(1)

AAEC/E151
Supplement No. 2

AAEC/E151 Supplement No. 2

AUSTRALIAN ATOMIC ENERGY COMMISSION
RESEARCH ESTABLISHMENT
LUCAS HEIGHTS

ENVIRONMENTAL SURVEY AT THE A.A.E.C. RESEARCH ESTABLISHMENT, LUCAS HEIGHTS. RESULTS FOR 1968

by

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July 1970
Reprinted May 1979

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ABSTRACT

This report is a second supplement to AAEC/E151 'Results of the Lucas Heights Biological Survey, December 1959 – December 1964'. The results of the environmental survey during 1968 are tabulated and compared with derived maximum permissible concentrations appropriate to the local environment of the A.A.E.C. Research Establishment.

Radioisotope concentrations attributable to Research Establishment operations were less than one thousandth of the derived maximum permissible concentrations and a calculation of possible doses to members of the local population gives results less than one tenth of one percent of the natural radiation background.

CONTENTS

1. INTRODUCTION

This report gives results obtained from samples collected for the environmental survey programme at Lucas Heights during 1968. It continues the tabulation of results reported by Giles and Stockdale (1966) and Cook, Dudaitis and Giles (1969). The 1966 report described the methods of measurement used.

2. SAMPLING PROGRAMME

Details of collection and preparation of estuarine samples are given in Table 1 and of terrestrial samples in Table 2. During 1968 two further weekly sampling points for tritium in the Woronora estuary were added (Figure 1).

3. TABULATION OF RESULTS

Tables 3 to 11 refer to samples collected from the Woronora estuary which receives treated low level aqueous waste from the Research Establishment. Tables 12 to 15 refer to samples taken from the terrestrial environment which could show traces of radioactivity from airborne waste. Table 16 refers to samples taken from the solid waste burial ground and Table 17 refers to 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

The Woronora estuary results in Tables 3 to 11 are summarised in Table 18 which compares annual average concentrations with derived maximum permissible concentrations (Fry 1966), and also shows the results for 1965, 1966 and 1967 for comparison. The radioisotopes detected were the same as those found in previous years. Those attributed to Research Establishment waste disposal operations were tritium in water; cobalt-60 in zostera, fish and bottom sand; strontium-90 in bottom sand and possibly in fish; caesium-137 in bottom sand and possibly in fish; and possible thorium-232 daughters and gross alpha activity in excess of background levels in bottom sand. The concentration of strontium-90 in oyster flesh is attributed to weapons test fallout and the gross alpha and beta activity in beach sand is attributed to natural activity (Cook, Dudaitis and Giles 1969). The concentrations are all less than one thousandth of the derived maximum permissible concentrations, except those for gross alpha activity in beach sand, and strontium-90 in fish and oysters which in each case are not greater than two thousandths of the derived maximum permissible concentrations.

The radioisotopes found in rain, grass and milk samples, Tables 12 to 15, are all attributed to weapons test fallout. France conducted tests in the Pacific in July and August of 1968 but these had little effect, probably because of the low rainfall during the subsequent months. An indication of an increase in the deposition of medium half-life fission products, for example zirconium/niobium-95, in the latter part of the year appears in the rainfall and grass sample results shown in Tables 13 and 14. There is no indication in these samples of any deposition of airborne waste from the Research Establishment.

The results for milk are summarised in Table 19 which gives annual average concentrations of strontium-90 and caesium-137 in milk for 1968 with those for 1965, 1966 and 1967, and provides, for comparison, the derived maximum permissible concentrations (Bryant 1966). The figures for 1968 are about one third of those for 1967 and this is probably due to the absence of southern hemisphere weapons tests during 1967 and the first six months of 1968.

Table 16 contains results of analyses of ground water and vegetation samples taken during 1968 from the solid waste burial ground, one mile from the Research Establishment (Figure 2). Gross alpha and beta activity in vegetation and water samples is attributed to natural activity and that from gamma emitters in vegetation is attributed to weapons test fallout. No gamma activity was detected in water samples.

