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RESEARCH ESTABLISHMENT

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1982

by

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ABSTRACT

Results are presented of the environmental survey conducted in the neighbourhood of the Lucas Heights Research Laboratories during 1982. 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 dose to the general public from airborne waste discharges during this period is estimated to be less than 0.01 millisieverts, which is 1% of the most conservative limit recommended by the National Health and Medical Research Council for exposure extending over many years.

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AAEC; AIR; AUSTRALIA; CESIUM 137; COBALT 60; CONTAMINATION; ENVIRONMENT; EXPERIMENTAL; DATA; FISHES; FRESH WATER; GASEOUS WASTES; GROUND WATER; HUMAN POPULATIONS; IODINE 131; LIQUID WASTES; MAN; MILK; OYSTERS; PLANTS; RADIATION DOSES; RADIATION MONITORING; RADIOACTIVITY; RIVERS; SAND; SOILS; STRONTIUM 90; TRITIUM;

CONTENTS

(Continued)

1. INTRODUCTION

Since 1959, a survey has been made by the Australian Atomic Energy Commission (AAEC) of the radioactive content in samples collected in the vicinity of the Lucas Heights Research Laboratories (LHRL) to ensure that no unacceptable health effects will occur as a result of nuclear research and operation. The results obtained from this survey have been published regularly, and details of previous publications are listed in Appendix A.

During the early part of the survey (i.e. throughout the 1960s), readily detectable amounts of weapons test fallout were present in samples collected around Lucas Heights [Giles and Stockdale 1966]. A large program of sampling was therefore required to establish the general levels of radioactivity arising from weapons test fallout, before it became possible to measure additional radioactivity that may have been caused by nuclear operations at Lucas Heights. 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 surveys were published by various authors in the Australian Journal of Science between 1957 and 1970 [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]. All of these studies provide a basis for comparison with the results for milk samples reported in the AAEC 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 Health Commission) 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 1977] and by the National Health and Medical Research Council of Australia [NHMRC 1981].

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. (Note:

isotope symbols used in the tables are listed in Appendix D.)

3. ANALYTICAL METHODS

Analytical methods have not been modified since the previous survey.

4. RESULTS

Environmental survey measurements taken during 1982 are presented in Tables 2 to 14. Authorised airborne releases are given in Appendices B1 and B2. Authorised liquid effluent discharges to the Metropolitan Water Sewerage and Drainage Board (MWSDB) sewers are given in Appendix C.

5. DISCUSSION OF RESULTS

5.1 Airborne Releases

The site boundary monitoring data for iodine-131 are given in Table 2; at no time was more than a trace detected. The limit of determination of the method is 0.003 Bq m^{-3}, and the derived air concentration for child members of the public [ICRP 1977, 1979], i.e. the most sensitive individuals, is ~10 Bq m^3, so the peak concentrations were at least a factor of 30 000 below the limit.

The milk monitoring data for caesium-137 and iodine-131 are given in Table 3. At most, a trace of caesium-137 was found, with a limit of determination of 0.3 mBq g^{-1} (fresh weight). This represents less than 0.006 of the derived limit, based on the assumption that an infant consumes 700 mL of milk per day.

5.2 Woronora Estuary Samples

Collection of Woronora estuary samples was continued during 1982 to monitor residual radioactivity remaining from discharges made before 1 July 1980. (The discharge of low level liquid effluent was diverted from the Woronora River to the MWSDB sewers at that time.) Except for very small and diminishing quantities of ^{60}Co in marine estuarine zostera, none of the

samples tested contained measurable quantities of radioactivity other than amounts due to natural isotopes.

5.3 Stormwater Outlets

Small amounts of ^{137}Cs and ^{60}Co were found in soil and vegetation samples collected near stormwater outlets. Tritium (^{3}H) was present in stormwater in low concentrations, the highest being 2.1 Bq mL^{-1}. (The derived working limit for ^{3}H is 274 Bq mL^{-1}.)

5.4 Effluent Discharge Pipeline (Tables 14 and 14(a))

The survey of radiation being emitted from the discharge pipeline revealed the doserates shown in Table 9. The maximum annual radiation dose for members of the public recommended by the ICRP is 5000 µSv per year. This represents 0.57 µSv h^{-1} for a continuous 24-hour per day exposure. Because of the isolated position of the aboveground sections of the discharge pipe, an occupancy factor for members of the public must be very low and the allowable doserate correspondingly very high. Checks on water and soil at points along the pipeline revealed no extraneous radioactivity.

5.5 Freshwater Sections of the 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 the Research Establishment. Samples were also collected at the Heathcote Road crossing, upstream and above any possible input from Lucas Heights, to provide a direct measure of background levels. These are presented in Table 11. All readings represent normal background levels.

In general the concentrations of ^{90}Sr in sand and water measured in 1982 samples, including those from the Heathcote Road crossing, are higher than those reported in previous years. The ^{90}Sr analyses for 1982 samples were done by the ARL whereas the previous analyses were done by the AAEC at Lucas Heights, so this change may be due to interlaboratory differences at the prevailing low level of ^{90}Sr concentrations. Duplicates of the 1982 samples have been sent to the New Zealand Radiation Laboratories for a further analysis.

5.6 Little Forest Burial Ground

Tritium was found in three of the groundwater bores from within the fenced area of the burial ground. No extraneous radioactivity was found in boreholes outside the fenced area (boreholes BHA to BHE.)

6. SUMMARY

No radioactivity which could be attributed to operations at Lucas Heights was detected in samples related to possible human foodchains which were collected in the environs of the site.

