

RADIOLOGICAL EFFECTS ON NON-HUMAN BIOTA

ARISING FROM THE WILUNA URANIUM PROJECT

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A report prepared for

TORO ENERGY LIMITED

by

Philip Crouch BSc(Hons) PhD MARPS

PAPARI RADIATION SERVICES

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EXECUTIVE SUMMARY

An assessment of the potential for radiological effects on the terrestrial environment resulting from dust emissions from the operation of the Wiluna Uranium Project has been conducted using the ERICA assessment tool.

The Assessment indicates that any potential for harmful effects is restricted to small areas, up to 2 km across, which are unlikely to extend significantly beyond the actual areas of mining operations.

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1. INTRODUCTION

Toro Energy Limited (TRL) intends to develop the Wiluna Uranium Project in central Western Australia. The resource is in two deposits, Centipede and Lake Way, together containing approximately 11 kt of U_3O_8 . A processing plant is expected to be established near the southern (Centipede) deposit. Each deposit will be mined over approximately 5 years, with ore from the Lake Way deposit being trucked to the processing plant. Both orebodies are shallow and will be mined by open cut methods. Uranium production is expected to be at the rate of approximately 800 t per annum [1].

This report concerns the potential radiological effects of the proposed operations on non-human biota (NHB) in the terrestrial environment. It is concerned only with the dispersion of radionuclides into the environment through airborne pathways, and does not consider any effects that may arise from transport of radionuclides in surface or groundwater.

2. THE ERICA TOOL

The ERICA assessment tool (Environmental Risk from Ionising Contaminants) was developed under the European Commission to provide a method of assessing the impact of radiological contaminants on the natural environment [2, 3]. The tool contains two major data sources. The first, the database FREDERICA, contains information on the effects of radiation exposure on populations, and includes data on four main “endpoints”: morbidity, mortality, reproduction and mutation [4]. The second is a collection of databases that allows estimation of the radiation doses that will accrue to biota from radiological contaminants in their environment.

The International Commission on Radiological Protection has recommended that environmental radiological effects should be assessed on a series of “reference organisms”, and these are incorporated into the ERICA tool [5].

The starting point for an ERICA assessment is the radionuclide concentrations of the medium in which the reference organisms are living, in this case soil. This allows the external dose rate for the organisms to be derived, and in addition “concentration factors” from the ERICA database are used to calculate the radionuclide concentrations in the organisms to be calculated, and hence the internal dose rates.

The assessment process can be carried out in three “tiers”. Tier 1 is a simple highly conservative assessment, designed to easily identify situations which can be considered of negligible radiological concern. Tier 2 is used where a Tier 1 assessment indicates that there may be organisms at risk, and allows the use of more realistic and less conservative parameters to allow the estimation of dose rates to the organisms. These dose rates are then assessed against a screening dose rate to determine if there is a likelihood that populations are likely to suffer harm. Tier 3 is not a screening tier but is designed to provide guidance in further investigation of situations where Tier 2 indicates that there may be a significant concern of radiological harm.

The default screening dose rate adopted by ERICA is 10 μ Gy/h. This dose rate (described as the “predicted no-effect dose rate”, PNEDR) was derived from the dose estimated to give a 10% effect (ie to one of the end points noted above) to 5% of the species present by applying a safety factor of 5. This screening rate is thus

expected to protect the most radiosensitive organisms likely to be present in an environment [6]. The ERICA tool allows other screening dose rates to be adopted. For example several organisations have suggested that no measureable effects would be observed for dose rates of 40 $\mu\text{Gy/h}$ (terrestrial animals) and 400 $\mu\text{Gy/h}$ (terrestrial plants) [7-9]. The ERICA tool presents the results as the dose rates to the organisms, and also in terms of the “Risk Quotient”: the ratio of the dose rate to the screening rate. Dose rates and risk quotients are presented both for the “expected value” and a “conservative value”. The default conservative value is three times higher than the expected value and represents the value at which there is only a 5% chance that the calculated dose rate exceeds the screening level. This then represents a further level of conservatism.

