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Radon Assessment of the Yeelirrie Uranium Project

Prepared for

Cameco Australia Pty Ltd

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Term	Definition
Bq	Becquerel
$Bq/m^2/s$	Becquerels per square meter per second
Bq/m^2	Becquerels per cubic metre
GBq	Giga-Becquerel (10^9 Bq)
ha	hectare
km	kilometre
km/h	kilometre per hour
m	metre
m/s	metres per second
t	tonnes
Mtpa	Million tonnes per annum
Abbreviations	
EPA	Western Australia Environment Protection Authority
ERMP	Environmental Review and Management Programme
Cameco	Cameco Australia Pty Ltd
DER	Department of Environment Regulation
HG ore	High grade ore
MG ore	Medium grade ore
UHG ore	Ultra high grade ore
VHG ore	Very high grade ore

EXECUTIVE SUMMARY

Cameco Australia Pty Ltd (Cameco) proposes to develop an open pit uranium mine and associated processing facility at Yeelirrie in the Northern Goldfields region of Western Australia, approximately 420 km north of Kalgoorlie and 60 km west of Mt Keith. The proposed Yeelirrie Uranium Project would produce up to 7,500 tpa of uranium peroxide ($UO_4.2H_2O$), more commonly referred to as uranium oxide concentrate (UOC), through the development and operation of an open pit mine and on-site Metallurgical Plant. The proposed Yeelirrie Uranium Project has the potential to emit radon (Rn) to the atmosphere.

Katestone Environmental Pty Ltd (Katestone) has been commissioned by Cameco to prepare a radon assessment of the proposed Yeelirrie Uranium Project, as part of a Public Environmental Review. Katestone has also prepared an air quality assessment of the proposed Yeelirrie Uranium Project (Katestone, 2014). This radon assessment has investigated the potential for radon impacts to occur due to mining operations and the Metallurgical Plant for a scenario representing a stage in the development that is likely to result in highest ground-level concentrations at the closest sensitive receptors.

The radon assessment used meteorological and dispersion models to assess the potential dispersion of radon emissions from the proposed Yeelirrie Uranium Project. The meteorological and dispersion models are consistent with those used in the air quality assessment of the proposed Yeelirrie Uranium Project (Katestone, 2014).

The results of the dispersion modelling of radon from the proposed Yeelirrie Uranium Project during operation of the mine show that the maximum 1-hour average concentration of radon at Yeelirrie Pool, which is the nearest receptor located 10.2km southeast of the ore body, was predicted to be 13% of the maximum concentration within the MLA. The 24-hour and annual average concentrations at Yeelirrie Pool were predicted to be less than 10% and 5%, respectively, of the maximum concentrations within the MLA. Predicted concentrations at all other sensitive receptors were predicted to be less than 10% of the maximum concentrations within the MLA.

1. INTRODUCTION

Katestone Environmental Pty Ltd (Katestone) was commissioned by Cameco Australia Pty Ltd (Cameco) to undertake a dispersion modelling assessment of radon emissions from the Yeelirrie Uranium Project in Western Australia.

Cameco is currently proposing to submit a Public Environmental Review for the project that includes an increase in uranium ore production from 1.2 million tonnes per annum (Mtpa) to 2.4 Mtpa. Katestone has completed an air quality assessment of the Yeelirrie Uranium Project for Cameco (Katestone, 2014) and the modelling system developed during that study has been utilised for this radon assessment.

1.1 Project description

Cameco proposes to develop an open pit uranium mine and associated processing facility at Yeelirrie in the Northern Goldfields region of Western Australia, approximately 420 km north of Kalgoorlie, 60 km west of Mt Keith, 70 km southwest of Wiluna and 110 km northwest of Leinster (Figure 1). The proposed Yeelirrie Uranium Project would involve mining of up to 14 Mtpa of mineralised uranium ore and waste material using open cut mining techniques over an anticipated mine life of over 22 years. Processing of the uranium ore will be carried out at the on-site metallurgical Plant. The project will produce up to 7,500 tpa of uranium peroxide ($UO_4.2H_2O$), more commonly referred to as uranium oxide concentrate (UOC), through the development and operation of an open pit mine and on-site Metallurgical Plant.

Associated mine infrastructure, including ore processing facilities, water supply infrastructure, roads, accommodation, offices and workshops, stockpile and lay down areas and evaporation pond will also be constructed. Tailings will be discharged back into the mine open pit. A quarry will be established approximately 8km north of the project. Extracted quarry material will be used in the construction of the processing plant and infrastructure. The quarry is expected to operate during the first three years of mining. A schematic of the final project layout is shown in Figure 2.

1.2 Scope of works

The purpose of this assessment is to:

- Quantify radon emission rates from all mine related sources representative of operational years of the mine
- Conduct air dispersion modelling using accepted and best-practice techniques
- Predict the ground-level radon concentrations due to the proposed Yeelirrie Uranium Project
- Present the results as ground-level radon concentrations (Bq/m^3) at each of the nearest sensitive receptors as well as contours on a cartesian grid

This report describes the process and results of air dispersion modelling assessment of radon emitted from the proposed Yeelirrie Uranium Project. Radon emissions will occur from disturbed surfaces and exposed ore. Emissions of radon have been estimated for a year of operations that is likely to generate the highest radon concentrations in the region. Dispersion modelling has been conducted using a year of representative meteorological data.

