ATTACHMENT 2

ENVIRONMENTAL RADIATION BASELINE REVIEW

FOR THE TORO ENERGY PUBLIC ENVIRONMENTAL REVIEW

APRIL 2016

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1 INTRODUCTION

This document provides a response to the issues raised by the Department of the Environment (DotE) from their review of Toro's Public Environmental Review (PER) (Toro Energy, 2015) for the mining and associated activities with the Millipede and Lake Maitland uranium deposits. It specifically discusses radiation related baseline and background monitoring that has been conducted in the vicinity of proposed mining at Millipede and Lake Maitland. These comments may also be suitable for questions and comments made by other government agencies and members of the public.

This key issues are shown in Table 1.

Table 1: Issues Raised by Submitters

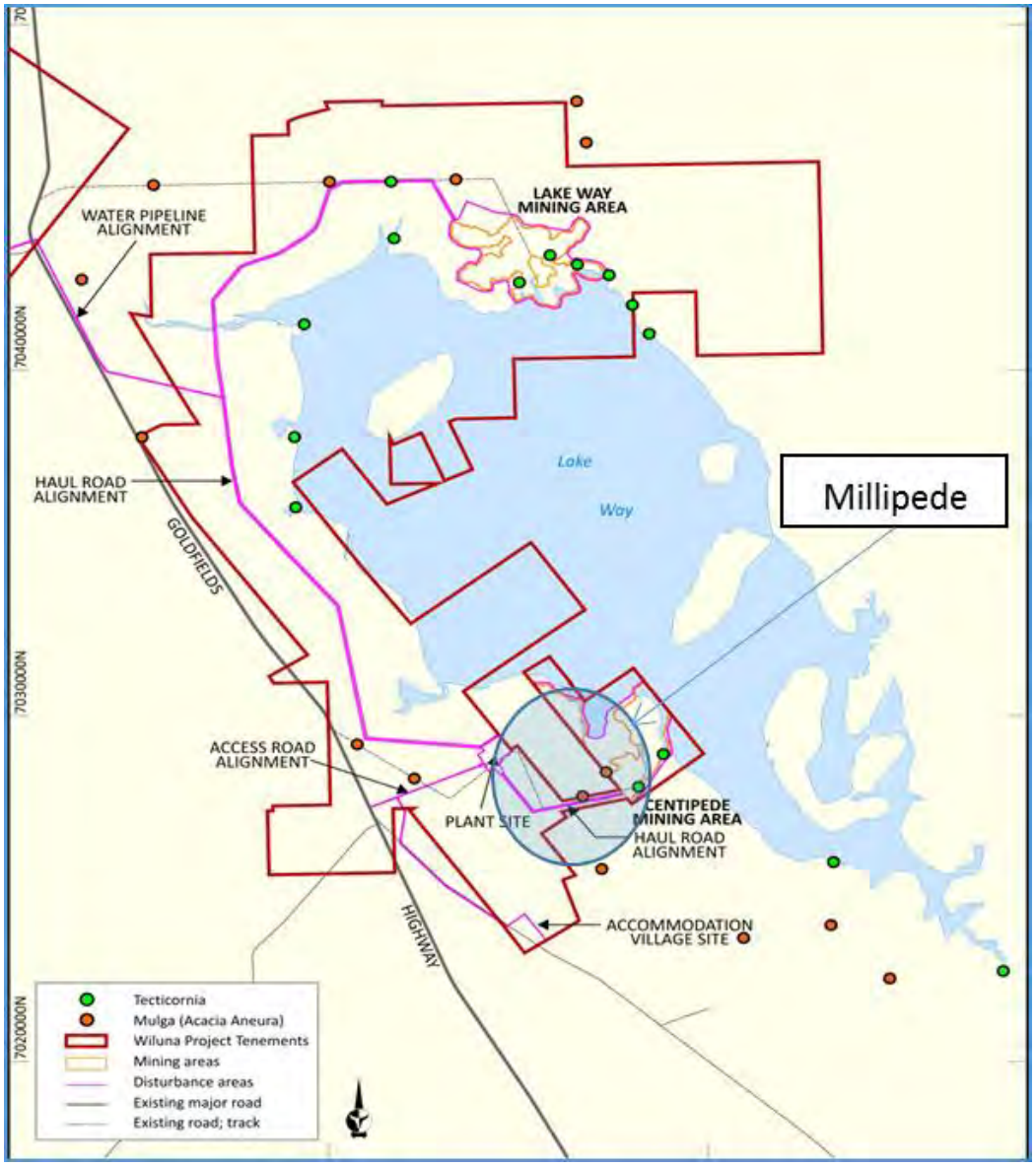
Submitter	PER Item	Issue	Response
DotE	Section 14.6.2 and Appendix 10.66	Inconsistency in background radon concentrations at Lake Maitland—Section 14.6.2 an average of 69 Bq/m^3 is given—Appendix 10.66 states that the site-wide radon concentration is 150 Bq/m^3	This is clarified in section 3.
PND	General comments	A high level of uncertainty relating to baseline dust/air surveys due to flawed methodology. Comment that baseline radiation conditions have yet to be established to inform air monitoring and dust suppression regimes by the company	This attachment addresses this issue.

