Lynas Rare Earths Ltd

Mt Weld Mining Pty Ltd

Radiation Management Plan

Mt Weld Mine Site

MTW-MT-PLA-0001_10

Effective – 21 March 2022

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TERMINOLOGY, DEFINITIONS AND ABBREVIATIONS

Term	Definition
ALARA	As Low As Reasonably Achievable
AMAD	Activity Median Aerodynamic Diameter
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
Bq/g	Becquerels Per Gram
BOS	Blended Ore Stockpile
dmt	Dry Metric Tonne
DMIRS	Department of Mines, Industry Regulation and Safety
EPA	Environmental Protection Authority
ERMP	Emergency Response Management Plan
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IMT	Incident Management Team
ISO	International Organization for Standardisation
LAMP	Lynas Advanced Materials Plant
Lynas	Lynas Rare Earths Ltd
MDL	Minimum Detectable Limit
MSIA	Mines Safety and Inspection Act 1994
MSIR	Mines Safety and Inspection Regulations 1995
NORM	Naturally Occurring Radioactive Material
OSL	Optically Stimulated Luminescence
ppm	Parts Per Million
RBA	Radionuclide Balance Analysis
RE	Rare Earth
REPF	Rare Earth Processing Facility
REO	Rare Earth Oxide
RMP	Radiation Management Plan
ROM	Run of Mine Pad
RSA	Radiation Safety Act 1975
RSO	Radiation Safety Officer
SEG	Similar Exposure Group
SOP	Standard Operating Procedure
SVO	Surface Ventilation Officer
TLD	Thermo-luminescence Dosimeters
TMP	Transport Management Plan
TSF	Tailings Storage Facility
WTP	Water Treatment Plant

1 SCOPE OF PLAN

Mt Weld Mining Pty Ltd, (Mt Weld) a wholly owned subsidiary of Lynas Rare Earths Ltd, (Lynas) has prepared the present Radiation Management Plan (RMP) to satisfy the requirements of the Radiation Safety Act (1975) (*RSA*), Mines Safety and Inspection Act (1994) (*MSIA*) and their accompanying legislation with regards to the management of radiation hazards and risks associated with Mt Weld Operations.

The lanthanide ore, concentrate and flotation tailings treated at Mt Weld contain naturally occurring radioactive material (NORM) at concentrations exceeding the recognised level for radioactive classification. The mining and subsequent processing of ore containing NORM may result in employee radiation doses exceeding 1 mSv/year, therefore necessitating the application of Part 16 of the Mines Safety and Inspection Regulations (1995) (*MSIR*). The present RMP is prepared in accordance with Regulation 16.7 of the MSIR.

Guidance has been taken in the preparation of the RMP from both Guideline NORM–2.2: Preparation of a radiation management plan – mining and processing (DMP now DMIRS (2010)) and the ARPANSA Code of Practice and Safety Guide “Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing” (RPS-9) (ARPANSA (2005)).

In accordance with requirements of regulation 16.7.(4) of the MSIR, the RMP will be reviewed in the event of any material changes to the operation that may impact radiation exposures or at intervals designated by the State Mining Engineer. More frequent reviews will be carried out in accordance with regulation 16.7.(6) when the “plan for the mine is amended”.

1.1 Principal Employer

The formal details of the proponent are: Mt Weld Mining Pty Ltd, ABN 96 053 160 400

Mt Weld Mining Pty Ltd is a wholly owned subsidiary of Lynas Rare Earths Ltd.

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1.2 Application of the Radiation Management Plan

This Radiation Management Plan applies to the following Mt Weld Mining Pty Ltd operations:

- Lanthanide ore surface mining and concentrating at the Mt Weld site located 35 km south-east of Laverton in Western Australia;
- Transport of RE concentrate from the Mt Weld site to the Port of Fremantle for export, including temporary storage of RE concentrate (where necessary over a 24 hour period) at holding yards along the transport route;
  - Commissioning of the Lynas Kalgoorlie Rare Earth Processing Facility (REPF) will see transport of RE Concentrate from the Mt Weld site to the REPF, which is located at 70 Johns Road, Yilkari 6430, approximately 8 km west of Kalgoorlie on Great Eastern Highway.
- Ship loading at the Port of Fremantle.

1.3 Details of Leases and Tenements

The licences associated with the Mt Weld site are listed in Table 1. The locations of all tenements are presented on the map in Appendix A.

Table 1. Mt Weld Site Licences

Exploration	Mining	Miscellaneous	General Purpose
E38/2224	M38/58	L38/65	G38/34
E38/2935	M38/59	L38/224	G38/35
	M38/326		
	M38/327		

2 PROJECT OVERVIEW

The Mt Weld Lanthanide deposit lies over the centre of the Mt Weld carbonatite, a circular intrusive igneous complex approximately 3 km in diameter located 35 km south-east of Laverton in Western Australia (Figure 1). Layers of weathered carbonatite, laterite and lake sediments overlie the carbonatite host deposits and zones of rare earths, phosphate and niobium-tantalum mineralisation. These deposits are in turn overlain by 30 to 50 m of barren lake clay and transported alluvium.

Mining occurs on a campaign basis due to the low volumes of ore treated. Table 2 below summarises the various mining campaigns during Mt Weld operations. Future mining campaigns will be scheduled depending on required production volumes. The anticipated mine life for the Mt Weld Lanthanide deposit is 25 years.

Table 2. Mt Weld Mining Campaign Summary

Mining Campaign	Dates	Ore Mined *(wmt)*	Waste Mined *(wmt)*
Campaign 1	Jul 2007 – Jun 2008	773,000	4,061,000
Campaign 1B	Jan 2007 – May 2007	279,000	120,000
Campaign 2	Sep 2017 – Nov 2018	613,000	3,275,000
Campaign 3	Dec 2018 – Feb 2020	673,000	1,250,000
Campaign 4-1	Jul 2021 - Current	0 to date	to be advised
Total	**-**	**2,338,000**	**8,706,000**

The concentration plant at Mt Weld was commissioned in 2011 and is now licenced for production capacity of 443 ktpa of RE lanthanide ore. The processing method at the concentration plant has been progressively optimised and utilises existing, well-tested and state-of-the-art technology to produce RE concentrate.

At present, screened ore is hauled and blended to achieve a target feed grade prior to being supplied to the concentration plant. The plant utilises the process illustrated in Appendix L to generate a mixed RE concentrate for downstream processing.

- Single stage comminution;
- Froth flotation;
- Concentrate dewatering and drying;
- Concentrate bagging.

Flotation tailings are pumped to the Tailings Storage Facility (TSF) for deposition and storage. The RE concentrate is packed in sealed containers, trucked to Leonora, railed to Fremantle, and then shipped to the LAMP at Kuantan, Malaysia. The RE concentrate will become the feed source for the Lynas Kalgoorlie Rare Earth Processing Facility (REPF) that is scheduled for commissioning in H2 2022.

A summary of process streams and their associated specific activity for the 2021 financial period is displayed in Table 3.

Table 3. FY21 Mt Weld Operating Summary

Stream	Throughput *(dmt)*	ThO_2 Conc. *(ppm)*	U_3O_8 Conc. *(ppm)*	Specific Activity *(Bq/g)*
Lanthanide Ore	254,000	790	34	3.2
RE Concentrate	90,000	1,630	43	6.3
Flotation Tailings	164,000	353	30	1.6

The Lanthanide ore, RE concentrate and flotation tailings contain naturally occurring radioactive uranium and thorium at combined concentrations exceeding 1 Bq/g and are therefore classified as radioactive.

2.1 Site Description

The Mt Weld carbonatite was discovered after data from a Bureau of Mineral Resources aeromagnetic survey in 1966 revealed a pronounced magnetic anomaly. Originally explored as a phosphate resource, it was later explored for RE potential. In 2002, Lynas acquired 100% of Mt Weld Pty Limited, which held the title to the deposit, and has since proved Australasian Joint Ore Reserves Committee (JORC) compliant RE resources and reserves.

The Mt Weld mine site is located 35km southeast of Laverton (Figure 1). The locality is well serviced by a transport infrastructure airstrip at Laverton. An access road joins Laverton with the Sunrise Dam gold operation located a further 30km to the south of the Mt Weld leases. A 9 km gravel road provides access to the Mt Weld operation.

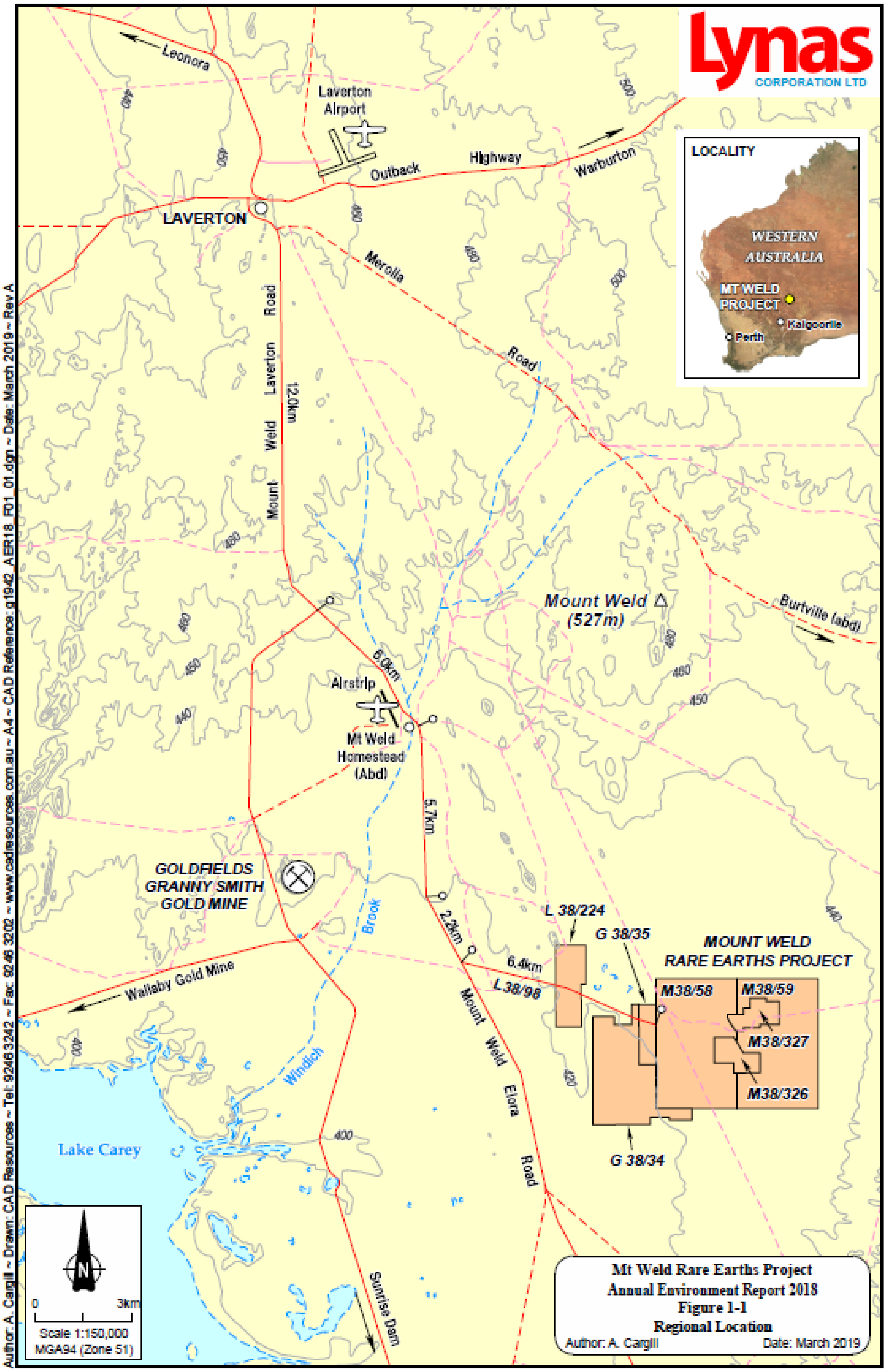

Figure 1. Mt Weld Regional Location

2.2 Process Description

2.2.1 Mining Operations

Ore is mined through conventional open pit mining methods in distinct mining campaigns according to processing and business requirements. A mining contractor is mobilised to carry out mining operations during the periods of active mining. Mined ore is hauled and stockpiled on-site according to grade and ore type.

2.2.2 ROM & BOS Ore Handling Operations

Ore handling at the ROM has seen various iterations of mobile crushing and excavator bucket screening employed since 2010. At the time of submitting this document, excavator bucket crushing and screening is being used on the ROM to reduce the mined ore to acceptable size prior to treatment at the concentration plant.

Ore is transported from the ROM to the BOS via a road train side tipper that arranges ore according to grade for subsequent blending by front-end loader.

2.2.3 Plant Operation

A front-end loader is used to feed ore from the BOS into the mill feed hopper which reports to the comminution circuit consisting of a single-stage ball mill in closed circuit with hydrocyclones. The throughput of the concentration plant is approximately 30-40 dry tonnes per hour (dtph). Water, sodium silicate and sodium hydroxide are introduced to reduce viscosity and increase pulp pH to 10-10.5. The comminution circuit product becomes feed for the flotation circuit.

