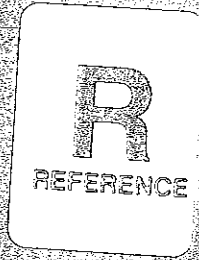


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ENVIRONMENTAL SURVEY AT
LUCAS HEIGHTS
RESEARCH LABORATORIES, 1986

by

M.S. GILES
J.J. FOY
E.L. HOFFMANN



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EDITORIAL NOTE

The Australian Nuclear Science and Technology Organisation replaced the Australian Atomic Energy Commission on 27 April 1987. Reports issued after April 1987 have the prefix ANSTO with no change of the symbol (E, M, S or C) or numbering sequence.

AUSTRALIAN NUCLEAR SCIENCE
AND TECHNOLOGY ORGANISATION
LUCAS HEIGHTS RESEARCH LABORATORIES

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ABSTRACT

Results are presented of an environmental survey conducted in the neighbourhood of the Lucas Heights Research Laboratories during 1986. No radioactivity which could have originated from these laboratories was found in samples collected from possible human food chains. All low-level liquid and gaseous waste discharges were within authorised limits. The maximum possible annual dose to the general public from airborne waste during this period is estimated to be less than 0.01 millisieverts, which is one per cent of the limit for long-term exposure that is recommended by the National Health and Medical Research Council.

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1 INTRODUCTION

Since 1959, surveys have been made by the Australian Atomic Energy Commission (and the newly formed Australian Nuclear Science and Technology Organisation (ANSTO)) of the radioactive content of samples collected in the vicinity of the Lucas Heights Research Laboratories (LHRL) to ensure that no unacceptable health effects either have occurred or will occur as a result of nuclear research and operation. The results obtained in these surveys have been published regularly and are listed in **appendix A**.

During the early surveys (*i.e.* throughout the 1960s), weapons test fallout was readily detectable in samples collected around Lucas Heights [Giles and Stockdale 1966]. Because of this, a large program of sampling was undertaken to establish the general levels of radioactivity arising from weapons test fallout, and so enable additional radioactivity caused by nuclear operations at Lucas Heights to be assessed. To establish this general background, samples were collected within a 60 km radius of the site; this expanded program was scaled down in 1970 because the Australian Radiation Laboratory (ARL) had set up a monitoring system throughout Australia and routinely measured samples from the Sydney region. Results of these early surveys were published between 1957 and 1970, as described by Giles and Dudaitis [1982]. Further reports have been made by the Australian Ionising Radiation Advisory Council [AIRAC 1975] and the United Nations Scientific Committee on the Effects of Atomic Radiation [UNSCEAR 1977]. These studies are used as a basis for comparison with the results for milk samples reported in the later surveys.

The present monitoring system is designed to detect radioactive contaminants which may have been released from the LHRL either routinely (under authorisations from the New South Wales Department of Health) or accidentally, and to ensure that such concentrations do not result in radiation doses to members of the public in excess of limits recommended by the International Commission on Radiological Protection (ICRP) and by the National Health and Medical Research Council of Australia [NH&MRC 1981]. Doses recommended by these bodies are set for periods which extend over a normal life-time span.

2 SAMPLE COLLECTION AND PREPARATION

Samples were collected at the sites shown in **figure 1**, and details of collection and sample preparation methods are given in **table 1**. (The isotope symbols used in this report are listed in **appendix C**.)

3 ANALYTICAL METHODS

Analytical methods which have been modified and those which have been introduced since the previous survey are described in **appendix B**.

4 RESULTS

Environmental survey measurements taken during 1986 are presented in **tables 2 to 15**. Authorised airborne releases are given in **tables 16 and 17**. Authorised liquid effluent discharges to the Metropolitan Water Sewerage and Drainage Board (MWS&DB) sewers are given in **table 18**.

5 DISCUSSION OF RESULTS

Throughout the tables, where gamma spectrometry has revealed small unresolvable peaks at particular energies, these have been reported as trace amounts. This indicates the possible presence of the isotope in question but the amount is not quantifiable.

5.1 Airborne Release

Measurable concentrations of iodine-131 were occasionally recorded in air samplers during the year. The highest reading was registered for the week ending 15 April 1986 and was 2.8×10^{-3} of the derived working limit of 10 Bq m^{-3} . The derived air concentration for child members of the public [ICRP 1977, 1979], *i.e.* the most sensitive individuals, is 10 Bq m^{-3} . The average iodine-131 in air concentration for the year would have resulted in an effective dose of $0.22 \mu\text{Sv y}^{-1}$ or 2.2×10^{-4} of the limit.

The milk monitoring data for caesium-137 and iodine-131 are given in table 3. No iodine-131 was detected in milk during the year, and the possible trace amounts of caesium-137 found were below the minimum detectable level of $3 \times 10^{-4} \text{ Bq g}^{-1}$ (fresh weight).

Noble gas releases were always below the authorised limit during the year. See tables 16 and 17. The method of Petersen [1982] was used to calculate that, for an average year and given maximum authorised discharge levels, the most exposed individual would receive less than 0.01 mSv y^{-1} , *i.e.* less than one per cent of the NH&MRC recommendation.

5.2 Woronora Estuary Samples

Discharges of liquid effluent to the Woronora River ceased on 1 July 1980. Residual levels of radioactivity in samples from the estuary were monitored until December 1983 when no further radioactivity could be measured. In response to an incident involving vandalism, samples of seagrass (*Zostera sp*) were collected in September 1985 as previously reported (ANSTO/E677) and were followed up by further measurements in January 1986. Following a second incidence of vandalism in July 1986 more samples of seagrass and beach sands were collected. The routine water samples which are measured for tritium as a precaution against unknown accidental discharges continued to be collected throughout the year. No tritium was detected in these samples during 1986.

5.2.1 Seagrass samples

Samples of seagrass collected in January 1986 contained ^{60}Co which was just above the detectable limit. No ^{60}Co could be measured in the samples collected in July immediately after the damage to the pipeline.

5.2.2 Beach sand

Data for Woronora beach sand, sampled in July 1986, are given in table 20. There was no increase in the radioactivity on beach sand from the breakage of the low-level effluent pipeline. The activity is well below the limit for swimmers using the beaches [Fry 1966].

5.3 Stormwater Outlets

Results for samples of soil and vegetation collected near stormwater outlets as a check on good housekeeping are shown in table 5. Results for water samples collected at the same site are given in table 6. The levels of ^{60}Co , ^{137}Cs , ^{95}Zr , and ^3H found in the water samples are just above the limit of detection.

If it is assumed that a person took all his or her drinking water supplies from the stormwater, the highest concentrations of ^{60}Co , ^{137}Cs , ^{95}Zr , and ^3H measured represent 6×10^{-3} , 10^{-5} , 3×10^{-4} and 10^{-2} of the derived working limit (DWL) respectively. When, as recommended by the ICRP, the concentrations are averaged over the year, the

corresponding ratios to DWL become 2×10^{-4} , 3×10^{-7} , 6×10^{-6} and 6×10^{-4} respectively. The ephemeral creek into which this stormwater flows is not used as a source of drinking water.

During 1986, water samples were collected from Strassman, Barden and MDP Creeks at points designated by the State Pollution Control Commission (SPCC). These points are shown on **figure 1**. Results for these samples are given in **table 7**. All results were well below the Clean Waters Regulations limits of 1.1 Bq L^{-1} for gross alpha activity and 11.1 Bq L^{-1} for gross beta activity.

Samples of water were collected from the SPCC sampling weir on Barden Creek at weekly intervals during 1986 to measure tritium and the results are shown in **table 8**. The highest concentration recorded represents 10^{-2} of the DWL which assumes that all drinking water is taken from that source. Average concentrations over the reported period represent 3×10^{-3} of the DWL.

5.4 Effluent Discharge Pipeline

Table 9 shows the dose rates at various points on the discharge pipeline during the 1986 survey. The maximum annual radiation dose for members of the public recommended by the ICRP [1979] is $1000 \mu\text{Sv}$ per year. Because of the isolated position of the exposed sections of the discharge pipe, the likelihood of occupancy by members of the public is very low, so the limits would not be exceeded. Checks on water and soil at points along the pipeline revealed no radioactivity above background levels with the exception of a soil sample collected near scour valve no. 1. This soil contained $0.03 \text{ Bq g}^{-1} {}^{137}\text{Cs}$. As it was unlikely that the radioactivity of this soil could enter the human food chain there was no impact on members of the public. Results of soil analyses are given in **table 10**.

