – Leucoxene</td>
<td>98</td>
<td>1,590</td>
<td>80.75</td>
<td>7.58</td>
</tr>
<tr>
<td>Mineral Concentrate – Non-magnetics</td>
<td>152</td>
<td>358</td>
<td>40.92</td>
<td>3.33</td>
</tr>
<tr>
<td>MSP Process Waste</td>
<td>471</td>
<td>6,262</td>
<td>332.91</td>
<td>30.94</td>
</tr>
<tr>
<td>Blended Process Waste</td>
<td>3</td>
<td>39</td>
<td>2.09</td>
<td>0.19</td>
</tr>
</tbody>
</table>

1 Refer to Section 1.2 for descriptions of materials.
2 Cristal Mining (pers. comm., 15 October 2012).
3 Bemax Resources Limited (2012a).
4 Cristal Mining (pers. comm., 16 October 2012).
5 Bemax Resources Limited (2012b).
6 Calculated assuming 80 ppm uranium = 1 Bq U$^{238}$/g and 250 ppm thorium = 1 Bq Th$^{232}$/g and secular equilibrium (rounding to 2 decimal places).

Metallurgical analysis has been conducted on ore from both the Atlas and Campaspe deposits and pilot plant testwork product and process waste streams. The results of the metallurgical analysis and proposed production schedule have been used to estimate the thorium and uranium concentrations of the blended process waste (Table 3).
4.2 Classification

This section classifies the ore, HMC, mineral concentrates, MSP process waste and blended process waste in accordance with the RC Act and classifies the MSP process waste and blended process waste in accordance with the NSW Protection of the Environment Operations Act, 1997 (PoEO Act).

Radiation Control Act, 1990

The RC Act provides for the regulation and control of radioactive substances, radioactive sources and radiation apparatus in NSW. The RC Act prescribes material as a “radioactive ore” or a “radioactive substance” and details licensing and registration requirements.

Radioactive Ore

Section 4(1) of the RC Act defines a radioactive ore as follows (our underlining):

*radioactive ore means an ore or mineral containing more than the concentration of uranium or thorium prescribed for the purposes of this definition.*

Clause 4 of the RC Regulation defines the prescribed concentrations of uranium and thorium referred to above as:

4 Definition of “radioactive ore”: section 4

(1) For the purposes of the definition of *radioactive ore* in section 4(1) of the Act, the prescribed concentrations of uranium and thorium are:

(a) in the case of an ore that contains uranium but not thorium, 0.02 per cent by weight of uranium, or

(b) in the case of an ore that contains thorium but not uranium, 0.05 per cent by weight of thorium, or

(c) in the case of an ore that contains both uranium and thorium, a percentage by weight of uranium and thorium such that the expression:

\[
\frac{U}{0.02} + \frac{Th}{0.05}
\]

is equal to, or greater than, one.

(2) In the expression referred to in subclause (1)(c):

*U* represents the percentage by weight of uranium.

*Th* represents the percentage by weight of thorium.

As the ore at the Project would include both uranium and thorium, clause 4(1)(c) of the RC Regulation is the relevant method to determine if the ore would be a “radioactive ore”.
As the ore from the Atlas deposit has a higher specific activity than the Campaspe deposit (Table 3), the Atlas deposit ore has been considered in this classification. The Atlas deposit ore has a uranium concentration of approximately 5 ppm and a thorium concentration of approximately 25 ppm. (It should be noted that these levels are within the range of natural soils, the worldwide average for which is quoted to be uranium – 2 ppm and thorium – 10 ppm.) These concentrations (uranium - 5 ppm and thorium – 25 ppm) translate via the above formula into $0.025 + 0.05 = 0.075$, which is less than 1 (the prescribed concentration) and thus the ore would not be a “radioactive ore” under the RC Act.

**Radioactive Substance**

Section 4(1) of the RC Act defines a “radioactive substance” as follows (our underlining):

> radioactive substance means any natural or artificial substance whether in solid or liquid form or in the form of a gas or vapour (including any article or compound whether it has or has not been subjected to any artificial treatment or process) which emits ionising radiation spontaneously with a specific activity greater than the prescribed amount and which consists of or contains more than the prescribed activity of any radioactive element whether natural or artificial.