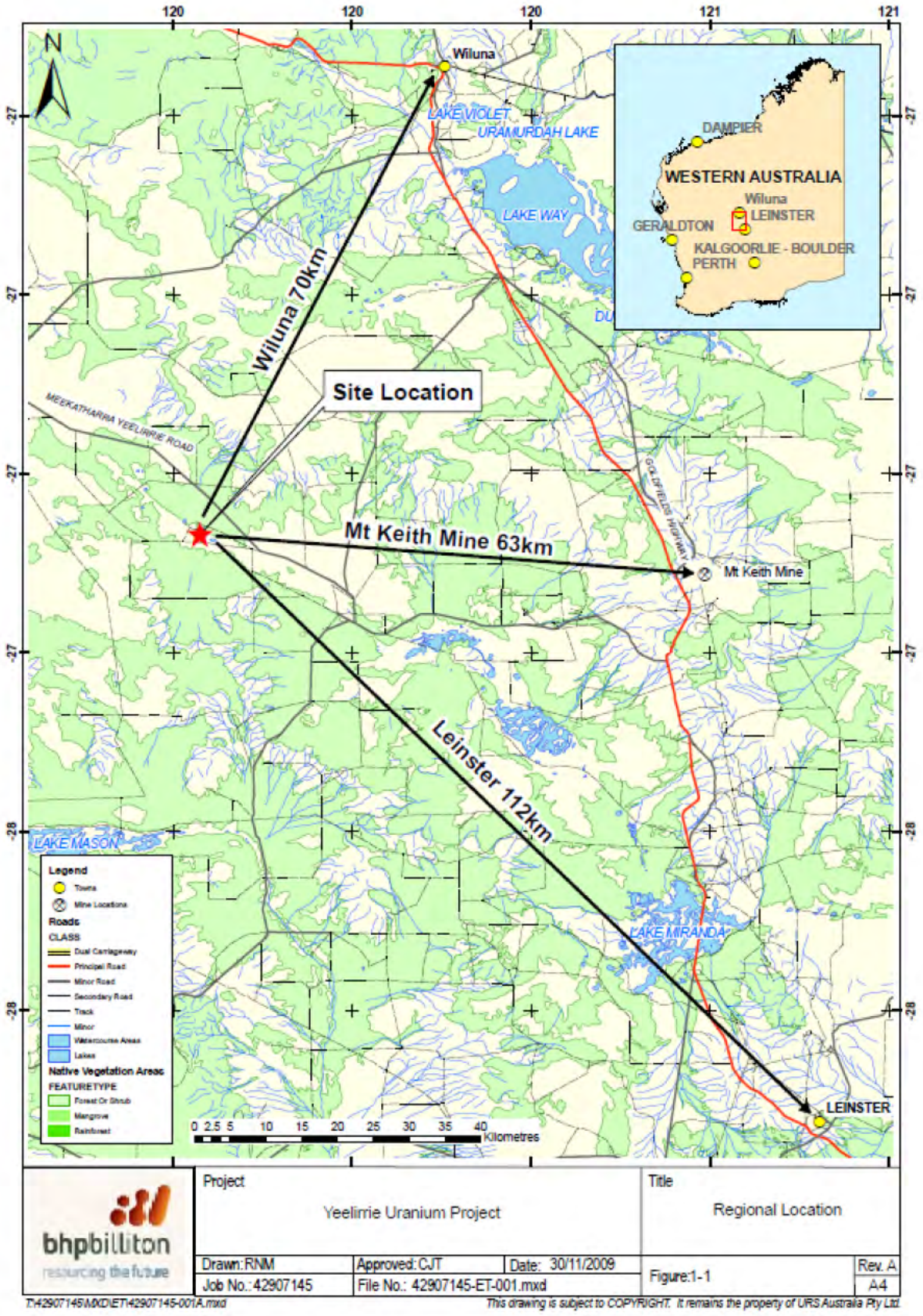

Figure 1 **Location of the proposed Yeelirrie Uranium Project**

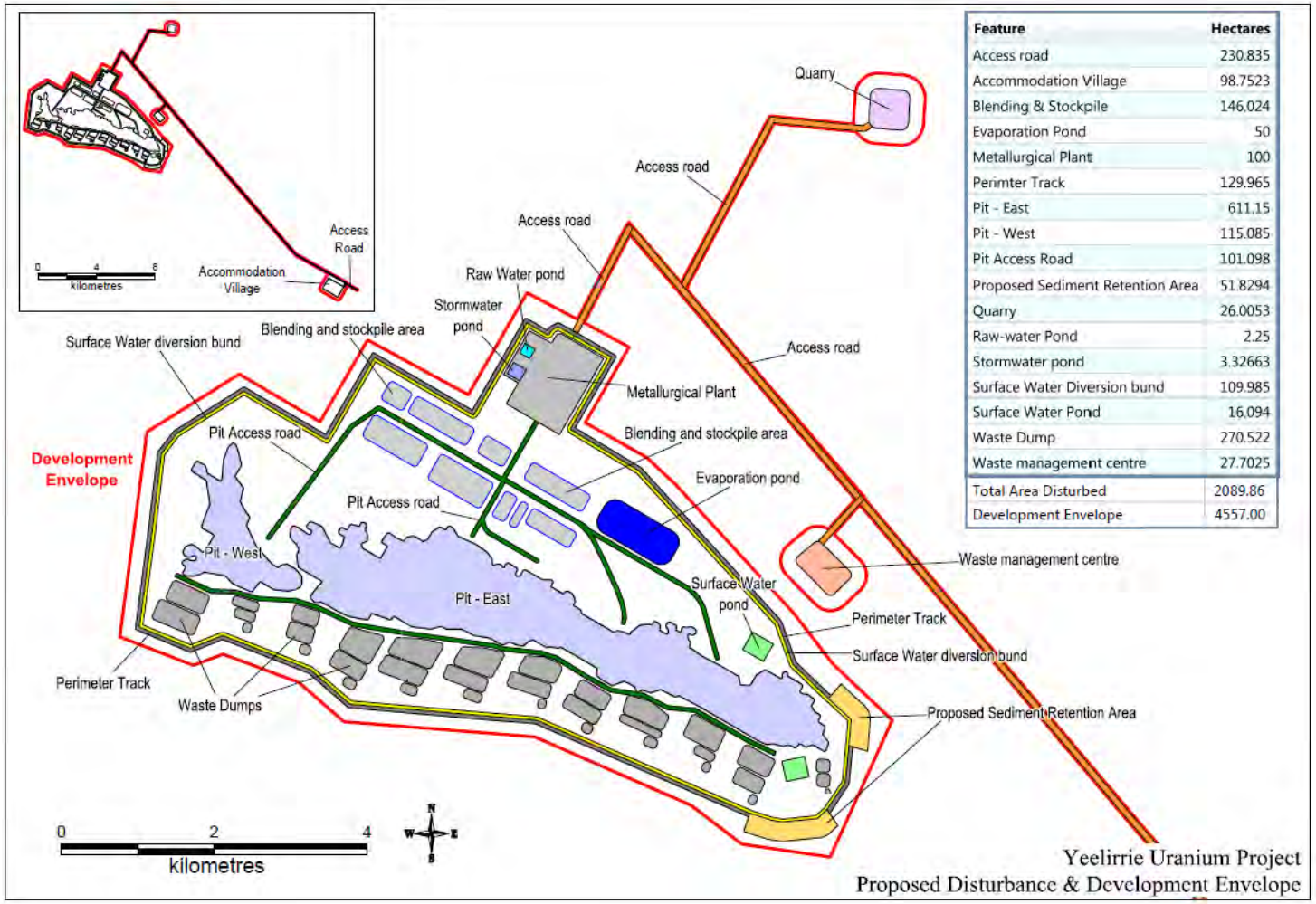

Figure 2 **Proposed disturbance footprint and final project layout**

2. METHODOLOGY

This radon assessment was conducted in accordance with recognised techniques for dispersion modelling. Emission rates have been estimated based on radon emanation rates provided by Cameco. The dispersion modelling study incorporates radon source characteristics and emission rates, local meteorology, terrain, land use and the geographical location of sensitive receptors.

2.1 Meteorological modelling

The meteorological data for the radon assessment was generated by coupling TAPM, a prognostic mesoscale model to CALMET, a diagnostic meteorological model. The coupled TAPM/CALMET modelling system was developed by Katestone to enable detailed air dispersion modelling capabilities for regulatory and environmental assessments. The modelling system incorporates synoptic, mesoscale and local atmospheric conditions, detailed topography and land use categorisation schemes to simulate synoptic and regional scale meteorology for input into pollutant dispersion models, such as CALPUFF.