The results of an ERICA assessment can then be described in terms of three dose rate bands [2]:

- $RQ_{\text{Expt}} > 1$ (ie expected dose rate > 1)
Screening dose is exceeded. Further assessment needed.
- $RQ_{\text{Cons}} > 1$ but $RQ_{\text{Exp}} < 1$ (ie expected dose rate 3.3 – 10 $\mu\text{Gy/h}$)
Substantial probability that screening dose rate is exceeded. Assessment should be reviewed.
- $RQ_{\text{Cons}} < 1$ (ie expected dose rate $< 3.3 \mu\text{Gy/h}$)
Low probability that screening dose rate will be exceeded. Environmental risk is arguably negligible.

A disadvantage in using the ERIC tool for Australian situations is that many of the parameters are derived for temperate northern hemisphere conditions. The most obvious is the case of kangaroos. ICRP has recommended as one of the set of reference animals a “large mammal”, and deer were chosen because of their widespread occurrence (in the northern hemisphere), and the large amount of radioecological data available for them [5]. In Australia the equivalent niche (grazing mammal) is filled by kangaroos, but the radioecological data for them is relatively sparse [10]. For the purposes of this assessment, the kangaroo is assumed to have the same radiological parameters as the deer. As will be noted below, this assumption is not likely to affect the overall conclusions of the assessment.

3. ENVIRONMENTAL RADIONUCLIDE CONCENTRATIONS

The only pathway of significance in this assessment is dispersion of project generated radioactive dust. As noted above, waterborne pathways are not considered, and the only other pathway of potential significance is the dispersion of radon. However radon being gaseous is widely dispersed in the environment and its subsequent decay products do not accumulate in the vicinity of the project.

Atmospheric dispersion modelling has been conducted for the project, and as part of this dust deposition contours have been calculated [11]. Figures 1 and 2 show these contours: Fig 1 for year 4 of the project, when the Centipede orebody is being mined, and Fig 2 for year 8 when the Lake Way orebody is mined. These two plots do not include dust generated from ore haulage between the two minesites and the processing plant. This haulage will be along roads which are surfaced with materials that are not mineralised and thus have radionuclide concentrations typical of normal soils from the area. Consequently deposition of dust arising from this source will

have no significant effect on the radionuclide concentrations in the surrounding areas.

To estimate the increase in soil radionuclide concentrations as a result of this dust deposition, the first step was to calculate the radionuclide concentrations of the dust. For the mining operations, the uranium ore grades of “all mined material” (that is, ore plus waste) were estimated by Toro as 303 ppm (Centipede) and 197 ppm (Lake Way). For the purposes of the assessment, 300 ppm was used for both mines. The overall grade of “ore” is approximately 600 ppm U and this concentration was used for dust arising from the processing plant. It was assumed that each minesite would be operated for 5 years, and the processing plant would operate for 10 years.