Clause 5 of the RC Regulation defines the “prescribed amount” and “prescribed activity” referred to above as (our underlining):

**5 Definition of “radioactive substance”: section 4**

(1) For the purposes of the definition of radioactive substance in section 4 (1) of the Act:

(a) the prescribed amount is 100 becquerels per gram, and

(b) a substance has the prescribed activity if the expression:

$$\frac{A_1}{40} + \frac{A_2}{400} + \frac{A_3}{4000} + \frac{A_4}{40000}$$

is equal to, or greater than, one.

(2) In the expression referred to in subclause (1)(b):

- $A_1$ represents the total activity, in kilobecquerels, of the Group 1 radionuclides contained in the substance.
- $A_2$ represents the total activity, in kilobecquerels, of the Group 2 radionuclides contained in the substance.
- $A_3$ represents the total activity, in kilobecquerels, of the Group 3 radionuclides contained in the substance.
- $A_4$ represents the total activity, in kilobecquerels, of the Group 4 radionuclides contained in the substance.

The first step to determining if a material is a “radioactive substance” is to check its specific activity is below the prescribed amount (i.e. 100 Bq/g – see above). The specific activity of the ore, HMC, mineral concentrates, MSP process waste and blended process waste are provided in Table 3.
As the specific activities of the ore, HMC, mineral concentrates and blended process waste would be less than 100 Bq/g (Table 3), these materials would not be classified as a “radioactive substance” under the RC Act.

The MSP process waste does however have a specific activity greater than 100 Bq/g (Table 3) and therefore the prescribed activity for the MSP process waste must be calculated to determine the mass of MSP process required for it to be classified as a “radioactive substance”. The prescribed activity of a material is calculated as follows in accordance with clause 5(1)(b) of the RC Regulation (refer above).

The radioactive elements in the MSP process waste are categorised as Group 4 radionuclides (i.e. U nat and Th nat). The prescribed activity calculation therefore becomes:

\[
\text{Prescribed Activity} = \frac{0}{40} + \frac{0}{400} + \frac{0}{4000} + \frac{A4}{40000}
\]

To not be classified as a “radioactive substance”, the MSP process waste (i.e. A4) would have to have a total activity of less than 40,000 kiloBecquerels (kBq). As the MSP process waste head of chain specific activity is expected to be approximately 30.9 Bq/g (see Table 3), approximately 1.3 tonnes (t) of MSP process waste is required for the level of activity of 40,000 kBq to be exceeded.

As more than 1.3 t of MSP process waste would be stored and transported (e.g. rail and road transport) as part of the Project, the MSP process waste would be classified as a “radioactive substance” under the RC Act.

**Protection of the Environment Operations Act, 1997**

The PoEO Act provides for the classification and management of waste in NSW. Schedule 1 of the PoEO Act provides waste classification definitions, including:

**hazardous waste** means waste (other than special waste or liquid waste) that includes any of the following:

(a) anything that is classified as:

(i) a substance of Class 1, 2, 5 or 8 within the meaning of the Transport of Dangerous Goods Code, or

(ii) a substance to which Division 4.1, 4.2, 4.3 or 6.1 of the Transport of Dangerous Goods Code applies,

(b) containers, having previously contained:

(i) a substance of Class 1, 3, 4, 5 or 8 within the meaning of the Transport of Dangerous Goods Code, or

(ii) a substance to which Division 6.1 of the Transport of Dangerous Goods Code applies, from which residues have not been removed by washing or vacuuming,

(c) coal tar or coal tar pitch waste (being the tarry residue from the heating, processing or burning of coal or coke) comprising more than 1% (by weight) of coal tar or coal tar pitch waste,

(d) lead-acid or nickel-cadmium batteries (being waste generated or separately collected by activities carried out for business, commercial or community services purposes),
(e) lead paint waste arising otherwise than from residential premises or educational or child care institutions,

(f) anything that is classified as hazardous waste pursuant to an EPA Gazettal notice,

(g) anything that is hazardous waste within the meaning of the Waste Classification Guidelines,

(h) a mixture of anything referred to in paragraphs (a)–(g).