Data referred to in this attachment is available in the PER. The aim of this attachment is to provide a concise summary and interpretation of that data. The Millipede baseline information is presented in Section 2 and the Lake Maitland information is presented in Section 3.

2 BASELINE RADIATION – MILLIPEDE

PER Section 14.5 provides a comprehensive overview of the baseline monitoring that was conducted by Toro Energy for proposed mining at Lake Way and Centipede. This information was originally presented in the Environmental Review and Management Programme EPA Assessment No 1819 July 2011, Wiluna Uranium Project ('ERMP'). An example of the monitoring undertaken at the time is shown in Figure 1. The monitoring was regional in nature and it incorporated the Millipede area which is adjacent to Centipede.

Figure 1: Vegetation and Soil Monitoring Undertaken for ERMP



It is important to note that the Millipede deposit is an extension of the Centipede deposit. They are directly adjacent, separated only by Department of Mining and Petroleum (DMP) tenement number. They are in the same environmental setting. Therefore, the monitoring and other information obtained for the Lake Way region, in particular around the Centipede mining area, is just as applicable to Millipede.

While no additional radiation baseline monitoring was undertaken specifically for mining at Millipede, [JH asks us to confirm happy with this?] some additional regional baseline monitoring has been conducted since the publication of the ERMP and a summary is provided herein.

The following is a summary of the baseline information.

2.1 Gamma Radiation

The aerial gamma survey that was conducted by Toro and reported in the ERMP also covers the Millipede deposit and is shown in Figure 2. It shows that gamma radiation levels are generally consistent with the Centipede deposit.

Figure 2: Aerial Gamma Radiation Survey Showing Millipede and Centipede Mining Areas