5.5 Freshwater Section of Woronora River

Checks were made throughout the year on radioactivity in the freshwater section of the Woronora River at the point of entry for drainage from LHRL. Samples were also collected at the Heathcote Road crossing, upstream and above any possible input from LHRL, to provide a direct measure of background levels. These are presented in **table 11**.

5.6 Little Forest Burial Ground

Results of measurements at the Little Forest Burial Ground (LFBG) are given in **tables 12, 13, 14 and 15**. The positions of sampling points are shown on **figure 2**. Tritium was found in BH10, OS2, OS3 and BHF. Of these, BHF is the only one which lies outside the fenced area. The concentration of tritium in all boreholes was similar to that found previously. The tritium found in BHF, which is acting as a tracer, has no health significance since groundwater is not used from this area. No tritium was found in creeks draining the LFBG. No ${}^{239}\text{Pu}$ or beryllium (Be) was detected on remotely operating air sampler filters. The minimum detectable level for Be is $0.2 \mu\text{g m}^{-3}$ and for ${}^{239}\text{Pu}$ $2.0 \times 10^{-5} \text{ Bq m}^{-3}$ after sampling 20 m^3 of air. If more air is sampled, these limits are lowered proportionally. The threshold level value (TLV) for Be is $2 \mu\text{g m}^{-3}$ and the DWL for ${}^{239}\text{Pu}$ is $5 \times 10^{-4} \text{ Bq m}^{-3}$. These limits were calculated assuming permanent exposure for 24 hours each day.

6 SUMMARY

None of the samples taken from possible human food chains in the vicinity of the Lucas Heights Research Laboratories contained radioactivity which could be attributed to the operation of the site.

Discharges of airborne radioactive gases were always within authorised limits (tables 16 and 17). The dose to the most sensitive members of the public from ^{131}I releases, calculated from results in table 2, was $0.22 \mu\text{Sv y}^{-1}$ and the calculated dose from released noble gases to the most exposed individuals was less than 0.01mSv y^{-1} . These figures represent one per cent of the most restrictive limit recommended by the NH&MRC.

7 ACKNOWLEDGEMENTS

The authors would like to thank Mr J.A. Fogden for his assistance in field and laboratory work. Potassium levels were determined by the CSIRO's Division of Energy Chemistry (now the Division of Fuel Technology). The strontium-90 levels were determined by the Environmental Chemistry Section. Beryllium levels and initial estimates of plutonium-239 on the Little Forest Burial Ground air filters were determined by the AAEC's Health and Safety Division.

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TABLE 1
SAMPLE COLLECTION SCHEDULE AND PREPARATION DETAILS

Sample	Station	Frequency	Collection Details	Special Preparations
Stormwater	MDP Creek 60 m from LHRL outlet No. 1	Weekly	Sampled by bucket at outlet of the drain	10 L sample evaporated to dryness and the residue counted and 50 mL collected and distilled for tritium
	Barden Creek	Weekly	Sampled at the weir	50 mL collected and distilled for tritium
	Others	Quarterly	Sampled by beaker at the outlet of the drain	Distilled for tritium
Estuary water	E5.9	Weekly	From surface by bottle	Distilled for tritium
Radioactive iodine in air	TO	Weekly	Collected on Maypacks (charcoal filters)	Gamma spectrometry of Maypacks
Milk	T3	Monthly	Sampled from milk produced by locally grazed cows	Gamma spectrometry of whole milk
Vegetation	T1, LHRL stormwater outlets	Six-monthly	Cut by hand clippers	Whole unwashed vegetation ashed
Sand/soil	TO, T1; LHRL stormwater	Six-monthly	Scooped from surface	Sample ashed and sieved. Sample passing 10 mesh BSS counted for beta and gamma emitters. Sample between 60 and 120 mesh BSS counted for alpha emitters.
Groundwater	Little Forest Burial Ground	Six-monthly	Boreholes pumped dry, allowed to refill and sampled from the bottom	15 L sample evaporated to dryness and the residue counted. 50 mL collected and distilled for tritium.
Be, ²³⁹ Pu	Little Forest Burial Ground	Monthly	Collected on 0.8 µm filter	Disc, 1 cm diameter cut out for Be analysis. Composite made of the monthly samples for ²³⁹ Pu analysis by alpha spectrometry.
Creekwater	T2	Yearly	Sampled by bucket	5 L collected and passed through cation-exchange resin then ashed and counted. 50 mL collected and distilled for tritium.
	Barden Creek MDP Creek Strassman Creek	Monthly	Sampled by bottle, after rain	Prepared according to Clean Waters Act Regulations

TABLE 2
RADIOACTIVE IODINE IN AIR, 1986

Week ending	¹³¹ I (Bq m ⁻³)	Week ending	¹³¹ I (Bq m ⁻³)
7/1/86	LLD	8/7/86	LLD
14/1/86	LLD	15/7/86	LLD
21/1/86	6.1x10 ⁻³	23/7/86	LLD
31/1/86	LLD	29/7/86	LLD
4/2/86	LLD	5/8/86	LLD
12/2/86	LLD	12/8/86	LLD
19/2/86	LLD	19/8/86	LLD
25/2/86	LLD	26/8/86	LLD
4/3/86	LLD	3/9/86	LLD
11/3/86	LLD	10/9/86	LLD
18/3/86	LLD	16/9/86	LLD
25/3/86	LLD	23/9/86	LLD
1/4/86	LLD	30/9/86	LLD
8/4/86	LLD	7/10/86	3.0x10 ⁻³
15/4/86	2.8x10 ⁻²	14/10/86	LLD
22/4/86	2.6x10 ⁻²	21/10/86	LLD
29/4/86	8.6x10 ⁻³	28/10/86	LLD
6/5/86	LLD	4/11/86	2.5x10 ⁻³
15/5/86	LLD	11/11/86	LLD
20/5/86	6.3x10 ⁻³	19/11/86	4.2x10 ⁻³
27/5/86	LLD	25/11/86	LLD
3/6/86	LLD	2/12/86	LLD
11/6/86	LLD	9/12/86	6.6x10 ⁻³
18/6/86	LLD	16/12/86	5.5x10 ⁻³
24/6/86	4.9x10 ⁻³	23/12/86	4.9x10 ⁻³
1/7/86	LLD	31/12/86	5.7x10 ⁻³

Three air samplers are located along the eastern boundary of the site, where suburban residences are closest. Results are calculated making the conservative assumptions that (1) all activity was released during the first day of sampling period; and (2) all the activity was concentrated at one sampling point.

LLD = Less than the limit of detection. The limit of detection for iodine-131 in air is 2.5x10⁻³ Bq m⁻³.

TABLE 3
RADIOACTIVITY IN MILK SAMPLES, 1986

Station	Date	Radioactivity (Bq g ⁻¹ fresh volume)	
		¹³⁷ Cs	¹³¹ I
T3 (Menai)	29/1/86	LLD	LLD
	27/2/86	LLD	LLD
	31/3/86	LLD	LLD
	30/4/86	LLD	LLD
	30/5/86	LLD	LLD
	25/6/86	LLD	LLD
	5/8/86	LLD	LLD
	28/8/86	LLD	LLD
	29/9/86	LLD	LLD
	29/10/86	LLD	LLD
	21/11/86	LLD	LLD
	16/12/86	LLD	LLD

The analytical method used for ¹³¹I in milk has a minimum detectable level of 1x10⁻³ Bq g⁻¹ fresh volume. For ¹³⁷Cs the minimum detectable level was 3x10⁻⁴ Bq g⁻¹.

LLD = Less than the limit of detection.

TABLE 4
TRITIUM IN WORONORA RIVER WATER SAMPLES
AT STATION E5.9, 1986

Date	Tritium (Bq mL ⁻¹)	Date	Tritium (Bq mL ⁻¹)	Date	Tritium (Bq mL ⁻¹)
6/1/86	LLD	5/5/86	LLD	1/9/86	LLD
13/1/86	LLD	12/5/86	LLD	9/9/86	LLD
20/1/86	LLD	20/5/86	LLD	15/9/86	LLD
29/1/86	LLD	26/5/86	LLD	23/9/86	LLD
7/2/86	LLD	2/6/86	LLD	29/9/86	LLD
14/2/86	LLD	12/6/86	LLD	7/10/86	LLD
19/2/86	LLD	17/6/86	LLD	13/10/86	LLD
26/2/86	LLD	23/6/86	LLD	21/10/86	LLD
3/3/86	LLD	30/6/86	LLD	27/10/86	LLD
10/3/86	LLD	7/7/86	LLD	3/11/86	LLD
17/3/86	LLD	15/7/86	LLD	10/11/86	LLD
26/3/86	LLD	21/7/86	LLD	19/11/86	LLD
1/4/86	LLD	28/7/86	LLD	24/11/86	LLD
7/4/86	LLD	4/8/86	LLD	1/12/86	LLD
15/4/86	LLD	12/8/86	LLD	9/12/86	LLD
21/4/86	LLD	18/8/86	LLD	16/12/86	LLD
28/4/86	LLD	25/8/86	LLD	22/12/86	LLD
				30/12/86	LLD

Derived limiting concentration (DLC) [ICRP 1979].

