Chapter 7
Human health and safety

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7 HUMAN HEALTH AND SAFETY

7.1 INTRODUCTION

This chapter considers the potential human health and safety impacts that could arise from the Ranger 3 Deeps underground mine (the Project). The systems of health and safety management and control will be based on those at the existing Ranger mine. Additional treatments that ERA will implement through project design, construction, operations and decommissioning to mitigate impacts on these health and safety risks are also described.

This chapter outlines the worker health and safety risks associated with the change in operations from open pit to underground mining and the new radiation risks with the potential to increase exposure to workers and the public.

The methods used to assess health and safety aspects for the Project were based on the EIS Guidelines, this includes:

- a summary and review of existing ERA health and safety management system and performance to date;
- identification of new practices or situations that may introduce new health and safety risks;
- assessment of the new health and safety risks;
- a description of the design and management methods for controlling risks; and
- assessment of the adequacy of the controls, ensuring that residual risks are acceptable.

A detailed discussion of the methods to estimate radiation doses is provided in **Appendix 8**, and a summary is provided in this chapter.

Assessment of potential health and safety hazards presented by the Project is undertaken with particular reference to the Safe Work Australia model for worker health and safety, the Rio Tinto approach to health and safety and the Code of Practice for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing (2005). All identified risks have been evaluated using the risk assessment method described in **Chapter 5**.

The human health and safety, including radiation issues, presented by the Project will be addressed separately under each of these main sections:

- the approach to health and safety (**Section 7.2**);
- key health and safety risks (**Section 7.3**); and
- mitigations (**Section 7.4**).

Chapter 2 describes the existing radiation environment, within the study area. Impacts and risks to the environment from radiation (the ERICA assessment) are addressed later in **Section 9.3**.

7.2 APPROACH TO HEALTH AND SAFETY

The health and safety of workers and the public is a primary goal for the mining industry, with significant improvements over recent decades. Underground mining, while generally considered to be more hazardous than other forms of mining, also continues to improve in the area of health and safety (see **Section 7.2.8**).

These improvements have been achieved through the implementation of a formal approach to health and safety built on safe workplaces, rigorous management systems, and an overall culture of health and safety. This requires commitment at all levels in an organisation. Energy Resources of Australia Ltd (ERA) has developed, implemented, and currently maintains, a formal approach to health and safety, making it a core value of the organisation; guiding all aspects of work and applicable to contractors, employees and visitors.

Broadly, health and safety are considered separately, with safety usually addressing the acute or short-term impacts and health covering the more chronic or longer term impacts. For example, vehicle accidents and rock falls are generally considered to be safety matters, while health is generally related to the longer term exposure risks such as noise induced hearing loss and long-term effects from exposure to toxic or hazardous materials. Generally, the two require different management approaches.

Protecting workers and the public from the effects of radiation is an important occupational health and public health issue in uranium mining, requiring particular management focus and attention.

7.2.1 Health and Safety in the Northern Territory

In the Northern Territory (NT), the applicable occupational health and safety legal requirements are:

- *Work Health and Safety (National Uniform Legislation) Act 2011.*
- *Work Health and Safety (National Uniform Legislation) Implementation Act 2011.*
- Work Health and Safety (National Uniform Legislation) Regulations 2011*.*

The legal requirements adopt the Safe Work Australia model and include a series of approved codes of practice.

ERA does, and will continue to, comply with the codes of practice (and other requirements), as a minimum, for all work activities.

7.2.2 Health and Safety Performance Standards

ERA maintains a Health, Safety and Environment management system, refer **Chapter 15**. This management system aligns with the standards to which we are certified (ISO 14001:2004 Environmental management systems and AS 4801:2001 Occupational health and safety management systems) and is designed along the principles of the "Plan, Do, Check and Review" continual improvement cycle.

Beneath this broader management system are a number of health and safety performance standards, which are provided in **Table 7-1**.

The management system and performance standards are consistent with the health and safety management systems and standards of our major shareholder Rio Tinto.

Table 7-1: Health and Safety Performance Standards

Health	Safety
Particulate and gas/vapour exposures	Isolation
Hearing conservation	Electrical safety
Manual handling and vibration	Vehicles and driving
Hazardous substances	Working at heights
Radiation	Confined spaces
Thermal stress	Cranes and lifting equipment
Fitness for work	Aviation safety
Legionnaire's disease	Underground safety
Travel and remote site health	Management of pit slopes, stockpiles, spoil and waste dumps
Occupational exposure limits	

7.2.3 Health and Safety Management at Ranger Mine

The management of safety at ERA is structured and formal with the implementation of the ERA performance standards as described in the previous section.

At a practical level, safety at ERA revolves around leadership. All leaders undergo general leadership training with specific attention placed on responsibilities, necessary skills (such as auditing, risk management and hazard identification) and leadership competencies (such as communication and consultation) for effective management of health and safety.

Engagement, consultation and communication between leaders, employees and contractors means that safety and health issues in the workplace are identified and rectified in the most effective and efficient manner, with issues best resolved by those who have identified them.

ERA also regularly conducts targeted safety and health programs to complement the health and safety management system. For example, recent programs include traffic safety and heat stress management. Key messages about the particular topics are communicated through team meetings and training sessions. The programs consider additional controls to reduce accidents, incidents or near misses.

ERA places particular attention on catastrophic risks, which are defined as hazards or risks that could potentially lead to fatalities. A set of critical controls for the management of these hazards and risks has been identified. These controls are subjected to a critical control monitoring program, where senior leaders audit their effectiveness and verify them in the field.

Implementation of the safety management system is regularly audited by internal personnel and independent external authorities. Audits are based on recognised standard methods and can focus on particular processes or systems, or target the adequacy and implementation of the management system as a whole (or part thereof).

The system is regularly reviewed and updated to ensure that it is effective and efficient at managing health and safety. An integral part of this review process is the incorporation of learnings and corrective actions from incidents and near misses.

7.2.4 Radiation Protection at Ranger

ERA has extensive experience managing radiation and exposures in uranium mining and processing and maintains an overriding commitment to radiation protection through its *Radiation Protection Policy*. The basis of the policy is the ERA core value of ensuring the safety and wellbeing of all employees and the protection of the environment. This translates to keeping radiation exposure to workers, the public and the environment as low as reasonably achievable (ALARA).[1]

The fundamental principles of radiation protection have been established by the International Commission on Radiological Protection (ICRP) which is recognised as the international authority on radiation protection. The ICRP has developed, over many years, a series of recommended standards for radiation protection, based on a system of dose limitation (ICRP 2007). The recommendations are universally incorporated into national laws and regulations and comprise three key elements:

- Justification – where a practice involving radiation exposure should only be adopted if the benefits of the practice outweigh the risks associated with the radiation exposure.
- Optimisation – where the radiation doses should be ALARA, taking into account economic and social factors (also known as the ALARA principle).
- Limitation – establishment of an upper limit on exposure.

Within the ICRP system for radiation protection, the ALARA principle is recognised as the most important element for the control and management of radiation.

Radiation dose limits apply to the total radiation dose from all exposure pathways (excluding natural background radiation and medical radiation), and are:

- 20 mSv per year for a worker (at work) averaged over 5 consecutive calendar years with a maximum of 50 mSv in any single year; and
- 1 mSv per year for a member of the public.

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1 ALARA - As low as reasonably achievable, with economic and social factors being taken into account.

For the public, doses may also be averaged over a five-year period; however, this is only allowable in special circumstances.

In Australia, there are national codes of practice relating to radiation protection in the mining or processing of radioactive materials. These are consistent with the international approach to radiation protection and are the:

- Code of Practice and Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing 2005 (ARPANSA 2005); and
- Code of Practice for the Safe Transport of Radioactive Material 2008 (ARPANSA 2008).

For the Project, radiation will be managed and controlled in a manner that is consistent with the ICRP system of radiation protection and these codes of practice, with a focus on optimising radiation doses through effective design and appropriate ongoing operational management systems.

7.2.5 Emergency Management

An important element of ERA's safety management system is the emergency response and disaster management system. This system consists of two components, i.e., the emergency response function and the business resilience function and is based on the requirements of International and Australian standards document on environmental management systems (Australian/New Zealand Standard 2004) and the Australian standard for health and safety management systems (Australian/New Zealand Standard 2001).

The emergency response function is managed by the emergency response team (which directly responds to a given situation). This team has a number of full time dedicated staff and is complemented with volunteers from the workforce. All members of the team receive ongoing training and participate in regular full scale and desktop exercises.

The current mines rescue team established for the exploration decline will be expanded to include team members from the underground mine workforce. The team will be led by full time emergency response personnel and will receive ongoing training in mines rescue, firefighting, first aid and first response.

The business resilience team has overall responsibility for recovery of the ERA site, this includes providing appropriate resources and support for the emergency response team.

7.2.6 Other Existing Management Systems

ERA maintains a number of additional hazard and risk management systems, as briefly described below.

7.2.6.1 Workplace Fitness for Work

Effective workplace health and safety involves assurances that employees are fit for work, and ERA has established a number of fit for work programs.

A fatigue management program has been implemented which covers:

- Training so that workers can identify the signs of fatigue in themselves and co-workers.
- Procedures which require constant communication between operators and supervisors or other staff.
- Equipment design in some cases, such as truck driving, which uses smart technology to detect whether workers require rest.

ERA maintains a strict policy on the use and effects of drugs and alcohol and has established a testing program where workers (employees and contractors) are randomly selected for testing at work. Use of illicit drugs and overuse[2] of alcohol is not tolerated and there is zero tolerance policy for workers who are found to breach this policy.

7.2.6.2 Employee Health Program

ERA runs a number of employee programs aimed at improving the overall health of workers. These programs include: healthy living; personal fitness; and fatigue management.

7.2.6.3 Risk Management

ERA maintains a risk management system (as outlined in **Chapter 5**, risk assessment), which is a standard company-wide method for systematically reviewing projects and identifying and quantifying risks.

For example, throughout the life of a project, there will be ongoing risk assessments, which deal with successively higher levels of detail in relation to a project. In this way, all new projects undergo a number of risk assessments at differing phases of the project in order to verify that risks are identified and properly managed.

7.2.6.4 Hygiene Monitoring and Management

Long-term exposure to dust, noise and chemicals may result in detrimental health impacts and therefore must be managed. ERA has a hygiene management plan that outlines the management measures, controls and monitoring for these hazards. All workers are made aware of the potential long-term hazards in the workplace and receive training as necessary. Ergonomic factors are also taken into account in the design of workplaces and in job assessments to minimise the potential for chronic musculoskeletal impacts on workers.

Hazardous chemicals are managed and used according to their safety data sheets and safe use instructions.

Workplace monitoring occurs to check the effectiveness of controls and to identify potential new hazards. This includes: regular inspections of workplaces; monitoring of noise, gasses and dust; and the maintenance of a hazardous substances inventory, together with a database of safety data sheets.

All ERA employees and contractors currently undergo medicals prior to commencing employment to provide an individual health baseline. These medicals are repeated every two years to track key health issues, including hearing loss and chronic musculoskeletal issues.

[2] An employee with a blood alcohol level of above zero at the commencement of work is deemed unfit for work.