The flotation circuit consists of a pre-rougher StackCell, with concentrate reporting directly to final concentrate and the tails undergoing one stage of rougher flotation and three stages of scavenger flotation. The combined rougher-scavenger concentrate feeds a cleaner-scalper StackCell, with concentrate reporting directly to final concentrate. The tails report to a cleaner circuit containing two stages of cleaner flotation and one stage of cleaner-scavenging. The resulting combined flotation concentrate is pumped to the dewatering circuit where two thickeners and two plate filters operate in parallel to reduce slurry moisture from approximately 70-80% to 15-20%.

The concentrate produced following dewatering is dried to a moisture around 10-15% through a combination of solar dying and treatment by an indirect fired concentrate dryer with a capacity of 30 t/hr.

2.2.4 Tailings Storage

Flotation tailings are pumped from the plant at a density of approximately 12% solids for deposition within the tailings storage facility (TSF). Tailings are mixed with flocculant prior to deposition in a process known as ‘enhanced tailings deposition’ (ETD) which aids tails consolidation.

Mechanically assisted dewatering of tailings is also employed through mudfarming and subsequent dozer compaction to further enhance consolidation. The ETD and mudfarming techniques raise the density of tailings from approximately 0.7 t/m^3 (37% solids) to over 1.3 t/m^3. Supernatant water released from the tailings are recovered for treatment via the return water pond (RWP) and subsequently the recycle water treatment plant (WTP).

Tailings are generated at an average rate of 70% of the feed rate, which equates to 170,000 tpa at current production capacity.

Evaporation ponds are utilised for the evaporation of salt brine from the RO plant.

2.2.5 Transport of RE Concentrate

The RE concentrate produced is currently packaged in lined, sealed bags and loaded into containers. Sea containers are then transported to Fremantle Port for export to the Lynas Advanced Materials Plant (LAMP) in Malaysia for further processing.

With the commissioning of the Kalgoorlie Rare Earth Processing Facility (REPF) scheduled for H2 2022, a new transport method will be employed in which concentrate will be loaded directly into closed containers at Mt Weld. The containers will then be transported by a mix of road/rail to the Kalgoorlie REPF site for processing.

Temporary storage locations at which the concentrate is stored for more than 24 hours are registered with the Radiological Council. A map of the road and rail transport routes can be found in Appendix B.

2.3 Workforce

As of September 2021, 113 persons are currently employed at the Mt Weld site, of which 84 are employees of Lynas and 29 are contractors. An employee breakdown by work category is displayed in Table 4.

Table 4. Typical Workforce Distribution (September 2021)

Work Category	Lynas Employees		Contractors		Total
	Male	*Female*	*Male*	*Female*	
Concentrator Operational Staff	26	3	9	4	42
Concentrator Maintenance Staff	15	3	6	2	26
Concentrator Support Services	19	6	4	0	29
Mining Operational Staff	7	2	2	0	11
Clerical Staff	0	3	1	1	5
TOTAL	**67**	**17**	**22**	**7**	**113**

The following shift roster system is in use on the mine site:

- 8/6 – 8x 12hr shifts on, 6 days off. Typical roster for concentrator and mining services staff.

The typical annual working duration to be utilised for dose assessments (accounting for 20 annual leave days) is 2,260hrs for the 8/6 roster.

It shall be noted that due to the campaign style of mining and project construction activities, there are at times in which the contractors will utilise different roster systems, particularly 14 days on, 7 days off. When necessary, the different roster systems will be used for dose assessments of contract mining staff and construction staff.

2.3.1 Similar Exposure Groups

There are two Similar Exposure Groups (SEGs) at the Mt Weld Operations:

- SEG #1 – Concentrator Staff:
  - Comprised of Concentrator Operational Staff, Concentrator Support Services, Site Clerical Staff and Technical Support employees based in administration offices.
  - Work conducted in non-radiation classified and supervised radiation areas.
- SEG #2 – Mining Staff:
  - Comprised of Mining Operational Staff and Mining Support Services.
  - Work conducted in non-radiation classified, supervised and controlled radiation areas.

2.4 Critical Group Information

The Mt Weld site lies in a remote region with no permanent settlement in close proximity, with the nearest homestead (Hack's Well – abandoned though utilised seasonally for mustering camps), located approximately 10 km to the south.

There are no members of the public in the vicinity that can be impacted by Mt Weld operations as access is controlled with only inducted employees, contractors and supervised visitors permitted entry.

Several Critical Groups of the general public have been identified along the route of the transport of the concentrate. Their possible exposures are assessed in Section 6.

3 SOURCES AND PATHWAYS OF RADIATION EXPOSURE

3.1 Radiation Exposure Types

Three main types of radiation associated with mining and mineral processing are alpha (α), beta (β) and gamma (γ) radiation.

Alpha-radiation is considered a hazard if its source is located inside the body, highlighting an internal radiation risk. In mining and mineral processing, the main way in which the source can get into the body is when it is breathed in as dust (inhalation). Small amounts may be taken in through the mouth (ingestion), but this material is typically disposed from the body by excretion.

Dust that is inhaled could stay in the lungs for long periods. If the dust contains alpha-emitters, the lungs will be subject to a certain dose of alpha-radiation. Other sources of internal alpha-radiation within the body are decay products of radon (^{222}Rn) and thoron (^{220}Rn), radioactive gases in the decay chains of uranium and thorium.

Beta-radiation mainly affects skin and the tissue that lies immediately underneath the skin.

Sources of gamma-radiation could cause radiation damage without residing within the body. A person located near any radioactive material, which emits gamma-radiation, will be subject to a certain radiation dose. Gamma radiation affects skin, deep tissue and organs depending on the dose received. Beta and gamma radiation both present an external radiation risk.

3.2 Background Radiation

Naturally occurring background radiation is the ionising radiation within the environment that people are continuously exposed to. Soils, water, air and cosmic radiation all contribute to natural ionising background radiation that is highly variable dependent on geographic location.

Background radiation varies globally from 1-13 mSv per year dependent on exposure to naturally occurring radiation (i.e., higher altitude, distance from equator, geological formations, etc.). *Australian Radiation Protection and Nuclear Safety Agency* (ARPANSA) estimates the average natural background radiation in Australia to be approximately 1.5 mSv/year.

3.3 Radiation Exposure Pathways

The following exposure pathways have been identified as being relevant to Mt Weld operations. Their respective inclusion in the radiation monitoring program will be assessed in terms of the potential contribution to total occupational dose.

- External Exposure – Gamma Radiation
- Internal Exposure – Radon and Thoron
- Internal Exposure – Airborne Dust
- Surface Contamination
- Ingestion of Drinking Water
- Ingestion of Food, Dust and Soil

3.3.1 External Radiation Exposure – Gamma Radiation

At Mt Weld operations, naturally occurring ^{238}U and ^{232}Th contained within the lanthanide ore is the source of NORM. Both uranium and thorium are continuously decaying, producing other elements, which are also radioactive. Figure 8 & Figure 9 in Appendix C show the various stages of decay of thorium and uranium chains, the type of radiation emitted at each step and half-lives for each particular radioisotope both for thorium and uranium decay chains.

Many isotopes listed in these schemes emit gamma-radiation, the strongest gamma-radiation being emitted by actinium-228 (^{228}Ac) and thallium-208 (^{208}Tl) in the thorium chain, and by protactinium-234 (^{234}Pa), bismuth-214 (^{214}Bi) and thallium-206 (^{206}Tl) in the uranium chain. Other isotopes also emit gamma rays, but these have much less effect on the exposure rate due to their relative weakness.

The Mt Weld ore and concentrate both contain radionuclides from thorium and uranium series emitting gamma radiation, and as such are a potential external radiation hazard. The external dose rate depends primarily on the concentration of thorium and uranium, the volume of the material and geometry factors (distance from a source, the source area, etc.).

Five radiation gauges containing radioactive isotope ^{137}Cs present another source of the external gamma-radiation at various positions within the flotation plant. These gauges are not located in the vicinity of control/crib rooms and appropriate signs are attached to them.

Other potential sources of external radiation exposure from gamma-radiation are the X-ray analytical machines located in the laboratory and at the top of the flotation circuit.

Details of all irradiating apparatus used at Mt Weld are provided in Appendix D.

3.3.2 Internal Radiation Exposure – Airborne Dust

The presence of radionuclides in airborne dust at the Mt Weld site is primarily generated through fugitive dust from ore and concentrate stockpiles. Monitoring of radionuclides in airborne dust will be conducted in both Mining and Concentrator work areas due to generation of dust from ore stockpiles on the ROM and the BOS and RE concentrate in bagging areas.

3.3.3 Internal Radiation Exposure – Radon and Thoron

Concentrations of radon, thoron and their daughter decay products in ground level air at operations dealing with NORM have previously contributed insignificantly to the total occupational radiation dose. The recent revision of dose conversion factors for radon and thoron set out in NORM-V Dose Assessment (DMIRS, 2021) have considerably increased the dose contribution from inhalation of radon and thoron.

Concentrations of radon (^{222}Rn) and thoron (^{220}Rn) gases are typically far greater in mining areas (mining pit & ROM) than the concentration plant due to the larger volumes of ore present and the ability for gas to accumulate in the pit.

3.3.4 Surface Contamination

The primary purpose of surface contamination monitoring is to ensure no equipment is released from site with surfaces contaminated with radioactive material in excess of statutory limit of 0.4 Bq/cm^2.

Measurements to date indicate that the contamination of surfaces is not expected to contribute significantly to overall levels of radiation exposure of workers at the Mt Weld site.

Measurements are carried out on the outside surfaces of mining equipment, trucks used for ore haulage and front-end loaders used to load ore or concentrate during operations and prior to the equipment leaving Mt Weld site to ensure that no contaminated equipment is released from site.

3.3.5 Ingestion of Drinking Water

Mt Weld drinking water is supplied by water bores shown in Appendix E, which is subjected to Reverse Osmosis (RO) treatment and dosed with chlorine.

Radionuclide concentrations in the bore water supply are low and have not increased during Mt Weld operations. A check of Ra-226 & Ra-228 concentrations in potable water supply was conducted in January 2020. Table 5 shows that the total annual occupational dose from ingestion of drinking water is approximately 0.04 mSv. It must be noted that no background concentration has been incorporated within the dose calculation.

Table 5. Ra-226 & Ra-228 in Potable Water

	Concentration *(Bq/L)*	**Dose Coefficient *(mSv/Bq)***	**Dose *(mSv/year)***
Ra-226	0.119 ± 0.015	0.00013	0.01 ± 0.001
Ra-228	0.138 ± 0.025	0.00034	0.03 ± 0.002
Total	**-**	**-**	**0.04 ± 0.003**

Intake of radionuclides in drinking water represents less than 5% of occupational dose (0.92 mSv 2020/21 total CED) and is considered an insignificant contribution to total dose.

Ingestion of drinking water as a pathway of radiation exposure will only be assessed in the future if there is a measurable increase in bore water radionuclide concentration.

3.3.6 Ingestion of Food, Dust and Soil

There is no food produced for human consumption at Mt Weld. Suitable eating facilities (crib rooms) and personal hygiene standards are implemented, ensuring that the pathway of ingestion of radionuclides from food, dust and soil will not be considered for the purposes of occupational dose assessments.

3.4 Process Streams

A radionuclide balance conducted on the major Mt Weld processing streams in April 2020 is summarised in Table 6 and Table 7 below. The samples were collected during standard plant operation and analysed at IAF Radionuclide Laboratory in Germany. The laboratory certificate and radionuclide balance calculations are detailed in Appendix F.

Table 6. Th-232 Chain Radionuclide Balance

Process Stream	**^{232}Th *(MBq/day)***	**^{228}Ra *(MBq/day)***	**^{228}Th *(MBq/day)***
Mill Feed	1986 ± 397	2177 ± 192	2170 ± 193
RE Concentrate	1172 ± 211	1240 ± 89	1292 ± 102
Flotation Tails	853 ± 230	965 ± 86	906 ± 81
Balance (MBq/day)	**39 ± 839**	**27 ± 367**	**28 ± 376**
Balance (%)	**2% ± 42%**	**1% ± 17%**	**1% ± 17%**

Table 7. U-238 Chain Radionuclide Balance

Process Stream	**^{238}U *(MBq/day)***	**^{234}U *(MBq/day)***	**^{230}Th *(MBq/day)***	**^{226}Ra *(MBq/day)***	**^{210}Pb *(MBq/day)***	**^{210}Po *(MBq/day)***
Mill Feed	222 ± 89	288 ± 115	314 ± 107	318 ± 79	264 ± 132	275 ± 41
RE Concentrate	98 ± 39	122 ± 49	200 ± 58	125 ± 25	97 ± 49	152 ± 23
Flotation Tails	165 ± 66	206 ± 82	166 ± 55	204 ± 51	173 ± 87	173 ± 24
Balance (MBq/day)	**41 ± 194**	**41 ± 247**	**53 ± 220**	**11 ± 155**	**6 ± 267**	**50 ± 88**
Balance (%)	**19% ± 87%**	**14% ± 86%**	**17% ± 70%**	**4% ± 49%**	**2% ± 101%**	**18% ± 32%**

The Th-232 chain (Table 6) balances very well and shows all major streams are in secular equilibrium throughout the concentration plant.

