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Gamma dose rates and ^{222}Rn activity flux densities at the El Sherana containment

Andreas Bollhöfer, Che Doering, Gary Fox

July 2015

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Authors of this report:

Andreas Bollhöfer – Environmental Research Institute of the Supervising Scientist, GPO Box 461, Darwin NT 0801, Australia

Che Doering – Environmental Research Institute of the Supervising Scientist, GPO Box 461, Darwin NT 0801, Australia

Gary Fox – Environmental Research Institute of the Supervising Scientist, GPO Box 461, Darwin NT 0801, Australia

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Department of the Environment
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Executive summary

Gamma dose rates and radon exhalation flux densities are measured at the El Sherana containment every two years as part of the approved environmental monitoring program. This report presents the measurements from 2015, the fourth set of measurements since construction of the containment in 2009. Gamma dose rates on top of the containment in 2015 were no different to those measured prior to its construction and remain at typical environmental background levels. Radon exhalation flux densities on top of the containment in 2015 were higher than those measured prior to its construction, but have not increased since the last set of measurements in 2013. The levels of gamma dose rate and radon exhalation flux density measured at the containment in 2015 would not lead to above background doses of Parks Australia employees or the public in excess of the dose constraint of 30 μSv per year.

1 Introduction

The El Sherana airstrip containment (or South Alligator containment facility) is a near-surface disposal facility located in the South Alligator River valley in the south of Kakadu National Park. It was constructed in the 2009 dry season and contains approximately 22,000 m^3 of naturally occurring radioactive material (NORM) contaminated waste from the remediation of legacy uranium mining and processing sites in the area (see Waggitt (2004) for details of the uranium mining history of the South Alligator River valley). Following closure of the facility it is currently in the institutional control period, during which public access to, or alternative use of, the site must be restricted. The containment is managed by the Director of National Parks, with regulatory oversight by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). The Supervising Scientist currently assists the Director of National Parks by conducting biennial monitoring to assess the radiological conditions on site. Table 1 gives the engineering details of the containment.

Table 1 Engineering details of the El Sherana airstrip containment[1]

Parameter	Description
Surface footprint	8750 m^2 (175 m × 50 m)
Maximum capacity	25,000 m^3
Maximum excavation depth below natural ground level	5 m
Side slopes	3:1 (horizontal:vertical)
Maximum thickness of waste material	4.5 m
Base layer	0.5 m compacted clay
Capping layer	0.5 m compacted clay
Cover (growth medium)	1.8–2.4 m uncompacted natural soil

[1]Information from O'Kane Consultants (2012)

As part of their licence conditions for the South Alligator containment facility, the Director of National Parks has to provide to the CEO of ARPANSA within 28 days of the end of each financial year information about compliance with the licence conditions for the previous year. This report should include a status update on the integrity of the surface cover, any changes in environmental circumstances of the facility and a summary of information collected through an approved monitoring programme. This approved monitoring programme includes the measurement of gamma dose rates and radon-222 (^{222}Rn) exhalation flux densities from the containment every two years and is shown in Table 2. The previous set of measurements were conducted in October 2013.

After an inspection of the South Alligator Disposal facility by ARPANSA in 2011 (ARPANSA 2011), ARPANSA requested that Parks Australia undertake a radiological impact assessment of the South Alligator containment facility to establish appropriate dose constraints, in line with the requirements outlined in the Code of Practice for the near surface disposal of radioactive waste (NHMRC 1993). The Environmental Radioactivity group of the Supervising Scientist was approached by the Director of National Parks to undertake this impact assessment, and modelling of doses to Parks employees and the general public using the ResRad Offsite computer code (Yu et al. 2009) has shown that effective radiation doses will be below 10 µSv per year (Bollhöfer et al 2013; Supervising Scientist 2013). A dose constraint of 30 µSv per year was set for the South Alligator Disposal facility and approved by ARPANSA in 2013.

