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ENVIRONMENTAL SURVEY AT
LUCAS HEIGHTS RESEARCH LABORATORIES, 1988

BY

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ABSTRACT

Results are presented of an environmental survey conducted in the neighbourhood of the Lucas Heights Research Laboratories during 1988. 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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EDITORIAL NOTE

The Australian Nuclear Science and Technology Organisation (ANSTO) replaced the Australian Atomic Energy Commission (AAEC) 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.

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5.1 Airborne Release

Measurable concentrations of iodine-131 were occasionally recorded in air samplers during the year (see table 2). The highest reading was registered for the week ending 27 January 1988 and was 1.3×10^{-3} (or 0.13 percent) 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 $0.4 \mu\text{Sv y}^{-1}$ or 4×10^{-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 levels of caesium-137 found were just above 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 15 and 16. 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. 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 1988 (see table 4).

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 traces of ^{238}U and ^{232}Th series found in the water samples were due to soil being washed down the stormwater drain during repairs to the pipes.

Tritium was detected in only one of the stormwater samples, and this was just above the limit of detection.

During 1988, 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 1988 to measure tritium and the results are shown in table 8. The only tritium concentration recorded on 31/5/88 was just above the limit of detection, which is 0.25 Bq mL^{-1} . No tritium was detected in the remaining water samples.

5.4 Effluent Discharge Pipeline

Table 9 shows the dose rates at various points on the discharge pipeline during the 1988 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. Results of soil analyses are given in table 10.

5.5 Little Forest Burial Ground

Results of measurements at the Little Forest Burial Ground (LFBG) are given in **tables 11, 12, 13, and 14**. The positions of sampling points are shown on **figures 2 and 3** (which shows the position of the new MB series of monitoring bores. These will replace the old BH & OS boreholes which are becoming silted-up and unusable). Tritium was found in BH10, OS2, OS3, BHF, MB12, MB13, MB16 and MB17. 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 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}Pu $2.0 \times 10^{-5} \text{Bq m}^{-3}$ after sampling 20m^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 DWC for ^{239}Pu is $5 \times 10^{-4} \text{Bq m}^{-3}$. These limits were calculated assuming permanent exposure for 24 hours each day. The level of ^{239}Pu found on a composite of 4 air filters for 1988 was 0.18 of the DWC.

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 15 and 16**). The dose to the most sensitive members of the public from ^{131}I releases, calculated from results in **table 2**, was $0.4 \mu\text{Sv y}^{-1}$ 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.

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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 with polyethylene bottle at outlet of the drain	3 L weekly samples evaporated to dryness and the residue combined to form a monthly composite sample for α, β, γ counting and 50 mL collected and distilled for tritium.
	Barden Creek	Weekly	Sampled at the weir	50 mL distilled for tritium
	Others	Quarterly	Sampled by bottle at the outlet of the drain	Distilled for tritium
Estuary water (Woronora River)	E5.9	Weekly	From surface by bottle	Distilled for tritium
Radioactive iodine in air	Along eastern boundary of the site (TO)	Weekly	Collected on Maypacks (charcoal filters)	Gamma spectrometry of Maypacks
Milk	T ₃	Monthly	Sampled from milk produced by locally grazed cow	Gamma spectrometry of whole milk
Vegetation	LHRL stormwater outlets	Six monthly where available	Cut by hand clippers	Gamma spectrometry of whole unwashed vegetation (ashed)
Groundwater	Little Forest Burial Ground (LFBG)	Six monthly	MB series bore holes pumped dry, allowed to refill and sampled from the bottom	10 L sample evaporated to dryness and the residue counted. 50 mL collected and distilled for tritium
Sand/soil	LFBG; LHRL stormwater outlets	Six monthly; quarterly	Scooped from surface	Sample ashed and sieved
Be, ²³⁹ Pu on air filters	Little Forest Burial Ground	Quarterly	Collected on 0.8 μ m aerosol filter	Disc, 1 cm diameter cut out for Be analysis. Composite made of the quarterly samples for ²³⁹ Pu analysis by α spectrometry
Creekwater	T2	Yearly	Sampled by bottle	5 L collected and passed through cation-exchange resin then ashed and counted. 50 mL collected and distilled for tritium.

Table 1 contd.

Sample	Station	Frequency	Collection Details	Special Preparations
	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, 1988

Week ending	¹³¹ I (Bq m ⁻³)	Week ending	¹³¹ I (Bq m ⁻³)
5.1.88	LLD	5.7.88	2.6x10 ⁻³
12.1.88	LLD	12.7.88	1.2x10 ⁻²
19.1.88	LLD	19.7.88	5.6x10 ⁻³
27.1.88	1.3x10 ⁻²	26.7.88	8.1x10 ⁻³
2.2.88	7.5x10 ⁻³	2.8.88	LLD
9.2.88	1.1x10 ⁻²	9.8.88	LLD
16.2.88	LLD	16.8.88	LLD
23.2.88	LLD	23.8.88	3.0x10 ⁻³
1.3.88	3.5x10 ⁻³	30.8.88	7.7x10 ⁻³
8.3.88	LLD	6.9.88	6.0x10 ⁻³
15.3.88	LLD	13.9.88	2.6x10 ⁻³
23.3.88	LLD	20.9.88	LLD
29.3.88	LLD	27.9.88	LLD
5.4.88	LLD	4.10.88	LLD
12.4.88	LLD	11.10.88	LLD
19.4.88	LLD	18.10.88	LLD
26.4.88	LLD	25.10.88	LLD
3.5.88	LLD	1.11.88	LLD
10.5.88	LLD	8.11.88	LLD
17.5.88	LLD	16.11.88	LLD
24.5.88	LLD	22.11.88	LLD
31.5.88	5.2x10 ⁻³	29.11.88	LLD
7.6.88	1.1x10 ⁻²	6.12.88	LLD
14.6.88	LLD	13.12.88	LLD
21.6.88	3.0x10 ⁻³	20.12.88	LLD
28.6.88	LLD	28.12.88	LLD

