Response to Fingerboards Mineral Sand Project Environment Effects Inquiry and Advisory Committee

Radiation Act 2005

VICTORIA State Government | Health and Human Services

Contents

Summary

- On 23 December 2020, the Fingerboards Mineral Sand Project Environment Effects Inquiry and Advisory Committee (IAC) requested the department to comment on the Project, and specifically in relation to the potential impacts of radiation from the project and how they might be mitigated, if mitigation is required. Specifically, the IAC requested advice on:

  – the adequacy of the radiation assessment undertaken for the Environment Effects Statement (EES) for the mine site and for the transport of product
  – the results obtained and where they sit within the regulatory environment for radiation
  – the adequacy of the environmental management measures proposed for this issue

  and noted that the IAC had also commissioned a separate review of the Radiation Assessment Report.
- The Kalbar Operations Pty Ltd (Kalbar) Fingerboards mineral sands orebodies contain trace amounts of naturally occurring radioactive materials.
- In the event that the project proceeds, Kalbar mining practices will have to comply with the legislative requirements governing worker protection, public protection, and environmental protection from radiation. The legislative requirements are the *Radiation Act 2005* (the Act) and the *Radiation Regulations 2017* (the Regulations). The Act and Regulations are administered by the Department of Health and Human Services (the department). A management licence will need to be obtained by Kalbar prior to commencing operations.
- The department's assessment is that the methods used by Kalbar to estimate the radiation related impacts of the project is well established and appropriate for the task. Furthermore, the department's assessment is that the methods have been implemented appropriately and the conclusions regarding radiation safety impacts based on these methods are valid. However, there is one additional radiation exposure pathway that the department will insist be modelled pre-mining and quantified as far as practicable following the commencement of mining operations. This potential exposure of members of the public is associated with the consumption of meat products in areas that are shown to be impacted by relocation of naturally occurring radionuclides from the mine site to meat producing areas. Based on the department's experience with other mineral sand mining activities and understanding the assessment method and the scale of the potential doses involved, the department anticipates that this radiation exposure pathway will not contribute significantly to the radiation exposure of a member of the public.
- The department is satisfied that the estimates of radiation doses to workers and to members of the public provided by Kalbar in the EES are accurate based on the information available prior to the commencement of mining operations. The radiation dose estimates made prior to mining need to be verified at the commencement of mining operations and periodically during mining operations.
- Potential radiation exposure of members of the public is estimated to be 37 microSieverts [1] and significantly less than the public radiation dose limit of 1000 microSieverts (1 milliSievert) prescribed in the Regulations. Radiation monitoring will be required throughout the life of the mining project.
- When applying for the necessary Management licence under the Act, Kalbar will be required to submit a comprehensive Radiation Management Plan (RMP) and Radioactive Waste Management Plan (RWMP) that address aspects of on-site and off-site radiation exposures. The radiation exposures will consider atmospheric transport of radionuclides, groundwater transport of radionuclides, surface water transport of radionuclides, and gamma radiation exposure. The RMP and RWMP will need to demonstrate how Kalbar can satisfy the requirements of the Act and Regulations.

[1] Appendix A011 Radiation Assessment Report Table 19: Estimated annual radiation doses for a Critical Group individual – March 2020

- The Australian Radiation Protection and Nuclear Safety Agency's Code of Practice for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing would be applied as a condition of a Management licence issued to Kalbar. This Code provides for radiation protection in mining and mineral processing industries and for protection of human health and the environment from the effects of radioactive waste from mining and mineral processing. The RMP and RWMP would be periodically reviewed by the department in conjunction with inspection of mining, mineral processing and waste management operations.

Introduction

This document has been prepared at the request of the Committee and should be read in conjunction with the document entitled 'Regulation of Radiation Safety in Victoria' as that document provides background to the overfall regulatory system.

This document consists of:

- A brief description of our understanding of the background to the project
- An outline of how the project would be regulated should it proceed including a summary of the various licensing conditions that are typically applied to this type of project
- Answers to the questions posed to the department by the Committee.

What is Kalbar Operations Pty Ltd proposing to do?

With respect to the legislative requirements of the Victorian *Radiation Act 2005* ('the Act'), the department understands that Kalbar Operations Pty Ltd (Kalbar) intends to mine mineral sands ore from the Glenaladale deposit and extract the heavy minerals from that ore to make what is referred to as a 'Heavy Mineral Concentrate' (HMC).

It is expected that the HMC, produced from a water and gravity process, will meet the definition of 'radioactive material' under the Act. This proposed process will require authorisation by the department under the Act prior to being conducted.

The proposed Kalbar mine will be located at Glenaladale, approximately twenty kilometres (km) northwest of Bairnsdale in East Gippsland as shown in **Figure 1**.

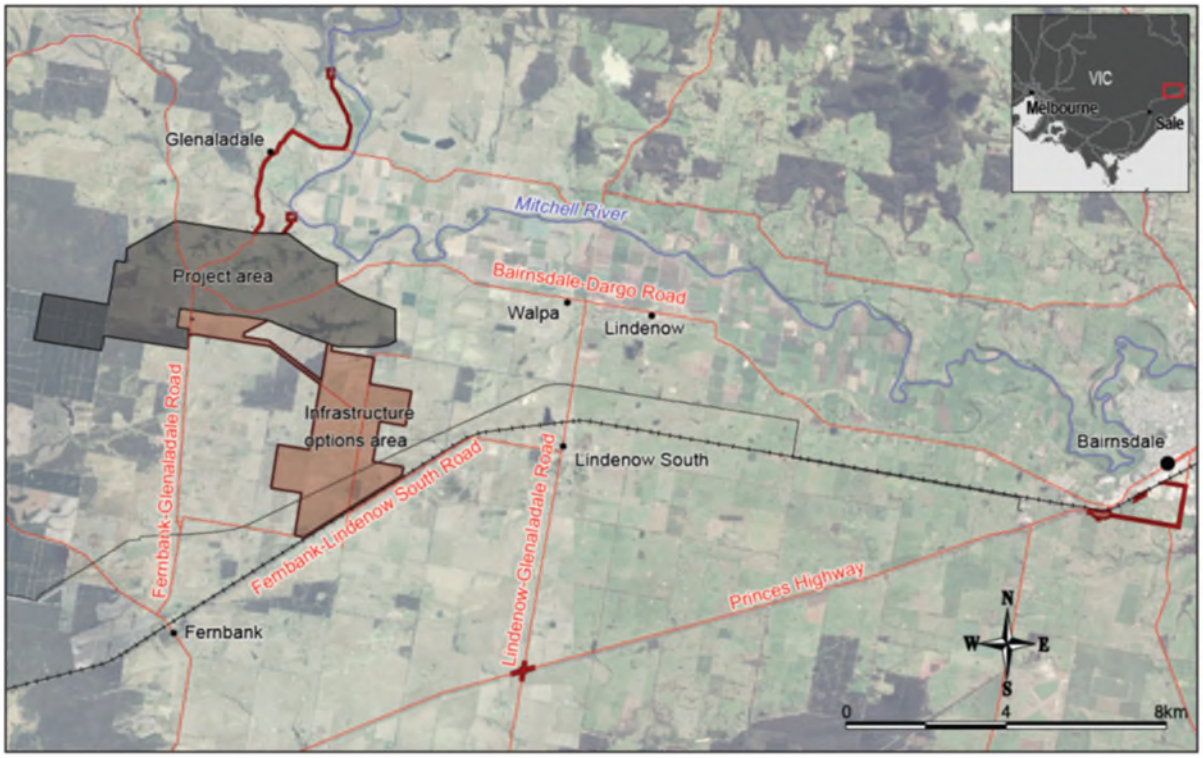


Figure 1
The location of the proposed Kalbar mine at Glenaladale

The location of the proposed Glenaladale mine in relation to other Victorian proposed and historical mineral sand operations is shown in **Figure 2**.