7.2.6.5 Management of Change Program

Management of change is a mechanism to reduce potential risk of serious injury or fatality from a change to equipment or operations.

All changes to operations, plant layout, processing or mining methods, company structure, standards and work procedures undergo a review aimed at identifying potential health and safety issues with the change process. Resolution of the issues then forms part of the change management process and are implemented as part of the change.

7.2.7 Current Performance

7.2.7.1 Safety

Safety performance in the mining industry is usually measured over the longer term using lag indicators such as lost time injury frequency rate or all injury frequency rate with some companies developing their own performance measures. Lagging indicators are useful in that they provide an objective measure for comparison. Another way to measure safety performance is to use lead or positive performance indicators which are more subjective and provide an indication of preventative safety performance. These include measures such as number of safe work observations, number of safety audits, and training conducted.

Lagging indicators are generally used to compare performance between industries and companies. Lead indictors are usually used as internal measures of safety performance.

ERA lagging indicators are lost time and all injury frequency rates, scaled to 200,000 exposure hours. In 2013, the lost time frequency rate was 0.52 and the all injury frequency rate was 0.91. These measures are different to that typically used by other mining companies, which generally use the total recordable injury frequency rate per 1,000,000 exposure hours. Adjusting ERA's all injury frequency rate to the total recordable injury frequency rate shows that ERA has similar statistics to that reported[3] by other large mining companies operating in Australia.

In general, the mining industry in Australia is relatively safe. Safework Australia compared serious claims per 1,000 employees for the period 2010 to 2011. This showed that mining is approximately average, having less claims than manufacturing, construction, agriculture and transport, but having more than education and retail (Safe Work Australia 2013a; b). The performance rate for mining is reported as being similar to the health and community services and catering industries.

7.2.7.2 Radiation Protection

Radiation exposure of workers in the open cut mine[4] and processing plant at Ranger mine have been monitored under the current approved radiation monitoring plan, and doses have

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[3] Total recordable injury rate is reported by large mining companies in their annual reports.

[4] Active open cut mining from Pit 3 ceased in November 2012. Since that time waste rock and low grade ore have been returned to the mining void.

been calculated from exposure to external gamma radiation, long lived alpha emitting radionuclides in dust, and radon decay products.[5]

Overall, doses have been very low and well below the annual worker limits (refer **Section 7.2.5**) with the average annual dose to open pit miners being 2 mSv per year. Of this, the largest contribution is from gamma radiation (60%) with approximately equal contributions from radon decay products and dust (approximately 20% each).

In the processing plant, the annual average doses to operators is approximately 2.4 mSv per year, with the largest contribution from gamma radiation (about 60%), with dust contributing approximately 30% and radon decay products about 10%. Again, doses are very low and well below the annual worker dose limits.

7.3 ASSESSMENT OF RISKS

Health and safety issues fall broadly into two areas: hazards and risks. For this worker health and safety assessment, it is also important to review and discuss the health and safety hazards associated with the Project.

Hazards are defined as those issues that are likely to occur and for which controls must be implemented to eliminate or reduce the impacts of those hazards. For example, build-up of contaminants in the underground air is a hazard and the control is to provide adequate ventilation to reduce concentrations to acceptable levels. In this case, the acceptable levels are defined by internal exposure standards and recognised exposure limits.

Risk is defined as either an unforseen event or the failure of a hazard control. Using the example above, a risk may be that the ventilation system is inadequate or that it fails. Therefore the contingencies to minimise the risk would be to conservatively design the ventilation system to provide slightly higher ventilation rates and to have regular preventative maintenance of the ventilation system to minimise the risk of failure.

It is expected that most of the potential health and safety hazards and risks associated with the Project would be satisfactorily managed with the existing systems and controls that are currently in place at Ranger mine. This chapter therefore focuses only on the new activities that are expected to occur as a result of the Project. Activities that are already occurring on site, and are already being managed, are generally not considered further in this chapter (although a number are mentioned in the context of demonstrating successful hazard control that will be extended for the Project). It also includes an assessment of the radiological hazards associated with the Project.

5 An introduction to radiation and information regarding many of the terms in radiation protection is provided in **Appendix 8**.

This section outlines the key health and safety hazards and risks that have been identified as being important for the Project. These were identified by:

- reviewing the guidelines for the Draft EIS;
- including health, safety and radiation in the environmental risk assessment;
- comparing the Project with existing operations and identifying what is new; and
- industry experience.

7.3.1 Risk Assessment

The environmental risk assessment identified a total of 80 risks, of which 46 are associated with human health and safety. A description of the risk assessment method is provided in **Chapter 5** with additional discussion of the risks associated with the Project being provided in **Appendix 5**.

Of the 46 health and safety risks, 18 were identified as having a current (inherent) high (Class III) risk ranking and one had a critical (Class IV) risk ranking, these are provided in **Table 7-2**.[6] All remaining risks had either an inherent or residual low (Class I) or moderate (Class II) risk rating. A comparison of the current and residual risk profile shows that these risks have been reduced to 15 high risks and no critical risks with the identification of additional controls and treatments. The majority of these residual high risks are high consequence - low likelihood risks; that is, the consequence is always one or multiple fatalities and mitigation in these cases can only reduce the likelihood to as low as possible with the end ranking always being at least high.

The level of certainty associated with the overall risk ranking, based on the quality of data and information available, and the effectiveness of the treatments in mitigating the risk has also been included in **Table 7-2**.

The one health and safety risk identified as having critical (Class IV) current risk ranking was "*Workforce may be exposed to gamma radiation that exceeds the annual dose limit*" (TF3-04). This risk and the other identified radiation risks were subjected to a Bow Tie analysis to gain a better understanding of the extent, quality and effectiveness of mitigation measures being proposed. Details of the Bow Tie analysis are provided in **Appendix 5**, with the overview shown in **Figure 7-1**. The preventative and mitigation controls identified in this Bow Tie analysis may be deemed to be critical risk controls, i.e. they are controls associated with the most significant risks. As such these controls will be embedded in ERA management systems to ensure ongoing application. The controls for protection of workers from radiation are provided in **Section 7.4**, with details of how they will be incorporated into the existing ERA management systems provided in **Chapter 15**.

The remaining high (Class III) risks are grouped where relevant and discussed in more detail later in the section.

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[6] This table of risks includes a short summary of the treatments that will be used to manage each risk. With the large number of health and safety risks this additional column has not been included to allow the reader to quickly identify the relevant mitigations for each risk. This was not required in other chapters of the draft EIS where only a small number of high and critical risks were identified.

Table 7-2: High and critical current health and safety risks

Risk identification and title	Possible causes	Potential impacts	Treatments [1]	Risk ranking [2]		Certainty level [3]
				Current	Residual	
TA2-01: Person/fauna may fall into vent raise.	Open borehole during construction and decommissioning. Public access to borehole construction or decommissioning location.	Worker or public injury. Fauna mortality or injury.	Current working at heights standards Holes will be covered or cordoned off during construction. Access to the area by the public restricted.	III	III	C3
TB5-02: Brine transported from Pit 3 may react with the paste backfill.	Brine from Pit 3 into underground working chemically reacts with paste backfill.	Geotechnical stability of paste leads to mine instability.	Mine design has a buffer from Pit 3 to stoping areas. Inspections of paste fill when mining occurs adjacent.	III	III	C2
TB7-01: Ambient air quality in surface and underground work areas may exceed the level acceptable for worker health.	NOx emissions from the project power generations combined with existing operations. Building wake turbulence during certain meteorological conditions influences concentration.	Human health.	Power station designed with 25 m stack to improve dispersion. Monitoring for NOx in work areas. Trigger action response plan	III	II	C2
TB7-02: Primary ventilation system may not perform to design expectations.	Increased fleet above planned level. Poor maintenance of primary ventilation fan. Damage to primary fans from blast. Primary fans do not perform to specification.	Occupational exposure to dust, diesel particulates and fumes above the occupational exposure limit. Thermal stress to workforce.	Design of primary ventilation based on modelling with inputs for maximum possible diesel emissions, equipment temperatures and host rock temperatures Preventative maintenance Ventilation Management Plan. Refrigeration of air. Low emission diesel equipment.	III	II	C3
TB7-03: Secondary ventilation system may not provide acceptable air quality to all work places.	Poor installation. Poor maintenance of system. Bag tears not repaired. Changes to primary flow. Recirculation. Undersized for current mining locations (too many activities supported at once).	Occupational exposure to dust, diesel particulates and fumes above the occupational exposure limit. Thermal stress to workforce.	Ventilation Management Plan. Continuous ventilation monitoring stations. Preventative maintenance. Stope Ventilation Plan. Equipment selection. Operator training and competency.	III	II	C2

Risk identification and title	Possible causes	Potential impacts	Treatments [1]	Risk ranking [2]		Certainty level [3]
				Current	Residual	
TF1-03: Loss of control of machinery/ equipment may occur during surface activities.	Equipment failure. Operator error. Collision. Poor surface conditions.	Injury to worker.	Equipment design standards.	III	III	C3
TF1-04: Surface infrastructure construction and maintenance may impact on other infrastructure.	Proximity to Pit 3 wall. Proximity to road. Proximity to power lines. Proximity to brine injection points.	Injury to worker. Community impacts.	Infrastructure design and location has been subject to detailed engineering assessment.	III	III	C3
TF1-07: Collision may occur between underground equipment and surface equipment/personnel.	Use of common haul road. Disparity in size of equipment. Pedestrian use of the road.	Injury to worker.	Develop specific underground equipment Traffic Management Plan.	III	III	C2
TF2-01: Major fall of ground may occur in drive/decline.	Blasting in poor ground conditions causing failure of workings. Unknown structures. Poor design of ground support. Poor maintenance of ground support. Poor construction of ground support. Non-compliance with ground support regimes. Earthquake.	Injury to workers.	Mine design (e.g. stope dimensions and access drive locations) is based on geotechnical studies. Implement underground standard.	III	III	C3

Risk identification and title	Possible causes	Potential impacts	Treatments [1]	Risk ranking [2]		Certainty level [3]
				Current	Residual	
TF2-02: Minor fall of ground may occur in drive/decline.	Blasting in poor ground conditions causing failure of workings. Unknown structures. Poor design of ground support. Poor maintenance of ground support. Poor construction of ground support. Operators not following the unsupported ground procedures.	Injury to workers.	Implement underground standard.	III	III	C3
TF2-05: Flooding of underground may occur.	Intersection with fault. Mud/water rush into underground workings may occur during vent raise construction. Surface water ingress.	Injury to workers.	Collar on vent raises minimises water inflow. Flood mitigations for vent raises. Hydrogeological investigations have established fault and underground water locations. Mine water management system. Implement underground standard.	III	III	C3
TF2-06: Uncontrolled detonation of explosives may occur.	Mishandling. Operator error. Fire in magazine.	Injury to workers.	Majority of explosive stored in above ground magazine; small volume for use taken underground. Implement underground standard.	III	III	C3
TF2-07: Loss of control of vehicle may occur.	Mechanical failure. Poor visibility. Loss of control or overheating of trucks on steep 1 in 6 decline. Operator error. Slippage.	Injury to workers.	Develop Traffic Management Plan for construction and operations, and consider design controls to reduce risk. Develop vehicle specifications and audit / inspection. Develop training and qualification requirements. HME vehicle design - e.g. emergency braking.	III	III	C3