DLC = 80 Bq mL⁻¹ (if taken as drinking water).

LLD = Less than the limit of detection. The limit of detection for tritium is 0.25 Bq mL⁻¹.

TABLE 5
RADIOACTIVITY IN SAMPLES OF SOIL AND VEGETATION FROM
STORMWATER OUTLETS, 1986

Station	Date	Sample type	Radioactivity (Bq g ⁻¹ FW or DW [*])			K (µg g ⁻¹ DW)
			Gross α	Gross β (less ⁴⁰ K)	γ-emitters	
Drain on road at West fence	10/1/86	Soil	0.37	0.24	²³⁸ U+ ²³² Th series	534
	17/4/86	Soil	0.39	0.17	²³⁸ U+ ²³² Th series	417
	16/7/86	Soil	0.41	0.14	²³⁸ U+ ²³² Th series	466
	10/10/86	Soil	0.41	0.11	²³⁸ U+ ²³² Th series	455
Drain at Fermi St.	10/1/86	Soil	0.31	0.21	¹³⁷ Cs trace	1107
	17/4/86	Soil	0.33	0.31	²³⁸ U+ ²³² Th series	164
	16/7/86	Soil	0.35	0.24	²³⁸ U+ ²³² Th series	1646
	10/10/86	Soil	0.38	0.29	²³⁸ U+ ²³² Th series	2148
Drain opposite Bld.23	10/1/86	Soil	0.26	0.19	⁶⁰ Co = 0.013 ²³⁸ U+ ²³² Th series	294
	17/4/86	Soil	0.28	0.22	²³⁸ U+ ²³² Th series	412
	16/7/86	Soil	0.38	0.15	⁶⁰ Co = 0.016 ¹³⁷ Cs = 0.008 ²³⁸ U+ ²³² Th series	402
Drain No.1 opposite	10/1/86	Vegetation	<0.01	0.04	²³⁸ U+ ²³² Th series	3417
	10/1/86	Soil	0.17	0.17	Trace ²³⁸ U+ ²³² Th series	490
Strassman Cr.	17/4/86	Vegetation	<0.01	0.02	Trace ²³⁸ U+ ²³² Th series	3952
	17/4/86	Soil	0.35	0.26	²³⁸ U+ ²³² Th series	588
	16/7/86	Vegetation	<0.01	0.02	Trace ²³⁸ U+ ²³² Th series	3914
	16/7/86	Soil	0.19	0.18	Trace ²³⁸ U+ ²³² Th series	598
	10/10/86	Vegetation	0.01	0.02	LLD	3636
	10/10/86	Soil	0.19	0.17	Trace ²³⁸ U+ ²³² Th series	353
Drain No.2 opposite	10/1/86	Soil	0.14	0.10	Trace ²³⁸ U+ ²³² Th series	446
	17/4/86	Soil	0.14	0.15	Trace ²³⁸ U+ ²³² Th series	485
Strassman Cr.	16/7/86	Soil	0.22	0.19	Trace ²³⁸ U+ ²³² Th series	657
	10/10/86	Soil	0.24	0.15	Trace ²³⁸ U+ ²³² Th series	627
Drain opposite meteorological tower	10/1/86	Soil	0.49	0.20	Trace ²³⁸ U+ ²³² Th series	617
	17/4/86	Soil	0.48	0.21	Trace ²³⁸ U+ ²³² Th series	764
	16/7/86	Soil	0.50	0.26	Trace ²³⁸ U+ ²³² Th series	176
	10/10/86	Soil	0.46	0.25	Trace ²³⁸ U+ ²³² Th series	698

*Radioactivity in Bq g⁻¹ fresh weight (FW) for vegetation samples and Bq g⁻¹ dry weight (DW) for soil samples.

Table 5 contd.

Station	Date	Sample type	Radioactivity (Bq g ⁻¹ FW or DW ^{**})			K (µg g ⁻¹ DW)
			Gross α	Gross β (less ⁴⁰ K)	γ-emitters	
Drain behind	10/1/86	Soil	0.27	0.06	Trace ²³⁸ U+ ²³² Th series	248
Bld. 20	17/4/86	Soil	0.80	0.05	Trace ²³⁸ U+ ²³² Th series	220
20 m from LHRL	10/1/86	Vegetation	0.01	0.04	Trace ²³⁸ U+ ²³² Th series	4029
stormwater outlet No.1	10/1/86	Soil	0.54	0.38	¹³⁷ Cs = 0.04 Trace ²³⁸ U+ ²³² Th series	582
	17/4/86	Vegetation	<0.01	0.11	¹³⁷ Cs = 0.01 ⁶⁰ Co = trace 0.50 MeV = trace Trace ²³⁸ U+ ²³² Th series	3744
	17/4/86	Soil	0.48	0.61	¹³⁷ Cs = 0.23 ⁵⁴ Mn = 0.05 ⁶⁰ Co = 0.01	816
	16/7/86	Vegetation	0.01	0.07	Trace ²³⁸ U+ ²³² Th series ¹³⁷ Cs = trace 0.50 MeV = trace	4503
	16/7/86	Soil	0.58	0.47	Trace ²³⁸ U+ ²³² Th series ¹³⁷ Cs = 0.13 ⁶⁰ Co = 0.01	480
	10/10/86	Vegetation	<0.01	0.09	Trace ²³⁸ U+ ²³² Th series ¹³⁷ Cs = 0.01	3996
	10/10/86	Soil	1.04	0.50	Trace ²³⁸ U+ ²³² Th series ¹³⁷ Cs = 0.01 ⁶⁰ Co = 0.06	1083

**Radioactivity in Bq g⁻¹ fresh weight (FW) for vegetation samples and Bq g⁻¹ dry weight (DW) for soil samples.

TABLE 6
RADIOACTIVITY IN WATER SAMPLES FROM STORMWATER OUTLETS, 1986

Station	Date	Radioactivity (Bq L ⁻¹)			Tritium (Bq mL ⁻¹)
		Gross α	Gross β (incl. ⁴⁰ K)	γ -emitters	
Drain behind Bld. 1	10/1/86	-	-	-	LLD
	17/4/86	-	-	-	LLD
	16/7/86	-	-	-	0.72
	10/10/86	-	-	-	0.35
Drain on road at west fence	17/4/86	-	-	-	LLD
	10/10/86	-	-	-	LLD
Drain at Fermi St.	17/4/86	-	-	-	LLD
	16/7/86	-	-	-	LLD
	10/10/86	-	-	-	0.31
Drain opposite Bld. 23	16/7/86	-	-	-	0.37
	10/10/86	-	-	-	LLD
Drain No.1 opposite Strassman Cr.	10/1/86	-	-	-	LLD
	17/4/86	-	-	-	LLD
	16/7/86	-	-	-	LLD
	10/10/86	-	-	-	LLD
Drain No. 2 opposite Strassman Cr.	16/7/86	-	-	-	LLD
	10/10/86	-	-	-	LLD
Drain opposite meteorological tower	17/4/86	-	-	-	LLD
	10/10/86	-	-	-	LLD
Drain behind Bld. 20	10/1/86	-	-	-	LLD
	17/4/86	-	-	-	LLD
	10/10/86	-	-	-	LLD
LHRL stormwater outlet No.1 near south gate	10/1/86	-	-	-	LLD
	17/4/86	-	-	-	LLD
	16/7/86	-	-	-	LLD
	10/10/86	-	-	-	LLD
20 m from LHRL stormwater outlet No.1	10/1/86	-	-	-	LLD
	17/4/86	-	-	-	LLD
	16/7/86	-	-	-	LLD
	10/10/86	-	-	-	LLD
60 m from LHRL stormwater outlet No.1	6/1/86	0.25	0.24	LLD	LLD
	13/1/86	0.27	0.23	LLD	LLD
	20/1/86	0.23	0.30	Trace ²³⁸ U+ ²³² Th series	LLD
	28/1/86	0.14	0.45	LLD	LLD
	7/2/86	0.28	0.19	LD	LLD
	14/2/86	0.16	0.16	LLD	LLD
	19/2/86	0.18	0.14	LLD	LLD
	26/2/86	0.37	0.23	LLD	LLD
	3/3/86	0.59	0.27	LLD	0.76
	10/3/86	0.60	0.24	Trace ²³⁸ U+ ²³² Th series	LLD
	17/3/86	0.18	0.10	LLD	LLD
	26/3/86	0.29	0.13	LLD	LLD
	1/4/86	0.14	0.15	LLD	LLD
	7/4/86	0.13	0.26	LLD	LLD
	15/4/86	0.11	0.24	LLD	LLD

Table 6 contd.