Discharges of airborne radioactive wastes were always within authorised limits (Appendix B2) and it is estimated that the maximum dose to the nearest member of the public would be less than 0.01 millisieverts. This can be compared to the most conservative limit of 1 millisievert recommended by the NHMRC for exposure extending over many years.

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 members of the CSIRO's Division of Energy Chemistry.

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TABLE 1

SAMPLE COLLECTION SCHEDULE AND PREPARATION DETAILS

Sample	Station	Frequency	Collection Details	Special Preparations
Stormwater	No. 1 Others	Weekly Quarterly	Sampled by bucket at the outlet of the drain	10 L sample evaporated to dryness and the residue counted
Estuary water	E5.9	Weekly	From surface by bucket	Distilled for tritium
Radioactive iodine in air	TO	Weekly	Collected on May-packs (charcoal filters)	Gamma spectrometry of Maypacks
Milk	T3	Monthly	Sampled from milk produced by locally grazed cows	Gamma spectrometry of whole milk
Fish*	E1.3, 6.4 (or wherever available)		Taken by gill net	Whole fish ashed
Beach sand*	E1.3, 5.9		Taken by scoop from top 50 mm in inter-tidal region	Sample ashed and sieved. Sample passing 10 mesh BSS counted for beta-gamma emitters. Sample between 60 and 110 mesh BSS counted for alpha emitters
Zostera*	E1.6, 2.4, E4.6, 7.0, E9.3		Harvested by hand or rake	Ashed
Vegetation	T1, LHRL stormwater outlets	Six-monthly	Cut by hand clippers	Whole unwashed vegetation ashed
Sand/Soil	TO,T1; LHRL stormwater outlets	Six-monthly	Scooped from surface	As for beach sand
Groundwater	T1	Six-monthly	Boreholes pumped dry, allowed to refill and sampled from bottom	10 L sample evaporated to dryness and the residue counted
Creekwater	T2	Yearly	Sampled by bucket or bottle	As for groundwater

* Collection of these samples was discontinued during 1982 because discharges to the Woronora River ceased two years previously (on 1.7.80) and residual radioactivity on all these samples had diminished to levels at or below the detectable limit.

TABLE 2

RADIOACTIVE IODINE IN AIR, 1982*

Week Ending	^{131}I (Bq m^{-3})	Week Ending	^{131}I (Bq m^{-3})
4 January 1982	n.d.	6 July 1982	n.d.
11 "	n.d.	13 "	n.d.
19 "	n.d.	20 "	trace
		27 "	trace
2 February 1982	n.d.		
9 "	trace	3 August 1982	n.d.
16 "	trace	10 "	trace
23 "	n.d.	19 "	trace
		24 "	trace
2 March 1982	n.d.	31 "	trace
10 "	n.d.		
16 "	n.d.	7 September 1982	trace
23 "	n.d.	23 "	n.d.
31 "	trace	29 "	n.d.
6 April 1982	n.d.	5 October 1982	n.d.
13 "	trace	12 "	n.d.
20 "	trace	19 "	trace
27 "	trace	26 "	n.d.
4 May 1982	trace	2 November 1982	n.d.
18 "	n.d.	9 "	n.d.
25 "	trace	16 "	n.d.
1 June 1982	trace	1 December 1982	trace
8 "	n.d.	7 "	n.d.
16 "	n.d.	14 "	n.d.
22 "	n.d.	21 "	n.d.
29 "	n.d.	30 "	n.d.

* Three air samplers are located along the eastern boundary of the site, where suburban residences are closest.

n.d. = not detected

TABLE 3

RADIOACTIVITY IN MILK SAMPLES, 1982

Station	Date	Radioactivity (Bq g^{-1} fresh weight)	
		^{137}Cs	^{131}I
T3 (Menai)	2 Feb.	trace	n.d.
	28 Feb.	trace	n.d.
	29 March	trace	n.d.
	30 April	n.d.	n.d.
	28 May	n.d.	n.d.
	14 July	trace	n.d.
	31 Aug.	n.d.	n.d.
	30 Sept.	n.d.	n.d.
	28 Oct.	trace	n.d.
	30 Nov.	trace	n.d.
	31 Dec.	n.d.	n.d.

The analytical method used for ^{131}I in milk has a minimum measurable level of $1x10^{-3}$ Bq g^{-1}. For ^{137}Cs the minimum measurable level is $3x10^{-4}$ Bq g^{-1}.

n.d. = not detected

TABLE 4

TRITIUM IN WORONORA WATER SAMPLES AT STATION E5.9, 1982

Date	Tritium (Bq mL^{-1})	Date	Tritium (Bq mL^{-1})	Date	Tritium (Bq mL^{-1})
4 Jan.	<0.25	5 May	<0.25	18 Aug.	<0.25
20 Jan.		11 May		24 Aug.	
26 Jan.		18 May		31 Aug.	
9 Feb.		25 May		7 Sept.	
16 Feb.		1 June		23 Sept.	
23 Feb.		8 June		29 Sept.	
2 March		16 June		5 Oct.	
10 March		23 June		12 Oct.	
16 March		29 June		19 Oct.	
23 March		6 July		26 Oct.	
31 March		13 July		2 Nov.	
6 April		20 July		9 Nov.	
13 April		27 July		16 Nov.	
20 April		3 Aug.		1 Dec.	
27 April	<0.25	10 Aug.	<0.25	7 Dec.	
				14 Dec.	
				21 Dec.	
				30 Dec.	<0.25

Derived limiting concentration (d.l.c.) taken from ICRP [1979]

d.l.c. = 80 Bq mL^{-1} (if taken as drinking water).