... restricted solid waste means any waste (other than special waste, hazardous waste or liquid waste) that includes any of the following:

(a) anything that is restricted solid waste within the meaning of the Waste Classification Guidelines,

... “Hazardous waste” definitions (b) (i.e. containers), (c) (i.e. coal tar), (d) (lead-acid or nickel-cadmium batteries) and (e) (i.e. lead paint waste) are not relevant to the process wastes at the Project. The other “hazardous waste” definitions and the “restricted solid waste” definitions may apply to the process wastes at the Project and are therefore discussed further below.

**Hazardous Waste Definition (a) – Transport of Dangerous Goods Classification**

The *Australian Code for the Transport of Dangerous Goods by Road and Rail* (National Transport Commission Australia, 2011) (the Transport of Dangerous Goods Code) defines the following relevant classes:

- Class 1 – Explosives.
- Class 2 – Gases.
- Class 5 – Oxidizing substances and organic peroxides.
- Class 8 – Corrosive substances.

The MSP process waste and blended process waste at the Project would not comprise Class 1, Class 2, Class 5 or Class 8 materials. The MSP process waste and blended process waste would therefore not be a “hazardous waste” under definition (a)(i).

In addition, the Transport of Dangerous Goods Code defines the following relevant divisions:

- Division 4.1 – Flammable solids, self-reactive substances and solid desensitized explosives.
- Division 4.2 – Substances liable to spontaneous combustion.
- Division 4.3 – Substances which in contact with water emit flammable gases.
- Division 6.1 – Toxic substances.

The MSP process waste and blended process waste at the Project would not comprise Division 4.1, Division 4.2, Division 4.3 or Division 6.1 materials. The Project MSP process waste and blended process waste would therefore not be a “hazardous waste” under definition (a)(ii).

Given the above, the Project MSP process waste and blended process waste would therefore not be a “hazardous waste” under definition (a).
**Hazardous Waste Definition (f) – NSW Government Gazette**

No additional waste types have been classified as “hazardous” in the NSW Government Gazette. “Hazardous waste” definition (f) has therefore not been considered further.

**Hazardous Waste Definition (g) – Waste Classification Guidelines**


**Step 1**

*The radioactivity of the waste must be assessed in accordance with the Radiation Control Act 1990 and the Radiation Control Regulation 2003.*

**Step 2**

*Liquid or non-liquid wastes with a specific activity greater than 100 becquerels per gram and consisting of, or containing more than, the prescribed activity of a radioactive element in Schedule 1 of the Radiation Control Regulation 2003, whether natural or artificial, must be classified as hazardous wastes.*

Step 2 of the Waste Classification Guidelines outlines the process for determining if a waste is a “hazardous waste”. If the specific activity of the waste is above 100 Bq/g it may be a “hazardous waste”. As the specific activity of the MSP process waste is greater than 100 Bq/g (Table 3), the prescribed activity for the MSP process waste must be calculated in accordance with Schedule 1 of the RC Regulation to determine if it is a “hazardous waste” (refer to Step 2 of the Waste Classification Guidelines above).

The radioactive elements in the MSP process waste would only include Group 4 radionuclides (i.e. U nat and Th nat). To not be classified as a “hazardous waste”, the MSP process waste would have to have a total activity of less than 40,000 kBq. As the MSP process waste specific activity is expected to be approximately 333 Bq/g (Table 3), approximately 120 kg of MSP process waste is required to attain a total activity of 40,000 kBq. As more than 120 kg of MSP process waste would be stored and transported (e.g. rail and road transport) as part of the Project, the MSP process waste would be classified as “hazardous waste” under the Waste Classification Guidelines.