It is acknowledged that the U-238 chain reconciliation is poor compared to the Th-232 chain (Table 7). The high laboratory uncertainty associated with the uranium chain assays results in a high error for the overall balance. The low concentrations of radionuclides within the U-238 chain may be a factor in the high laboratory uncertainty.

Due to the absence of any evidence to the contrary, it is believed that the U-238 chain is in secular equilibrium throughout the concentration plant.

4 INSTITUTIONAL CONTROLS

The approach to radiation management and protection at Mt Weld draws on knowledge accumulated through 10 years of operational experience across both Mt Weld and LAMP operations.

4.1 Radiation Protection Standards

Radiation protection is generally legislated at a state level through adoption of publications from national and international organisations who specialise in radiation protection.

Radiation protection is administered through adherence to the as low as reasonably achievable (ALARA) principle which requires radiation doses be maintained "as low as reasonably achievable" with consideration of social and economic factors.

In Western Australia, regulation of radiation protection is through the following legislative articles:

- *Radiation Safety Act 1975* (RSA)
  - *Radiation Safety (General) Regulations 1983*
  - *Radiation Safety (Qualifications) Regulations 1980*
  - *Radiation Safety (Transport of Radioactive Substances) Regulations 2002*
- *Mines Safety and Inspection Act 1994* (MSIA)
  - *Mines Safety and Inspection Regulations 1995* (MSI Regulations)

While the ALARA principle guides the approach to maintaining radiation protection, radiation dose limits established in IAEA (2014) and adopted in Australia provide structural protection from radiation exposures. The dose limits apply to the sum of all radiation exposure pathways and do not take background radiation into consideration. The IAEA dose limits have been adopted under the RSA which are:

Radiation workers:

- Maximum effective dose of 20 mSv per year averaged over 5-year period.
- Maximum effective dose of 50 mSv in one-year pro rata over any period less than 12 months.

Non-radiation workers/members of the public:

- Maximum effective dose of 1 mSv per year averaged over 5 years.
- Maximum effective dose of 5 mSv per year in one year.

The DMIRS published NORM Guidelines 2010 are a series of explanatory documents outlining best practice and regulatory compliance for WA mining operations that involve NORM. Guidance from the NORM Guidelines has been used in the preparation of the present RMP.

Preparation of this management plan has also taken guidance from the ARPANSA Codes RPS 09 (2005), RPS C-1 (2020) and NORM-V Dose Assessment (2021).

4.2 Radiation Safety Expertise

A suitably qualified Radiation Safety Officer is appointed and responsible for the implementation of the RMP and Radiation Protection Monitoring Program. A fully qualified Surface Ventilation Officer is appointed to ensure that all air monitoring is undertaken in accordance with the Australian Standards and West Australian Guidelines.

The current appointed Radiation Safety Officer (RSO) and Surface Ventilation Officer (SVO) for Mt Weld Mining are as follows:

Table 8. Appointed Personnel

Appointed Position	Name	Date Started	Title	Licence Number
Radiation Safety Officer	Kallan McElroy	March 2016	Process Engineer	LS 550/2018 29668
Surface Ventilation Officer	Gareth Neczypor	January 2012	HSE Manager	N/A

A Radiation Safety Officer Deputy (or deputies) may be appointed by the RSO or Registered Manager to fulfil the duties of the RSO should they be offsite.

4.3 Classification of Workplaces and Employees

Workplaces and employees are provided classifications based on the level of radiological risk presented by their respective operational function and interaction with radionuclides.

4.3.1 Classification of Workplaces

Guidance is provided for radiological classification of workplaces in ARPANSA (2005) as follows:

Supervised Area: "*an area in which working conditions are kept under review but in which special procedures to control exposure to radiation are not normally necessary.*"

Controlled Area: *"an area to which access is subject to control and in which employees are required to follow specific procedures aimed at controlling exposure to radiation."*

NORM-6 provides further guidance around workplace implementation by establishing gamma exposure limits for each classification as follows:

Supervised Area: *Gamma dose rate greater than 0.50 µGy/hr (0.50 µSv/hr) above background. Dose equivalent to >1 mSv/year for employees.*

Controlled Area: *Gamma dose rate greater than 2.50 µGy/hr (2.50 µSv/hr) above background. Dose equivalent to >5 mSv/year for employees.*

Results of the measured occupational doses presented in Section 5.4.1 confirms worker doses will remain well below 5 mSv/year; however, gamma surveys in mining areas have exceeded 2.5 µSv/hr, necessitating the implementation of controlled radiation areas.

The classification of workplaces at Mt Weld is listed below and displayed in Appendix G:

- Supervised radiation areas:
  - Concentration plant
  - Tailings storage facility (TSF) and evaporation ponds
  - Waste dump
- Controlled radiation areas:
  - Run-of-mine (ROM) pad
  - Mining pit floor

4.3.2 Signage

The following signage is in place for entry to supervised and controlled radiation areas to provide awareness of radiation risks in the workplace and administer radiation safety procedures.

Figure 2. Supervised Radiation Area Signage

Figure 3. Controlled Radiation Area Signage

4.3.3 Classification of Employees

Guidance is provided for radiological classification of employees in ARPANSA (2005) and the MSIR which recommend the intensity of employee monitoring to be commensurate with the exposures potentially received. Any employee who may receive an annual effective dose >5 mSv/year is to be classified a ‘designated’ radiation employee which requires a greater degree of monitoring relative to ‘non-designated’ employees.

No employee has ever received an annual radiation dose exceeding 5 mSv and therefore all employees are classified ‘non-designated’ radiation workers.

4.4 Dust Suppression and Extraction

A comprehensive housekeeping program is in place for crushing and/or screening (when operational), flotation plant, and for the ore/concentrate storage/handling area. Potentially contaminated surfaces are periodically hosed down and/or as directed by the Radiation Safety Officer.

Roads on site and within controlled and supervised areas are regularly sprayed with a water truck to keep the dust generation at low levels.

Filters of air conditioning systems of machinery, vehicles and site buildings are periodically inspected and cleaned.

An extensive dust extraction unit has been installed within the Metallurgical Laboratory. Given the analytical tasks and test work projects undertaken within the lab, excessive fine particles are constantly generated. The operation of the dust extraction unit allows this dust to be removed from the lab environment, safely collected and disposed of through reincorporation into the process.

4.5 Housekeeping and Personal Hygiene

The housekeeping and personal hygiene requirements within controlled radiation areas are maintained at higher standards than other areas on site due to the inherently higher radiological risk level.

Controlled radiation areas are classified as ‘No Smoking & Eating Zones’ and will be subject to greater scrutiny regarding cleanliness and work practices to ensure radiation exposures are maintained as low as possible. Should surface contamination monitoring of employee clothing exceed the statutory 0.4 Bq/cm^2 limit, a work procedure will be introduced requiring employees remove and wash contaminated clothing prior to leaving site.

4.6 Surface Contamination Control

The purpose of surface contamination monitoring is to ensure no radioactive material in excess of the statutory limit of 0.4 Bq/cm^2 in a 300 cm^2 area is released from site through transport on equipment, plant or worker clothing.

Surface contamination inspections and monitoring are routinely conducted on the following:

- All mobile plant demobilising from site that has operated in controlled radiation areas;
  - E.g. loaders, haul trucks, screening buckets etc.

- All mobile plant demobilising from site that has worked primarily on the BOS or TSF
  - E.g. BOS loader, MudMaster etc.
- Periodic inspections of personnel hygiene practices of those working in controlled areas.

4.7 Work Permit System and Special Exposures

Mt Weld ore and RE concentrate are categorised as low specific activity radioactive materials, the handling of which cannot give rise to high dose rates. No employees would receive an effective dose of 1 mSv or higher during one or a few shifts. Nevertheless, if any special works involving handling of material where higher than usual exposures may be expected, the Radiation Safety Officer will develop a Work Permit System for the minimisation and monitoring of personal radiation exposures.

4.8 Employee Training

All employees and contractors are required to complete an online radiation induction outlining sources of radiation exposures, personal exposures in different work areas, radiation health risks, management of radiation exposures, principles of radiation protection monitoring, etc.. Inductions are re-taken on a 2-yearly basis.

Employees working in controlled radiation areas will be required to undertake a further induction containing additional information and training commensurate with the radiation hazards presented by elevated radionuclide concentrations in the workplace. Records will be maintained of employees who undergo controlled radiation area inductions.

4.9 Records Management and Reporting

A comprehensive computer-based record keeping system will be established and maintained. The system will include:

- Records of radiation protection training of employees and contractors.
- Records of occupational radiation monitoring and survey results.
- Records of environmental radiation monitoring.
- Records of tailings deposited into the TSF, including tonnages and thorium and uranium concentrations.
- Calibration documentation of radiation monitoring equipment.
- Records of any special and/or accidental exposures.
- Any other relevant information that may be required to be recorded as instructed by the Radiological Council or DMIRS.

Annual occupational and environmental radiation monitoring results will be provided in a consolidated report to the Radiological Council and State Mining Engineer.

4.10 Operating Procedures

A range of standard radiation operating procedures and work instructions have been developed to support implementation of the RMP. The relevant work procedures are listed in Appendix H.

4.11 Quality Assurance Program

ARPANSA (2005) prescribes implementation of a quality assurance (QA) program that complies with relevant Australian Standards and incorporates traceability of radiation measurements, calibration documentation and auditing systems.

The present RMP including the monitoring program, operating procedures, monitoring results and administrative practices shall be periodically appraised. An internal audit of the RMP will be carried out every two years in accordance with the DMIRS regulations and guidelines.

This RMP will continue to be analysed and modified to ensure the scope and frequency of radiation monitoring is commensurate with the ongoing radiological risk at the Mt Weld site.

Radiation matters at Mt Weld operations are managed in accordance with the following management frameworks:

- Occupational, Health and Safety Management System (ISO 45001)
- Environmental Management System (EMS – ISO 14001)
- Quality Management System (QMS – ISO 9001)

Lynas' adherence to the ISO management systems is externally audited to ensure operations identify, manage and control processes in a holistic manner that promotes continual improvement.

5 RADIATION MONITORING PROGRAM

Occupational and environmental monitoring programs form the basis for radiation monitoring at Mt Weld.

As per guidance provided in NORM Guideline 2.2, previous radiation monitoring programs have been comprehensive to build a substantial dataset of monitoring data. The radiation levels associated with Mt Weld operations are now well established, allowing an adjustment to the monitoring scope and frequency to a level commensurate with the ongoing radiological risk.

The following radiation monitoring program is aligned with the radiological risk profile of Mt Weld operations:

5.1 Occupational Radiation Monitoring Program

5.1.1 External Gamma Radiation Exposure

- All Mining Operational Staff (excludes Mining Support Services) within the Mining Staff work group will be issued OSL badges;
- 20 OSL badges will be randomly assigned to employees within the Concentrator Staff work group, of which 10 badges (50%) are to be issued to process technicians.
- Handheld GM area surveys conducted at:
  - Mining pit floor (if active) or boundary two times per year.
  - ROM area and boundary two times per year
  - Tailings storage facility and evaporation pond boundary once per year.
  - Concentrate temporary storage areas at RSO discretion.

5.1.2 Internal Radiation Exposure – Inhalable Dust

- A minimum 12 personal dust samples per quarter (48 samples per year) with representation of SEG #1 and #2 (if mining active).
- Positional (area) samples will be taken at the discretion of the RSO or SVO.

5.1.3 Internal Radiation Exposure – Radon and Thoron

- Static radon and thoron pairs deployed for a minimum 3-month period in:
  - Two areas within the concentration plant.
  - Two areas within mining areas (if active).

5.1.4 Surface Contamination Monitoring

- Any vehicles/equipment potentially exposed to radioactive material are to be tested prior to leaving site:
- Measurements from employees' clothing at the discretion of RSO.

5.2 Environmental Radiation Monitoring Program

5.2.1 Gamma Radiation

- Handheld GM area survey of the site boundary once per year.
- Survey of the concentrate transport route – only in the event of an incident in which material is released into the environment.

5.2.2 Dust Monitoring

- One high volume sample from each identified location every six months, representing a total of 8 samples per year.

5.2.3 Water Monitoring

- Water sampling from monitoring bores every six months analysing for concentrations of gross alpha and gross beta.

5.3 Radiation Monitoring Equipment

The following equipment is used to monitor radiation exposure pathways:

Mt Weld Site:

- 1x RadAlert 'Inspector' – for gamma-radiation and surface contamination monitoring.
- 1x Ludlum 26-1 pancake frisker – gamma radiation monitoring.
- Quarterly sets of OSL badges – to be supplied by Landauer.
- Quarterly sets of radtrak[2] passive radon and thoron pairs supplied by Landauer.
- Dust monitoring sample pumps, including electronic calibrator and sample heads – for inhalable dust monitoring.
- High volume sampling skid unit – for environmental high-volume dust monitoring.
- Canberra 7401 alpha-spectrometer with calibration sources – for alpha counting of dust samples.

Lynas Perth Office:

- One RadAlert 'Inspector' - for gamma-radiation and surface contamination monitoring.

5.4 Annual Dose Assessment

As there are no designated employees at Mt Weld and there are not expected to be any in the foreseeable future, an average dose assessment is determined for the SEGs identified in Section 0.

Employees deployed in SEG #1 or #2 are separated by work area with no overlap between workgroups. An average dose assessment will be determined for both SEGs along with a combined workforce assessment.

