ONSLOW RARE EARTHS PLANT

NORM RESIDUE MANAGEMENT PLAN

DOCUMENT NO. YB-2-2000-000-HE-EN-PLN-00004

REVISION HISTORY

Revision	Date	Issued for	Prepared By	Reviewed By	Approved By
A	15/05/21	Issued for Review	Lara Jefferson	Anle Tieu Bob Winn Stuart Parr	Bob Winn
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EXECUTIVE SUMMARY

Hastings Technology Metals Limited (Hastings) Onslow Rare Earths Plant (the Project) is hydrometallurgical processing of a beneficiation concentrate.

The objective of this NORM Residue Management Plan (NRMP), as stated in the Mining Code (ARPANSA 2005) is to:

"…ensure that there is no unacceptable health risk to people, both now and in the future, and no long-term unacceptable detriment to the environment from the waste so managed, and without imposing undue burdens on future generations."

Nearest sensitive environmental receptors include:

- Chevron accommodation village (approx. 2km away).
- Horizon Power Plant (approx. 3 km away)
- Quick Mud Creek (approx. 500m away); and
- Employees at the Project site.

The risks associated with the NORM residue include:

- Dust generation from transfer of concentrate from the trucks to the processing plant and transfer of NORM residue from the plant to the trucks; and
- Spillage from the transfer of concentrate from the trucks to the processing plant and transfer of NORM residue from the plant to the trucks and potential for contaminated surface water
- Incorrect disposal of miscellaneous wastes that may have become contaminated through contact with radioactive materials (referred to as contaminated waste).

A description of the proposed system for waste management during design, construction, operation, and closure of the Project is provided, a program for monitoring and contingency planning should risk mitigation fail, and reporting are also described. Periodic review of the adequacy and effectiveness of the NRMP takes account of potential improvements consistent with best practicable technology.

This NRMP will be further developed throughout each phase of the Project and will also be reviewed whenever there is a significant change in the operation process plant.

1. INTRODUCTION

1.1 OVERVIEW

Hastings Technology Metals Limited (Hastings) is proposing to develop the Onslow Rare Earths Plant (the Project), which is situated approximately 15 km (direct) from the Onslow township in the Pilbara region of Western Australia (Figure 1). The Project involves construction and operation of a hydrometallurgical process plant, services infrastructure, and an evaporation pond (Figure 2).