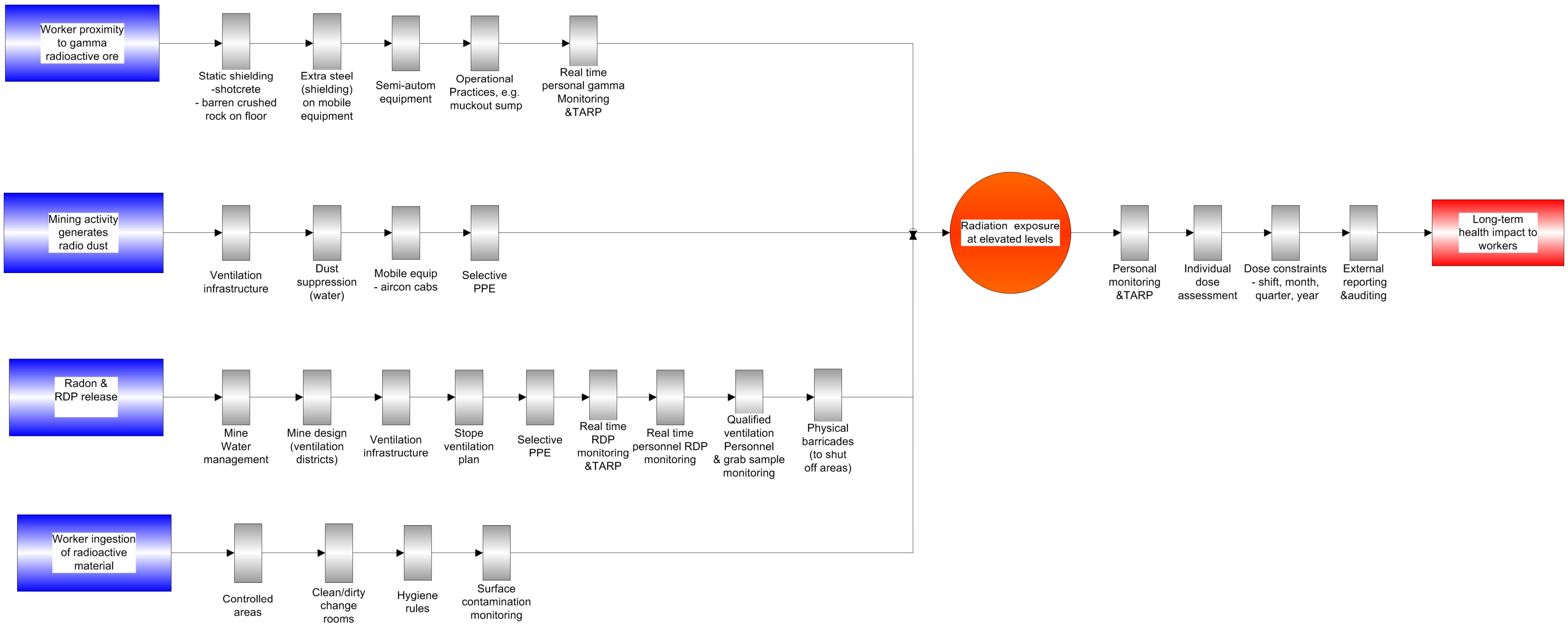
Risk identification and title	Possible causes	Potential impacts	Treatments [1]	Risk ranking [2]		Certainty level [3]
				Current	Residual	
TF2-08: Fire may occur underground causing heat and smoke in the mine.	Equipment failure - e.g. overheating brakes. Refuelling. Collision. Poor housekeeping.	Shutdown of the ventilation system and potential for injury/illness to workforce.	Implement underground standard.	III	III	C3
TF2-09: Cumulative noise exposure may lead to increased risk of industrial noise induced hearing loss in workers.	Operating equipment. Blasting. Ventilation fan noise.	Worker hearing loss.	Equipment design and selection. Worker hearing protection	III	III	C3
TF2-10: Entrapment of workforce underground may occur.	Collapse of ground resulting in loss of access. Vehicle fire or uncontrolled explosion. Power outage. There may be inadequate resources to respond to an underground emergency.	Workforce trapped for prolonged period, possible unbreathable atmosphere. Community concern.	Mine design incorporates a secondary means of egress.	III	III	C3
TF2-13: Person may fall from height while working underground.	Falling over stope edges. Falling into internal raises. Falling down ladder ways. Fall from work platform. Vehicle fall over stope edge.	Injury to worker.	Solid barricading of stopes. Signage. Training and competency. Standard operating procedures. Current working at heights standard	III	III	C3

Risk identification and title	Possible causes	Potential impacts	Treatments [1]	Risk ranking [2]		Certainty level [3]
				Current	Residual	
TF3-03: Underground workforce may be exposed to radon decay products and dust (long lived alpha activity) [radioactive dust] at levels above acceptable standards.	Poor ventilation. Dusty conditions. Poor dust suppression. Changing compliance levels (ranging from a factor of 2-5). Ventilation failure (e.g., power outage). Increased radon emissions from groundwater. Build-up of spilt ore may occur in the decline. Specific tasks - Radon exposure of workers placing backfill pipe.	Elevated dose levels. Potential long term health impacts. Reputation & compliance impacts.	Ventilation system design. Single pass ventilation. Exhaust ducting and a range of other secondary ventilation options. Air conditioned cabs on equipment. Continuous personal and area monitoring and associated Trigger Action Response Plan. Dust suppression. Provision of sufficient staff for ventilation monitoring and management. Stope Ventilation Plan. Ventilation Management Plan.	III	II	C2
TF3-04: Workforce may be exposed to gamma radiation that exceeds the annual dose limit.	Proximity of people to ore material through mining method and transport to surface	Elevated dose levels. Potential long-term health impacts.	Continuous personal monitoring. Shotcreting of walls, backs and face. Equipment shielding. Semi automation of selected production equipment. Barren crushed rock or steel plates on floor for shielding. Minimising worker time in ore. Regular mucking out of sumps.	IV	III	C2

1 – Treatment column is a summary of the controls proposed in the risk assessment. For details of the specific existing controls and additional treatments refer to the risk assessment in Appendix 5.

2 – Risk ranking: Class IV – Critical; Class III – High; Class II – Moderate; Class I – Low.

3 – Certainty level: C1 – Low; C2 – Moderate; C3 – High. (refer Chapter 5)



Abbreviations:

PPE: Personal Protective Equipment
RDP: Radon decay products
TARP: Trigger Action Response Plan

Figure 7-1: Bow Tie analysis of radiation risks presented by the Project

7.3.2 Identification of New Hazards

The environmental risk assessment identified a number of worker health hazards presented by the Project. Many of these, while new for the Project, are not new to ERA; therefore current health and safety management systems are in place to effectively manage the risks. Each of the identified hazards have been grouped by Project area and presented in **Table 7-3**, along with an indication of whether the issue is currently being managed on site (new to ERA). The remainder of this chapter discusses only those hazards that are new to ERA.

Table 7-3: Health and safety aspects of the Project

Project area	Description	Related risk ID's	Activity having potential new hazards	New to ERA?
Surface preparation	Clearance of ground, construction of ventilation raises and installation of surface fan facilities and their operation	TA2-01, TF1-04	Vent raise construction Large diameter open holes on surface	Yes No
Ancillary service	Power and water supplies	TB7-01, TF1-04	Construction activities Operation of facilities	No No
Paste backfill plant	Tailings from the processing facility will be thickened and mixed with cement and pumped to underground workings	TA5-04[1]	Construction activities Pumping high density fluids (paste)	No Yes
Underground mining operations - development	Mining using conventional drill, blast and haulage will establish a network of drives and access around the underground mine to provide access to mineralised zones and for haulage of materials to the surface.	TB7-02, TB7-03, TF2-01, TF2-02, TF2-05, TF2-06, TF2-07, TF2-08, TF2-09, TF2-10, TF2-13	Underground mining Ground control Underground traffic management Underground vehicle fires Underground vehicle safety Underground water management Airborne contaminant control Explosives (underground) Hazardous substances (underground) Underground dust, noise, diesel fumes Underground heat and humidity	Yes Yes Yes Yes Yes Yes No Yes Yes Yes Yes
Underground mining operations - production	Ore extraction using the open stoping sequential retreat and/or primary secondary methods. Note that mining methods are described in detail in **Chapter 3**)	TB7-02, TB7-03, TF2-01, TF2-02, TF2-05, TF2-06, TF2-07, TF2-08, TF2-09, TF2-10, TF2-13, TF3-03, TF3-04	As above (underground mining operations – development) Entry mining method (see **Section 7.3.4.2**) Remote mining Underground radiation exposure	- Yes Yes Yes

Project area	Description	Related risk ID's	Activity having potential new hazards	New to ERA?
Underground mining operations – stope backfilling	Pumping of cemented aggregate paste (consisting of concrete and tailings) into empty stopes	TB5-02	Establishing piping infrastructure Pumping large volumes of paste around the mine Containment of paste backfill material Underground radiation exposure	No Yes Yes Yes
Processing	Ore from Ranger 3 Deeps will be trucked to the existing process plant where it will be treated with no changes to process.	TF1-03, TF1-07	Conventional ore processing	No

Note: A number of the activities described in the table are currently being undertaken as part of the Ranger 3 Deeps exploration decline project; however, the extent and nature of the activity will increase for underground mining.

1 – This is a Class I residual risk, with the main impact area being to soils from spillage. There are also some health and safety implications from this hazard that are discussed in this chapter.

7.3.3 Worker Health and Safety Hazards

This section provides details of the newly identified worker health and safety hazards associated with the Project. Although the hazards may be new to the operation, the approach and management measures are not new to the mining industry or ERA's major shareholder Rio Tinto. ERA will draw on this industry experience in underground mining to form the basis for the control of the new hazards at ERA. General information on how these hazards will be managed is provided in this section. Full details of the additional (new) treatments that will be implemented as part of the Project are provided in **Section 7.4**.

7.3.3.1 Ventilation Raise Construction

The construction of ventilation shafts is a specialist task undertaken by an experienced and dedicated mining crew. It usually involves drilling a small diameter pilot hole down to the underground workings and then attaching a larger diameter cutting head that is drawn up to the surface. When the cutting head reaches the surface, an open hole exists. The inside surface of the raise is concreted to minimise water entrainment and to stabilise the hole. Surface infrastructure, e.g., exhaust fans, are then installed.

The main hazards in this work include: use of high energy mechanical equipment; failure of the cutting head; the final open hole; failure of the vent shaft resulting in inrush and subsidence; falling objects into the underground workings; and stability of the surrounding shaft walls. The diameter of the hole is governed by the geotechnical characteristics of the surrounding ground which determines the maximum diameter for shaft stability.

To control the hazards, existing ERA working from height procedures will be implemented. Drilling areas at the top and bottom of the hole will be restricted access areas, when breakthrough to the surface occurs, creating an open hole, which will be either capped with steel plating or cordoned off. In both cases, a physical barrier is placed to keep the hole safe. When work occurs on the open hole (such as placing infrastructure on top of the hole), workers wear safety harnesses as if working at heights and appropriate working at heights procedures are implemented. The maximum shaft stability is determined from geotechnical logging of core from the activity.