Table 2 Approved monitoring programme for the South Alligator Containment Facility

Containment performance	meteorology	rainfall net solar radiation	quarterly data download annual analysis report post-wet season annual summary report pre-wet season
	cover	water content suction temperature radon-222 concentration	quarterly data download annual analysis report post-wet season annual summary report pre-wet season
	waste	water content suction temperature	quarterly data download annual analysis report post-wet season annual summary report pre-wet season
	liner	water content suction liner seepage	quarterly data download annual analysis report post-wet season annual summary report pre-wet season
	hydrology	surface runoff flow	quarterly data download annual analysis report post-wet season annual summary report pre-wet season
	erosion	volume gully dimensions extent of clay cracking	annual report post-wet season
Surficial radioactivity	grid survey	surface gamma radon-222 surface exhalation	biennial report post-wet season
Groundwater	standing water levels	ESMBs 5-15	biannual report pre- and post-wet season
	in field	pH electrical conductivity	annual analysis report post-wet season
	lab assay (filtered)	uranium magnesium sulphates manganese calcium iron radium-226	annual analysis report post-wet season
Vegetation	cover	percentage foliage percentage mulch/debris	annual report post-wet season
	response to fire	percentage regrowth after 12 months	after five years (cool burn after 4 years)
	radionuclide uptake in plants	in foliage of selected species	after five years

The ***eriss*** Environmental Radioactivity program has measured gamma dose rates and ^{222}Rn activity flux densities at the containment site prior to construction and again in 2010 one year after construction (Doering et al 2011). Gamma dose rates and ^{222}Rn activity flux densities were also measured in September 2012 as part of an ongoing (biannual) monitoring program. These 2012 measurements were used to make an assessment of expected maximum annual doses for occupational and public exposure scenarios (Bollhöfer et al 2013). Because radon exhalation had increased between 2010 and 2012, a further set of measurements of radon exhalation was taken between 7 and 10 October 2013. This was approximately 3 months after vegetation in the middle of the containment was cleared and 1 metre of clean soil placed on top of the existing capping to re-contour the surface and prevent erosion of the capping material at the containment. The survey also coincided with an inspection of the containment by an ARPANSA officer. Results of the 2013 survey were published in Supervising Scientist Report 205 (Supervising Scientist, 2013) and reported in a Minute to the Director of National Parks in May 2014.

The measurements taken in 2013 showed that the average gamma dose rate measured in 2012 and 2013 (0.13±0.01 μGy/hr) was no different to the baseline gamma dose rate measured in 2007. Consequently, the above baseline gamma dose rate three (2012) and four (2013) years after containment construction was zero. However, the radon flux from the containment measured in 2013 was still higher than the pre-construction radon fluxes measured in the area, but has not increased further compared to the measurements taken in 2012.

The report presented here details the results of gamma dose rate and radon flux density measurements conducted in May 2015, within the fenced area of the containment and outside the fence, down gradient of the containment.

2 Methods

2.1 Geospatial coordinates

Site locations were recorded as projected coordinates (easting and northings) based on the WGS84 standard, using a hand-held global positioning system (GPS) device. The site coordinates project into Universal Transverse Mercator (UTM) zone 53S.

2.2 External gamma radiation measurements

A gamma survey was conducted at the containment on 22 May 2015 using a compensated Geiger Müller (GM) tube (Mini Instrument MC70) connected to a Thermo Scientific RadEye GX gauge.

Measurements were made of the total counts per 60 s in air at a height of 1 m above the ground surface. A total of 45 measurements were made: 40 within the fenced area of the containment (of which 30 points were on top of the buried waste) and 5 south of the fenced area outside the containment facility. The gamma dose rate monitor was calibrated in January 2015, the calibration certificate for this monitor is shown in Figure A1 in Appendix 1. Table A1 in the Appendix shows the results of the gamma dose rate measurements.

2.3 ^{222}Rn activity flux density measurements

^{222}Rn activity flux density measurements at the containment were made over the period 22-26 May 2015. The prevailing meteorological conditions over the measurement period were typical of the tropical Northern Territory dry season, with maximum daytime temperatures around 30°C and zero rainfall.

Brass canisters containing activated charcoal to entrap radon emanating from the ground surface were used for the field sampling of ^{222}Rn. Forty five canisters were deployed on and around the containment. The canisters were embedded in the ground surface to a depth of approximately 1 cm in order to ensure a good seal and prevent leakage of radon from the canister to the atmosphere. Three additional canisters were carried into the field but remained sealed at all times. These canisters were 'controls' and used to determine the background activity of ^{222}Rn collected on the charcoal.

The ^{222}Rn activity flux density was calculated from the measured ^{222}Rn progeny activity in the canisters according to the method described in Doering et al (2011) and Spehr & Johnston (1983). The ^{222}Rn progeny activity in each canister was counted for ten minutes using a sodium iodide detector and the resulting energy spectrum displayed on a multi-channel analyser. Regions of interest were established around the characteristic photopeaks of lead-214 (242 keV, 295 keV and 352 keV) and bismuth-214 (609 keV) from which the net count rate was determined by summing the total counts under each peak for the individual field samples and then subtracting the mean sum of the counts under the corresponding regions of interest in the control canisters' spectra. The efficiency of the detector for ^{222}Rn progeny counting via this method was 9.6%. Table A1 in the Appendix shows the results of the ^{222}Rn activity flux density measurements.