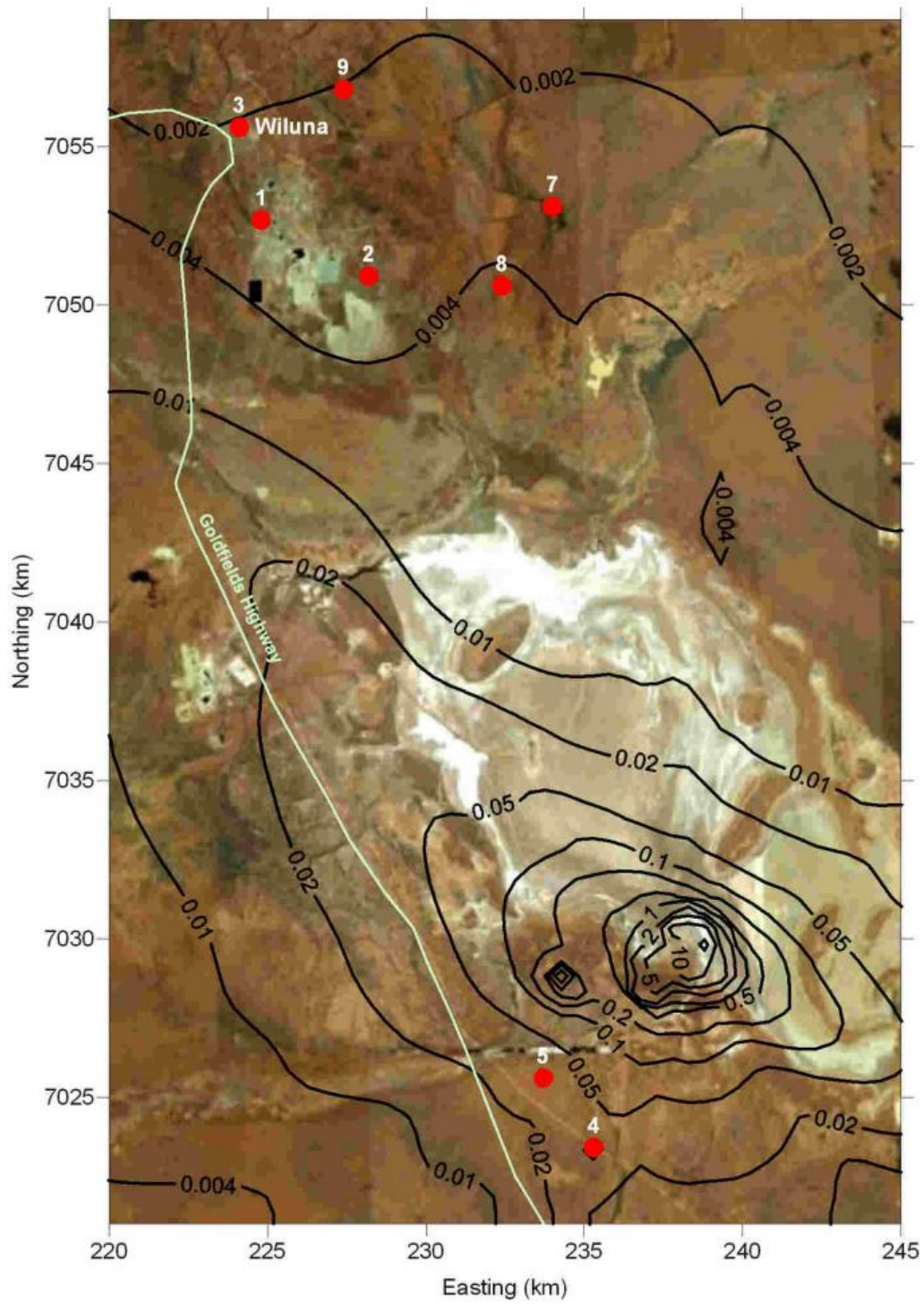


Figure 1 Dust deposition from mining and processing the Centipede deposit ($\text{g}/\text{m}^2/\text{month}$)