Table 17 shows analyses of samples taken in 1968 near the effluent pipeline (Figure 2). As in 1967 most samples show only natural activity and weapons test fallout. The activity (cobalt-60 and caesium-137 in excess of fall-out levels) found previously near scour valves numbers 4 and 5 is still present. The creek in which tritium was detected at a concentration of the order of 0.01 percent of the derived maximum permissible concentration runs in wet weather from the site waste treatment area to the Woronora River.

5. RADIOLOGICAL SIGNIFICANCE OF OBSERVED CONCENTRATIONS

An assessment of possible doses to members of the local population from ingestion of oysters, fish and local milk and from other possible exposure routes is made in the Appendix and the results are summarised in Table 20. The largest dose is that due to fallout strontium-90 in milk (and diet generally), giving 4 mrem per year to growing bone (that is, the bones of young children). The next highest figure is 2 mrem per year to skin, which might result from regular contact with natural activity in beach sands (15 hours per week, Fry 1966). Regular swimming at the discharge point (1 hour per day) could give a dose of 0.1 mrem per year due to the uptake of tritium, while the regular consumption of 70 grams of each of oysters and fish per day could give a whole body dose of 0.075 mrem per year from tritium, zinc-65 and caesium-137 together and a dose of 0.1 mrem per year to the lower large intestine from cobalt-60. It is estimated that the dose from caesium-137 in milk could be 0.06 mrem per year whole body, and the dose from the diet as a whole could be of the order of 0.1 mrem per year.

It appears therefore that the members of the local population who could receive the largest dose from observed concentrations are young children, with a possible 4 mrem per year to bone from fall-out strontium-90. Whole body dose to all members of the population from fallout caesium-137 could be of the order of 0.1 mrem per year. Doses from Research Establishment waste disposal operations would be largest for those possible members of the local population who obtain all their protein requirement as oysters and fish from the Woronora estuary or who spend significant recreation time in the estuary, and the levels could be of the order of 0.1 mrem per year.

It is concluded that radiation exposure of the local population due to Research Establishment operations (possibly of the order of 0.1 mrem per year to a few persons and much less for the great majority) is insignificant when compared with doses of the order of several millirem per year in bone to all young children due to strontium-90 in fallout and with natural radiation exposures for the whole population of the order of 100 millirem per year.

6. SUMMARY

During 1968 no radioactivity attributable to aerial dispersion from the Research Establishment was detected in the local environment. No leaching of low level solid waste was detected at the low level solid waste burial ground.

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

Levels of activity attributable to Research Establishment operations were generally less than one thousandth of the appropriate derived maximum permissible concentrations, with the exception of gross alpha and beta activity of the bottom sand at the discharge point and in soil at one point along the pipe-line, where the concentrations were respectively of the order of one hundredth and one tenth of the derived maximum permissible concentrations.

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

7. ACKNOWLEDGEMENTS

The authors acknowledge the assistance received from members of Health and Safety Division, Operations Division and Chemistry Division in the collection, processing, and chemical and radiochemical analysis of samples.

8. REFERENCES

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APPENDIX

DERIVATION OF POSSIBLE RADIATION DOSES TO MEMBERS OF THE LOCAL POPULATION

The possible sources of exposure of members of the local population to radioactivity measured in the environment of Lucas Heights and attributable to operations at the Research Establishment are ingestion of radioisotopes in fish and oysters and uptake by immersion while swimming in the Woronora Estuary. The radioisotopes of interest are tritium, cobalt-60, zinc-65 and possibly strontium-90 and caesium-137. Because of the widespread occurrence of the two latter radioisotopes in weapons test fallout, the doses due to ingestion through consumption of local milk and diet generally are considered for comparison.

Ingestion of Strontium-90

The findings of Bryant and Loutit (1961, 1964) and their application to Australian conditions by the National Radiation Advisory Committee (1962, 1965) may be used as the basis for estimating doses received through the ingestion of strontium-90. Strontium-90 is mainly fixed in the skeleton; its distribution depends on the rate of bone growth and is consequently strongly age dependent. Also its uptake is more dependent on the ratio of strontium-90 to calcium in the diet than on the actual intake.