Three air samplers are located along the eastern boundary of the site, where suburban residences are closest. On 23.8.88 a fourth air sampler was commissioned along the southern boundary of the site. 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, 1988

Station	Date	Radioactivity (Bq g ⁻¹ fresh volume)	
		¹³⁷ Cs	¹³¹ I
T3	Jan.88*	-	-
T3	Feb.88*	-	-
T3	March 88*	-	-
T3	7.4.88	LLD	LLD
T4†	26.5.88	LLD	LLD
T4	28.6.88	5.2x10 ⁻⁴	LLD
T4	29.7.88	7.5x10 ⁻⁴	LLD
T4	30.8.88	4.0x10 ⁻⁴	LLD
T4	29.9.88	4.0x10 ⁻⁴	LLD
T4	7.11.88	LLD	LLD
T4	30.11.88	LLD	LLD
T4	20.12.88	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.

* No sample available, cow removed from local area.

† Milk sample obtained from same cow, now on a farm along New Illawarra Road (called Station T4).

TABLE 4
TRITIUM IN WORONORA RIVER WATER SAMPLES
AT STATION E5.9, 1988

Date	Tritium (Bq mL ⁻¹)	Date	Tritium (Bq mL ⁻¹)	Date	Tritium (Bq mL ⁻¹)
4.1.88	LLD	3.5.88	LLD	30.8.88	LLD
12.1.88	LLD	10.5.88	LLD	6.9.88	LLD
19.1.88	LLD	17.5.88	LLD	13.9.88	LLD
27.1.88	LLD	24.5.88	LLD	20.9.88	LLD
2.2.88	LLD	31.5.88	LLD	27.9.88	LLD
9.2.88	LLD	7.6.88	LLD	4.10.88	LLD
16.2.88	LLD	14.6.88	LLD	11.10.88	LLD
23.2.88	LLD	21.6.88	LLD	18.10.88	LLD
1.3.88	LLD	28.6.88	LLD	25.10.88	LLD
8.3.88	LLD	5.7.88	LLD	1.11.88	LLD
15.3.88	LLD	12.7.88	LLD	8.11.88	LLD
22.3.88	LLD	19.7.88	LLD	15.11.88	LLD
29.3.88	LLD	26.7.88	LLD	22.11.88	LLD
5.4.88	LLD	2.8.88	LLD	29.11.88	LLD
12.4.88	LLD	9.8.88	LLD	6.12.88	LLD
19.4.88	LLD	16.8.88	LLD	13.12.88	LLD
26.4.88	LLD	23.8.88	LLD	20.12.88	LLD
				28.12.88	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 6
RADIOACTIVITY IN WATER SAMPLES FROM STORMWATER OUTLETS, 1988

Station	Date	Radioactivity (Bq L ⁻¹)			Tritium (Bq mL ⁻¹)
		Gross α	Gross β (incl. ⁴⁰ K)	γ -emitters	
Drain behind Bld. 1	29/1/88	-	-	-	LLD
	15/4/88	-	-	-	LLD
	22/7/88	-	-	-	LLD
	12/10/88	-	-	-	LLD
Drain on road at west fence	29/1/88	-	-	-	LLD
	15/4/88	-	-	-	LLD
	22/7/88	-	-	-	LLD
Drain at Fermi St.	29/1/88	-	-	-	LLD
	15/4/88	-	-	-	LLD
	22/7/88	-	-	-	LLD
	12/10/88	-	-	-	LLD
Drain opposite Bld. 23	15/4/88	-	-	-	LLD
Drain No.1 opposite Strassman Cr.	29/1/88	-	-	-	LLD
	15/4/88	-	-	-	LLD
	22/7/88	-	-	-	LLD
	12/10/88	-	-	-	1.01
Drain opposite meteorological tower	29/1/88	-	-	-	LLD
	15/4/88	-	-	-	LLD
	22/7/88	-	-	-	LLD
20 m from LHRL stormwater outlet No.1	29/1/88	-	-	-	LLD
	15/4/88	-	-	-	LLD
	22/7/88	-	-	-	LLD
60 m from LHRL stormwater outlet No.1	4/1/88	0.23	0.21	N.D.	LLD
	12/1/88	0.25	0.30	N.D.	LLD
	19/1/88	0.32	0.30	N.D.	LLD
	27/1/88	0.14	0.23	N.D.	LLD
	2/2/88	0.43	0.34	N.D.	LLD
	9/2/88	0.28	0.28	N.D.	LLD
	16/2/88	0.19	0.31	N.D.	LLD
	23/2/88	0.17	0.24	N.D.	LLD
	1/3/88	0.22	0.25	N.D.	LLD
	8/3/88	0.21	0.15	N.D.	LLD
	15/3/88	0.16	0.20	N.D.	LLD
	22/3/88	4.36	1.79	Trace ²³⁸ U+ ²³² Th series	LLD
	29/3/88	0.14	0.18	N.D.	LLD
	5/4/88	0.31	0.32	N.D.	LLD
12/4/88	0.32	0.17	N.D.	LLD	
19/4/88	0.28	0.24	N.D.	LLD	
26/4/88	0.31	0.24	N.D.	LLD	