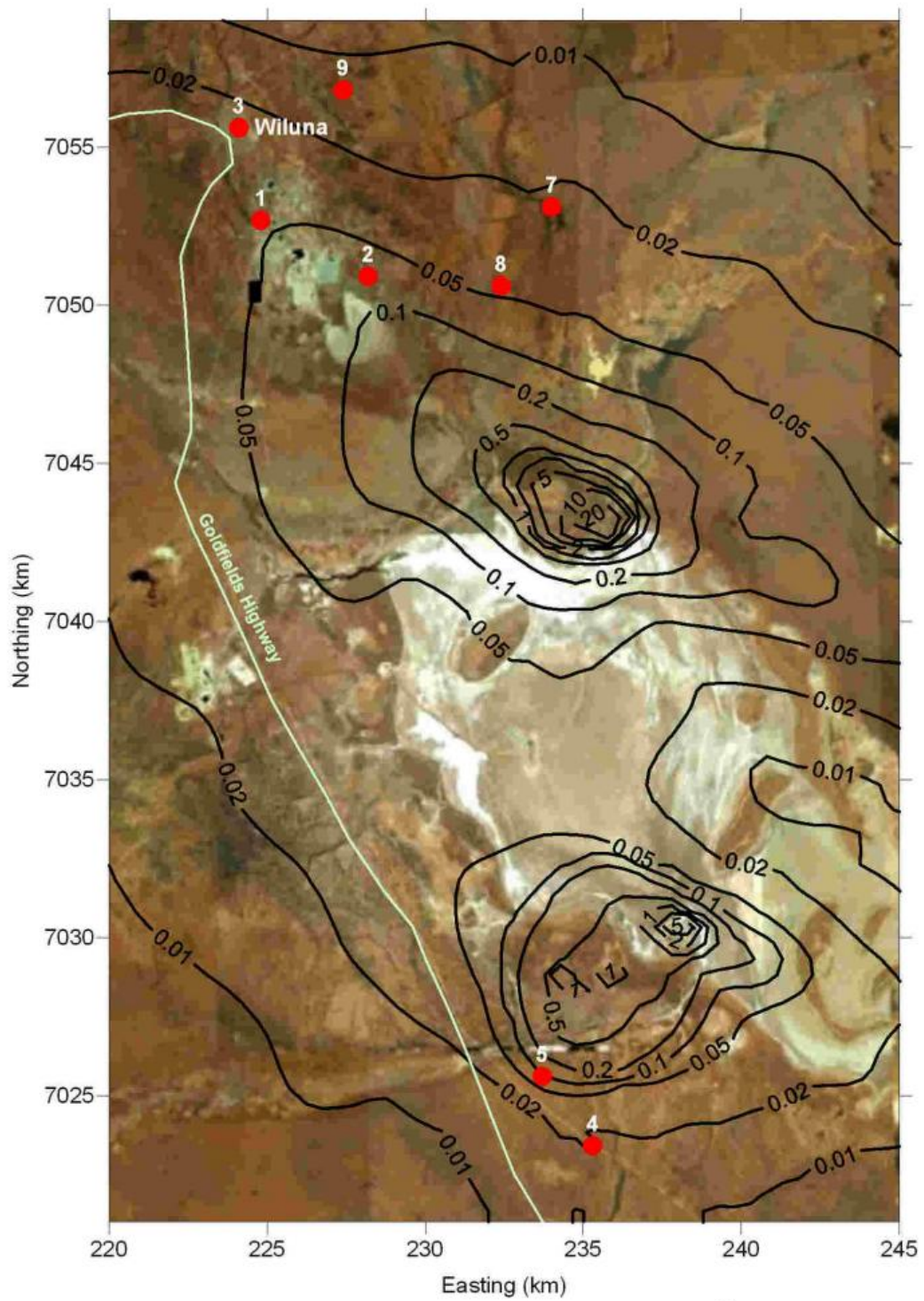


Figure 2 Dust deposition from mining and processing the Lake Way deposit ($\text{g}/\text{m}^2/\text{month}$)

After depositing on the soil surface, dust will mix with the soil through a combination of physical, chemical and biological processes. For the purposes of this assessment, it was assumed that the mixing depth was 10 mm, which is consistent with measurements in SE Australia and in grasslands [12]. The soil density was assumed to be 1.5 t/m³.

For a location where dust deposition from mining was 1g/m²/month, the amount of dust deposited over a five year mining period would be 60g/m². This would contain 3.75 Bq/g of uranium (²³⁸U), and thus the resulting increase in soil radionuclide concentration would be 15 Bq/kg for each uranium series radionuclide. For areas affected by dust deposition from the processing plant, the soil radionuclide content resulting from ten years' deposition at 1g/m²/month will be 60 Bq/kg.

4. ASSESSMENT

A Tier 1 assessment was conducted, using a soil radionuclide concentration of 150 Bq/kg (each uranium series radionuclide), equivalent to the 10 g/m²/month dust deposition contour for the minesites. The result of this assessment was that at least one organism (lichen and bryophytes) was above the 10 µGy/h screening level, and accordingly a Tier 2 assessment was conducted.

The Tier 2 assessment again used 150 Bq/kg soil radionuclide concentration and used the ERICA default values for concentration ratio, and the 10 µGy/h screening level. The resulting derived dose rates are shown in Table 1.

Organism	Dose Rate (µGy/h) (expected value)	Dose Rate (µGy/h) (conservative value)
Lichen & bryophytes	35	104
Detritivorous invertebrate	2.1	6.3
Soil Invertebrate (worm)	2.1	6.3
Flying insects	2.0	6.0
Grasses & Herbs	1.7	5.2
Gastropod	1.1	3.4
Shrub	1.1	3.4
Bird	0.8	2.5
Amphibian	0.8	2.4
Bird egg	0.8	2.4
Reptile	0.8	2.4
Mammal (Rat)	0.7	2.0
Mammal (Deer)	0.6	1.8
Tree	0.3	0.9

Table 1 Derived dose rates for the reference organisms based on a soil concentration of 150 Bq/kg

For the area surrounding the processing plant, a deposition rate of 2.5 g/m²/month gives the same increment in soil radionuclide concentration over the project life (150 Bq/kg) and consequently the same result would be obtained from ERICA.

