



**AUSTRALIAN ATOMIC ENERGY COMMISSION  
RESEARCH ESTABLISHMENT  
LUCAS HEIGHTS**

**ENVIRONMENTAL SURVEY AT THE A.A.E.C.  
RESEARCH ESTABLISHMENT LUCAS HEIGHTS  
RESULTS FOR THE PERIOD JANUARY - JULY, 1970**

by

**N.F. CONWAY  
A. DUDAITIS**

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ABSTRACT

This fourth supplement to AAEC/E151, 'Results of the Lucas Heights Biological Survey, December 1959 to December 1964', tabulates the results of the environmental survey for the period January to July 1970 and compares them with derived maximum permissible concentrations appropriate to the local environment.

Possible doses to individual members of the local population as a result of Research Establishment operations are less than those due to weapons test fallout and much less than those due to natural radiation background.

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CESIUM 137; COBALT 60; ENVIRONMENT; ESTUARIES; FISHES; GRASS;  
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## 1. INTRODUCTION

This report gives results obtained from samples collected for the environmental survey programme at Lucas Heights for the period January to July 1970. As from August 1970 the programme was amended and these and subsequent results will be the subject of a separate report and associated supplements. This report continues the tabulation of results reported by Giles and Stockdale (1966), Cook, Dudaitis and Giles (1969), Cook and Dudaitis (1970 a) and Cook and Dudaitis (1970 b). The 1966 report described the methods of measurement used.

## 2. SAMPLING PROGRAMME

The Woronora estuary receives treated low level aqueous waste from the Research Establishment. Table 1 gives details of collection and preparation of samples taken from the estuary for the environmental survey programme. Sampling sites and frequency remained the same except the frequency for bottom sand at the discharge point which reverted to a quarterly basis. Figure 1 gives the location of estuary sampling stations.

Table 2 gives details of terrestrial samples and their preparation and Figure 2 gives the location of terrestrial sampling stations.

## 3. TABULATION OF RESULTS

Tables 3 to 10 refer to samples collected from the Woronora estuary and Tables 11 to 14 refer to samples from the terrestrial environment which could show traces of radioactivity from airborne waste arising from the Research Establishment. Table 15 refers to samples taken from the solid waste burial ground (Station T 1, one mile from the Research Establishment) while Table 16 refers the samples taken along the route of the effluent pipeline (which runs above ground for the greater part of its length) from the Research Establishment to the Woronora estuary.

## 4. DISCUSSION OF RESULTS

### 4.1 Woronora Estuary

The results for estuarine water, oysters, fish and beach sand are summarised in Table 17 where the average results for the period are expressed as fractions of the derived maximum permissible concentrations (Fry 1966); the results for 1965 to 1969 are included for comparison.

The isotopes detected were the same as were found in the previous years with the exception of caesium-137 which was not found in fish. The levels for tritium in water, zinc-65 in oysters and cobalt-60 in fish were all less than one thousandth of the derived maximum permissible concentrations. Positive results for strontium-90 in oyster flesh have still not been obtained with the

limit less than three thousandths of the derived maximum permissible concentration. Strontium-90 in whole fish averaged 0.006 pCi/g fresh weight, less than one hundredth of the derived m.p.c. Gross alpha and gross beta activities in beach sand samples, attributed to natural activity, were the same as last year at respectively three thousandths and one thousandth of the derived maximum permissible concentrations.

Bottom sand samples taken at the discharge point showed levels of gross alpha activity, gross beta activity, strontium-90, cobalt-60, caesium-137 and gamma emitters in the thorium-232 decay chain significantly higher than those taken 1.5 miles downstream. These levels are attributed to waste discharge operations. The levels of gross alpha and gross beta activity at 1.5 miles are not significantly different from those in beach sand samples and are attributed to natural activity.

Water samples taken from the discharge point and 0.3 miles above the discharge point showed no significant changes from previous years.

Zostera, Table 10, showed the same activity concentrations as in previous years with cobalt-60 the only gamma emitter detected. The activity of this radioisotope, 4.4 miles from the discharge point was lower by a factor of 25 than the activity measured one mile from the discharge point. There are no identifiable human exposure routes for zostera and hence no derived maximum permissible concentrations.

#### 4.2 Terrestrial Samples Relating to Possible Airborne Waste

The radioisotopes found in rain, grass and milk samples (Tables 11, 12, 13, 14) are all attributed to weapons test fallout and natural activity. (The lower limit of detection of iodine-131 in milk (Table 13) is 0.3 pCi/g fresh weight, at the 95% confidence level). There is no indication in these samples of any deposition of airborne waste from the Research Establishment.

Results for milk samples (Table 12) are summarised in Table 18. Comparative figures for 1965 to 1969 are given, together with derived maximum permissible concentrations. The figures are comparable to those of previous years and can be attributed to the expected activity from weapons test fallout.

#### 4.3 Other Terrestrial Samples

Samples from the solid waste burial ground are listed in Table 15. Vegetation taken from the nearest point to the actual buried waste showed the presence of cobalt-60. Other vegetation showed only fallout activity. Water from the bore hole nearest to the buried waste (No. OS 3,) also showed cobalt-60 but the actual level is low, corresponding to less than one

thousandth of the non-occupational maximum permissible concentrations in drinking water for cobalt-60 (I.C.R.P. 1960).

Sub-surface water from the burial ground is expected to drain into Mill Creek north of the burial ground (see Figure 2). For this reason five bore holes in a line (designated A to E) were drilled just outside the northern perimeter of the burial ground. The highest activity detailed in water samples from these holes was alpha activity in samples from bore hole D. This was identified by alpha spectroscopy as being due to alpha emitters in the natural uranium-238 decay chain.