To manage the risk of injury to the public, access to Project construction and operational areas will be restricted; however, arrangements and procedures will be established to enable access for Traditional Owners when necessary.

7.3.3.2 Paste Backfill

ERA will fill empty stopes with a mixture of tailings, aggregate, waste rock and cement (known as paste backfill) to maintain stability of the mining area and to minimise open void space. The paste will be made in a surface facility and pumped to the underground voids via a surface pipe network, a drill hole to the mine workings and an underground pipe reticulation system (see **Chapter 3** for more details).

There are four primary potential hazards with the paste management system:

- poor structural integrity of the paste, leading to geotechnical instability of the mine;
- failure of a backfilled stope before the paste has fully set, leading to inrush of paste material into the mine;
- failure of paste handling infrastructure (such as the pipes); and
- geotechnical stability of the paste is reduced when contacted by water treatment brines, disposed of in the base of Pit 3 and transported into the underground mining areas.

The paste backfill is designed so that it will set with sufficient strength to allow mining to be conducted adjacent to or on top of the material. Quality control procedures will be implemented to ensure that paste meets these design standards.

The hazard of paste backfill failure before it is set is managed inherently by the backfilling method. This involves partially filling the stope with paste and allowing material to initially set to create a stable barrier (or plug) at the base of the stope. Once this has occurred, the rest of the stope is filled. A failure during the plug installation would result in a relatively small amount of paste escaping, thereby reducing the hazard. Paste pumping occurs at a rate of approximately 150 m^3/h; thereby removing the risk of rapid inundation.

Additional measures that will be implemented to control the hazards of handling paste include: pressure monitoring of the pipes; regular inspection of the pipework; flushing of pipes; and safe and secure joining and placement of pipes.

The last hazard would only be present if the brines from Pit 3 are able to transport through the host rock into the underground areas in sufficient quantity, and are of an aggressive chemical nature compared to the paste backfill, thereby affecting the geotechnical stability of the paste. The likelihood of all these things occurring is extremely rare; however, the effect of the paste failure could be multiple fatalities. In order to manage this high consequence low likelihood risk, ERA will keep a safety margin between Pit 3 and the stoping areas. In addition the paste backfill has been designed so that it will set with sufficient strength to allow mining to be conducted adjacent to, or on top of, the material. Quality control procedures will be implemented to confirm that paste meets these design standards.

7.3.3.3 Underground Mining

Underground mining encompasses a number of important health and safety hazards. The general approach is to manage these hazards through effective workplace design, safe work practices and appropriate mining equipment selection.

Through systematic hazard and risk identification, and drawing on industry experience, it is expected that the majority of hazards have been identified and controlled in the design of the mine. These design controls ensure that mining equipment has inherent safety features such as robust operator compartments, ventilated cabins, noise controls and fire suppression.

Strict industry standard work practices will be adopted, including safe systems of work and work permit arrangements for non-routine work or where safe work procedures do not exist.

Ongoing audits, inspections and assessments will identify new or emerging hazards.

7.3.3.4 Ground Control

When developing underground tunnels (or drives), newly exposed ground in the walls and roof[7] of the drives will be made stable to prevent significant rock falls and collapses of the ground. Following blasting of a development heading, larger loose rocks in the roof and walls will be mechanically knocked to the ground with mining equipment such as a mobile drill rig (jumbo). The jumbo will then install rock bolts[8] into the roof and walls. The roof and walls will then be visually inspected and smaller unstable rocks removed if safe to do so, in a process known as scaling. Additional ground support will be installed for added stability, depending upon the conditions. The ground support techniques can include; a layer of reinforced concrete (known as shotcrete[9]), cable bolts,[10] and meshing.

The cardinal rule[11] for ERA is that no one is allowed to work under unsupported ground, i.e. ground that does not have physical support such as rock bolts, meshing and/or shotcrete.

Ensuring the safety of the roof is not possible e.g. large voids or stopes and in these instances worker access will be forbidden. And any operation required in these areas will only be possible through the use of remotely operated equipment.

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7 The roof is also known as the backs in underground mining terminology.

8 Long anchor bolt used to stabilise the mining area.

9 An all-inclusive term for both wet mix and dry mix version of concrete. Shotcreting is "the spraying of concrete via air or hydraulic pressure".

10 Similar to anchor bolts, these are longer versions of bolts used to provide ground support and stability to mining areas.

11 Cardinal Rules are the most fundamental safety rules that exist at ERA and must be followed by all people on site. The rules are associated with high risk areas that if not in place could result in serious injury or fatality.

7.3.3.5 Traffic Management

The enclosed spaces often encountered in an underground mine require control systems for managing underground vehicles. Light vehicles and heavy mining equipment interact in close proximity, resulting in the need for strict management controls. These include:

- speed controls for all vehicles, including lock out of higher gears on light vehicles;
- emergency braking on heavy vehicles;
- installation of passing bays to allow safe passing vehicles;
- regular maintenance and inspection of vehicles, including inspection of brake assemblies;
- additional driver training for all underground operators; and
- development of a underground traffic management plan, that includes the requirement for smaller vehicles to always give way to larger vehicles.

In addition to the vehicle traffic, there is also pedestrian traffic with some tasks requiring workers to be on foot when underground. In these situations, pedestrian controls will include:

- high visibility work gear;
- delineated pedestrian areas, where vehicles access is controlled; and
- protocols in shared work areas, including mandatory radio communications.

Haul trucks exiting the underground mine will use surface roadways that connect the existing open pit mine to the processing plant. Surface traffic management has been in place at Ranger mine since commencement of operations and once the underground trucks are on the surface they will follow the existing surface traffic management rules.

7.3.3.6 Vehicle Fires

All underground vehicles will be diesel powered and will not have turbo charges fitted. This minimises the risk of fire; however, all underground vehicles will require a higher level of fire protection than surface vehicles due to the potential hazards associated with underground fires.

Underground fires can be difficult to fight, due to restricted access and generation of excessive heat. In addition, smoke and carbon monoxide can affect other areas of the mine through the ventilation system. Mines rescue personnel undergo specialist training in vehicle firefighting.

In the event of a fire, evacuation of the mine may be require, this usually occurs by mine districts (defined by the ventilation system). The number and location of districts requiring evacuation will depend upon the size and location of the fire.

7.3.3.7 Water Management

Inrush of water into an underground mine can occur when mining intersects aquifers or existing natural or manmade voids that contain water. This can result in flooding which can be potentially catastrophic given the enclosed space of the mine. As part of the Ranger 3 Deeps exploration decline work, the Project orebody and surrounding areas have been subjected to extensive exploration drilling and hydrogeological test work (including monitoring inflow rates). This knowledge of the local hydrogeology has been used to identify zones within the Ranger 3 Deeps resource that may contain larger reservoirs of water, thereby significantly reducing the likelihood of intersecting large amounts of water and minimising the chance of a catastrophic situation. In addition, ongoing inspections and monitoring of water in the mine will assist in the ongoing identification of underground water reservoirs.

Water management is incorporated into the mine design by establishing low points in the mine where water can accumulate. Pump stations will be established at these points to remove water from the underground mine to the surface. Mobile diesel driven pumps will provide a backup in the event of power failure. Should an inrush of water occur, it would be managed with the rapid construction of barriers or dams using rock to contain the water until adequate pumps and lines are installed.

Evacuation of all mine workers will provide the final level of protection, if required.

7.3.3.8 Hazardous Substances and Explosives

The expected consignments of all bulk materials for the Project are shown in **Table 12-9**, **Section 12.6.3.1**.

In general, the bulk materials for the Project will be the same as those used for current operations, and procedures and standards have been established for their safe use and storage. Some of the existing consumable quantities will increase; however, the only additional materials required in any quantity are cement for backfill and shotcrete[12] and sand/aggregate for shotcrete, which are not classified as hazardous substances. The increase in materials is shown in **Table 7-4**, along with their dangerous goods classification and use.

With the exception of diesel, it is not expected that increases in materials usage would result in the need for larger or new storage facilities. Existing site facilities will be used for storage and distribution of these materials and existing health and safety management measures are therefore sufficient.

Explosives use will not change because the quantity of explosive previously used for the open cut will be the same as that required for underground operations.

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[12] Materials for shotcrete will be supplied to the Jabiru industrial area, where the shotcrete will be mixed and trucked to the mine ready for use underground.

The transport, storage and use of all hazardous substances and chemicals used in the Project will be in accordance with the appropriate regulations[13].

In addition, ERA maintains a system whereby all new chemicals or substances undergo a hazard and risk assessment prior to being introduced on site. Therefore any new substances not previously identified would be assessed prior to their use.

Table 7-4: Hazardous substances for the Project

Consumable	Dangerous good class and packing group	Description	Project only (average)	Existing [2] (average)	Increase due to Project (%)
Sulfuric acid	8 PGII	Used in uranium leach circuit	38 kt	116 kt	33
Quicklime	N/A	Used for pH control in process	14 kt	36 kt	39
Diesel	9 PG III	For underground vehicles	24,400 kL	44,400 kL	55
Alamine 336	9 PG III	Used in solvent extraction of uranium	29 kL	22 kL	132
ShellSol 2046 (kerosene)	N/A	Used in solvent extraction of uranium	400 kL	1,100 kL	36
Anhydrous ammonia	2.3	Used to precipitate uranium	1 kt	1 kt	100
Cement	N/A	For shotcrete and backfill	48 kt	0	New
Sand/aggregate	N/A	For shotcrete and backfill	6 kt	0	New
Sodium hydroxide	8 PG II	Used for pH control in process	23 kL	18 kL	128
Explosives [1]	1.1	For underground use	770 t	-	-
Uranium oxide	7	Final product	2 kt	2 kt	100

1 – Note that explosives use will not change because the quantity of explosive previously used for the open cut will be the same as that required for underground operations.

2 – Existing taken as an estimate of average use by current operations between 2016 and 2020.

13 Australian Code for the Transport of Dangerous Goods by Road and Rail, Seventh edition 2011, Work Health and Safety (National Uniform Legislation) Regulations 2013, *Transport of Dangerous Goods by Road and Rail (National Uniform Legislation) Act 2013*.

7.3.3.9 Underground Noise

The enclosed workings of underground mines and the use of high-powered machinery creates workplaces that are usually noisy. Despite noise attenuation on equipment, noise is reflected from walls, potentially resulting in un-attenuated levels above the noise exposure standard of 85 dB(A).[14]

In the underground mine, all workplaces will be designated hearing protection areas and all personnel will be required to wear protection. Properly fitted, hearing protection can provide up to 30 dB(A) attenuation. All underground workers will undergo training in hearing protection and the correct fitting of protective equipment.

Workplaces will be monitored for noise and personal noise monitoring of workers will occur. Management of workplace noise levels will be through a Trigger Action Response Plan[15].

7.3.3.10 Dust and Diesel Fume

The enclosed workings of underground mines and the use of diesel equipment can result in the contamination of workplace air with dust and diesel fumes.