TABLE 5

RADIOACTIVITY IN WORONORA FISH, 1982

Station & Variety	Date	Radioactivity (Bq g^{-1} fresh weight)			K
		Gross Alpha	Gross Beta (less ^{40}K)	Gamma Emitters	($\mu g\ g^{-1}$)
EO mullet	25.1	0.02	<0.01	^{238}U + ^{232}Th series & trace	3,000
E6.6 mullet	26.1	0.02	<0.01	^{238}U + ^{232}Th series & trace	2,700

TABLE 6

RADIOACTIVITY IN WORONORA ZOSTERA SAMPLES, 1982

Station	Date	Radioactivity (Bq g^{-1} fresh weight)				K ($\mu g\ g^{-1}$)
		Gross Alpha	Gross Beta (less ^{40}K)	Gamma Emitters		
				^{60}Co	^{238}U+^{232}Th series	
E1.3	21.1	0.08	0.02	trace	trace	2700
	27.10	0.06	0.02	n.d.	n.d.	8900
E1.6	21.1	0.04	<0.01	0.005	trace	4500
	27.10	0.03	0.07	trace	trace	4000
E2.4	21.1	0.03	<0.01	0.004	trace	4000
	17.3	0.03	<0.01	0.005	trace	5500
	27.10	0.03	0.02	n.d.	n.d.	5200
E4.6	21.1	0.1	<0.01	trace	trace	5300
	27.10	0.2	0.06	n.d.	n.d.	3400

n.d. = not detected.

TABLE 7

RADIOACTIVITY IN WORONORA BEACH SAND, 1982

Station	Date	Radioactivity (Bq g^{-1} dry weight)			K ($\mu g\ g^{-1}$)
		Gross Alpha	Gross Beta (less ^{40}K)	Gamma Emitters	
E1.3	21.1	0.4	0.05	$^{238}U+^{232}Th$ series = trace	250
	17.3	0.3	0.08	" " "	100
	27.10	0.3	0.07	n.d.	300
E5.9	21.1	0.1	0.1	$^{238}U+^{232}Th$ series = trace	300
	17.3	0.05	0.2	" " "	300
	27.10	0.06	0.09	n.d	250
Average (all samples)		0.2	0.1		
d.l.c.		111	92.5		
Average fraction of d.l.c.		$1.8x10^{-3}$	$1x10^{-3}$		

Derived limiting concentration (d.l.c.) taken from Fry [1966]

n.d. = not detected

TABLE 8

RADIOACTIVITY IN SAMPLES FROM STORMWATER OUTLETS, 1982

Station	Date	Sample	Radioactivity (Bq g^{-1} fresh weight)			^{3}H	K
			Gross Alpha	Gross Beta (less ^{40}K)	Gamma Emitters	(Bq mL^{-1})	(µg g^{-1})
Drain behind Bld 1	22.4	water	-	-	- -	<0.25	-
	19.7	"	-	-	-	<0.25	-
	20.10	"	-	-	-	<0.25	-
	31.12	"	-	-	-	<0.25	
Drain rear of Bld 9	22.4	soil	0.32	0.35	$^{238}U+^{232}Th$ series = trace	-	1900
	22.4	water	-	-	-	<0.25	-
	19.7	"	-	-	-	<0.25	-
	19.7	soil	0.50	0.32	$^{238}U+^{232}Th$ series = trace	-	1000
	20.10	"	0.39	0.29	$^{238}U+^{232}Th$ series = trace	-	1800
	20.10	water	-	-	-	<0.25	-
	31.12	soil	0.47	0.30	$^{238}U+^{232}Th$ series = trace	-	700
Drain on road at west fence	22.4	soil	0.18	0.10	$^{238}U+^{232}Th$ series = trace	-	400
	19.7	soil	0.23	0.07	n.d.	-	300
	19.7	water	-	-	-	<0.25	-
	20.10	water	-	-	-	<0.25	-
	20.10	soil	0.28	0.13	$^{238}U+^{232}Th$ series = trace	-	400
	31.12	soil	0.22	0.12	$^{238}U+^{232}Th$ series = trace	-	300
Drain opposite sub-station	20.10	soil	0.36	0.25	$^{238}U+^{232}Th$ series = trace	-	1300
	31.12	soil	0.34	0.19	$^{238}U+^{232}Th$ series = trace	-	700
Drain at Boom Gate	22.4	soil	0.18	0.10	$^{238}U+^{232}Th$ series = trace		400
	19.7	soil	0.11	0.07	n.d.		200
	20.10	soil	0.19	0.04	$^{238}U+^{232}Th$ series = trace	-	200
	31.12	soil	0.20	0.05	$^{238}U+^{232}Th$ series = trace	-	200
Drain west of test compound	22.4	soil	0.43	0.92	$^{238}U+^{232}Th$ series = trace	-	1100
	19.7	soil	0.71	0.88	$^{238}U+^{232}Th$ series = trace	-	700
	20.10	soil	0.53	0.88	$^{238}U+^{232}Th$ series = trace ^{137}Cs = trace	-	1100
	31.12	soil	0.81	0.88	$^{238}U+^{232}Th$ series = trace	-	700

TABLE 8 (Continued)