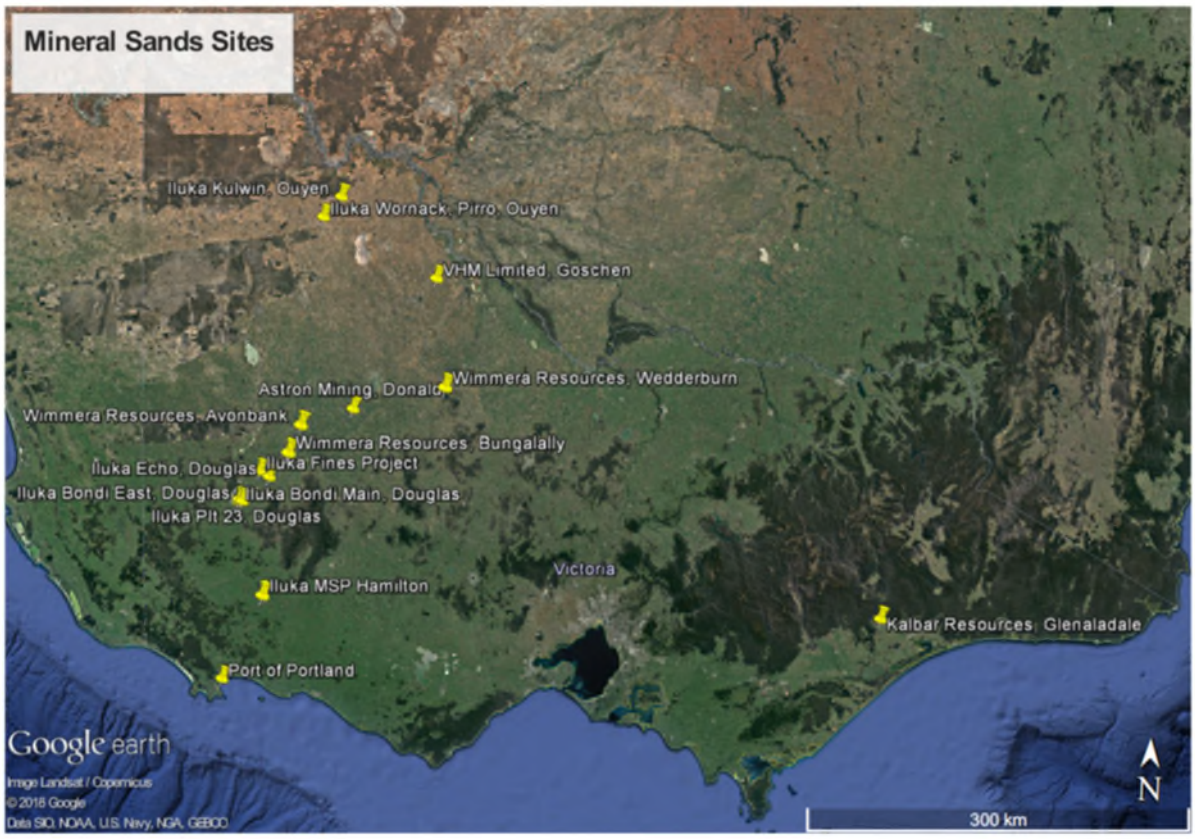


Figure 2
Location of the Kalbar project site in relation to other mineral sand mining projects

Heavy Mineral Concentrate

The HMC produced by Kalbar is proposed to be transported from the mine site by road or rail to a port for export. This process is proposed to continue for the next 20 years.

The HMC proposed to be produced at the Kalbar mine site would result from a primary separation process. This process involves washing the ore through a series of spiral separators that utilise sizing and gravity differentiation to separate the heavy minerals from the clay and the oversize material such as quartz sand and rock that accompany the heavy minerals. A diagram showing the typical processing operations at a mine site such as the proposed Kalbar mine site is shown in Figure 3 below.[2]

Heavy minerals in the HMC include monazite [$(Ce,La,Y,Nd,Th)PO_4$], zircon ($ZrSiO_4$), rutile (TiO_2), ilmenite ($FeO.TiO_2$) where Mg^{2+}, Mn^{2+}, and Fe^{3+} can substitute for Fe^{2+} in the ilmenite structure, and leucoxene ($Fe_2O_3.TiO_2$). A typical composition of heavy minerals in HMC is 73% ilmenite, 20% zircon, 5% rutile, 1% leucoxene, and 1% monazite.[3]

[2] Reference: Kalbar Operations Pty Ltd.

[3] Technical Report No. 165. Proposed Expansion of the Australian National Radiation Dose Register to the Mineral Sands Mining and Processing Industry. Australian Radiation Protection and Nuclear Safety Agency. Page 7.