Soil and vegetation samples taken along the length of the effluent pipeline from the site to the Woronora Estuary (Table 16) show activities which do not vary significantly from those obtained in 1968 (Cook and Dudaitis 1970a) and 1969 (Cook and Dudaitis 1970b).

#### 5. RADIOLOGICAL SIGNIFICANCE OF OBSERVED CONCENTRATIONS

An assessment of possible doses to members of the local population from ingestion of oysters, fish, local milk and from other possible exposure routes has been made using the same assumptions as for the 1968 results (Cook and Dudaitis 1970a). The results are summarised in Table 19. Whole body doses from tritium and zinc-65, attributable to Research Establishment operations, were each 0.03 millirem per year while a trace only of cobalt-60 and no caesium-137 was detected. The cumulative dose could amount to 0.1 millirem per year for the hypothetical person consuming 70 grams each of oyster and fish per day and swimming daily at the discharge point. This is less than one thousandth of the maximum permissible dose limit for individual members of the public (I.C.R.P. 1966).

Doses due to weapons test fallout ingested in diet are estimated to be 5 millirem per year to rapidly growing bone in young children due to strontium-90 and 0.1 millirem for year whole body dose for caesium-137.

Regular contact with beach sands, assuming 15 hours exposure per week, (Fry 1966) could give up to 5 millirem per year due to natural beta activity.

By comparison, whole body dose from all natural radiation, internal and external, would be of the order of 100 millirem per year.

#### 6. SUMMARY

During the period January to July 1970 no radioactivity attributable to aerial dispersion from the Research Establishment was detected in the environment.

In the Woronora estuary a number of radioisotopes other than those that occur naturally or in fallout, or in quantities in excess of natural or fallout

concentrations were detected. These are attributed to low level liquid effluent discharges in the estuary. Those found were tritium (as water) cobalt-60 (in fish, zostera and bottom sand from the discharge point), strontium-90 (in fish and bottom sand from the discharge point), caesium-137 (in bottom sand from the discharge point) zinc-65 (in oysters) and traces of excess thorium-232 daughters and excess gross alpha and beta activity (in bottom sand at the discharge point). These radioisotopes, with the exception of zinc-65, were also found in selected soil and vegetation samples taken along the liquid effluent pipe-line.

At the solid waste burial ground, cobalt-60, attributed to buried waste, has been detected in vegetation taken near the buried material and in the bore hole nearest to the buried material.

Levels of activity attributable to Research Establishment operations were similar to those of previous years and generally of the order of, or less than, one thousandth of the appropriate derived maximum permissible concentrations.

Estimates of possible doses to individual members of the public from Research Establishment operations give results less than those due to weapons test fallout and much less than natural radiation background.

#### 7. ACKNOWLEDGEMENTS

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#### 8. REFERENCES

- Bryant, P.M. (1966). - Derivation of working limits for continuous release rates of  $^{90}\text{Sr}$  and  $^{137}\text{Cs}$  to atmosphere in a milk producing area. Health Physics, 12: 1383.
- Cook, J.E., Dudaitis, A., and Giles, M.S. (1969). - Environmental Survey at the A.A.E.C. Research Establishment, Lucas Heights. Results for 1965, 1966 and 1967. AAEC/E151, Supplement No. 1.
- Cook, J.E., and Dudaitis, A. (1970a). - Environmental Survey at the A.A.E.C. Research Establishment, Lucas Heights. Results for 1968. AAEC/E151, Supplement No. 2.
- Cook, J.E., and Dudaitis, A. (1970b). - Environmental Survey at the A.A.E.C. Research Establishment, Lucas Heights. Results for 1969. AAEC/E151, Supplement No. 3.
- Giles, M.S., and Stockdale, J.A. (1966). - Results of the Lucas Heights Biological Survey, December 1959 - December 1964. AAEC/E151.

Fry, R.M. (1966). - A reformulation of the Lucas Heights liquid effluent discharge authorisation. AAEC/E156.

ICRP (1960). - Recommendations of the International Commission on Radiological Protection. Report of Committee II on Permissible Dose for Internal Radiation (1959). ICRP Publication 2. Pergamon Press, London.

ICRP (1966). - Recommendations of the International Commission on Radiological Protection (Adopted September 17, 1965). ICRP Publication 9. Pergamon Press, Oxford.



ENVIRONMENTAL SURVEY RESULTS JANUARY - JULY, 1970

TABLES 1 - 19

NOTE: Upper limits shown in Tables 3 - 17 are at the 95 per cent confidence level of the counting statistics. Where an upper limit is given for an average, this is the upper limit of the average of all results. Dashes indicate that no activity was detected and blank spaces indicate that no measurement was made.



TABLE 1

DETAILS OF COLLECTION AND PREPARATION OF ESTUARINE SAMPLES

Sample	Stations	Collection Frequency	Collection Details	Special Steps in Preparation
Oysters	E4.4, E5.8 Control	Quarterly	Obtained from commercial leases	Opened by commercial openers. Drained on sieve for 5 minutes. Ashed.
Fish	E0.8, E4.0	Quarterly	Caught by seine net	Whole fish ashed.
Beach Sand	E0.8, E2.9 E3.7	Quarterly	Taken by scoop from top 2 in. in the intertidal region	Fraction between 60 and 120 mesh B.S.S. removed after ashing.
Bottom Sand	E0 E1.5	Monthly Quarterly	Taken by pump	As for beach sand.
Estuary Water	E0, E1.5 E3.6, E5.0	Weekly	From surface by bucket	Boiled to dryness, ashed (Distilled for tritium).
River Water	E0.3	Monthly	From surface by bucket	As for estuary water.
Zostera	E1.0, E1.5 E4.4, E5.8	Quarterly	Pulled from bottom by rake or hand	Ashed.