5.4.1 Dose Assessment Summary

A summary of measured occupational doses from the 2020/2021 radiation monitoring period is shown below in Table 9. The total dose for workers at Mt Weld remains approximately 10% of the radiation worker limit (20 mSv/year) as set by the Regulations under the MSIA.

Table 9. Summary of 2020/21 Personal Dose Assessment

Exposure Pathway	Radiation Dose *(mSv/year)*
Gamma	0.23
Radon Inhalation	0.09
Thoron Inhalation	0.06
Dust Inhalation	0.53
Total	**0.9**

Dose assessments were conducted for both workgroups alongside a combined workforce ('All Staff') assessment in in the 2019/20 Annual Occupational & Environmental Radiation Report that found the combined workforce assessment to be the most conservative. As such, current and future reporting will show a single dose assessment for both workgroups, while continuing to monitor both separately.

The assessment methodology employed for individual exposure pathways as part of the total annual dose is further detailed below:

5.4.2 External Exposure – Gamma Radiation

All employees who work within radiation controlled areas and a selection of employees who work in radiation supervised areas are issued optically stimulated luminescence (OSL) badges for the purposes of monitoring personal gamma radiation exposure. Control badges are stored inside site offices, where the level of gamma radiation is comparable to the natural background. Results of OSL monitoring will comprise the external exposure used to determine total annual dose.

Checks of gamma radiation levels around the Mt Weld site are conducted through periodic area surveys. Typical results of gamma radiation area surveys are as follows:

- Mining pit floor – 1.5 µSv/hr
- Mining pit boundary – 0.2 µSv/hr
- Ore storage area (ROM) – 1.1 µSv/hr
- Waste dump boundary – 0.4 µSv/hr
- Tailings storage facility boundary – 0.3 µSv/hr;
- Concentrator and surroundings – 0.5 µSv/hr.

5.4.3 Internal Exposure – Inhalation of Airborne Dust

The committed effective dose per unit of specific activity of ^{232}Th and ^{238}U due to inhalation of ore, concentrate and tailings airborne dust can be derived for the thorium and uranium weight ratio in the RE concentrate of Th:U = 40:1 using the following dose conversion factor (DCF) derived from NORM-V (DMIRS, 2021):

- 0.0161 mSv/Bq, for the 5 µm AMAD (activity median aerodynamic diameter)

The internal dose assessment for a worker from the exposure to radionuclides in airborne dust is calculated in accordance to the NORM-V (DMIRS, 2021), as follows:

$$\mathrm{Dose_{dust}}\left[\frac{\mathrm{mSv}}{\mathrm{year}}\right] = \mathrm{AM} * \mathrm{HW} * \mathrm{BR} * \mathrm{DCF}$$

Where:

- *AM* is arithmetic mean of gross alpha-activity concentration (Bq/m^3).
- *HW* is the exposure time (hours).
- *BR* is the worker breathing rate (m^3/hr).
- *DCF* is the dose conversion factor (mSv/Bq).

5.4.3.1 Particle Size (Aerial Median Aerodynamic Diameter – AMAD)

The mean AMAD was determined during the 2012/13 monitoring period using the Marple Cascade Impactor in accordance with the Guideline NORM-3.5: Measurement of Particle Size (DMP now DMIRS, 2010). Measurements from the concentration plant ranged between 9.4 – 10.3 µm with an average 9.8 µm. To ensure a conservative dose assessment is conducted, a 5 µm AMAD will continue to be used for DCF determination.

Further AMAD measurements were conducted in March 2017 with an average 8.2 µm again confirming the use of 5 µm AMAD for DCF determination.

5.4.4 Internal Exposure – Inhalation of Radon and Thoron

The internal dose assessment for a worker from the exposure to radon and thoron is calculated in accordance with the NORM-V Guideline (DMIRS, 2021).

Potential alpha energy exposures to radon and thoron progeny are determined from the concentrations of radon and thoron gas in air using the following formulae:

$$\mathrm{P_{RnP}}\,[\mathrm{mJh/m^3}] = 5.56 * 10^{-6} * \mathrm{t} * \mathrm{F_{RnP}} * \mathrm{C_{RnP}}$$

$$\mathrm{P_{TnP}}\,[\mathrm{mJh/m^3}] = 7.57 * 10^{-5} * \mathrm{t} * \mathrm{F_{TnP}} * \mathrm{C_{TnP}}$$

Where:

- P_{RnP}, P_{TnP} are the potential alpha energy exposures to radon and thoron progeny (mJh/m^3).
- *t* is the exposure time (hours).

- F_{RnP}, F_{TnP} are the radon & thoron progeny equilibrium factors.
- C_{Rn}, C_{Tn} are the radon & thoron gas concentrations (Bq/m^3).

The subsequent dose from radon and thoron exposure is then calculated using the following formulae:

$$\mathrm{Dose}_{\mathrm{Rn}}\left[\frac{\mathrm{mSv}}{\mathrm{year}}\right] = \mathrm{P}_{\mathrm{RnP}} * \mathrm{DCF}_{\mathrm{Rn}}$$

$$\mathrm{Dose}_{\mathrm{Tn}}\left[\frac{\mathrm{mSv}}{\mathrm{year}}\right] = \mathrm{P}_{\mathrm{TnP}} * \mathrm{DCF}_{\mathrm{Tn}}$$

Where:

- DCF_{Rn}, DCF_{Tn} are the respective dose conversion factors for radon and thoron mSv/(mJh/m^3) as set out in ICRP Publication 137 (ICRP, 2017).
  - DCF_{Rn} is 3.0 mSv/(mJh/m^3).
  - DCF_{Tn} is 1.5 mSv/(mJh/m^3).

Testwork conducted at Mt Weld has previously established a site-specific thoron progeny equilibrium factor to be 0.002. Data used to establish the equilibrium factor is detailed in Appendix I.

5.5 Investigation Thresholds

The thresholds for radiation monitoring results, above which an investigation will be instigated have been extracted from NORM 6 (DMP now DMIRS, 2010) and are displayed in Appendix J. The thresholds have been revised based on ICRP Publication 137 (ICRP, 2017) .

6 TRANSPORT OF RADIOACTIVE MATERIAL

RE concentrate produced at Mt Weld is currently packaged in lined, sealed bags and loaded into sea containers. Sea containers are then transported to Fremantle Port via road and rail for export to the Lynas Advanced Materials Plant (LAMP) in Kuantan, Malaysia for further processing.

All temporary storage locations at which the concentrate is stored for more than 24 hours are registered with the Radiological Council. A map of the road and rail transport routes can be found in Appendix B.

6.1 Applicability of Transport Regulations

The thorium (ThO_2) and uranium (U_3O_8) concentrations in the RE concentrate are approximately 1,630 ppm ThO_2 and 43 ppm U_3O_8 (Table 3), which yields a specific activity in the order of 6.3 Bq/g.

The Australian (ARPANSA, 2014) and International Transport Safety Regulations (International Atomic Energy Agency, 2012) do not apply to the lanthanide ore or concentrate produced at Mt Weld. Table 2 in Section IV – "Basic Radionuclide Values" gives the values for Th (nat) and U (nat) at 1.0 Bq/g each (paragraphs 401-407). Paragraph 107 provides an exclusion applicable for the Mt Weld ore and RE concentrate:

> *107. The Regulations do not apply to any of the following:*
>
> *"(f) Natural material and ores containing naturally occurring radionuclides, which may have been processed, provided the activity concentration of the material does not exceed 10 times the values specified in Table 2, or calculated in accordance with paras 403(a) and 404–407. For natural materials and ores containing naturally occurring radionuclides that are not in secular equilibrium the calculation of the activity concentration shall be performed in accordance with para. 405."*

Section 3.4 characterises the radionuclide deportment of the major process streams and asserts that thorium and uranium chains remain in secular equilibrium throughout the concentration plant. The transport of RE concentrate will therefore remain exempt from transport regulations so long as the combined concentrations of uranium and thorium do not exceed 10 Bq/g.

6.2 Kalgoorlie Rare Earth Processing Facility (REPF) Transport

With the commissioning of the Kalgoorlie Rare Earth Processing Facility (REPF) scheduled for H2 2022, a new transport method will be employed in which concentrate will be loaded directly into closed containers at Mt Weld. The containers will then be transported by a currently undetermined mix of road/rail to the Kalgoorlie REPF site for processing. Concentrate transport to the REPF will either utilise the current arrangement (road from Mt Weld to Leonora and rail between Leonora and Kalgoorlie) or the previously utilised road transport from Mt Weld to Kalgoorlie.

The potential RE concentrate transport route between Mt Weld and the Kalgoorlie REPF is shown in Appendix B. Any change to the current transport arrangements will be covered under the Mt Weld Transport Management Plan (TMP).

As a part of the Kalgoorlie REPF operations, the gypsum and iron phosphate by-products will eventually be transported to Mt Weld and stored in suitably constructed engineered structures (such as tailings dam). As the prospect of by-product transport to Mt Weld is still a number of years away (there is 2+ years by-product storage capacity on site in Kalgoorlie), the transport and storage details will be covered under a future RMP update or amendment.

6.3 General Radiation Exposure Scenario

Whilst the specific activity of RE concentrate is well below applicable transport limits, the gamma-radiation emitted is above natural background levels, typically in the order of 0.3 – 1.3 µSv/hr. It is therefore necessary to determine the potential radiation exposure to employees involved with transport of RE concentrate from Mt Weld.

In the past, every container loaded with RE concentrate was measured for gamma-radiation at a distance of 1 metre from the container on all sides prior to leaving site. A summary of container gamma measurements is displayed in Table 10 below.

Table 10. Gamma Survey Results for Loaded RE Concentrate Containers

Period	Number of Measurements	Gamma Radiation (µSv/hr)	
		Range	*Average*
April 2012 – March 2013	608	0.13 – 1.24	0.63±0.22
April 2013 – March 2014	3,272	0.29 – 1.18	0.63±0.19

TLD badges worn by RE concentrate truck drivers have established that the gamma exposure inside the truck cabin is equivalent to natural background – the average result being 0.10 µSv/hr. The disparity between gamma surveys and TLD results is attributed to the shielding provided by the truck cab and the increased distance of truck drivers to the concentrate (minimum 5 metres when in cab).

Gamma radiation surveys have been conducted at registered premises to monitor potential exposure to storage yard and port workers. Gamma radiation levels vary between 0.1 and 2.3 µSv/hr and average 0.58±0.13 µSv/hr. Some elevated gamma radiation readings at the Fremantle Port can be attributed to natural radiation occurring within limestone used in the construction of North Quay.

Gamma radiation surveys along the RE concentrate transport route from Mt Weld were carried out between 2012 to 2015 to establish the baseline levels in the unlikely case of a traffic accident causing concentrate spillage requiring a clean-up to return the area to background levels.

The typical gamma radiation levels varied between 0.1 and 0.7 µSv/hr and averaged 0.21±0.11 µSv/hr.

6.4 Potential Radiation Exposures to Members of the Public

It is expected that no member of the public will receive a radiation dose exceeding 1 mSv/year, which is the limit as set by the Regulations under the RSA.

There are several potential scenarios in which members of the public may be exposed to radiation; all of them through exposure to external gamma-radiation from RE concentrate located in containers.

Scenario A. Members of the public driving alongside truck/train:

A member of the public may drive alongside a truck or train transporting RE concentrate along certain sections of the route. The annual exposure time is conservatively estimated at 30 hours per annum at a distance of greater than 20 metres.

Scenario B. Member of the public at a rail crossing waiting for train to pass:

There are several level crossings along the railway line between the freight depot and the port. It is assumed that a member of the public meets the train at one of the level crossings once a week. The vehicle stops at a distance of 6 m away from the side of the rail tracks and waits for this ~ 250 m long line source to pass at a speed of 30 km/hr (0.5 minutes). Total exposure time is approximately 0.5 hours per year.

Scenario C. Public in suburban and rural areas:

The Brookfield railway runs through rural areas where members of the public may be exposed in varying degrees. It is unlikely that any dwellings are closer than 10 m from railway. A member of the public residing at this location would be exposed to approximately 6 containers a day for about 30 seconds. The total exposure time is estimated at 18 hours/year.

The following equation was used to estimate the gamma-radiation dose rate from two containers at various distances:

$$\text{Dose Rate} = \text{EDR}_{\text{surface}} * \left[1 - \text{d}/(\text{d}^2 + \text{A} * \frac{\text{B}}{3.14})^{0.5}\right]$$

Where:

- $EDR_{surface}$ is the emitted dose rate at the container surface (2 µSv/hr)
- d is the distance from the source
- A is the container height (2m)
- B is the container width (14m)

The results of the assessments are summarised in the table below:

Table 11. Summary of Possible Public Exposures

Scenario	A	B	C
Distance (m)	20	6	10
Exposure (hr/year)	30	0.5	18
Dose Rate (µSv/hr)	0.02	0.21	0.08
Dose (mSv/year)	**0.0007**	**0.0001**	**0.0015**
Percentage of Public Limit	0.07%	0.01%	0.15%

The above assessments show that the public radiation exposure from transport of RE concentrate is extremely low and would be indistinguishable to natural background radiation. No member of the public is expected to receive a radiation dose exceeding the public limit of 1 mSv/year during the transport of RE concentrate from Mt Weld.