3 Results

3.1 External gamma radiation

Figure 1 shows the location and magnitude of the baseline (left) and 2015 (right) gamma dose rate measurements at the containment site overlaid on an aerial photograph of the area from March 2007. The outer white rectangle indicates the approximate location of the boundary fence around the containment. The inner rectangle shows the approximate location of the containment and buried waste.

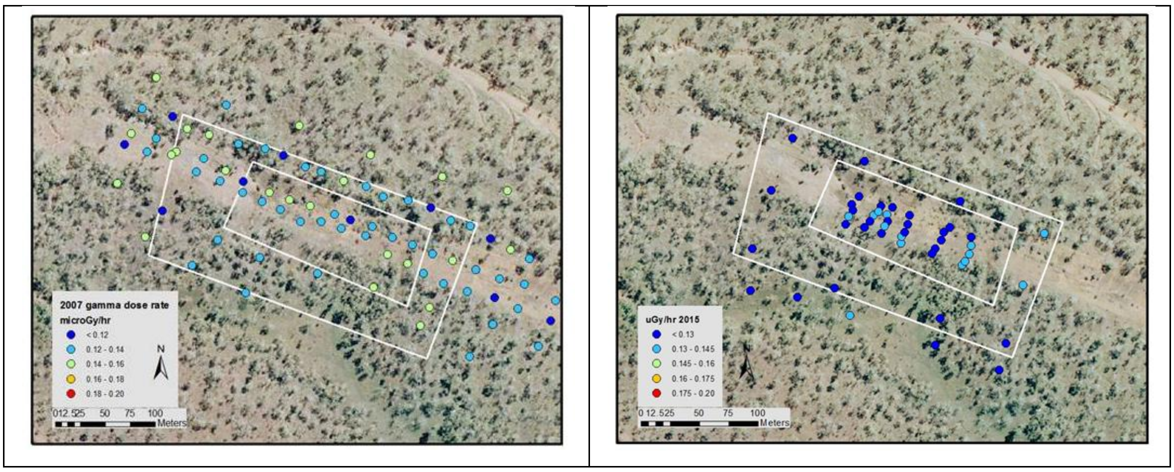

Figure 1 2007 (baseline) and 2015 external gamma dose rates [$\mu Gy \cdot hr^{-1}$] measured at the South Alligator Containment Facility.

It has been shown that the 2007 baseline gamma dose rate measurements were normally distributed, with an average value inside the fenced area of 0.13 $\mu Gy \cdot hr^{-1}$ (Bollhöfer et al 2009). The data measured in 2015 within the fenced area also fit a normal distribution and a histogram of the measured gamma dose rates is shown in Figure 2. Within uncertainties, gamma dose rates measured in 2007 and in 2015 (0.124 ± 0.012 $\mu Gy \cdot hr^{-1}$) are the same, and there has been no increase in the measured gamma dose rates within the fenced area of the containment over the years (see also Bollhöfer et al 2013).

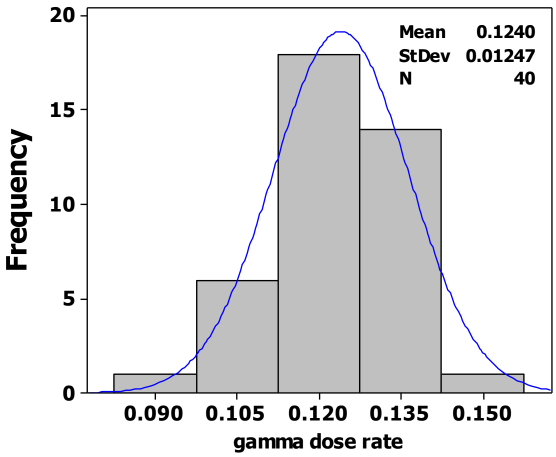

Figure 2 Histogram of gamma dose rates [$\mu Gy\ hr^{-1}$] measured within the fenced area of the South Alligator Containment Facility in May 2015.