TABLE 2

## DETAILS OF COLLECTION AND PREPARATION OF TERRESTRIAL SAMPLES

Sample	Stations	Collection Frequency	Collection Details	Special Steps in Preparation
Grass	TO	Quarterly Quarterly Quarterly	Cut by rotary mower or hand clippers to within 1 in. of the ground	Whole unwashed grass is ashed.
	T1.2			
	T32			
Milk	T3.1	Monthly	Obtained from bulk milk supplies	Gamma spectrometry of whole milk for iodine-131. Whole milk ashed for other assays.
	TO	Quarterly	Collected in polythene pots having a funnel diameter of 10 in. 50 ml of A.R.HNO <sub>3</sub> , 50 mg Cs <sup>++</sup> and 50 mg Sr <sup>++</sup> are added as carrier	The water is passed through 200 ml of Amberlite IRC 120 resin, which is then ashed.
Vegetation	T1	Six Monthly	Cut by hand clippers	Whole unwashed vegetation is ashed.
	T1	Six Monthly	Bore holes pumped out, allowed to refill, sample taken from bottom	The water is passed through 200 ml of Amberlite IRC 120 resin, which is then ashed.
Creek Water	TO	Six Monthly	Taken in bucket	As for ground water (Distilled for tritium).
	T2	Six Monthly		

TABLE 3

## WORONORA SAMPLES - OYSTER FLESH, 1970

Station	Date 1970	Radioactivity, pCi/g Fresh Weight					K ppm	Ca ppm	Be ppm
		Gross Alpha	Gross Beta (less $^{40}\text{K}$ )	$^{90}\text{Sr}$	$^{65}\text{Zn}$				
E4.4	4.2	0.13	0.15	<0.001	0.08	3300	1700	0.002	
Average	1.5	0.33	0.72	0.005	0.29	5900	3100	0.001	
E5.8	4.2	0.23	0.43	<0.003	0.19				
Average	15.4	0.18	0.06	<0.001	0.09	3500	1600	0.004	
Hawkesbury River (H.R.)	17.7	0.22	0.73	<0.001	trace	6000	3100	0.005	
Average		0.33	0.08	<0.001	0.15	2900	4700	0.004	
		0.24	0.29	<0.001	0.08				
Hawkesbury River (H.R.)	4.2	0.36	0.39	<0.001	-	2800	4500	0.003	
Average	15.4	0.16	0.42	<0.001	-	3100	2100	0.003	
	17.7	0.13	0.56	<0.001	-	3500	2200	0.002	
Average		0.22	0.46	<0.001					
Oyster Shell Composite	4.2-1.5	0.60	0.36	<0.072	-	100	36100	0.010	
Derived m.p.c.				1	1000				
E4.4 Fraction of m.p.c.				$<3 \times 10^{-3}$	$2 \times 10^{-4}$				
E5.8				$<1 \times 10^{-3}$	$8 \times 10^{-5}$				
H.R.				$<1 \times 10^{-3}$	-				
Oyster Shell Composite				-	-				

TABLE 4

## WORONORA SAMPLES - WHOLE FISH, 1970

Station	Date 1970	Radioactivity, pCi/g Fresh Weight					K ppm	Ca ppm	Be ppm
		Gross Alpha	Gross Beta (less $^{40}\text{K}$ )	$^{90}\text{Sr}$	Gamma Emitters				
EO.8 Mullet	17.2	0.31	0.36	0.009	trace	$^{60}\text{Co}$	3300	9700	0.008
"	28.5	0.10	0.18	0.007	trace	$^{60}\text{Co}$	3200	11500	0.002
Herring	17.2	0.10	0.31	<0.003	trace	$^{60}\text{Co}$	3200	12500	0.001
Average		0.17	0.28	<0.006	trace	$^{60}\text{Co}$			
E4.0 Mullet	24.2	0.95	0.59	<0.005	-	-	2800	8000	0.017
Blackfish	"	0.50	1.20	<0.005	-	-	2000	9400	0.017
Average		0.73	0.90	<0.005	-	-			
Derived m.p.c.				1	500	$^{60}\text{Co}$			
EO.8 Fraction of m.p.c.				<0.006	-	-			
E4.0				<0.005	-	-			

TABLE 5

WORONORA SAMPLES - BEACH SAND, 1970

Station	Date 1970	Radioactivity, pCi/g Dry Weight		K ppm	Be ppm
		Gross Alpha	Gross Beta (less $^{40}\text{K}$ )		
EO.8	14.4	4	4	300	0.05
Average	15.5	8	4	390	0.08
		6	4		
E 2.9	15.5	5	2	300	0.04
E 3.7	14.4	11	2	400	0.11
Average	15.5	13	2	400	0.10
		12	2		
Derived m.p.c.		3000	2500		
Average fraction of m.p.c.		0.003	0.001		