Complete details of the model configuration for the worst-case scenario and a review of the models performance can be found in Appendix A of the Air Quality Assessment of the Yeelirrie Uranium Project (Katestone, 2014).

2.2 Emissions

Radon emission rates have been estimated based on emanation rates provided by Cameco and proposed surface areas of material that will be exposed to the wind during the mining operation. All working pit areas, storage stockpiles, prior pit area and in-pit tailings disposal, rehabilitated land, and the adjacent quarry have been considered as potential sources of radon emissions. Emission rates were estimated for year 10 of operations, as this year is expected to generate the highest radon emissions due to the extent of exposed areas on-site. Full details are presented in Section 3.

2.3 Dispersion modelling

Atmospheric dispersion modelling was carried out using the CALPUFF Version 6.4 dispersion model (EarthTec) to predict the ground-level concentrations of radon.

The CALPUFF dispersion model utilises the three-dimensional wind fields from CALMET to simulate the dispersion of air pollutants to predict ground-level concentrations across a gridded domain. The emission rates of radon were modelled as a tracer gas with no depletion, deposition or chemical transformations. Full details regarding the configuration of the CALPUFF dispersion model, limitations of dispersion modelling, and sensitive receptors included in the model are presented in Appendix A of the Air Quality Assessment of the Yeelirrie Uranium Project (Katestone, 2014).

The results of the dispersion modelling are presented at each of the nearest sensitive receptors and as contours generated from predictions across a Cartesian grid. For the worst-case operations, the predicted maximum 1-hour, maximum 24-hour and annual average radon concentrations are presented.

3. EMISSIONS

This assessment predicts the potential concentrations of radon due to the emanation of radon from exposed ore. The estimated radon emanation rates for the proposed Yeelirrie Uranium Project, provided by Cameco, are presented in Table 1 and are based on a unit emission rate of 50 Bq/m^2/s per %U.

Table 1 Estimate radon emanation rates for the Yeelirrie Uranium Project

Material	U grade (ppm)	Radon emanation rate ($Bq/m^2/s$)
Ultra high grade ore	> 2000	20.00
Very high grade ore	1500-2000	8.75
High grade ore	1000-1500	6.25
Medium grade ore	500-1000	3.75
Low grade ore	250-500	1.75
Waste Rock	<250	0.5
Tailings (yr 4)	Various	11.90
Tailings (yr 8)	Various	8.18
Processing plant	-	0 (Assume all radon lost during mining)

Emissions of radon have been estimated using the projected exposed areas during Year 10 operations. These are illustrated in Figure 3 and presented along with the estimated radon emission rates in Table 2. The following assumptions have been made to estimate radon emission rates:

- There is no reduction in radon emanation rates due to revegetation and therefore an emanation rate of 0.5 $Bq/m^2/s$ has been used for rehabilitated areas
- The radon emanation rate of the active pit area is equal to the average emanation rate of the grades being extracted
- The areas in Figure 3 shown as not yet excavated have been treated as pre-stripped during Year 10. The radon emanation rate of these pre-strip areas is assumed to be equal to the average of the active pit, overburden and tailings emanation rates.
- Areas coloured green in Figure 3 are rehabilitated
- The quarry is likely to be a source of radon emissions. Although the quarry is expected to operate during the first three years of the Yeelirrie Uranium Project, the area of disturbance of the quarry may continue to emit radon.

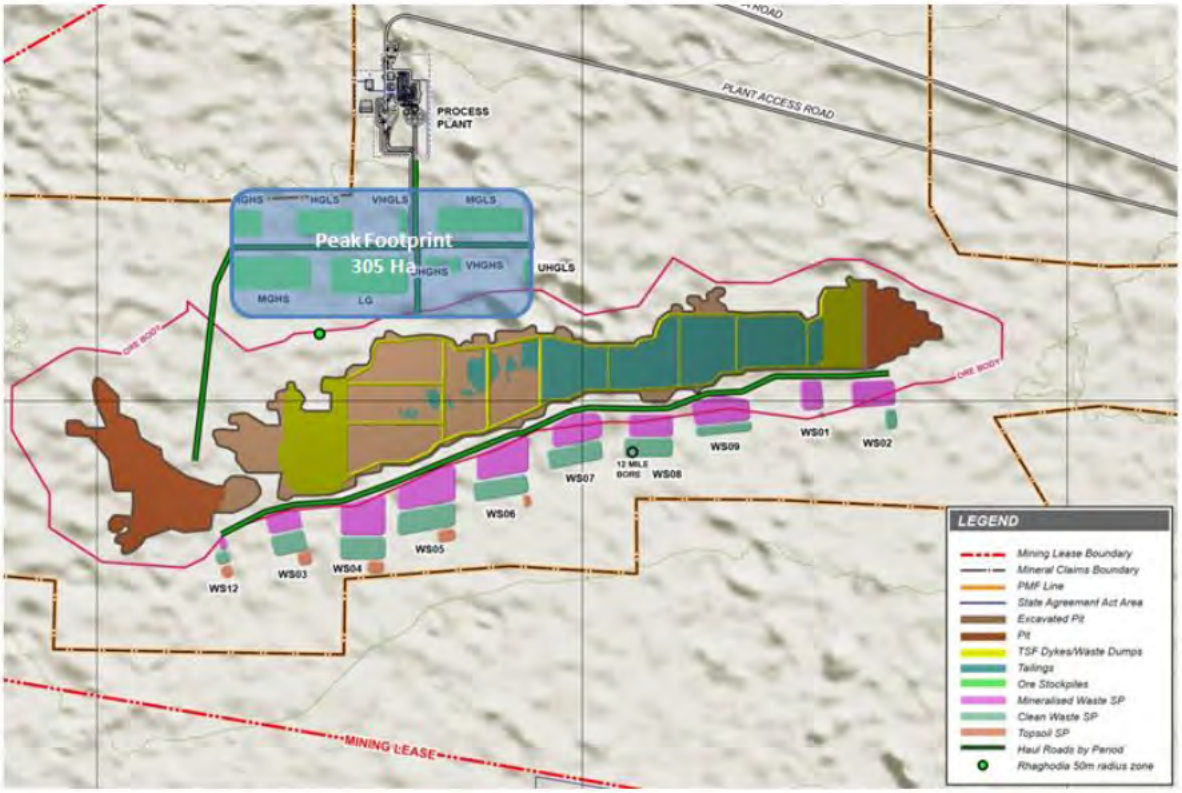

Figure 3 **Layout of the Yeelirrie Uranium Project during Year 10**

Table 2 **Estimated radon emission rates due to Year 10 operations of the Yeelirrie Uranium Project**

Type of exposed ground	Area exposed to wind erosion (ha)	Radon emission rate (Bq/s)
Pre-strip	143.9	12,268,005
Active pit	283.7	27,481,770
Tailings in-pit disposal	170.4	13,934,642
Overburden stockpiles	228.7	1,143,389
ROM stockpile at processing plant	0.9	126,050
UHG ore stockpile	4.9	981,427
VHG ore stockpile	5.4	470,256
HG ore stockpile	26.2	1,636,258
MG ore stockpile	59.7	2,239,720
LG ore stockpile	33.6	588,574
Quarry	10.0	50,000

4. RESULTS OF DISPERSION MODELLING

The results of the dispersion modelling assessment to predict ground-level concentrations of radon from the proposed Yeelirrie Uranium Project are presented below. No background radon levels have been included in this assessment. The results of dispersion modelling represent the influence of the Yeelirrie Uranium Project and the associated quarry in isolation.