TABLE 6 continued

Station	Date	Radioactivity (Bq L ⁻¹)			Tritium (Bq mL ⁻¹)
		Gross α	Gross β (incl. ⁴⁰ K)	γ -emitters	
	3/5/88	0.34	0.32	N.D.	LLD
	10/5/88	0.16	0.16	N.D.	LLD
	17/5/88	0.32	0.19	N.D.	LLD
	24/5/88	0.16	0.23	N.D.	LLD
	31/5/88	1.06	0.36	N.D.	LLD
	7/6/88	0.48	0.24	N.D.	LLD
	14/6/88	0.18	0.04	N.D.	LLD
	21/6/88	0.12	0.07	N.D.	LLD
	28/6/88	0.18	0.13	N.D.	LLD
	5/7/88	0.24	0.12	N.D.	LLD
	12/7/88	0.18	0.14	N.D.	LLD
	19/7/88	0.13	0.05	Trace ²³⁸ U+ ²³² Th series	LLD
	26/7/88	1.73	0.30	N.D.	LLD
	Aug.88*	0.14	0.16	N.D.	LLD
	Sept.88	0.29	0.18	N.D.	LLD
	Oct.88	0.22	0.22	N.D.	LLD
	Nov.88	0.19	0.29	N.D.	LLD
	Dec.88	0.24	0.27	N.D.	LLD

n.d. = not detected

- = 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.

* This collection point is still sampled weekly, however all the weekly samples for a particular month are combined to make a single composite sample. This is then analysed following normal procedure.

TABLE 7
RADIOACTIVITY AT SPCC SAMPLING POINTS, 1988
(Bq L⁻¹)

Date 1988	Strassman Creek		Barden Creek		MDP Creek	
	Gross α	Gross β^*	Gross α	Gross β^*	Gross α	Gross β^*
20.1.88	LLD	LLD	LLD	LLD	LLD	0.17
17.2.88	0.03	LLD	LLD	0.31	LLD	0.16
9.3.88	LLD	LLD	LLD	LLD	LLD	LLD
14.4.88	LLD	LLD	LLD	LLD	LLD	0.18
30.5.88	LLD	LLD	LLD	LLD	LLD	LLD
10.6.88	LLD	0.20	LLD	0.10	LLD	0.15
27.7.88	LLD	LLD	LLD	LLD	LLD	LLD
31.8.88	LLD	LLD	LLD	LLD	LLD	0.13
19.9.88	LLD	LLD	LLD	0.11	LLD	LLD
26.10.88	LLD	LLD	LLD	LLD	LLD	0.17
25.11.88	LLD	LLD	LLD	LLD	LLD	0.17
15.12.88	LLD	LLD	LLD	LLD	LLD	0.13

LLD = Less than the minimum detection limit

Minimum detection limit α = 0.03 Bq L⁻¹

Minimum detection limit β = 0.10 Bq L⁻¹

* includes ⁴⁰K contribution

Note: The Clean Waters Act Regulations permit a gross α level of 1.1 Bq L⁻¹ and a gross β level of 11.1 Bq L⁻¹ at the SPCC sampling points.

TABLE 8
TRITIUM IN WATER FROM SPCC SAMPLING POINT
AT BARDEN CREEK WEIR, 1988

Date	Tritium (Bq mL ⁻¹)	Date	Tritium (Bq mL ⁻¹)
4.1.88	LLD	5.7.88	LLD
12.1.88	LLD	12.7.88	LLD
19.1.88	LLD	19.7.88	LLD
27.1.88	LLD	26.7.88	LLD
2.2.88	LLD	2.8.88	LLD
9.2.88	LLD	9.8.88	LLD
16.2.88	LLD	16.8.88	LLD
23.2.88	LLD	23.8.88	LLD
1.3.88	LLD	30.8.88	LLD
8.3.88	LLD	6.9.88	LLD
15.3.88	LLD	13.9.88	LLD
22.3.88	LLD	20.9.88	LLD
29.3.88	LLD	27.9.88	LLD
5.4.88	LLD	4.10.88	LLD
12.4.88	LLD	11.10.88	LLD
19.4.88	LLD	18.10.88	LLD
26.4.88	LLD	25.10.88	LLD
3.5.88	LLD	1.11.88	LLD
10.5.88	LLD	8.11.88	LLD
17.5.88	LLD	15.11.88	LLD
24.5.88	LLD	22.11.88	LLD
31.5.88	0.35	29.11.88	LLD
7.6.88	LLD	6.12.88	LLD
14.6.88	LLD	13.12.88	LLD
21.6.88	LLD	20.12.88	LLD
28.6.88	LLD	28.12.88	LLD

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, 1988

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	
10.6.88*	All joints (except #16)	<0.12	<0.16	0.06 to 0.14
10.6.88	Joint #16	0.12	0.90	0.08
25.11.88*	All joints (except #16)	<0.18	<0.18	0.05 to 0.18
25.11.88	Joint #16	0.10	0.60	0.06

* Joints No. 18 and 19 not inspected due to continuing inaccessibility.
Note: there are 22 numbered joints in the effluent discharge pipeline.