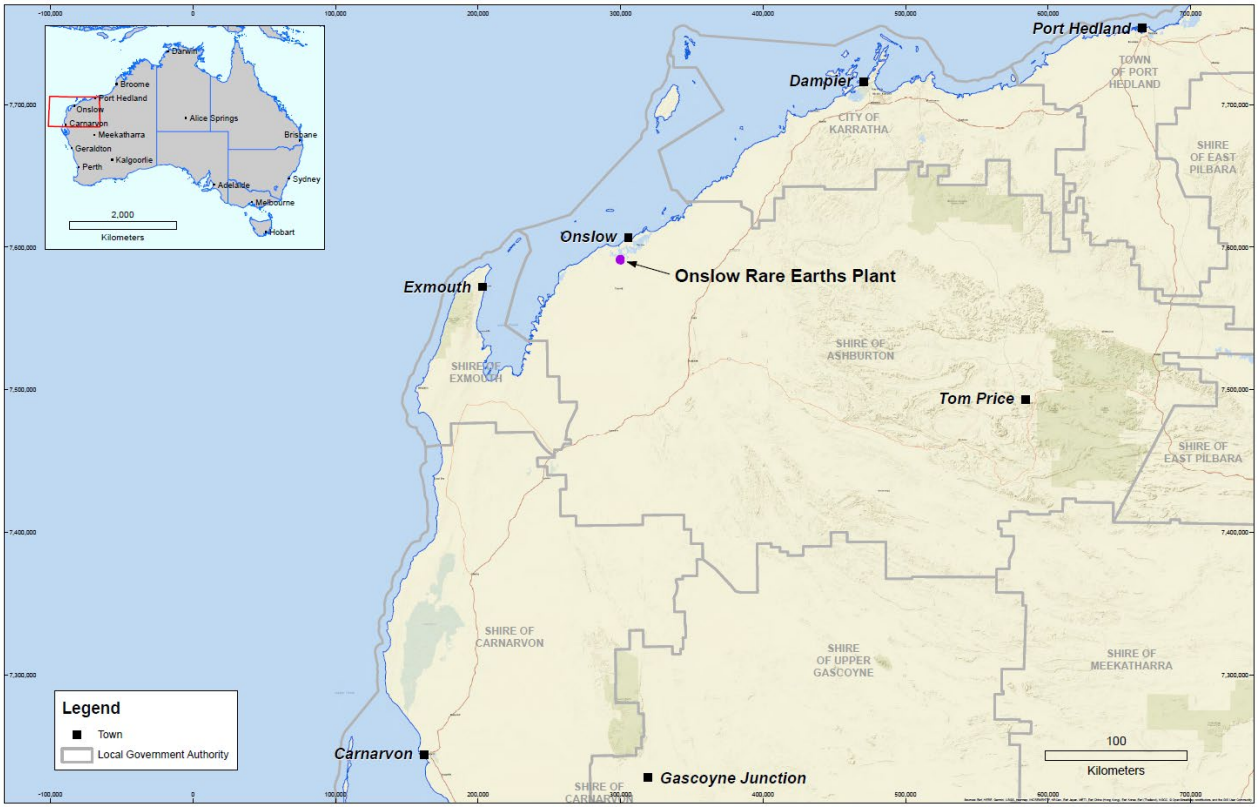

Figure 1 Location of the Onslow Rare Earths Plant

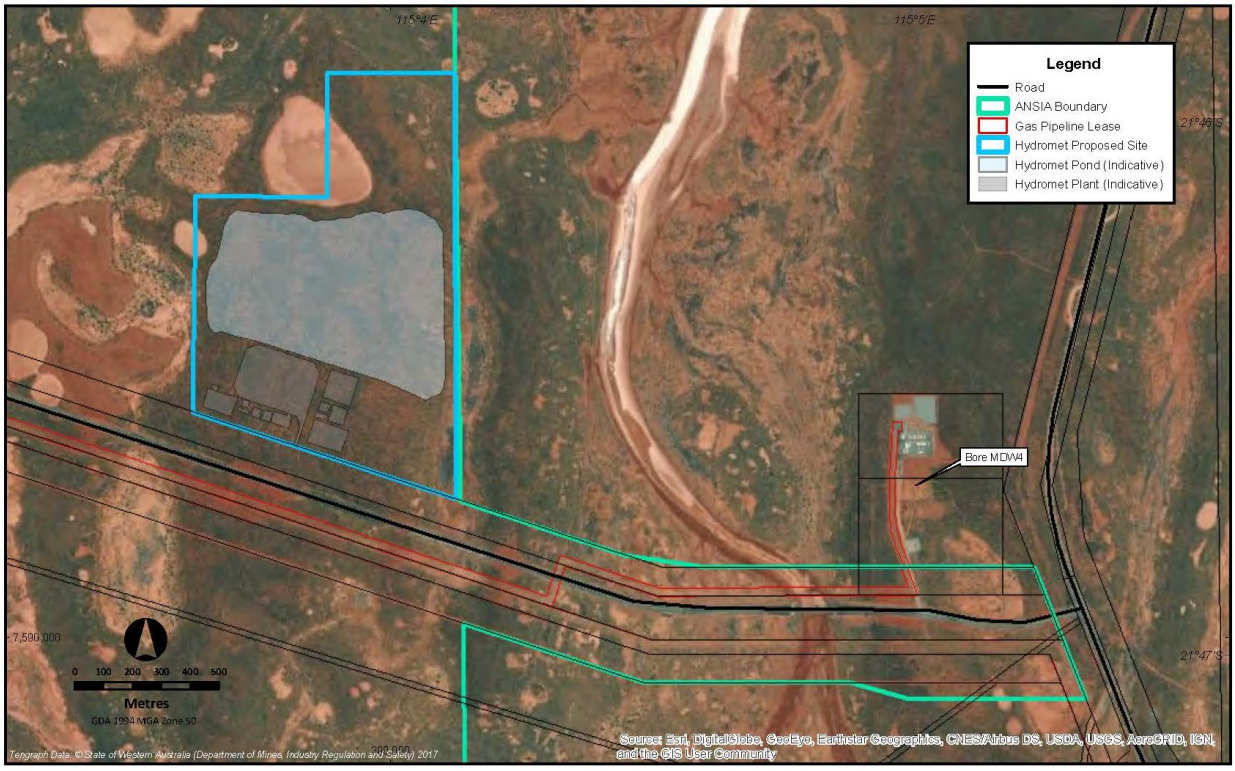

Figure 2 Proposed layout of the Onslow Rare Earths Plant

1.2 SCOPE

The hydrometallurgical plant shall receive, process, and return radioactive materials. This Naturally Occurring Radioactive Material (NORM) Residue Waste Management Plan (NRMP) describes how the following NORM residue will be managed at the Project:

- Water that may have come into contact with radioactive materials including surface runoff, from areas which contain process material, and
- Miscellaneous wastes that may have become contaminated through contact with radioactive materials (referred to as contaminated waste).

This NRMP does not describe how NORM residues from the process plant are managed because they are transported back to the mine site for storage in an approved Tailings Storage Facility. The Yangibana Rare Earths Project NRMP describes the management of NORM residue.

This NRMP meets the requirements set out in the following documents:

- *Code of Practice for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing* (ARPANSA 2005) (the Mining Code); *and*
- *Managing naturally occurring radioactive material (NORM) in mining and mineral processing guideline. NORM 4.2. Management of radioactive waste* (Department of Mines and Petroleum 2010).

This NRMP will form a component of the Yangibana Environmental and Social Management System (ESMS), which operates on a continual improvement cycle of plan, do, check and act. This NRMP is considered a 'live' document and will be further reviewed regularly during the detailed design phase. Formal approval of this document will be sought from the Radiological Council and DMIRS prior to the operations phase of the Project.

1.3 OBJECTIVE

The objective of this NRMP, as stated in the Mining Code (ARPANSA 2005) is to:

"…ensure that there is no unacceptable health risk to people, both now and in the future, and no long-term unacceptable detriment to the environment from the waste so managed, and without imposing undue burdens on future generations."

1.4 KEY ELEMENTS

The key elements of this NRMP (as set out in *NORM Guideline 4.2*) include:

- An outline of the processes generating waste (Section 3 Background).
- A description of waste including nature of material (chemical, physical and radiological), contaminants, and quantities and rate of production (Section 3 Background).
- A description of the environment into which the waste will be discharged or disposed (climate, terrain, soils, vegetation, hydrology), including the baseline radiological characteristics (Section 3 Background).

- Heritage (social and cultural) and land use (present and potential) (Section 3 Background).
- A description of the proposed system for waste management including the facilities and procedures involved in the handling, treatment, storage, and disposal of NORM residue (Section 4 Management).
- Predictions of environmental concentrations of radionuclides and radiation doses to the public from the proposed waste management practice, including demonstration that the statutory radiation protection requirements will be met both now and, in the future, (Section 4 Management).
- A program for monitoring the concentration of radionuclides in the environment and assessment of radiation doses to members of the public arising from the waste management practices (Section 5 Monitoring).
- Contingency plans for dealing with accidental releases and the circumstances which might lead to uncontrolled releases of NORM residue in the environment (Section 6 Contingency Planning).
- Contingency plan to cover cases of early shutdown or temporary suspension of operations (Section 6 Contingency Planning).
- A schedule for reporting on the waste disposal operations and results of monitoring and assessments (Section 7 Reporting).
- A plan for the decommissioning of the operation and associated waste management facilities, and for the rehabilitation of the site (Section 4 Management).
- A system of periodic assessment and review of the adequacy and effectiveness of the NRMP to take account of potential improvements consistent with best practicable technology (Section 8 Review).