The primary controls for dust and diesel fume in an underground mine are good ventilation and minimising sources of contamination. ERA has committed to installing an appropriate ventilation system in the underground workings for the control of radon, dust, diesel fumes and heat.

The overall ventilation system is described in **Chapter 3**, and consists of primary and secondary ventilation circuits that distribute fresh air[16] to underground workplaces. The primary ventilation circuits provide bulk quantities of fresh surface air into the vicinity of the workings and the secondary system distributes this air to the workplaces. The primary ventilation circuit is based on a series of surface ventilation raises, with large air fans used to extract exhaust air from the mine through a number of these exhaust raises, while surface air enters the mine through the intake raises or the decline. The secondary ventilation system is designed to take fresh air from the primary circuit and distribute it to working areas with the use of secondary ventilation fans and ducting. The fans blow fresh air to the workplaces, with the exhaust air flowing back along drives to the exhaust side of the primary ventilation system. In some cases it is necessary to extract exhaust air from a work area through more rigid steel ducting.

Due to the dynamic nature of the mine workings, the ventilation system will expand with the mine. ERA will engage the services of ventilation specialists to ensure the ventilation system meets required standards.

This ventilation system will be the primary control for workplace airborne contamination. In addition to the ventilation system, airborne dust and particulate concentrations will be controlled through standard dust suppression measures, including regular watering of roads

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14 Refer to Work Health and Safety (National Uniform Legislation) Regulations 2013.

15 A Trigger Action Reponses Plan is a set of actions to be taken if monitoring results for the parameter are over the trigger value. They typically include a number of triggers and associated actions, each having a higher value with the upper level presenting the highest risk.

16 Fresh air is air that has not been in contact with the mineralised zone and has not been in contact with exhaust air.

and watering of broken rock piles. Diesel emissions from vehicles remain controlled by having low emission technology on heavy mobile equipment and through regular maintenance to these systems.

7.3.3.11 Heat and Humidity

The Ranger mine is in an area of Australia with relatively high surface air temperatures and humidity. The mine will be ventilated with this surface air resulting in similar conditions underground. In addition, rock temperatures underground will be naturally elevated. To minimise potential heat stress conditions in the underground mine during the hotter months of the year, refrigerated air will be added to the primary ventilation system to cool intake air during these times.

ERA will expand its current programs for managing heat stress in the processing plant and the Ranger 3 Deeps exploration decline. This will involve conducting an assessment on all underground workplaces for heat stress conditions to identify design controls, e.g. cool air refuges, multiple cool water stations, and additional ventilation, where necessary.

Preventative programs already in place (such as, worker education, acclimatisation, workplace and personal hydration monitoring and Trigger Action Response Plans) will be extended to the underground mine workforce to continue minimising the heat stress hazard.

A key to managing heat stress is recognising the symptoms, and all workers will undergo initial and ongoing training in this area.

7.3.3.12 Remote Mining

Remote mining equipment may be used for specific tasks, such as operating under unsupported ground and working in areas with potential inrush hazards. Equipment and operating procedures will comply with all appropriate national standards (Australian/New Zealand Standard 2009).

Generally, this type of equipment can be operated by line-of-sight or tele-remotely. Line-of-sight requires operators to be in the vicinity of the equipment and presents significant hazards; ERA will not be using this type of equipment. For tele-remote equipment, workers can be located well away from the area where the equipment is working, providing a very high level of safety.

Remotely operated equipment requires specific controls so that equipment is not active or activated during maintenance work, this is outlined in the standard.

7.3.4 Underground Radiation Hazards

This section provides a summary of the radiation doses that may potentially be received by underground workers. Additional detail on the radiation assessment, including an introduction to radiation and information regarding many of the terms used in this section, is provided in **Appendix 8**.

For underground uranium mines, the main exposure pathways are:

- irradiation by external gamma radiation;
- inhalation of radionuclides in dust; and
- inhalation of the decay products of radon[17].

Assessments have been conducted for three main groups of mine workers:

- production miners, who predominately work in mineralised material;
- development miners, who work across all areas of the mine; and
- service personnel, who also work across all areas of the mine.

7.3.4.1 Gamma Radiation

The underground mining method is based on long-hole open stoping (entry), meaning that production and some development miners will work within the uranium mineralised ore zone. These workers will be exposed to higher grades of uranium, and therefore a more detailed assessment of the potential doses from gamma radiation has been conducted for all workgroups. The dose assessment allowed for protection factors from control measures such as shielding from shotcreted walls and roof, and protection afforded by the mining equipment. Protection measures for gamma radiation are outlined in **Section 7.4.3**.

Estimates of exposure to gamma radiation include the following:

- consideration of actual estimated exposure hours;
- passive shielding from mining equipment;
- shielding from shotcrete on walls and roof; and
- shielding from the inert road base.

The actual exposure hours have been estimated based on the percentage of time spent by workgroups undertaking three key activities:

- underground production and development work:
    - the actual time that workers will spend developing headings and workplaces or undertaking production mining.
- work preparation and/or delays, this includes both:
    - travel time;
    - work setup;

[17] The short-lived radioactive decay products of radon-222, also known as radon progeny.
This includes the decay chain up to but not including lead-210, namely polonium-218 (sometimes called radium A), lead-214 (radium B), bismuth-214 (radium C) and polonium-214 (radium C). (IAEA 2007; p 161-162)

  - mine services work, for example cleaning up spillages and grading roads;
  - pre-starts and equipment checks; and
  - delays for breakdown or maintenance.
- time spent on the surface at the start and end of shift and for meal breaks, this also includes time for safety meetings, training and time spent in the surface workshops.

Table 7-5 provides a summary of the potential gamma radiation doses for underground miners. This shows that significant dose reduction can be achieved through the use of engineered shielding (shotcrete, road base and mine equipment).

ERA will further reduce gamma doses by implementing additional controls as described in **Section 7.4**. It is important to note that that the actual gamma doses for workers are expected to be less than that predicted. This is because the gamma dose reductions that will be achieved through the use of remote equipment and administrative management measures could not be fully quantified so have not been included in the assessment.

Table 7-5: Estimates of gamma doses to worker groups

Workgroup	Gamma Dose (mSv/y)[1]			
	Production and development work		Work preparation	Total
	No attenuation	With attenuation factors		
Loading/trucking	12 – 14	2	1	3
Jumbo operator	11	3	1	4
Charge up	9	4	2	6
Services	3	1	4	5
Long hole driller	21	6	1	7
Radiation/ventilation officers	6	2	2	4
Cable bolter	18	5	1	6
Shotcrete operator	11	4	12	6
Nipper	10	4	2	6
Maintenance	3	1	2	3
Service	3	1	4	5

1 – Note the annual limit for total dose is 20 mSv per year

7.3.4.2 Inhalation of Radionuclides in Dust

Dust is generated in mining operations from drilling, blasting and materials handling. Dust in the underground mine will contain radionuclides proportional to the ore grade, i.e. the higher the ore grade, the higher the radionuclide dose. Worker doses from dust inhalation will depend upon the amount of dust inhaled and its radionuclide content.

For this assessment, the gravimetric (non-radioactive) dust monitoring results from the exploration decline were assumed to be an indication of typical underground dust concentration for the Project. These results were used to estimate radioactive dust concentrations assuming that all dust contains 500 ppm of uranium.[18] The resulting dose received from inhalation of radioactive dust, for a full (working) year, is approximately 0.67 mSv.

This assessment does not take into account the protection provided by air conditioned cabs on mining machinery that most workers will be working in. Therefore, in practice, it is expected that the actual doses from inhalation of radionuclides in dust will be significantly less than the predicted levels.

7.3.4.3 Inhalation of Radon Decay Products

The control of radon and its decay products is a primary concern in underground uranium mining. The mine and ventilation system is designed to maintain radon and radon decay product concentrations in workplaces to levels that will, as a minimum, comply with dose limits and, more usually, to levels that demonstrate that the exposures are optimised, i.e. ensuring that exposures are ALARA.

To assess the potential doses from the inhalation of radon decay products, a number of factors were considered:

- The amount of radon entering the mine from the exposed uranium mineralised surfaces and groundwater inflow.
- The amount of air moving through the mine workings and at the individual workplaces (known as the ventilation rate).
- The estimated time that workers would spend in the differing radon decay product concentrations.

The assessment for radiation dose from the inhalation of radon decay products combined estimated workplace concentrations with hours worked in those concentrations to give an annual exposure. This exposure is then combined with the recommended dose conversion factor to calculate a potential dose to the workers.

The dose conversion factor for radon decay products is currently being reviewed by the ICRP, who have recently indicated that it has been underestimating the risk from the inhalation of radon decay products (ICRP 2010). The latest dose conversion factor provided by the ICRP, although not yet adopted in Australia, has been used in this assessment.

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18 This is calculated using the weighted average of the uranium grade for all material planned to be mined on the Project, including ore and non-mineralised material.

Three exposure situations were considered for the assessment, with complete details and calculations provided in **Appendix 8**:

- miners working at the end of a 100 m development drive in ore;
- a production miner working on a stope with flow through ventilation; and
- a production miner working on a stope where the last blast has created a broken rock pile that prevents ventilation from entering the stope (this is termed a closed brow).

These three exposure scenarios provide an indication of typical exposure conditions, with exposures to other underground workers expected to be less than, or consistent with, the doses estimated for these scenarios.

The estimated radon decay product concentration in air in the workplace, for the first two scenarios, is approximately 1 μJ/m^3. When combined with the estimated exposure times for these scenarios, and using the new ICRP recommended radon decay product dose conversion factor, the estimated doses to miners from exposure to radon decay products is approximately 4 mSv per year.

For the second case the stope exhaust drive has the potential to have some elevated radon decay products concentrations above that predicted; however, this would be an area of low occupancy with no routine work being performed while a stope was operating. Any visits to this area would generally be short, for the purpose of inspection, ventilation monitoring or adjustment, and would only be performed with the use of respiratory protection (for example, airstream helmets).

For the third scenario, the radon decay product exposure to workers is expected to be very low and at background concentrations, due to fresh air[19] being provided directly to the workplace and air moving across the stope to the exhaust drives located on the other side of the stope. Doses are expected to be less than 1 mSv per year for this situation.

The concentration in the exhaust drive for this third case has the potential to be very high. However, as noted above the exhaust drive would be a restricted area of low occupancy, with use of respiratory protection being mandatory. Further restrictions on access would be imposed when the low ventilation conditions that might result in these concentrations were likely. This situation would need very careful management: for example negative pressure would need to be maintained in the area to ensure that the exhaust air flowed directly to the exhaust raise, and did not find its way into occupied areas. The procedures to ensure this are outlined in **Section 7.4**.

[19] Fresh air from the intake side of the primary ventilation system is provided to workplaces directly or through the secondary ventilation, which consists of underground fans and ventilation ducting. These controls are also described in the management controls section of this report.

Workers will spend time in all these situations throughout the year and are also expected to spend time in air conditioned cabins,[20] the filters of which will remove radon decay products from the air and significantly reduce doses. Taking this into consideration the estimated radiation doses to underground workers from the inhalation of radon decay products are likely to be less than 4 mSv per year and average between 1 and 2 mSv per year.