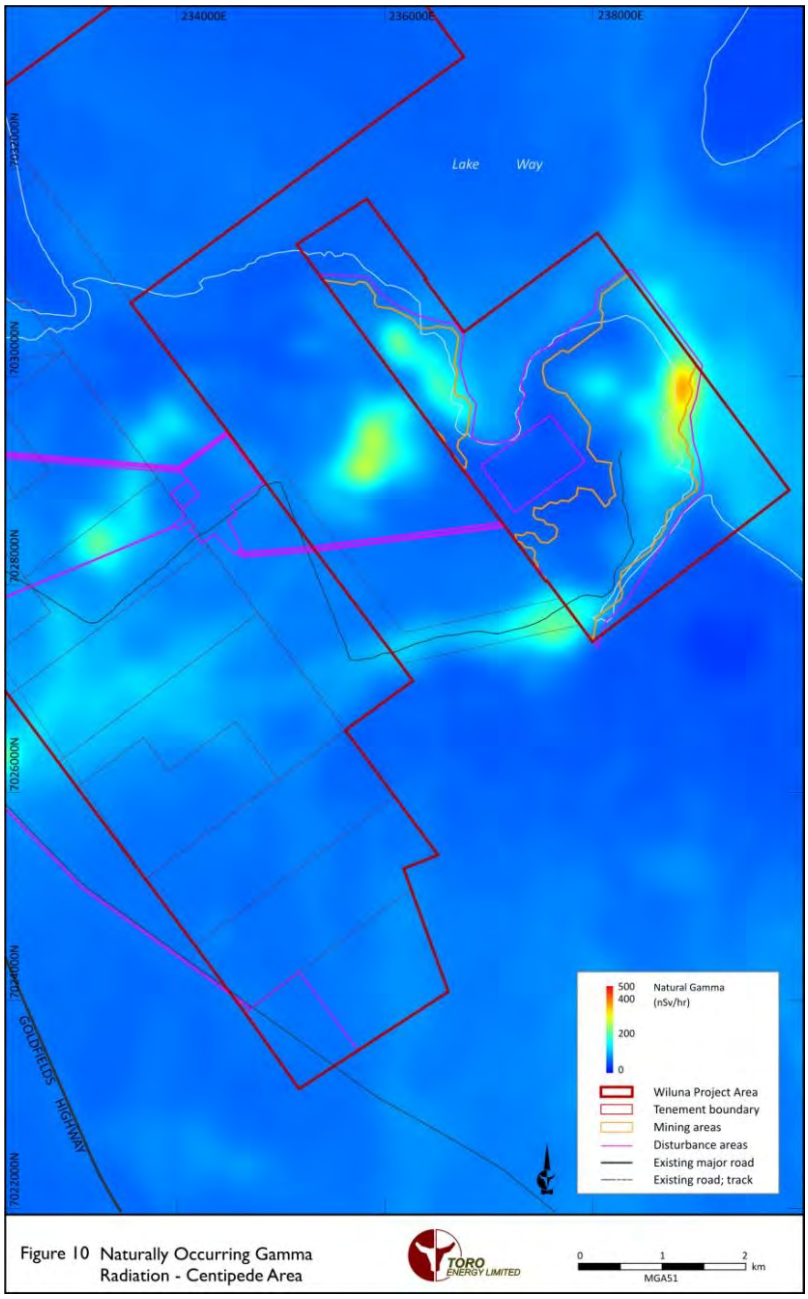


Figure 10 Naturally Occurring Gamma Radiation - Centipede Area

2.2 High Volume Dust Sampling

In 2011, 11 high volume dust samples were taken at various locations in the Lake Way region for the measurement of the airborne radionuclide concentrations. Sampling occurred for periods of approximately one month. Table 2 summarises all the results.

Table 2: Summary of High Volume

	Alpha Activity Concentrations (mBq/m^3)			
	U238	Th230	Ra226	Pb210
Average	0.014	0.115	0.011	0.752
Minimum	0.003	0.035	0.002	0.394
Maximum	0.032	0.300	0.060	1.480
Number of Samples <MDL[1]	8	10	3	0

Note: 1. For analysis purposes, when a sample was reported as <MDL, half of the MDL value was used in the statistical assessment. For example, if a result was reported as <6µ Bq/m^3, then for averaging purposes, 3µ Bq/m^3 was used.

2.3 Other Dust Sampling

Medium volume dust sampling continued in the region, using a 'microvol' sampler and a summary of the mass concentration results for 2012 is in Table 3 and Table 4. Note that due to the low sample mass, analysis of individual radionuclide concentration is not possible. However, gross alpha and gross beta counting were conducted.

Table 3: Microvol Mass Concentrations

	Mass Concentration (mg/m^3)		
	Average	Minimum	Maximum
~100m West of controlled area	14.2	3.6	35.6
~100m West of controlled area	7.9	1.3	17.6
~100m West of controlled area	10.1	1.6	24.3
~100m West of controlled area	9.6	2.4	20.1
South of East Bore	5.3	3.4	7.2

Table 4: Microvol Gross Alpha Concentrations

	Alpha Activity Concentration (αmdps/m^3)[1]		
	Average	Minimum	Maximum
~100m West of controlled area	2.4	0.1	22.8
~100m West of controlled area	1.2	0.1	6.2
~100m West of controlled area	2.3	0.1	18.1
~100m West of controlled area	1.6	0.1	13.6
South of East Bore	0.1	0.1	0.1

Note: 1. αmdps refers to alpha milli-disintegrations per second which is equivalent to one one-thousandth of an alpha radiation emission per second. It can also be referred to as the milliBecquerels of alpha radiation.

2.4 Radon Concentrations

Radon concentration sampling included both passive monitoring using track etch detectors and real time monitoring using a Durridge Rad7.

The extensive passive monitoring results (some of which were reported in the ERMP) continued across the region until the end of October 2011 and the average results are shown in Table 5.

Table 5: Average Radon Concentrations (Passive Detectors)

	Radon Concentration (Bq/m^3)		Number of Samples
	Average	Max	
June 2010 – Sept 2010	38	83	30
Sept 2010 – Nov 2010	56	93	30
Dec 2010 – May 2011	21	59	39
May 2011 – Oct 2011	32	69	36

In addition to passive monitors, Toro used a real time radon concentration monitor when available. Results are shown in Table 6 and confirm the diurnal nature of the radon concentrations, with higher natural concentrations occurring during night time periods as outlined in the ERMP.

Table 6: Summary Information from Real Time Radon Monitor

Locations	Sampling Month (days)	Radon Concentration (Bq/m^3)		
		Average	Night Average (7pm – 10am)	Day Average (10am – 7pm)
Core Farm	Jan 2011 (5)	54	78	17
Lake Way Dust Monitoring Site	Sept 2011 (5)	11	16	5
Apex Mining Camp	Dec 2011 (3)	12[1]		

Note: 1. The monitoring in December showed no significant variation in concentration

2.5 Radon Decay Product Monitoring

Limited additional active radon decay product (RnDP) monitoring has been conducted due to in-field instrument difficulties. One extra run was conducted at Toro House about 2 km from the Wiluna township and a summary of the results can be seen in Table 7.

Table 7: Radon Decay Product Real Time Monitoring Summary

Location	Sampling Month	RnDP Concentration (µJ/m^3)		
		Average	Maximum	Minimum
Toro House	24 Dec 2011 – 8 Jan 2012	0.017	0.033	0.003

2.6 Summary of Millipede Baseline Radiation

Due to the location of the Millipede deposit, the baseline radiological conditions are considered to be consistent with the baseline conditions for the region and in particular, sampling conducted near Centipede.

3 BASELINE RADIATION – LAKE MAITLAND

This section provides a summary of the radiation baseline monitoring conducted at Lake Maitland. Much of the data is provided in PER Section 14.