6.5 Concentrate Spill Management

A Transport Management Plan (TMP) and Emergency Response Management Plan (ERMP) have been developed to govern the response to a spill of concentrate during the transport process.

In the case of a concentrate spill during transport, the transport provider is responsible for providing the resources required to manage and clean-up the spill. The Mt Weld RSO will be notified and mobilised to the spillage site to monitor radiation levels and ensure the spill site is returned to background following spill clean-up.

A number of emergency exercises have been enacted (and will continue to be enacted) by the Mt Weld Incident Management Team (IMT) in conjunction with external crisis practitioners to prepare for scenarios based around concentrate spillage along the transport route.

An exposure assessment has been conducted to estimate the potential dose to a member of the public should an incident occur in which concentrate is spilled along the transport route between Mt Weld and the Kalgoorlie REPF.

RE concentrate typically has a surface (5 cm) gamma dose-rate between 1.0-1.5 Bq/g, for this assessment a conservative figure of 2 µSv/hr will be employed.

Should an incident occur in which RE concentrate spills outside a container, a member of the public would need to be within 5cm of the IP for a constant period of 500 hours (≈3 weeks) before they exceed the radiation dose limit of 1.0 mSv/yr (1000 µSv) as set by the Regulations under the Radiation Safety Act (1975).

$$\frac{1000\ [\mu Sv]}{2.0\ [\frac{\mu Sv}{hr}]} = 500\ hrs$$

This assessment highlights the low risk posed by any potential spillage of concentrate along the transport route to members of the public.

7 RADIOACTIVE WASTE MANAGEMENT

There are a range of substances generated at Mt Weld that may be considered radioactive waste including:

- Flotation tailings
- Miscellaneous solid waste generated through contact with radioactive process streams
- Water that has come into radioactive materials

7.1 Flotation Tailings

Flotation tailings are generated at an approximate rate of 70% of the concentration plant feed rate, equating to 170,000 tpa at current maximum production capacity. Table 3 shows approximately 164,000 tonnes of flotation tailings were generated in the FY21 period.

Flotation tailings are pumped from the plant at a density of 12% solids for deposition within the tailings storage facility (TSF). The total TSF is comprised of multiple storage areas (TSF1, TSF2 & TSF3) that are displayed in Appendix F. A summary of the TSF storage as of September 2021 is displayed below in Table 12.

Table 12. Tailings Storage Facility Summary (September 2021)

	Tailings Stored *(dmt)*	**Volume Capacity** *(m^3)*	**Volume Filled** *(m^3)*	**Filled Capacity** *(%)*
TSF1	309,700	484,200	300,600	62%
TSF2	511,900	612,700	457,400	75%
TSF3	281,300	581,100	203,700	35%
Total	**1,102,900**	**1,678,000**	**961,700**	**57%**

The flotation tailings stored within the TSF contain an average 353 ppm ThO_2 and 29 ppm U_3O_8 giving a specific activity of 1.6 Bq/g, meaning the tailings are classified as radioactive.

The flotation tailings contain between 6-8% REO, meaning the TSF stores a significant quantity of rare earth that Lynas hopes to recover through alternative processing techniques in the future.

Supernatant water generated through consolidation of the tailings within the TSF is recovered for treatment through the Water Treatment Plant (WTP) and re-used in the concentration plant. The benefits of the reclamation of supernatant water from the TSF include:

- Sustainable water balance with significantly reduced accumulation of water in the TSF;
- Recycling of process water, reducing reliance on underground aquifer water source;
- Consolidation of tailings to enable effective rehabilitation/closure of TSF;
- More efficient use of TSF footprint.

Raffinate generated by reverse osmosis (RO) units in the WTP is discharged into evaporation ponds for solar evaporation.

7.2 Management of Radioactive Waste

A solid radionuclide-bearing waste program deals with miscellaneous solid waste that has come into contact with radioactive process streams. Where possible, radionuclide-bearing solid waste is cleaned and disposed of through normal waste disposal methods. Where it is not possible and depending on the nature of the waste, radionuclide-bearing solid waste will be disposed of in a dedicated section of the TSF.

Records of radionuclide-bearing waste will be maintained that documents disposal including type of material, quantity and disposal method.

The seepage rate of material deposited into the TSF is very low and well within the Water Quality Protection Guidelines target of less than 0.04%.

7.3 Management of Runoff Water

Rainwater runoff from the ore stockpiles and around the processing plant is directed to a storm water sediment pond. Clean surface water runoff is directed to dispersion channels or collected in a sediment pond.

7.4 Closure Considerations

Development of a Closure Plan will be implemented in consultation with all applicable regulatory agencies and authorities including Radiological Council, DMIRS, EPA and key stakeholders to ensure that any residual tailings remaining onsite post closure will be safe, stable and non-polluting. Lynas will continue to investigate re-treatment of floatation tailings to recover contained rare earth.

Rehabilitation of the TSF will require capping with radionuclide-barren material to return radiation levels to the natural background as measured during pre-operational monitoring.

The envisaged capping method is best described as multilayered soil cover with vegetation. The TSF cap will include a covering of coarse waste rock approximately 500 mm thick to provide a capillary break between the tailings and the topsoil covering. The coarse waste rock will be covered with mining waste rock and topsoil, and then seeded with shallow rooting plant species. The coarse waste layer will extend across the tailings surface. The overlying mining waste and topsoil layers will extend across the coarse waste rock layer and embankment crests and downstream slopes. All of the TSF final landform will be subject to revegetation.

Capping material for the capillary break and mining waste layers is expected to be sourced from mine waste dumps where material deemed suitable for capping purposes will be selected and stored during mining operations. Topsoil stripped from the TSF basin and embankment footprint areas at the beginning of construction was stockpiled and will be used during rehabilitation.

8 LIST OF COMMITMENTS

Several commitments made throughout this RMP are summarised below:

Section 1: In accordance with requirements of regulation 16.7.(4) of the Mines Safety and Inspection Regulations (1995) the Plan will be reviewed in the event of any material changes to the operation that may impact radiation exposures or at intervals designated by the State Mining Engineer. More frequent reviews will be carried out in accordance with regulation 16.7.(6) when the “plan for the mine is amended”.

Section 3.3.5: Ingestion of drinking water as a pathway of radiation exposure will only be assessed in the future if there is a measurable increase in bore water radionuclide concentration.

Section 4.5: Should surface contamination monitoring of employee clothing exceed the statutory 0.4 Bq/cm^2 limit, a work procedure will be introduced requiring employees remove and wash contaminated clothing prior to leaving site.

Section 4.7: If any special works involving handling of material where higher than usual exposures may be expected, the Radiation Safety Officer will develop a Work Permit System for the minimization and monitoring of personal radiation exposures.

Section 4.11: This RMP will continue to be analysed and modified to ensure the scope and frequency of radiation monitoring is commensurate with the ongoing radiological risk at the Mt Weld site.

Section 5.4.1: Both SEGs will continue to be monitored separately, however only a single dose assessment will be conducted in future reporting.

Section 6.4: A number of emergency exercises have been enacted (and will continue to be enacted) by the Mt Weld Incident Management Team (IMT) in conjunction with external crisis practitioners to prepare for scenarios based around concentrate spillage along the transport route.

Section 7.4: Development of a Closure Plan will be implemented in consultation with all applicable regulatory agencies and authorities including Radiological Council, DMIRS, EPA and key stakeholders to ensure that any residual tailings remaining onsite post closure will be safe, stable and non-polluting. Lynas will continue to investigate re-treatment of floatation tailings to recover contained rare earth.

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APPENDICES

Appendix A: Map of Mt Weld Mining Leases & Tenements
Appendix B: Maps of Concentrate Transport Route
Appendix C: ^{238}U and ^{232}Th Decay Series
Appendix D: Irradiating Apparatus Information
Appendix E: Mt Weld Water Bore Locations
Appendix F: Mt Weld Water Bore Locations
Appendix G: Radiation Workplace Classifications
Appendix H: List of Work Procedures
Appendix I: Determination of Thoron (^{222}Rn) Equilibrium Factor
Appendix J: Investigation and Action Limits
Appendix K: Safety Data Sheets (SDS)
Appendix L: Process Flowsheet

