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at GPSC Hearing - uranium smelter
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**11 NELSON PARADE
HUNTER'S HILL, NEW SOUTH WALES**

BACKGROUND RADIATION ASSESSMENT

July 2008

Document Record

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1.0 Introduction

The study site is located at 11 Nelson Parade, Hunter's Hill (Woolwich) and is an unoccupied residence with a rear garden that faces onto Sydney Harbour. The adjacent block of land to the east is known to have been contaminated by radioactive residues from the processing of uranium ore for extraction of radium by the Radium Hill Company between 1911 and 1916. In recent years there have been several studies of the radioactive contamination of the land.

Australian Radiation Services Pty. Ltd. (ARS) was initially requested by Environmental Resources Management Australia Pty. Ltd. (ERM) to conduct a preliminary investigation of the current state of the radioactive contamination on the block at the rear of the house. A brief measurement was also conducted in Kelly's Bush, a nearby nature reserve, which at the time of the survey, was thought to be representative of the local natural background gamma radiation levels. This work was conducted by ARS on 9 April 2008 and is reported elsewhere (ARS, May 2008).

ARS were requested to return to the Woolwich area on the 1st July 2008 to obtain further data on typical natural background gamma radiation levels in the area. This report presents the results of measurements of the background gamma radiation levels at several pre-determined locations. Several different types of radiation monitors were used in order to provide an indication of the performance of these monitors at background radiation levels.

Mr. Darren Billingsley a Senior Health Physicist with ARS conducted the measurements. An appropriately qualified Environmental Scientist from ERM assisted Mr. Billingsley on the day.

2.0 Scope of the Radiation Assessment

The following aspects were covered in this study:

- (i) to determine the natural background gamma radiation levels typical for the local Woolwich area for comparison with the external gamma radiation dose rates measured at number 11 Nelson Parade, and
- (ii) to determine the performance of several hand-held radiation monitors for measuring natural background gamma radiation levels.

3.0 Radiation Monitoring Equipment

All dose and dose rate radiation monitoring equipment used by ARS had been calibrated within the past 12 months to Cs-137 radioactive sources whose outputs are traceable to the Australian Primary Standard of Exposure maintained by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA).

3.1 Mini Instruments, Model 6-80 / MC-71 Environmental Meter

The Mini Instruments Model 6-8 / MC-71 Environmental Meter was used by ARS during the April 2008 survey. It was not available for the background gamma radiation assessment performed on the 1 July 2008.

3.2 Health Physics Instrument, Model 1010 Tissue Equivalent Monitor

The Health Physics Instrument (HPI) Model 1010 Tissue Equivalent Monitor is an ion chamber and is designed to measure dose and dose rate measurements in 'free-in-air'. The instrument has a flat dose rate response from 0.060 $\mu\text{Gy}\cdot\text{h}^{-1}$ (60 $\text{nGy}\cdot\text{h}^{-1}$) to well in excess of 2 $\mu\text{Gy}\cdot\text{h}^{-1}$ (2000 $\text{nGy}\cdot\text{h}^{-1}$) with a conversion factor of $7.98\pm 0.24 \mu\text{Gy}\cdot\text{mrad}^{-1}$. The instrument has a resolution equivalent to 2 nGy and a near uniform energy response over a large dynamic range

3.3 Exploranium GR-135 Mini-spectrometer

The Exploranium GR-135 minispectrometers are used to search, locate and identify any penetrating gamma ray emitting radionuclides. This instrument is suitable for a 'search and locate' exercise as it contains a highly sensitive NaI scintillation detector. Efficiency tests have identified that the GR-135 minispectrometer can "see" a planar surface of diameter 2 metres from a height of 30 cm from the ground. The minispectrometer can identify gamma ray emitting radionuclides to a depth of approximately 10 cm to 50 cm in soil.

The instrument has been calibrated in terms of ambient dose equivalent rates greater than 1.5 $\mu\text{Sv}\cdot\text{h}^{-1}$ but has a resolution of 0.001 $\mu\text{Sv}\cdot\text{h}^{-1}$. Due to this low resolution, the instrument, and the previous model GR-

130, are used for large scale environmental radiation surveys requiring hand held devices. Results can be normalised with absolute dose and dose rate measurements obtained using the HPI 1010 ion chamber or other suitable environmental monitor. For this particular survey the reported results have not been normalised.