Station	Date	Radioactivity (Bq L ⁻¹)			Tritium (Bq mL ⁻¹)
		Gross α	Gross β (incl. ⁴⁰ K)	γ -emitters	
60 m from LHRL stormwater outlet No.1	21/4/86	0.04	0.16	LLD	LLD
	23/4/86	-	-	-	LLD
	28/4/86	0.25	1.03	¹³⁷ Cs = 0.017 ⁹⁵ Zr = 0.017 Trace ²³⁸ U+ ²³² Th series	LLD
	5/5/86	0.13	0.24	LLD	LLD
	21/5/86	0.12	0.11	LLD	LLD
	26/5/86	0.13	0.07	LLD	LLD
	2/6/86	0.14	0.12	LLD	LLD
	12/6/86	0.25	0.13	LLD	LLD
	17/6/86	0.12	0.1	LLD	0.54
	23/6/86	0.10	0.10	LLD	LLD
	30/6/86	0.18	0.08	LLD	LLD
	7/7/86	0.06	0.06	LLD	LLD
	15/7/86	0.14	0.10	LLD	LLD
	21/7/86	0.11	0.12	LLD	LLD
	28/7/86	0.05	0.05	LLD	LLD
	4/8/86	7.19	2.51	0.50 MeV = 0.024 ¹³⁷ Cs = 0.597 ⁶⁰ Co = 0.048 Trace ²³⁸ U+ ²³² Th series	LLD
	12/8/86	0.24	0.19	LLD	LLD
	18/8/86	0.12	0.14	LLD	LLD
	25/8/86	0.25	5.09	¹³⁷ Cs = 0.431 ⁶⁰ Co = 0.014 0.50 MeV=trace Trace ²³⁸ U+ ²³² Th series	LLD
	1/9/86	0.04	0.07	LLD	LLD
	09/9/86	0.06	0.07	LLD	LLD
	15/9/86	0.18	0.77	0.50 MeV = 0.026 ¹³⁷ Cs = 0.154 Trace ²³⁸ U+ ²³² Th series	LLD
	23/9/86	0.03	0.08	LLD	LLD
	29/9/86	0.10	0.26	LLD	LLD
	7/10/86	0.15	0.08	LLD	LLD
	13/10/86	0.06	0.08	LLD	LLD
	21/10/86	0.06	0.17	LLD	LLD
	27/10/86	0.07	0.16	LLD	LLD
	03/11/86	0.12	0.24	LLD	LLD
	10/11/86	0.18	0.30	LLD	LLD
	19/11/86	0.17	0.58	¹³⁷ Cs = 0.044	LLD
	24/11/86	0.11	0.29	LLD	LLD
	27/11/86	0.03	0.30	-	LLD
28/11/86	0.03	0.28	-	LLD	
1/12/86	0.14	0.21	LLD	LLD	
9/12/86	0.09	0.29	LLD	LLD	
16/12/86	0.30	0.63	LLD	LLD	
22/12/86	0.33	0.42	LLD	LLD	
30/12/86	0.63	0.23	LLD	LLD	

- = not measured

Radioactivity (Bq L⁻¹) refers to the radioactivity present per litre of water sample (suspended and dissolved).LLD = Less than the limit of detection. The limit of detection for tritium is 0.25 Bq mL⁻¹.

TABLE 7
RADIOACTIVITY AT SPCC SAMPLING POINTS, 1986
(Bq L⁻¹)^(a)

Date 1986	Strassman Creek		Barden Creek		MDP Creek	
	Gross α	Gross β^*	Gross α	Gross β^*	Gross α	Gross β^*
29/1/86	LLD	0.10	LLD	LLD	LLD	0.20
26/2/86	LLD	0.10	LLD	LLD	LLD	0.14
3/3/86	LLD	LLD	LLD	LLD	LLD	LLD
18/4/86	LLD	LLD	LLD	0.14	LLD	0.12
7/5/86	LLD	0.11	LLD	LLD	LLD	0.20
18/6/86	LLD	0.12	LLD	LLD	LLD	0.12
18/7/86	LLD	0.11	LLD	0.12	LLD	LLD
29/8/86	LLD	0.10	LLD	LLD	LLD	0.15
15/9/86	LLD	0.15	LLD	0.11	LLD	0.17
3/10/86	LLD	0.28	LLD	0.23	LLD	0.13
7/11/86	LLD	0.10	LLD	0.10	LLD	0.19
27/11/86	-	-	-	-	LLD	0.18
28/11/86	-	-	-	-	LLD	0.13
18/12/86	LLD	0.14	LLD	LLD	LLD	0.22

- (a) Minimum detection limit $\alpha = 0.07 \text{ Bq L}^{-1}$,
 Minimum detection limit $\beta = 0.10 \text{ Bq L}^{-1}$,
 * includes ⁴⁰K contribution,
 - = not measured.

LLD = Less than the minimum detection limit.

TABLE 8
TRITIUM IN WATER FROM SPCC SAMPLING POINT
AT BARDEN CREEK WEIR, 1986

Date	Tritium (Bq mL ⁻¹)	Date	Tritium (Bq mL ⁻¹)
6/1/86	0.32	7/7/86	0.68
13/1/86	0.37	15/7/86	0.30
20/1/86	LLD	21/7/86	0.35
28/1/86	LLD	28/7/86	0.30
7/2/86	LLD	4/8/86	LLD
14/2/86	LLD	12/8/86	LLD
19/2/86	LLD	18/8/86	LLD
26/2/86	LLD	25/8/86	LLD
3/3/86	LLD	1/9/86	0.27
10/3/86	LLD	9/9/86	0.38
17/3/86	0.25	15/9/86	0.44
26/3/86	LLD	23/9/86	0.38
1/4/86	LLD	29/9/86	0.80
7/4/86	LLD	7/10/86	0.40
15/4/86	LLD	13/10/86	0.37
21/4/86	LLD	21/10/86	0.59
28/4/86	LLD	27/10/86	0.65
5/5/86	LLD	3/11/86	0.58
12/5/86	LLD	10/11/86	0.70
20/5/86	LLD	19/11/86	0.26
26/5/86	LLD	24/11/86	0.31
2/6/86	LLD	1/12/86	0.42
12/6/86	LLD	9/12/86	0.45
17/6/86	LLD	16/12/86	0.42
23/6/86	LLD	22/12/86	0.48
30/6/86	LLD	30/12/86	0.55

Derived limiting concentration (DLC) [ICRP 1979]

DLC = 80 Bq mL⁻¹ (if taken as drinking water).

LLD = Less than the limit of detection for tritium, which is 0.25 Bq mL⁻¹.