Appendix A: Map of Mt Weld Mining Leases & Tenements

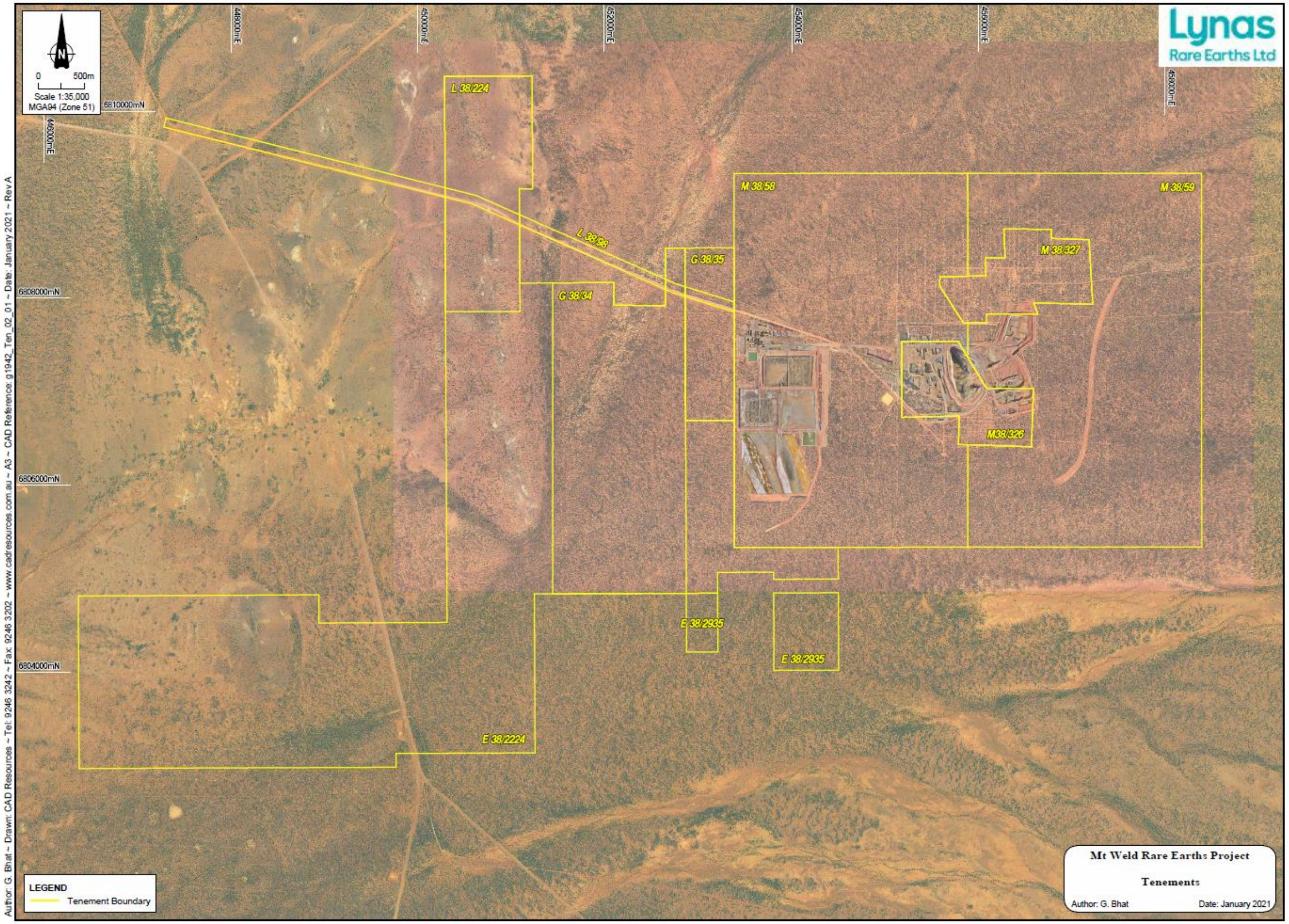

Figure 4. Mt Weld Tenement Map

Appendix B: Maps of Concentrate Transport Route

Figure 5. Road Concentrate Transport Route Map

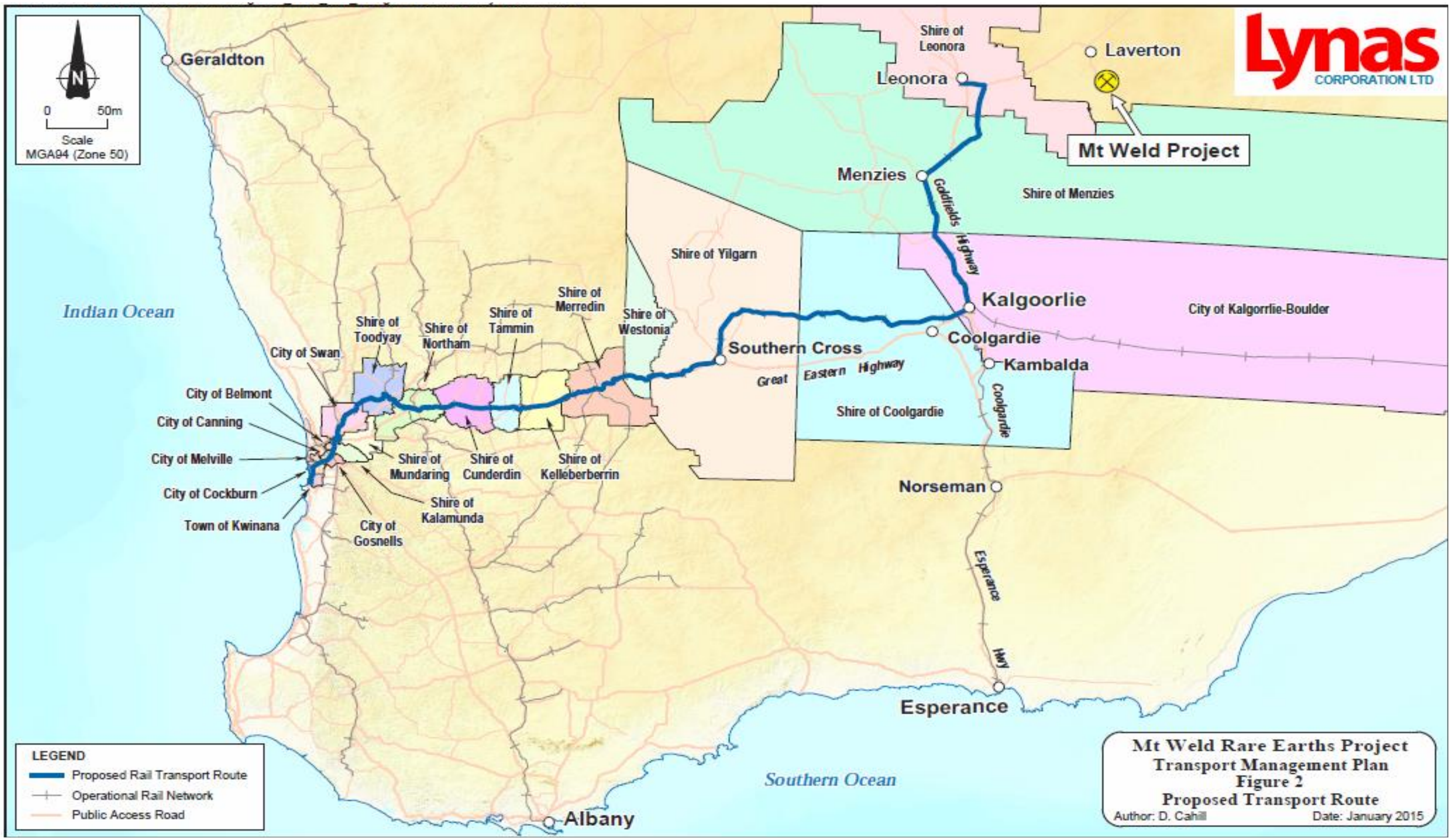

Figure 6. Rail Concentrate Transport Route Map

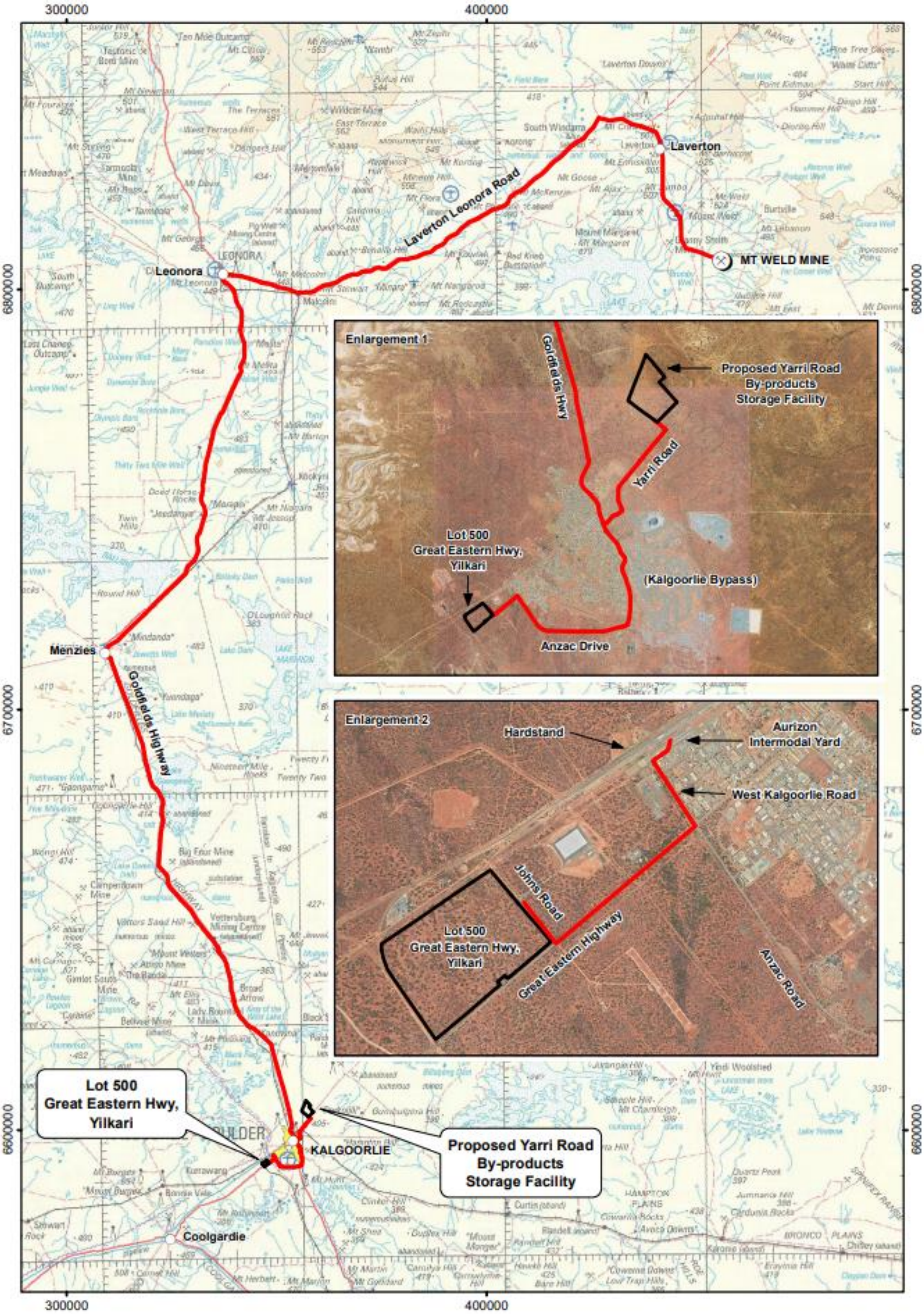

Figure 7. Potential Transport Route from Mt Weld to Kalgoorlie REPF

Appendix C: ^{238}U and ^{232}Th Decay Series

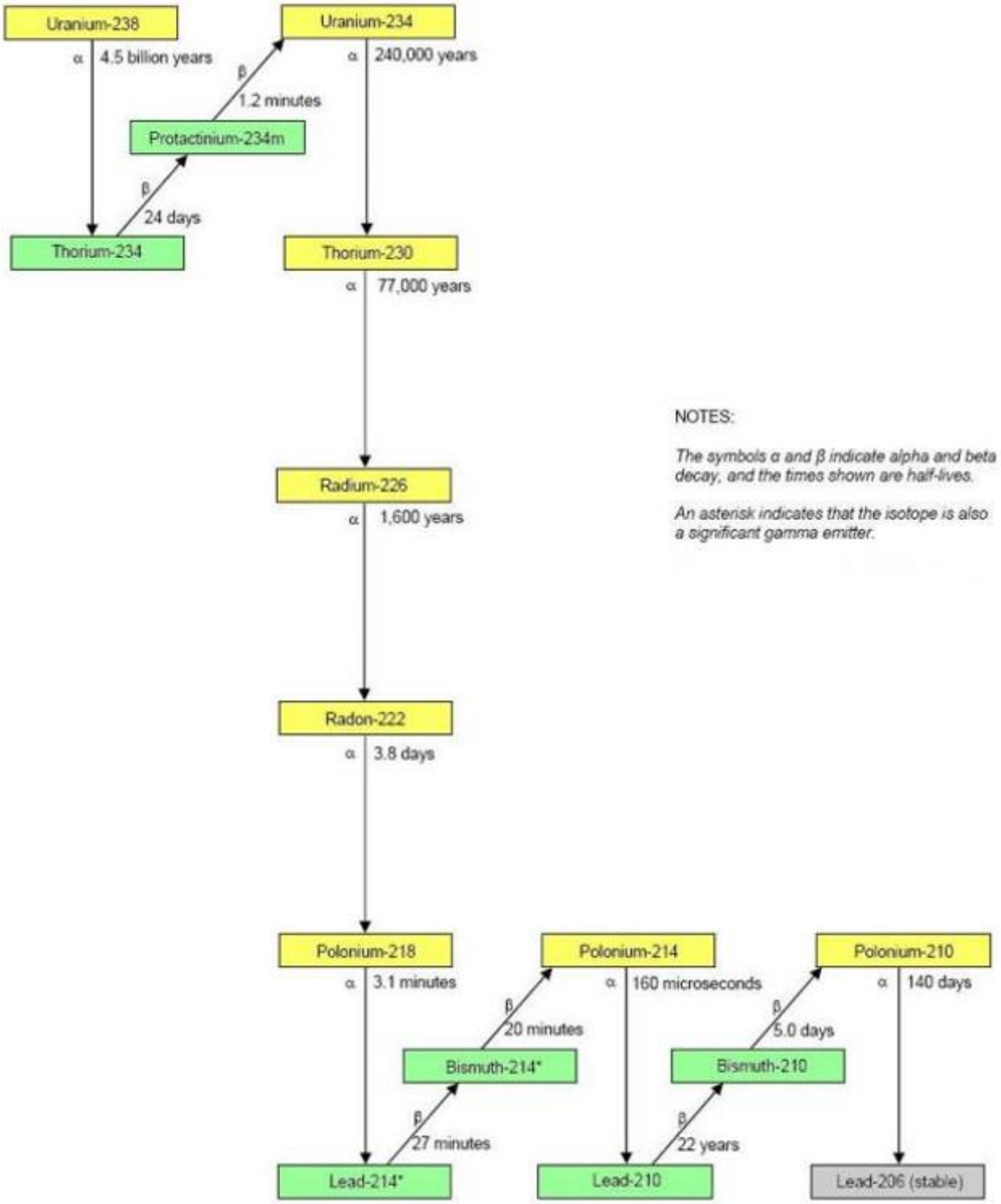

Figure 8. ^{238}U Decay Chain

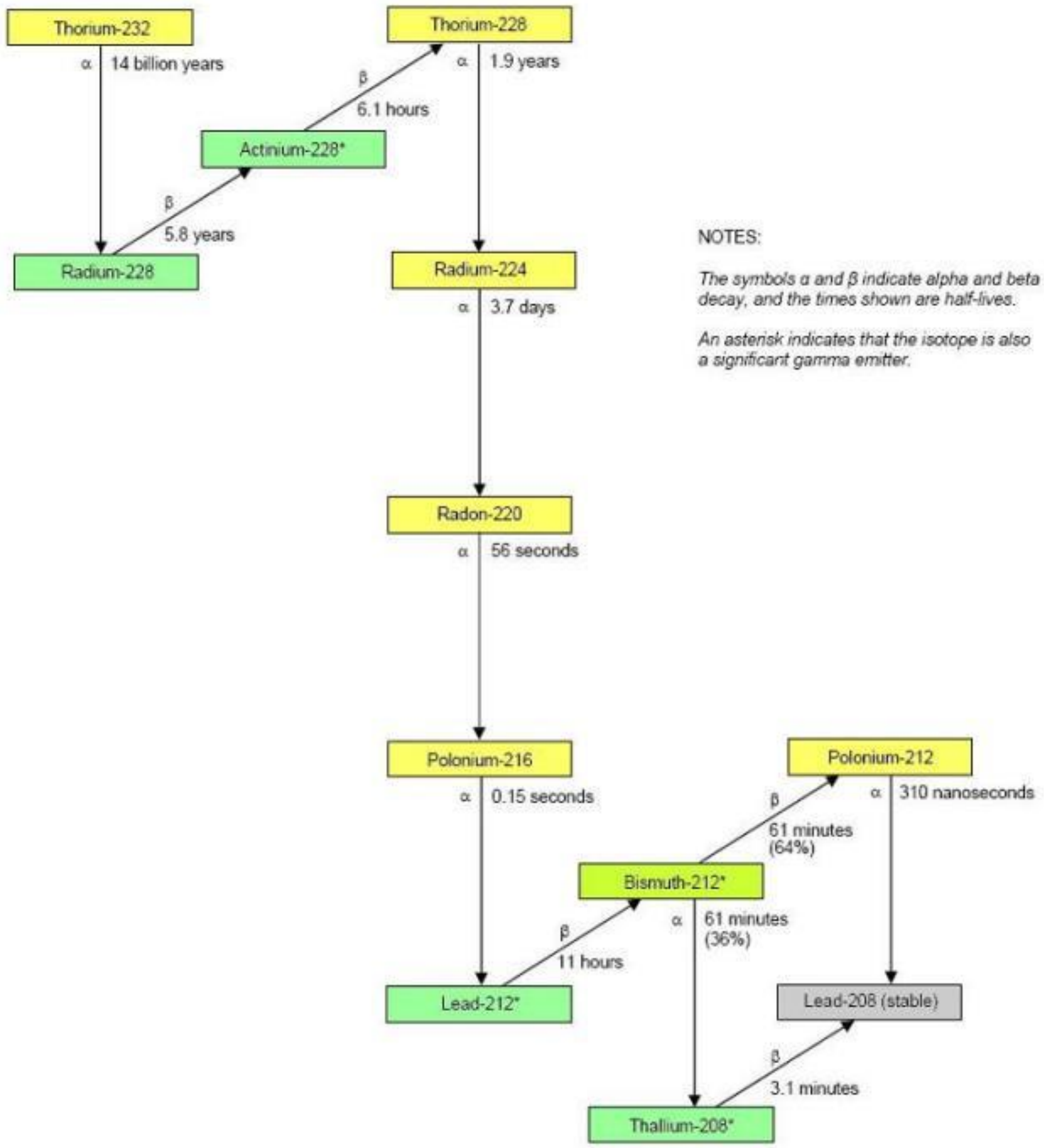

Figure 9. ^{232}Th Decay Chain

Appendix D: Irradiating Apparatus Information

Table 13. Radiation Gauge Information

Unit	Manufacturer	Isotope	Activity (MBq)	Source S/N	Container S/N
Mill Discharge	Ohmart/Vega	^{137}Cs	370	1887CO	19077695
Thickener 1 Feed	Ohmart/Vega	^{137}Cs	740	2569CO	19077699
Thickener 1 UF	Ohmart/Vega	^{137}Cs	185	2524CO	19077697
Thickener 2 Feed	Ohmart/Vega	^{137}Cs	185	5211CO	23574943
Thickener 2 UF	Ohmart/Vega	^{137}Cs	185	5209CO	23574942

Audits are carried out internally every six months, with a compliance audit completed every 3 years. Wipe tests will be performed internally at an interval of 12 months.