The dose rates for all organisms are significantly below the screening level (10 µGy/h) with the exception of lichen and bryophytes.

5. RAPTORS

A separate assessment was conducted to estimate the doses and potential radiological effects to raptors eating animals from areas adjacent to operations.

Wedge-tailed eagles (*Aquila audax*) were selected for study. The method adopted for this assessment was to estimate the radionuclide content of prey species living in contaminated areas, then use this to estimate the radionuclide content that would arise in eagles feeding on them, and finally use the ERICA tool to calculate the doses arising from those radionuclide concentrations. The “small mammal” group was considered to be representative of prey, although wedge-tailed eagles have a wide range of food sources[13]. Prey was assumed to be gathered approximately uniformly across the eagles’ territory, which can range from 30-100 km² [14]. A 30 km² territory was selected, equivalent to a circular area approximately 6 km across. From the dust deposition plots (**Error! Reference source not found.** and Figure 2), it can be seen that in the worst (highest deposition) case, this corresponds approximately to the 0.5 g/m²/month deposition contour. Accordingly, a worst case average dust deposition over the eagles’ territory of 1 g/m²/month was adopted. Using the concentration factors in ERICA, the estimated radionuclide concentrations in the eagles’ diet are shown in Table 2.

Radionuclide	Concentration factor	Radionuclide content (Bq/kg)
U-238	0.0001	5.10E-03
U-234	0.0001	5.84E-03
Th-234	0.0001	5.84E-03
Th-230	0.0265	1.27E+00
Ra-226	0.0265	1.27E+00
Pb-210	0.0388	1.86E+00
Po-210	0.0028	1.33E-01

Table 2 Radionuclide concentration factors and resulting wedge-tailed eagle prey radionuclide content

The estimated food intake of a wedge-tailed eagle is approximately 130 kg per annum [13]. Not all of the radionuclides in food will be absorbed from the gut: for humans the maximum absorption (for radium and lead) is 0.2. This figure will be

adopted for eagles for all radionuclides. The annual uptake was then thus calculated as one fifth of the product of the radionuclide content of prey and the 130 kg annual food intake. It was further assumed that this radionuclide content accumulated over 5 years to give the total radionuclide content of an eagle. This is likely to be an overestimate as it does not allow for excretion of radionuclides over that period. It should also be noted that, particularly in the important case of radium, radionuclides may preferentially accumulate in the bone of prey, which is largely rejected by feeding eagles.

The resulting wedge-tailed eagle radionuclide concentrations were then used as input to a Tier 2 ERICA assessment. The results are shown in Table 3...

Radionuclide	Dose rate (µGy/h) (expected value)	Dose rate (µGy/h) (conservative value)
U-238	0.04	0.13
U-234	0.01	0.02
Th-234	0.00	0.01
Th-230	0.01	0.02
Ra-226	7.05	21.16
Pb-210	0.02	0.05
Po-210	0.15	0.45
Total	7.28	21.84

Table 3 Expected and conservative dose rates for wedge-tailed eagles from each radionuclide

The total dose rate was approximately 7.3 µGy/h (expected value), almost entirely from the intake of radium. The expected dose rate is below the screening level, but the conservative value is above. This is considered to be an extreme example, corresponding to an eagle effectively nesting within the actual area of project operations, and collecting all of its food from within an approximately 3 km radius. There are other worst-case assumptions noted above. An eagle nesting outside the operational area, and drawing much of its food from outside the 0.5 g/m²/month contour would thus have an expected dose rate well below the screening level, and would be assessed as being at negligible risk.

6. DISCUSSION

6.1.1 Lichen and Bryophytes

The expected dose rate derived for lichen and bryophytes is approximately 3.5 times the screening level (at a deposition rate of 10 g/m²/month, and is more than fifteen times higher than any other organism. The reason for this is likely to be that lichens (in particular) do not have a well developed root system, and derive most of their nutrients from dust falling upon them. Consequently they might be expected to receive a higher dose from the fallout of mine and processing dusts than is the case for other organisms.