Drain near yellow cake store	22.4	soil	0.21	0.23	$^{238}U+^{232}Th$ series = trace	-	800
	19.7	soil	0.40	0.29	$^{238}U+^{232}Th$ series = trace	-	800
	19.7	water	-	-	-	<0.25	-
	20.10	water	-	-	-	<0.25	-
	20.10	soil	0.40	0.28	n.d.	-	700
	31.12	soil	0.37	0.22	$^{238}U+^{232}Th$ series = trace	-	700
Drain at Fermi Street	22.4	soil	0.17	0.22	$^{238}U+^{232}Th$ series = trace	-	1200
	22.4	water	-	-	-	<0.25	-
	19.7	water	-	-	-	<0.25	-
	19.7	soil	0.31	0.37	^{137}Cs = 0.12 $^{238}U+^{232}Th$ series = trace	-	500
	20.10	soil	0.18	0.14	$^{238}U+^{232}Th$ series = trace	-	600
	20.10	water	-	-	-	0.29	-
	31.12	soil	0.22	0.15	$^{238}U+^{232}Th$ series = trace	-	400
Drain opposite Bld 23	22.4	soil	0.34	0.31	$^{238}U+^{232}Th$ series = trace	-	1000
	19.7	soil	0.34	0.36	^{137}Cs = trace ^{60}Co = trace $^{238}U+^{232}Th$ series = trace	-	600
	20.10	soil	0.43	0.34	$^{238}U+^{232}Th$ series = trace	-	1000
	31.12	soil	0.36	0.24	$^{238}U+^{232}Th$ series = trace	-	600
Drain No. 1 opposite Strassman Cres.	22.4	veg.	<0.01	<0.01	0.5 Mev <0.01 $^{238}U+^{232}Th$ series = trace	-	4500
	22.4	soil	0.29	0.21	$^{238}U+^{232}Th$ series = trace		1100
	22.4	water	-	-	-	<0.25	-
	19.7	water	-	-	-	<0.25	-
	19.7	soil	0.41	0.31	^{60}Co = 0.04 $^{238}U+^{232}Th$ series = trace	-	800
	20.10	soil	0.51	0.65	n.d.	-	100
	20.10	water	-	-	-	<0.25	-
	31.12	soil	0.28	0.17	$^{238}U+^{232}Th$ series = trace	-	300
Drain No 2 opposite Strassman Cres.	19.7	soil	0.50	0.32	$^{238}U+^{232}Th$ series = trace	-	700
	20.10	soil	0.38	0.28	$^{238}U+^{232}Th$ series = trace	-	1100
	31.12	soil	0.55	0.33	$^{238}U+^{232}Th$ series = trace	-	600

TABLE 8 (Continued)

Station	Date	Sample	Radioactivity (Bq L^{-1})			^{3}H	K
			Gross Alpha	Gross Beta (incl. ^{40}K)	Gamma Emitters	(Bq mL^{-1})	(µg g^{-1})
Drain rear of Bld 20	22.4	soil	0.02	0.10	$^{238}U+^{232}Th$ series = trace	-	800
	22.4	water	-	-	-	<0.25	-
	19.7	water	-	-	-	<0.25	-
	19.7	soil	0.16	0.02	n.d.	-	1100
	20.10	soil	0.21	0.09	n.d.	-	400
	31.12	soil	0.19	0.07	$^{238}U+^{232}Th$ series = trace	-	400
LHRL Storm-water outlet No 1 near south gate	4.1	water	0.1	0.2	n.d.	0.7	-
	11.1	water	0.09	0.2	n.d.	0.6	-
	19.1	water	0.06	0.2	n.d.	0.7	-
	29.1	water	0.5	0.4	n.d.	0.5	-
	9.2	water	0.09	0.1	n.d.	0.5	-
	16.2	water	0.1	0.1	n.d.	1.1	-
	23.2	water	0.07	0.1	n.d.	0.6	-
	2.3	water	0.1	0.08	n.d.	<0.25	-
	10.3	water	0.2	0.3	n.d.	0.9	-
	16.3	water	0.1	0.4	$^{238}U+^{232}Th$ series = trace	0.6	-
	23.3	water	0.2	0.2	n.d.	0.5	-
	31.3	water	0.2	0.1	n.d.	<0.25	-
	6.4	water	0.06	0.06	n.d.	<0.25	-
	13.4	water	0.05	0.04	n.d.	<0.25	-
	20.4	water	0.08	0.1	n.d.	0.3	-
	27.4	water	0.08	0.1	n.d.	<0.25	-
	4.5	water	0.09	0.1	n.d.	<0.25	-
	11.5	water	0.1	0.1	n.d.	<0.25	-
	18.5	water	-	-	n.d.	0.9	-
	25.5	water	-	-	-	1.2	-
	1.6	water	0.2	0.1	n.d.	0.7	-
	8.6	water	0.7	3.5	$^{238}U+^{232}Th$ series = trace	<0.25	-
	16.6	water	0.03	0.08	n.d.	<0.25	-
	22.6	water	-	-	-	0.7	-
	29.6	water	0.01	0.04	n.d.	<0.25	-
	6.7	water	-	-	n.d.	<0.25	-

TABLE 8 (Continued)

	13.7	water	0.05	0.1	n.d.	0.6	-
	20.7	water	0.02	0.1	n.d.	0.5	-
	27.7	water	0.07	0.1	n.d.	0.6	-
	3.8	water	0.04	0.1	n.d.	0.8	-
	10.8	water	-	-	-	0.9	-
	18.8	water	0.05	0.1	n.d.	0.5	-
	24.8	water	0.05	0.1	n.d.	0.9	-
	31.8	water	0.2	0.1	n.d.	<0.25	-
	7.9	water	0.1	0.1	n.d.	<0.25	-
	23.9	water	0.08	0.1	n.d.	<0.25	-
	29.9	water	0.1	0.2	n.d.	0.6	-
	5.10	water	0.07	0.1	n.d.	0.3	-
	12.10	water	0.06	0.1	n.d.	<0.25	-
	19.10	water	0.04	0.1	n.d.	<0.25	-
	26.10	water	0.04	0.1	n.d.	0.5	-
	2.11	water	0.2	0.1	n.d.	0.5	-
	9.11	water	0.08	0.1	n.d.	0.7	-
	16.11	water	0.06	0.1	n.d.	0.6	-
	1.12	water	0.1	0.1	n.d.	1.0	-
	7.12	water	0.2	0.2	n.d.	0.8	-
	14.12	water	0.08	0.1	n.d.	0.8	-
	21.12	water	0.2	0.2	n.d.	0.3	-
	30.12	water	-	-	-	2.1	-