7.3.4.4 Total Dose

Based on the radiation dose estimates provided in the previous sections, radiation doses to underground miners at Ranger mine are predicted to be up to a maximum of 7 mSv from gamma radiation, 1 mSv from inhalation of radioactive dust, and 4 mSv from inhalation of radon decay products, resulting in a maximum total effective dose of approximately 12 mSv per year.[21] This is well below the annual limit of 20 mSv per year averaged over 5 years, with a maximum of 50 mSv in any single year.

Average radiation doses for the Project are expected to be much less than the predicted maximum, with a significant number of employees expected to have annual doses below 5 mSv per year. Gamma doses are expected to average less than 4 mSv per year, and with fresh air being delivered to all work areas and air conditioned cabins on vehicles, the doses from the inhalation of radon decay products and dust are expected to average 1 and 2 mSv per year.

These predicted averages and maximum are slightly higher than for current operations, with averages currently less than 2 mSv per year and the maximum total effective dose being between 4 and 7 mSv per year. While the increase is to be expected due to the move to underground mining placing workers closer to the uranium mineralisation, it is consistent with doses currently experienced in other underground uranium mining operations around the world (see **Section 7.3.4.6)**.

7.3.4.5 Comparison with Other Projects

On the global scale, most underground uranium mining currently occurs in Canada. Olympic Dam in Australia also produces uranium from an underground operation, although the average uranium grade is much less than at Ranger and in the Canadian mines.

A review of the various Canadian operations showed that the Eagle Point underground uranium mining operation in Northern Saskatchewan uses a similar mining method to that proposed for the Project, but has a higher average grade of approximately 0.9% U_3O_8 (or 9,000 ppm), compared to the Project average of 0.25% U_3O_8 (or 2,500 ppm). The radiation protection aspects of this operation are reported annually to the Canadian Nuclear Safety Commission. The most recent available data (2012) shows that the annual total effective doses to underground mine workers at Eagle Point are well below the annual limit with an average of 4.3 mSv per year and a maximum of 14.4 mSv per year. The distribution of the reported worker doses with a breakdown by workgroup (**Figure 7.2**) shows that the majority

[20] All large underground mining equipment will have air conditioned cabins installed, as described in the management controls section of this report.

[21] It is noted that the dose estimates are based on implementation of some design controls.

of doses are less than 5 mSv per year with only a small number of workers, from specific workgroups likely to get higher doses.

The worker radiation doses reported at Eagle Point are very similar to that predicted for the Project. This confirms that:

- it is possible to manage radiation doses to underground workers in higher grade uranium mines using entry mining methods;
- the predicted doses for the Project are similar to that of other operations in the world; and
- the actual doses for the Project are likely to be lower than that predicted in this conservative assessment, based on the lower grade for the Project compared to the Canadian operation.

In comparison, the average dose to underground mine workers at the Olympic Dam mine is approximately 4 mSv per year, with maximum doses being approximately 7 mSv per year (BHP Billiton 2009). Olympic Dam is a low grade uranium mine with average uranium grades of 500 to 600 ppm.

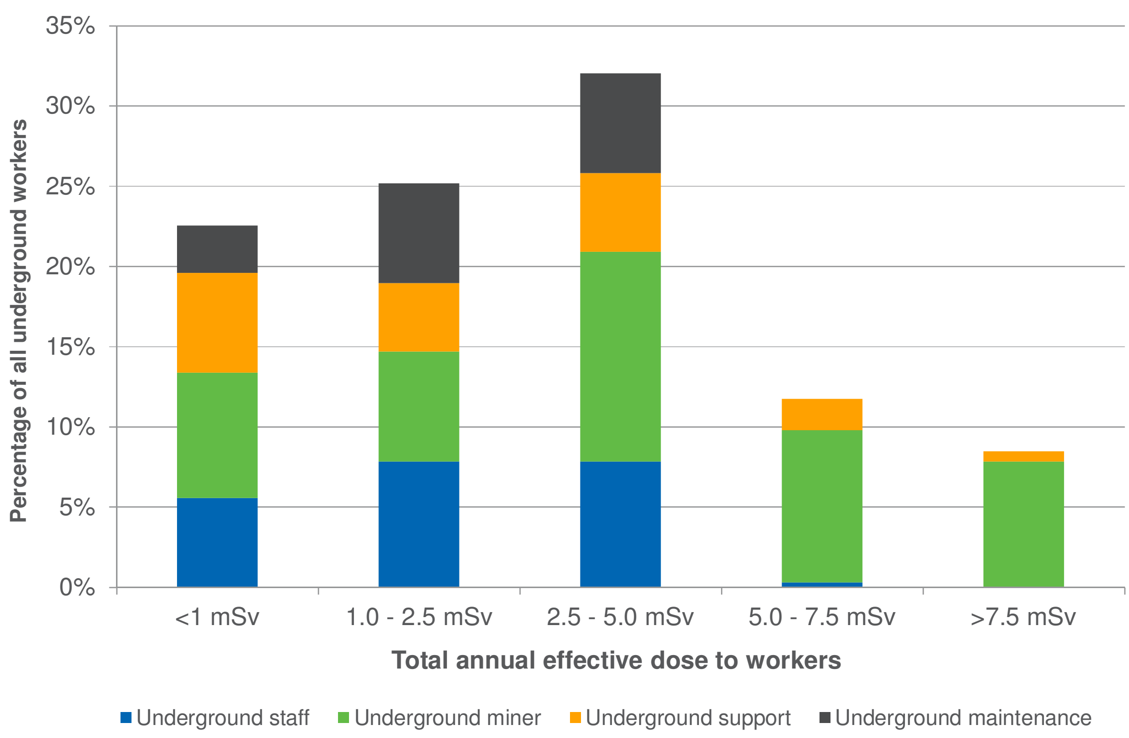

Figure 7-2: Distribution of annual radiation doses to workers at Eagle Point

7.3.5 Public Health and Safety

7.3.5.1 Radiation Exposure

An assessment of the potential radiation doses to the public from the Project was conducted and details are provided in **Appendix 8**.

The main exposure pathways are from inhalation of radionuclides in dust, inhalation of radon decay products, and ingestion of bush foods. Gamma radiation exposure is expected to be negligible due to the distances between the sources of gamma radiation and the public.

The main public exposure groups that were identified for the assessment were residents of:

- Mudginberri (Aboriginal community);
- Camp 009 (an area used intermittently by Traditional Owners);
- Jabiru (nearest major residential population);
- Ranger mine village contractor camp; and
- workers at Jabiru East and the Airport (day time work only, no residents).

For inhalation, the assessments were based on the modelled average annual concentrations of radon in air and radionuclides in airborne dust, at the locations of the identified exposure groups.

The concentrations at the identified locations were determined from air quality modelling (as outlined in **Chapter 6**) which is based on estimates of dust and radon emissions from the Project. The estimated emission rates used in the modelling were;

- radon emissions from underground mining – 1 MBq/s
- radionuclides in dust emissions[22] from underground mining – 34 Bq/s
- radionuclides in dust emissions from surface crushing of either ore prior to entering the ore sorter or low grade material for backfill – 146 Bq/s

The emissions of radon and dust from the Project ore and waste rock have been considered part of existing operations. Ore material from underground is intended to be direct hauled to the current run of mine pad for subsequent feed into the primary crusher or ore sorter. The volume of waste rock will be very small (refer **Section 3.3.5**) and stockpiled according to current operations management plans. This small volume will have a negligible contribution to overall radon and dust emissions.

Outputs from the air quality modelling provide predicted dust (total suspended particulates) and radon concentrations originating from the Project (**Figures 7-3** and **7-4)**. These concentrations were then converted to potential doses by applying standard factors such as occupancy time, breathing rate, and dose conversion factors.

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22 Note that dust emission represents the concentration of ^{238}U and assumes that all decay products are in secular equilibrium.