3.4 Rotem Industries RAM R-200 Survey meter

The Rotem Industries RAM R-200 survey meter is a general purpose protection level hand held gamma ray survey meter. The manufacturer recommends a measurement range of $0.1 \mu\text{Sv}\cdot\text{h}^{-1}$ to $1 \text{Sv}\cdot\text{h}^{-1}$ and suitable for measuring gamma radiation in the energy range 60 keV to 1.5 MeV. Since the instrument is a protection level instrument, it is normally calibrated in terms of ambient dose equivalent rate. This is the same hand held survey meter used by ANSTO in their survey carried out in February 2008.

3.5 Automess 6150 AD5 Survey meter

The Automess 6150 AD5 dose rate meter has a photon detection range of 45 keV to 3.0 MeV. This meter records dose rate in terms of microsieverts per hour ($\mu\text{Sv}\cdot\text{h}^{-1}$), and has a manufacturer specified range of $0.1 \mu\text{Sv}\cdot\text{h}^{-1}$ to $1000 \text{mSv}\cdot\text{h}^{-1}$. The instrument is calibrated in terms of ambient dose equivalent rate.

4.0 Methodology and Results

4.1 Locations chosen

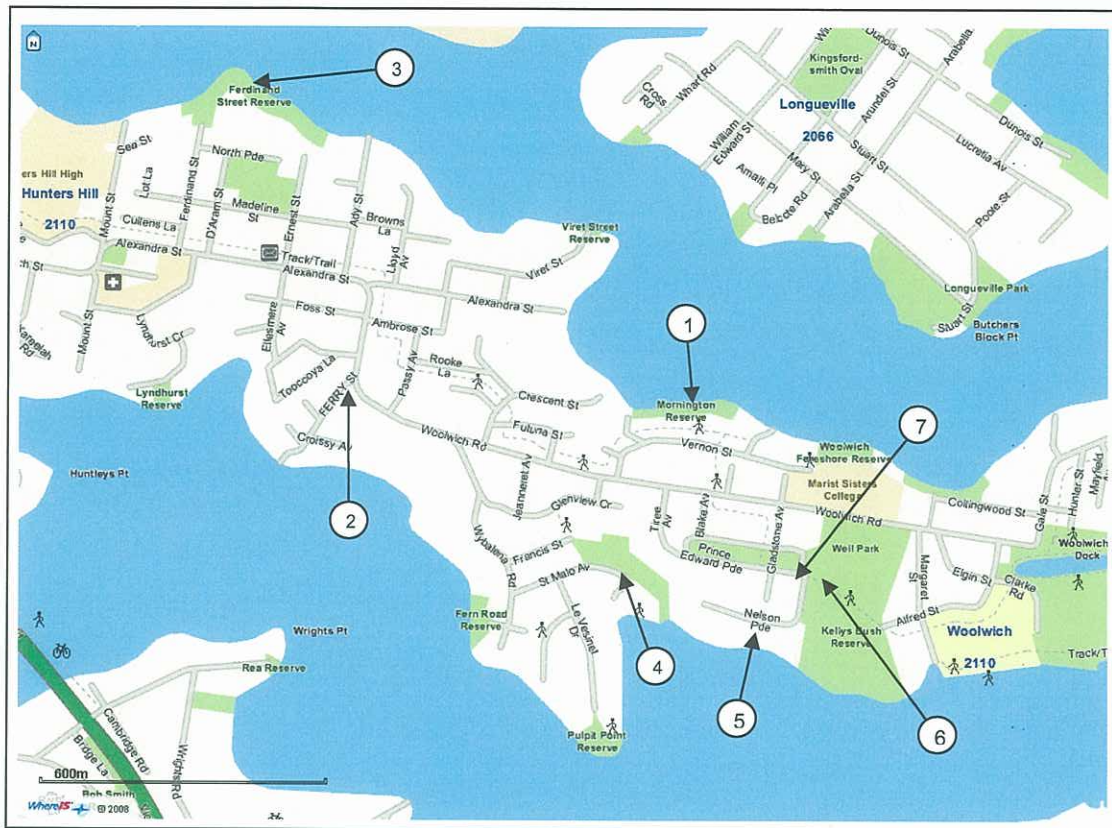
Several locations were identified in the Woolwich/Hunter's Hill area that were considered suitable for conducting measurements of natural background radiation levels, to a maximum distance of 1.5 km from the No.11 Nelson Parade property. These locations are shown in Figure 1.