Station	Date	Sample	Radioactivity (Bq g^{-1} fresh weight)			^{3}H	K
			Gross Alpha	Gross beta (less ^{40}K)	Gamma Emitters	(Bq mL^{-1})	(µg g^{-1})
20 m from LHRL storm-water outlet No 1	24.6	soil	0.7	0.6	^{137}Cs = 0.2 ^{60}Co = 0.2 $^{238}U+^{232}Th$ series = trace	-	400
	24.6	water	-	-	-	<0.25	-
	21.10	water	-	-	-	<0.25	
	21.10	soil	0.9	0.4	$^{238}U+^{232}Th$ series = trace ^{60}Co = trace	- -	1300

TABLE 8 (Continued)

Water-pool across road from LHRL storm-water outlet No 1	22.4	veg.	<0.01	<0.01	0.5 MeV <0.01 $^{238}U+^{232}Th$ series = trace	-	4500
	23.6	water	-	-	-	<0.25	-
	20.7	veg.	<0.01	<0.01	$^{238}U+^{233}Th$ series = trace	-	3600
	20.7	soil	0.4	0.3	$^{238}U+^{232}Th$ series = trace	-	600
	20.7	water	-	-	-	0.5	-
	20.10	water	-	-	-	0.5	-
	20.10	soil	0.9	0.4	$^{238}U+^{232}Th$ series = trace	-	600
	20.10	veg.	<0.01	0.04	0.5 MeV <0.01 $^{238}U+^{232}Th$ series = trace	-	3300

The gamma-ray peaks detected at approximately 0.5 MeV could be ^{7}Be (0.48), ^{103}Ru (0.5 MeV) or ^{106}Ru (0.51 MeV); ^{7}Be is a cosmic-ray produced spallation product; and ^{103}Ru and ^{106}Ru are fission products. In column 6 of this table, Bq g^{-1} refers to the numbers of disintegrations per second per gram at the energies indicated.

n.d. = not detected

\- = not measured

TABLE 9

GAMMA SURVEY - EFFLUENT DISCHARGE

PIPELINE, 1982

Surveys of exposed portions of pipeline between the LHRL and the sewer connection using an Ericsson type 1368A field ratemeter.

Date	Location	Dose Rate ($\mu Sv\ h^{-1}$)
23.6	Joint No. 9	0.8
	All other pipe sections	<0.4
	Soil below joints	<0.3
17.12	All pipe sections	<0.5
	Soil below joints	<0.3

TABLE 10

RADIOACTIVITY IN SAMPLES TAKEN NEAR EFFLUENT

DISCHARGE PIPELINE, 1982

Station	Date	Sample	Radioactivity (Bq g^{-1} dry weight)			^{3}H (Bq mL^{-1})	K ($\mu g\ g^{-1}$)
			Gross Alpha	Gross Beta (less ^{40}K)	Gamma Emitters		
Near scour valve No.1	23.6	soil	0.3	0.08	$^{238}U+^{232}Th$ series = trace	--	400
	23.6	water	--	--	--	<0.25	--
	17.12	soil	0.5	0.04	$^{238}U+^{232}Th$ series = trace	--	300
	17.12	water	--	--	--	<0.25	--
River at point where crossed by effluent discharge pipe	17.12	soil	0.3	0.04	n.d.	--	300

TABLE 11

RADIOACTIVITY IN FRESHWATER SECTION OF WORONORA RIVER, 1982

Station	Date	Radioactivity		
		Sand	Water	
		^{90}Sr (Bq g^{-1})	^{90}Sr (Bq L^{-1})	^{3}H (Bq L^{-1})
Woronora River at Heathcote Road crossing (upstream of Lucas Heights)	1.4.82	0.0011	0.048	<0.25
	23.6.82	0.0017	n.d.	<0.25
	13.10.82	0.0015	0.041	<0.25
	17.12.82	0.0009	0.027	<0.25
Woronora River at the point of entry of Lucas Heights' drainage	1.4.82	0.0011	0.024	<0.25
	23.6.82	0.0009	n.d.	--
	13.10.82	0.0011	--	<0.25
	17.12.82	0.0003	0.020	--