The blended process waste would however, have a specific activity less than 100 Bq/g being less than 2.5 Bq/g (Table 3), and therefore would not be classified as “hazardous waste” and the classification process continues on to Steps 3 and 4 of the Waste Classification Guideline (our underlining):

**Step 3**

*For liquid or non-liquid wastes with a specific activity of 100 becquerels per gram or less and/or consisting of, or containing, the prescribed activity or less of a radioactive element in Schedule 1 of the Radiation Control Regulation 2003, whether natural or artificial, the total activity ratio and specific activity ratio must be calculated according to the mathematical expressions below:*
**Total activity ratio** is calculated using the expression:

\[
\text{Total activity ratio} = (A_1 \times 10^{-3}) + (A_2 \times 10^{-4}) + (A_3 \times 10^{-5}) + (A_4 \times 10^{-6})
\]

where \( A_1 \) to \( A_4 \) are the total activity of Group 1 to Group 4 radionuclides, as set out in Column 1 of Schedule 1 of the Radiation Control Regulation 2003.

[It has been assumed that units for \( A_1 \) to \( A_4 \) are kBq as per the RC Regulation in accordance with Step 1 of the Waste Classification Guidelines].

**Specific activity ratio** is calculated using the expression:

\[
\text{Specific activity ratio} = S_{A1} + (S_{A2} \times 10^{-1}) + (S_{A3} \times 10^{-2}) + (S_{A4} \times 10^{-3})
\]

where \( S_{A1} \) to \( S_{A4} \) are the specific activity (of the material) of Group 1 to Group 4 radionuclides, as set out in Column 1 of Schedule 1 of the Radiation Control Regulation 2003.

[It has been assumed that units for \( S_{A1} \) to \( S_{A4} \) are Bq/g and the specific activity is “all nuclides” activity as per the RC Regulation in accordance with Step 1 of the Waste Classification Guidelines].

... 

**Step 4**

Where the specific activity ratio or total activity ratio is greater than one, the waste must be classified as follows:

... 

Non-liquid wastes must be classified as restricted solid waste ... 

As the specific activity of the blended process waste would be below 100 Bq/g, the specific activity ratio and the total activity ratio may have to be determined. As the radioactive elements in the blended process waste would only include Group 4 radionuclides (i.e. U nat and Th nat), the specific activity ratio calculation becomes:

\[
\text{Specific Activity Ratio} = 0 + (0 \times 10^{-1}) + (0 \times 10^{-2}) + (2.5 \times 10^{-3}) = 0.0025
\]

As the specific activity ratio of the blended process waste is less than one, the total activity ratio for the blended process waste must be calculated to determine if it is a “restricted solid waste” (refer to Steps 3 and 4 of the Waste Classification Guidelines above). The total activity ratio calculation:

\[
\text{Total Activity Ratio} = (0 \times 10^{-3}) + (0 \times 10^{-4}) + (0 \times 10^{-5}) + (A_4 \times 10^{-6})
\]

To not be classified as a “restricted solid waste”, the blended process waste (i.e. \( A_4 \)) would have to have a total activity of greater than 1,000,000 kBq. As the blended process waste head of chain specific activity is expected to be 2.5 Bq/g (Table 3), approximately 400 t of blended process waste is required for the level of activity of 1,000,000 kBq to be exceeded.

As more than 400 t of blended process waste would be deposited at the Atlas-Campaspe Mine as part of the Project, the blended process waste must be classified as “restricted solid waste” (refer to Step 4 of the Waste Classification Guidelines above).

Given the above, the blended process waste would be “restricted solid waste” under definition (g).
It is noted that under the Waste Classification Guideline (Steps 3 and 4), a sufficient quantity of any material (irrespective of its specific activity) can be classified as “restricted solid waste” if it is present in an amount such that its total activity ratio exceeds one. For example, garden soil (Section 2.2) would be classified as “restricted solid waste” at a quantity of 1,300 t as its total activity ratio then exceeds one. This arises because the definition applies when specific activity ratio or total activity ratio exceeds one.

Summary of PoEO Act Classification

Given the blended process waste would be classified “restricted solid waste” under definition (g) (i.e. the Waste Classification Guidelines), the blended process waste would be classified as “restricted solid waste” under the PoEO Act.