A summary of the following data is provided:

- Gamma monitoring;
- Radionuclides in dust;
- Radon and radon decay product concentrations;
- Soil radionuclide concentrations;
- Vegetation radionuclide concentrations; and
- Groundwater sampling.

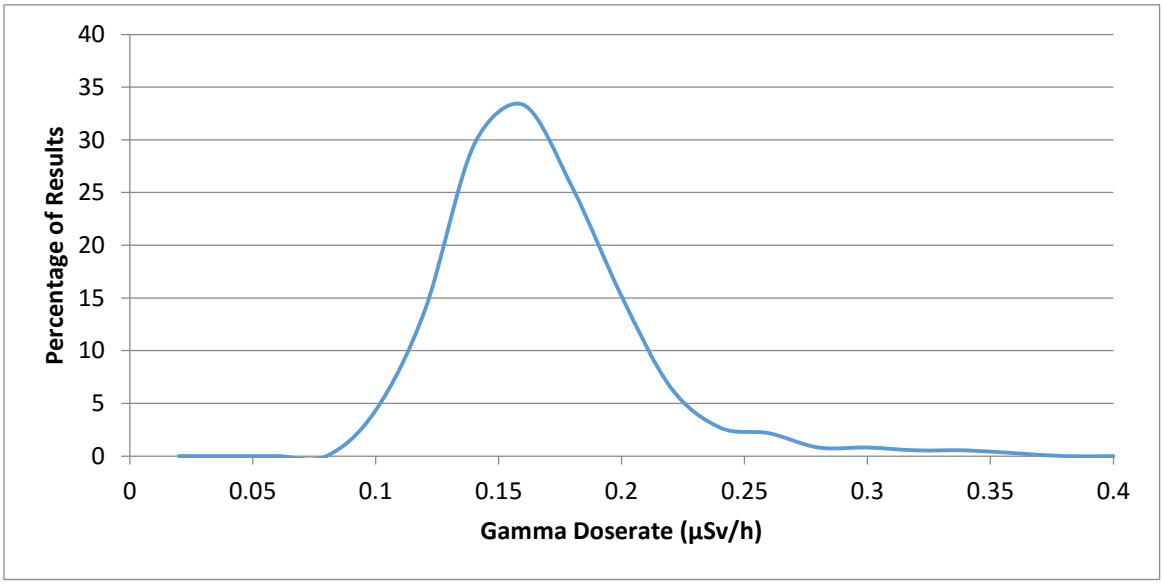
3.1 Gamma Radiation

Extensive gamma radiation monitoring was conducted from 2006 through to 2011. The results across the Project area are relatively consistent. Table 8 provides statistics for the four main monitoring campaigns and Figure 3 shows the distribution of results.

Table 8: Summary Statistics for Gamma Radiation Measurements

Area	Number of Samples	Gamma Dose Rate (µSv/h)		
		Average	Max	Min
Proposed Camp Area	12	0.13	0.18	0.09
Site Area	369	0.16	0.37	0.09
Exploration Area	91	0.16	0.34	0.08
Earlier Survey	138	0.17	0.36	0.10

Figure 3: Distribution of Gamma Results from Site Area



3.2 Radon Concentrations

Radon concentrations were measured at Lake Maitland using both passive and active monitoring techniques.

This summary provides some additional data not available at the time of the original collation of the baseline data. The additional data do not affect the impact assessment outcomes and provide further information on the existing environment.

3.2.1 Passive Monitors

Over the course of more than two years (March 2010 to August 2012), radon concentrations in the Lake Maitland region were measured using passive radon monitors provided by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). These monitors were placed in the field and provided a time integrated average radon concentration over the sampling period.