TABLE 6

WORONORA SAMPLES - BOTTOM SAND, 1970

Station	Date	Radioactivity, pCi/g Dry Weight						K ppm	Be ppm
		Gross Alpha	Gross Beta (less <sup>40</sup> K)	<sup>90</sup> Sr	Gamma Emitters				
EO	16.1	45	25	0.05	trace 45	<sup>137</sup> Cs <sup>60</sup> Co	1300	0.42	
	20.2	47	19	0.09	trace 37	<sup>232</sup> Th+dtrs <sup>137</sup> Cs <sup>60</sup> Co	400	0.45	
	15.5	27	18	0.03	trace 18	<sup>232</sup> Th+dtrs <sup>137</sup> Cs <sup>60</sup> Co	1900	0.25	
Average		40	21	0.06	Trace 33	<sup>232</sup> Th+dtrs <sup>60</sup> Co			
E 1.5	15.5	9	2	<0.01		-	400	0.05	

TABLE 7

WORONORA SAMPLES - WATER FROM DISCHARGE POINT (EO)  
AND FROM TOLOFIN (E1.5), 1970

Station	Radioactivity, pCi/ml (Annual Averages)	
	Gross Alpha	Gross Beta (less <sup>40</sup> K)
EO	<0.03	<0.07
E1.5	<0.04	<0.08

TABLE 8

WORONORA SAMPLES - FRESH WATER FROM ABOVE CAUSEWAY  
0.3 MILES ABOVE DISCHARGE POINT, 1970

Date 1970	Radioactivity, pCi/ml			<sup>3</sup> H
	Gross Alpha	Gross Beta (less <sup>40</sup> K)	Gamma Emitters	
2.1	<0.002	0.004	-	<1.0
18.2	<0.002	0.002	-	<1.0
10.3	<0.001	<0.001	-	<1.0
23.4	<0.001	0.004	-	<1.0
7.5	<0.002	0.004	-	<1.0
6.7	<0.001	0.003	trace 0.14 MeV trace 0.50 MeV trace Zr+ <sup>95</sup> Nb	<1.0

TABLE 9

WORONORA SAMPLES - TRITIUM IN SURFACE WATER

Date 1970	Tritium, pCi/ml				Date 1970	Tritium, pCi/ml			
	Station EO	Station E1.5	Station E3.6	Station E5.0		Station EO	Station E1.5	Station E3.6	Station E5.0
2.1	<1		2		22.5	50	5	2	3
9.1	3	3	<1	<1	29.5	5	17	3	1
16.1	7	7	1	<1	5.6	25	9	<1	11
23.1	3	3	1	<1	12.6	7	8	2	<1
30.1	<1	<1	2	<1	19.6	8	<1	<1	<1
6.2	8	10	<1	<1	3.7	1	<1	<1	<1
13.2	12	13	1	<1	10.7	6	<1	<1	<1
20.2	11	11	3	1	17.7	10	19	55	4
27.2	30	14	3	<1	23.7	27	12	<1	3
6.3	50	59	12	<1	31.7	14	12	2	<1
13.3	35	21	11	2	Average	15	12	6	3
20.3			7						
26.3			5						
3.4			4						
10.4			3						
17.4			2						
24.4			2						
1.5	3	3	41	27					
8.5	4	1	2	<1					
15.5	37	14	1	1					
Derived m.p.c. = $3 \times 10^4$ pCi/ml					Average fraction of m.p.c.				
					$5 \times 10^{-4}$		$4 \times 10^{-4}$		$1 \times 10^{-4}$

TABLE 10

WORONORA SAMPLES - ZOSTERA, 1970

		Radioactivity, pCi/g Fresh Weight					
Station	Date 1970	Gross Alpha	Gross Beta (less $^{40}\text{K}$ )	Gamma Emitters			
				$^{60}\text{Co}$	0.5 MeV	Zr+ $^{95}\text{Nb}$	
E1.0	15.1	2.0	3.9	4.5	-	-	
	14.4	0.9	1.3	5.5	-	-	
Average		1.5	2.6	5.0	-	-	
E1.5	15.1	1.4	2.5	2.8	-	-	
	14.4	1.2	1.8	3.2	-	-	
Average		1.3	2.2	3.0	-	-	
E2.9	15.1	1.1	1.0	1.2	-	-	
	14.4	2.1	1.0	0.9	-	-	
Average		1.6	1.0	1.0	-	-	
E4.4	15.1	1.2	1.6	0.2	-	-	
	14.4	0.7	1.0	0.2	-	-	
Average		1.0	1.3	0.2	-	-	
E5.8	15.1	1.5	1.1	trace	-	-	
	14.4	1.1	0.9	trace	-	-	
Average		1.3	1.0	<1.0	-	-	

TABLE 11  
TERRESTRIAL SAMPLES - GRASS, 1970

Station	Date 1970	Radioactivity, pCi/g Fresh Weight					K ppm	Ca ppm	
		Gross Alpha	Gross Beta (less $^{40}\text{K}$ )	$^{90}\text{Sr}$	Gamma Emitters				
T0	22.1	0.2	3.0	0.12	0.1	0.14 MeV	6000	900	
					0.1	0.5 MeV			
					0.1	$^{137}\text{Cs}$			
	11.5	0.8	6.8	0.30	0.1	Zr+ $^{95}\text{Nb}$	4400	1900	
					0.2	0.14 MeV			
					0.2	0.5 MeV			
	10.7	2.3	7.5	0.26	0.5	$^{137}\text{Cs}$	3600	1500	
					0.2	0.14 MeV			
					0.3	0.5 MeV			
T1.2	11.2	0.2	2.0	0.04	0.7	Zr+ $^{95}\text{Nb}$	6700	700	
						0.3			
						0.3			
T32	9.2	0.5	4.6	0.44	0.2	0.14 MeV	7900	1900	
					0.4	0.5 MeV			
					0.2	$^{137}\text{Cs}$			
	7.5	0.3	1.0	0.06	0.2	Zr+ $^{95}\text{Nb}$	6100	800	
					0.05	0.14 MeV			
					0.05	0.5 MeV			
	15.7	1.0	2.3	0.19	1.12	Zr+ $^{95}\text{Nb}$	6900	900	