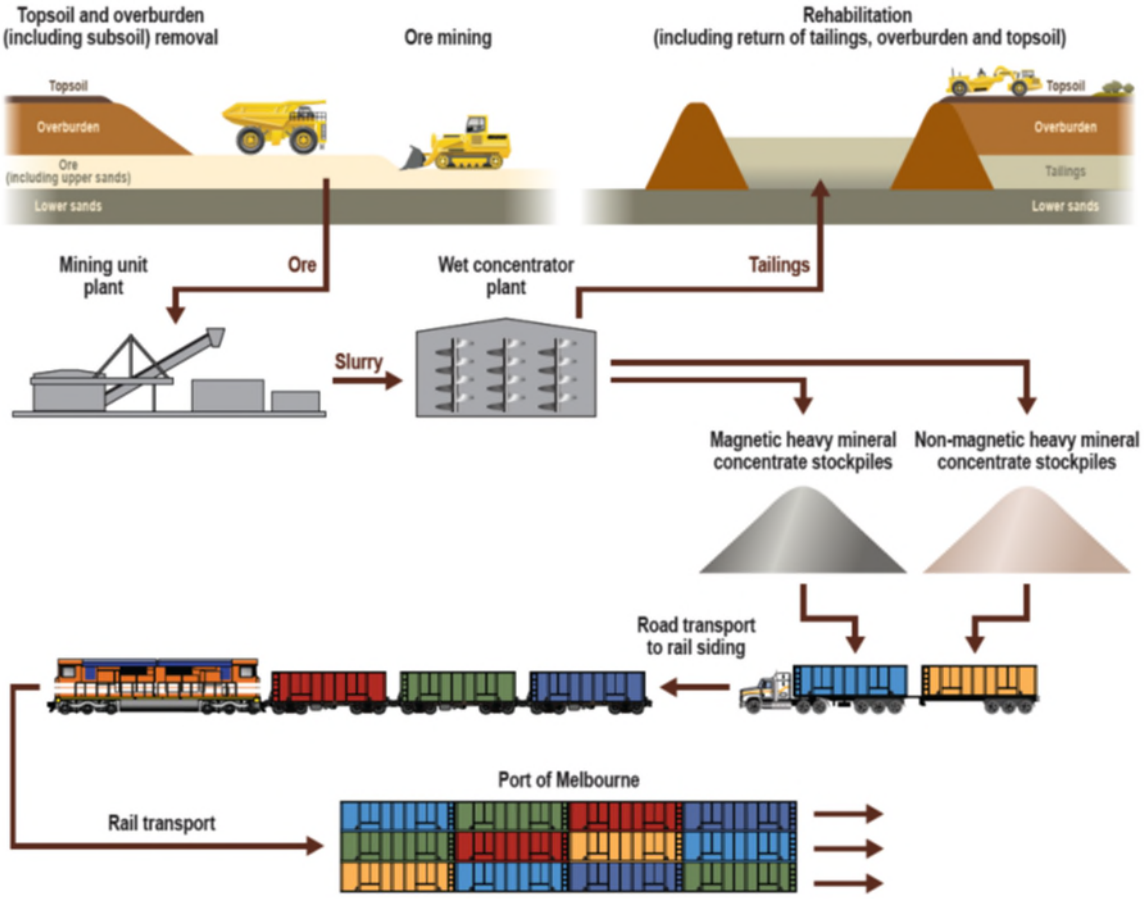


Figure 3
Processing operations typical of those proposed at the Kalbar mine

Monazite, rutile, and zircon are primary minerals that form in igneous or metamorphic environments associated with orogenesis or mountain building. The minerals are subsequently transported and deposited as marine sand. The existence of these minerals in their primary form demonstrates the stability of the minerals. Ilmenite and leucoxene are secondary minerals. The iron oxide goethite, found in ilmenite and leucoxene, is the most common iron oxide in soils and is extremely stable under atmospheric conditions.[4]

Naturally Occurring Radioactive Material

The Heavy Mineral Concentrate arising from the separation and concentration of mined ore contains Naturally Occurring Radioactive Material (NORM). Such naturally occurring radiation sources, commonly referred to as primordial radionuclides, are ubiquitous in the living environment. The NORM consists of thorium-232 ((Th-232)(half-life, 1.41 x 10^{10} years)) and its decay products, uranium-238 ((U-238)(half-life, 4.47 x 10^{9} years)) and its decay products, uranium-235 ((U-235)(half-life, 7.04 x 10^{8} years)) and its decay products, the non-series radionuclide potassium-40 ((K-40) (half-life, 1.25 x 10^{9} years)), and other primordial radionuclides such as rubidium-87 ((Rb-87)(half-life, 4.92 x 10^{10} years)), lanthanum-138 (La-138)(half-life, 1.05 x 10^{11} years)), samarium-147 ((Sm-147)(half-life, 1.05 x 10^{11} years)), and lutetium-176 ((Lu-176)(half-life, 3.78 x 10^{10} years)). These elements have always been present in the Earth's crust and atmosphere.[5]

For radiation protection purposes, the U-238 and Th-232 decay series are the main radionuclides of interest. The levels of other primordial radionuclides in minerals and raw materials are not normally of concern for

[4] Ibid.

[5] IAEA. Naturally Occurring Radioactive Material (NORM VII). Proceedings of an International Symposium. Bejing, China, 22-26 April 2013.

radiation protection purposes.[6] For the oil and gas industries, the International Atomic Energy Agency (IAEA) considers only the radionuclides from the uranium and thorium series in relation to radiation protection.[7]

Thorium-232 undergoes ten transformations to become stable lead 208.

Uranium-238 undergoes fourteen transformations to become stable lead-206.

The products of the decay of Th-232 include radium-228 (Ra-228) (half-life, 5.76 years) and the gas radon-220 (Rn-220) (half-life, 56 seconds), commonly referred to as thoron.

The products of the decay of U-238 include radium-226 (Ra-226) (half-life, 1,600 years) and the gas radon-222 (Rn-222) (half-life, 3.8 days).

Thorium-232 and U-238 are geochemically immobile.[8] The decay chains for Th-232 and U-238 are shown in Appendix 2 and Appendix 3, respectively.

Of the heavy minerals that contain NORM in the HMC, the monazite is the mineral that has the highest radioactivity level. Moreover, the radioactivity level in the Heavy Mineral Concentrate is mainly due to the monazite content of the original ore, which varies according to the location of the ore body.[9]

Monazite, a phosphate mineral containing rare earth elements, contains between five and seven per cent thorium and between 0.1 and 0.3 percent uranium, resulting in relatively high concentrations of Th-232 and its decay products compared with other radionuclides and their decay products. The activity of Th-232 and its daughter products may be up to 140 Bq/g in monazite[10].

How would radiation safety be regulated if the project proceeds?

The mining of mineral rich sands across Australia generally triggers the need for regulation of the radiation safety aspects of the operation due to the presence of naturally occurring radioactive material in low but still significant concentrations.

Regulation is equally focussed on the protection of worker health as well as protection of public health and the protection of the environment.

Licensing

In the event that the project proceeds, Kalbar Operations Pty Ltd will need to apply to the department for a radiation management licence issued under the Act. A management licence, if issued, would authorise radiation practices associated with mining and milling processes to be conducted at the Kalbar mine site. This will also include any related activities such as the transport of radioactive material.

[6] Ibid.

[7] IAEA. Safety Report Series No.34. Radiation Protection and the Management of Radioactive Waste in the Oil and Gas Industry.

[8] Kraus, W. Management of Waste from Mining and Minerals Processing (Keynote paper).

[9] Technical Report No. 165. Proposed Expansion of the Australian National Radiation Dose Register to the Mineral Sands Mining and Processing Industry. Australian Radiation Protection and Nuclear Safety Agency. Page 11.

[10] IAEA. Safety Report Series No. 68.

The licence must authorise all of the radiation practices to be conducted by the licence holder. All management licences issued by the department are issued subject to conditions which include conditions related to:

- Requirements relating to the acquisition and disposal of radiation sources
- Incident reporting.

Most licences, including all licences related to mining, are also issued requiring compliance with at least one nationally agreed Code. In this type of project, we would expect the licence to require compliance with at least two, and probably three, such Codes.

What would a management licence authorise?

Based on our current understanding of the project, it is reasonable to expect that in the event that a management licence is issued to Kalbar Operations Pty Ltd that it would authorise the company to:

1. Possess, dispose of, and consign (for transport):
    a. Sealed source apparatus (this apparatus is designed to measure product characteristics or analyse the structure of materials).
    b. Unsealed radioactive material in the form of mineral sands.
    c. Unsealed radioactive material in the form of processed mineral sands.
2. Sell processed mineral sands.
3. Mine mineral sands.
4. Transport of radioactive material (if this is to be conducted directly by the company rather than by a contractor).

Licence conditions

At the moment and based on our understanding of the proposed project, a management licence issued to Kalbar Operations Pty Ltd would be expected to, as a minimum, require the company to comply with:

1. The obligations of the operator and employer in the Code of Practice for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing (2005) published by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA).
2. The obligations of the consignor in the Code of Practice for the Safe Transport of Radioactive Materials (2019).
3. The obligations specified in the approved Radiation Management Plan and Radioactive Waste Management Plan.
4. The obligations to report certain types of radiation incidents to the department and to notify the department regarding the disposal and acquisition of radiation sources.
5. The obligation to prepare a report that contains the radiation doses received by occupationally exposed workers arising from gamma radiation, radon gas, inhaled dust, and ingested dust. Such a report would be submitted to the department two times each year.

An additional licence condition is also likely to be applied by the time that the licence would be expected to be required. The condition would require compliance with a relatively new Code; the Code for Radiation Protection in Planned Exposure Situations (2020), RPS C-1 (Rev.1) published by ARPANSA. This Code sets out the requirements in Australia for the protection of occupationally exposed persons, the public and the environment in planned exposure situations.

Each of these requirements is discussed in detail below.