1.5 SUPPORTING DOCUMENTATION

Documentation that should be read in conjunction with and complement this NRMP include:

- Baseline Radiation Report (Aurora Environmental, 2021).
- Radiation Impact Assessment (JRHC Enterprises, 2021)
- Radiation Management Plans (Hastings, 2021).
- Closure Plan (Hastings, 2021).

1.6 RELEVANT LEGISLATION

An assessment of environmental legislation relevant to the Project highlighted several approvals required prior to commencement of proposed activities. Legislation relevant to one or more phases of the Project includes:

- Aboriginal Heritage Act 1972.
- Biodiversity Conservation Act 2016.
- Contaminated Sites Act 2003.
- Dangerous Goods Safety Act 2004.
- Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act).
- Environmental Protection Act 1986.
- Health Act 1911.
- Mines Safety and Inspection Act 1994.
- Mines Safety and Inspection Regulations 1995.
- Mining Act 1950.
- Radiation Safety Act 1975.
- Radiation Safety (General) Regulations 1983; and
- Rights in Water and Irrigation Act 1914.

2. BACKGROUND

2.1 PROCESSES GENERATING WASTE

2.1.1 Processing

The Onslow Rare Earths Plant consists of a Hydrometallurgical (Hydromet) Process Plant and Evaporation Pond. A beneficiation concentrate (33 Bq/g) will be transported by truck, initially from the Yangibana Rare Earths Project to the Onslow Rare Earths Plant, where it will be processed to produce a Mixed Rare Earths Carbonate (MREC). The process (illustrated in Figure 1) includes:

- Acid-bake rotary kiln: Acidification and roasting of the mineral concentrate to crack the mineral structure.
- Acid bake rotary kiln off-gas treatment.
- Water leaching to bring metals into solution.
- Purification and ion exchange to remove impurities.
- Precipitation of rare earths carbonate product.
- Neutralisation of waste streams prior to disposal.

Gypsum and waste liquors will be stored in an evaporation pond adjacent to the plant. NORM residue (32 Bq/g) will be transported back to the mine site for storage in an approved Tailings Storage Facility (TSF). Natural gas, power and water service infrastructure lies in close to the plant site. Water will be abstracted from the Birdrong Aquifer (MDW4 water bore) but will need to be treated in a Reverse Osmosis (RO) Plant to remove salt and naturally occurring low level radionuclides.

2.2 DESCRIPTION OF WASTE

2.2.1 Nature of Material (Chemical, Physical & Radiological)

Waste characterisation studies have been undertaken on bench scale and pilot plant metallurgical test work samples. The outcomes from characterisation studies are summarised as follows:

The Hydromet tailings-solids are expected to be NAF and may be slow / difficult to drain and consolidate to a trafficable surface. Radionuclide levels are in excess of expected thresholds (~33 Bq/g; *JRHC,* 2021) and are not water soluble in these tailings.

2.2.2 Contaminants

Elevated radionuclide concentrations in the process plant are the only contaminants that may trigger consideration under the *Contaminated Sites Act 2003* (WA) at closure of the facility.

2.2.3 Quantities and rate of production

A NORM residue (tailings) stream will be produced from the processing plant and disposed of in an approved TSF at the Yangibana mine site. Further details can be found in the *Yangibana NRMP*. Chemical and physical characteristics, source and disposal location of the tailings stream is summarised in Table 1.

Table 1 Disposal & General Characteristics of Tailings Streams

PROCESSING SOURCE	ANNUAL RATE (TPA)	PHYSICAL PROCESSING	CHEMICAL PROPERTIES	RADIONUCLIDE CONCENTRATION	STORAGE
Hydrometallurgical	40,000	Acid Heating, Water Leach, Neutralisation & Waste Removal Thickening	Trace Sulphuric Acid; U and Th; Iron Phosphates Aluminium; Gypsum Metal Hydroxides pH7-8	~ 33 Bq/g (Head of Chain)	Hydromet TSF at mine site

2.3 DESCRIPTION OF ENVIRONMENT

A summary of the following environmental values at the Project site are described in the following sections.

2.3.1 Climate

The survey area is in the Pilbara region of Western Australia which has an arid-tropical bi-seasonal climate. The Bureau of Meteorology (BoM) weather station (Onslow Airport) reports the 55-year average total rainfall for the area from January to November is 304.1 mm. The long-term average temperature is 31.72 °C (*RPS*, 2021a).

2.3.2 Terrain

The terrain of the project area is characterised as hummock grasslands on inland sand dunes (height of up to 13m ADH) surrounded by plains and claypans (*RPS*, 2021a).

2.3.3 Vegetation

Vegetation of the Project area and near surrounds is consistent with the dune land system as summarised in Table 2 (*RPS*, 2021a).

Table 2 Vegetation characterised by landform and soil type

LANDFORM	SOIL	VEGETATION
Linear and reticulate dunes: up to 15 m high and 2.5 km long by 100 to 200 m apart becoming reticulate, hummocky crests, flanks extending 100 m or so with steeper western sides to 20%.	Dark red sands, loamy sands	Hummock grasslands of *Triodia schinzii* with numerous low shrubs and forbs
Swales: sandy surfaces 50 to 300 m wide between dunes.	Dark red sands, loamy sands	Hummock grasslands of *Triodia epactia* and some *Triodia lanigera*, sparse low shrubs such as *Acacia* *stellaticeps* and forbs
Swamps and depressions: low lying areas between dunes, circular or oval up to 500 m in diameter or extent.	Surface cracking reddish brown clay soils	Low open woodland of *Eucalyptus victrix* with *Muehlenbeckia cunninghamii* and perennial grasses such as *Sporobolus mitchellii* and *Eriachne benthamii*
Claypans: bare, circular, oval, or elongated surfaces mostly less than 150 m in diameter or length but up to 500 m, up to 1.5 m below adjacent sandplains or swale with abrupt marginal slopes.	Dark red clay soils after with lime or gypsum in profile, sealed, glazed surfaces or crusted surfaces with desiccation cracks	No vegetation

2.3.4 Hydrology

Surface water flows from the highest point of the dunes to the east and west in the Quick Mud Creek and Hooley Creek catchments, respectively (Figure 3). The Quick Mud Creek is approximately 500m to the east of the Project area (*RPS*, 2021b).