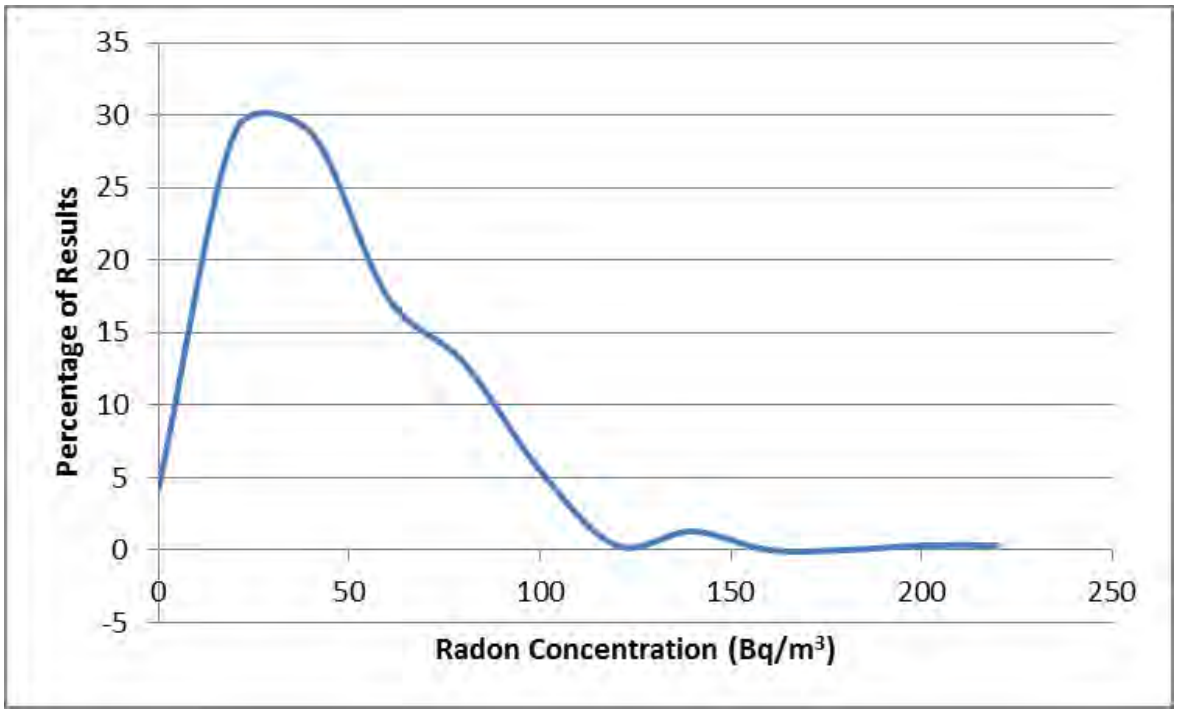
The monitoring at Lake Maitland was generally conducted in four campaigns. However, many of the detectors remained in the field for timeframes of between three months and up to one year. It is therefore difficult to provide any seasonal or time based interpretation of the data. A meta-analysis (which includes all of the results) provides an overview and average of the radon concentrations across the proposed operational area.

A summary is provided in Table 9 and the distribution of results can be seen in Figure 4.

Table 9: Summary of Passive Radon Concentrations

Radon Concentration (Bq/m^3)	
Number of Samples	309
Average	39
Median	32
Range (min–max)	0.2–211
Range (5^{th} and 95^{th} Percentiles)	5–91

Figure 4: Distribution of Passive Radon Concentration Results



3.3 Active Radon Monitoring

Active radon monitoring was conducted using a Durridge Rad7 at various locations across the proposed Project area during excavation and drilling trials in 2010 and 2011. This particular monitor samples air and records the radon concentrations for defined sampling periods. In most cases, the sampling at Lake Maitland occurred over 30 minutes, with one set of data being collected on a 15 minute basis.

An output of a typical monitoring run is shown in Figure 5 and a summary of the monitoring is in Table 10.

A comparison of the active and passive monitoring results gives good agreement, and indicates an average annual radon concentration in the region of approximately 30–35 Bq/m^3.