TABLE 10
RADIOACTIVITY IN SAMPLES TAKEN NEAR
EFFLUENT DISCHARGE PIPELINE, 1988

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	10.6.88	Soil	0.48	0.23	Trace ²³⁸ U+ ²³² Th series	-	210
	10.6.88	Water	-	-	-	LLD	-
	25.11.88	Soil	0.39	0.19	Trace ²³⁸ U+ ²³² Th series	-	509
	25.11.88	Water	-	-	-	LLD	-
Woronora River at point where crossed by pipeline	10.6.88	Soil	0.18	0.08	N.D.	-	134
	10.6.88	Water	-	-	-	LLD	-
	25.11.88	Soil	0.51	0.10	Trace ²³⁸ U+ ²³² Th series	-	409
	25.11.88	Water	-	-	-	LLD	-

- = not measured

LLD = Less than the limit of detection

LLD for ³H is 0.25 Bq mL⁻¹

TABLE 11
RADIOACTIVITY IN SAMPLES OF SOIL
FROM LITTLE FOREST BURIAL GROUND, 1988

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	29.6.88	0.80	0.74	Trace ²³⁸ U + ²³² Th series	2432
Point No.5	29.6.88	0.56	0.57	Trace ²³⁸ U + ²³² Th series	877
Point No.6	29.6.88	0.73	2.81	Trace ²³⁸ U + ²³² Th series ⁶⁰ Co = 0.294	2099
Point No.5	7.12.88	0.61	0.64	Trace ²³⁸ U + ²³² Th series Trace ⁶⁰ Co	1732
Point No.6	7.12.88	1.02	3.59	Trace ²³⁸ U + ²³² Th series ⁶⁰ Co = 0.454 ¹³⁷ Cs = 0.026	2591

TABLE 12
RADIOACTIVITY IN SAMPLES OF GROUNDWATER FROM
LITTLE FOREST BURIAL GROUND, 1988

Bore Hole No.	Date	Sediment (Bq g ⁻¹)			³ H (Bq mL ⁻¹)
		Gross α	Gross β*	γ-Emitters	
BHA	29.6.88	0.29	0.47	Trace ²³⁸ U+ ²³² Th series	LLD
BHB	29.6.88	0.19	0.11	Trace ²³⁸ U+ ²³² Th series	LLD
BHC	29.6.88	0.16	0.18	N.D.	LLD
BHD	29.6.88	0.71	0.66	N.D.	LLD
BHE	29.6.88	0.22	0.23	N.D.	LLD
BHF	29.6.88	2.00	3.89	Trace ²³⁸ U+ ²³² Th series	1.34
BH1	29.6.88	2.94	0.71	Trace ²³⁸ U+ ²³² Th series	LLD
BH2	29.6.88	1.60	0.51	Trace ²³⁸ U+ ²³² Th series	LLD
BH3	29.6.88	2.20	0.74	Trace ²³⁸ U+ ²³² Th series	LLD
BH4	29.6.88	2.50	0.53	N.D.	LLD
BH6	29.6.88	0.56	0.26	N.D.	LLD
BH10	29.6.88	0.24	0.43	N.D.	3.09
OS1	29.6.88	1.34	0.58	N.D.	LLD
OS2	29.6.88	1.83	1.07	N.D.	4.22
OS3	29.6.88	1.73	9.85	Trace ²³⁸ U+ ²³² Th series	5.64
MB11	29.6.88	0.33	0.19	Trace ²³⁸ U+ ²³² Th series	LLD
MB12	29.6.88	0.39	0.18	Trace ²³⁸ U+ ²³² Th series	LLD
MB13	29.6.88	0.86	0.94	N.D.	8.82
MB14	29.6.88	0.38	0.21	N.D.	LLD
MB15	29.6.88	0.88	0.42	Trace ²³⁸ U+ ²³² Th series	LLD
MB16	29.6.88	1.83	6.07	⁶⁰ Co = 0.65	24.12