The groundwater table is shallow at between 2-3 m depth within the Project area. The groundwater is hypersaline (*RPS*, 2021b).

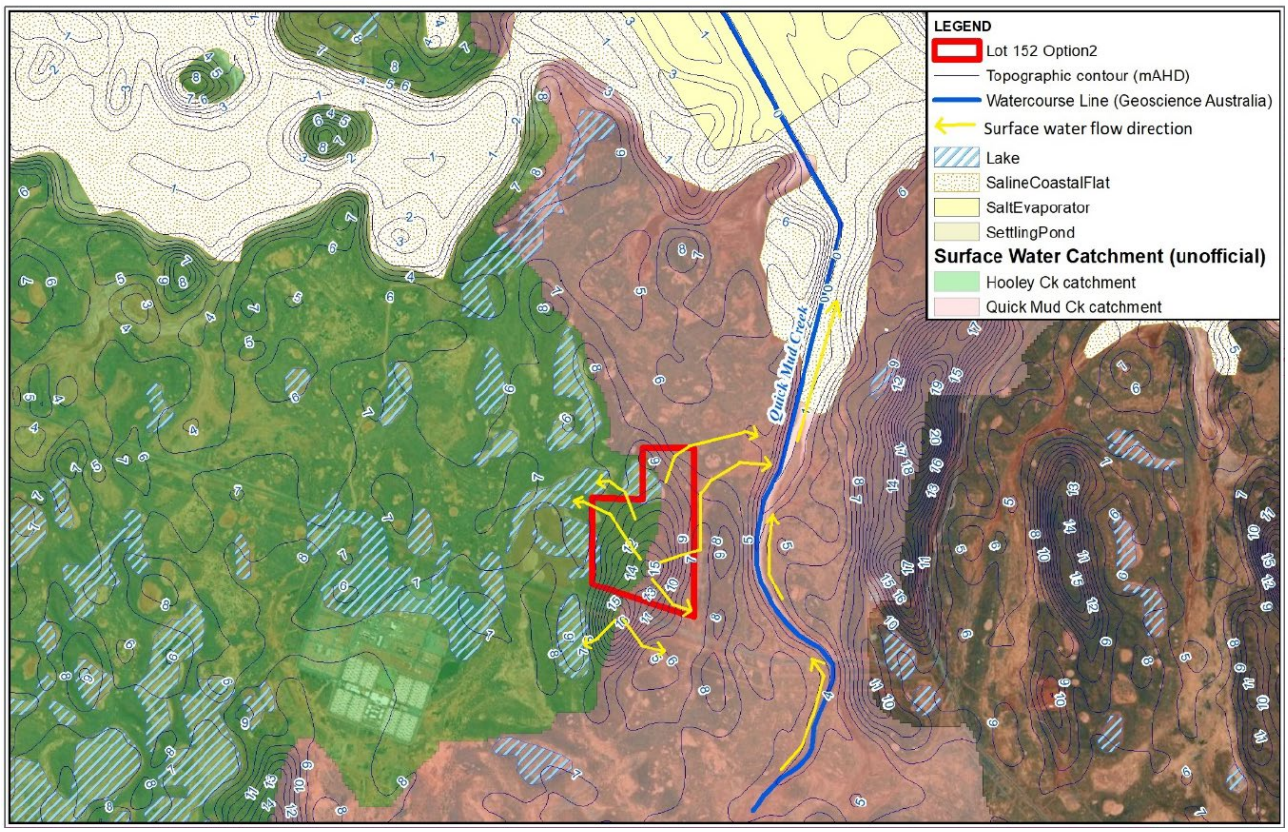

Figure 3 Surface water flow

2.4 BASELINE RADIOLOGICAL CHARACTERISTICS

Surveys have been partially completed over areas that are significant to the operation, prior to any disturbance of local conditions (*Aurora Environmental*, 2021).

The baseline data includes:

- Gamma radiation.
- Radionuclides in dust.
- Radon and thoron concentrations.
- Radionuclides in soil.
- Radionuclides in water.

This Baseline Radiation Report (*Aurora Environmental*, 2021) summarises data collected in monitoring programs and shows sample locations. Monitoring on site is ongoing.

2.4.1 Gamma Radiation

Baseline gamma radiation levels have been determined via handheld instrument gamma surveys.

The monitoring shows that background gamma radiation levels are very low and characteristic of the township and almost half the concentration of the roads (*Aurora Environmental*, 2021;Table 3).

Table 3 Gamma survey summary

	PROJECT AREA	ONSLOW TOWN	ROADS
Locations	50	9	7
Average# counts per 30 seconds	1040.7	1110.7	2040.2
Std Dev#	102.6	181.6	38.9
Maximum#	1458.7	1473.0	2116.3
Minimum#	898.3	837.3	1985.3

2.4.2 Radionuclides in Dust

No dust sampling has been done to date at the proposed Hydromet Plant location.

However, *Aurora Environmental* (2021) includes dust sampling locations completed for Water Corporation as a baseline for a proposed water treatment plant for bore water extracted from MDW4, which contains radionuclides. The dust deposition gauges were changed out monthly (every 30 days). Dust radioanalysis was conducted in accordance with *AS/NZ 3580.10.1:2003*. Total Deposited Solids (TDS) and gross alpha levels (and if needed other specific radionuclides) were analysed using a National Association Testing Authorities (NATA) accredited laboratory.

Gross alpha activity levels in dust were reported as less than the minimum detection limit at all sampling locations.

2.4.3 Radon & Thoron Concentrations

No radon/thoron sampling has been done to date at the proposed Hydromet Plant location.

Radon and thoron monitoring was collocated with the dust sampling stations. The monitors were changed-out on a quarterly basis (every 90 days). Radon and thoron concentrations were reported as less than the minimum detection limit at all sampling locations ranging from 30-50 Bq/m^3 thoron and 15-20 Bq/m^3 radon, respectively (*Aurora Environmental*, 2021).