TABLE 9

GAMMA SURVEY - EFFLUENT DISCHARGE PIPELINE, 1986

Survey of exposed portions of pipeline between LHRL and the MWS&DB sewer connection using an EBERLINE type PRM-7 field rate meter

Date	Location	Dose rate ($\mu\text{Sv h}^{-1}$)		Background range
		Ground	Pipeline	
10.7.86	All pipe joints	<0.25	<0.30	0.10 to 0.16
21.11.86	All pipe joints	<0.13	<0.17	0.05 to 0.16

TABLE 10
RADIOACTIVITY IN SAMPLES TAKEN NEAR
EFFLUENT DISCHARGE PIPELINE, 1986

Station	Date	Sample Type	Radioactivity (Bq g ⁻¹ DW)			³ H (Bq mL ⁻¹)	K (μg g ⁻¹)
			Gross α	Gross β (Less ⁴⁰ K)	γ-Emitters		
Near Scour valve No.1	10.7.86	Sand	0.71	0.06	Trace ²³⁸ U+ ²³² Th	-	214
	10.7.86	Water	-	-	-	LLD	-
	27.11.86	Sand	0.51	0.12	Trace ²³⁸ U+ ²³² Th ¹³⁷ Cs=0.03	-	398
	27.11.86	Water	-	-	-	LLD	-
Woronora River at point where crossed by effluent discharge pipe	10.7.86	Sand	0.75	0.06	Trace ²³⁸ U+ ²³² Th	-	256
	10.7.86	Water	-	-	-	LLD	-
	27.11.86	Sand	0.24	0.08	Trace ²³⁸ U+ ²³² Th	-	598
	27.11.86	Water	-	-	-	LLD	-

- = not measured

LLD = Less than the limit of detection

LLD for ³H is 0.25 Bq mL⁻¹

TABLE 11
RADIOACTIVITY IN FRESHWATER SECTION
OF WORONORA RIVER, 1986

Station	Date	Radioactivity		
		Sand	Water	
		⁹⁰ Sr (Bq Kg ⁻¹ DW)	⁹⁰ Sr (Bq L ⁻¹)	³ H (Bq mL ⁻¹)
Woronora River at Heathcote Rd crossing (upstream of LHRL)	29.1.86	0.08	0.0046	LLD
	23.4.86	0.13	0.0057	LLD
	18.7.86	0.10	0.0124	-
	3.10.86	0.03	0.0062	-
Woronora River at the point of Lucas Heights drainage	29.1.86	2.70	0.0028	LLD
	23.4.86	0.11	0.0014	LLD
	18.7.86	0.20	0.0025	-
	3.10.86	0.14	LLD	-

DW = Dry Weight

- = not measured

Limit of detection : for ⁹⁰Sr in water is 0.0007 Bq.L⁻¹
: for ⁹⁰Sr in sand is 0.0007 Bq Kg⁻¹DW
: for ³H in water is 0.25 Bq mL⁻¹

LLD = Less than the limit of detection.

TABLE 12
RADIOACTIVITY IN SAMPLES OF SOIL
FROM LITTLE FOREST BURIAL GROUND, 1986

Sampling Location	Date	Radioactivity (Bq g ⁻¹ Dry Weight)			Potassium (µg g ⁻¹)
		Gross α	Gross β (Less ⁴⁰ K)	γ-Emitters	
Point No.1	28.1.86	0.47	0.42	Trace ²³⁸ U + ²³² Th series ¹³⁷ Cs = 0.02	2372
Point No.5	28.1.86	0.38	0.29	Trace ²³⁸ U + ²³² Th series	2198
Point No.6	28.1.86	0.54	0.93	Trace ²³⁸ U + ²³² Th series ⁶⁰ Co = 0.04	3068
Point No.1	4.6.86	0.64	0.61	Trace ²³⁸ U + ²³² Th series	4005
Point No.5	4.6.86	0.49	0.54	Trace ²³⁸ U + ²³² Th series	2081
Point No.6	4.6.86	0.71	1.53	Trace ²³⁸ U + ²³² Th series ⁶⁰ Co = 0.08	1903
Point No.1	5.12.86	0.74	0.74	Trace ²³⁸ U + ²³² Th series	4100
Point No.5	5.12.86	0.49	0.50	Trace ²³⁸ U + ²³² Th series	2989
Point No.6	5.12.86	0.83	2.20	Trace ²³⁸ U + ²³² Th series ⁶⁰ Co = 0.24	2545

TABLE 13
RADIOACTIVITY IN SAMPLES OF GROUNDWATER FROM
LITTLE FOREST BURIAL GROUND, 1986

Bore Hole No.	Date	Sediment (Bq g ⁻¹)			³ H (Bq mL ⁻¹)
		Gross α	Gross β (Less ⁴⁰ K)	γ -Emitters	
BH1	28/1/86	2.65	0.83	LLD	LLD
BH2	28/1/86	3.15	1.12	LLD	LLD
BH3	28/1/86	2.76	1.17	Trace ²³⁸ U + ²³² Th series	LLD
BH4	28/1/86	2.12	0.66	LLD	LLD
BH6	28/1/86	1.94	0.86	LLD	LLD
BH10	28/1/86	0.29	0.59	LLD	1.42
OS1	28/1/86	0.85	0.65	LLD	LLD
OS2	28/1/86	1.83	1.34	Trace ²³⁸ U + ²³² Th series	3.63
OS3	28/1/86	1.73	5.64	LLD	5.09
BHA	28/1/86	1.32	0.83	LLD	LLD
BHB	28/1/86	0.09	0.14	Trace ²³⁸ U + ²³² Th series	LLD
BHC	28/1/86	0.10	0.18	LLD	LLD
BHD	28/1/86	0.49	0.53	LLD	LLD
BHE	28/1/86	0.10	0.18	LLD	LLD
BHF	28/1/86	1.55	4.37	LLD	1.42
BH4	4/6/86	4.06	0.80	Trace ²³⁸ U + ²³² Th series	LLD
BH6	4/6/86	0.81	0.25	Trace ²³⁸ U + ²³² Th series	LLD
BH10	4/6/86	0.26	0.25	LLD	3.07
OS2	4/6/86	1.67	1.06	Trace ²³⁸ U + ²³² Th series	3.68
OS3	4/6/86	1.55	2.71	LLD	19.72
BHA	4/6/86	0.29	0.20	Trace ²³⁸ U + ²³² Th series	LLD
BHB	4/6/86	0.16	0.16	LLD	LLD
BHC	4/6/86	0.17	0.16	LLD	LLD
BHD	4/6/86	0.29	0.32	Trace ²³⁸ U + ²³² Th series	LLD
BHE	4/6/86	0.36	0.17	LLD	LLD
BHF	4/6/86	1.61	1.95	LLD	1.56
BH2	5/12/86	3.56	0.98	Trace ²³⁸ U + ²³² Th series	LLD
BH4	5/12/86	3.13	0.56	Trace ²³⁸ U + ²³² Th series	LLD
BH6	5/12/86	1.93	0.29	Trace ²³⁸ U + ²³² Th series	LLD
BH10	5/12/86	0.51	0.36	Trace ²³⁸ U + ²³² Th series	3.01
OS1	5/12/86	1.36	0.49	LLD	LLD
OS2	5/12/86	1.48	0.85	Trace ²³⁸ U + ²³² Th series	2.69

Table 13 contd.

OS3	5/12/86	1.04	2.41	Trace ^{238}U + ^{232}Th series	15.8
BHA	5/12/86	0.27	0.29	Trace ^{238}U + ^{232}Th series	LLD
BHB	5/12/86	0.15	0.13	Trace ^{238}U + ^{232}Th series	LLD
BHD	5/12/86	0.55	0.39	LLD	LLD
BHE	5/12/86	0.28	0.20	LLD	LLD
BHF	5/12/86	1.87	3.44	Trace ^{238}U + ^{232}Th series	1.02

LLD = Less than the limit of detection - LLD for ^3H is 0.25 Bq mL^{-1} .

TABLE 14
RADIOACTIVITY IN SAMPLES TAKEN FROM CREEKS NORTH OF LITTLE FOREST BURIAL
GROUND, 1986

SAND						
Sample Station	Date	Radioactivity (Bq g ⁻¹ DW)			K (μg g ⁻¹)	
		Gross α	Gross β (less ⁴⁰ K)	γ-emitters		
Barden Creek above junction with Mill Ck.	3/12/86	0.44	0.07	Trace ²³⁸ U + ²³² Th series	239	
Mill Creek above junction with Barden Ck.	3/12/86	0.20	0.03	Trace ²³⁸ U + ²³² Th series	279	
WATER						
Sample Station	Date	Radioactivity (Bq g ⁻¹ DW)			³ H (Bq mL ⁻¹)	
		Gross α	Gross β (less ⁴⁰ K)	γ-emitters		
Barden Ck. above junction with Mill Ck.	3/12/86	0.04	0.16	LLD	LLD	
Mill Ck. above junction with Barden Ck.	3/12/86	0.16	0.08	LLD	LLD	

LLD = Less than the limit of detection

LLD for ³H is 0.25 Bq mL⁻¹

TABLE 15
RESULTS OF AIR SAMPLING AT LITTLE FOREST
BURIAL GROUND, 1986

Period	Air volume Sampled (m ³)	(2) Be (μg m ⁻³)	(3) ²³⁹ Pu (Bq m ⁻³)
21/11/85-2/1/86	31.39	LLD	<0.8x10 ⁻³
2/1/86-25/3/86	108.68	LLD	LLD
25/3/86-26/6/86	50.39	LLD	LLD
26/6/86-24/9/86	79.39	LLD	LLD
24/9/86-22/12/86	108.74	LLD	LLD
Composite ⁽¹⁾	378.59	-	LLD