Plate 1, Plate 2 and Plate 3 show the predicted maximum 1-hour, 24-hour and annual average ground-level radon concentrations, respectively, due to the proposed Yeelirrie Uranium Project during Year 10 operations.

Plate 4 and Plate 5 illustrate the predicted diurnal variation in 1-hour average radon concentrations at locations of maximum predicted concentrations inside and outside of the MLA, respectively. The predicted 1-hour average concentrations reach several thousand Bq/m^3 inside the MLA over night, and are significantly lower during the day.

Plate 6 to Plate 10 show the diurnal profile of the 1-hour average ground-level concentrations of radon predicted to occur at each sensitive receptor. The predicted 1-hour ground-level concentrations of radon at the Yeelirrie Pool and Homestead, and at the Accommodation Village and the Ululla Homestead reach several hundred Bq/m^3 over night and are significantly lower during the day.

The predicted maximum 1-hour, 24-hour and annual average ground-level radon concentrations at the nearest sensitive receptors due to the proposed Yeelirrie Uranium Project are shown in Table 3. The predicted maximum radon concentrations within the project boundary, and also the predicted maximum concentrations outside the project boundary for each averaging period are also presented in Table 3. The maximum 1-hour concentration at Yeelirrie Pool, which is the nearest receptor located approximately 10km from the ore body, is predicted to be 13% of the maximum concentration within the MLA. The 24-hour and annual average concentrations at Yeelirrie Pool are predicted to be less than 10% and 5% respectively of the maximum concentrations within the MLA.

Table 3 Predicted maximum ground-level radon concentrations due to the proposed Yeelirrie Uranium Project

Description	Location	Predicted maximum ground-level radon concentration (Bq/m^3)		
		1-hour	24-hour	Annual
Maximum within MLA	Exposed pit area	4102.5	1022	355.1
Maximum within model domain and outside MLA	Western edge of MLA	1819.5	549.74	69.4
Yeelirrie Pool	10.2 km northeast of ore body	539.0	90.2	5.0
Accommodation Village	~ 16.4 km southeast of ore body	242.0	28.4	0.4
Yeelirrie Homestead		226.0	24.9	0.4
Ululla Homestead	28.5 km north of ore body	145.1	25.2	1.2
Palm Springs	50.4 km east-southeast of ore body	17.4	2.3	0.06

5. CONCLUSIONS

Cameco Australia Pty Ltd (Cameco) proposes to develop an open pit uranium mine and associated processing facility at Yeelirrie in the Northern Goldfields region of Western Australia, approximately 420 km north of Kalgoorlie and 60 km west of Mt Keith. The proposed Yeelirrie Uranium Project would produce up to 7,500 tpa of uranium peroxide ($UO_4.2H_2O$), more commonly referred to as uranium oxide concentrate (UOC), through the development and operation of an open pit mine and on-site Metallurgical Plant. The proposed Yeelirrie development has the potential to emit radon (Rn) to the atmosphere.

A radon assessment has been conducted to investigate the potential for radon to disperse from the mine and Metallurgical Plant. The radon assessment has investigated the potential for radon impacts to occur due to mining operations and the Metallurgical Plant for a scenario representing a stage in the development that is likely to result in highest ground-level concentrations at the closest sensitive receptors.

The assessment used meteorological and dispersion models to assess the potential dispersion of radon emissions from the proposed Yeelirrie Uranium Project. These were based on the modelling conducted for the air quality assessment of the proposed Yeelirrie Uranium Project (Katestone, 2014).

The results of the dispersion modelling of radon from the proposed Yeelirrie Uranium Project during operation of the mine show that the ground-level radon concentrations are predicted to be as follows at the nearest sensitive receptors:

Description	Location	Predicted maximum ground-level radon concentration (Bq/m^3)		
		1-hour	24-hour	Annual
Yeelirrie Pool	10.2 km northeast of ore body	539.0	90.2	5.0
Accommodation Village	~ 16.4 km southeast of ore body	242.0	28.4	0.4
Yeelirrie Homestead		226.0	24.9	0.4
Ululla Homestead	28.5 km north of ore body	145.1	25.2	1.2
Palm Springs	50.4 km east-southeast of ore body	17.4	2.3	0.06

The maximum 1-hour average concentration at Yeelirrie Pool, which is the nearest receptor located approximately 10.2 km from the ore body, was predicted to be 13% of the maximum concentration within the MLA. The 24-hour and annual average concentrations at Yeelirrie Pool were predicted to be less than 10% and 5%, respectively, of the maximum concentrations within the MLA. Predicted concentrations at all other sensitive receptors are predicted to be less than 10% of the maximum concentrations within the MLA.

6. REFERENCES

Katestone Environmental 2014, Air Quality Assessment of the Yeelirrie Uranium Project, prepared for Cameco Australia.

