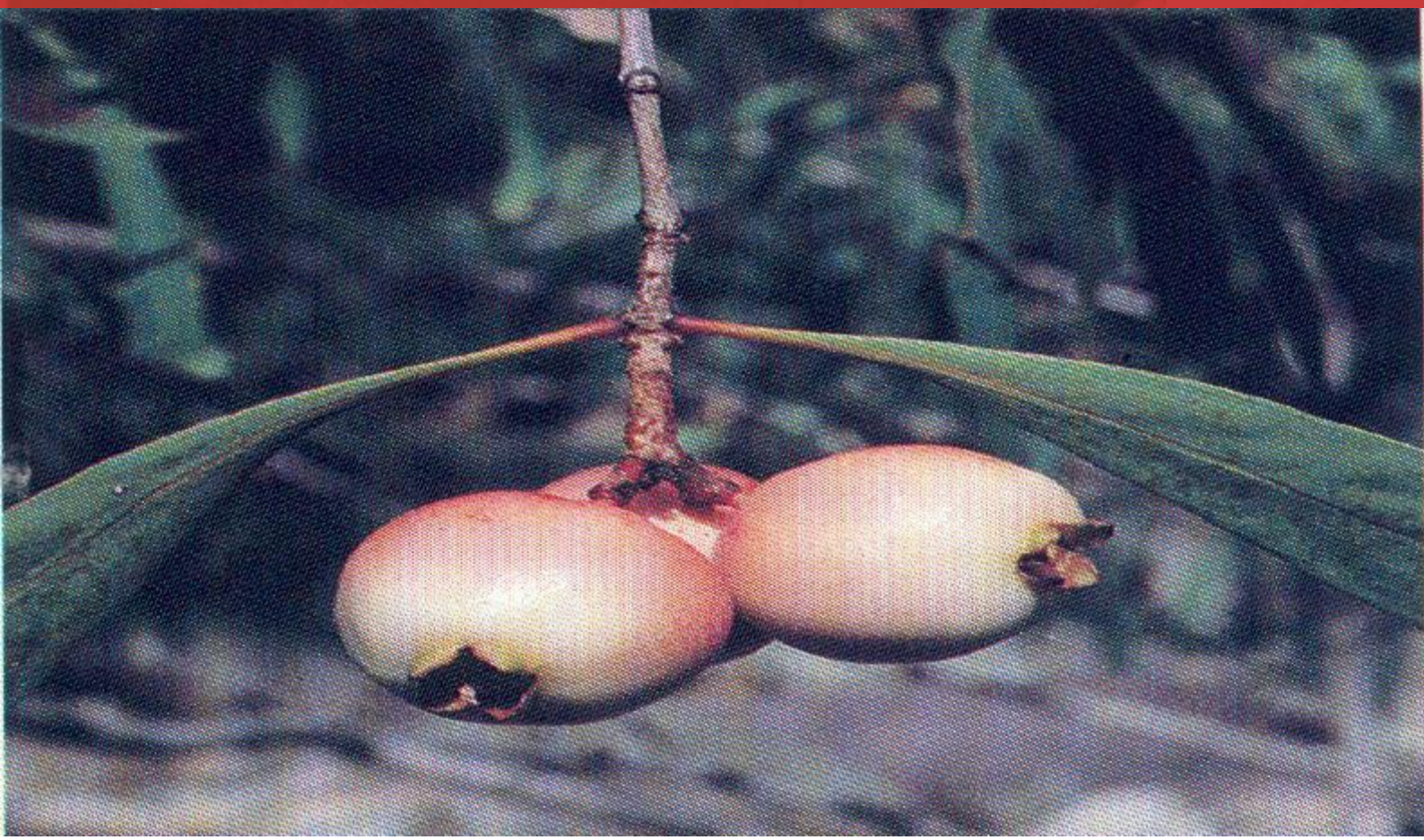
Radiation Management Plan

Rum Jungle Mine Rehabilitation



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DOCUMENT CONTROL RECORD

Job	EZ18228
Document ID	ID 182092
Author(s)	Bruce Ryan

DOCUMENT HISTORY

Rev	Reviewed by	Approved by	Issued to	Date
1	Glen Ewers	Glen Ewers	DPIR	13/09/2019
2	Mitchell Thompson	Glen Ewers	DPIR	25/11/2019
3	Jackie Hartnett	Glen Ewers	DPIR	25/11/2019

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Acronyms

ALARA	as low as reasonably achievable
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
Bq	Becquerel
DPIR	Department of Primary Industry and Resources
EIS	Environmental Impact Statement
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
LSA	low specific activity
mSv	milliSievert
NT	Northern Territory
PPE	personal protective equipment
RDP	radon decay products
RMP	Radiation Management Plan
RSO	Radiation Safety Officer
SRA	Senior Radiation Advisor
µSv	microSievert

1 INTRODUCTION

1.1 Background

The Rum Jungle deposit is approximately 75 km south-west of Darwin in the Northern Territory and was mined for copper and uranium between 1954 and 1971. The Rum Jungle mine severely impacted the environment on site, and downstream of the mine along the East Branch of the Finniss River, and the Finniss River itself. The site was effectively abandoned after mining had ceased with no significant efforts to rehabilitate the disturbed areas. Community concerns about the downstream environmental impacts of the site grew through the 1970s and ultimately a rehabilitation program for Rum Jungle was instigated by the Commonwealth and Northern Territory Governments.