TABLE 12 continued
 RADIOACTIVITY IN SAMPLES OF GROUNDWATER FROM
 LITTLE FOREST BURIAL GROUND, 1988

Bore Hole No.	Date	Sediment (Bq g ⁻¹)			³ H (Bq mL ⁻¹)
		Gross α	Gross β*	γ-Emitters	
MB17	29.6.88	0.85	0.53	Trace ²³⁸ U+ ²³² Th series	3.19
MB18	29.6.88	1.29	0.65	Trace ²³⁸ U+ ²³² Th series	LLD
MB19	29.6.88	0.37	0.20	N.D.	LLD
MB20	29.6.88	0.38	0.36	N.D.	LLD
MB21	29.6.88	0.32	0.25	N.D.	LLD
MB11	7.12.88	0.45	0.19	N.D.	LLD
MB12	7.12.88	0.53	0.28	N.D.	0.58
MB13	7.12.88	0.29	0.24	Trace ²³⁸ U+ ²³² Th series	4.97
MB14	7.12.88	0.13	0.14	N.D.	LLD
MB15	7.12.88	0.22	0.15	N.D.	LLD
MB16	7.12.88	1.52	5.68	Trace ²³⁸ U+ ²³² Th series ⁶⁰ Co = 0.54	23.20
MB17	7.12.88	0.36	0.42	N.D.	3.95
MB18	7.12.88	1.15	0.56	Trace ²³⁸ U+ ²³² Th series	LLD
MB19	7.12.88	0.41	0.31	Trace ²³⁸ U+ ²³² Th series	LLD
MB20	7.12.88	0.44	0.60	N.D.	LLD
MB21	7.12.88	0.50	0.40	N.D.	LLD
MB22	21.12.88	0.72	0.43	Trace ²³⁸ U+ ²³² Th series	LLD

LLD = Less than the limit of detection - LLD for ³H is 0.25 Bq mL⁻¹

* All gross beta results include the contribution from natural potassium-40.

TABLE 13
RADIOACTIVITY IN SAMPLES TAKEN FROM CREEKS NORTH OF LITTLE FOREST
BURIAL GROUND, 1988

SAND					
Sample Station	Date	Radioactivity (Bq g ⁻¹ DW)			K (µg g ⁻¹)
		Gross α	Gross β†	γ-emitters	
Barden Creek (pre-confluence with Mill Ck.)	19.12.88	0.66	0.05	Trace ²³⁸ U + ²³² Th series	536
Mill Creek (pre-confluence with Barden Ck.)	19.12.88	0.32	0.06	Trace ²³⁸ U + ²³² Th series	319

WATER					
Sample Station	Date	Radioactivity (Bq L ⁻¹)			³ H (Bq mL ⁻¹)
		Gross α	Gross β*	γ-emitters	
Barden Ck. (pre-confluence with Mill Ck.)	19.12.88	0.08	0.15	N.D.	LLD
Mill Ck. (pre-confluence with Barden Ck.)	19.12.88	0.09	0.07	N.D.	LLD

LLD = Less than the limit of detection

LLD for ³H is 0.25 Bq mL⁻¹

N.D. = not detected

† Gross beta results have had the potassium-40 contribution deducted.

* Gross beta results include the contribution from natural potassium-40.

TABLE 14
RESULTS OF AIR SAMPLING AT LITTLE FOREST
BURIAL GROUND, 1988

Sampling Period	Air volume Sampled (m ³)	(2) Be (μg m ⁻³)	(3) ²³⁹ Pu (Bq m ⁻³)
11.12.87 to 21.3.88	196.8	LLD	-
21.3.88 to 29.6.88	71.3	LLD	-
29.6.88 to 30.9.88	62.9	LLD	-
30.9.88 to 19.12.88	128.9	LLD	-
Composite for 1988 ⁽¹⁾	477.79	-	9.3x10 ⁻⁵

- (1) Composite sample of duplicate sets of air filters for 1989. Result determined by alpha spectrometry.
- (2) TLV for Be = 2 μg m⁻³.
- (3) DWC for ²³⁹Pu = 5x10⁻⁴ Bq m⁻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 15
AIRBORNE RADIOACTIVITY DISCHARGES FROM INDIVIDUAL DISCHARGE POINTS, 1988

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	<5	1390	<0.1	-	99.7	5120
3	<5	1.3	<0.1	-	-	-
15(Hifar)	<2	2.1	<0.4	960	19.5	70
19	<11	-	<0.2	-	-	-
20	<5	<2	<0.1	-	-	-
23A	<9	6960	<0.2	-	-	-
23B	<1	2.1	<0.01	-	-	-
41	<3	0.4	<0.1	-	-	-
56	<14	<1.8	<0.2	-	-	-
57	<1	<1.0	<0.02	0.5	-	-
Quarter No.2						
Bld.2	<5	1420	<0.1	-	105.7	5030
3	<4	0.9	<0.1	-	-	3300
15	<2	1.7	<0.4	1040	17.1	50
19	<11	<1	<0.2	-	-	-
20	<5	<2	<0.1	41	-	-
23A	<9	2900	<0.2	-	-	206
23B	<1	0.1	<0.02	-	-	-
41	<3	0.7	<0.1	-	-	-
56	<14	<0.9	<0.2	-	-	-
57	<1	<0.3	<0.02	1.0	-	-
Quarter No.3						
Bld.2	<5	1380	<0.1	-	75.8	4510
3	<7	0.6	<0.1	-	-	-
15	<2	1.8	<0.6	960	17.4	61
19	<11	3	<0.2	-	-	-
20	<5	<2	<0.1	74	-	-
23A	<9	5720	<0.2	-	-	-
23B	<1	0.6	<0.02	-	-	-
41	<3	0.4	<0.1	-	-	-
56	<14	<2.0	<0.2	-	-	-
57	<1	<0.2	<0.02	0.8	-	-
Quarter No.4						
Bld.2	8	2140	0.1	-	91.9	7430
3	<6	0.9	<0.1	-	-	-
15	3	1.4	<0.6	1010	18.2	51
19	<14	2	<0.2	-	-	-
20	<7	<2	<0.1	136	-	-
23A	<14	3810	<0.2	-	-	1608
23B	<2	0.5	<0.02	-	-	-
41	<4	0.1	<0.1	-	-	-
56	<19	<4.1	<0.3	-	-	-
57	<2	<0.1	<0.02	3.2	-	-

