Yeelirrie Uranium Project

Response to Submissions

Attachment 10

Radiation Assessment - Revised

CAMECO

YEELIRRIE DEVELOPMENT

RADIATION ASSESSMENT

REVISED

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INDEX

1. Introduction

This technical note addresses the following issues identified in the public comments phase of the Cameco Yeelirrie PER;

- Lack of inclusion of U234 and Th234 in the assessment
- Provision of clarity on confusing text
- Addressing errors in the concentration ratio for uranium and radium which inadvertently occurred in the original document
- Lack of assessment for post closure scenarios.

As a result, a new ERICA assessment has been undertaken incorporating the changes and the results are presented in this note.

For the ERICA assessment in the PER and this revised assessment, version 1.2 of the ERICA software was conducted.

2. Areas Requiring Addressing

2.1 Use of U234 and Th234 in Assessment

For the original assessment, U234 was included, although Th234 was not.

Th234 has been included in the new assessment.

2.2 Clarity in Text

The original PER, in referring to table 42, states that;

> "The concentration ratios for kangaroos are for specific tissues and have been converted to "whole of organism" ratios for the ERICA assessment using the factors provided by Yankovic 2010. The average whole of organism concentration ratios are shown in Table 42. Maximums of reported arithmetic means from ARPANSA 2014 are also included for comparison purposes."

This statement is unclear and should read as follows;

> "The concentration ratios for kangaroos derived from baseline monitoring are for specific tissues and have been converted to "whole of organism" ratios for the ERICA assessment using the factors provided by Yankovic 2010 and are shown in Table 42. The average whole of organism concentration ratios for kangaroos from ARPANSA 2014 are also shown for comparison purposes. The ARPANSA figures in Table 42 are

obtained from arithmetically averaging the relevant figures in table A3-1 of Appendix 3 of ARPANSA 2014.

For shrubs, the APRANSA 2014 figure is from Table A4-2 of Appendix 4 of ARPANSA 2014."

2.3 CONCENTRATION RATIO ERRORS

The changes to the concentration ratios compared to the original PER are indicated with footnotes in table 1 below.

Table 1: Australian Concentration Ratios (Cameco specific and ARPANSA 2014)

Organism	Concentration Ratio				
	Uranium	**Thorium**	**Radium**	**Lead**	**Polonium**
Kangaroo (Cameco)	0.005	0.0086	0.062	0.0165	0.0308
Kangaroo [ARPANSA 2014]	0.010[1]	no data	0.41[2]	0.02	0.55
Plant (shrub and tree) (Cameco)	0.13	0.13	0.03	0.29	0.44
Shrubs [ARPANSA 2014]	no data	no data	0.15	no data	no data

Note 1: In the PER, this figure was reported as 0.005 which was a typographical error. The revised figure is the arithmetic mean of the three average kangaroo figures for uranium as shown in table A3-1 of Appendix 3 of ARPANSA 2014 (actual figures are; 2.12×10^{-2}, 7.99×10^{-4}, 8.53×10^{-3}).

Note 2: In the PER, this figure was reported as 0.041 which was a typographical error. The revised figure is the arithmetic means of two average kangaroo figures for radium as shown in table A3-1 of Appendix 3 of ARPANSA 2014 (actual figures are; 7.6×10^{-1}, 5.38×10^{-2}).

It is worth noting that the Cameco data derived concentration ratios are less than the ARPANSA 2014 figures. In the case of polonium, there is a factor of almost 20 difference between the values. For radium, the Cameco derived concentration ratio is almost a factor of 7 less.

2.4 POST CLOSURE SCENARIOS

The post closure ERICA scenarios are based on the scenarios described in section 9.6.6.6 of the PER which describes to potential erosion scenarios. They are;

- The first scenario involves a loss of 0.5m of tailings cover through erosion
- The second scenario involves gullying across 20% of the cover (to a depth of 1.5m) as a result of rainfall.