Locations were chosen that were considered to be undisturbed, and consist of natural soils, where there would be no contribution from any introduced fill material. This was not easy as the majority of the Woolwich area has been developed into residential housing. The locations identified included 'Morningside Reserve' (location 1) and 'Ferdinand Street Reserve' (location 3). A measurement was also conducted at Kelly's Bush (location 6) at the corresponding location where a preliminary measurement was conducted by ARS during the April 2008 visit. Without any details of the past history of these locations, they appeared to display no signs that they had been developed in the past (i.e. thick vegetation and ground cover, well established trees etc.).

Realising Woolwich is a residential area; measurements were also conducted in other public locations with close proximity to the No 11 property. This included a grassed area known as 'Frances Street Reserve' (location 4). A measurement was also conducted on a 2 metre wide nature strip with a soil base at the 'Corner of Woolwich and Perry Street' (location 2). The medium strip is delineated by a major roadway and a brick paved path. A measurement was also conducted on a roadway at the 'top of Nelson Parade (location 6).

For completeness, a repeat measurement was conducted in the backyard at No. 11 Nelson parade (location 5), at the approximate location that an environmental measurement was conducted previously by ARS, known as location 'Y' (see ARS, May 2008).

Figure 1: Background survey locations in the Woolwich/Hunters Hill Area, NSW – July 2008.



4.2 Measurement technique

In order to obtain absolute dose rates free-in-air ($\text{nGy}\cdot\text{h}^{-1}$) the HPI Model 1010 Tissue Equivalent Monitor was positioned on a stand with the effective centre of the detector approximately 1 metre off the ground. The radiation incident on the detector was allowed to integrate (accumulate the radiation field) on the meter for a period of approximately 40 minutes. The average dose rate in units of $\text{mrad}\cdot\text{h}^{-1}$ was then calculated based on the total dose accumulated and the integration period.

Measurements were also conducted with the hand-held monitors including the Exploranium GR-135 Minispectrometer, the Rotem R-200 survey meter and the Automess 6150 AD5 survey meter. Measurements were conducted beside the position of the HPI Model 1010 and out to a distance of approximately 2 metres in all directions, to allow for any potential localised variations that may have been present. A total of twenty (20) measurements were conducted with each instrument, at 8 second intervals, and averaged to obtain a dose rate for the location. A total measurement time of ~160 seconds.

GPS locations were obtained using a Garmin Model GPS60, which has a reported accuracy of less than 5 metres. Approximate elevations were also recorded. Photographs were taken at each monitoring location.

4.3 Results

For comparison purposes all measurements were converted to environmental quantities, namely 'dose rate, free-in-air', with the units $\text{nGy}\cdot\text{h}^{-1}$. Dose rates calculated from the measurements conducted with the HPI Model 1010 were converted to 'free-in-air' quantities using a conversion factor obtained from the calibration of the instrument at low dose rates. The ambient dose equivalent rate measurements recorded with the hand held survey instruments were converted to the 'free-in-air' dose rates using an empirical conversion factor (ICRU47, 1992). The results of the external gamma radiation dose rate survey are presented in Table 1.

Table 1: Radiation Monitoring results at 11 Nelson Parade, Hunters Hill, NSW – April 2008. The ARS report of May 2008 identified background levels of gamma radiation at the site known as Kelly's Bush of ~0.12 microgray per hour (0.12 $\mu\text{Gy}\cdot\text{h}^{-1}$). In this report, the unit used is nanogray per hour ($\text{nGy}\cdot\text{h}^{-1}$). 1 nanogray is 1/1000th of a microgray. Therefore 0.12 $\mu\text{Gy}\cdot\text{h}^{-1}$ is 120 $\text{nGy}\cdot\text{h}^{-1}$.