Figure 5: Typical Radon Monitoring Results Using a Rad7

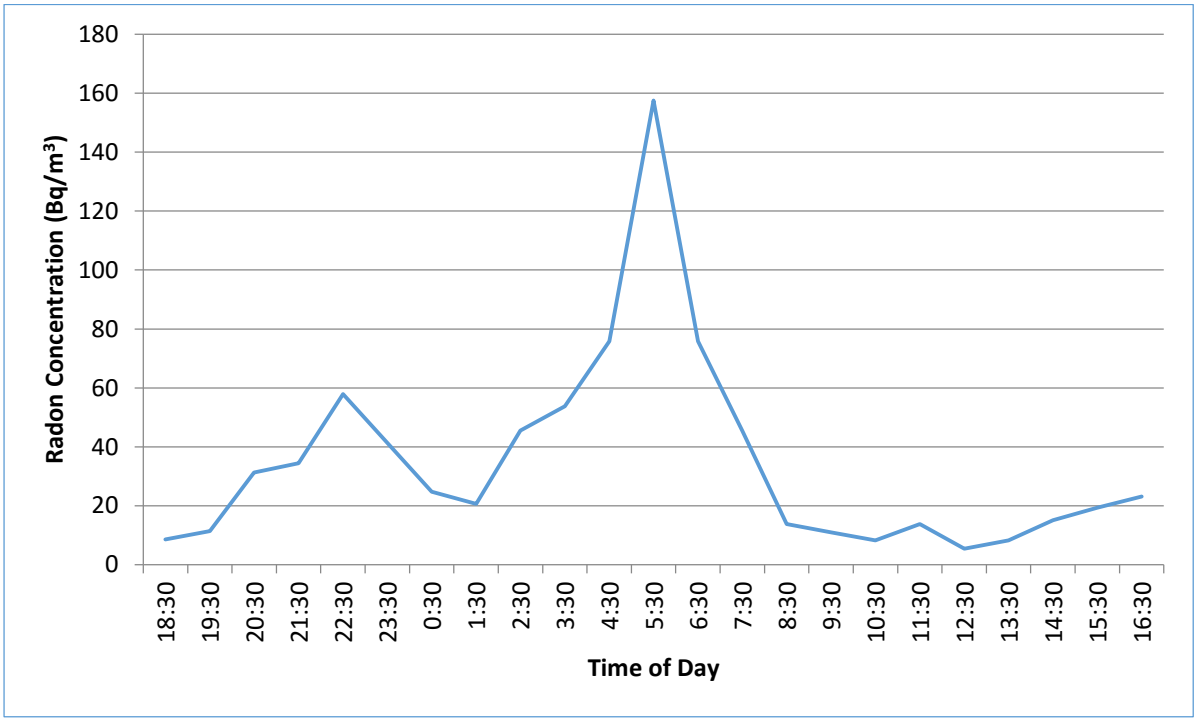


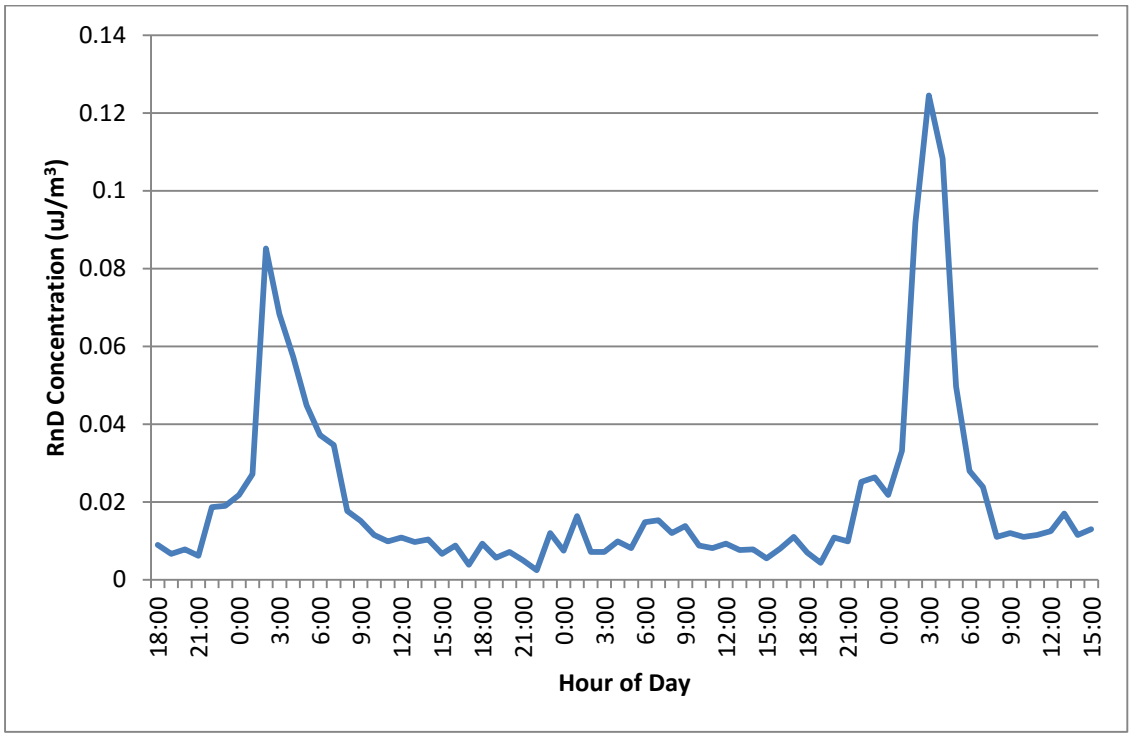
Table 10: Summary of Active Radon Monitoring

Date	Run Time	Location	Radon Concentration (Bq/m^3)			Activity
			Average	Min–Max	5th–95th Percentiles	
August 2010	2 days	Test Pit 2	34	5.5–138	5.5–105	Drilling
November 2011	1 day	Test Pit 1	35	2.3–174	6.3–89	Excavation
November 2011	1 day	Test Pit 2	30	2.8–116	2.8–107	Excavation
November 2011	1 day	Test Pit 2	15	2.7–69	2.7–57	No activity

3.4 Radon Decay Products

RnDP monitoring was conducted during late 2010 and 2011 using an environmental radon decay product monitor (ERDM). This instrument measures RnDP concentrations in real time in a similar manner to the Rad7 measuring radon concentrations. An example of the output is shown in Figure 6. This shows that like radon, a diurnal variation generally occurs.

Figure 6: Hourly RnDP Concentrations (NE of Costean, Lake Maitland, January 2011)



A summary of the results is in Table 11.