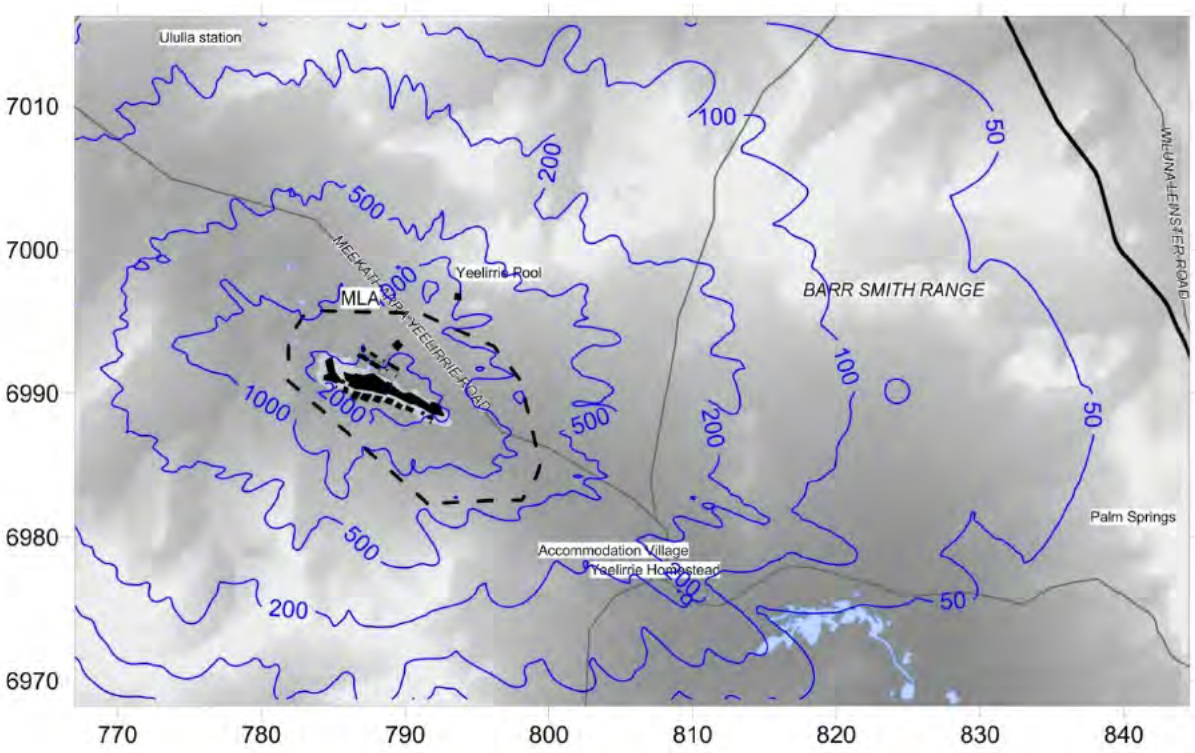

Plate 1 **Predicted maximum 1-hour average ground-level concentration of radon due to the proposed Yeelirrie Uranium Project**

Location:	**Averaging period:**	**Data source:**	**Units:**
Yeelirrie, WA	1-hour	CALPUFF	Bq/m^3
Type:		**Prepared by:**	**Date:**
Maximum contours, no background		Tania Haigh	December 2014

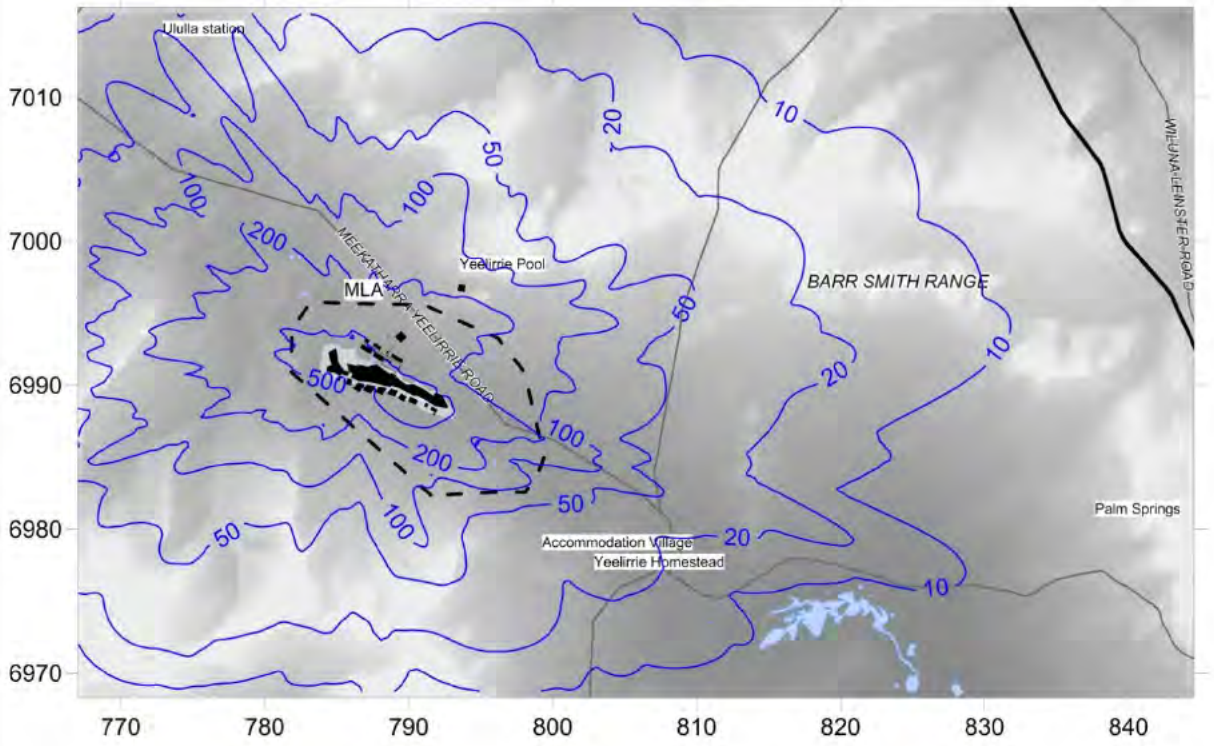

Plate 2 **Predicted maximum 24-hour average ground-level concentration of radon due to the proposed Yeelirrie Uranium Project**

Location: Yeelirrie, WA	**Averaging period:** 24-hour	**Data source:** CALPUFF	**Units:** Bq/m^3
Type: Maximum contours, no background		**Prepared by:** Tania Haigh	**Date:** December 2014