- = 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 16
AIRBORNE RADIOACTIVITY DISCHARGES FROM INDIVIDUAL DISCHARGE
POINTS EXPRESSED AS FRACTIONS OF AUTHORISED QUARTERLY POINT
DISCHARGE FOR 1988

Period & Bldg. No.	Gross α	^{131}I	^{90}Sr	^3H	Fission Product Noble Gases	Other Activity
Quarter No. 1						
Bld.2	$<7.6 \times 10^{-6}$	0.02	$<1.6 \times 10^{-7}$	-	0.59	3.2×10^{-3}
3	$<3.1 \times 10^{-3}$	8.1×10^{-5}	$<7.7 \times 10^{-5}$	-	-	-
15(Hifar)	$<6.1 \times 10^{-5}$	1.3×10^{-4}	$<1.5 \times 10^{-5}$	7.4×10^{-3}	0.72	1.1×10^{-3}
19	$<3.3 \times 10^{-5}$	-	$<7.7 \times 10^{-7}$	-	-	-
20	$<1.6 \times 10^{-3}$	$<1.1 \times 10^{-4}$	$<2.0 \times 10^{-4}$	-	-	-
23A	$<5.6 \times 10^{-4}$	0.44	$<1.5 \times 10^{-5}$	-	-	-
23B	$<1.5 \times 10^{-4}$	1.3×10^{-4}	$<1.6 \times 10^{-6}$	-	-	-
41	$<9.1 \times 10^{-6}$	2.5×10^{-5}	$<3.8 \times 10^{-7}$	-	-	-
56	$<1.8 \times 10^{-3}$	$<4.1 \times 10^{-5}$	$<1.8 \times 10^{-4}$	-	-	-
57	$<1.4 \times 10^{-3}$	$<2.4 \times 10^{-4}$	$<2.0 \times 10^{-4}$	2.4×10^{-4}	-	-
Quarter No. 2						
Bld.2	$<7.6 \times 10^{-6}$	0.02	$<1.6 \times 10^{-7}$	-	0.62	3.14×10^{-3}
3	$<2.5 \times 10^{-3}$	5.6×10^{-5}	$<7.7 \times 10^{-5}$	-	-	-
15	$<6.1 \times 10^{-5}$	1.1×10^{-4}	$<1.5 \times 10^{-5}$	8.0×10^{-3}	0.63	7.6×10^{-4}
19	$<3.3 \times 10^{-5}$	$<3.0 \times 10^{-5}$	$<7.7 \times 10^{-7}$	-	-	-
20	$<1.8 \times 10^{-3}$	$<1.2 \times 10^{-4}$	$<2.5 \times 10^{-4}$	5.1×10^{-3}	-	-
23A	$<5.6 \times 10^{-4}$	0.18	$<1.5 \times 10^{-5}$	-	-	6.2×10^{-3}
23B	$<1.5 \times 10^{-4}$	6.3×10^{-6}	$<3.1 \times 10^{-6}$	-	-	-
41	$<9.1 \times 10^{-6}$	4.4×10^{-5}	$<3.8 \times 10^{-7}$	-	-	-
56	$<1.8 \times 10^{-3}$	$<2.0 \times 10^{-5}$	$<1.8 \times 10^{-4}$	-	-	-
57	$<1.7 \times 10^{-3}$	$<8.3 \times 10^{-5}$	$<2.2 \times 10^{-4}$	5.5×10^{-4}	-	-
Quarter No. 3						
Bld. 2	$<7.6 \times 10^{-6}$	0.02	$<1.6 \times 10^{-7}$	-	0.45	2.8×10^{-3}
3	$<4.4 \times 10^{-3}$	3.8×10^{-5}	$<7.7 \times 10^{-5}$	-	-	-
15	$<6.1 \times 10^{-5}$	1.1×10^{-4}	$<2.3 \times 10^{-5}$	7.4×10^{-3}	0.64	9.2×10^{-4}
19	$<3.3 \times 10^{-5}$	9.1×10^{-5}	$<7.7 \times 10^{-7}$	-	-	-
20	$<1.8 \times 10^{-3}$	$<1.2 \times 10^{-4}$	$<2.5 \times 10^{-4}$	9.1×10^{-3}	-	-
23A	$<5.6 \times 10^{-4}$	0.36	$<1.5 \times 10^{-5}$	-	-	-
23B	$<1.5 \times 10^{-4}$	3.8×10^{-5}	$<3.1 \times 10^{-6}$	-	-	-
41	$<9.1 \times 10^{-6}$	2.5×10^{-5}	$<3.8 \times 10^{-7}$	-	-	-
56	$<1.8 \times 10^{-3}$	$<4.5 \times 10^{-5}$	$<1.8 \times 10^{-4}$	-	-	-
57	$<1.7 \times 10^{-3}$	$<5.6 \times 10^{-5}$	$<2.2 \times 10^{-4}$	4.4×10^{-4}	-	-
Quarter No. 4						
Bld. 2	1.1×10^{-5}	3.4×10^{-2}	1.4×10^{-7}	-	0.51	4.4×10^{-3}
3	$<3.5 \times 10^{-3}$	5.3×10^{-5}	$<7.1 \times 10^{-5}$	-	-	-
15	8.3×10^{-5}	8.2×10^{-5}	$<2.1 \times 10^{-5}$	7.2×10^{-3}	0.63	7.2×10^{-4}
19	$<3.9 \times 10^{-5}$	5.5×10^{-5}	$<7.1 \times 10^{-7}$	-	-	-
20	$<2.3 \times 10^{-3}$	1.1×10^{-4}	$<2.5 \times 10^{-4}$	1.6×10^{-2}	-	-
23A	$<8.2 \times 10^{-4}$	0.22	$<1.4 \times 10^{-5}$	-	-	4.5×10^{-2}
23B	$<2.8 \times 10^{-4}$	2.9×10^{-5}	$<2.9 \times 10^{-6}$	-	-	-
41	$<1.1 \times 10^{-5}$	5.9×10^{-6}	$<3.6 \times 10^{-7}$	-	-	-
56	$<2.3 \times 10^{-3}$	$<8.7 \times 10^{-5}$	$<2.5 \times 10^{-4}$	-	-	-
57	$<2.9 \times 10^{-3}$	$<2.6 \times 10^{-5}$	$<2.0 \times 10^{-4}$	1.7×10^{-3}	-	-