1.2 Rehabilitation

The rehabilitation program was started in the early 1980s and the works were originally conceived to have an effective life of at least 100 years. A three-layer cover system was constructed for the overburden heaps (Whites, Intermediate and Dysons). The tailings were placed in the bottom of Dyson's open cut pit and covered with heap leach material, contaminated soil and other material, before placement of a final clean cover layer. Water in the Whites (Main) and Intermediate open cut pits was partially treated to establish a layer of clean water overlying a denser layer of contaminated untreated water (Kraatz, 2004).

The rehabilitation work was completed in 1986. One of the objectives was a reduction in public health hazards, in particular the reduction of radiation levels (NT Department of Mines and Energy, 1986). Recent assessments have indicated that the rehabilitation works, in particular the covers over the waste dumps, have deteriorated (increased infiltration and oxygen penetration) and the flux of metals may have started to increase.

1.3 Purpose

To mitigate the above, a new stage of site rehabilitation is proposed. That project will require movement of radioactive materials The intent of this document is to ensure the Rum Jungle rehabilitation project meets all of its regulatory obligations for the management of radiation and radioactive materials at the site during the construction and excavation project. Compliance with this plan will ensure that radiation exposure to contractors and members of the public is minimised and kept *as low as reasonably achievable* (ALARA), as defined by the International Commission on Radiological Protection (ICRP) – the premier international body for radiation protection.

1.4 Scope

This Radiation Management Plan (RMP) addresses the potential radiological risk and necessary mitigation measures associated with the excavation, and the transport and placement of radiologically-contaminated materials at the Rum Jungle site. It provides mechanisms for the safe management and control of radiological exposures likely to impact humans. It outlines the systems and processes that will be put in place to ensure compliance with standards and regulatory requirements relating to radiation protection.

The radiation residual risks associated with this excavation and construction project are low to medium (see Risk Register in the EIS); this is because much of the material encountered is of low radioactivity. This RMP has been prepared according to this low risk category and to meet the requirements of ARPANSA (2005).

This RMP does not cover post-rehabilitation activities that may occur onsite.

2 SITE MANAGEMENT

2.1 Personnel

2.1.1 General

The following is the anticipated management structure for the proposed works at the Rum Jungle:

- Senior Management
  - Project Manager
  - Contract Manager
- Professional
  - Project Engineers, including Quality Control
  - Surveyors
  - Health, Safety and Environment
  - Radiation Advisor (see below)
  - Radiation Officer (see below)
  - First Aid
- Supervision
  - Superintendents and Supervisors
- Tradesman
  - Vehicle Maintenance
- Operators/Technicians
  - Medium and heavy vehicle operators
  - Barge Operators
  - Weed and Fire Control
  - Security
  - Trainees
  - Soil Technicians

As a rule, contractors whose occupational exposure to radiation may exceed a radiation dose of 5 mSv per year are declared 'designated' workers and their exposure is closely monitored. For this project, all contractors will be designated workers.

All work will be completed on day shift. Contractor employees will work 5 x 12 hour days, and all personnel (except for security staff) will be accommodated off site.

2.1.2 Radiation-related

There will be two Government-appointed roles that relate specifically to radiation – a Senior Radiation Advisor (SRA) and a Radiation Safety Officer (RSO). The presence of a RSO will be required for the entire duration of the works. However, a SRA will visit the site weekly and will:

- Be present during the initial personnel inductions to ensure that safe working procedures have been adequately discussed with workers

- Implement and maintain the radiation monitoring(as per Section 7), including
  - Weekly area and personal radiation measurements
  - Maintaining data collection equipment
  - Downloading and managing radiation data
- Conduct inspections at least weekly, to ensure that safe working practices and records are being maintained
- Be available for discussion of any issues and potential safety concerns that arise
- Brief the management on appropriate radiation safety oversight matters
- Conduct and oversee the close of project radiological schedule including all equipment clearances.