3.2 ^{222}Rn activity flux densities

Figure 3 shows the location and magnitude of post-construction ^{222}Rn activity flux density measurements conducted in 2010 (left) (Doering et al 2011) and in 2015 (right) at the containment, overlaid on an aerial photograph of the area from March 2007. The outer white rectangle indicates the approximate location of the boundary fence around the containment. The inner rectangle shows the approximate location of the containment and buried waste.

^{222}Rn activity flux densities measured on the containment in 2015 were still higher than those measured in 2010, but there has been little change in ^{222}Rn activity flux densities outside the fenced area at the control sites. The typical value (geometric mean) measured in 2010 outside the fenced area was 16 $mBq \cdot m^2 \cdot s^{-1}$ (similar to the baseline value of 14 $mBq \cdot m^2 \cdot s^{-1}$ measured in 2009) with values ranging from 10–36 $mBq \cdot m^2 \cdot s^{-1}$. In 2015, the typical value outside the fenced area was 10 $mBq \cdot m^2 \cdot s^{-1}$, with values a little lower, showing a range of 6-17 $mBq \cdot m^2 \cdot s^{-1}$.

Figure 4 shows that the ^{222}Rn activity flux densities measured in 2015 follow a lognormal distribution ($p = 0.1$) although there is still some indication, albeit less pronounced than in 2012, of a bimodal distribution that was observed in 2012 (Bollhöfer et al 2012).

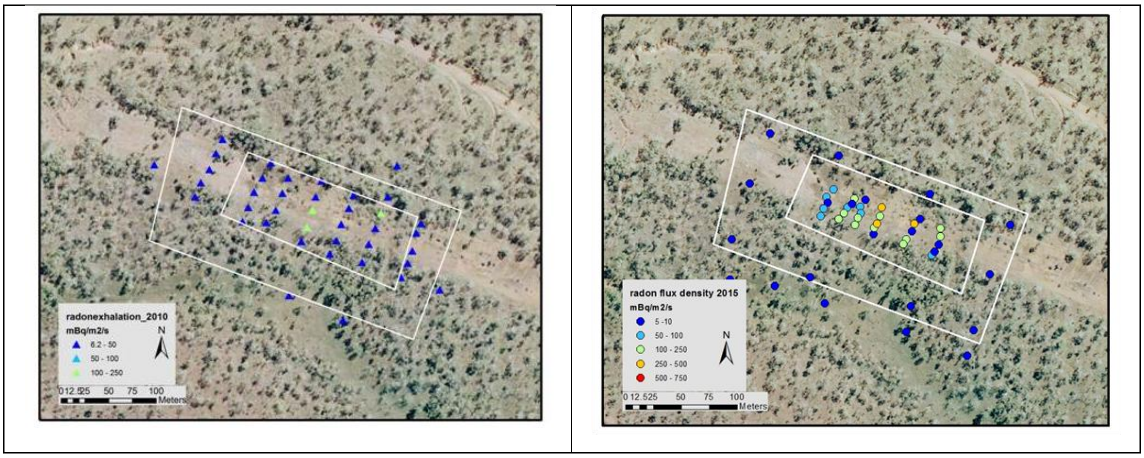

Figure 3 ^{222}Rn activity flux densities [mBq·m^{-2}·s^{-1}] measured at the South Alligator Containment Facility in September 2010 (left) and May 2015 (right).

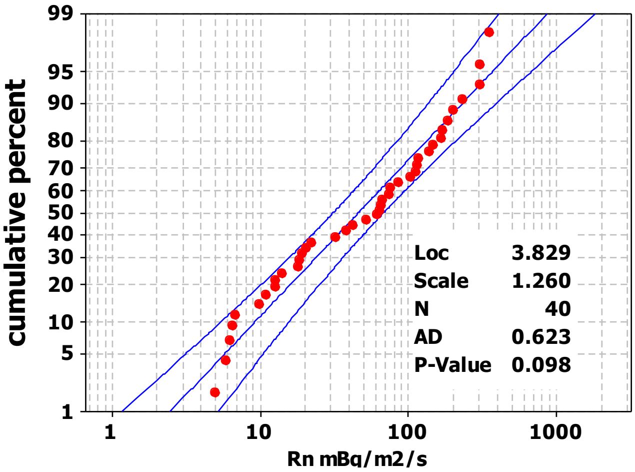

Figure 4 Frequency distribution of ^{222}Rn activity flux densities measured in May 2015 at the South Alligator Containment Facility.

4 Discussion and Conclusion

The survey of external gamma dose rates and ^{222}Rn exhalation flux densities across the El Sherana containment in May 2015 was the fourth of its kind since its construction in 2009. External gamma dose rates on top of the containment have not changed and stayed at typical environmental levels without any noticeable increase above typical environmental levels.