Table 11: Summary of Real Time RnDP Monitoring

Date	Run Time (days)	Location	Average (µJ/m³)	Maximum (µJ/m³)
October 2010	2	Office Area	0.007	0.023
December 2010	3	Water Bore	0.013	0.069
Dec 2010 /Jan 2011	24	Old Costean	0.014	0.292
January 2011	14	Core Shed	0.012	0.082
January 2011	3	NE of Costean	0.021	0.157
February 2011	7	Camp	0.009	0.039
February 2011	7	Julia Road	0.010	0.085
February 2011	3	LMSL 01	0.014	0.033
May 2011	3	Bruce's Turnoff	0.002	0.016

The results give an overall average of 0.011 µJ/m^3. Locational sampling during trial mining gave similar results using the Kusnetz method.

3.4.1 Calculated Equilibrium Factor

The equilibrium factor is the ratio of radon concentration to RnDP concentration (measured as the potential alpha energy concentration) and is used for estimating doses from RnDP from modelled radon concentrations.

UNSCEAR (2000) provides an equation to calculate the equilibrium factor as follows:

$$F = PAEC(nJ/m^3) / (5.56 \times C(Rn222)\ (Bq/m^3))$$

Where: F is Equilibrium Factor,

PAEC is potential alpha energy concentration of the RnDPs, and

C(Rn222) is the concentration of radon.

Therefore, using the average monitored results, the average equilibrium factor for the Lake Maitland region is calculated to be approximately 0.05. When comparing the maximum levels, the equilibrium factor reaches 0.3. The low ratio is likely to be due to the open air and high dilution that is occurring.

3.5 Surface Water

An opportunistic surface water sample was obtained and analysed for radionuclides in 2011. The results are presented in Table 12.

Table 12: Summary of Surface Water Sample

Radionuclide Concentration (Bq/L)					
U238	Th230	Ra226	Pb210	Po210	Ra228
<4	<50	0.22	<10	0.4	0.28

3.6 Sediment Sampling

The PER reports sediment radionuclide results (PER Section 14) and a summary of the main radionuclide concentrations is provided in Table 13. In all, 10 samples from across the region were collected and analysed.

Table 13: Summary of Sediment Radionuclide Content

Radionuclide Concentration (Bq/L)				
	U238	Ra226	Pb210	Ra228
Average	128	57	64	12
Minimum–Maximum	18–330	4–201	63–64	7–21

3.7 Groundwater

Groundwater was collected from a series of 16 bores across the project area over a 9 month period from the end of 2010 to mid-2011 in three separate campaigns. Samples were analysed for various radionuclides and grouped to identify those samples from inside the mineralised area and outside the mineralised area. Average concentrations are shown in Table 14.

Table 14: Average Radionuclide Concentrations in Groundwater

Locations	Radionuclide Concentration (Bq/L)							
	Th230	Ra226	Rn222	Pb210	Po210	Ra228	Gross Alpha	Gross Beta
In Ore Areas (6 bores)	0.08	9.15	451.68	0.28	0.34	1.26	4.34	10.00
Outside Ore Areas (10 samples)	0.06	3.52	185.11	0.12	0.11	0.65	1.75	4.32

The results show that groundwater samples from bores within the mineralised zone have higher radionuclide concentrations than those outside the mineralised zone. The results are generally consistent with those from Lake Way (ERMP) and for the Yeelirrie deposit (Cameco, 2015), with both having higher radionuclide concentrations in groundwater in the mineralised zones.

3.8 Soil and Vegetation Sampling

For the purposes of baseline assessment, a number of environmental monitoring locations were established and were called the 'Lake Maitland Critical Group' (LMCG) locations (see Figure 7). Results are available in the PER, and are summarised here.

Vegetation sampling occurred on two occasions at the LMGC in August 2009 and October 2010 and one set of soil samples was obtained in August 2009. A summary of the results is in Table 15.

Figure 7: Location of Environmental Monitoring Locations at Lake Maitland

Table 15: Summary of Soil and Vegetation Samples

Survey (Number of samples)	Radionuclide Concentration (Bq/kg) (Average and range)				
	U238	Th230	Ra226	Pb210	Po210
2009 (8 veg)	0.01 (all <MDL)	N/A[2]	2 (<MDL–3)	67 (44–90)	51 (39–65)
2010 (11 veg)	0.16 (<MDL–0.25)	1 (all <MDL)	2[1] (<MDL–7)	49 (30–61)	40 (22–60)
2009 (11 soil)	19[1] (11–44)	60[1] (<MDL–180)	130 (50–370)	80 (<MDL–160)	80 (<MDL–180)

Notes: 1. One sample excluded from the summary because it was greater than 10 times the average and there was no evidence of other elevated radionuclides.
2. N/A refers to no samples taken.
3. <MDL refers to less than minimum detectable level. This value varies depending upon sample size and radionuclide analysed.

Elemental uranium and thorium were present in the soil samples at an average of 1.5 ppm and 3.6 ppm, respectively. The average crustal value for these two elements is 3 ppm and 6 ppm, respectively (UNSCEAR, 2000).