2.2 Equipment

Associated equipment types are as follows:

- 4 x excavators
- 7 x Cat 777 (60 m^3 capacity)
- 2 x graders
- 2 x 835 compactor
- 2 x 825 compactor
- 3 x smooth drum rollers
- 8 x B-double road trains (30 m^3 capacity)
- 1 x D10 dozer with tine
- 1 x spreader
- 2 x water trucks
- 1 x fuel truck
- 1 x maintenance truck
- 1 x material movement truck
- 6 x light vehicles

3 EXPOSURE PATHWAYS

The history of the Rum Jungle mine site suggests that the main radionuclides of concern for this assessment are members of the uranium decay series. Radiation exposure only occurs when there is a pathway or exposure route between the radioactive material and the person. There are two general types of exposure, external and internal. External exposure occurs when the source of radiation is outside of the body. An example is the exposure received during a medical x-ray. Internal exposure arises from radioactive material inside the body. The most common ways that radioactive materials enter the body are by inhalation (breathing) or ingestion (swallowing).

3.1 External exposure – gamma radiation

The external exposure pathway at the Rum Jungle site is gamma radiation from radionuclides in soils, rocks and mining residues. Possible pathways for external gamma radiation exposure from the project include:

- Working in areas of elevated gamma levels
- Working in areas of any exposed mineralised materials
- The moving and potential handling of radioactive material from overburden area to storage sites, and then back into the excavation.

In addition, with the movement and handling of radioactive contaminated material as part of this operation, surfaces of vehicles and plant material will become contaminated with radioactive material. Sometimes, this contamination is not easily detected, as the metal surrounding the radioactive material will shield it from detection especially if the material enters cracks in a vehicle's chassis.

3.2 Internal exposure – inhalation of radon decay products

Radon-222 (^{222}Rn) is a radioactive noble gas in the uranium decay series and the immediate progeny of radium-226 (^{226}Ra). Gaseous radon emanates from soil grains and rocks following ^{226}Ra decay. It then diffuses through the interstitial soil space and is exhaled from the ground surface to the atmosphere, where it is dispersed by diffusion and by wind currents.

Airborne radon concentration shows large seasonal and diurnal variations as well (Bollhöfer et al., 2004; Martin et al., 2004; Lawrence, 2005). These are caused by meteorological parameters such as wind speed and direction, rainfall and humidity and barometric pressure. Day-to-day variations can be quite large and average daily airborne radon concentrations can vary by a factor of 25 in extreme cases (Bollhöfer et al., 2004). The average radon concentration between 9.00 -18:00 hrs (daytime) will only be approximately one quarter of the average radon concentration during the night time (20:00-9:00 hrs) (Bollhöfer et al., 2007).

Inhalation of radon gas itself does not contribute significantly to one's exposure because it is immediately exhaled. The main contribution to dose is from the inhalation of radon decay products (RDP) in air. Some of the inhaled RDP are retained in the soft tissue of the lung, with the subsequent alpha decay delivering a radiation dose to the respiratory system.

The pathways of any significance for the inhalation of radon decay products during construction will be working in areas with above background ^{222}Rn emanation levels or ^{222}Rn in air. These areas have been defined in the Radiological Hazard Assessment Report.

3.3 Internal exposure – inhalation of dust-bound radionuclides

The inhalation of *long-lived alpha activity* radionuclides contained in or on dust can contribute to the radiation dose received at/or near a radiologically contaminated site. This pathway has the potential to be a major conduit for dose during the disturbance of this contaminated material at the Rum Jungle site.

3.4 Internal exposure – ingestion of radionuclides

Radioactive contamination can be transferred from hands to mouth when eating, drinking or smoking or through poor personal hygiene.

The current Australian Drinking Water Guidelines (NHMRC, NRMMC 2011) recommend a screening level for radiological quality of drinking water of 0.5 Bq/L for both gross alpha and gross beta activity. It was reported by Tropical Solutions (2008) that the activity in Intermediate Open Cut and Main Open Cut pit waters is above this screening level. These pits will not be used for drinking water supply.

The accumulation of radionuclides in bushfoods and their consumption can be an important exposure pathway. Bushfoods common to Rum Jungle site include pigs, fish from the East Finniss River, terrestrial fruits and vegetables, including passionfruit and yam, which can be found growing at the site. It is recommended no bush foods are consumed by workers whilst engaged in this project.

3.5 Summary

Table 1 below presents possible sources and pathways for radiation exposure at the Rum Jungle mine site during construction.

Table 1. Summary of sources/pathways of radiation exposure

Source	Pathway	Exposure type
Surface exposure of radioactive material	Working on top of, or with, exposed elevated radiological material	External gamma
Radioactive material brought to surface during excavation etc.	Airborne material from disturbance	Inhalation of dust
	Handling of radioactive waste material	Ingestion
	Working near excavations	External gamma Inhalation of dust
Handling of radioactive waste material	General handling of radioactive waste material or stockpiled material	Inhalation of dust
		Ingestion
		External gamma
Airborne radon gas and its decay products	Radon decay product build-up in confined spaces near material	Inhalation of RDP

4 DOSE LIMITS

4.1 Context

Fundamental to radiation protection is the implementation of a system for controlling the risks associated with radiation. Although risks associated with the project are extremely low, a system for radiation protection is still required, as recommended by the International Atomic Energy Agency (IAEA) in their Basic Safety Standards. The system should be graded to allow implementation according to risk.