In addition, the MSP process waste would be classified “hazardous waste” under definition (g) (i.e. the Waste Classification Guidelines), the MSP process waste would be classified as “hazardous waste” under the PoEO Act.

Classification Summary

A summary of the classification of the ore, mineral concentrates, MSP process waste and blended process waste under the RC Act and the PoEO Act is provided below.

Ore

• Not a “radioactive ore” or “radioactive substance” under the RC Act.

HMC

• Not a “radioactive substance” under the RC Act.

Mineral Concentrates

• Not a “radioactive substance” under the RC Act.

MSP Process Waste

• Is a “radioactive substance” under the RC Act.
• Is a “hazardous waste” under the PoEO Act.

Blended Process Waste

• Not a “radioactive substance” under the RC Act.
• Is a “restricted solid waste” under the PoEO Act.
5 Impact Assessment

Potential dose delivery pathways for employees and members of the public resulting from the Project would include:

- irradiation by gamma radiation;
- inhalation of dusts containing long lived alpha emitting radionuclides (LLAE);
- inhalation of the decay products of radon (Rn$^{222}$ and Rn$^{220}$); and
- ingestion of radionuclides.

These potential dose delivery pathways could occur during the following Project activities:

- handling and stockpiling of HMC, mineral concentrates, MSP process waste and blended process waste at the Atlas-Campaspe Mine;
- transporting (via road) mineral concentrates and MSP process waste between the Atlas-Campaspe Mine and the Ivanhoe Rail Facility;
- handling and stockpiling of mineral concentrates and MSP process waste at the Ivanhoe Rail Facility; and
- transporting (via rail) of mineral concentrates and MSP process waste between the Ivanhoe Rail Facility and the MSP.

A discussion of the potential impacts at each of these Project components is provided below.

5.1 Atlas-Campaspe Mine

The long-term accrual of radiation dose (via irradiation, inhalation and/or ingestion) of employees and/or members of the public during the handling and stockpiling of HMC, mineral concentrates, MSP process waste and blended process waste at the Atlas-Campaspe Mine could cause potential doses in excess of relevant limits (Section 2.3) in the absence of management measures. Table 4 provides a summary of the potential activities and associated dose delivery pathways that would potentially occur at the Atlas-Campaspe Mine.

Management of HMC, mineral concentrates, MSP process waste at the Atlas-Campaspe Mine would be conducted as described in Sections 6.1 and 6.2. With the implementation of these management measures, the risk of harm to employees, members of the public and the environment from the handling and stockpiling of the HMC, mineral concentrates, MSP process waste and blended process waste would be negligible.
### Table 4
Potential Dose Delivery Pathways at the Atlas-Campsaspe Mine

<table>
<thead>
<tr>
<th>Activity</th>
<th>Potential Dose Delivery Pathway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handling and stockpiling HMC, mineral concentrates and MSP process waste.</td>
<td>• Inhalation or ingestion of LLAE in dust during handling and stockpiling activities.</td>
</tr>
<tr>
<td></td>
<td>• Doses of gamma radiation through close proximity to the mineral concentrates and MSP process waste.</td>
</tr>
<tr>
<td>Loading of mineral concentrates onto haulage vehicles.</td>
<td>• Inhalation or ingestion of LLAE in dust during loading activities.</td>
</tr>
<tr>
<td></td>
<td>• Doses of gamma radiation through close proximity to the mineral concentrates.</td>
</tr>
<tr>
<td>Unloading of MSP process waste from haulage vehicles.</td>
<td>• Inhalation or ingestion of LLAE in dust during unloading activities.</td>
</tr>
<tr>
<td></td>
<td>• Doses of gamma radiation through close proximity to the MSP process waste.</td>
</tr>
<tr>
<td>Mixing of MSP process waste with sand residues and coarse rejects.</td>
<td>• Inhalation or ingestion of LLAE in dust through activities associated with loading MSP process waste prior to mixing.</td>
</tr>
<tr>
<td></td>
<td>• Doses of gamma radiation through close proximity to the MSP process waste.</td>
</tr>
<tr>
<td>Deposition of blended process waste.</td>
<td>• Very little risk of either gamma radiation or dust generation as the blended process waste is wet and material has been blended with non-radioactive material.</td>
</tr>
<tr>
<td>Incident or accident resulting in loss of containment of material.</td>
<td>• Inhalation of LLAE in dust or doses of gamma radiation.</td>
</tr>
<tr>
<td></td>
<td>• Environmental exposure to radioactive material.</td>
</tr>
</tbody>
</table>