Code of Practice for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing (2005)

The Code is available at https://www.arpansa.gov.au/sites/default/files/legacy/pubs/rps/rps9.pdf

The objective of the Code is to provide a regulatory framework to manage the protection of workers, of members of the public, and of the environment from the harmful effects of radiation exposures arising from mining or mineral processing and from the waste resulting from these activities. The framework established in the Code includes:

- Applying uniform standards inconsistent with current international standards.
- Fostering uniform outcomes in radiation protection and the management of radioactive waste in the mining and processing industries.
- Allocating responsibilities and provision for independent regulatory audit and inspection.
- Developing and implementing a Radiation Management Plan and a Radioactive Waste Management Plan.

The purpose of the Radiation Management Plan is to control the exposure of workers and the public to radiation. All pathways that can potentially deliver radiation doses are assessed prior to the awarding of a Management Licence and periodically monitored for regulatory compliance with radiation dose limits. Such pathways include exposure to workers on-site (for example via ingestion, airborne inhalation and naturally occurring gamma radiation). For the public, such pathways include ingestion via translocation of dusts to ingested vegetable produce, inhalation of blown dusts, and ingestion of meat and dairy products via consumption of animals or animal products grazing on lands where they may be a mine-related increase in radioactivity levels. With regard to the environment, assessments are made of dose rates for selected flora and fauna species to ensure radiation dose rates remain acceptably low. This latter element is becoming increasingly included as part of a separate Radiation Environment Plan.

The Radiation Management Plan must include post-operational practices including decommissioning, closure, decontamination, rehabilitation, monitoring, long term surveillance, reporting, records management, and land use.

The purpose of the Radioactive Waste Management Plan is to provide for the proper management of radioactive waste arising from the operations and to identify the relevant pathways for radiation exposure to ensure that optimised procedures are put in place to protect people and the environment.

Code for Radiation Protection in Planned Exposure Situations (2020)

This Code has not yet been implemented in Victoria but the department expects that it will move to vary all existing radiation management licences to require compliance with the Code by the middle of 2022.

The Code sets out the nationally agreed requirements in Australia for the protection of occupationally exposed persons, the public and the environment in planned exposure situations. Planned exposure situations is a term used in radiation safety which in the context of this project will apply to all of the activities associated with the radiation practices.

The Code will be complimentary to the Mining Code and provides more detailed requirements relating to the operation of the radiation practice particularly in the areas of public health, protection of the environment and worker health.

The Code is available at https://www.arpansa.gov.au/sites/default/files/legacy/pubs/rps/rpsc-1.pdf

Code of Practice for the Safe Transport of Radioactive Materials (2019)

This Code is available at https://www.arpansa.gov.au/sites/default/files/rps_c-2-2019.pdf

It contains the requirements including for placarding. These Codes are updated very regularly to reflect any internationally agreed requirements.

Reporting obligations

A licence condition is typically applied to mineral sand mining operations that requires a six monthly report to be given to DHHS that describes the radiation doses received by occupationally exposed workers and members of the public arising from gamma radiation, radon gas, inhaled dust, and ingested dust.

Incident reporting

The licence condition relating to incident reporting includes a requirement for the management licence holder to report any transport accidents involving radioactive material where there has been a spill or release of radioactive material into the environment.

The incident reporting requirements may be found at the following weblink:

https://www2.health.vic.gov.au/about/publications/ResearchAndReports/mandatory-reporting-of-radiation-incidents

Answers to the Committee's Questions

Background and Process

The department has been asked to provide advice to the Inquiry and Advisory Committee on:

- the adequacy of the radiation assessment undertaken for the Environment Effects Statement (EES) for the mine site and for the transport of product
- the results obtained and where they sit within the regulatory environment for radiation
- the adequacy of the environmental management measures proposed for this issue

The department has assessed the FINGERBOARDS PROJECT RADIATION ASSESSMENT REPORT APRIL 2020 PREPARED FOR KALBAR OPERATIONS PTY LIMITED BY SGS AUSTRALIA (the Report) to ensure it addresses all relevant aspects of worker, public, and environmental radiation protection associated with the proposal.

In doing so the department examined the Report with regard to:

- specific worker and public annual radiation dose limits of the *Radiation Act 2005* (the Act) and *Radiation Regulations 2017* (the Regulations) (Appendix 3)
- the Code of Practice for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing (2005), and
- the Code of Practice for the Safe Transport of Radioactive Materials (2019).

Summary - Advice to the Inquiry and Advisory Committee

The adequacy of the radiation assessment undertaken for the Environment Effects Statement:

- The department's assessment is that the methods used by Kalbar to estimate the radiation related impacts of the project are well established and appropriate for the task. Furthermore, the department's assessment is that the methods have been implemented appropriately and the conclusions based on these methods are valid. The calculations of potential public doses for the pathways considered demonstrate that the proposed project can be conducted with acceptably low doses to members of the public. The department considers that an additional radiation dose assessment for public radiation dose from consumption of nearby meat and dairy produce is warranted (although the derived potential dose outcome of such an assessment is predicted to be exceedingly low) and will require the submission of a Radiation Environment Plan with any future Management Licence application to include an environmental assessment of agreed flora and fauna in the manner outlined in the Australian Radiation Protection and Nuclear Safety Agency's *Guide on Radiation Protection of the Environment* (the Guide).This Plan will need to be prepared to the department's satisfaction before a licence will be issued.
- The department's assessment is that the methods used by Kalbar to estimate the radiation related impacts of the project are well established and appropriate for the task. Furthermore, the department's assessment is that the methods have been implemented appropriately and the conclusions regarding potential radiation exposure from transport of product based on these methods are valid. The calculations of potential public radiation doses demonstrate that the product can be transported safely. The Panel is advised that any third-party transport contractors (either road or rail) will be required to hold a management licence issued under the Radiation Act 2005. Compliance with the Code of Practice for the Safe Transport of Radioactive Materials (2019) would be a condition of licence applied to such a licence.

The results obtained and where they sit within the regulatory environment for radiation:
The numerical calculations of the potential doses to the public are acceptably low and comprise a small fraction of the annual public radiation dose limit. The estimated worst-case scenario of a member of the public being subjected to radiation via all identified pathways is 40 uSv per annum, which is 4 percent of the annual public radiation dose limit.

As a comparison, the majority of public exposure in Victoria is from medical radiation exposure with computed tomography procedures delivering doses in the millisievert range. The Panel is advised that medical radiation procedures, while optimised, are not subject to radiation dose limits.

The estimated maximum annual radiation doses for a worker on-site at the mine and for a worker transporting the mining processed product are 1.36 mSv and 2.93 mSv, respectively. These radiation doses are significantly below the prescribed dose limit for occupational exposure.

The adequacy of the environmental management measures proposed for this issue

The department's assessment is that the environmental management measures proposed to be used by Kalbar are appropriate. Routine environmental monitoring for radionuclides will inform the options (if required) for mitigation to achieve the objectives of the environmental management measures. The department considers that the mitigation measures proposed will (if required) ensure that the environmental radiation objectives can be satisfied.

The Department's assessment of the Kalbar Proposal

Background Radiation Levels

Regarding the characterisation of the existing background radiation in the vicinity of the project area, including assessments of the radionuclide content in air, soil, vegetation, surface water and groundwater, the department concludes that the investigative efforts by Kalbar are sufficient to adequately describe the pre-mining background radiation levels of the mine site and surrounds.

This conclusion is warranted based upon the evidence provided in the Report which provides data regarding the following:

- Terrestrial gamma radiation levels;
- Radionuclide content of surface soils;
- Radionuclide content of surface and groundwater sources;
- Radionuclide content of vegetation;
- Ambient long-lived radionuclide concentrations in airborne dust; and
- Ambient radon and thoron concentrations.