2.4.4 Radionuclides in Soil

Soil sampling was conducted in 2013 by Chevron and in 2018 by Water Corporation, showing levels of Radium-226, Radium-228 and Radon-222. Soils samples were collected from Quick Mud Creek and near the Onslow Salt ponds. Table 4 provides the summary of radiometric results (*Aurora Environmental*, 2021).

Table 4 Radiometric analysis results for soil samples

NO.	SAMPLE ID	SAMPLING DATE	U238	TH232	RA226	RA228	TH228	PB210	K40
			Bq/kg						
1	001A	17.07.18	10.9 ± 2.6	22.4 ± 0.66	9.01 ± 1.19	9.3 ± 1.8	13.5 ± 1.7	13.2 ± 4.0	233 ± 31
2	001B	17.07.18	25.1 ± 4.1	40.7 ± 4.6	24.5 ± 2.6	35.1 ± 4.2	36.2 ± 4.2	40.2 ± 8.0	476 ± 57
3	005A	17.07.18	20.5 ± 3.6	23.1 ± 2.8	17.9 ± 2.0	30.5 ± 3.7	31.3 ± 3.7	23.4 ± 5.8	278 ± 36
4	005B	17.07.18	7.3 ± 2.2	2.65 ± 0.77	1.34 ± 0.79	5.8 ± 1.3	2.37 ± 0.60	<21.0	32.9 ± 8.6
5	007	18.07.18	28.8 ± 4.4	38.1 ± 4.3	19.6 ± 1.7	28.8 ± 2.7	28.6 ± 2.7	35.7 ± 5.9	353 ± 35
6	014A	18.07.18	15.2 ± 3.1	19.5 ± 2.5	17.4 ± 1.5	19.6 ± 1.9	19.5 ± 2.1	20.9 ± 3.7	215 ± 23
7	014B	18.07.18	17.7 ± 3.3	25.2 ± 3.0	90.8 ± 7.8	104 ± 9	106 ± 12	46.3 ± 8.8	217 ± 32
8	014C	18.07.18	9.6 ± 2.5	14.5 ± 2.0	459 ± 36	493 ± 38	558 ± 60	72.0 ± 14.9	216 ± 33
9	014D	18.07.18	13.7 ± 3.0	22.9 ± 2.8	24.4 ± 2.5	24.3 ± 3.1	25.9 ± 3.1	17.2 ± 5.2	289 ± 37
10	002	22.09.18	20.9 ± 3.6	34.1 ± 3.9	14.7 ± 1.7	19.6 ± 2.5	17.6 ± 2.2	26.2 ± 5.4	282 ± 36
11	003	22.09.18	16.2 ± 3.2	24.5 ± 3.0	12.2 ± 1.5	16.6 ± 2.5	16.0 ± 2.1	47.1 ± 7.8	278 ± 36
12	004	22.09.18	20.6 ± 3.6	26.9 ± 3.2	16.0 ± 1.8	25.7 ± 3.1	22.7 ± 2.7	30.7 ± 5.9	357 ± 42
13	006	22.09.18	20.0 ± 3.6	28.2 ± 3.4	17.2 ± 1.8	24.1 ± 2.9	22.9 ± 2.7	23.5 ± 5.2	364 ± 42
14	008	22.09.18	17.4 ± 3.3	36.2 ± 4.1	16.0 ± 1.8	24.3 ± 3.1	26.8 ± 3.2	115 ± 15	495 ± 56
15	012	22.09.18	28.8 ± 4.4	43.2 ± 4.8	22.9 ± 2.3	32.4 ± 3.5	32.7 ± 3.8	33.8 ± 6.3	449 ± 51
16	013	22.09.18	23.2 ± 3.8	31.4 ± 3.7	22.3 ± 2.3	29.5 ± 3.4	31.7 ± 3.7	29.8 ± 6.1	424 ± 49
17	009	22.10.18	28.3 ± 4.3	31.5 ± 3.7	20.2 ± 2.2	23.5 ± 3.0	23.3 ± 2.8	42.7 ± 7.2	378 ± 44

2.4.5 Radionuclides in Water

Radiometric analysis sampling of the bore water MDW4 was also conducted in 2013 by Chevron and in 2018 by Water Corporation, showing levels of Radium-226, Radium-228 and Radon-222. From the radiometric results, the levels of Radium-228, gross alpha and gross beta were above

the trigger values for radioactive contaminants in irrigation or livestock drinking water (*Aurora Environmental*, 2021).

2.5 HERITAGE

2.5.1 Aboriginal

The Native title party for the Project area is the Thalanyji People. Development WA, as managers of the land on behalf of the Western Australian government have consulted with the Thalanyji People. Cultural heritage surveys have been conducted over the Project area. Two significant cultural heritage sites occur on the lease boundaries; however, Hastings has been able to avoid any impact to these sites.

As a leaseholder of the land, Hastings shall comply with any agreed cultural heritage mitigation actions.

2.5.2 European

The existence of European heritage values within the Yangibana Project area has been investigated through the Australian Heritage Commission and Heritage Council of Western Australia databases. No sites of European heritage were identified within or immediately adjacent to the Project.

2.5.3 Land Use (Present & Potential)

The predominant land use in the local area is industry, tourism, and pastoralism.

The Project area lies within the Minderoo pastoral lease.

Onslow is the nearest town (population of approximately 848) and is situated approximately 15 km from the Project area.

3. MANAGEMENT

3.1 RISK ASSESSMENT

A risk-based approach has been used to identify hazards, unwanted events and risks associated with the processing and disposal of NORM residue. A risk assessment, based on the *Leading Practice Sustainable Development Program for the Mining Industry - Risk Assessment and Management* (Department of Resources, Energy and Tourism (DRET) 2008), is a component of the Hastings EMS (*Risk Procedure*). The risk assessment is applicable to all phases of the Project, including the *Definitive Feasibility Study* (DFS). The risk assessment and associated register is a living process and will be updated during subsequent phases of the Project and then annually following commencement of operations (unless change management or major incidents dictate that it should be sooner):

- Detailed Engineering phase.
- Construction phase; and
- Operations phase.