It is noted that there are elevated Pb210 and Po210 concentrations in both sets of vegetation samples. This effect is not unexpected and has been observed in results from analysis of vegetation samples at Lake Way (ERMP) and Olympic Dam (BHP Billiton, 2009) and is recognised by UNSCEAR (2000). It is a natural occurrence and due to the decay products of radon in air.

The following species of vegetation were sampled:

- *Casurina obesa* (4 locations);
- *Acacia heteroneura* var. *jutsonii* (1 location);
- *Acacia aneura* var. *aneura* (3 locations); and
- *Acacia aneura* var. *macrocarpa* (3 locations).

There was no observable difference in radionuclide concentrations between the species.

3.9 Dust Sampling

Various sampling was conducted to characterise the naturally occurring radionuclides in dust in the Lake Maitland region. The sampling was conducted at the soil and vegetation locations and included:

- Short-term high volume sampling for periods of 24 hours (March 2011);
- Longer term high volume sampling for periods greater than 24 hours for the purposes of collecting sufficient material for radionuclide analysis (late 2010);
- High volume sampling for total suspended solids (TSP), PM_{10} and $PM_{2.5}$ (late 2010); and
- Dust deposition monitoring (January and February 2011).

Data is available in PER Appendix 10.67.

For the radiation assessment, the TSP high volume sampler results and the dust deposition results are presented as follows:

3.9.1 High Volume Sampling

From the Lake Maitland region, 18 high volume filter results from late 2010 were analysed for gross alpha and gross beta activity. These analyses provide a broad assessment of radioactivity in air and include alpha and beta radionuclides in the uranium and thorium decay chains, as well as airborne K40. The average results and range over the whole sampling period are shown in Table 16. The run time for these samples was between three and six days.

Another 29 samples were obtained during March and April 2011. A summary of the mass concentrations for both sets of data is shown in Table 17.

Table 16: High Volume Dust Sample Results

	Activity Concentration (mBq/m^3)		
	Average	Minimum	Maximum
Gross Alpha	0.12	0.06	0.20
Gross Beta	0.11	0.06	0.17

Table 17: Summary of High Volume Dust Sampling

	Number of Samples	Activity Concentration (µg/m^3)		
		Average	Minimum	Maximum
TSP (>24 hour samples) June 2010 to March 2011	18	10.3	3.9	30.0
TSP (24 hour samples) March 2011 to April 2011	29	10.2	4.2	16

The radionuclide concentrations can be calculated by assuming that the dust in air is mainly resuspended soils with radionuclide concentrations (as shown in Table 15) and are summarised in Table 18.

Table 18: Calculated Radionuclide Concentrations in Dusts

	Activity Concentration (mBq/m^3)				
	U238/U234	Th230	Ra226	Pb210	Po210
TSP (>24 hour samples) June 2010 to March 2011	0.36	6.2	0.13	2.4	2.4
TSP (24 hour samples) March 2011 to April 2011	0.55	6.2	0.55	1.3	1.3

3.9.2 Dust Deposition

A brief dust deposition program was conducted in the region where samplers monitored for a period of approximately 1 month. The dust deposition rates can be seen in Table 19.

Table 19: Dust Deposition Rates

	Number of Samples	Deposition Rate (g/m^2/month)		
		Average	Minimum	Maximum
Dust Deposition	5	2.5	0.6	4.3

Assuming that local soil is depositing, then the radionuclide deposition rate can be calculated from the values in Table 15 and the results are shown in Table 20.

Table 20: Calculated Radionuclide Deposition Rates

	Average Radionuclide Deposition Rate (Bq/m^2/month)				
	U238/U234	Th230	Ra226	Pb210	Po210
Dust Deposition	0.05	0.15	0.33	0.20	0.20

4 SUMMARY

This report has aimed to provide some clarity to the results reported in the PER. This document only reports on the existing environment.

A comparison of the baseline monitoring from the mining areas is shown in Table 21, Table 22and Table 23 and demonstrates good agreement.

Table 21: Baseline Characteristics

	Gamma Radiation (µSv/h)	Radon Concentration (Bq/m^3)	RnDP Concentration ($µJ/m^3$)
Lake Way Region	0.10	37	0.02–0.03
Lake Maitland	0.15	35	0.011

Table 22: Radionuclides in Soils and Vegetation

	Average Concentration (Bq/kg)			
	Ra226 in Soil	Pb210 in Soil	Ra226 in Vegetation	Pb210 in Vegetation
Lake Way Region	80	100	4	58
Lake Maitland	130	80	2	57

Table 23: Airborne Dust Characteristics

	TSP Concentration (ug/m^3)	Alpha Activity Concentration ($mαdps/m^3$)	Dust Deposition (g/m^2/month)
Lake Way Region	12.6	0.04	0.7[1]
Lake Maitland	10.2	0.12	2.5

Note: 1. Inferred from Table 14.4 of PER.

5 REFERENCES

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