The system of radiation protection will follow the basic principles recommended by the International Commission of Radiological Protection (ICRP) and adopted in the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) National Directory of Radiation Protection:

- The principle of ***justification***: Any decision that alters the radiation exposure situation should do more good than harm. The justification for undertaking the rehabilitation of the Rum Jungle site is that it will provide a net positive benefit to society predominantly from the potential reduction of radiation exposure to members of the public whilst using or visiting the Rum Jungle Site.
- The principle of ***optimisation*** of protection: the likelihood of incurring exposures, the number of people exposed, and the magnitude of their individual exposures should all be kept *as low as reasonably achievable* (ALARA), taking into account economic and societal factors.

These radiation protection arrangements have been designed to comply with all relevant legislation, including the *Australian Radiation Protection and Nuclear Safety Act 1998*, RPS F-1 (2014); RPS C-1 (2016); RPS G-2 (2017) and the NT *Radioactive Ores and Concentrates (Packaging and Transport) Act* and regulations.

4.2 Critical groups

Four critical groups exist for the project:

- Critical Group 1 (construction workers): On site for the duration of the construction period.
- Critical Group 2 (Traditional Owners): Taking into account the ceremonial, tourism or any future potential customary harvesting activities.
- Critical Group 3 (people living 5 km downstream): Receiving the bulk of the dose from ingestion of aquatic food items.
- Critical Group 4 (general members of the public).

4.3 Dose limits and reference levels

The dose limits for radiation workers are:

- in any period of 5 years, an average effective dose of 20 mSv per year; and
- in a period of 12 months, an effective dose of 50 mSv.

Reference levels for workers are:

- in any period of less than 12 months, but not less than 1 month, an effective dose of the amount which is the product of 50 mSv and the ratio of that period in weeks to 52 weeks; and
- in any period of less than 1 month, an effective dose of 1/12 of 50 mSv.

The dose limits for a radiation worker who has notified her employer that she is pregnant are:

- for external radiation exposure, an equivalent dose to the surface of her abdomen for the remainder of her pregnancy of 1 mSv total (external and intakes) as per RPS C-1(2016); and
- for internal radiation exposure, 1/20th of the annual limit on intake determined by reference to the values set out in the publication entitled *Dose Coefficients for Intakes of Radionuclides by Workers* (ICRP Publication 68, 1994)

Persons under the age of 16 years are, as per RPS C-1 (2016), not allowed to work in a controlled area under any circumstances. They may visit radiologically-classified areas for educational purposes, provided that management, SRA or RSO accompanies them.

The total effective dose equivalent to individual members of the public should not exceed 1 mSv in a year, exclusive of the dose contributions from background radiation.

5 CONTROL OF RADIATION EXPOSURE

DPIR is committed to maintaining the safety of its employees and contractors through its Health and Safety Policies and to minimising environmental harm through its Environment Policy. These commitments encompass all operational risks associated with the project including radiation. In addition, DPIR will further commit to ensuring that any radiation dose to workers, the public and the environment are in accordance with the ALARA principle.

In this section, a number of control measures are described to minimise radiation exposure to workers at Rum Jungle site. All radiation controls implemented will follow the Department of Primary Industry and Resources (DPIR) general risk and hazard management system, where the treatment of all risks will follow the hierarchy of controls:

- Elimination
- Substitution
- Engineering controls
- Administration (procedural) controls
- Personal protective equipment (PPE).

5.1 Responsibilities for management

To ensure its commitment to the safety of its employees and the environment is fully implemented, DPIR will allocate responsibilities to key staff members and/or consultants as appropriate.

5.1.1 Project Manager

The Project Manager has the overall responsibility for radiation protection at their construction site. Specifically, this includes responsibility to:

- Provide the necessary support to enable their staff to implement all aspects of this RMP and allocate funds, materials and equipment where appropriate to address requirements.
- Allocate the necessary resources such that company operations and procedures are in compliance with relevant legislation and codes.
- Have radiation protection as a primary consideration in project planning with respect to the overall development of the project, the administration of work schedules and the procurement of machinery, plant or equipment.

5.1.2 Health, Safety and Environment Professional

The Health Safety and Environment Professional will work closely with the SRA/RSO to:

- Implement the radiation management and radioactive waste management procedures detailed in this document.
- Ensure sufficient and adequate PPE is issued to all staff.
- Ensure that radiation work in all areas is carried out safely.
- Provide inductions and appropriate training in radiation safety at a local level with the SRA/RSO.
- Undertake monitoring for radiation exposures.