Figure 5 shows the results of the ^{222}Rn exhalation flux densities measured from environmental areas nearby and from the top of the containment, in September 2010, September 2012, October 2013 and May 2015. It is obvious that there is a tendency towards higher ^{222}Rn exhalation flux densities from the containment 3, 4 and 5.5 years after construction compared to 1 year after construction in 2010.

The reason for this increase may be associated with changes of the physical properties of the containment cover, as outlined in the 2012-13 Supervising Scientist Annual Report (Supervising Scientist 2013). In June 2013, vegetation in the middle of the containment was cleared and approximately 1 metre of clean soil placed on top of the existing capping to re-contour the surface and prevent erosion of the capping material at the containment.

This additional layer does not appear to have lowered overall radon activity fluxes from the containment measured in October 2013.

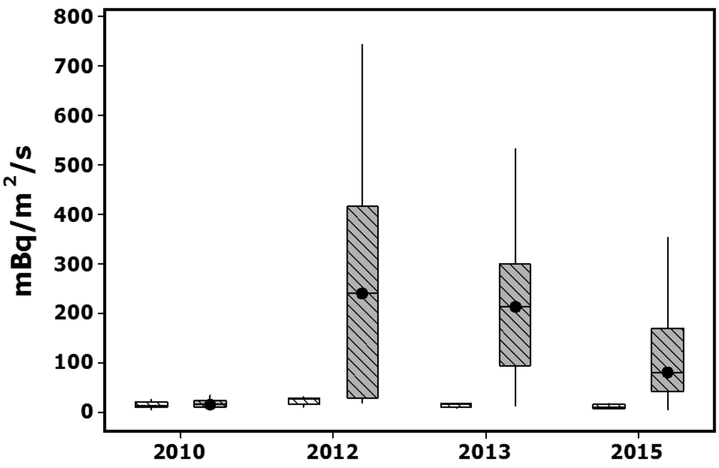

Figure 5 Box plot of environmental background (open boxes) and containment (grey boxes) ^{222}Rn exhalation flux densities. The marker indicates the median, the length of the box is the interquartile range, whiskers indicate the upper and lower 25% of the distribution.

The apparent decrease of the ^{222}Rn activity flux densities in May 2015 compared to the previous two surveys is most likely associated with the time of year of the measurements: the 2015 survey was conducted in May, at the end of the wet season, when ^{222}Rn exhalation flux densities from soils are typically lower due to the higher soil moisture that limits radon exhalation from a substrate (Bollhöfer & Doering 2015). In contrast, the previous three surveys were conducted during peak dry season conditions at the end of the dry. The higher volumetric water (VWC) content in May 2015 is clearly visible in VWC profiles at the containment shown in O'Kane (2015). ^{222}Rn activity flux densities measured outside the fenced area in 2015 were also slightly lower compared to the previous surveys.

The measurements conducted in May 2015 show that gamma dose rates and ^{222}Rn exhalation flux densities from the containment have not increased between 2012 and 2015. Consequently, the dose constraint of 30 μSv per year (which was determined based on the 2012 monitoring results) is not exceeded. ^{222}Rn exhalation flux densities measured at the El Sherana containment do not lead to unacceptable radiation doses to workers or the public, and continue to be less than 10 μSv per year.

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Appendix

Figure A1: Calibration certificate for gamma probe used for dose rate measurements in May 2015.

Safe Radiation
Pty Ltd
ABN 64 122 520 183

SAFE RADIATION
Post: Unit 19, 8 St Jude Court, Browns Plains Q4118
Phone: (07) 3800 9196 **Email:** safe@saferadiation.com
Web: www.saferadiation.com

Dose rate monitor calibration check

CLIENT **Environmental Research Institute of the Supervising Scientist**
GPO Box 461, Darwin NT 0801, Australia

MONITOR Probe mini MC70 with Thermo Scientific RadEye GX
SERIAL NO 00828

SOURCE
Emission source | Gamma, ^{137}Cs 662 keV, Serial Number 0127/14
Souce dimensions | Dimeter 6mm, Length 8 mm, stainless steel case
Activity (Bq) | 1969 MBq ± 1.0 % on 8/01/2015

CONTAINER Number: SR0197, 85 mm lead shielding in 5mm steel casing, surface painted

BEAM Collimator: Steel copper lining; Beam diameter 1m distance from source: 250 mm

AIR KERMA TRACEABILITY Primary standard, ARPANSA Certificate CAL00619, Expiry 1 July 2017
Air Kerma - Dose Conversion: 1.21 Sv/Gy; ICRP Publication 74, 1996

PROCEDURE The monitor was mounted on a remotely movable platform and source to monitor distance was varied to different values. The corresponding count rate was noted and compared with the expected dose rate.