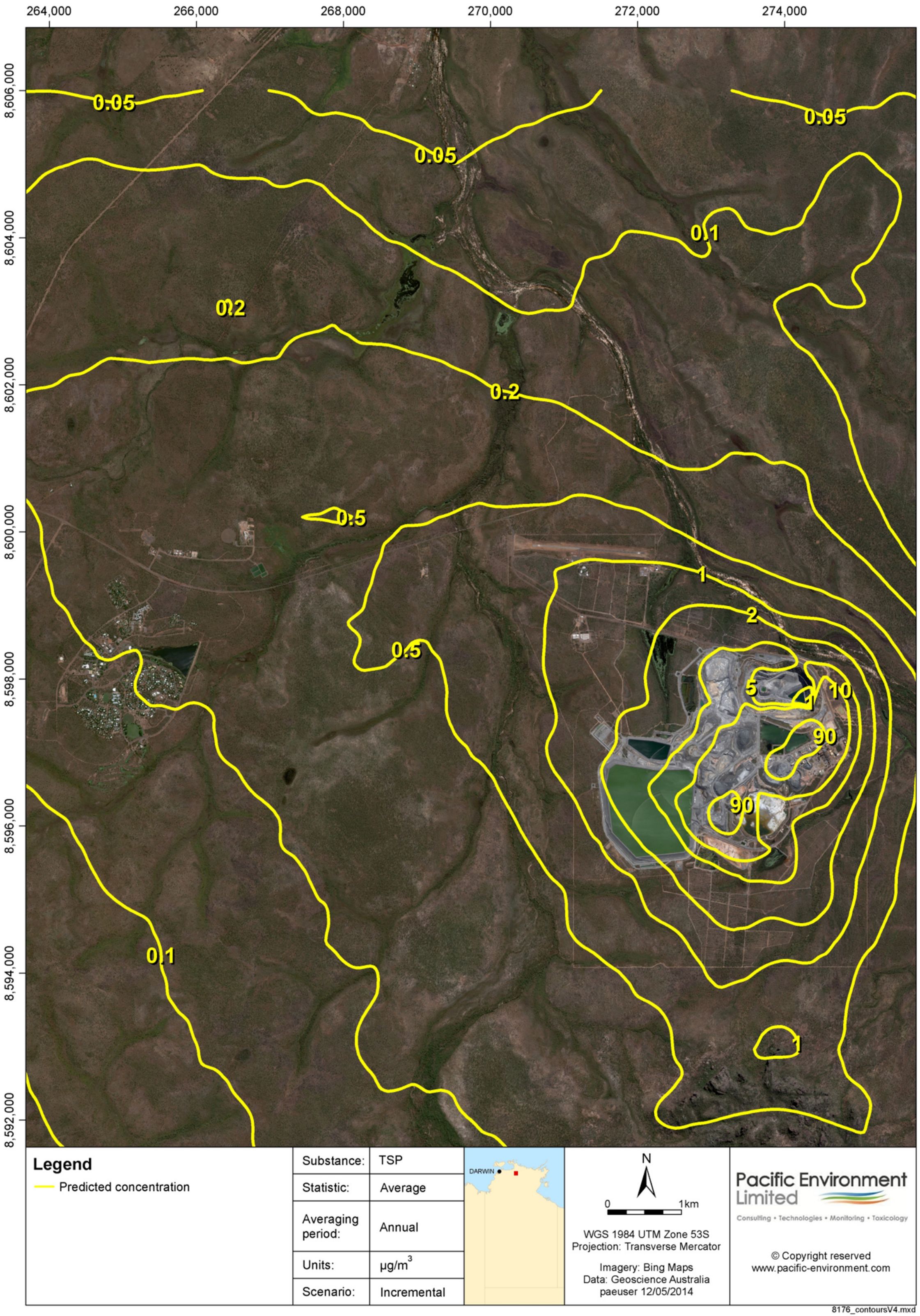

Figure 7-3: Modelled annual average total suspended particulate concentrations

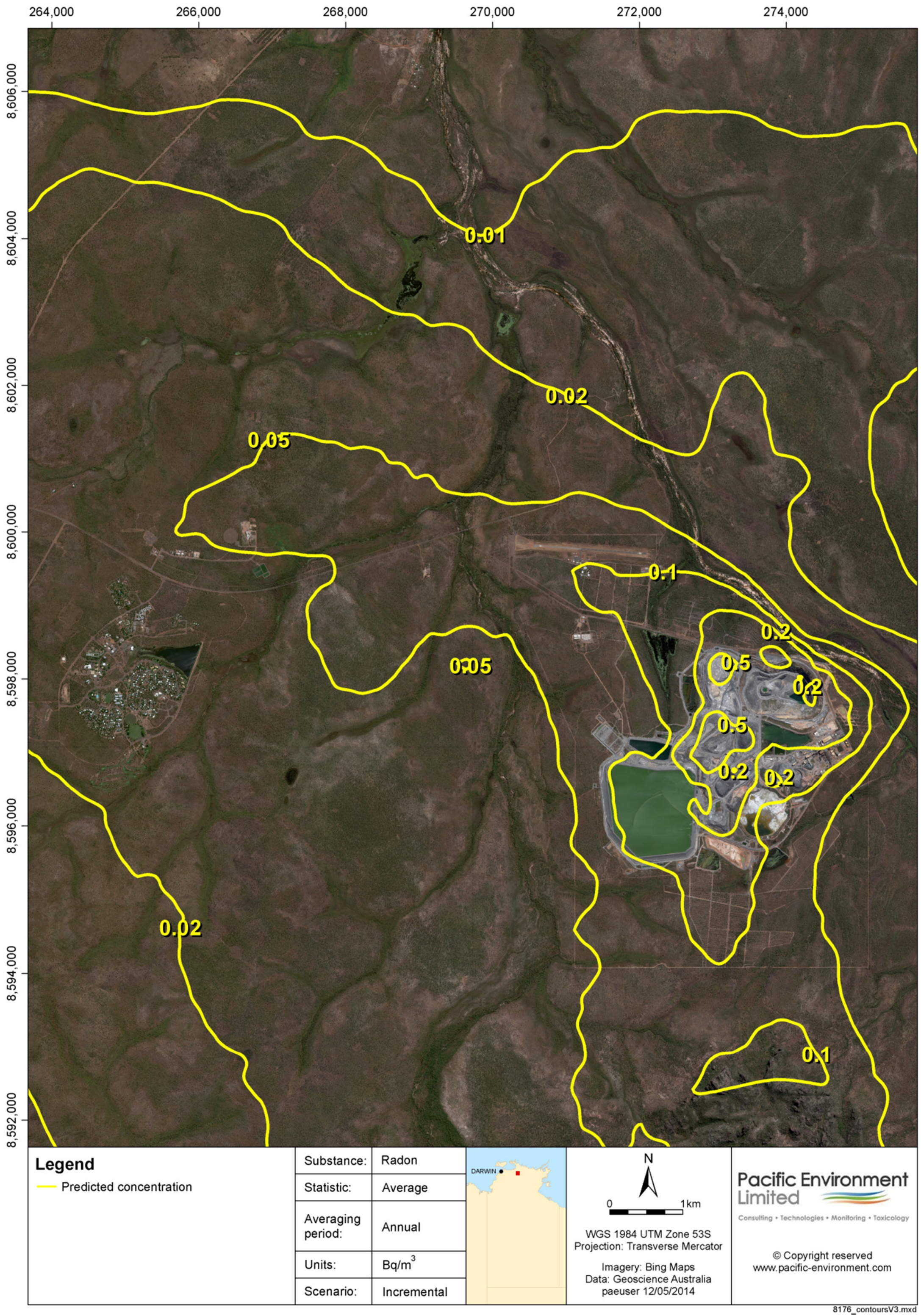

Figure 7-4: Modelled annual average radon concentrations

The estimated annual radiation doses to residents at locally occupied areas, from inhalation of dust and radon, are shown in **Table 7-6**. The highest estimated annual doses were to the residents of the Ranger mine village, where a full time resident (that is, 8,760 hours per year) is expected to receive an annual dose of about 0.012 mSv per year. This is a conservative estimate as there are no permanent residents at the site. Similarly there are no residents in the Jabiru Airport area in Jabiru East.

The largest local population centre is Jabiru, where the expected annual radiation dose to a full time resident is predicted to be 0.0007 mSv per year from the inhalation of cumulative dust from Ranger mine and 0.0017 mSv per year from Project incremental radon decay products. Current monitoring conducted by ERA shows that residents in Jabiru currently receive on average 0.020 mSv per year from the inhalation of Ranger mine sourced radon decay products (refer **Chapter 2**). This gives a cumulative dose to members of the public living in Jabiru from inhalation of 0.022 mSv per year, well below the limit of 1 mSv per year.

The potential for uptake of radionuclides into bush foods and the subsequent dose to members of the public consuming these foods has been assessed. Transport of radionuclides through both dust emissions and the release of treated water to Magela Creek were assessed. The assessment was based on the cumulative emissions of the Project with current Ranger mine operations. The aquatic assessment was based on a worst case, with no dilution in concentrations occurring between the mine and Mudginberri Billabong. The results showed a possible additional ingestion dose of 0.066 mSv per year for an adult and 0.077 mSv per year for a child. In comparison, a recent study by ERISS determined existing background ingestion doses and showed that consumption of bush foods from the Alligator Rivers Region resulted in an estimated background dose (from naturally occurring radiation in the environment) to residents of approximately 0.85 mSv per year (Ryan et al, 2009).

Table 7-6: Summary of inhalation doses to members of the public

Location	**Inhalation of radioactive dust[2] (mSv per year)**	**Inhalation of radon decay products (mSv per year)**	**Total inhalation dose (mSv per year)**
Mudginberri	0.0001	0.0003	0.0004
009 camp	0.0004	0.0008	0.001
Jabiru	0.0007	0.0017	0.002
Jabiru Airport (and businesses)[1]	0.0041	0.0052	0.009[1]
Ranger mine village (contractor camp)[1]	0.0074	0.0045	0.012[1]

1 – Non-residential receptors; full time occupancy assumed giving over estimate of dose.

2 – Dose calculation made on cumulative concentrations of radioactive dust.

The estimated maximum possible total effective radiation dose to an adult living in Jabiru having a tradition diet of bush foods from the cumulative operations of the Project and the Ranger mine was 0.088 mSv per year. This conservative assessment is well below the annual dose limit of 1 mSv per year, demonstrating that the risks to members of the public from the Project and the Ranger mine in general are low.

7.3.5.2 Traffic Management

Chapter 12 outlines the assessment of transport-related impacts and risks for the Project.

The assessment notes that, during operations, the Project is not expected to contribute to additional light vehicle traffic on the road network and that the additional heavy vehicle traffic for the Project will be minor compared to the heavy vehicle load for the existing operations.

During the proposed construction period, it is anticipated that there will be an increase in heavy vehicle traffic bringing construction materials and large loads to the site (such as the backfill plant, power generation, refrigeration units and mine ventilation infrastructure).

For the life of the Project, it is expected that the combined light and heavy vehicle trips to and from Ranger mine will increase by up to approximately 20%.

The assessment also included a road capacity review that showed how additional Project traffic will not result in the capacity of the roads being exceeded, i.e. significant capacity remains on all roads.

The traffic assessment concluded that the Project does not materially alter the existing transport risk profile and that the current safeguards and mitigation measures (controls) will continue to provide a high level of ongoing protection to the public.

7.4 MITIGATION

The previous section has identified and discussed each of the health and safety hazards presented by the Project that are new to ERA and therefore will require additional or new treatments. This section provides details of these treatments, grouping them as follows:

- underground mining;
- radiation;
- airborne contamination; and
- general mine worker health and safety.

Where possible, treatments have been identified by first considering design controls or by developing specific design criteria and secondly through the identification of management measures. Each of the identified management measures have also been included in relevant action plans, listed in **Chapter 15**. The action plans will be incorporated into relevant site management plans following Project approval.

7.4.1 Underground Mining

In order to effectively manage the additional health and safety risks presented by underground mining, ERA will develop and implement an underground performance standard. This standard will be based on the equivalent Rio Tinto performance standard that has the benefit of their extensive experience in designing, constructing and operating underground mines worldwide.

An integral component of the underground standard is that aspects must be developed and regularly reviewed by competent persons, who are independent, qualified and experienced. The reviews ensure that the approach to managing the risk or hazard is appropriate and considers recent developments or changes in accepted or best practices.

The mitigations that will be implemented as part of this new underground performance standard are summarised in the following sections.

7.4.1.1 Adequacy of Ground Control

A primary safety concern for underground mining is the major fall of ground and subsequent entrapment of workers. The underground mining areas for the Project have been subjected to extensive geotechnical studies, the outcomes of this work have been fed into the mine design for access drives and stopes to minimise this risk.

The primary mitigations for ground control, that will form part of the underground performance standard and be implemented for the Project include:

- suitably qualified engineers to undertake all design work;
- development of a ground control management plan;
- establishment of authorisation levels required for any changes to the ground control plan;
- programs for the maintenance of the documented mine plans;
- workplace design so that all work occurs in a secure environment;
- designs to consider the effects of hydrology and hydrogeology of the area;
- specified types or ground support materials that must be used in certain circumstances;
- specified requirements for pillars if used for ground control;
- operational rules specifying that no person can work under unsupported ground;
- training for ground support for workers and supervisors;
- protocols for inter shift communications regarding ground control; and
- procedures for verification of ground support including workplace inspections.

7.4.1.2 Establishment of Emergency Response Plan

Mine evacuation infrastructure to be installed for the Project will comprise a means for secondary egress to the surface, refuge chambers, communications and internal ladder ways.

The primary systems for emergency response, that will form part of the underground performance standard and be implemented for the Project include:

- an emergency response plan, which is to be based on an underground emergency risk assessment;
- installation of a warning system to alert all workers in the event of an emergency;
- written procedures for emergencies;
- a personal tagging system for all personnel entering the mine;
- evacuation procedures for a single entry mine; and
- self-contained refuges must be installed.

7.4.1.3 Fire Precautions for Underground Workings

The primary systems for fire management, that will form part of the underground performance standard and be implemented for the Project include:

- an underground fire risk assessment must be conducted;
- petrol-powered equipment banned from use underground;
- all equipment must have portable firefighting equipment;
- automatic fire suppression on equipment with more than 100 L of flammable liquids;
- detailed existing rules and limitations of underground fuel storage;
- all miners to have self-rescuers on their persons at all times when underground;
- fire risk plan to take consideration of the mine ventilation system; and
- detailed existing standards for use of fire resistant material.