Nearest sensitive environmental receptors include:

- Quick Mud Creek (approx. 500m away)
- Chevron's accommodation village (approx. 2 km away)
- Horizon Power Plant (approx. 3 km away), and
- Employees at the Project site.

The risks associated with the NORM residue include:

- Dust generation from transfer of concentrate from the trucks to the processing plant and transfer of NORM residue from the plant to the trucks
- Spillage from the transfer of concentrate from the trucks to the processing plant and transfer of NORM residue from the plant to the trucks and potential for contaminated surface water
- Incorrect disposal of miscellaneous wastes that may have become contaminated through contact with NORM (referred to as contaminated waste).

The risks associated with NORM residue are also applicable to other contaminants in the tailings material. The following describes mitigation actions to be implemented.

3.2 MITIGATION OF RISK

3.2.1 Design Criteria

The residues from the offsite Hydromet processing facility are defined as radioactive and are to be transported to the mine site and stored into the approved tails storage facility. As such, design and engineering of this facility is described in the *Yangibana Rare Earths Project NRMP* for the initial operations phase.

Design and engineering of the process plant will incorporate sedimentation ponds within the transfer areas for incoming concentrate and outgoing NORM residue. The design of the sedimentation ponds will ensure any surface water within the transfer areas is captured.

3.2.2 Construction & Operations

The residues from the offsite Hydromet processing facility are defined as radioactive and are to be transported to the mine site and disposed into the approved tails storage facility. As such, management of this facility is described in the *Yangibana Rare Earths Project NRMP* for the initial operations phase.

Water that has come in contact with NORM residue, such as storm water runoff from the processing plant will be managed on-site. Collection bunds and channels will be used to manage potentially contaminated surface water runoff. Wastewater in the sedimentation ponds or other collection facilities shall be transferred to the lined evaporation pond where it will be diluted.

Wastewater collected from the site including wash down areas and clean-up water would be either reused in the processing plant or directed to the evaporation ponds.

Miscellaneous waste materials may include contaminated equipment and wastes from operational areas, steel, rubber lining material, pipes, filter media and used protective equipment. Where practical, potentially contaminated waste would be decontaminated and disposed of via normal waste disposal methods. Where this is not possible and depending on the nature of the waste, disposal options include:

- Disposal in the mine site Hydromet TSF, or
- Decontamination and disposal at the Onslow Waste Facility.

Requirements and constraints to be considered[1], specific to the current state of knowledge, and relevant to the Project, include:

- Solubility of thorium is very sensitive to pH at around 4. The pH of tailings in the Beneficiation and Hydromet TSFs range from 10-12 and 7-8, respectively. This will reduce the concentration of thorium in water (*NORM Guideline 4.2*, DMP, 2010). Any changes to the process that may result in a change to the chemistry of the tailings will need to assess the implications to pH and solubility of thorium.

[1] Continuing consultation between the operator and the relevant regulatory authority (i.e., DMIRS, Radiological Council, DWER) is required to ensure an optimum design of TSFs will be achieved to meet the requirements for radiation protection and waste management (the Mining Code; ARPANSA, 2005). Consultation will allow all parties to be clear on the requirements and constraints that should be considered (the Mining Code; ARPANSA, 2005).

- Drainage and water management pre- and post-closure to be considered during detailed engineering design phase.

3.2.3 Decommissioning & Closure

A Closure Plan will be developed in accordance with the *Guidelines for Preparing Mine Closure Plans* (DMIRS, 2020). Planning for decommissioning and closure of the process plant will occur during all phases of the Project based on:

- Research outcomes
- Rehabilitation outcomes
- Monitoring results
- Annual review of the risk register against performance indicators
- Lessons learned from environmental performance and management measures in the mining industry.

3.2.3.1 Decommissioning

The Mining Proposal has a whole-of-site approach to decommissioning activities. In addition to the Mining Proposal, a Decommissioning Plan must be approved by the DMIRS Resources Safety Branch and the Radiological Council prior to any site closure activities commencing. The disposal of contaminated plant and equipment will be the focus during the decommissioning phase.

An inventory will be developed, and an assessment of contamination will be conducted for all plant and equipment. Where recycling or reuse of plant or equipment is feasible, items will be decontaminated to radiation levels less than 1 Bq/g (exempt from regulation) before leaving site. An appropriate disposal method will then be determined for each plant and equipment, identified as waste, based on level of contamination.

3.2.3.2 Closure

Should the monitoring program (described in Section 4) reveal that a credible exposure pathway exists between the source of contaminants (i.e., Hydromet process plant) and potential receptors, then a Detailed Site Investigation will be instigated, and the outcomes communicated with the Department of Water and Environmental Regulation (DWER), as required under the *Contaminated Sites Act 2003*. A remediation and management plan for the site at closure will then be developed in consultation with DWER.

4. MONITORING

4.1 PRE-OPERATIONAL MONITORING

A pre-operational monitoring program has been undertaken during the pre-construction phase taking into account *NORM Guideline 3.1. Monitoring NORM – pre-operational guideline* (DMP, 2010) and provided in the Baseline Radiation Report (*Aurora Environmental*, 2021).

Monitoring of the construction process to ensure the process plant is built in accordance with design specifications will occur during the construction phase.

4.2 OPERATIONAL MONITORING

During operations, an environmental radiation monitoring program will be developed taking into account *NORM Guideline 3.2. Monitoring NORM – operational monitoring requirements* (DMP, 2010). In the design of the monitoring program, the following elements are or will be considered:

- A change in the physical and chemical characteristics of radionuclides due to the hydrometallurgical process.
- Possible pathways of exposure of workers includes dust generation from the processing plant.
- Design parameters that have addressed the possible pathways of exposure will be monitored to ensure their effectiveness.
- Some areas on-site will be classified as supervised or controlled areas.