TABLE 12

TERRESTRIAL SAMPLES - MILK, 1970

Station	Date 1970	Radioactivity, pCi/g Fresh Weight					K ppm	Ca ppm
		Gross Alpha	Gross Beta (less $^{40}\text{K}$ )	$^{137}\text{Cs}$	$^{90}\text{Sr}$			
T3.1	21.1	<0.01	<0.30	0.010	0.010	1600	1300	
T32	21.1	<0.01	0.16	0.014	0.004	1600	1000	
	7.5	<0.01	<0.10	0.014	0.003	2400	1100	
	15.7	<0.01	<0.35	0.010	0.004	1100	1000	
Averages								
T3.1				0.010	0.010			
T32				0.013	0.004			
<u>Fractions of derived m.p.c. (a)</u>								
T3.1				0.0003	0.009			
T32				0.0003	0.004			

(a) Derived maximum permissible concentrations taken from Bryant (1966)

TABLE 13

TERRESTRIAL SAMPLES - MILK (FOR RADIOIODINE), 1970

Station	Date 1970	Radioactivity, pCi/g Fresh Weight	
		<sup>137</sup> Cs	<sup>131</sup> I
T3 (Menai)	21.1	0.009	-

Note: Minimum detectable level for iodine-131 in milk is 0.3 pCi/g fresh weight (0.3 nCi/litre). A regular monthly supply of milk from Station T3 was not available from February to August, 1970.

TABLE 14

TERRESTRIAL SAMPLES - RAIN, 1970

Station	Date 1970	Rainfall (points)	Radioactivity, pCi/m <sup>2</sup> /day							
			Gross Alpha	Gross Beta	<sup>90</sup> Sr	<sup>137</sup> Cs	0.14 MeV	0.5 MeV	Zr+ Nb	
T0	22.1	1587	4	67	8	7	4	6		
	11.5	901	1	18	3	<1	5	<1		
	10.7	210	2	13	-	-	-	-		
T32	21.1	1428	6	69	5	5	3	7	3	
	7.5	627	2	26	2	<1	3	<1		
	15.7	148	4	9	-	-	-	-		

TABLE 15

TERRESTRIAL SAMPLES - SOLID WASTE BURIAL GROUND, 1970

Location	Sample	Date 1970	Radioactivity, pCi/g Fresh Weight			K ppm	Be ppm
			Gross Alpha	Gross Beta (a)	Gamma Emitters		
Bore Hole D	Acacia	8.4	0.4	2.0	0.17 0.5 MeV 0.11 <sup>137</sup> Cs trace Zr+ <sup>95</sup> Nb	4000	0.005
Centre	Acacia	8.4	0.2	44.9	1.9 0.5 MeV 0.8 <sup>60</sup> Co	3300	0.002
Bore Hole 10	Grass	8.4	0.2	2.3	0.18 0.5 MeV 0.08 <sup>137</sup> Cs trace Zr+ <sup>95</sup> Nb	4500	0.007

(a) including <sup>40</sup>K for water results; excluding it for vegetation

.../Cont'd.

TABLE 15 (Cont'd.)

TERRESTRIAL SAMPLES - SOLID WASTE BURIAL GROUND, 1970

Location	Sample	Date 1970	Radioactivity, pCi/litre			K ppm	Be ppm
			Gross Alpha	Gross Beta (a)	Gamma Emitters		
Bore Hole 5	Ground Water	5.3	<1	4	-		
" 6	"	"	10	10	-		
" 1	"	17.3	1	5	-		
" 2	"	"	4	5	-		
" 3	"	"	3	6	-		
" 4	"	"	2	6	-		
" 10	"	"	15	15	trace <sup>232</sup> Th+dtrs		
" OS1	"	"	2	4	-		
" OS2	"	"	1	5	-		
" OS3	"	"	8	63	3.2 0.5 MeV		
" A	"	"	6	6	-		
" B	"	"	13	11	-		
" C	"	"	14	8	-		
" D	"	"	113	53	trace <sup>238</sup> U+dtrs		
" E	"	"	16	12	trace <sup>238</sup> U+dtrs		
" 1	"	26.5	3	8	-		
" 2	"	"	4	6	-		
" 3	"	"	1	5	-		
" 4	"	"	1	5	-		
" 5	"	"	3	5	-		
" 6	"	"	11	11	-		
" 10	"	"	14	13	trace <sup>232</sup> Th+dtrs		
" OS1	"	"	1	4	-		
" OS2	"	"	3	7	-		
" OS3	"	"	5	33	2.7 <sup>60</sup> Co		
" A	"	27.5	10	8	-		
" B	"	"	18	11	-		
" C	"	"	9	7	-		
" D	"	"	75	33	trace <sup>238</sup> U+dtrs		
" E	"	"	16	11	trace <sup>238</sup> U+dtrs		