For this assessment, for the second scenario, it is assumed that the gullying reaches through the top soil cover into the waste rock cover later. (Note that for tailings to be exposed, the gullying would need to be approximately 3m deep and is therefore unlikely.)

An additional assessment was conducted on potential exposures to burrowing animals.

3. ERICA PARAMETERS

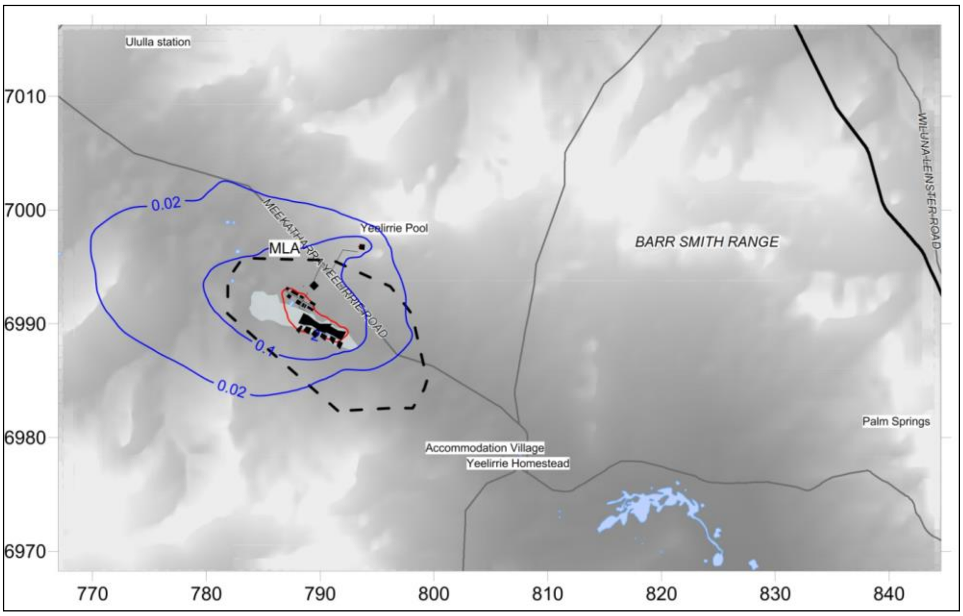
The following parameters were used in the revised ERICA assessment.

The only pathway of significance is dispersion of project-generated radioactive dust. As noted in the original ERICA assessment in the PER, water-borne pathways are not considered because there are no permanent water features in the region, and the only other pathway of potential significance is the dispersion of radon. Radon impacts were assessed in the PER in section 5.6 of Appendix J1.

The project air quality modelling was used to determine the dust deposition rates. The assessment was conducted at the approximate project boundary. Figure 1 shows that this aligns approximately with the 0.4g/m^2.month contour.

For a 15 year project, the total predicted dust deposition is calculated to be 72 grams per m^2. The average uranium in dust concentration for the whole operation is 9.4Bq/g per radionuclide.

Figure1: Modelled Dust Deposition (g/m^2.month)



Once deposited, the project dust would mix with the soil through a combination of physical, chemical and biological processes. For this assessment, it has been assumed that the mixing depth is 10 mm [Kaste 2007]. The soil density was assumed to be 1.5t/m^3.

Therefore the increase in radionuclide concentration in the soil at the project boundary after 15 years of operations can be calculated as follows;

- Total radionuclide deposition per m^2 = 72g x 9.4Bq/g = 677Bq
- Total mass of soil per m^2 = 1m x 1m x 0.01m x 1.5t/m^3 = 15kg
- Increase in soil radionuclide concentration = 677Bq/15kg = 45Bq/kg

4. ERICA Assessment Concentration Ratios

ERICA default concentration ratios were used for the default terrestrial species.