- Assess risks of any altered procedures involving radioactive materials prior to implementation.
- Report and record any radiation incidents or accidents.
- Direct decontamination procedures in the event of a spill.
- Implement local emergency procedures and working rules.
- Understand the regulations, codes of practice and local rules relevant to their work and, when informed by a female employee that they are pregnant, make modifications to their work to ensure their dose will not exceed an additional 1mSv in one year via all pathways.

5.1.3 Contractors

All contractors on site have the responsibility to:

- Follow radiation protection and waste management practices as directed and comply with legitimate instructions related to these.
- Participate in radiation training programs as directed.
- Make proper use of plant and equipment supplied for radiation protection, or for the monitoring or assessment of radiation exposures.
- Not engage in any careless or reckless action which might result in unnecessary radiation exposure to themselves or others, or compromise the management of radioactive waste.
- Report any defects of which they become aware, in plant equipment or procedures, which may compromise radiation protection or the management of radioactive waste.
- Report all incidents or accidents.
- Advise of previous employment involving occupational exposure to radiation, and cooperate in obtaining records of such previous exposure.
- If a female employee or contractor becomes pregnant they must, as soon as is practicable, notify the manager of the site.

5.2 Administrative controls

The implementation of administrative controls is based entirely on risk. As this project is considered a medium to low risk operation, only basic administrative controls are deemed necessary. Those that will be implemented include:

- The area immediately surrounding the excavation areas and any stockpiled radioactive material will be designated as controlled areas.
- All workers will be classified as ‘designated’.
- Relevant standard operating procedures will be developed as required.
- Induction for all operational personnel, including basic radiation information and guidance in personal protection and management.
- Training will be undertaken as detailed in Section 8.
- Housekeeping and personal hygiene standards.

- Personal Protective Equipment will be issued, including disposable P2 dust masks for use during dusty conditions, gloves for handling radioactive material, and work clothing that will be removed and washed at the end of the day.
- Radiation warning signs will be installed as required.

5.3 Management measures

5.3.1 Minimising external gamma radiation exposure

A key risk associated with the remediation of a radioactive site is that not all areas within the project area with elevated radionuclide content are identified prior to works commencing. Consequently, a Radiological Hazard Assessment (an appendix of the EIS) was undertaken that covered all three sites where mining activities had occurred.

For known sites, the basic principles for radiation protection from external sources will be applied:

- Minimise TIME spent near the source
- Maximise the DISTANCE from the source, and
- Construct SHIELDING between source and workers if necessary.

In the context of current activities at the Rum Jungle site, specific control measures will include:

- Any radioactive material that is stored will be kept in one storage area that is clearly delineated, sign-posted and remote from general occupied areas.
- Highly radioactive material will be identified as such and covered with metal lids or equivalent shielding and placed in a designated area at low occupancy areas if storage is necessary.
- Highly radioactive material will not be kept in offices or other occupied areas.
- If workers are unsure whether material they are working with is radioactive, the RSO will test it using a radiation contamination meter.

Plant and equipment clearance

All equipment that has potentially been exposed to contaminated material (including plant air-conditioner filters and engine air filters) will be cleaned and checked for contamination before being allowed to leave the project area at the completion of the works program. The equipment will be decontaminated on a wash-down pad which drains into an on-site approved sump.

There is no predictable rule as to whether the contamination could be in or on the equipment. Therefore, in each instance, there needs to be an assessment by a competent person as to the likelihood of concealed contamination, the degree of contamination, and the risk from that contamination to persons handling the equipment.

A radiation clearance level has been set at 0.4 Bq/cm^2 alpha for all equipment. No piece of equipment shall be allowed to leave the site without a completed radiation clearance certificate and written approval from the Project Manager. Results of these clearance survey measurements will be recorded.

Non-mineral radioactive waste

It is not expected that significant amounts of non-mineral radioactive waste material will be generated as a result of this work; however, some radiologically-contaminated material may be transported and stored (limited storage for reuse on site) within the project boundary. Wastes generated may include:

- Material from wash-down areas after equipment decontamination
- Airborne dust affected materials
- Contaminated PPE.

The contaminated waste material throughout the entire project area will be treated as low level radioactive waste until proven otherwise. Empty sample bags, used PPE, and other miscellaneous waste are unlikely to be contaminated to the extent that they are considered a 'radioactive waste' material requiring special disposal arrangements. These wastes should be disposed of in a licensed landfill. Any sumps containing contaminated material from wash-down areas will be allowed to dry and covered with at least 1m of compacted clean soil cover.

5.3.2 Inhalation of radioactive dust material

During the excavations and the construction of the Waste Storage Facility the generation of dust will occur. Under these circumstances, the radioactive dust material will be minimised predominately through engineering controls. This may include the provision of a dust suppression system that either involves water to prevent dusting or ventilation to remove dust from work areas.