(a) including <sup>40</sup>K for water results; excluding it for vegetation

TABLE 16  
 TERRESTRIAL SAMPLES - EFFLUENT PIPELINE, 1970

Location	Date 1970	Sample	Radioactivity, pCi/g Fresh Weight				K ppm	
			Gross Alpha	Gross Beta (less 40K)	<sup>3</sup> H	Gamma Emitters		
Near Scour Valve No. 1 (a)	16.4	Acacia	0.3	3		0.42	0.14 MeV 137Cs	3200
"	"	Sand	11	3		1.08 0.76 trace trace	137Cs 137Cs 60Co 232Th+dtrs	500
Near Site South Gate	"	Sand	27	12		0.5 1.88 1.62	0.39 MeV 137Cs 60Co	700
Second Joint above Scour	"	Sand	6	7		0.98 trace	137Cs 232Th+dtrs	800
Under Joint above Scour	"	Soil	229	297		221 434	137Cs 60Co	2400
Valve No. 5 Below Joint above Scour	"	"	176	193		trace 96 266	232Th+dtrs 137Cs 60Co	3000
Valve No. 5 "	"	Fern	1	11		trace 8 0.21 trace	232Th+dtrs 137Cs 60Co 232Th+dtrs	5300
Near Scour Valve No. 4	"	Soil	25	11		trace 0.79 trace	137Cs 60Co 232Th+dtrs	3000
" Creek near Site South Gate	"	Gymea Lily Water	0.1	2	13	0.70	137Cs	3400
Creek near South Gate under Pipe- line	"	"			<1			
Creek near Scour Valve No.1	"	"			5			

(a) There are 6 scour valves along the length of the pipeline from Research Establishment to the discharge point in the Woronora Estuary, numbered from the Site.

TABLE 17

WORONORA SAMPLES: ANNUAL AVERAGES EXPRESSED AS FRACTIONS  
OF THE DERIVED MAXIMUM PERMISSIBLE CONCENTRATIONS (a)

Sample	Radioisotope and m.p.c.	Fraction of m.p.c.					
		1965	1966	1967	1968	1969	1970
Water	$^3\text{H}$ , 30 nCi/ml		$2 \times 10^{-4}$ $4 \times 10^{-4}$	$8 \times 10^{-4}$ $3 \times 10^{-4}$	$7 \times 10^{-4}$ $4 \times 10^{-4}$ $1 \times 10^{-4}$ $7 \times 10^{-5}$	$2 \times 10^{-4}$ $1 \times 10^{-4}$ $7 \times 10^{-5}$ $3 \times 10^{-5}$	$5 \times 10^{-4}$ $4 \times 10^{-4}$ $2 \times 10^{-4}$ $1 \times 10^{-4}$
Oyster Flesh	$^{65}\text{Zn}$ , 1000 pCi/g	$1 \times 10^{-4}$ $2 \times 10^{-5}$ -	$2 \times 10^{-4}$ $1 \times 10^{-5}$ -	$1 \times 10^{-4}$ - -	$1 \times 10^{-4}$ - -	$5 \times 10^{-5}$ $4 \times 10^{-5}$ -	$2 \times 10^{-4}$ $8 \times 10^{-5}$ -
Hawkesbury	$^{90}\text{Sr}$ , 1 pCi/g	$< 1 \times 10^{-3}$ $< 1 \times 10^{-3}$ $1 \times 10^{-3}$	$< 1 \times 10^{-3}$ $< 2 \times 10^{-3}$ $< 1 \times 10^{-3}$	$< 2 \times 10^{-3}$ $< 2 \times 10^{-3}$ $< 1 \times 10^{-3}$	$< 2 \times 10^{-3}$ $< 1 \times 10^{-3}$ $< 2 \times 10^{-3}$	$< 2 \times 10^{-3}$ $< 2 \times 10^{-3}$ $< 2 \times 10^{-3}$	$< 3 \times 10^{-3}$ $< 1 \times 10^{-3}$ $< 1 \times 10^{-3}$
Fish (Averages of all samples)	$^{60}\text{Co}$ , 500 pCi/g $^{90}\text{Sr}$ , 1 pCi/g $^{137}\text{Cs}$ , 2000 pCi/g	- $3 \times 10^{-2}$ -	$2 \times 10^{-4}$ $9 \times 10^{-3}$ -	$1 \times 10^{-4}$ $8 \times 10^{-3}$ $5 \times 10^{-5}$	$4 \times 10^{-4}$ $8 \times 10^{-3}$ $2 \times 10^{-4}$	$2 \times 10^{-4}$ $7 \times 10^{-3}$ $3 \times 10^{-5}$	- $< 6 \times 10^{-3}$ -
Beach Sand (Averages of all samples)	Gross Alpha 3000 pCi/g Gross Beta 2500 pCi/g	$1 \times 10^{-3}$ $1 \times 10^{-3}$	$2 \times 10^{-3}$ $5 \times 10^{-4}$	$1 \times 10^{-3}$ $5 \times 10^{-4}$	$2 \times 10^{-3}$ $8 \times 10^{-4}$	$3 \times 10^{-3}$ $< 1 \times 10^{-3}$	$3 \times 10^{-3}$ $1 \times 10^{-3}$

(a) Derived maximum permissible concentrations are taken from Fry (1966)

TABLE 18

MILK SAMPLES: ANNUAL AVERAGE STRONTIUM-90 AND CAESIUM-137 CONTENTS AND FRACTIONS  
OF THE DERIVED MAXIMUM PERMISSIBLE CONCENTRATIONS (a)