Location			Dose Rate 'free-in-air' ($\text{nGy}\cdot\text{h}^{-1}$)					
Number	Description	GPS Coordinates	Approximate Elevation (metres)	HPI Model 1010 tissue equivalent monitor ^a	Mini 6-80 / MC-71 environmental meter (May 2008 survey)	Exploranium GR-135 survey meter ^b	Rotem R-200 survey meter ^c	Automess 6150 AD5 survey meter ^c
1	Mornington Reserve (natural)	E033004 N6254297	NR	60 ± 16	-	31 ± 3	155 ± 34	< 50
2	Corner Woolwich and Perry Street (nature strip)	E0329346 N6254400	36	75 ± 18	-	43 ± 5	193 ± 36	< 50
3	Ferdinand Street Reserve (natural)	E0329050 N6255024	11	62 ± 10	-	33 ± 4	116 ± 34	< 50
4	Frances Street Reserve (lawned)	E0329902 N6254013	18	73 ± 22	-	43 ± 3	189 ± 53	< 50
5	No. 11 Nelson Parade	E0330353 N6253942	15	505 ± 92	573 ± 18	499 ± 17	643 ± 63	200 ± 340
6	Kellys (natural)	E0330353 N6253942	45	75 ± 6	118 ± 3	50 ± 4	142 ± 32	< 50
7	Roadway, top Nelson Parade	E0330319 N6253956	41	152 ± 26	-	162 ± 45	308 ± 42	< 50

NR – not recorded

a – measured integrated dose measurements (mrad) converted for reporting purposes.

b – average measured ambient dose equivalent rate ($\text{nSv}\cdot\text{h}^{-1}$) converted for comparison purposes.

c – average measured ambient dose equivalent rate ($\mu\text{Sv}\cdot\text{h}^{-1}$) converted for comparison purposes.

5.0 Discussion

5.1 Background radiation levels

Monitoring results obtained with the HPI Model 1010 ion chamber indicate that dose rates measured at the locations that appeared relatively undisturbed and natural, namely the 'Mornington Reserve' (location 1) and 'Ferdinand Reserve' (location 3) were in good agreement (60 ± 16 nGy·h⁻¹ and 62 ± 10 nGy·h⁻¹ respectively). This is lower than the level ARS measured at Kelly's Bush recorded in April 2008 of 120 nGy·h⁻¹.

Average dose rates at the two areas where there was potential for contributions from introduced material (i.e. topsoil, pavers, road fill), namely 'Frances Street Reserve' (location 4) and the 'corner of Woolwich and Perry Streets' (location 2) recorded marginally higher dose rates (73 ± 22 nGy·h⁻¹ and 75 ± 18 nGy·h⁻¹). However, considering the standard deviations involved, these results are comparable with dose rates measured at Location 1 and 3.

Following the ARS site visit in April 2008, ARS was advised that their once had been a tin smelter located in the Kelly's Bush area, which may give rise to elevated external gamma radiation levels. ARS were unaware of this during the first visit. Repeat measurements conducted at approximately the same location indicated an average dose rate (75 ± 6 nGy·h⁻¹) comparable with those obtained at other 'background' areas (i.e. locations 1-4). The results are also comparable with the Mini 6-80 / M-71 Environmental Meter dose rates measured during the ARS April 2008 survey of 118 ± 3 nGy·h⁻¹. Considering the April 2008 measurement integration time was limited to ~10 minutes, thus small errors may be involved with this initial short measurement period.

Of interest was a measurement conducted at the 'roadway, top of Nelson Parade' (location 7). This location indicated an elevated average dose rate (152 ± 26 nGy·h⁻¹) compared to other locations chosen. It was also noted that this dose rate was considerably higher than dose rates observed on roadways elsewhere in Woolwich area. ARS were advised that material from the Radium Hill Mining Company or the tin processing plant may have been used for fill material in local roads which would explain the elevated levels measured at location 7. Under these circumstances, this location should be considered an anomaly, and the measurements conducted at this location cannot be considered typical of natural background radiation levels.

A measurement conducted at 'No. 11 Nelson Parade' (location 5, corresponding approximately to point 'Y' from the ARS April 2008 survey) revealed a dose rate of 505 ± 92 nGy·h⁻¹. This is in good agreement with the measurement obtained with the Mini 6-80 instrument in April 2008 of 573 ± 18 nGy·h⁻¹.