4.2.1 Sources

An *Environmental Radiation Monitoring Work Instruction*, a component of the Hastings ESMS, will be developed to provide specific protocols for environmental radiation monitoring from the following sources:

- Direct gamma radiation: A survey of the perimeter of the Development Envelope to measure gamma radiation levels will be conducted on an annual basis.
- Radon decay products: Track etch monitors will rotate between off-site locations.
- Contamination of surface water run-off: Surface water sampling will be conducted opportunistically following significant rainfall events or on a quarterly basis.
- Contamination of potable water supply: Sampling and radiometric analysis will be conducted as detailed in the *Drinking Water Quality Management Plan* (to be developed and as required by the Department of Health).
- Dust containing long-lived alpha-emitting radionuclides: Dust deposition gauges and high-volume samplers will collect dust samples at pre-determined locations for composite analysis on an annual basis and rotate between approved off-site locations, respectively.

NORM Guideline 6 Reporting Requirements (DMP, 2010) states that each measurement must be undertaken using an agreed technique and appropriate monitoring equipment. Once approved

these techniques do not need to be detailed in the reports. However, any changes in the techniques must be approved before being used as the basis of the reports

4.2.2 Containment Controls

Monitoring of controls for containment of NORM residue will include:

- Weekly visual inspection of surface water management structures including bunds, drainage channels, water pipelines, and evaporation ponds.
- Inspections of management controls following major rainfall or extreme weather events.
- Annual inspection/audit by closure specialist to identify potential hazards, risks, and opportunities for continual improvement, including aspects that require further investigation or research.
- Periodic area gamma and contamination monitoring.
- Internal audits (in accordance with the ESMS *Audit Procedure*) of the implementation of this NRMP.

4.2.3 Trigger Values

Trigger values are based on authorised limits and/or baseline values and take account those identified in *NORM Guideline 6 Reporting Requirements* (DMP, 2010) (Table 5).

Table 5 Investigation level recommended for each Radiation parameter (DMP, 2010d)

RADIATION PARAMETER	INVESTIGATION LEVEL	COMMENT
1 *Area Gamma Dose Rate*		
1.1 Site Boundary	>1.1 µGy/hr above background	> 1 mSv/year for a member of the public (8760 hrs/year)
1.2 Supervised Area	> 0.5 µGy/hr above background	> 1 mSv/year for an employee (2000 hrs/year)
1.3 Controlled Area	> 2.50 µGy/hr above background	> 5 mSv/year for an employee (2000 hrs/year)
1.4 Restricted	> 7.50 µGy/hr above background	> 15 mSv/year for an employee (2000 hrs/year)
2 *Personal External Dose*		
2.1 Designated Worker	> 2.5 mSv in a quarter	> 10 mSv/year
2.2 Non-Designated Worker	> 0.5 mSv in a quarter	> 2 mSv/year
3 *Personal Internal Dose*		

RADIATION PARAMETER	INVESTIGATION LEVEL	COMMENT
3.1 Designated Worker	> 5.0 mSv in a quarter	Assessed from air sampling
4 *Airborne Radioactivity*		
4.1 Total alpha activity on the personal air sample – U dust	> 9.9 Bq/m^3 for 12-hr shift sample	~ 0.5 mSv/shift
4.2 Total alpha activity on the personal air sample – Th dust	> 4.3 Bq/m^3 for shift sample	~ 0.5 mSv/shift
4.3 Total alpha activity on the personal air sample – U dust	4 consecutive samples > 2.4 Bq/m^3	Indicates potential for significant exposure
4.4 Total alpha activity on the personal air sample – Th dust	4 consecutive samples > 1.0 Bq/m^3	Indicates potential for significant exposure
4.5 Total alpha activity	> Mean + 3 standard deviations	Indicates potentially unusual working conditions
4.6 Total alpha activity on environmental air sample – U dust	> 2 mBq/m^3 on high volume air sampler	> 100 µSv/year for a member of the public continuously exposed (> 10% of exposure limit)
4.7 Total alpha activity on environmental air sample – Th dust	> 1 mBq/m^3 on high volume air sampler	> 100 µSv/year for a member of the public continuously exposed (> 10% of exposure limit)
5 *Airborne Dust*		
5.1 Inhalable dust on personal air sample	> 10 mg/m^3	Statutory limit for respirable dust concentration
5.2 Respirable dust on personal air sample	> 3 mg/m^3	Statutory limit for respirable dust concentration
6 *Radon / Thoron in Air*		
6.1 Radon (^{222}Rn) in air - workplaces	> 3.5 mJh/m^3	> 5 mSv/year for an employee (2000 hrs/year)
6.2 Thoron (^{220}Rn) in air - workplaces	> 10.7 mJh/m^3	> 5 mSv/year for an employee (2000 hrs/year)
7 *Radionuclides in Water*		
7.1 ^{226}Ra in ground water or surface water	> 0.5 Bq/L ^{226}Ra or 2x average pre-operational levels for waters containing high levels of radium	100 µSv/year for ingestion of 2L/day for a year See section 5 for contingency measures

RADIATION PARAMETER	INVESTIGATION LEVEL	COMMENT
7.2 *^{228}Ra in ground water or surface water*	> 0.2 Bq/L ^{228}Ra or 2x average pre-operational levels for waters containing high levels of radium	100 µSv/year for ingestion of 2L/day for a year See section 5 for contingency measures

Exceedances of a trigger value will be considered an incident unless significant seasonal environmental variation of background levels are expected, e.g., salinity levels in permanent ponds. In such instances, a trend of exceedances in trigger values will then be treated as an incident.

4.2.4 Quality Assurance

NORM Guideline 3.2. Monitoring NORM – operational monitoring requirements (DMP, 2010) highlights the importance of having a quality assurance program. ARPANSA (2005) requires that the quality assurance program, which is compliant with Australian Standards should be implemented, including traceability of all radiation measurements to Australian metrological[2] standards where possible.

Quality assurance is integrated throughout the Hastings ESMS. Other applicable systems include a Quality Management System, and Occupational Health and Safety System. Hastings management system framework integrates the requirements of the above listed systems international standards (ISO 14001, 9001, 4500 and AS/NZS 4801 and 4804), which is currently in development and will be implemented.