Quantification of the above listed parameters is provided in the Report, with the exception of the radionuclide content within vegetation grown in the district. For this latter component of the pre-mining background radiation level assessment Kalbar has provided in the Report an international best practice estimate using an agreed method developed by the International Atomic Energy Agency [11]. This approach uses soil concentration data measured by Kalbar and soil to plant transfer factors [12] to estimate the baseline radionuclide concentrations in the plant matter with subsequent derivation of pre-mining radiation dose

[11] International Atomic Energy Agency, Handbook of Parameter values for the prediction of radionuclide transfer in terrestrial and freshwater environments, Technical Report Series No. 472, 2010.

[12] Kalbar Report, Tables 3 and 4, Pages 17 &18

estimates to persons consuming such plant matter. [13] This approach pre-mining is acceptable due to the inherent difficulties of directly measuring radionuclides in biological plant matter. The department notes that the numerical estimates for radiation doses to persons consuming leafy vegetables due to the current naturally occurring background radiation measured in the soils using the modelled consumption parameters is, in some cases, a significant fraction of the 1 mSv per annum public dose limit. It should be noted that the public dose limit does not apply to natural sources of radiation that are unamenable to control. The department makes this point with the view to discussing the potential impact from mining activities on this radiation pathway later in this submission.

The Report provides a suitable level of pre-mining background radiation level information to permit the department to be in a position to assess any potential changes to the environment that may arise should the project proceed.

Terrestrial background gamma radiation levels are as expected for this type of mineral sands deposit in this region of Victoria. The radionuclide content of surface soils[14] in the project area is mostly within the range for worldwide variability of the parameters measured [15] with some elevated radium and thorium in the Perry Gully Creek bed and Ridge areas. Such is not unexpected in a highly mineralised region. The radionuclide content of soils in the broader farming district [16] is also within range for worldwide variability of the parameters measured. It is noted that the River Flats area that has been intensively farmed for leafy vegetable crops has elevated levels of naturally occurring potassium-40 when compared to other farming areas. This suggests the regular use of fertilizers in the River Flats area.

The department uses a source-pathway-receptor approach for determining the potential for radionuclide migration pathways to significantly change environmentally delivered radiation doses. Detailed knowledge of pre-mining radionuclide concentrations of surface water and groundwater sources plays an integral part in the department's ability to provide assurance that prescribed radiation dose limits can be satisfied. Water borne pathways potentially present the major pathway for the relocation of mine-related radionuclides to other areas where people or the environment might receive an increased radiation dose through ingestion of such waters or their use to irrigate crops or water livestock.

The background investigations of the radionuclide concentrations of surface water and groundwaters provide adequate information on the pre-mining natural waterborne radionuclide concentrations in the area.

Pre-mining airborne concentration measurements of long-lived naturally occurring radionuclides over a sixteen month period are cited in the Report. These measurements were made in parallel with the Victorian EPA requirements for PM10 and PM2.5. Such results form an integral part of the pre-mining background used as part of the department's future compliance determinations.

Pre-mining radon and thoron concentrations have been well characterised by Kalbar through the use of passive radon and thoron monitoring devices. The department also has a parallel program of confirmatory radon and thoron monitoring in place.

Conclusion: The department's assessment is that the methods used by Kalbar are well established and appropriate for the task and that the methods have been used appropriately and the conclusions regarding background radiation levels based on these methods are valid.

Knowledge of the Mineral Sand Orebody

Mineral sand mining companies have a client driven requirement to know the radionuclide content of their product. The department has the requirement to know the radionuclide concentrations through the mining and

[13] Kalbar Report, Table 17, Page 46.

[14] Kalbar Report, Table 2, Page 16.

[15] UNSCEAR 2008: ANNEX B: EXPOSURES OF THE PUBLIC AND WORKERS FROM VARIOUS SOURCES OF RADIATION, Page 233

[16] Kalbar Report, Table 3, Pages 17 & 18.

related processing streams to ensure that all potential radionuclide concentration points and exposure pathways are identified prior to and during mining operations.

The Report provides information regarding the radionuclide content of the project orebody [17] and proposed product. [18] This information includes the mine tailings produced which, given the removal of the radioactive thorium via the inclusion of the mineral monazite in the Heavy Mineral Concentrate product, are predicted to have radionuclide concentration levels comparable to worldwide [19] and regional [20] soils.

Conclusion: The department's assessment is that the methods used by Kalbar to estimate the radiation related impacts of the project are well established and appropriate for the task. Further, the department's assessment is that the methods have been implemented appropriately and the conclusions regarding the mineral sand orebody based on these methods are valid.

Assessment of Potential Radiation Exposures to Workers

Radiation protection requirements for mine workers in the mineral sands sector are designed to ensure that potential sources of radiation exposure to workers via the inhalation or ingestion of airborne dusts, inhalation of radon or thoron, external gamma radiation from the naturally occurring radioactive material in the orebody being mined and processed is kept well below the prescribed occupational dose limit of 20 mSv per annum.

The Report provides data regarding the following:

- External radiation dose estimates indicating a maximum anticipated annual worker gamma radiation dose of 1.25 mSv.
- Internal dust dose inhalation dose estimates indicating a maximum anticipated annual worker dust dose of 0.21 mSv.
- Consideration of the potential radiation dose from the ingestion of dusts.
- Consideration of the potential radiation dose from radon and thoron.
- An estimated maximum on-site worker annual dose of 1.36 mSv.
- Transport considerations indicating an estimated maximum annual radiation dose to drivers moving HMC product of 2.93 mSv.

Conclusion: The department's assessment is that the methods used by Kalbar to estimate the radiation related impacts of the project are well established and appropriate for the task. Furthermore, the department's assessment is that the methods have been implemented appropriately and the conclusions regarding the radiation exposure of workers based on these methods are valid.

Assessment of Potential Radiation Exposures to the Public

Mineral sand mining and processing operations are potential sources of exposure to members of the public via the off-site dispersal of airborne dusts or radon or thoron, the migration of contaminated groundwater into other water stocks, and long-term effects from tailings disposal and rejected materials management. The Regulations prescribe a dose limit of 1 mSv in any 12-month period for a member of the public.

Regarding the assessment of the potential radiation exposure pathways that relate to all aspects of the project including mining, processing and transport, including dose estimation for critical exposures groups the department concludes that all but one pathway of potential exposure to persons have been adequately assessed prior to mining. This latter pathway is discussed later in this section of the submission.

[17] Kalbar Report, Table 10, Page 27.

[18] Kalbar Report, Table 11, Page 29.

[19] UNSCEAR 2008: ANNEX B: EXPOSURES OF THE PUBLIC AND WORKERS FROM VARIOUS SOURCES OF RADIATION, Page 233

[20] Kalbar Report, Table 3, Pages 17 & 18.