TABLE 12

RADIOACTIVITY IN SAMPLES OF SOIL AND VEGETATION

FROM LITTLE FOREST BURIAL GROUND, 1982

Location	Sample	Date	Radioactivity (Bq g^{-1} fresh weight)					$\mu g\ g^{-1}$
			Gross Alpha	Gross Beta (less ^{40}K)	Gamma Emitters			
					0.5 MeV	^{60}Co	238U+232Th	
Near trench 1-5	soil	23 Apr	0.29	0.49	n.d.	n.d.	trace	5600
	soil	27 Jul	0.76	0.58	n.d.	trace	trace	4600
	soil	23 Dec	0.58	0.51	n.d.	n.d.	trace	4100
Near trench 56-57	soil	23 Apr	1.28	0.68	n.d.	trace	trace	5900
	soil	27 Jul	1.23	0.68	n.d.	trace	trace	4100
	soil	23 Dec	1.90	0.73	n.d.	trace	trace	3800
Near trench 68-69	soil	23 Apr	1.26	1.01	n.d.	trace	trace	6000
	soil	27 Jul	1.09	1.17	n.d.	trace	trace	5200
	soil	23 Dec	0.94	0.89	n.d.	trace	trace	6700
Near trench 72-73	soil	23 Apr	0.72	0.74	n.d.	trace	trace	7900
	soil	27 Jul	0.93	0.92	n.d.	trace	trace	3400
	soil	23 Dec	0.91	1.06	n.d.	trace	trace	3600
Near trench 58-59	acacia	23 Apr	0.01	<0.01	<0.01	trace	trace	2600
	acacia	27 Jul	<0.01	<0.01	<0.01	n.d.	trace	2100
	acacia	23 Dec	0.02	0.02	<0.01	n.d.	trace	2300
Near trench 70-71	acacia	23 Apr	0.01	2.51	trace	0.01	trace	2000
Near trench 52-57	grass	27 Jul	0.05	1.10	0.01	0.03	trace	1600

n.d. = not detected

TABLE 13

RADIOACTIVITY IN SAMPLES OF GROUNDWATER FROM

LITTLE FOREST BURIAL GROUND, 1982

Bore Hole No.	Date	Sediment (Bq g^{-1})			^{3}H (Bq mL^{-1})
		Gross Alpha	Gross Beta*	Gamma Emitters	
BH4	11 Mar	3.14	0.83	Trace $^{238}U+^{232}Th$ series	<0.25
	9 Jul	1.30	0.51	Trace $^{238}U+^{232}Th$ series	<0.25
	28 Dec	2.56	0.87	Trace $^{238}U+^{232}Th$ series	<0.25
BH6	11 Mar	4.13	0.98	Trace $^{238}U+^{232}Th$ series	--
	9 Jul	3.01	0.83	Trace $^{238}U+^{232}Th$ series	<0.25
	23 Dec	2.14	0.79	Trace $^{238}U+^{232}Th$ series	<0.25
BH10	11 Mar	0.45	0.22	Trace $^{238}U+^{232}Th$ series	--
	9 Jul	0.80	0.38	Trace $^{238}U+^{232}Th$ series	1.10
	23 Dec	0.43	0.33	Trace $^{238}U+^{232}Th$ series	1.21
OS1	11 Mar	1.82	0.73	Trace $^{238}U+^{232}Th$ series	--
	9 Jul	0.11	0.27	n.d.	<0.25
OS2	11 Mar	1.52	1.20	Trace $^{238}U+^{232}Th$ series	--
	9 Jul	1.02	1.16	n.d.	2.65
	23 Dec	1.08	1.09	Trace $^{238}U+^{232}Th$ series	3.12
OS3	11 Mar	0.82	2.65	Trace $^{238}U+^{232}Th$ series	--
	9 Jul	1.13	2.19	Trace $^{238}U+^{232}Th$ series	30.74
	23 Dec	1.26	2.67	Trace $^{238}U+^{232}Th$ series	34.59
BHA	11 Mar	0.16	0.16	n.d.	--
	9 Jul	0.06	0.15	Trace $^{238}U+^{232}Th$ series	<0.25
	23 Dec	0.12	0.19	n.d.	<0.25
BHB	11 Mar	0.16	0.16	n.d.	--
	9 Jul	0.09	0.11	n.d.	<0.25
	23 Dec	0.11	0.16	n.d.	<0.25
BHC	11 Mar	0.03	0.14	n.d.	--
	9 Jul	0.02	0.12	n.d.	<0.25
	23 Dec	0.05	0.15	n.d.	<0.25
BHD	11 Mar	0.16	0.15	Trace $^{238}U+^{232}Th$ series	--
	9 Jul	0.19	0.15	Trace $^{238}U+^{232}Th$ series	<0.25
	23 Dec	0.22	0.15	n.d.	<0.25
BHE	11 Mar	0.05	0.14	Trace $^{238}U+^{232}Th$ series	--
	9 Jul	0.05	0.13	n.d.	<0.25
	23 Dec	0.10	0.19	n.d.	<0.25

* includes ^{40}K contribution

n.d. = not detected

-- = not measured

TABLE 14

RADIOACTIVITY IN SAMPLES TAKEN FROM CREEKS NORTH OF LITTLE FOREST BURIAL GROUND, 1982

Sand:

Station	Date	Radioactivity (Bq g^{-1} dry weight)			K ($\mu g\ g^{-1}$)
		Gross Alpha	Gross Beta (less ^{40}K)	Gamma Emitters	
Barden Creek above junction with Mill Creek	22.12	1.1	0.05	n.d.	300
Mill Creek above junction with Barden Creek	22.12	0.7	0.08	$^{238}U+^{232}Th$ series = trace	500

Water:

Station	Date	Radioactivity (Bq L^{-1})			^{3}H (Bq mL^{-1})
		Gross Alpha	Gross Beta (Incl. ^{40}K)	Gamma Emitters	
Barden Creek above junction with Mill Creek	22.12	0.1	0.1	n.d.	<0.25
Mill Creek above junction with Barden Creek	22.12	0.3	0.3	n.d.	<0.25