### 5.2 Mineral Concentrate and MSP Process Waste Transport

Table 5 provides a summary of the potential activities and associated potential dose delivery pathways that would potentially occur during transport of mineral concentrates and MSP process waste.

Management of the transport of mineral concentrates and MSP process waste for the Project would be conducted as described in Sections 6.1 and 6.2. With the implementation of these management measures, the risk of harm to employees, members of the public and the environment from the transport of mineral concentrates and MSP process waste would be negligible.
Table 5
Potential Dose Delivery Pathways during Transport of Mineral Concentrates and MSP Process Waste

<table>
<thead>
<tr>
<th>Activity</th>
<th>Potential Dose Delivery Pathway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport of mineral concentrates and MSP process waste.</td>
<td>• Doses of gamma radiation through close proximity to the road haulage vehicles and rail wagons containing mineral concentrates or MSP process waste.</td>
</tr>
<tr>
<td>Wind blown dust during the transport of mineral concentrates and MSP process waste.</td>
<td>• Inhalation or ingestion of LLAE in dust dispersed from haulage vehicles or rail wagons.</td>
</tr>
<tr>
<td></td>
<td>• Doses of gamma radiation through close proximity to the mineral concentrates or MSP process waste.</td>
</tr>
<tr>
<td></td>
<td>• Environmental exposure to radioactive material.</td>
</tr>
<tr>
<td>Incident or accident resulting in loss of containment of mineral concentrates or MSP process waste.</td>
<td>• Inhalation or ingestion of LLAE in dust or doses of gamma radiation following loss of intended containment of material as a result of collision, failure of containment component, or interference by unauthorised personnel.</td>
</tr>
<tr>
<td></td>
<td>• Environmental exposure to radioactive material.</td>
</tr>
</tbody>
</table>

5.3 Ivanhoe Rail Facility

Table 6 provides a summary of the potential activities and associated dose delivery pathways that would potentially occur at the Ivanhoe Rail Facility. The handling and stockpiling of mineral concentrates and MSP process waste at the Ivanhoe Rail Facility would require the implementation of monitoring and management measures.

Management of the handling and stockpiling of mineral concentrates and MSP process waste for the Project would be conducted as described in Sections 6.1 and 6.2. With the implementation of these management measures, the risk of harm to employees, members of the public and the environment from the handling and stockpiling of mineral concentrates and MSP process waste at the Ivanhoe Rail Facility would be negligible.
### Table 6
**Potential Dose Delivery Pathways at the Ivanhoe Rail Facility**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Potential Dose Delivery Pathway</th>
</tr>
</thead>
</table>
| Unloading of mineral concentrates from haulage vehicles. | • Inhalation or ingestion of LLAE in dust through activities associated with unloading mineral concentrates from haulage vehicles.  
• Doses of gamma radiation through close proximity to the mineral concentrates. |
| Loading of the mineral concentrates onto rail wagons.   | • Inhalation or ingestion of LLAE in dust through activities associated with loading mineral concentrates onto rail wagons.  
• Doses of gamma radiation through close proximity to the mineral concentrates. |
| Temporary storage of mineral concentrates and MSP process waste. | • Doses of gamma radiation through close proximity to the mineral concentrates and MSP process waste. |
| Loading of the MSP process waste onto haulage vehicles. | • Doses of gamma radiation through close proximity to the MSP process waste. |
| Incident or accident along the mineral concentrate transport route or at the Ivanhoe Rail Facility. | • Inhalation or ingestion of LLAE in dust or doses of gamma radiation following loss of intended containment of material as a result of collision, failure of containment component, or interference by unauthorised personnel.  
• Environmental exposure to radioactive material. |

### 5.4 Environment

An incident or accident resulting in the loss of containment of HMC, mineral concentrates, MSP process waste or blended process waste (e.g. accident along the mineral concentrate transport route) could potentially result in local contamination of land or surface waters.