The Report provides data regarding the following:

- Exposure to airborne dust inhalation during operations indicating potential public radiation doses in the order of 29 uSv per annum. [21]
- Project related incremental exposure to radon/thoron gas will be acceptably low due to dilution and dispersion. Both Kalbar and the department have monitoring programs for background levels and such monitoring will continue to be conducted to inform of any changes in radon and thoron levels. The department's regulatory experience suggests that radon and thoron exposure from such projects is effectively indistinguishable from natural background levels. [22]
- Project related incremental exposure via ingestion of vegetables or soils has been assessed by Kalbar indicating potential doses in the order of 6 uSv per annum. [23]
- Project related incremental exposure via ingestion of ore as a result of airborne deposition has been assessed by Kalbar indicating potential doses of 1.2 uSv per annum. [24]
- Project related incremental exposure via the consumption of drinking water originating from Waterglen Water Treatment Plant which sources water from the Mitchell River has been assessed as being negligible. [25]
- Project incremental doses from transport via following a HMC loaded truck or waiting at rail crossing for HMC shipment to pass has been assessed by Kalbar indicating total a potential transport related dose of 1.2 uSv. [26]

There is one additional radiation exposure pathway that the department will insist be modelled pre-mining and quantified as far as practicable following the commencement of mining operations. This potential exposure of members of the public is associated with the consumption of meat products in areas that are shown to be impacted by relocation of naturally occurring radionuclides from the mine site to meat producing areas. Based on the department's experience with other mineral sand mining activities and understanding the assessment method and the scale of the potential doses involved, the department anticipates that this radiation exposure pathway will not contribute significantly to the radiation exposure of a member of the public. Nevertheless, the derivation of estimated public radiation doses from this radiation exposure pathway using internationally accepted best practice methods developed by the International Atomic Energy Agency will be required to be submitted to the department as part of a licence application.

Conclusion: The department's assessment is that the methods used by Kalbar to estimate the radiation related impacts of the project are well established and appropriate for the task. Furthermore, the department's assessment is that the methods have been implemented appropriately and the conclusions regarding the radiation exposure of members of the public based on these methods are valid.

Assessment of Potential Radiation Exposures to the Environment

Internationally and nationally, the legal and regulatory framework that governs management of radiation risks encompasses protection of both people and the environment. While the approach to protection of people has continually evolved for about a century, protection of the environment from the harmful effects of radiation is a relatively new addition to the protection framework.

[21] Kalbar Report, Table 19, Page 51.

[22] Submission to Horsham Rural City Council and the Environment Protection Authority in relation to applications by Iluka Resources Limited Douglas Mine Site - Pit 23

[23] Kalbar Report, Table 19, Page 51.

[24] Kalbar Report, Table 19, Page 51.

[25] Kalbar Report, Table 19, Page 51.

[26] Kalbar Report, Table 19, Page 51.

The purpose of the Act cites protection of people and the environment from the harmful effects of radiation.

Radiation protection of the environment has been achieved up by ensuring that people were adequately protected in the environment under consideration.

The two parameters that determine risk to a critical group of people, radiation exposure and radiation effect, are the same parameters that determine risk to the environment. Therefore, the environment was considered to be protected if the radiation dose received by a critical group of people in the particular environment did not exceed the prescribed radiation dose limits. The dose limits specified in legislation relating to occupational and public exposure also created an environmental standard that defined the limits of human actions with respect to radiation exposure of the environment. Indeed, with regard to the transfer of radionuclides through the environment, the International Commission on Radiological Protection (ICRP) continued up until recent years to believe that the standards of environmental radiation control needed to protect the general public would ensure that other species are not placed at risk.

Protection of the environment *per se* is a relatively recent development. The view of the International Commission on Radiological Protection (ICRP) changed in 2007. The Commission's recommendations included an approach for developing a framework to demonstrate radiological protection of the environment.[27]

The approach was to develop mathematical models of representative organisms in various environments and to assess the radiation dose to such modelled representative flora and fauna. The ICRP published advice on what considerations need to be made in calculating flora and fauna doses and what method needs to be used for reference plant and animals.[28]

Internationally accepted models for reference animals and plants have been published. [29]

There is considerable work being done to develop Australian biota models such that there is greater alignment of the computational model with the Australian modelled flora and fauna

There is no formal assessment of the potential environmental dose rate to representative flora and fauna in (the Report submitted by Kalbar. However, there is a clear undertaking to conduct such an assessment. [30] The Australian Radiation Protection and Nuclear Safety Agency has published the *Guide on Radiation Protection of the Environment* (the Guide). [31] The department anticipates that the Guide will inform Kalbar regarding its method for assessing environmental radiation exposures from the proposed mine site. The department does not expect that there will be any significant findings from an environmental radiation assessment for the Kalbar Project such that changes to the proposed practice will be required.

As an integral part of an application from Kalbar for a licence to conduct radiation practices, Kalbar will be required to submit a Radiation Environment Plan with an assessment of the potential exposure to agreed flora and fauna in accordance with the Guide.

Conclusion: The department's conclusion is that the undertaking by Kalbar to assess the environmental impacts from radiation is appropriate and consistent with contemporary radiation practice.

Mitigation and Management of Potential Public and Environmental Radiation Impacts

Periodic monitoring of the radiation parameters measured prior to commencement of the proposed mining operations would continue if a licence to conduct the relevant radiation practices is issued under the Act. A condition of licence issued under the Act would reference the Radiation Management Plan, Radioactive Waste

[27] ICRP, 2007. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann. ICRP 37 (2-4).

[28] ICRP 2008. Environmental Protection: the Concept and Use of Reference Animals and Plants, ICRP Publication 108, Volume 38, Issues 4–6.

[29] ICRP, 2009. Environmental protection: transfer parameters for reference animals and plants. ICRP Publication 114. Ann. ICRP 39(6).

[30] Kalbar Report, Radiation Environment Plan, Page 68.

[31] Guide for Radiation Protection of the Environment (2015)

Management Plan, and Radiation Environment Plan. In this way, any changes to pre-mining radiation levels are detected and mitigation measures can be considered.

With respect to proposed avoidance, mitigation, and management measures to reduce the significance of any potential radiation impacts, Kalbar has considered[32]

- The potential impact of surface water and mining related dusts upon terrestrial and aquatic biodiversity and identified appropriate mitigations;
- The potential effects of mining operations on surface waters and proposed appropriate containment methodologies; and
- The loss of control events and potential public radiation health impacts via pathways including surface water, airborne dust relocation, gamma radiation for transport and proximity to orebody/operations, and potential radon and thoron exposure with appropriate mitigation strategies identified and proposed for each pathway.

The department is committed to working with other Victorian Government agencies (such as DEDJTR and the EPA) to ensure that any proposed radiation mitigation measures do not compromise any requirements imposed by either DEDJTR or the EPA.

Conclusion: The department's assessment is that the methods used by Kalbar to estimate the radiation related impacts of the project are well established and appropriate for the task. Furthermore, the department's assessment is that the methods have been implemented appropriately and the conclusions regarding mitigation and management of radiation impacts based on these methods are valid.

Post-Mining Considerations

Assessment of potential radiation exposure pathways from future land use scenarios post-mining is an essential part of pre-mining and during-mining considerations by the department. The Mining Code requires the submission to the department of a Radioactive Waste Management Plan (RWMP) and this Plan plays a large part in shaping public health and environmental outcomes. The department will consider such a Plan at the time of a Management licence application should the project proceed.

Like the Radiation Management Plan, the RWMP is a document subject to change as the project matures and develops. However, the requirement to ensure compliance with the public radiation dose limits remains. [33]

The department is satisfied that Kalbar Resources has reasonably identified the required elements to be presented to the department within an RWMP.

In its Report, Kalbar has identified the following:

- The essential requirements for a proposed RWMP including decommissioning and rehabilitation of the mine site and associated operational areas;
- The measurements of environmental radionuclide concentrations and prediction of same with regard to waste management practices;
- The on-ongoing program of monitoring to continue to demonstrate compliance with the public dose limits from all relevant pathways; and
- The contingency plans for potential failures of rehabilitation efforts to ensure that such remediation measures maintain the safety integrity of the mine site post-closure.

[32] Kalbar Report, Table 22, Pages 57-64.

[33] Kalbar Report, Page 67.