To investigate the consequences of this higher dose rate, the radiosensitivity of the group was considered. In fact they are extremely radioresistant: a threshold no-effect dose rate has been estimated at approximately 125,000 $\mu\text{Gy/h}$, with some diversity reduction observed at 1.1 Gy/h [7]. These dose rates are over 10,000 times the default screening dose rate used in ERICA, and indicate that no effect at all would be expected from any doses that are potentially achievable in uranium mining. Lichen and bryophytes can therefore be considered not to be at any significant risk.

6.1.2 *Non-vertebrates*

The (expected) dose rate to the non-vertebrate groups are approximately 2 $\mu\text{Gy/h}$, one fifth of the ERICA screening rate. Thus at the 10 $\text{g/m}^2/\text{month}$ deposition contour, no effects would be expected. However, if the conservative dose rates are considered (approximately 6 $\mu\text{Gy/h}$ at the 10 $\text{g/m}^2/\text{month}$ mine contour), a deposition rate of approximately 15 $\text{g/m}^2/\text{month}$ would be required to exceed the screening level around the mining sites, or approximately 4 $\text{g/m}^2/\text{month}$ around the processing plant.

This group can be considered the critical organisms, in the sense that if doses to members of this group are assessed to present a negligible risk, then all other reference organisms will also be protected.

6.1.3 *Vertebrates*

All vertebrate groups gave expected doses of less than 1 $\mu\text{Gy/h}$ at the 10 $\text{g/m}^2/\text{month}$ deposition contour, approximately one half that of the invertebrate groups, and less than one tenth of the screening level. Thus at any level of deposition, the vertebrates will be not be at risk if the non-vertebrates are protected.

It is relevant to comment on the use of “deer” to represent the likely doses to kangaroos. The (conservative) dose that is derived for deer is approximately one third of that of the “critical organisms” noted above. Thus the choice of “deer” to represent “kangaroos” would have to underestimate the kangaroo doses by an approximate factor of three for the conservative kangaroo dose to exceed the screening level at the 15 $\text{g/m}^2/\text{month}$ contour. It should also be noted that kangaroos generally range widely, and thus would be expected to only spend a fraction of their time in the potentially affected areas, which would significantly reduce average doses that they might receive from project emissions..

6.1.4 *Affected areas*

All reference organisms (excepting lichen and bryophytes) have been assessed as receiving doses less than the screening level (with a conservative uncertainty factor of 3), and thus having a negligible risk, in areas receiving dust fallout less than 15 $\text{g/m}^2/\text{month}$ around the mining sites, and 4 $\text{g/m}^2/\text{month}$ around the processing plant. From Figures 1 and 2 it can be seen that for the two minesites these areas are small – approximately 2km across, and are unlikely to extend significantly beyond the mine operational areas: the pits, stockpiles and other facilities. The area in which reference organisms are potentially at radiological risk is thus very small. For the processing site, dust deposition does not appear to exceed the 4 $\text{g/m}^2/\text{month}$ level at any point, and so no organisms will be at risk in the vicinity of the plant. Beyond the immediate operational areas dust fallout is expected to be so low that no organisms are likely to be at risk.

In the long term (after closure of operations) mixing of deposited radionuclides with soil is expected to continue, with a consequent reduction in concentrations in the surface soil. The doses to the reference organisms would therefore be expected to reduce over time.

7. CONCLUSIONS

The risk of radiological harm is assessed as “negligible” for all reference organisms (with the exception of lichen and bryophytes) at points where dust fallout is less than 15 g/m²/month around the minesites, and 4 g/m²/month around the processing plant. Lichen and bryophytes are very resistant to radiation, and no effects are expected at any dust fallout level.

The areas where such dust fallout levels are expected are approximately 2 km across at each of the two minesites. Dust fallout from the processing plant is not expected to reach 4 g/m²/month. The areas in which reference organisms are potentially liable to be affected are thus quite small and are not likely to extend significantly beyond the actual areas of operations.

Raptors nesting beyond the area of operations are also assessed as having negligible risk.

Philip Crouch BSc(Hons) PhD, MARPS

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