In addition to this requirement the following administrative control measures will be implemented:

- Radioactive material will be moved only during times of low wind.
- Machinery will have air-conditioned cabins with high-efficiency particulate air filters to limit occupational exposure during loading.
- Whenever possible, workers will be positioned up-wind from any dust generating activities.
- Dust masks will be provided to all workers and required to be used during dusty conditions.
- Wetting down areas of dust generation, wherever possible.

5.3.3 Ingestion of radioactive material

Good personal hygiene practices are an essential part of any system to minimise ingestion of radioactive materials. The following personal hygiene control measures will be actively implemented:

- Use of gloves when handling radioactive material
- Washing of hands and face before eating, drinking or smoking
- Washing of hands and face and other exposed skin surfaces immediately after handling radioactive material
- Wearing of designated field clothing
- Showering and changing at the end of each day
- Regular cleaning of work areas used to handle radioactive material
- Use of plastic bags for any radioactive material samples to minimise the spread of contamination.

These requirements will form part of the site induction and be posted in visible locations. In addition, contamination can enter the body through any open wounds. It is therefore important to keep such wounds covered at all times when working.

5.3.4 Internal exposures to inhaled radon decay products

Radon decay products can only present an exposure risk if they are allowed to accumulate in a sealed area or location with little or no air movement. In open spaces, natural convection currents and wind all ensure that exposure is minimised. For situations where there is a risk of accumulation, additional control measures will be required.

6 TRANSPORT MANAGEMENT

The proposed method of transport of radioactive materials complies with the Code of Practice for the Safe Transport of Radioactive Materials (ARPANSA, 2018). All references to tables, figures or paragraphs in this section have been derived from this code of practice and the N*T Radioactive Ores and Concentrates (Packaging and Transport) Act.*

6.1.1 Material type

The contaminated materials being excavated from the Rum Jungle mine area are defined as low specific activity (LSA) type I materials as per the following definition:

LSA-I (Para. 409)

- *Uranium and thorium ores and concentrates of such ores, and other ores containing naturally-occurring radionuclides which are intended to be processed for the use of these radionuclides;*
- *Natural uranium, depleted uranium, natural thorium or their compounds or mixtures, providing they are un-irradiated and in solid or liquid form;*

These materials will be under exclusive use, therefore the LSA-I materials will be classified as an Industrial Package Type 1 (IP-1). The Code of Practice specifies that IP-1 material may be transported unpackaged when under conditions specified in para. 520, which specifies that:

- *All unpackaged material other than ores containing only naturally-occurring radionuclides shall be transported in such a manner that under routine conditions of transport there will be no escape of the radioactive contents from the conveyance nor will there be any loss of shielding;*
- *Each conveyance shall be under exclusive use.*

IP-1 shipments have no activity limit for conveyances by road. The quantity of LSA material in a single Type IP-1 shipment shall be so restricted that the external radiation level at 3 m from the unshielded material does not exceed 10 mSv/h (para. 517), which will be the case for material being brought in to Rum Jungle from Mount Burton.

Placarding of transport vehicles (haul trucks) will comply with LSA-I (IP-1) codes of practice and signs will be clearly displayed on both external lateral walls of the vehicle and on the rear wall.

6.1.2 Spill management

The impact of spillages of radioactive waste solids containing radioactive materials will be minimised as much as practicable utilising the following practices:

- The SRA/RSO shall be informed immediately
- Earthen bunds and signage will be placed around work areas that may contain the radioactive material
- The material shall be isolated
- The material shall be cleaned up with approved equipment
- A radiation clearance survey shall be performed by the SRA/RSO or approved delegate
- Education and training of workers in the importance of minimising spillages and prompt reporting of incidents.

6.1.3 Incidents

All radiation-related incidents must be reported to the Project Manager, Health Safety and Environment Professional and the SRA/RSO. If required, the SRA/RSO or nominated delegate will:

- Implement spill management procedures
- Investigate the incident
- Undertake monitoring where it is deemed necessary
- Calculate exposures to workers/public
- Determine reporting requirements
- Provide advice on mitigating actions, decontamination etc.
- Provide counsel to workers involved
- Record incident and corrective actions.

7 MONITORING

Legacy uranium mine sites, such as the Rum Jungle mine site, are an example of an existing exposure situation, which are exposure situations that already exist when a decision on control has to be taken. For this type of situation, the ARPANSA RPS G-2 (2017) recommends that source related reference dose levels, set typically in the range 10 mSv per year, should be used to restrict individual dose. This can be done, for example, by removing contaminated material and modifying exposure pathways or by restricting access and thus reducing the number of exposed people.

While the overall operation represents an existing situation, with most materials below regulatory dose limit guidelines, the work involved in constructing a waste storage facility is a planned exposure and is subject to the recommendations and dose limits in the ARPANSA RPS G-2 (2017) and *Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards* (IAEA, 2014).

In accordance with the medium to low risk associated with this project at Rum Jungle mine site, a monitoring plan is outlined below.