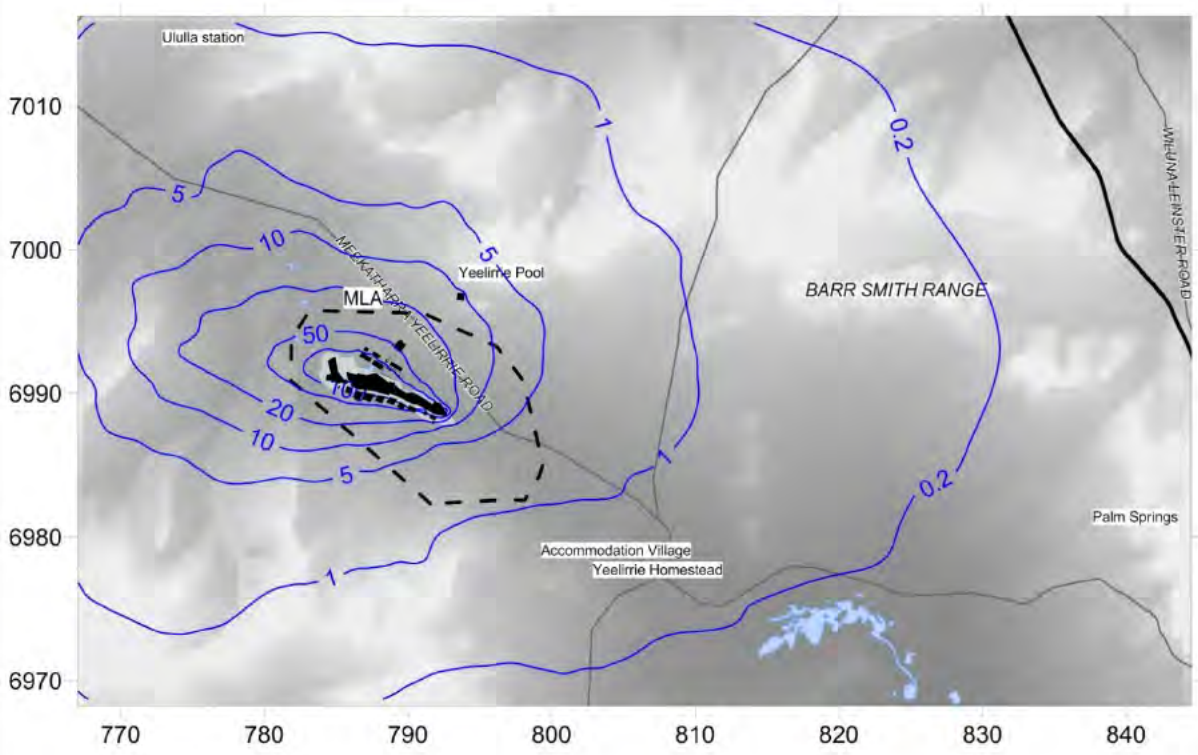

Plate 3 **Predicted annual average ground-level concentration of radon due to the proposed Yeelirrie Uranium Project**

Location:	**Averaging period:**	**Data source:**	**Units:**
Yeelirrie, WA	1-year	CALPUFF	Bq/m^3
Type:		**Prepared by:**	**Date:**
Maximum contours, no background		Tania Haigh	December 2014

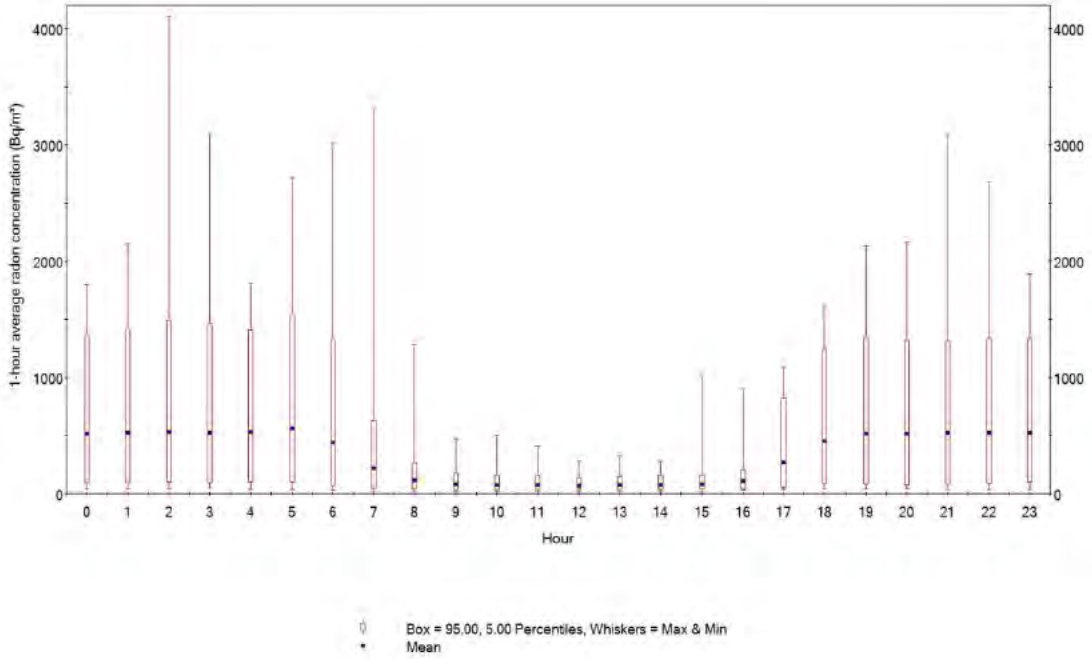

Plate 4 **Diurnal profile of predicted concentrations of radon inside the MLA at the proposed Yeelirrie Uranium Project**

Location:	**Averaging period:**	**Data source:**	**Units:**
Yeelirrie, WA - On-site	1-hour	CALPUFF	Bq/m³
Type:		**Prepared by:**	**Date:**
Box and whisker		Tania Haigh	December 2014

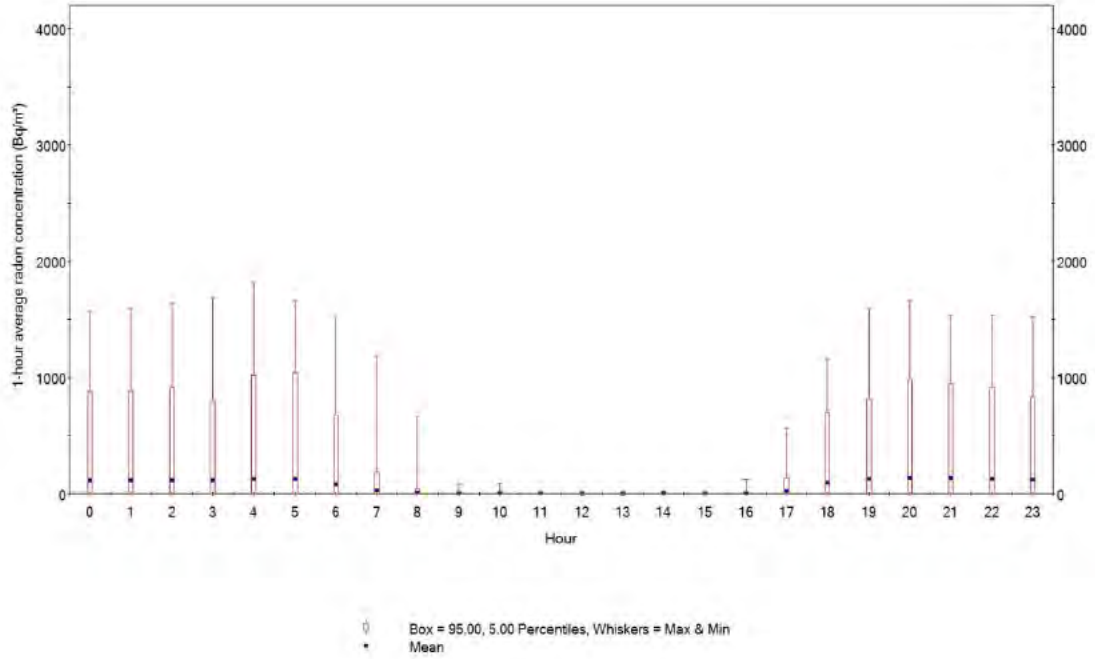

Plate 5 **Diurnal profile of predicted concentrations of radon outside the MLA at the location of highest concentration, immediately west of the MLA**

Location:	**Averaging period:**	**Data source:**	**Units:**
Yeelirrie, WA - On-site	1-hour	CALPUFF	Bq/m³
Type:		**Prepared by:**	**Date:**
Box and whisker		Tania Haigh	December 2014