- (1) Composite sample of all air filters for 1986. Result determined by alpha spectrometry.
- (2) TLV for Be = 2 μg m⁻³ DWC for ²³⁹Pu = 5x10⁴ Bq m⁻³
- (3) LLD = less than the limit of detection. The limit of detection for Be is 0.2 μg m⁻³ and for ²³⁹Pu is 2x10⁻⁵ Bq m⁻³

TABLE 16
AIRBORNE RADIOACTIVITY DISCHARGES FROM INDIVIDUAL DISCHARGE POINTS, 1986

Period and Bld. No.	Gross α (kBq)	^{131}I (MBq)	^{90}Sr (MBq)	^3H (GBq)	Fission product noble gases (TBq)	Other activity (MBq)
Quarter No. 1						
Bld. 2	<22	1.74×10^3	<1	-	46.6	1.5×10^4
3	1.31×10^2	1.7	<1	-	-	Nil
15(Hifar)	<4	2.2	2.0	7.80×10^2	19.9	75.9
19	<32	2.9	<1	-	-	Nil
23A	<19	1.2×10^3	<1	-	-	Nil
23B	<2	<1	<1	-	-	7.79×10^2
41	<6	1.1	<1	-	-	<1
56	<18	1.3	<1	-	-	Nil
57	<3	<1	<1	1.34	-	Nil
64A	28.7	<1	<1	-	-	Nil
64B	28.7	<1	<1	-	-	Nil
Quarter No. 2.						
Bld. 3	<6	2.2	$<1 \times 10^{-1}$	-	-	Nil
15	<6	3.8	1.8×10^{-1}	9.7×10^2	19.6	92
19	<31	5.1	3×10^{-1}	-	-	Nil
23A	<20	2.0×10^3	$<4 \times 10^{-1}$	-	-	9.7×10^2
23B	<1.0	8.0×10^{-1}	$<2.0 \times 10^{-2}$	-	-	Nil
41	<7.9	7×10^{-1}	$<1 \times 10^{-1}$	-	-	Nil
54	<74	2.4×10^3	1.4×10^{-1}	-	60	2.0×10^4
56	<18	3.4	$<2.0 \times 10^{-1}$	-	-	Nil
57	<3.4	6.0×10^{-1}	$<5.0 \times 10^{-2}$	74	-	Nil
64A	<3	<1	$<6.0 \times 10^{-2}$	-	-	Nil
64B	<6	1.5	$<1.0 \times 10^{-1}$	-	-	Nil
Quarter No. 3						
Bld. 2	<7	6124	<0.1	-	74.3	9.8×10^4
3	<5	2	<0.1	-	-	Nil
15	<2	3.0	<0.44	771	22.7	54
19	<13	5.0	<0.2	-	-	Nil
23A	<11	1295	<0.2	-	-	543
23B	<1	0	<0.01	-	-	Nil
41	<4	1	<0.1	-	-	Nil
56	<10	<1.9	<0.2	-	-	Nil
57	<2	<0.3	<0.04	1.8	-	Nil
64A	<3	<0.8	<0.05	-	-	Nil
64B	<5	<1.3	<0.09	-	-	Nil

Table 16 contd.

Period and Bld. No.	Gross α (kBq)	^{131}I (MBq)	^{90}Sr (MBq)	^3H (GBq)	Fission product noble gases (TBq)	Other activity (MBq)
Quarter No. 4						
Bld. 2	<7	1.95×10^4	<0.1	-	58.0	3.75×10^5
3	<5	1	<0.1	-	-	Nil
15	<2	3	<0.04	8.45×10^2	22.4	52
19	<13	3	<0.2	-	-	Nil
23A	<11	3.11×10^3	<0.2	-	-	89
23B	<1	0	<0.01	-	-	Nil
41	<4	1	<0.1	-	-	Nil
56	<10	<2	<0.2	-	-	Nil
57	<2	<0.6	<0.04	0.7	-	Nil
64A	<3	<0.4	<0.05	-	-	Nil
64B	<5	<2.1	<0.09	-	-	Nil

- = not measured

Where discharge figures are quoted as less than certain amounts, the figure is the maximum possible discharge, based on the limits of detection. It does not necessarily imply that the radioactivity has been detected in the effluent.

TABLE 17
AIRBORNE RADIOACTIVITY DISCHARGES FROM INDIVIDUAL DISCHARGE POINTS EXPRESSED
AS FRACTIONS OF AUTHORISED QUARTERLY POINT DISCHARGE FOR 1986

Period & Bldg. No.	Gross α	^{131}I	^{90}Sr	^3H	Fission Product Noble Gases	Other Activity
Quarter No. 1						
Bld 2	$<3.3 \times 10^{-5}$	2.6×10^{-2}	$<1.6 \times 10^{-6}$	-	0.27	9.4×10^{-3}
3	8.2×10^{-2}	1.1×10^4	$<7.7 \times 10^4$	-	-	Nil
15	$<1.2 \times 10^{-4}$	1.4×10^4	7.7×10^5	6.0×10^{-3}	0.74	1.2×10^{-3}
19	$<9.7 \times 10^{-5}$	8.8×10^{-5}	$<3.8 \times 10^{-6}$	-	-	Nil
23A	$<1.2 \times 10^{-3}$	7.5×10^2	$<7.7 \times 10^5$	-	-	Nil
23B	$<3.0 \times 10^{-4}$	$<6.3 \times 10^{-5}$	$<1.6 \times 10^4$	-	-	4.9×10^{-2}
41	$<1.8 \times 10^{-5}$	6.9×10^5	$<3.8 \times 10^{-6}$	-	-	Nil
56	$<2.3 \times 10^{-3}$	2.9×10^5	$<9.1 \times 10^4$	-	-	Nil
57	$<1.9 \times 10^{-3}$	$<1.1 \times 10^4$	$<4.5 \times 10^{-3}$	4.1×10^{-4}	-	Nil
64A	1.8×10^{-2}	$<1.2 \times 10^4$	$<4.8 \times 10^{-3}$	-	-	Nil
64B	9.6×10^{-3}	$<5.9 \times 10^4$	$<2.4 \times 10^{-3}$	-	-	Nil
Quarter No. 2.						
Bld. 3	$<3.8 \times 10^{-3}$	1.4×10^4	$<7.7 \times 10^{-5}$	-	-	Nil
15	$<1.8 \times 10^{-4}$	2.4×10^4	6.9×10^6	7.5×10^{-3}	0.73	1.4×10^{-3}
19	$<9.4 \times 10^{-5}$	1.5×10^4	1.2×10^6	-	-	Nil
23A	$<1.3 \times 10^{-3}$	0.13	$<3.1 \times 10^{-5}$	-	-	2.9×10^{-2}
23B	$<1.5 \times 10^{-4}$	5.0×10^5	$<3.1 \times 10^{-6}$	-	-	Nil
41	$<2.4 \times 10^{-5}$	4.4×10^5	$<3.8 \times 10^{-7}$	-	-	Nil
54	$<1.1 \times 10^{-4}$	3.6×10^2	2.2×10^{-7}	-	0.35	1.3×10^{-2}
56	$<2.3 \times 10^{-3}$	7.6×10^5	$<1.8 \times 10^{-4}$	-	-	Nil
57	$<2.1 \times 10^{-3}$	6.7×10^5	$<2.3 \times 10^{-4}$	2.2×10^{-2}	-	Nil
64A	$<1.9 \times 10^{-3}$	$<1.2 \times 10^4$	$<2.9 \times 10^{-4}$	-	-	Nil
64B	$<2.0 \times 10^{-3}$	8.8×10^4	$<2.4 \times 10^{-4}$	-	-	Nil
Quarter No. 3						
Bld. 2	$<1.1 \times 10^{-5}$	9.3×10^{-2}	$<1.6 \times 10^{-7}$	-	0.44	6.1×10^{-2}
3	$<3.1 \times 10^{-3}$	1.3×10^4	$<7.7 \times 10^{-5}$	-	-	Nil
15	$<6.1 \times 10^{-5}$	1.9×10^4	$<1.7 \times 10^{-5}$	5.9×10^{-3}	0.84	8.2×10^{-4}
19	$<3.9 \times 10^{-5}$	1.5×10^4	$<7.7 \times 10^{-6}$	-	-	Nil
23A	$<6.9 \times 10^{-4}$	8.1×10^2	$<1.5 \times 10^{-5}$	-	-	1.6×10^{-2}
23B	$<1.5 \times 10^{-4}$	Nil	$<1.6 \times 10^{-5}$	-	-	Nil
41	$<1.2 \times 10^{-5}$	6.3×10^5	$<3.8 \times 10^{-7}$	-	-	Nil
56	$<1.7 \times 10^{-3}$	$<5.8 \times 10^{-5}$	$<2.4 \times 10^{-4}$	-	-	Nil
57	$<1.6 \times 10^{-3}$	$<4.2 \times 10^{-5}$	$<2.2 \times 10^{-4}$	5.0×10^{-4}	-	Nil
64A	$<2.0 \times 10^{-3}$	$<9.5 \times 10^{-5}$	$<2.4 \times 10^{-4}$	-	-	Nil
64B	$<1.7 \times 10^{-3}$	$<7.8 \times 10^{-5}$	$<2.1 \times 10^{-4}$	-	-	Nil

Table 17 contd.