In the event of a loss of containment event, there would be limited radiological consequences, as the heavy nature of the radioactive material (i.e. monazite) and its insolubility in water, would limit the potential for dispersal and therefore the extent of contamination (Radiation Advice & Solutions, 2006). The coarse heavy nature of the radioactive material would also limit the potential for the material to become airborne. In addition, the Mineral Concentrate and MSP Process Waste Transport Management Plan (Section 6) would include a plan for dealing with incidents, accidents and emergencies to respond these events to limit the potential for land and surface water contamination.

Section 3.6.6 of the Mining and Processing Code states that:

> For the purposes of the Code it is assumed that by achieving adequate protection of human health, an acceptable level of protection will be afforded to the environment. However, this assumption may not be valid in all circumstances and specific additional control measures may be required.

It is therefore considered appropriate to afford protection of the environment through the application of human health exposure criteria. As the Project is expected to address the human health exposure criteria, it is considered that there would be no significant radiological impact on the environment.
6 Mitigation and Management Measures and Monitoring

The management of materials containing radioactive components at the Project would be detailed in a Radiation Management Plan for the Project in accordance with the Mining and Processing Code. The Radiation Management Plan would include details of best practicable technology to minimise potential occupational and member of public doses, and would include the following:

- identification of potential sources of potential does delivery pathways and potential doses;
- a description of operations and control measures;
- details of appropriate equipment, staff, facilities and operational procedures;
- induction and training courses;
- details of radiation monitoring (including baseline information);
- record keeping, reporting and periodic review procedures;
- a plan for dealing with incidents, accidents and emergencies involving exposure to radiation; and
- demonstration of access to professional expertise in radiation protection.

In addition to the Radiation Management Plan, the following management plans would also be prepared for the Project:


A summary of the management measures proposed to be implemented at the Project and these management plans is provided in the following sub-sections.

6.1 Atlas-Campaspe Mine

A description of the proposed management of HMC, mineral concentrates, MSP process waste and blended process waste at the Atlas-Campaspe Mine is detailed is Section 3.2.

From approximately Year 12 of the Project, MSP process waste would be transported to the Atlas-Campaspe Mine for subsequent unloading, stockpiling and placement behind the advancing ore extraction areas. The MSP process waste would be blended with other process wastes (i.e. brine from the RO plant, sand residues, coarse rejects) to dilute the radioactive material. The combined sand residues, coarse rejects and MSP process waste slurry would then be pumped and deposited in the process waste emplacement cells. Blended MSP process waste would be:

- placed above the groundwater table;
- placed no closer than 10 m from the natural ground surface; and
- covered under a minimum of 10 m of overburden and soil, such that the radiation level at the surface of the rehabilitated process waste emplacement cells would be equivalent to the natural background radiation level.

No MSP process wastes would be placed in off-path sand residue dams at the Atlas-Campaspe Mine.
Radioactive Waste Management Plan

A Radioactive Waste Management Plan would be prepared for the Project in accordance with the Mining and Processing Code. The Radioactive Waste Management Plan would include the following:

- a description of waste generating processes and waste;
- characterisation of the MSP process waste and blended process waste;
- a description of the proposed MSP process waste and blended process waste management measures (including the facilities and procedures involved in the handling, treatment, storage and disposal);
- predicted environmental concentrations of radionuclides and radiation doses to people from the proposed MSP process waste and blended process waste management practices;
- radiation monitoring program;
- contingency plans for dealing with accidental releases, or circumstances which might lead to uncontrolled releases of radioactive waste to the environment;
- reporting schedule;
- site decommissioning plan; and
- reporting and periodic review procedures.