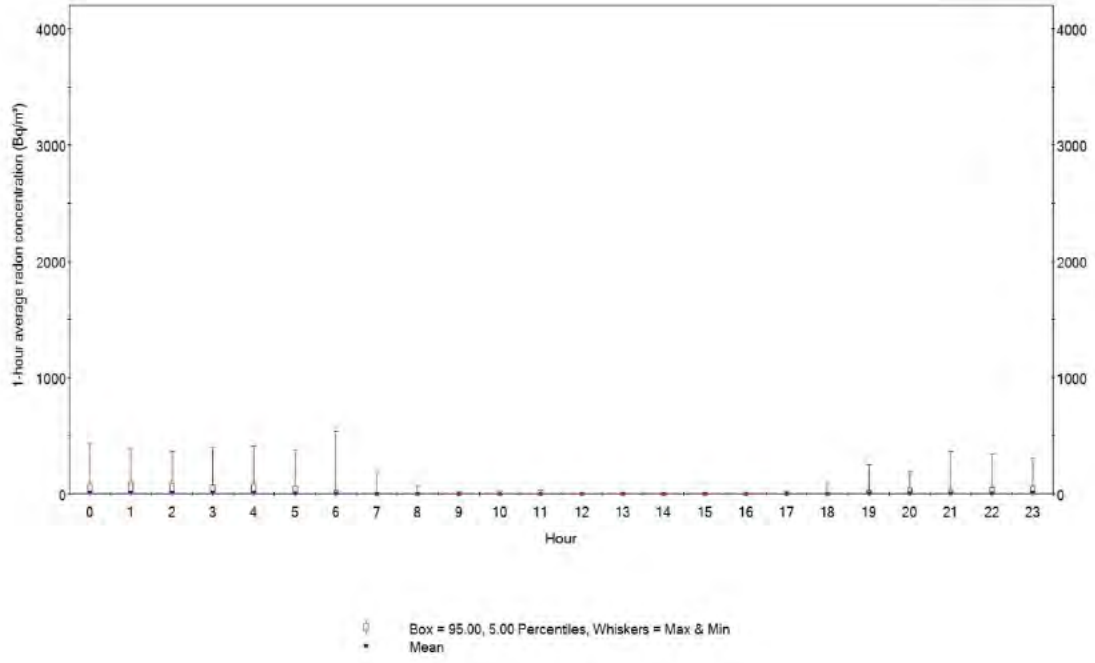

Plate 6 **Diurnal profile of predicted concentrations of radon at Yeelirrie Pool due to the proposed Yeelirrie Uranium Project**

Location:	**Averaging period:**	**Data source:**	**Units:**
Yeelirrie, WA - Yeelirrie Pool	1-hour	CALPUFF	Bq/m³
Type:		**Prepared by:**	**Date:**
Box and whisker		Tania Haigh	December 2014

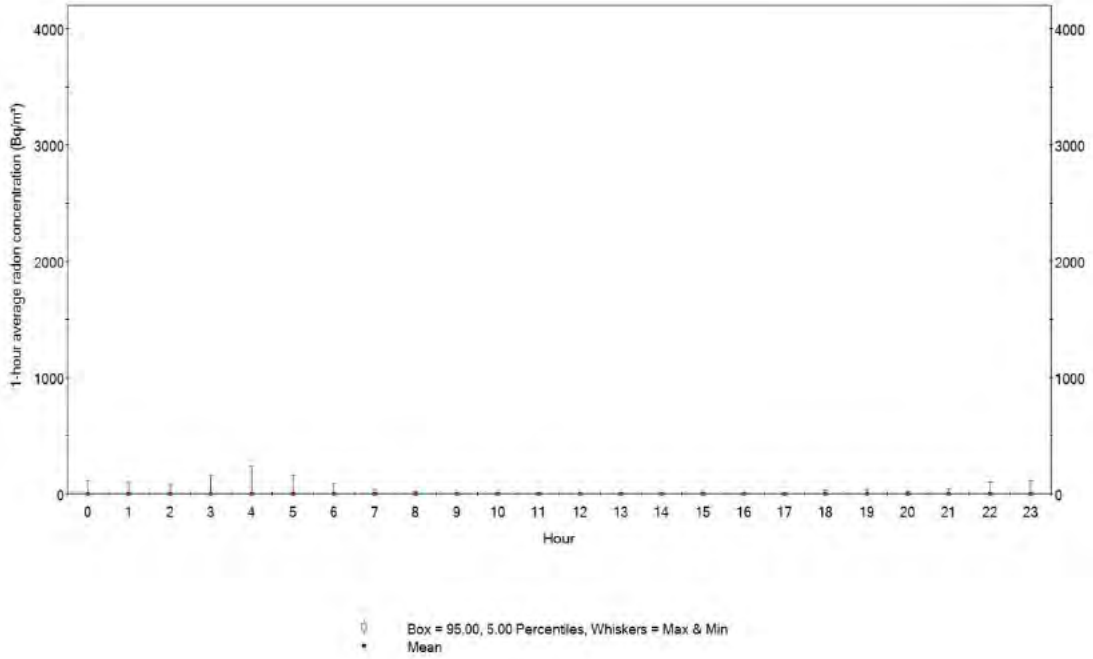

Plate 7 **Diurnal profile of predicted concentrations of radon at the Accommodation Village due to the proposed Yeelirrie Uranium Project**

Location:	**Averaging period:**	**Data source:**	**Units:**
Yeelirrie, WA - Accommodation village	1-hour	CALPUFF	Bq/m³
Type:		**Prepared by:**	**Date:**
Box and whisker		Tania Haigh	December 2014