Period & Bldg. No.	Gross α	^{131}I	^{90}Sr	^3H	Fission Product Noble Gases	Other Activity
Quarter No. 4						
Bld. 2	$<1.1 \times 10^{-5}$	0.29	$<1.6 \times 10^{-7}$	-	0.34	0.23
3	$<3.1 \times 10^{-3}$	6.2×10^{-5}	$<7.7 \times 10^{-5}$	-	-	Nil
15	$<6.1 \times 10^{-5}$	1.9×10^{-4}	$<1.5 \times 10^{-6}$	6.5×10^{-3}	0.83	7.9×10^{-4}
19	$<3.9 \times 10^{-5}$	9.1×10^{-5}	$<7.7 \times 10^{-7}$	-	-	Nil
23A	$<6.9 \times 10^{-4}$	0.19	1.5×10^{-5}	-	-	2.7×10^{-3}
23B	$<1.5 \times 10^{-4}$	Nil	1.6×10^{-6}	-	-	Nil
41	$<1.2 \times 10^{-5}$	6.3×10^{-5}	$<3.8 \times 10^{-7}$	-	-	Nil
56	$<1.7 \times 10^{-3}$	$<6.1 \times 10^{-5}$	$<2.4 \times 10^{-4}$	-	-	Nil
57	$<1.6 \times 10^{-3}$	$<8.3 \times 10^{-5}$	$<2.2 \times 10^{-4}$	1.9×10^{-4}	-	Nil
64A	$<2.0 \times 10^{-3}$	$<4.8 \times 10^{-5}$	$<2.4 \times 10^{-4}$	-	-	Nil
64B	$<1.7 \times 10^{-3}$	$<1.3 \times 10^{-4}$	$<2.1 \times 10^{-4}$	-	-	Nil

- = not measured.

TABLE 18
RADIOACTIVITY DISCHARGED TO THE MWS&DB SEWER
DURING 1986

Quarter ending	Radioisotopes measured (MBq)			Percentage of authorised limit**
	* α	^3H	† β	
31 March 1986	20.1	2.1×10^5	963.7	47.5
30 June 1986	27.3	1.9×10^6	1057.8	59.7
30 Sept 1986	24.2	1.3×10^5	422.0	27.2
31 Dec 1986	20.4	6.9×10^4	545.7	32.2

* α = a mixture of unidentified α -emitting nuclides taken as being all radium-226 (i.e. the worst possible case) when calculating percentage of authorised limit.

† β = a mixture of unidentified β -emitting nuclides taken as being all strontium-90 (i.e. the worst possible case) when calculating the percentage of authorised limit.

** In the case of discharge to the MWS&DB sewer, the authorised limit is outlined in the Regulations to the NSW Radioactive Substances Act published in Government Gazette No. 136, 19 September 1980.

TABLE 19
RADIOACTIVITY IN WORONORA ZOSTERA SAMPLES, 1986

Station	Date	Radioactivity (Bq g ⁻¹ fresh weight)					Potassium (µg.g ⁻¹)
		Gross α	Gross β (less ^{40}K)	^{60}Co	Gamma emitters		
					$^{238}\text{U} + ^{232}\text{Th}$	0.50 MeV	
E1.3	21.1.86	0.08	0.05	0.002	Trace	N.D.	2248
E2.4	21.1.86	0.11	0.07	0.003	Trace	N.D.	4416
E1.3	17.7.86	0.05	0.03	N.D.	Trace	N.D.	2150
E2.4	17.7.86	0.09	0.05	N.D.	Trace	N.D.	3458

N.D. = not detected

TABLE 20
RADIOACTIVITY IN WORONORA BEACH SAND, 1986

Station	Date	Radioactivity (Bq g ⁻¹ dry weight)			Potassium (µg.g ⁻¹)
		Gross α	Gross β (less ^{40}K)	Gamma emitters	
E1.3	21.1.86	0.17	0.17	Trace $^{238}\text{U} + ^{232}\text{Th}$ series	568
E2.4	21.1.86	0.22	0.40	Trace $^{238}\text{U} + ^{232}\text{Th}$ series	764