7.1 Waste placement

A materials management plan will be developed for the project and will include a detailed placement schedule of all radioactive rock and soil. The placement schedule of this waste material will include the volumes (cubic meters) and the allocated dumping locations based on the material's characterisation. The plan will be reviewed and updated at least every three months to ensure both the implementation of the detailed dump designs in the field, and the ongoing recording of the placement of different waste types, adhere to the plan.

The waste materials' compositional elements will be assessed through the monitoring of geochemical and geotechnical characteristics of placed waste on an ongoing basis, with the more frequent monitoring of other parameters – i.e. surface and ground waters. The results will be used to monitor the performance of measures put in place to prevent and mitigate any potential radiological issues. Such monitoring will be through:

- A program of progressive sampling and characterisation to identify radiologically-enhanced material.
- Regular visual inspections of the working areas, looking for any changes which would include any evidence of lithological changes, colour changes, mineralisation etc. and to identify contaminant issues.
- Tracking material placement so that the mass of inert waste and material with radiological risks delivered to the waste storage facilities is recorded and placed in appropriate cell.

If additional radiological material is found during the rehabilitation process, the material balance and disposal information collected will give guidance in determining how this waste will be encapsulated to minimise the potential radiological issues.

7.2 Radiation monitoring (internal and external)

Monitoring will include the collection of dose rate conditions on site and the assessment, interpretation and evaluation of this information (area monitoring). This, together with information on exposures to individuals (individual monitoring), will assist in establishing and enforcing safe working practices and engineering standards, and that radiological hazards are under effective control in a way which complies with international best practice and regulatory requirements.

The first type of monitoring (area) is based on survey measurements taken on the site where work is being undertaken. The second (individual) is based on measuring exposure to radioactivity, using personal dosimetry.

Routine monitoring is the foundation of the operational monitoring program, and consists of planned monitoring that confirms the radiological conditions and levels of individual dose are meeting radiation protection requirements and objectives. Radiation Safe Work Permits will be issued to conduct work in areas that are considered above normal radiation levels.

Task-related monitoring applies to a specific task, and can be used to provide data on the safe management of the task and inform decisions on protection techniques and their optimisation.

7.2.1 Routine area monitoring

The purpose of routine area monitoring is summarised above, and more specifically is to:

- Confirm effective control of sources of radiological hazards in all areas by the use of safe working procedures and engineering features
- Confirm the area classifications and any changes in radiological conditions
- Evaluate real and potential dose rates.

Nominated measurement points will be measured weekly by the SRA/RSO using high-sensitivity portable meters while excavation of materials are being carried out. The results will be recorded. Air samplers will be placed at strategic points to collect data.

7.2.2 Task-related area monitoring

Task-related area monitoring will use similar equipment to that described for routine area monitoring measurements. Dose reduction assessment monitoring for a specific activity or group of activities is an example of this type of monitoring. It is anticipated that this may occur at times when specific tasks are being undertaken during operational and remedial works. An example would be monitoring the immediate area around excavations, prior to entering these excavations.

7.2.3 Individual monitoring

This monitoring will consist of measurement of radiological exposure to an individual. Monitoring of occupationally exposed workers will be performed for selected personnel working in close contact with the contaminated materials. This will include the Project Manager and the individual responsible for the clearance surveys (the SRA/RSO or delegate). These individuals are expected to have closer contact with the radiological sources and will be monitored accordingly.

Personal monitoring will consist of having selected individuals using electronic dosimeters for effective (gamma) dose assessment. All designated workers will be required to wear Optically Stimulated Luminescence dosimeters which will be assessed at intervals of 12 weeks. Results of the individual monitoring will be recorded in compliance with regulatory requirements.

7.2.4 Dust monitoring

Both personal and area air samplers will be used to determine the concentration of long-lived, dust-borne, alpha emitters. Dust concentration measurements and determinations of radioactivity concentrations in the air will be carried out regularly to determine radioactive elements 'trapped' in or on dust. Dust monitoring and survey measurements will be also conducted along any haulage routes.

Filters will be submitted to a certified laboratory for analysis on a regular basis and the results shall be recorded in compliance with regulatory requirements.

7.2.5 Radon monitoring

Radon monitoring will be undertaken at the working sites. Thirty long-term passive radon/thoron radon gas monitors (RGMs) will be used across the Rum Jungle mine site for the duration of work. The start and end dates of the exposure of the track detector will be recorded and the monitors will be sent to an accredited laboratory. Results will be interpreted by the SRA/RSO.

Short term measurements will be taken with a radon monitor (RAD7) at selected sites at least once per week. This monitor will be portable with a direct read out, with a short time interval for integrating measurements.

The results of all radon monitoring will be recorded in compliance with regulatory requirements.

7.3 Clearance monitoring

The clearance limits on any rehabilitated works (if any) will be 1.15 µSv/hr (±20 %) based on full occupancy of 10 mSv per year.