- = not measured.

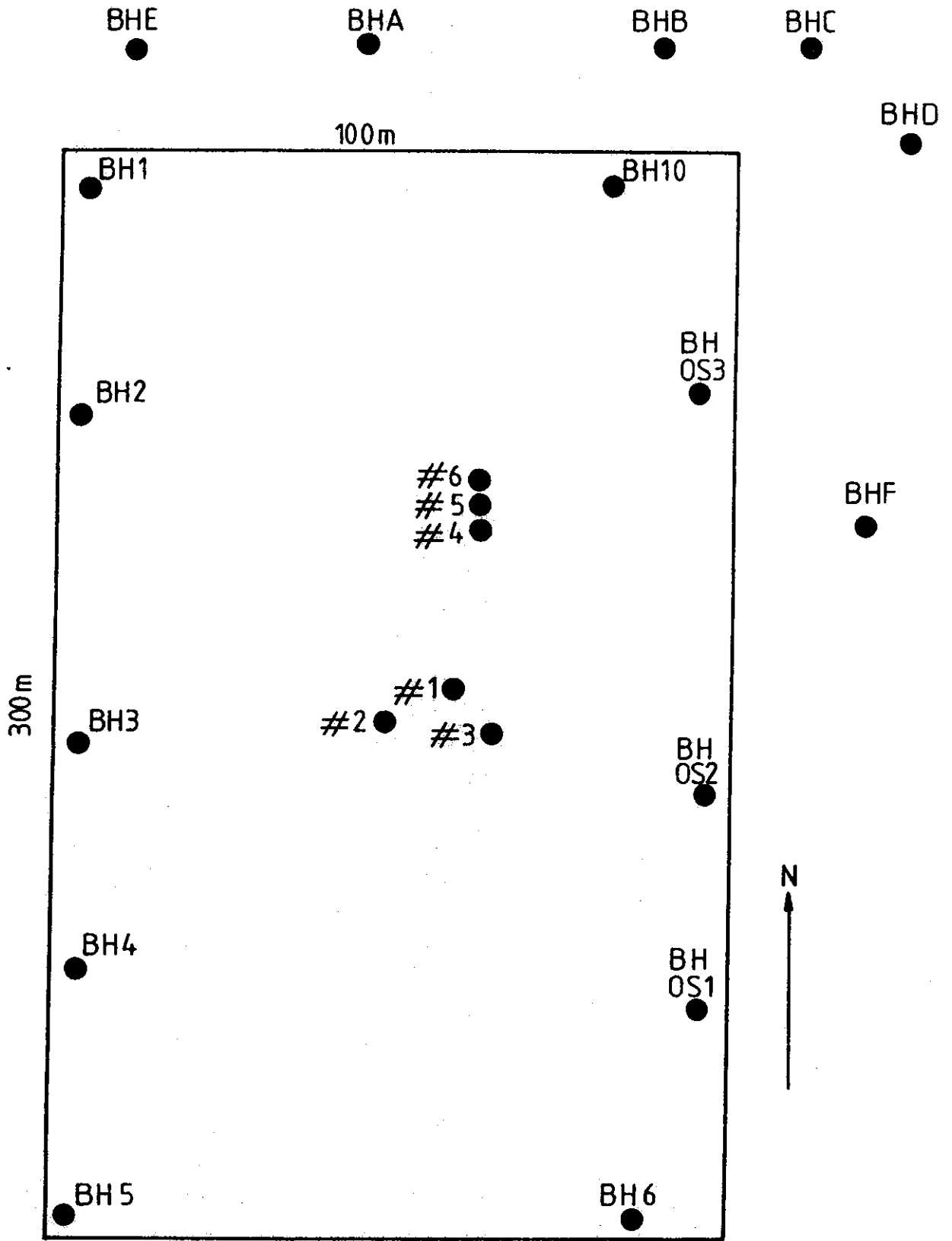
TABLE 17
RADIOACTIVITY DISCHARGED TO THE MWS&DB SEWER
DURING 1988

Quarter ending	Radioisotopes measured (MBq)			Percentage of authorised limit**
	* α_u	^3H	† β_u	
31 March 1988	19.17	1.5×10^5	250.14	21.02
30 June 1988	25.04	4.6×10^5	1188.31	51.81
30 September 1988	15.17	6.2×10^5	340.16	23.28
31 December 1988	13.55	2.3×10^5	183.84	14.95

* α_u = 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_u = 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 unit.