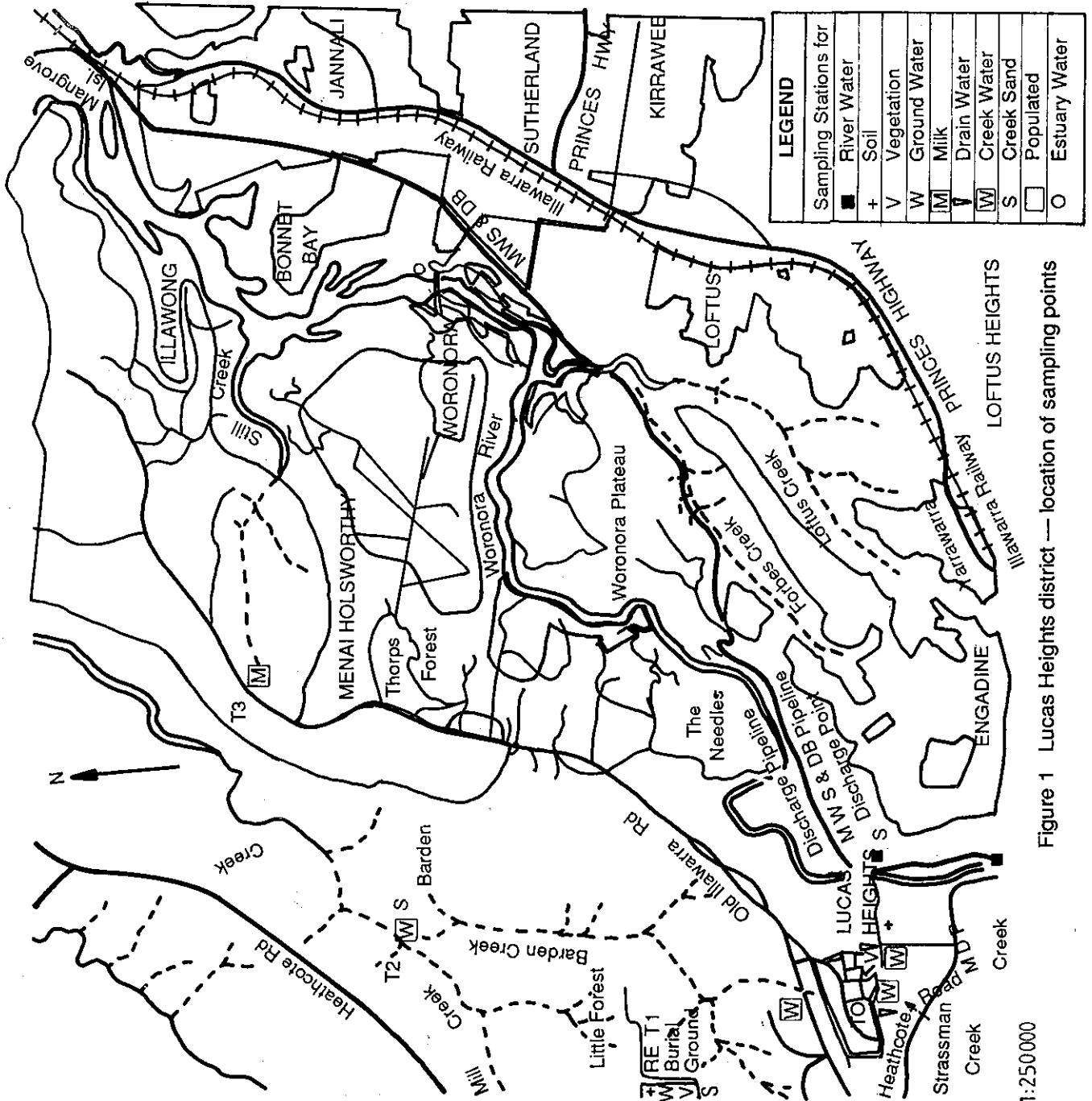
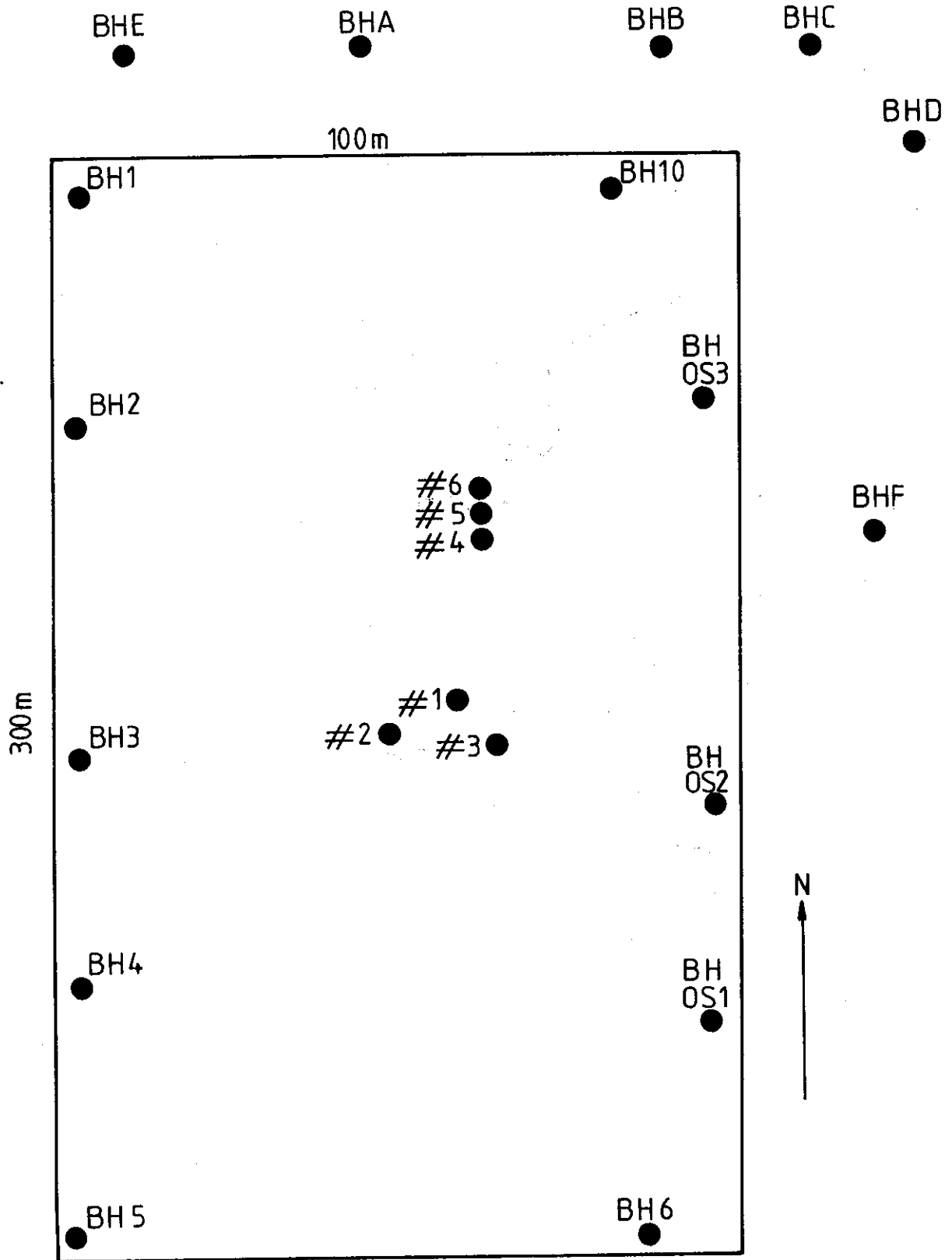


Figure 1 Lucas Heights district — location of sampling points

Scale-1:250000



BH = BOREHOLE
= SOIL SAMPLING STATION

not to scale

Figure 2 Little Forest Burial Ground — location of sampling stations

APPENDIX A
PREVIOUS ENVIRONMENTAL SURVEY REPORTS

- Giles, M.S., Stockdale, J.A. [1966] - Results of the Lucas Heights Biological Survey, December 1959 to December 1964. AAEC/E151.
- Cook, J.E., Dudaitis, A., Giles, M.S. [1969] - Environmental Survey at AAEC Research Lucas Heights. Results for 1965, 1966 and 1967. AAEC/E151 Supplement No. 1.
- Cook, J.E., Dudaitis, A. [1970] - Environmental Survey at the AAEC Research Establishment, Lucas Heights. Results for 1968. AAEC/E151 Supplement No. 2.
- Cook, J.E., Dudaitis, A. [1970] - Environmental Survey at the AAEC Research Establishment, Lucas Heights. Results for 1969. AAEC/E151 Supplement No. 3.
- Conway, N.F., Dudaitis, A. [1972] - Environmental Survey at the AAEC Research Establishment, Lucas Heights. Results for Period January-July 1970. AAEC/E246.
- Dudaitis, A. [1973] - Environmental Survey at the AAEC Research Establishment, Lucas Heights. Results for Period August 1970 to December 1971. AAEC/E271.
- Dudaitis, A. [1974] - Environmental Survey at the AAEC Research Establishment, Lucas Heights. Results for 1972. AAEC/E301.
- Davy, D.R., Dudaitis, A. [1974] - Environmental Survey at the Research Establishment, Lucas Heights. Results for 1973. AAEC/E335.
- Davy, D.R., Dudaitis, A. [1976] - Environmental Survey at the Research Establishment, Lucas Heights. Results for 1974. AAEC/E375.
- Hespe, E.D. [1979a] - Environmental Survey at the AAEC Research Establishment, Lucas Heights. Results for 1975, 1976 and 1977. AAEC/E467.
- Hespe, E.D. [1979b] - Results of the 1978 Environmental Survey at the AAEC Research Establishment, Lucas Heights. AAEC/E494.
- Giles, M.S., Dudaitis, A. [1980] - Environmental Survey at the Research Establishment, Lucas Heights. Results for 1979. AAEC/E508.
- Giles, M.S., Dudaitis, A. [1982] - Environmental Survey at the Research Establishment, Lucas Heights. Results for 1980. AAEC/E542.
- Williams, A.R., Dudaitis, A. [1983] - Environmental Survey at the Research Establishment, Lucas Heights, 1981. AAEC/E563.
- Giles, M.S., Dudaitis, A. [1984] - Environmental Survey at the Research Establishment, Lucas Heights, 1982. AAEC/E591.
- Giles, M.S., Dudaitis, A. [1985] - Environmental Survey at the Research Establishment, Lucas Heights, 1983. AAEC/E622.
- Giles, M.S., Dudaitis, A. [1986] - Environmental Survey at the Research Establishment, Lucas Heights, 1984. AAEC/E638.
- Giles, M.S., Foy, J.J., Hoffmann, E.L. [1988] - Environmental Survey at the Research Establishment, Lucas Heights, 1985. AAEC/E677.

**APPENDIX B
NEW ANALYTICAL PROCEDURES**

No new procedures were introduced since the previous report.

APPENDIX C
LIST OF ISOTOPE SYMBOLS USED IN
TABLES
OF SURVEY RESULTS

SYMBOL	NAME
²⁴¹ Am	americium-241
⁴¹ Ar	argon-41
⁷ Be	beryllium-7
⁶⁰ Co	cobalt-60
¹³⁷ Cs	caesium-137
³ H	tritium
¹³¹ I	iodine-131
K	potassium (stable)
⁴⁰ K	potassium-40
²³⁹ Pu	plutonium-239
²²⁶ Ra	radium-226
¹⁰³ Ru	ruthenium-103
¹⁰⁶ Ru	ruthenium-106
⁹⁰ Sr	strontium-90
²³² Th	thorium-232
²³⁸ U	uranium-238
⁶⁵ Zn	zinc-65