The department has successfully ensured the completeness of other large-scale radiation remediation projects within the mineral sands sector [34] in conjunction with both mining and environmental regulatory agencies (such as DEDJTR and the EPA) within Victoria.

In general terms, the rehabilitation radiation objectives are effectively mandated by the department at the time of the EES. In essence, Kalbar would be required to leave the rehabilitated mine site with no significant increased risk of radiation exposure compared with the radiation exposures that existed prior to mining.

Conclusion: The department's assessment is that the methods used by Kalbar to estimate the radiation related impacts of the project are well established and appropriate for the task. Furthermore, the department's assessment is that the methods have been implemented appropriately and the conclusions regarding post-mining considerations based on these methods are valid.

How would the department ensure regulatory compliance if the project proceeds?

Pre-mining Background Characterisation

The department conducts long-term pre-mining assessments of natural gamma radiation and naturally occurring radon and thoron gas activity concentration levels over several months and up to a year in order to ensure accurate background characterisation. This is achieved using passive monitors placed in and around the mineral lease at strategic locations dependent upon the relative proximity for potential public radiation doses.

The department requests each mineral sand mining company to perform comprehensive background radionuclide characterisation of soils, groundwater, surface water, airborne particulates as well as radon/thoron gas activity concentration levels and surface gamma radiation levels. This is essential in order to permit restoration of the pre-mining environment at the cessation of the mining practice following mine site rehabilitation.

The proposed processing methods are also examined with specific reference to measuring ore sample and mining product radionuclide characteristics to ascertain at which points in the mining and processing practices radiation protection efforts will need to be monitored. In this way, both direct and indirect measurement of specific parameters contributing to occupational and potential public radiation exposure are identified prior to the commencement of mining and factor into the specific radiation protection plans for each mining operation.

Periodic Document Review

Every six months mineral sand mining companies submit a report of their review of the implementation of their respective Radiation Management Plans and Radioactive Waste Management Plans. The department reviews the submitted reports and discusses with the mineral sand mining company any aspect that requires clarification. Should the department consider additional efforts are required in order to ensure compliance with public and occupational dose limits and/or protection of the environment, the Radiation Act provides powers for the department to direct improvements be made. The department will be confirming potential dose estimates via review of six-monthly periodic monitoring reports from Kalbar submitted as a condition of any Management Licence issued and through periodic site visits, inspections, discussions and independent monitoring of key radiological parameters as required.

[34] Submission to Horsham Rural City Council and the Environment Protection Authority in relation to applications by Iluka Resources Limited Douglas Mine Site - Pit 23

Inspections of Mineral Sand Mines

The department aims to conduct on-site inspections of mineral sand mines throughout Victoria twice per year. Each mine site and its operations are viewed and relevant aspects of Radiation Management Plans and Radioactive Waste Management Plans are discussed. This is dependent upon the progress of each mine and reflects the reality of the fact that such plans are living documents and may evolve as a mining practice evolves. On-site inspections also permit the department to assure that the radiation safety practices described in detail in the respective plans are given effect and are delivering upon the expected outcomes to achieve legislative compliance with the radiation dose limits and also to effect optimised environmental protection.

Monitoring and Testing

Periodic monitoring of the radiation parameters measured prior to commencement of the practice is designed to continue by virtue of the enforceable Radiation Management Plan, Radioactive Waste Management Plan and Radiation Environment Plan. In this way any changes to pre-mining radiation levels are detected and discussed with a licence holder regarding their significance and possible amelioration or remediation needs to reduce any significant radiation risk. In the experience of DHHS, such risks are highly unlikely to arise. The department will also require the confirmation of product radionuclide concentrations during production, particularly with respect to Heavy Mineral Concentrate product and associated transport and shipping requirements.

Verification of Code Requirements

The Australian Radiation Protection and Nuclear Safety Agency's Code of Practice for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing would be applied as a condition of a Management licence issued to Kalbar. This Code provides for radiation protection in mining and mineral processing industries and for protection of human health and the environment from the effects of radioactive waste from mining and mineral processing.

The Radiation Management Plan, Radioactive Waste Management Plan, and Radiation Environment Plan submitted at the time of application for any Management Licence sought by Kalbar are effectively operational statements of how Kalbar intend to achieve compliance with the requirements of the *Radiation Act 2005*.

As the project develops and matures, and additional information in known regarding the project, such Plans are subject to agreed changes with the department in order to optimise the radiation protection efforts and achieve the desired regulatory outcomes. As living documents, the department would assess the performance of Kalbar against the requirements of the *Radiation Act 2005*, the ARPANSA Mining and Transport Codes, and the Plans.

As a general rule, it is only Codes of Practice (such as the Code of Practice for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing) that are applied as formal conditions of licence. DHHS will be using the *Guide* as the basis for Kalbar submitting a Radiation Environment Plan. This will be the first time the *Guide* has been formally used by the department in this way.

Inter-Agency Cooperation

The department acknowledges that there are several differing and sometimes competing requirements on an operational minesite, such that actions which may be introduced to mitigate for one form of hazard may alter another potential aspect of an operational mine. The department is committed to working with and other Victorian Government agencies (such as DEDJTR and the EPA) to ensure that if any proposed radiation mitigation measures are required to be introduced that such does not compromise any requirements imposed by either DEDJTR or the EPA. It also recognises the need to liaise with the relevant local government in mining areas as a conduit to ensure community concerns are addressed.

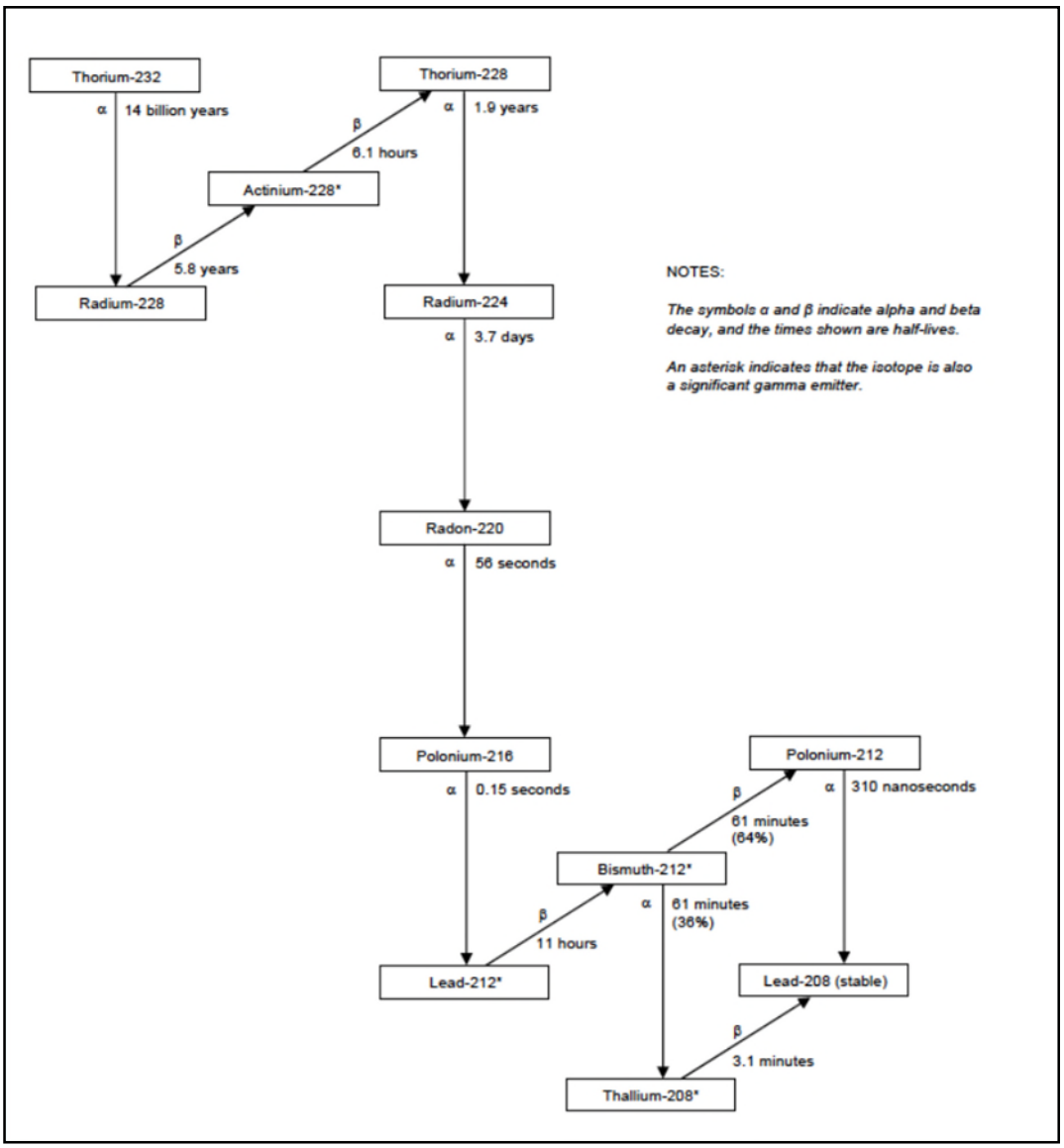
Comments on the Independent Review Report commissioned by the Panel