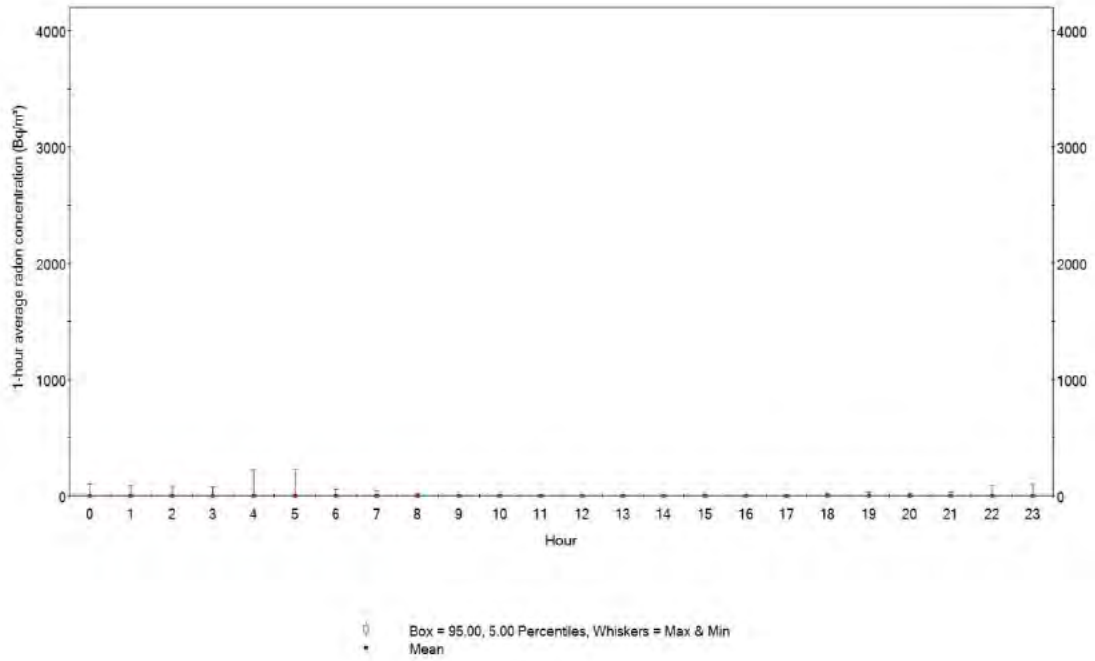

Plate 8 **Diurnal profile of predicted concentrations of radon at the Yeelirrie Homestead due to the proposed Yeelirrie Uranium Project**

Location:	**Averaging period:**	**Data source:**	**Units:**
Yeelirrie, WA - Yeelirrie homestead	1-hour	CALPUFF	Bq/m³
Type:		**Prepared by:**	**Date:**
Box and whisker		Tania Haigh	December 2014

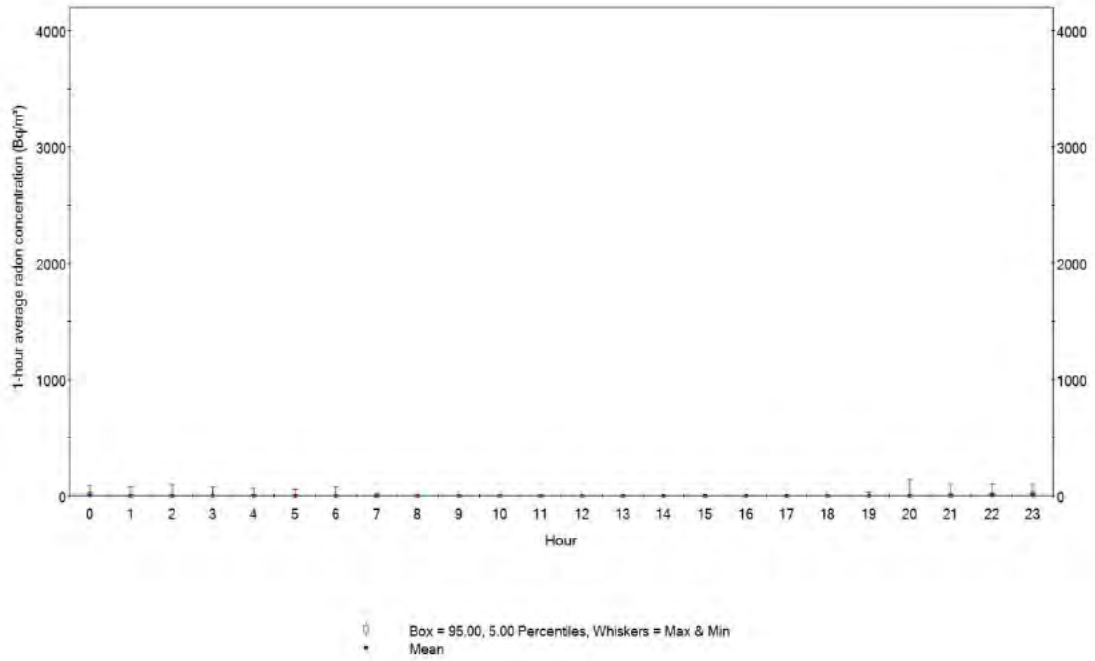

Plate 9 **Diurnal profile of predicted concentrations of radon at the Ululla Homestead due to the proposed Yeelirrie Uranium Project**

Location:	**Averaging period:**	**Data source:**	**Units:**
Yeelirrie, WA - Ululla homestead	1-hour	CALPUFF	Bq/m³
Type:		**Prepared by:**	**Date:**
Box and whisker		Tania Haigh	December 2014

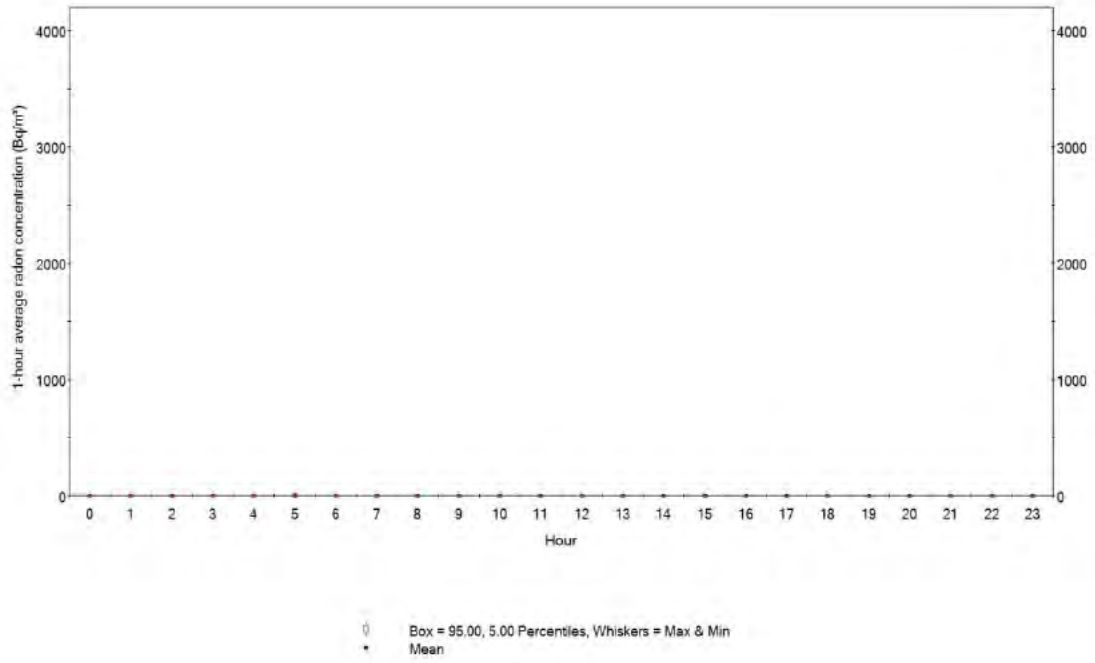

Plate 10 **Diurnal profile of predicted concentrations of radon at Palm Springs due to the proposed Yeelirrie Uranium Project**

Location:	**Averaging period:**	**Data source:**	**Units:**
Yeelirrie, WA - Palm Spring	1-hour	CALPUFF	Bq/m³
Type:		**Prepared by:**	**Date:**
Box and whisker		Tania Haigh	December 2014