7.4.1.4 Hoisting and Shaft Sinking

The primary mitigations for installation of ventilation raises (shafts) and the emergency egress hoisting equipment, that will form part of the underground performance standard and be implemented for the Project include:

- only competent persons to design the shafts and hosting system;
- development of a hoisting plan that is regularly reviewed by a competent person;
- development of a shaft sinking management plan by a competent person;

- programs for the maintenance and inspection of equipment and hoist ropes; and
- safety devices on hoisting systems to include back up braking systems, speed controls, interlocks and emergency switch.

7.4.1.5 Explosive and Hazardous Atmospheres

The primary mitigations for explosive and hazardous atmospheres, that will form part of the underground performance standard and be implemented for the Project include:

- a risk assessment to be conducted for hazardous atmospheres; and
- where there is a risk from hazardous atmospheres:
  - development of a ventilation management plan;
  - development of a Trigger Action Response Plan; and
  - training for recognition of explosive or hazardous atmospheres.

7.4.1.6 Inflow or Inundation of Liquids

The primary mitigations for minimising the potential for inflow or inundation of liquids, that will form part of the underground performance standard and be implemented for the Project include:

- a risk assessment for the inflow and inundation of water must be completed;
- development of an inflow and inundation management plan; and
- mine design and controls that are adequate to handle significant surface inflows.

7.4.1.7 In-Rush of Solids

The primary mitigations for minimising the potential for inrush of solids that will form part of the underground performance standard and be implemented for the Project include:

- identification of the potential for inrush of solids, for example from stope draw points and bulkhead failures;
- risk assessment to be conducted for inrush with particular attention to wet and fine materials and bulkhead failures;
- works where inrush may occur must be monitored on a regular basis; and
- detailed existing design controls and rules for:
  - draw points;
  - bulkheads;
  - ore passes;
  - chutes; and

- underground backfilling operations.

7.4.1.8 Air Blasts

The primary mitigations for air blasts, that will form part of the underground performance standard and be implemented for the Project include:

- a risk assessment to identify potential for air blasts;
- establishment of a cave management plan where there is the possibility that air blasts may occur;
- consideration of geotechnics[23] in all underground cave and cavity designs to identify and manage potential failures leading to air blasts;
- establishment of ongoing monitoring of caves or cavities where air blasts may occur; and
- compliance with specific design controls for air blasts for different mine types of mining.

7.4.1.9 Explosive Agents

The primary mitigations for explosives, that will form part of the underground performance standard and be implemented for the Project include:

- development of an explosives management plan covering procedures to handle, control, transport and use explosives;
- specific design controls for storage of explosives;
- risk assessments to be conducted for all phases of explosives use;
- processes to ensure that only authorised personnel are involved in explosives use; and
- regular audit and review of explosives used.

7.4.2 Radiation

The environmental risk assessment for the Project and subsequent radiation Bow Tie analysis (refer **Section 7.3.1**) identified a number of critical risk controls for radiation protection of workers.

ERA currently maintains an approved radiation management plan for existing operations (underground exploration decline and the existing processing plant facilities). This document would provide the basis for radiation protection of workers and will be updated with the additional controls for underground mining operations.

[23] The branch of engineering concerned with the study of soil and rock properties. In the mining context key issues are associated with rock strength and ground support requirements.

The dose assessment for the Project has shown that gamma radiation is the main contributor to predicted doses for underground workers. This assessment was based on the assumption that controls would be in place and operating effectively, and notes that doses could be significantly higher without the control mechanisms. Similarly, doses from the inhalation of the decay products of radon depend critically upon the effectiveness of the ventilation system.

This section therefore outlines the specific controls that ERA will implement to ensure that all doses remain below the annual dose limit and are ALARA.

For gamma radiation, the primary control will be to apply sufficient shotcrete to the walls, roof and face of new underground development areas, and clean fill or steel plates on the floor in order to reduce the gamma dose rate to below 10 µSv/h at the working location. Where this is not possible, one or all of the following will occur:

- additional shielding will be fitted to equipment working in higher grade locations;
- workers would be removed from exposure through the use of remotely operated equipment, for example:
  - production (long hole) drill rigs with semi-automatic controls enabling operators to leave the area during drilling;
  - production loaders with the capacity to use remote controls, thereby allowing operators to operate the equipment from remote and safe locations; and
  - shotcreting equipment fitted with extended booms allowing the shotcrete operators to be further away from the higher gamma radiation areas.
- occupancy times shall be reduced to ensure that workers do not receive more than 100 µSv per shift and 1 mSv per month.

Other gamma radiation controls will include:

- minimising the stockpiling of ore underground;
- electronic personal gamma monitoring of identified high exposure underground workers.
- establishment of a Trigger Action Response Plan for gamma exposures; this will include dose constraints for each shift, month, quarter and annual.

For inhalation of radon decay products and radioactive dust, the mine ventilation system is the primary control. Details of the ventilation system design and controls are provided in **Section 7.4.3.**

Other general management practices for radiation protection of workers will include:

- Access to areas of the underground mine with radon decay product concentrations above the Trigger Action Response Plan upper level will be prohibited unless under the direct control of a work permit, where the use specific protection measures will be outlined and required.

- ERA will employ suitably qualified and experienced personnel, including radiation safety and ventilation specialists who will be responsible for the overall management and maintenance of the underground ventilation system.
- During the design and operational stages of the mine, workplaces that are to be occupied for significant periods of time will be positioned in low grade areas to minimise gamma radiation exposure. For example, where exploration drilling is required, the drill sites will be placed in locations where the gamma doses are minimised and fresh air is directed into the workplace.
- Creation of operational practices including the regular cleaning out of sump to prevent build-up of radioactive materials and management of water to minimise the amount of radon from this source
- Implementation of a controlled areas and provision of clean/dirty change rooms. This will include the adoption of hygiene rules to minimise the risk of ingestion of radioactive materials.

Mine workers will be monitored for gamma and radon decay product exposure. Continuous personal monitors will be used for high exposure workgroups to ensure that radiation doses to individual workers can be managed if necessary. Details of the proposed monitoring program are provided in **Appendix 8**. The results of the monitoring will be managed using the Trigger Action Response Plan. This plan describes the specific actions that will be undertaken if certain levels are measured and provides a pre-planned response to escalating levels of hazard and risk. The proposed Trigger Action Response Plan is also provided in **Appendix 8**.

The monitoring and Trigger Action Response Plan will be used to track and manage radiation doses to workers, so that doses remain well below the annual limit of 20 mSv. Tracking doses on a shift, monthly and quarterly basis ensures that some workers do not accidently receive high doses and ensures that actions are put in place well before any worker will reach the annual dose limit. The proposed action levels for gamma exposure will be 0.1 mSv per shift, 1 mSv per month and 2 mSv per quarter. This will ensure worker doses stay below the predicted maximum annual radiation dose from gamma radiation of 7 mSv per year.

ERA currently has an approved radiation monitoring program for surface operations and this will be adequate to assess impacts to the environment and to surface workers from processing Project ores.

An approved radiation monitoring program is in place for the exploration decline and this will be expanded for the underground operation, and will include:

- continuous personal monitoring of higher exposed workers;
- personal monitoring for dose assessment;
- personal and location monitoring for workplace assessment; and
- monitoring to confirm the effectiveness of the ventilation system and other radiation controls (such as gamma reduction efficiency of the shotcrete on walls and the effects of shielding).

The Project will undergo regular radiation audits to verify the effectiveness of the control measures.

7.4.3 Airborne Contamination

A ventilation system will be installed that provides fresh air to all workplaces (see **Chapter 3** and **Section 7.3.3.10)**. The key design requirements of the Project ventilation system are:

- provide fresh air to all workplaces;
- multiple ventilation districts to enable areas to be isolated, with dedicated ventilation raises;
- utilisation of a one pass ventilation system, with no recycling of ventilation air;
- use of barricades and physical barriers to restrict and control airflows;
- exhaust ducting in areas of high radon that cannot be ventilated with the standard secondary systems; and
- continuous monitoring systems.

Management and maintenance of the ventilation system will be a priority and will include regular maintenance of ducting that may be damaged as a result of routine workings, air flow testing and barricade or ventilation control maintenance. During periods of significant maintenance (for example following a fan failure), respiratory protection will be used temporarily and access to affected areas will be restricted.

The ventilation system and standard dust controls (such as wetting of materials before handling and watering of roadways), and measures to reduce exposure (such as use of respiratory protection and air conditioned cabs) will ensure that dust exposures remain low.

When establishing stopes, the mine planner and ventilation specialist will develop a stope ventilation plan which will be signed off by the mine manager and the mine radiation safety officer. The plan will detail the specific ventilation requirements for the life of the stope including:

- identification of the particular tasks that will be carried out and the specific ventilation requirements;
- details of the placement of the secondary fan and ducting;
- locations of air flow barricades;
- consideration of potential impacts from adjacent stopes; and
- area and time restrictions that may be necessary.

An additional control for airborne contamination is that heavy mining equipment will be fitted with air conditioned cabins, with filters to reduce the concentration of contaminants in the operator's immediate air supply.

7.4.4 General Health and Safety

7.4.4.1 Approach to Health and Safety

A health and safety design criteria document has been developed that provides the basis for all processes, systems and component designs for the Project. The document provides guidance on general design principles and mandatory requirements that must be followed in design, and is based on the approach outlined in **Section 7.2**.

7.4.4.2 Health and Safety Management Plans

ERA maintains a number of health and safety management plans, which will be updated to incorporate the hazards and risks associated with the Project. New management plans will be developed for the underground operations. Details of the management plans that will be developed are provided in **Chapter 15**.

7.5 SUMMARY

ERA has been operating the Ranger mine for more than 30 years and has an established and mature system for the management of health and safety. The system is based on formal company safety standards that provide assurance that relevant hazards and risks are identified and controlled.

By undertaking underground mining operations at Ranger mine, additional hazards and risks will need to be considered and managed. The inherent hazards and risks of underground mining will be actively managed through:

- the implementation of: an underground safety performance standard;
- employing competent personnel to manage and operate the underground works;
- rigorously applying the underground safety procedures and rules; and
- instilling the existing ERA safety culture in the new workforce.

In addition to the worker health and safety risks, uranium mining also presents risks from radiation exposure. The radiation assessment conducted for the Project demonstrated that radiation doses to workers will be below the annual limit of 20 mSv per year. The predicted radiation doses were less than 12 mSv per year and typically average 5 mSv per year. This is slightly higher than that historically received by open pit mine workers at Ranger but similar to that of other underground uranium mines around the world.

The radiation assessment reflects mitigation measures that are based on industry experience and have been demonstrated to be feasible and successfully implemented in many underground uranium mines worldwide. The main mitigation measures include:

- Shotcreting of underground walls and placing of clean fill on underground drives to reduce gamma exposure to workers.
- Proving fresh air to all active work areas underground to reduce radon decay product exposure of workers.

The radiation assessment also estimated doses to the public from both inhalation of radon and dust and ingestion of bush foods. This demonstrated that radiation doses from the Project are very low, with the maximum predicted cumulative dose from Ranger mine being less than 10% of the public dose limit.

7.6 REFERENCES

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