**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.

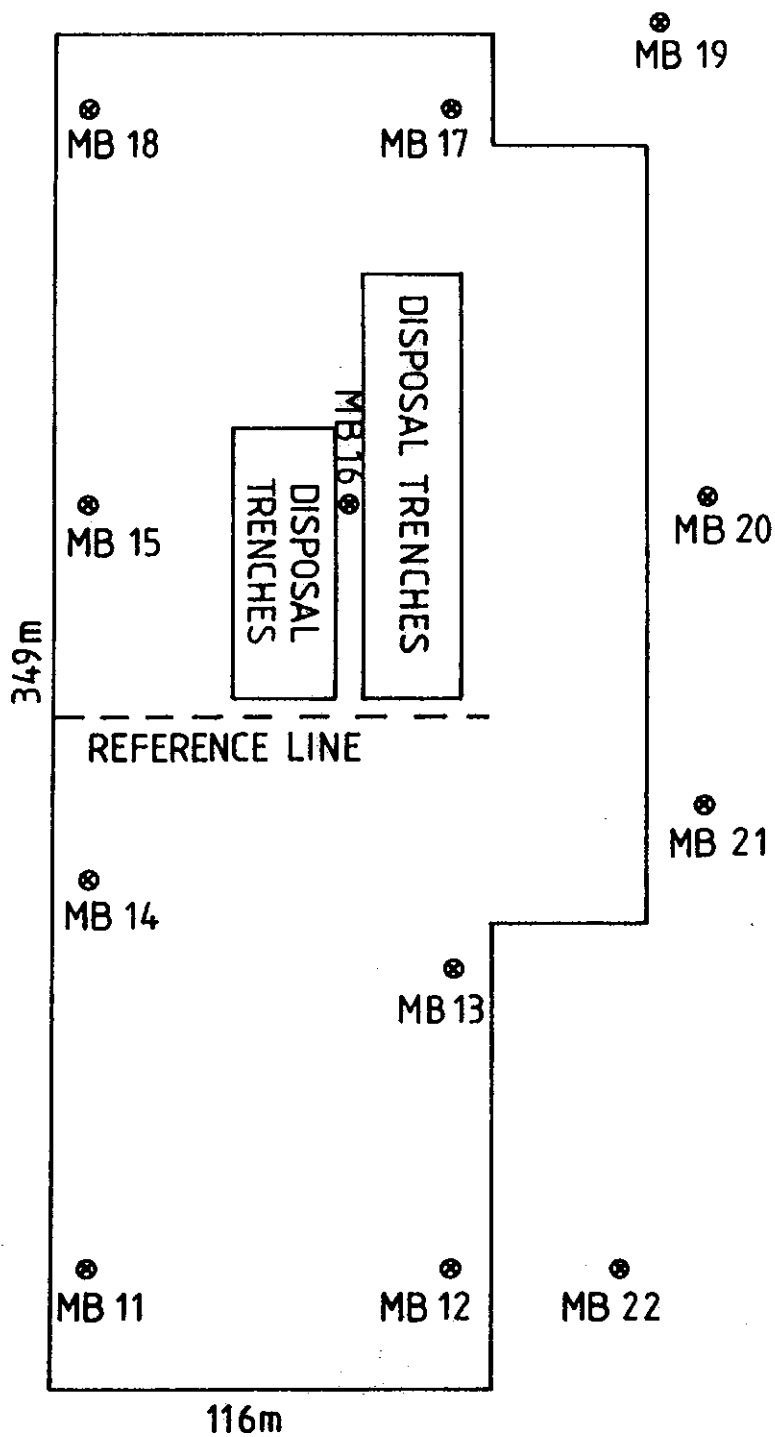


BH = BOREHOLE
= SOIL SAMPLING STATION

not to scale

Figure 2 Little Forest Burial Ground — location of sampling stations

Figure 3 : Little Forest Burial Ground - location of MB series monitoring bores.



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.
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- Conway, N.F., Dudaitis, A. [1972] - Environmental Survey at the AAEC Research Establishment, Lucas Heights. Results for Period January-July 1970. AAEC/E246.
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- 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.
- Giles, M.S., Foy, J.J., Hoffmann, E.L. [1989] - Environmental Survey at Lucas Heights Research Laboratories, 1986. ANSTO/E687.
- Giles, M.S., Foy, J.J., Hoffmann, E.L. [1989] - Environmental Survey at Lucas Heights Research Laboratories, 1987. ANSTO/E688.

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
⁵⁴ Mn	manganese-54
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