Sampling Station	Annual Average Content											
	pCi <sup>90</sup> Sr/g Ca					pCi <sup>137</sup> Cs/g K						
	1965	1966	1967	1968	1969	1970	1965	1966	1967	1968	1969	1970
T3.1 (Menai)	15	7	7	4	8.5	7.5	27	15	18	5	8.5	6.5
T11 (Campbelltown)	5	3.5	3.5	3	4	3	11	5	10	3	4.5	7
T32 (Richmond)	6	3.5	3.5	3	4	3	14	8	11	3	4.5	7
	Fractions of derived m.p.c. (a)											
T31	2x10 <sup>-3</sup>	9x10 <sup>-3</sup>	9x10 <sup>-3</sup>	6x10 <sup>-3</sup>	1x10 <sup>-2</sup>	9x10 <sup>-3</sup>	1x10 <sup>-3</sup>	8x10 <sup>-4</sup>	9x10 <sup>-4</sup>	3x10 <sup>-4</sup>	4x10 <sup>-4</sup>	3x10 <sup>-4</sup>
T11 (b)	6x10 <sup>-3</sup>	4x10 <sup>-3</sup>	4x10 <sup>-3</sup>	4x10 <sup>-3</sup>	5x10 <sup>-3</sup>	4x10 <sup>-3</sup>	7x10 <sup>-4</sup>	3x10 <sup>-4</sup>	5x10 <sup>-4</sup>	2x10 <sup>-4</sup>	2x10 <sup>-4</sup>	3x10 <sup>-4</sup>
T32	7x10 <sup>-3</sup>	4x10 <sup>-3</sup>	4x10 <sup>-3</sup>	4x10 <sup>-3</sup>	5x10 <sup>-3</sup>	4x10 <sup>-3</sup>	8x10 <sup>-4</sup>	4x10 <sup>-4</sup>	6x10 <sup>-4</sup>	2x10 <sup>-4</sup>	2x10 <sup>-4</sup>	3x10 <sup>-4</sup>

(a) Derived maximum permissible concentrations (Bryant 1966)

<sup>90</sup>Sr      0.8 nCi/gCa  
<sup>137</sup>Cs      20 nCi/g K

(b) Sampling discontinued as from January, 1969.

TABLE 19

POSSIBLE DOSES TO INDIVIDUAL MEMBERS OF THE LOCAL POPULATION  
AS A RESULT OF EXPOSURE TO MEASURED CONCENTRATIONS

Sample	Isotope	Exposure Route	Possible Annual Dose mrem	Critical Organ
Oyster flesh	Tritium Zinc-65	Ingestion Ingestion	0.01 0.03	Whole Body Whole Body
Fish	Tritium Caesium-137 Cobalt-60 Cobalt-60	Ingestion Ingestion Ingestion Ingestion	0.02 - <0.01 <0.01	Whole Body Whole Body Whole Body Lower Large Intestine
Milk	Strontium-90 Caesium-137	Ingestion Ingestion	5 0.1	Growing Bone (children) Whole Body
Estuary Water	Tritium	Daily swimming at Discharge Point	0.04	Whole Body
Beach Sand	Gross Beta Activity	Regular Contact	5	Skin