4.2.4.1 Equipment

Quality assurance of equipment and instruments, including calibration and maintenance, will form a component of the *Environmental Radiation Monitoring Procedure*.

4.2.4.2 Sample Analysis

Hastings will only engage recognised, accredited laboratories to conduct sample analysis. Accurate records of sampling and sample analysis will be maintained using Yangibana *Field Record Form* and *Chain of Custody Form.* Use of these forms and records to be maintained will be detailed in the *Environmental Radiation Monitoring Procedure* and will be in accordance with Hastings *Records Procedure.*

Control samples and the consistent use of standard methods for analysis will verify monitoring procedures detailed in the *Environmental Radiation Monitoring Procedure*.

4.2.4.3 Personnel

Hastings will employ competent, qualified, and experienced environmental professionals to conduct the monitoring activities. Prospective employees will be assessed and employed based on their experience in conducting environmental monitoring.

[2] Metrology is defined by the International Bureau of Weights and Measures (BIPM) as `the science of measurement, embracing both experimental and theoretical determinations at any level of uncertainty in any field of science and technology.'

4.2.4.4 Training

An on-going training program relevant to the NRMP will be in place in accordance with Hastings *Training Procedure*.

4.2.4.5 Audits & Inspections

An audit program in accordance with Hastings *Audit and Inspections Procedure* will assess whether or not monitoring is being undertaken against established requirements set out in this NRMP and the *Environmental Radiation Monitoring Procedure.*

5. CONTINGENCY PLANNING

Contingency planning will form a component of the risk assessment in case pre-determined mitigation is not effective. Contingency plans will form a component of the *Emergency Response Plan*.

The contingency plan should seepage of potentially contaminated water occur that presents a risk to the local drainage system or land surface, as identified from water quality monitoring will include:

- Developing and utilising the shallow monitoring bores for the early recovery of contaminated groundwater water and redirecting the water to the evaporation pond
- Construction of a downstream collection trench to intercept and recover any surface water or shallow lateral seepage.

Where containment of NORM residue fails, the Hastings *Emergency Response Plan* will include:

- Human health and safety first: HAZMAT response to exposure, evacuation, decontamination of the persons exposed to radiation.
- Stabilisation of the containment and prevention of impact to surrounding environmental receptors.
- Consideration of secondary containment and drainage.
- Clean-up procedures.
- Training of personnel on the Emergency Response Team to address HAZMAT containment failures.
- Identification of radiation specialists and engineering experts to review contingency plans; and
- Suspension of operations (also considered in the Care and Maintenance section of the Closure Plan).

6. REPORTING

6.1 DOCUMENTATION

Reporting requirements are outlined taking into account *NORM Guideline 6 Reporting Requirements* (DMP, 2010). The following reporting commitments (Table 6) align with the requirements of legislation or stakeholder concerns.

Table 6 Reporting Commitments

STAKEHOLDER	LEGAL REQUIREMENT	TIMIING
DWER	Incidents	At time of occurrence
DMIRS Resources Safety Branch	Environmental Radiation Monitoring Report for the period 1 October to 30 September. Details of the operation of the NORM residue management system as approved in the Radiation Management Plan.	Annually (within 8 weeks from 30 Sept)
DWER, public (via Hastings's website)	Annual Compliance Report	Annually
DoH*	Where the estimated annual radiation dose from radionuclide analysis of radium-226 and radium-228 exceeds 0.5 mSv in potable water supply.	Within 24 hrs
Employees	Monitoring results	Relevant to monitoring procedure

* DoH,2013

The Environmental Radiation Monitoring Report shall be prepared by a suitably qualified professional, typically an approved RSO, signed by the RSO and counter-signed by the Registered Manager.

The statutory report shall contain, as detailed in *NORM Guideline 6 Reporting Requirements* (DMP, 2010), for each radiation parameter listed in the radiation monitoring program, the following information:

Individual sample:

- Equipment used, calibration records, the type, number, date, and time of the measurement.
- Name or another suitable identifier for a personal air sample.
- Sampling location for an area gamma radiation measurement and for a positional air sample.

A group of data:

- The range and the mean with estimates of accuracy and precision (e.g., a standard deviation).
- A suitably scaled map or plan with direction indicator.
- Indications of trends in data, preferably in a graphical form.
- Comparison of the obtained results with authorised limits and/or baseline values collected prior to the commencement of operations.
- Reference to the techniques or equipment used.

The minimum contents of the annual Environmental Radiation Monitoring Report are listed in *NORM Guideline 6 Reporting Requirements* (DMP, 2010).

The annual environmental radiation monitoring report shall be submitted electronically with copies of all certificates of analyses obtained from off-site laboratories.

6.2 INCIDENTS

All hazards and incidents will be reported in accordance with Hastings *Incident Reporting Procedure*.

7. REVIEW

Constant review, application of latest scientific knowledge and 'lessons learnt' from similar operations are considered. An adaptive management approach will ensure optimum performance and management of risks are applied via this NRMP document.

This NRMP will be further developed throughout each phase of the Project and will also be reviewed whenever there is a significant change in the operation of the process plant that may impact the engineering considerations in the TSF design and implementation of the design criteria.

Review of this NRMP will include adaptive management actions or procedures to learn from the implementation of mitigation measures, monitoring and evaluation against trigger values. The following approach will be implemented:

- Monitoring data will be evaluated and compared to baseline and reference site data following the collection of monitoring data (as outlined in Section 5). Trends will also be assessed to verify modelling or the anticipated performance of mitigation measures.
- On-going research and assessment outcomes will identify opportunities or risks, which will be considered in the context of NORM residue management.
- When trigger level actions do not have the anticipated outcomes, revise mitigation measures, and obtain specialist advice.
- Continue to gain an increased understanding of site-specific environmental aspects (i.e., hydrological processes, sensitive receptors).
- External changes during the life of the proposal (e.g., changes to the sensitivity of the key environmental factor, implementation of other activities in the area).
- Review of risk register against performance measures, including (but not limited to) monitoring results, company culture, personnel changes, economic conditions, or changes to process plant.

8. REFERENCES

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