The department notes the provision of the Independent Review Report by Dr Ken Joyner to the Panel.

The department views the report provided by Dr Joyner constructively. The identification of potential exposure to the public via ingestion of animal or animal products shall be assessed by the department at the time of submission of the Management licence application by Kalbar Resources. The department will require that Kalbar Resources to address this potential radiation exposure pathway.

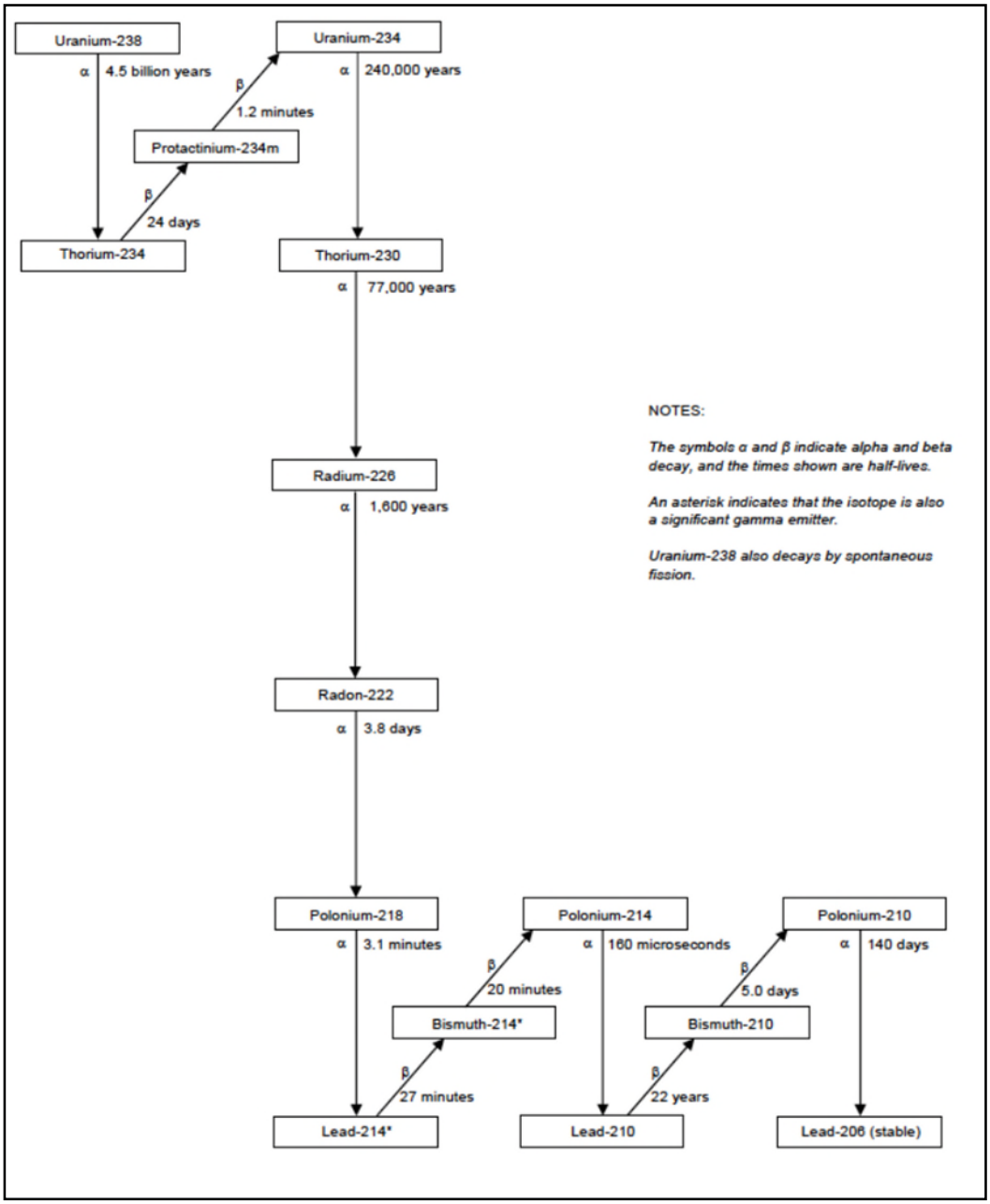
APPENDICES

Appendix 1: Thorium Decay Chain



Source: Argonne National Laboratory, EVS Human Health Fact Sheet, August 2005

Appendix 2: Uranium Decay Chain



Source: Argonne National Laboratory, EVS Human Health Fact Sheet, August 2005

Appendix 3: Radiation Dose Limits Prescribed in Schedule 4 of the Radiation Regulations 2017

Table A—Ionising radiation dose limits for occupational exposure

Circumstance	*Dose limit*
Receipt of ionising radiation doses in any 60 month period	Effective dose of 100 millisievert
Receipt of ionising radiation doses in any 12 month period	Effective dose of 50 millisievert
Receipt of ionising radiation to the lens of an eye of a person in any 60 month period	Equivalent dose of 100 millisievert
Receipt of ionising radiation to the lens of an eye of a person in any 12 month period	Equivalent dose of 50 millisievert
Receipt of ionising radiation to the skin of a person in any 12 month period	Equivalent dose of 500 millisievert averaged over 1 cm^2 of any part of the skin regardless of the total area exposed
Receipt of ionising radiation to the hands and feet of a person in any 12 month period	Equivalent dose of 500 millisievert

Table B—Ionising radiation dose limits for public exposure

Circumstance	*Dose limit*
Receipt of ionising radiation doses in any 12 month period	Effective dose of 1 millisievert
Receipt of ionising radiation to the lens of an eye of a person in any 12 month period	Equivalent dose of 15 millisievert
Receipt of ionising radiation to the skin of a person in any 12 month period	Equivalent dose of 50 millisievert averaged over 1 cm^2 of any part of the skin regardless of the total area exposed