6.2 Mineral Concentrate and MSP Process Waste Transport

A description of the proposed transport of mineral concentrates and MSP process waste for the Project is provided in Section 3.2.

The RC Act requires the transport of radioactive substances (i.e. the MSP process waste - Section 4.2) to be conducted in accordance with the Transport Code. The transport of MSP process waste would therefore be conducted in accordance with the Transport Code.

The Transport Code establishes uniform requirements for the transport of radioactive material in Australia. These uniform requirements aim to protect persons, property and the environment from the effects of radiation during the transport of radioactive material.

A brief overview of these requirements is outlined in the sub-sections below.

Storage

As described in Section 3.1, following the cessation of operations at the Snapper and Ginkgo Mines (i.e. Year 12 of the Project), MSP process waste would be railed from the MSP to the Ivanhoe Rail Facility for further transport via road to the Atlas-Campaspe Mine in sealed containers.

The sealed containers containing MSP process waste would be unloaded from trains at the Ivanhoe Rail Facility, and temporarily held in a designated area prior to loading onto haulage vehicles for the return trip to Atlas-Campaspe Mine.
**Placarding, Documentation and Waste Tracking**

Vehicles transporting MSP process waste would be placarded in accordance with the requirements of the Transport Code and the Transport of Dangerous Goods Code. In addition, all vehicles transporting MSP process waste would carry a properly filled out Dangerous Goods Class 7 Consignor’s Declaration accurately describing the material being transported.

MSP process waste movements would be recorded in accordance with the Environment Protection Licence issued under the PoEO Act.

**Training**

All drivers would be given a formal induction about radiation and radioactivity, so as to be able to understand the nature of the hazard associated with transporting this material.

Drivers would also be required to attend specific training on emergency response. This training would be competency based and recorded.

**Mineral Concentrate and MSP Process Waste Transport Management Plan**

A Mineral Concentrate and MSP Process Waste Transport Management Plan would be prepared for the Project. The Mineral Concentrate and MSP Process Waste Transport Management Plan would include:

- driver training;
- operating hours;
- vehicle identification;
- driver code of conduct;
- load covering;
- labelling and placarding requirements for transporting MSP process waste;
- fatigue management;
- drug and alcohol policy;
- radiation monitoring program;
- waste tracking program; and
- vehicle maintenance and safety program.

**6.3 Radiation Monitoring**

The Radiation Management Plan would describe monitoring proposed for the Project. A summary of the proposed radiation monitoring program is provided in Table 7.
### Table 7
Radiation Monitoring Program

<table>
<thead>
<tr>
<th>Project Component</th>
<th>Location</th>
<th>Method</th>
<th>Primary Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Environmental gamma monitor.</td>
<td>To confirm radiation levels at surface are equivalent to baseline radiation levels.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Personal TLDs; Personal Air Samplers (representative samples).</td>
<td>Occupational dose assessment.</td>
</tr>
<tr>
<td>Mine Path (200 m intervals)</td>
<td></td>
<td>Environmental gamma monitor.</td>
<td>Once-off survey prior to mining to record baseline radiation levels.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Environmental gamma monitor.</td>
<td>To confirm radiation levels at surface are equivalent to baseline radiation levels.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Locational dose rate measurements using hand held gamma radiation monitors inside driver’s cabin</td>
<td>Operational control.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gamma radiation readings taken outside of the containers and at 1 m from the truck/train.</td>
<td>Operational control.</td>
</tr>
<tr>
<td>Ivanhoe Rail Facility</td>
<td>Mineral Concentrate Stockpile and MSP Process Waste Container Storage Areas</td>
<td>Personal TLDs; Personal Air Samplers (representative samples).</td>
<td>Occupational dose assessment.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Environmental gamma monitor.</td>
<td>Once-off survey prior to construction to record baseline radiation levels.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Environmental gamma monitor.</td>
<td>To confirm radiation levels at surface are equivalent to baseline radiation levels.</td>
</tr>
</tbody>
</table>

Additional details of the radiation monitoring program would be detailed in the Radiation Management Plan.
7 References


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