ARPANSA 2014 concentration ratios were used for the kangaroo species assessment. For thorium, ARPANSA does not report any value, therefore the Cameco derived figure of 0.0086 has been used.

The Cameco concentration ratios and the one value from ARPANSA 2014 were used for the shrub assessment.

The concentration ratios used in this revised assessment are shown in table 2.

Table 2: Australian Concentration Ratios (Cameco specific and ARPANSA 2010)

Organism	Concentration Ratio				
	Uranium	**Thorium**	**Radium**	**Lead**	**Polonium**
Kangaroo value used in assessment	0.010	0.0086	0.41	0.02	0.55
Shrubs value used in assessment	0.13	0.13	0.15	0.29	0.44

The ERICA software allows for user defined species based on a geometrical model of the species.

A species called "kangaroo" was added, with the following parameters;

- Kangaroo; mass 50kg, height 1.5m, width 0.75m and depth 0.75m.

5. ERICA ASSESSMENT

An ERICA tier 2 assessment was conducted.

The ERICA assessment was conducted using the default concentration ratios for most standard species and a combination of ratios derived for kangaroos and shrubs from Cameco data and ARAPNSA 2014.

The resulting derived dose rates are shown in 3.

Table 3: Tier 2 ERICA Assessment

Organism	CR Origin	Risk Quotient (expected value)	Risk Quotient (conservative value)
Lichen & bryophytes	Default	1.06	3.18
Arthropod - Detritivorous	Default	0.04	0.11
Flying insect	Default	0.03	0.10
Grasses & herbs	Default	0.20	0.60
Mollusc - Gastropod	Default	0.04	0.12
Shrub	ARPANSA/Cameco	0.20	0.61
Bird	Default	0.03	0.08
Amphibian	Default	0.05	0.14
Reptile	Default	0.05	0.15
Mammal (kangaroo)	Cameco/ARPANSA	0.34	1.01
Tree	Default	0.02	0.06
Mammal (small burrowing)	Default	0.04	0.13

As identified in the original ERICA assessment presented in the PER, lichen and bryophytes as the only species that would trigger the screening level of 10µGy/h.

The original ERICA assessment also commented on the Yeelirie specific fauna species and the conclusion that no species are at radiological risk and it is concluded that none of the Yeelirrie species are at risk either remains valid.

6. CLOSURE

The assessment in the PER was based on the logic that during operations, the ERICA assessment indicated that no species are at risk. It was therefore considered to be highly unlikely that the outcome following closure would be higher than this given that after closure emissions would have ceased.

To assess the potential impacts post closure, the focus is on the tailings. Cameco intends to place tailings back into the mined out mining cells and then cover with waste rock as a capillary break and then with topsoil. The intention is to have 3m of cover across the tailings. Cameco defines waste rock as material that is less than approximately 250ppm of uranium. For this assessment, it is assumed that the average uranium grade of the waste rock is therefore 125ppm of uranium (equivalent to approximately 1.5Bq/g of each uranium decay chain radionuclide).

Two potential post closure failure scenarios have been considered based on 10,000 year estimates as seen in Appendix O1 as follows;

- The first scenario involves a loss of 0.5m of the topsoil tailings cover through erosion
- The second scenario involves gullying across 20% of the cover (to a depth of 1.5m) as a result of rainfall.

For the second scenario, it is assumed that the gullying reaches the waste rock resulting in exposure to material containing approximately 1.5Bq/g. (Note that any gullying to actual tailings is extremely unlikely due to the competency of the material in the waste rock cover).

These scenarios are discussed in the context of impacts to non human biota.

6.1 Loss of 0.5m of Cover

The TSF is expected to be covered by inert material to a depth of 3m. If it assumed that 0.5m of inert cover is lost due to erosion, then there would a remaining cover of at least 2.5m, of which 1.5m is natural soils.

The tailings would remain covered by inert material and therefore not available to dust.

The impacts to non human biota are therefore expected to be the same as if the whole of the cover remained.