Table 14. X-Ray Apparatus Information

Manufacturer	Model	Serial Number	Year of Manufacture	Output
Outotec	Courier 6SL Analyser	DK420558 (x-ray tube)	2011 – Courier 2021 – X-Ray Tube	50 kV
Panalytical	Minipal 4 X-Ray Spectrometer	200732	2010	30 kV
Panalytical	Epsilon 3 X-Ray Spectrometer	205860	2015	30 kV

The Outotec Courier 6SL Analyser has been in operation since 2011. An upgrade to the new Courier 6X system has been purchased and is scheduled for installation during H1 CY2022. The upgraded Courier 6X analyser will receive the x-ray tube currently installed in the Courier 6SL (serial number *DK420558*) as listed in Table 14.

All X-Ray machines are fitted with all the appropriate safety interlocks, shielding, warning signs, lights and labels as in accordance with the “Code of Practice for Protection Against Ionizing Radiation Emitted from X-ray Analysis Equipment (1984)”.

Figure 10. Location of Irradiating Apparatus

Appendix E: Mt Weld Water Bore Locations

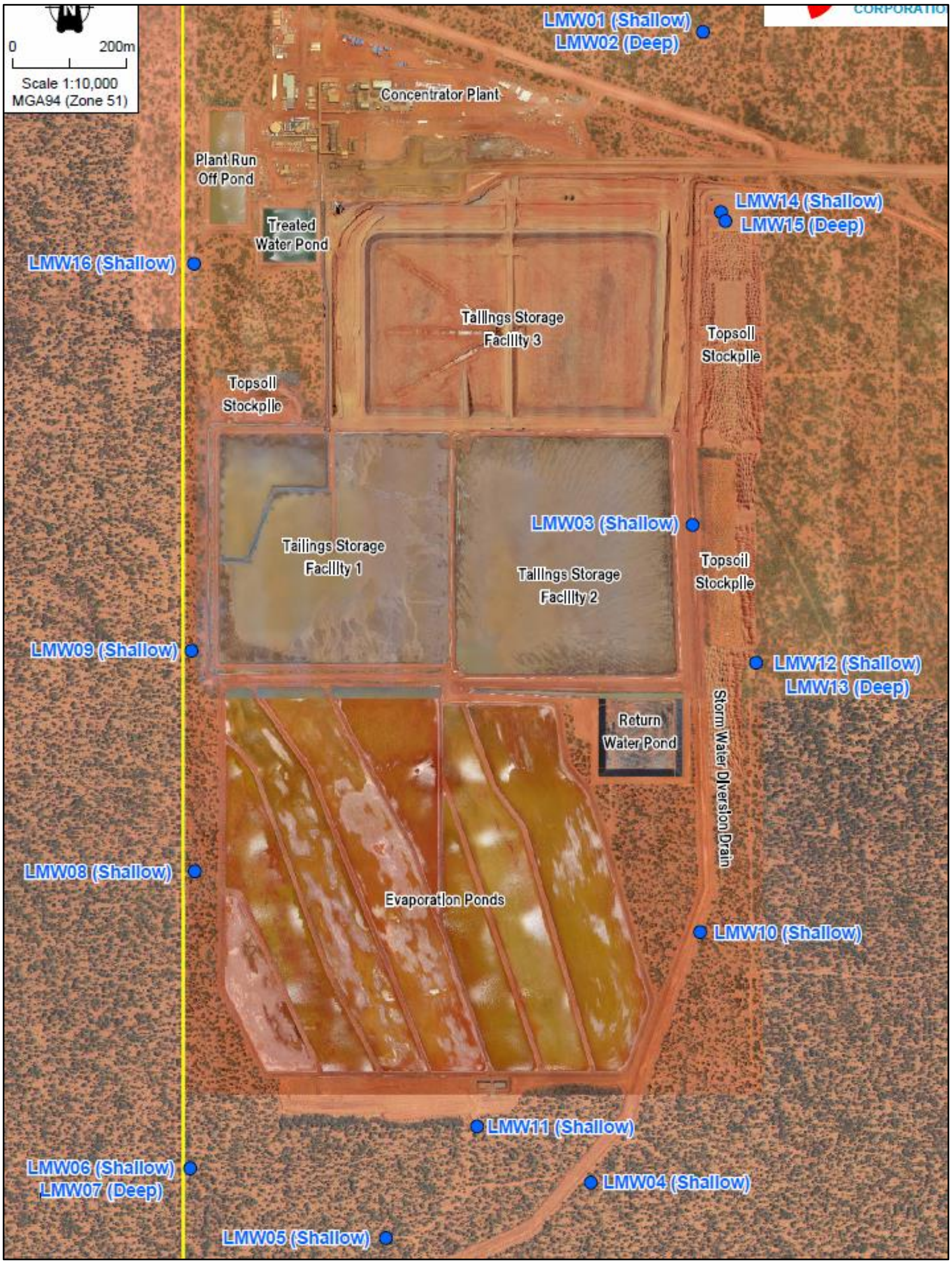

Figure 11. Location of Water Bores

Appendix F: April 2020 Radionuclide Balance

Table 15. 07 April 2020 Production Figures

	07 April 2020
Tonnes Milled (dmt)	764
Asset Utilisation (%)	100
Flotation Recovery (%REO)	66.6
Concentrate Grade (%REO)	32.9
Concentrate Produced (dmt)	234
Tailings Produced (dmt)	530
Mill Feed Rate (kg/day)	764,000
Concentrate Production Rate (kg/day)	234,000
Tailings Production Rate (kg/day)	530,000

Th-232 Chain Balance

Radionuclide concentrations and associated errors calculated from the lab certificate on the following pages.

Process Stream	^{232}Th *(Bq/kg)*	^{228}Ra *(Bq/kg)*	^{228}Th *(Bq/kg)*
Mill Feed	2600 ± 520	2850 ± 251	2840 ± 253
RE Concentrate	5010 ± 902	5300 ± 382	5520 ± 436
Flotation Tails	1610 ± 435	1820 ± 162	1710 ± 152

$$\text{Radionuclide Balance}\ \left(\frac{MBq}{day}\right) = \frac{\text{Radionuclide Concentration}\ \left(\frac{Bq}{kg}\right) * \text{Process Stream Rate}\ \left(\frac{kg}{day}\right)}{1000000}$$

Process Stream	^{232}Th *(MBq/day)*	^{228}Ra *(MBq/day)*	^{228}Th *(MBq/day)*
Mill Feed	1986 ± 397	2177 ± 192	2170 ± 193
RE Concentrate	1172 ± 211	1240 ± 89	1292 ± 102
Flotation Tails	853 ± 230	965 ± 86	906 ± 81
Balance (MBq/day)	**39 ± 839**	**27 ± 367**	**28 ± 376**
Balance (%)	**2% ± 42%**	**1% ± 17%**	**1% ± 17%**

U-238 Chain Balance

Radionuclide concentrations and associated errors calculated from the lab certificate on the following pages.

Process Stream	^{238}U (Bq/kg)	^{234}U (Bq/kg)	^{230}Th (Bq/kg)	^{226}Ra (Bq/kg)	^{210}Pb (Bq/kg)	^{210}Po (Bq/kg)
Mill Feed	290 ± 116	377 ± 151	411 ± 140	416 ± 104	346 ± 173	360 ± 54
RE Concentrate	418 ± 167	523 ± 209	856 ± 248	534 ± 107	416 ± 208	649 ± 97
Flotation Tails	311 ± 124	389 ± 156	314 ± 104	385 ± 96	327 ± 164	326 ± 46

$$\text{Radionuclide Balance}\left(\frac{MBq}{day}\right) = \frac{\text{Radionuclide Concentration}\left(\frac{Bq}{kg}\right) * \text{Process Stream Rate}\left(\frac{kg}{day}\right)}{1000000}$$

Process Stream	^{238}U (MBq/day)	^{234}U (MBq/day)	^{230}Th (MBq/day)	^{226}Ra (MBq/day)	^{210}Pb (MBq/day)	^{210}Po (MBq/day)
Mill Feed	222 ± 89	288 ± 115	314 ± 107	318 ± 79	264 ± 132	275 ± 41
RE Concentrate	98 ± 39	122 ± 49	200 ± 58	125 ± 25	97 ± 49	152 ± 23
Flotation Tails	165 ± 66	206 ± 82	166 ± 55	204 ± 51	173 ± 87	173 ± 24
Balance (MBq/day)	**41 ± 194**	**41 ± 247**	**53 ± 220**	**11 ± 155**	**6 ± 267**	**50 ± 88**
Balance (%)	**19% ± 87%**	**14% ± 86%**	**17% ± 70%**	**4% ± 49%**	**2% ± 101%**	**18% ± 32%**

IAF - Radioökologie GmbH

Radionuclide Laboratory | Radiation Safety | Radiological Consultants

DAkkS Deutsche Akkreditierungsstelle D-PL-11201-01-00

Accredited in accordance with DIN EN ISO 17025 by DAkkS, the official German accreditation body.

Test report no.:	200428-03_01
Client:	Mt Weld Mining Pty Ltd Suite 3, 5 Tully Road EAST PERTH WA 6004
Type of samples:	Solid material samples
Reference date:	08 June 2020

Analytical results			No. 1		No. 2		No. 3	
Specification			Mill Feed		Float Feed		Final Con	
Nuclide		Units	Result	U [%]	Result	U [%]	Result	U [%]
U-238-series								
U-238	α/γ	Bq/kg	290	40	282	40	418	40
U-234	α	Bq/kg	377	40	367	40	523	40
Th-230	α/γ	Bq/kg	411	34	410	37	856	29
Ra-226	γ	Bq/kg	416	25	422	30	534	20
Pb-210	β/γ	Bq/kg	346	50	322	50	416	50
Po-210	α	Bq/kg	360	15	337	16	649	15
U-235-series								
U-235	α/γ	Bq/kg	13	40	13	40	19	40
Th-232-series								
Th-232	α	Bq/kg	2600	20	2880	21	5010	18
Ra-228	γ	Bq/kg	2850	8,8	2790	8,8	5300	7,2
Th-228	α/γ	Bq/kg	2840	8,9	2780	8,9	5520	7,9
Further Radionuclides								
K-40	γ	Bq/kg	< 19	-	< 23	-	< 34	-
Physical parameters								
Dry matter		%	99,8		99,9		99,7	

U [%]: The uncertainty U comprises the uncertainty of the counting statistics and all uncertainties related to the laboratory such as calibration, nuclide data etc.; $k_{(1-\gamma/2)} = 1.96$.
Data indicated with "<" are below the decision threshold.
The results refer to the sample as delivered by the client.

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DAkkS Deutsche Akkreditierungsstelle D-PL-11201-01-00

Accredited in accordance with DIN EN ISO 17025 by DAkkS, the official German accreditation body.