MEASUREMENTS

Background 3.22 CPS

Reading	Distance (m)	Expected Dose Rate ($\mu Sv\ h^{-1}$)	Obtained count rate (CPS) 1	2	3	4	5	Average [a]	Conversion Factor CPS/$\mu Sv\ h^{-1}$
1	0.40	1226.2 ± 2.2	8449	8408	8376	8360	8491	8414 ± 27	6.9 ± 0.0 [b]
2	0.75	348.8 ± 0.6	4033	3980	4012	4092	4113	4043 ± 28	11.6 ± 0.1 [b]
3	1.00	196.19 ± 0.36	2645	2646	2643	2622	2644	2637 ± 5	13.4 ± 0.1 [b]
4	2.00	49.05 ± 0.09	711	714	711	707	715	708 ± 2	14.4 ± 0.1
5	3.00	21.80 ± 0.04	315	317	311	313	315	311 ± 1	14.3 ± 0.1
6	4.50	9.69 ± 0.02	141	142	144	142	142	139 ± 1	14.3 ± 0.1
7	6.00	5.45 ± 0.01	80.5	81.7	81.0	80.7	81.9	77.9 ± 0.3	14.3 ± 0.1

a: Background corrected b: Value not included in average Average conversion factor 14.3 ± 0.1

COMMENT This monitor reads 14.3 CPS / $\mu Sv\ h^{-1}$ ^{137}Cs (662 keV) gamma dose rate upto 50 $\mu Sv\ h^{-1}$ dose rate. At higher dose rate, the conversion factor may deviate from this value.

Certificate Number: 2015-01-08 ERISS 03
Date: 08-January-2015

Dr. Riaz Akber

Table A1: Eastings, northings and measured γdose rates and ^{222}Rn activity flux densities, May 2015.

Easting	Northing	Gamma dose rate	^{222}Rn activity flux
On containment		[µGy hr^{-1}]	[mBq m^{-2} s^{-1}]
228811	8506246	0.11±0.01	168±4
228777	8506255	0.13±0.01	52±2
228785	8506237	0.12±0.01	113±3
228796	8506263	0.13±0.01	43±2
228813	8506255	0.12±0.01	355±6
228784	8506264	0.12±0.01	138±3
228838	8506222	0.13±0.01	104±3
228872	8506216	0.13±0.01	10±1
228835	8506217	0.12±0.01	146±3
228749	8506246	0.13±0.01	65±2
228804	8506227	0.13±0.01	38±2
228790	8506256	0.13±0.01	64±2
228847	8506238	0.10±0.01	303±5
228791	8506249	0.11±0.01	86±2
228768	8506243	0.12±0.01	116±3
228805	8506234	0.14±0.01	201±4
228865	8506205	0.14±0.01	61±2
228782	8506259	0.13±0.01	22±1
228755	8506266	0.13±0.01	67±2
228788	8506244	0.14±0.01	184±4
228762	8506274	0.12±0.01	74±2
228868	8506209	0.14±0.01	5±1
228874	8506233	0.12±0.01	116±3
228756	8506260	0.13±0.01	32±2
228874	8506225	0.13±0.01	231±4
228853	8506243	0.12±0.01	7±1
228808	8506238	0.12±0.01	3035±
228844	8506230	0.13±0.01	13±1
228773	8506249	0.12±0.01	170±4
228752	8506254	0.14±0.01	76±2
Within fence			
228738	8506182	0.12±0.01	6±1
228909	8506127	0.13±0.01	19±1
228656	8506222	0.08±0.01	18±1
228926	8506185	0.14±0.01	13±1
228768	8506309	0.10±0.01	18±1
228947	8506237	0.13±0.01	21±1
228863	8506269	0.13±0.01	7±1
228675	8506280	0.10±0.01	14±1
228843	8506152	0.11±0.01	6±1
228696	8506332	0.12±0.01	11±1
Outside fence			
228701	8506173	0.12±0.01	6±1
228838	8506125	0.10±0.01	17±1
228902	8506100	0.13±0.01	12±1
228654	8506180	0.11±0.01	7±1
228753	8506155	0.13±0.01	10±1