Assuming locations 1 to 5 are typical of the natural background in the local area, then the background radiation levels are in the range ~0.060 to ~0.075 µGy·h⁻¹ (60 to 75 nGy·h⁻¹). These levels are between 2 and 21 times less than the levels recorded on the No. 11 Nelson Parade property during the April 2008 survey of ~0.21 to ~1.61 µGy·h⁻¹.

5.2 Radiation monitor performance

The HPI Model 1010 Tissue Equivalent Monitor is considered the only true environmental radiation monitor used during this survey. It is the only instrument that has been calibrated against a traceable source to dose rates of ~60 nGy·h⁻¹, and demonstrated a linear response above this level. It is also an ion chamber with a flat energy response over a wide dynamic range. It is important to note that this monitor requires the taking of measurements over an extended period, usually up to 1 hour. This is called an integrated measurement and is necessary as low level gamma radiation dose rates can fluctuate over time.

Of interest is the response of the Rotem Ram R-200 Survey Meter as it over-responds significantly at low dose rates. The manufacturer recommends the instrument is capable of measuring a radiation field as low as 100 nSv·h⁻¹, however the highest average ambient dose equivalent rate measured was 140 ± 40 nSv·h⁻¹ (or 116 ± 34 nGy·h⁻¹ dose rate 'free-in-air' at location 3). This instrument is an instantaneous measurement device and is usually used to measure gamma radiation at much higher levels than normally exist in background environments.

The Exploranium GR-135 survey meter also did not agree very well at low dose rates. However, its low resolution means that when used in conjunction with an environmental meter, the data can be normalised, and the results used to conduct a quantitative survey of an area. The higher the radiation levels, the greater confidence can be made on the data.

The performance of the Automess 6150 AD5 at very low dose rates was poor as was to be expected. The instrument is not designed to measure environmental radiation levels and as such only registered a reading at the 'No. 11 Nelson Parade' (location 5).

All three hand-held protection level survey meters responded as expected. The only true means of determining accurate natural background radiation levels is to integrate the reading of a suitably responsive radiation monitor irradiated over an extended period of time, as demonstrated with the HPI Model 1010 Tissue Equivalent Ion Chamber Monitor reported in this study.

6.0 Conclusions

- An assessment has been made of the ambient external gamma radiation dose rates associated with natural background radiation levels at 5 locations within approximately 1.5 km of No. 11 Nelson Parade, Hunter's Hill using a Health Physics Instruments Model 1010 Tissue Equivalent Monitor.
- Background radiation dose rates 'free-in air' are in the range of ~ 0.060 to $\sim 0.075 \mu\text{Gy}\cdot\text{h}^{-1}$ (~ 60 – $\sim 75 \text{ nGy}\cdot\text{h}^{-1}$). This is less than the level recorded during the ARS survey in April 2008 at Kelly's Bush of $0.12 \mu\text{Gy}\cdot\text{h}^{-1}$ ($120 \text{ nGy}\cdot\text{h}^{-1}$).
- The background dose rates reported here are well below the dose rates recorded on the No. 11 Nelson Parade property during the April 2008 survey (0.21 to $1.61 \mu\text{Gy}\cdot\text{h}^{-1}$) as conducted by ARS (ARS May 2008).
- Results obtained from hand-held dose rate monitors including the Rotem R-200 meter and the Automess 6150 AD5 survey meter whilst suitable for measuring elevated radiation fields are not suitable at natural background radiation levels.
- Environmental radiation levels should be measured using a suitably designed instrument capable of integrating over an extended period of time and exhibit a uniform energy response over a wide range, such as the Model 1010 ion chamber.
- The results reported here confirm our findings in April 2008; that is, the estimated effective dose from external gamma radiation for someone living at 11 Nelson Parade will be in the range of ~ 0.7 to $\sim 2.5 \text{ mSv}$ above natural background based on the assumptions as outlined in the ARS May 2008 report and the data reported by ANSTO from their February 2008 radiation survey.

References

ARS, May 2008. Australian Radiation Services Pty. Ltd., *Number 11 Nelson Parade Hunters Hill – Radiation Assessment*, May 2008.

ICRU47, 1992. International Commission on Radiation Units and Measurements, *Measurement of Dose Equivalents from External Photon and Electron Radiations*, ICRU Report 47, 1992.



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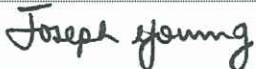

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