6.2 Gullying

A potential scenario is for gullying in the cover material to occur. If the gullying is deep enough to reach the waste rock cover layer, then there may be a possibility for exposure to this material.

It should be noted that radiation exposure to flora and fauna currently occurs in the region where there is outcropping mineralisation outcrops and is therefore a natural source of exposure.

The potential exposure scenario is that a gully forms a cavity where plants or animals may reside.

An ERICA assessment was conducted with the following paramters;

- Soil media radionuclide concentrations – 1,500Bq/kg
- Radionuclides; U238, U234, Th234, Th230, Ra226, Pb210, Po210
- Species considered; amphibian, arthropod, small burrowing mammal, mollusc, reptile, grasses and hers and shrubs.

- Occupancy factors for fauna was 0.5, assuming that they might spend half of their time in the cavity
- Default concentration ratios.

The output of the assessment was that all species exceeded the screening level of 10uGy/h, with highest exposures for the flora. The maximum total dose rate for the fauna was approximately 15uGy/h.

Note that this is for a conservative case where the gullying penetrates into the waste rock layer.

It is also possible for the hole to collect water and become a drinking source for animals. The impacts of this would be no different from water collecting in existing regions on top of the current orebody.

6.3 BURROWING ANIMALS

An assessment has been conducted on the potential radiological impacts to small burrowing animals and reptiles by considering their exposure to radon and their exposure into cover material.

Radon

Using the software tool of Vives i Batlle et al. (2008;2012) an assessment of potential radon impacts has been conducted.

It has been assumed that the soil radon concentration is 1,000Bq/m^3 and that this is the concentration that would exist in any burrows.

For the organism classifications reptile and rodent, the total dose rate was 3.1uGy/h and 8.9uGy/h respectively. This is using the default in soil occupancy times of 0.5 and 0.6 respectively.

Exposure in Cover

Cameco is intending to place a final cover on the rehabilitated tailings areas consisting of approximately 2m of local soil. Table 11 of Appendix J1 of the PER provides the background radionuclide concentrations in soils from the region. Excluding the mineralised calcrete and the water influenced results, the average concentrations for U238, Ra226 and Pb210 are approximately 0.2, 0.1 and 0.2 Bq/g respectively.

When these figures are inserted into the ERICA software as media concentrations, they do not trigger the screening value of 10uGy/h for the organism types; small burrowing mammal and reptile. (Note that the other organism types were not assessed as this is referring to small burrowing animals).

As a worst case, if it is assumed that the burrowing exceeds a depth of 2m and penetrates into the waste rock cover, where the average radionuclide concentration is 1.5Bq/g. The ERICA assessment gives a risk quotient for the two species of approximately 1.5, which is equivalent to a total dose rate of 15uGy/h.

7. REFERENCES

ARPANSA 2014	A review of existing Australian radionuclide activity concentration data in non-human biota inhabiting uranium mining environments, Technical Report 167 May 2014
Johansen and Twining 2010	Johansen MP & Twining JR, ‘Radionuclide concentrations in Australian terrestrial wildlife and livestock: data compilation and analysis’, Radiation and Environmental Biophysics, 2010. 49, pp. 603–611.
Kaste et al., 2007	Kaste JM, Heimsath AM & Bostick BC, ‘Short-term soil mixing quantified with fallout radionuclides’, Geology, 2007, 35, pp. 243–246.
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Yankovich et al 2010	Yankovich, TL, Beresford, NA, Wood, M, Aono, T, Andersson, P, Barnett, CL, Bennett, P, Brown, J, Fesenko, S, Fesenko, J, Hosseini, A, Howard, BJ, Johansen, M, Phaneuf, M, Tagami, K, Takata, H, Twining, J & Uchida, S (2010) 'Whole-body to tissue concentration ratios for use in biota dose assessments for animals.', *Radiation and Environmental Biophysics* 49: 549-565.