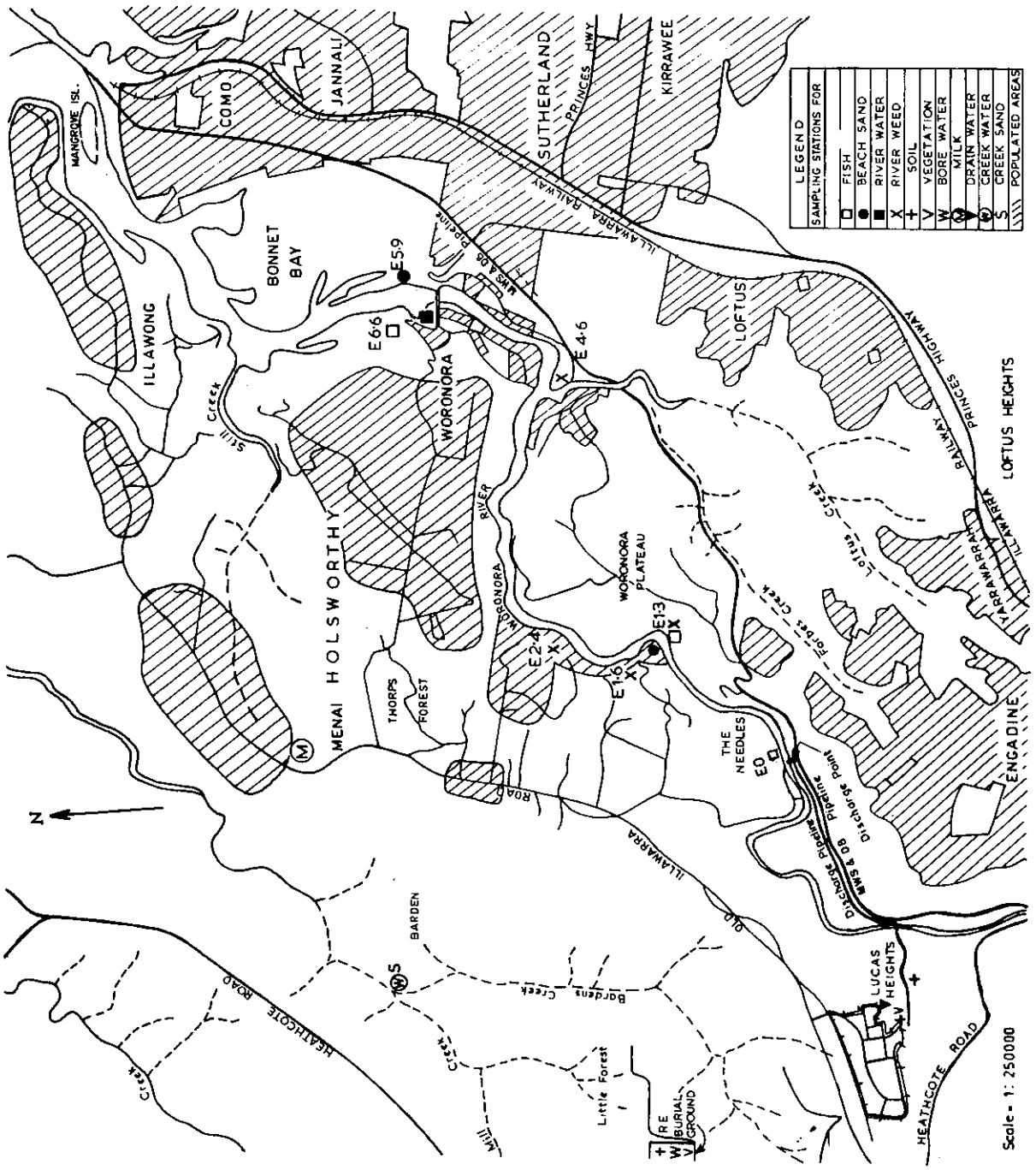

FIGURE 1. LUCAS HEIGHTS DISTRICT - LOCATION OF SAMPLING STATIONS

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 the AAEC Research Establishment, 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 AAEC Research Establishment, Lucas Heights. Results for 1973. AAEC/E335.

Davy, D.R., Dudaitis, A. [1976] - Environmental Survey at the AAEC 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 AAEC Research Establishment, Lucas Heights. Results for 1979. AAEC/E508.

Giles, M.S., Dudaitis, A. [1982] - Environmental Survey at the AAEC Research Establishment, Lucas Heights. Results for 1980. AAEC/E542.

Williams, A.R., Dudaitis, A. [1983] - Environmental Survey at the Lucas Heights Research Laboratories, 1981. AAEC/E563.

APPENDIX B1

AIRBORNE RADIOACTIVITY RELEASES, 1982

	Gross α (kBq)	^{131}I (MBq)	^{3}H (GBq)	^{41}Ar (TBq)	Other β/γ (MBq)	Fission product Noble Gases (TBq)
Quarter No. 1						
Bld. 2	<10	2.8×10^3	-	-	<10	18
15	<10	<10	7.3×10^2	21	71	-
19	<10	<10	-	-	<10	-
23A	<10	2.6×10^3	-	-	<10	-
23B	<10	<10	-	-	<10	-
41	<10	<10	-	-	<10	-
57	-	-	12	-	-	-
Quarter No. 2						
Bld. 2	<10	1.4×10^3	-	-	<10	18
15	<10	<10	9.1×10^2	20	38	-
19	<10	37	-	-	<10	-
23A	<10	4.2×10^3	-	-	<10	-
23B	<10	<10	-	-	<10	-
41	<10	<10	-	-	<10	-
57	-	-	-	-	-	-
Quarter No. 3						
Bld. 2	<10	1.6×10^3	-	-	64	38
15	<10	<10	9.1×10^2	20	26	-
19	<10	<10	-	-	<10	-
23A	<10	2.4×10^3	-	-	<10	-
23B	<10	<10	-	-	<10	-
41	<10	<10	-	-	<10	-
57	-	-	2.9	-	-	-
Quarter No. 4						
Bld. 2	<36	6.2×10^3	-	-	6.2×10^3	21
15	<16	<3	6.6×10^2	22	1.8×10^2	-
19	<14	<2	-	-	3	-
23A	<9	5.1×10^3	-	-	9	-
23B	<8	<2	-	-	<0.1	-
41	<8	<5	-	-	<0.1	-
57	-	-	18	-	-	-