If there is transportation and storage of any contaminated material, the storage site will require a high-resolution monitoring program for clearance of that site. Clearance monitoring will employ the same (or similar) portable instruments as those used for site monitoring.

Clearance surveys of any roadways used to haul contaminated material will be undertaken using contamination meters to ensure that no materials have been spilled during transport. Areas that need monitoring in particular are those where the potential for spillage is high, such as at corners and haul truck turnarounds. Results of these measurements will be recorded. The road clearance monitoring will be undertaken prior to the works starting at specified areas and will continue on a weekly basis until the works are completed. Visual checks for spilled materials will also be undertaken (at least daily) along roadways.

7.4 Water monitoring

Regular monitoring of surface and groundwater quality at both upstream and downstream locations of the waste storage facilities will take place in such a way as to provide early detection of any transport of radiological contaminants.

The water monitoring plan will include:

- Monitoring surface water quality for radionuclides and any other identified parameters downstream and upstream of the waste storage facilities
- Monitoring groundwater quality for radionuclides and any other identified parameters in aquifers surrounding waste storage facilities
- Management actions in the event that the monitoring results have exceeded the designated trigger values
- Allowance for increasing water monitoring (spatially and/or temporally) as is deemed necessary in response to any parameter changes
- Storage of all monitoring data in a database
- Investigation of long-term trends in water quality results within a required time frame
- Assurance that all water samples will be sent to a NATA-accredited laboratory for analysis

- Assurance that sampling frequencies, methods and parameters to be approved by regulator
- Advising relevant operational personnel if there are significant changes or non-compliances
- Procedures to ensure that all problems are swiftly addressed
- Compliance reporting to the regulator.

The monitoring data should be used to periodically assess the ongoing performance of the initially implemented management plans, and changes should be made if the required performance is not being achieved.

7.5 Record summary

All monitoring results and dose records will be documented and recorded in accordance with the tenets of good scientific practice. Records that will be kept may include any or all of the following:

- Radiation monitoring and survey data
- Equipment calibration information
- Quality assurance checks
- Radiation clearances issued (including radiation safe working permits)
- Radioactive material transport
- Sample analysis results.

These records may be provided to regulatory bodies upon request.

8 INDUCTION AND TRAINING

Training of all personnel in the principles of radiation protection specific to excavation and construction activities will be undertaken as part of the site induction. Signed records of these inductions will be kept by the company.

Suggested content for the radiation awareness section of the employee induction program is:

- Ionising radiation – types, quantities and units
- Biological effects of radiation exposures
- Natural background radiation – terrestrial gamma radiation, cosmic radiation, natural radionuclides in water and food and radon and radon daughters
- Radiation protection standards and regulations, including employee responsibilities and risks
- Potential health risks associated with ionising radiation
- Safe working methods and technique
- Use of protective equipment and clothing
- Importance and means of dust suppression
    - The use of water trucks, misters and sprays where necessary, in order to keep dust levels to a minimum
    - Covering of loads where necessary
    - The notification process, where excessive dust generation is visible
- Reporting of unusual occurrences
- Proper use, operation and care of personal monitoring equipment;
    - Site procedures around change of work clothing and showering after shift
    - importance of personal hygiene in limiting intake of radioactive materials
- Need for notification of any health problem
- Procedures for handling spills of radioactive materials.

A copy of the *Radiation Workers Handbook*, as published on the Australian Uranium Association website, will be made available at site for all personnel to access.

Additional radiation safety briefings may be given as the occasion arises – e.g. as toolbox Meeting topics – to reinforce personal monitoring, dust control, spillage control, or site clearance control measures. The dates of these safety briefings will be recorded.

9 LEGISLATION AND GUIDELINES

All activities shall be carried out in accordance with relevant radiation legislation and statutory requirements.

9.1.1 Commonwealth

- *Protection of the Environment Operations Act 1997*
- ARPANSA 2005. Code of Practice on Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing. Australian Radiation Protection and Nuclear Safety Agency.
- ARPANSA 2008. Code of Practice on the Safe Transport of Radioactive Material. Australian Government.
- ARPANSA AND NOHSC 2002. Recommendations for Limiting Exposure to Ionizing
- ARPANSA 2014 Fundamentals for Protection Against Ionising Radiation Commonwealth of Australia
- ARPANSA 2016. Radiation Protection Series C-1 Code for Radiation Protection in Planned Exposure Situations
- ARPANSA 2017. Guide for Radiation Protection in Existing Exposure Situations. Radiation Protection Series G-2.
- *Radioactive Ores and Concentrates (Packaging and Transport) Act*
- ARPANSA 1992 (previously NHMRC Code) Code of Practice for the Near-Surface Disposal of Radioactive Waste in Australia.

9.1.2 Northern Territory

- *Radiation Protection Act*
- *Mining Management Act*
- *Radioactive Ores and Concentrates (Packaging and Transport) Act.*

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