Test report no.: 200428-03_01

Client: Mt Weld Mining Pty Ltd
Suite 3, 5 Tully Road
EAST PERTH WA 6004

Type of samples: Solid material samples

Reference date: 08 June 2020

Analytical results			No. 4	
Specification			Scav3Tail	
Nuclide		Units	Result	U [%]
U-238-series				
U-238	α/γ	Bq/kg	311	40
U-234	α	Bq/kg	389	40
Th-230	α/γ	Bq/kg	314	33
Ra-226	γ	Bq/kg	385	25
Pb-210	γ	Bq/kg	327	50
Po-210	α	Bq/kg	326	14
U-235-series				
U-238	α/γ	Bq/kg	14	40
Th-232-series				
Th-232	α	Bq/kg	1610	27
Ra-228	γ	Bq/kg	1820	8,9
Th-228	α/γ	Bq/kg	1710	8,9
Further Radionuclides				
K-40	γ	Bq/kg	< 18	-
Physical parameters				
Dry matter		%	99,9	

U [%]: The uncertainty U comprises the uncertainty of the counting statistics and all uncertainties related to the laboratory such as calibration, nuclide data etc.; $k_{(1-\gamma/2)}$ = 1.96.
Data indicated with "<" are below the decision threshold.
The results refer to the sample as delivered by the client.

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Figure 12. April 2020 Radionuclide Balance Laboratory Certificate

Appendix G: Radiation Workplace Classifications

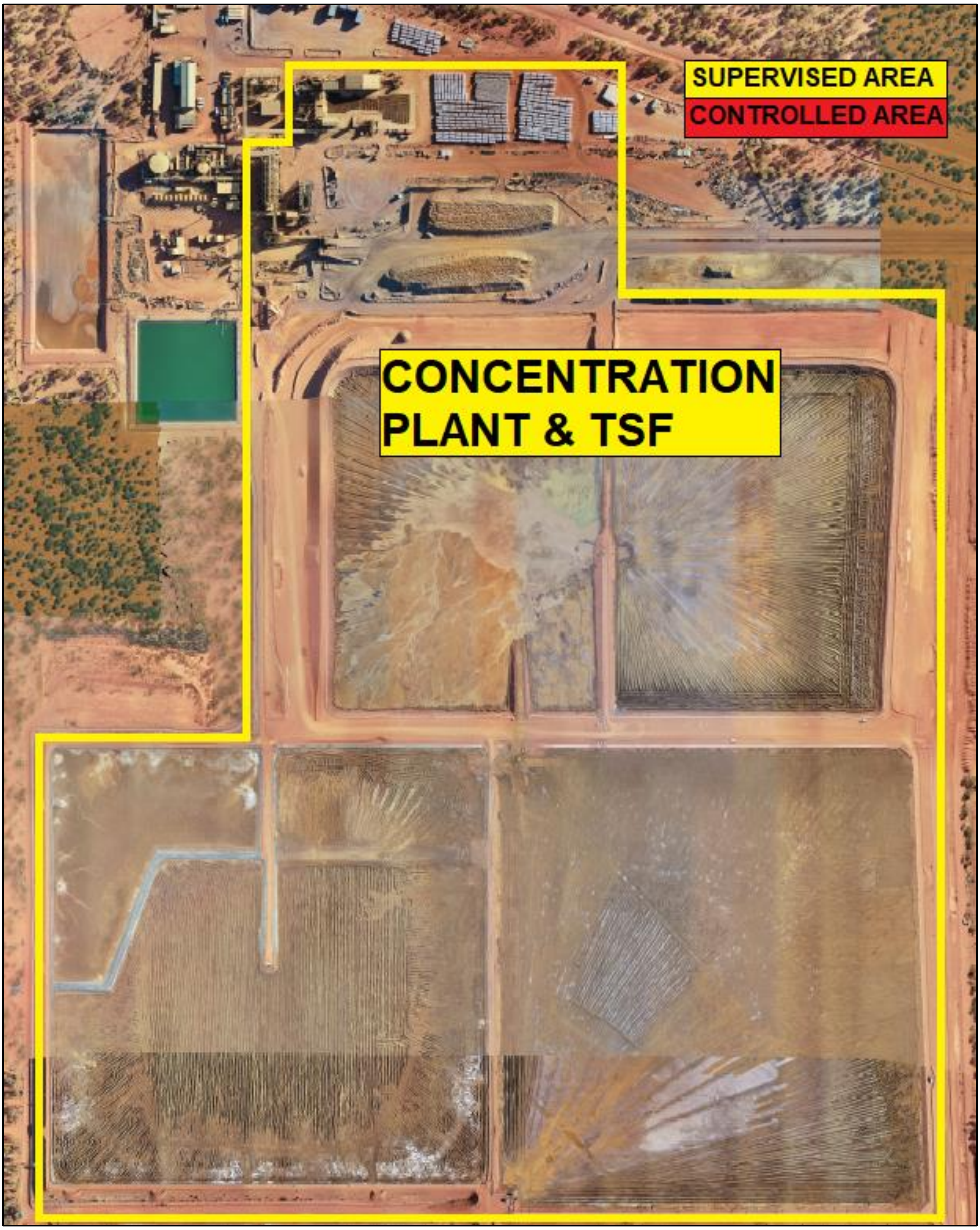

Figure 13. Concentrator Area Radiation Classifications

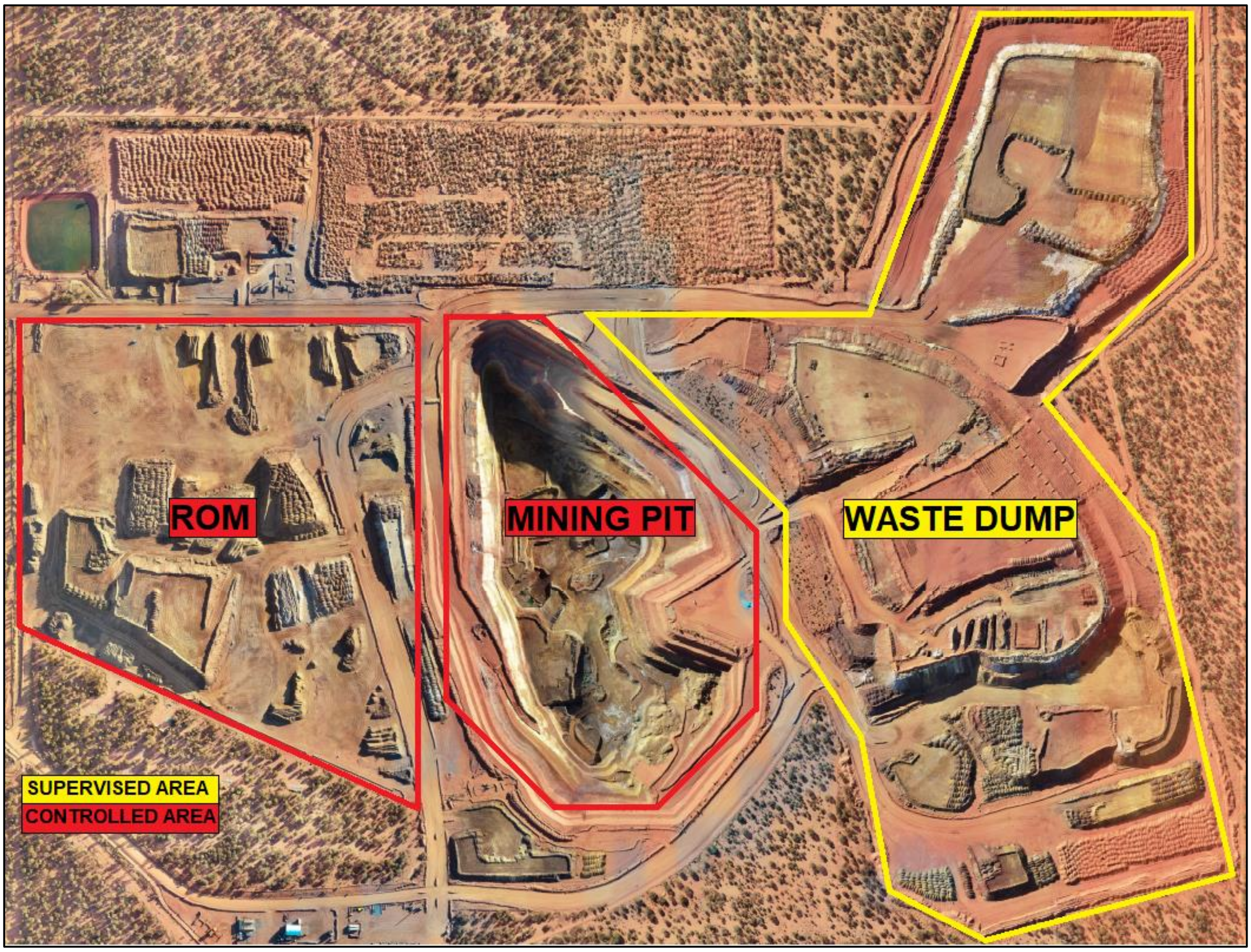

Figure 14. Mining Area Radiation Classifications

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Appendix H: List of Work Procedures

The following standard operating procedures (SOP's) and work instructions will be available upon request:

- SOP – External Gamma Monitoring (Area Survey)
- SOP – Passive Radon & Thoron Monitoring
- SOP – Surface Contamination Monitoring
- Work Instruction – Personal Gamma Monitoring (OSL)
- Work Instruction – Occupational Dose Assessment
- SOP – Routine Radiation Gauge Inspection
- SOP – Radiation Density Gauge Isolation
- SOP – Radiation Gauge Emergency Procedures
- SOP – Dust Alpha Radiation Counting

Appendix I: Determination of Thoron (^{222}Rn) Equilibrium Factor

A total 91 measurements of thoron and thoron progeny have been taken to establish an empirical thoron equilibrium factor for Mt Weld.

The measurements were collected over an eleven month period at different times of day to account for natural daily and seasonal variations. Results summarised in Table 16 show an equilibrium factor between thoron and its progeny of 0.002 has been established for Mt Weld.

Table 16. Thoron & Thoron Progeny Monitoring Results

	Progeny Concentration *(µJ/m3)*	**Progeny Concentration** *(Bq/m3)*	**Thoron Concentration** *(Bq/m3)*	**Equilibrium Factor**
January	0.030	0.4	517	0.0008
February	0.045	0.6	1068	0.0006
March	0.041	0.5	594	0.0009
May	1.160	15.5	2417	0.0077
July	1.308	17.4	4362	0.0052
August	0.012	0.2	2157	0.0001
October	0.014	0.2	2502	0.0001
November	0.046	0.6	1284	0.0005
Average	**0.423**	**5.6**	**2202**	**0.002**

Appendix J: Investigation and Action Limits

The following table has been reproduced from NORM 6 with appropriate levels and concentrations revised based on ICRP 137: OIR Part 3.

Table 17. Investigation Threshold Levels

Radiation Parameter	Investigation Level	Comment
Area Gamma Dose Rate		
Site Boundary	More than 0.11 µGy/hr (0.11 µSv/hr) above background	>1 mSv/year for member of the public (8760 hours)
Supervised Area	More than 0.50 µGy/hr (0.50 µSv/hr) above background	>1 mSv/year for radiation worker (2000 hours)
Controlled Area	More than 2.50 µGy/hr (2.50 µSv/hr) above background	>5 mSv/year for radiation worker (2000 hours)
Restricted Area	More than 7.50 µGy/hr (7.50 µSv/hr) above background	>15 mSv/year for radiation worker (2000 hours)
Personal Dose		
Designated Worker (External Dose)	>2.5 mSv in a quarter	>10 mSv/year
Non-Designated Worker (External Dose)	>0.5 mSv in a quarter	>2 mSv/year
Designated Worker (Internal Dose)	>5 mSv in a quarter	Assessed from air sampling
Airborne Radioactivity		
Total alpha activity on personal air sample (Th + U)	>2.1 Bq/m^3 for 12-hour shift sample	≈0.5 mSv/shift (5 µm, 0.0156 mSv/Bq)
Total alpha activity on personal air sample (Th + U)	4 consecutive samples >0.5 Bq/m^3	Indicates potential for significant exposure
Total Alpha Activity	>Mean + 3 Std Deviations	Indicates potentially unusual working conditions
Total alpha activity on environmental air sample – U dust	>2 mBq/m^3 on high volume air sampler	≈500 µSv/year for member of public (50% of limit) (1 µm, 0.0271 mSv/Bq)
Airborne Dust		
Inhalable dust on personal air sample	>10 mg/m^3	Statutory limit for inhalable dust concentration
Respirable dust on personal air sample	>3 mg/m^3	Statutory limit for respirable dust
Radon & Thoron		
Radon (^{222}Rn) in air	>1.7 mJh/m^3	>5 mSv/year for radiation worker (2000 hours)
Thoron (^{220}Rn) in air	>3.4 mJh/m^3	>5 mSv/year for radiation worker (2000 hours)
Radionuclides in Water		

Radiation Parameter	Investigation Level	Comment
^{226}Ra in ground or surface water	>0.5 Bq/L ^{226}Ra or 2x avg pre-operational levels	100 µSv/year for ingestion of 2 L/day
^{228}Ra in ground or surface water	>0.5 Bq/L ^{228}Ra or 2x avg pre-operational levels	100 µSv/year for ingestion of 2 L/day
Stack Emissions		
Amount of thorium emitted per day	>150 g/day	Operational control limit
Surface Contamination		
Low toxicity alpha emitters (^{238}U, ^{232}Th, ^{228}Th, ^{230}Th) on a surface	>0.4 Bq/cm^2	Averaged over 300 cm^2. Non-fixed: ca be removed from surface

Appendix K: Safety Data Sheets (SDS)

The following SDS's are available on request:

- Lanthanide Ore
- Lanthanide Concentrate
- Lanthanide Tailings

Appendix L: Process Flowsheet