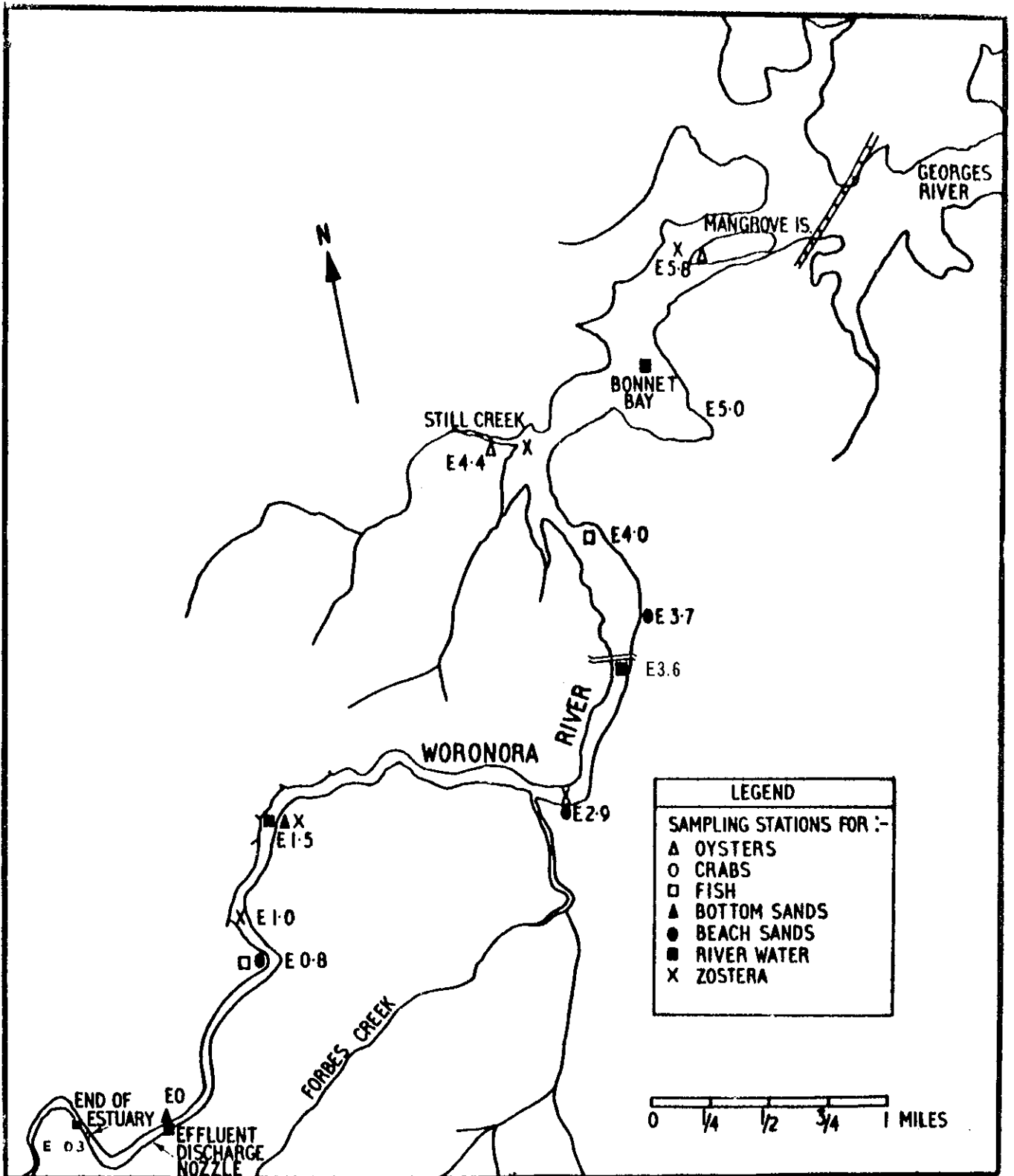


FIGURE 1. WORONORA ESTUARY SAMPLING STATIONS (1970)

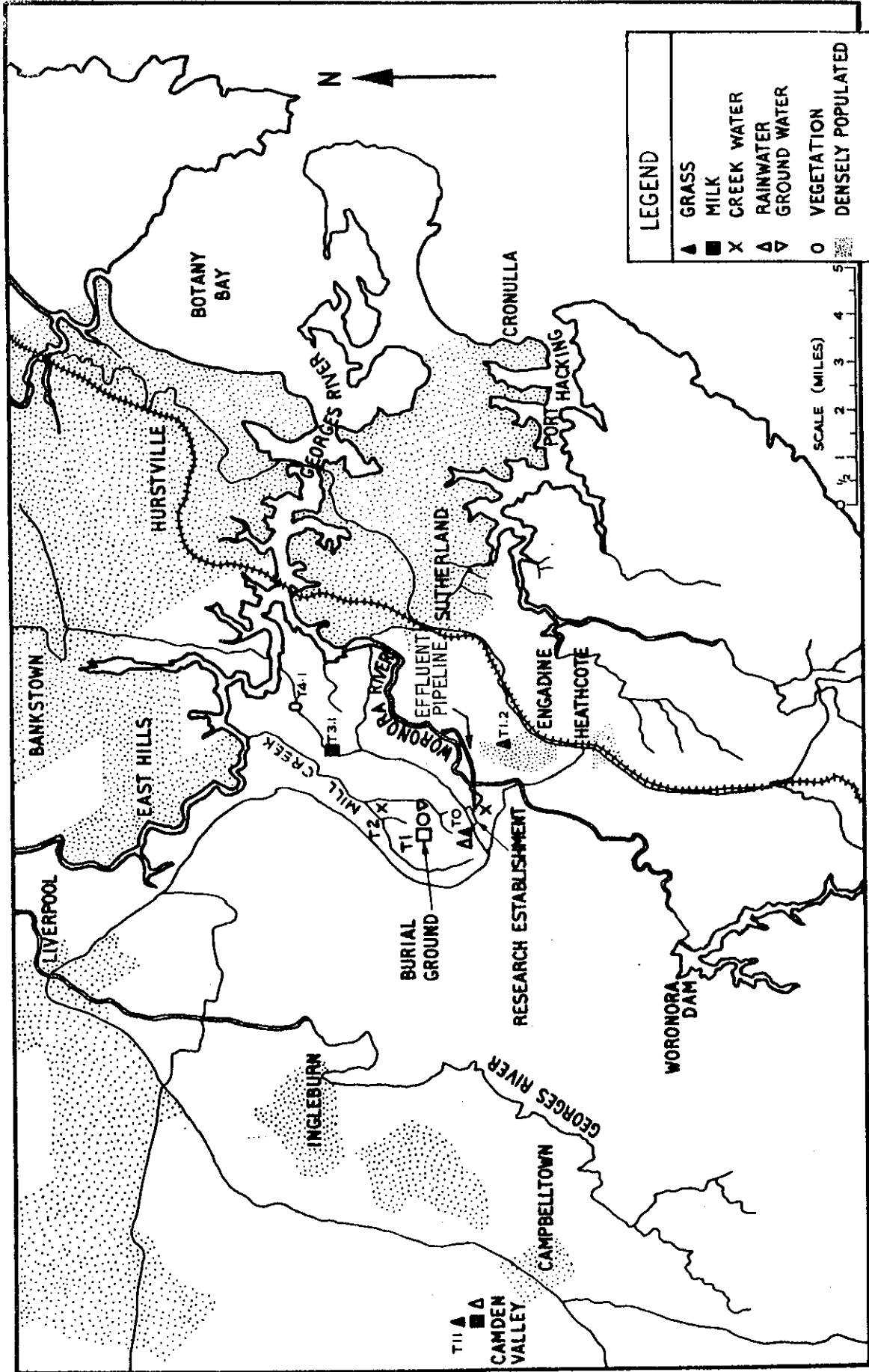


FIGURE 2. TERRESTRIAL SAMPLING STATIONS (1970)

(T32, NOT SHOWN ON THE MAP, IS AT RICHMOND, 32 MILES NORTH-WEST OF THE RESEARCH ESTABLISHMENT)