APPENDIX B2

AIRBORNE RADIOACTIVITY DISCHARGES FROM INDIVIDUAL DISCHARGE POINTS EXPRESSED AS FRACTIONS OF AUTHORISED QUARTERLY POINT DISCHARGE FOR 1982

	Gross α	^{131}I	^{3}H	^{41}Ar	Other β/γ	Fission Product Noble Gases
Quarter No.1						
Bld.2	$<1.5\times10^{-5}$	4.2×10^{-2}	$-$	$-$	$<6.3\times10^{-6}$	0.11
15	$<3.0\times10^{-4}$	$<6.3\times10^{-5}$	5.6×10^{-3}	0.78	1.1×10^{-3}	$-$
19	$<3.0\times10^{-5}$	$<3.0\times10^{-4}$	$-$	$-$	$<1.5\times10^{-4}$	$-$
23A	$<6.3\times10^{-4}$	0.16	$-$	$-$	$<3.0\times10^{-4}$	$-$
23B	$<1.5\times10^{-3}$	$<6.3\times10^{-5}$	$-$	$-$	$<6.3\times10^{-5}$	$-$
41	$<3.6\times10^{-2}$	$<6.3\times10^{-4}$	$-$	$-$	$<1.5\times10^{-2}$	$-$
57	$-$	$-$	8×10^{-2}	$-$	$-$	$-$
Quarter No.2						
Bld.2	$<1.5\times10^{-5}$	2.1×10^{-2}	$-$	$-$	$<6.3\times10^{-6}$	0.11
15	$<3.0\times10^{-4}$	$<6.3\times10^{-3}$	7.0×10^{-3}	0.74	5.8×10^{-3}	$-$
19	$<3.0\times10^{-5}$	1.1×10^{-4}	$-$	$-$	$<1.5\times10^{-4}$	$-$
23A	$<6.3\times10^{-4}$	0.26	$-$	$-$	$<3.0\times10^{-4}$	$-$
23B	$<1.5\times10^{-3}$	$<6.3\times10^{-5}$	$-$	$-$	$<6.3\times10^{-5}$	$-$
41	$<3.0\times10^{-2}$	$<6.3\times10^{-4}$	$-$	$-$	$<1.5\times10^{-2}$	$-$
Quarter No.3						
Bld.2	$<1.5\times10^{-5}$	2.4×10^{-2}	$-$	$-$	4.0×10^{-5}	0.23
15	$<3.0\times10^{-4}$	$<6.3\times10^{-5}$	7.0×10^{-3}	0.74	3.9×10^{-3}	$-$
19	$<3.0\times10^{-5}$	$<3.0\times10^{-4}$	$-$	$-$	$<1.5\times10^{-4}$	$-$
23A	$<6.3\times10^{-4}$	0.15	$-$	$-$	$<3.0\times10^{-4}$	$-$
23B	$<1.5\times10^{-3}$	$<6.3\times10^{-5}$	$-$	$-$	$<6.3\times10^{-5}$	$-$
41	$<3.0\times10^{-2}$	$<6.3\times10^{-4}$	$-$	$-$	$<1.5\times10^{-2}$	$-$
57	$-$	$-$	1×10^{-2}	$-$	$-$	$-$
Quarter No.4						
Bld.2	$<5.5\times10^{-5}$	9.4×10^{-2}	$-$	$-$	3.9×10^{-3}	0.12
15	$<4.8\times10^{-5}$	$<1.9\times10^{-5}$	5.1×10^{-3}	0.81	2.7×10^{-6}	$-$
19	$<4.2\times10^{-4}$	$<6.1\times10^{-4}$	$-$	$-$	4.5×10^{-4}	$-$
23A	$<5.6\times10^{-3}$	0.32	$-$	$-$	2.7×10^{-6}	$-$
23B	$<1.2\times10^{-5}$	$<1.3\times10^{-4}$	$-$	$-$	$<6.3\times10^{-7}$	$-$
41	$<2.4\times10^{-2}$	$<3.1\times10^{-2}$	$-$	$-$	$<1.5\times10^{-2}$	$-$
57	$-$	$-$	12×10^{-2}	$-$	$-$	$-$

APPENDIX C

RADIOACTIVITY DISCHARGED TO THE MWSDB SEWER DURING 1982

	Radioisotopes Measured (MBq)			Percentage of Authorised Limit**
	* α_μ	^3H	+ β_μ	
Quarter No. 1	15.7	3.86×10^5	109	12
Quarter No. 2	18.5	1.04×10^5	215	18
Quarter No. 3	17.6	1.06×10^5	281	18
Quarter No. 4	26.7	2.02×10^5	389	21

* α_μ = a mixture of unidentified α-emitting nuclides taken as being all ^{226}Ra (i.e. the worst possible case) in calculating percentage of authorised limit.

\+ β_μ = a mixture of unidentified β-emitting nuclides taken as being all ^{90}Sr (i.e. the worst possible case) when calculating the percentage of authorised limit.

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

APPENDIX D

LIST OF ISOTOPE SYMBOLS USED IN TABLES OF SURVEY RESULTS

Symbol	Name
^{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
^{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