The highest concentrations of fallout strontium-90 in bone occur in children particularly those aged 1 to 2 years. In Australia an annual average level of 1 pCi Sr-90/g Ca in milk gives rise to a level in the bone of 1 year olds of about 0.33 pCi Sr-90/g Ca and an annual increase in adult bone of the order of 0.01 pCi Sr-90/g Ca per year. (Fletcher et al. 1968). The average daily diet contains 825 milligrams of calcium of which 640 mg is derived from milk and milk products. A level of 1 pCi Sr-90/g Ca in milk corresponds to a level of 1.1 pCi Sr-90/g Ca in the average diet (National Radiation Advisory Council 1962).

The data given in the tables referred to in the main text show the concentrations of strontium-90 per gram of calcium in the local food to be as follows:

TABLE A.1

STRONTIUM-90 PER GRAM OF CALCIUM IN LOCAL FOODSTUFFS

Foodstuff	pCi Sr-90/gCa
Oysters	0.4
Fish	1
Milk	4

Concentrations of strontium-90 in calcium of both oysters and fish are less than that in milk; consequently the addition of oysters or fish to the diet will reduce the overall concentration of strontium-90 in dietary calcium and not lead to an increase in radiation exposure.

The consumption of local milk could have given concentrations in the bones of young children of the order of 1.5 pCi Sr-90/g Ca. A concentration of 200 pCi Sr-90/g Ca in bone gives 540 mrem/year to bone (UK Medical Research Council 1960). Hence annual bone doses to young children in the locality could have been of the order of 4 mrem. (It should be noted that this is attributable to weapons test fallout and not to Research Establishment operations).

APPENDIX (continued)

Ingestion of Other Isotopes

For other isotopes of interest the model and data of the International Commission on Radiological Protection (ICRP 1960) are used to calculate doses. This gives the following expression for the dose to the critical organ for unit ingested activity:

$$7.4 \times 10^{-5}\ f_w ET\,(1-e^{-\lambda t})/M \text{ rem per pCi},$$

where f_w = fraction reaching critical organ by ingestion

E = $\Sigma E(RBE)n$

= effective energy, in MeV, absorbed per disintegration in the critical organ

T = effective half-life, in days, in the critical organ

λ = effective decay constant

t = period over which the dose could possibly be received (50 years)

M = mass in grams of the critical organ.

For the isotopes of interest λt is large and $(1-e^{-\lambda t})$ is effectively unity. The expression thus reduces to:

$$7.4 \times 10^{-5}\ f_w ET/M \text{ rem per pCi}.$$

The large lower intestine is the critical organ for the ingestion of cobalt-60, for which case a different model applies. For cobalt-60 the dose per unit ingestion becomes:

$$2.6 \times 10^{-5}\ E\,T'/M \text{ rem per pCi},$$

where E is as above

T' = time spent by the gut contents in the section of interest

M = mass of gut contents in the section of interest.

Table A.2 gives the concentrations of other isotopes detected in Woronora oysters and fish, taking the highest measured annual averages from Tables 3 and 4 of the main text, and of fallout caesium-137 in milk from Table 13 of the main text.

Table A.3 gives the annual doses resulting from continuous ingestion of these foodstuffs. It should be noted that these doses are not doses actually received by members of the public but only by a hypothetical group whose major protein intake could be derived from cultivated Woronora oysters and fish caught in the upper reaches of the Woronora estuary and who might consume local milk.

Uptake by Immersion

The isotope of interest is tritium. Consider a hypothetical person who spends one hour a day in the upper reaches of the Woronora estuary. Osborne (1968) shows that immersion in tritiated water for one hour leads to a tritium intake equal to that contained in 40 grams of water. The average tritium concentration at the discharge point is 20 pCi/ml (Table 9 of the main text). The daily intake is thus 800 pCi. A continuous daily intake of 2200 ml of water at a concentration of 0.03 μCi/ml leads

APPENDIX (continued)

to an annual dose of 5 rem (ICRP 1960). Hence a continuous daily intake of 800 pCi gives an annual dose of:

$$5 \times 10^{3} \times 800 \times 10^{-6} / 0.03 \times 2200 \quad 0.06 \text{ mrem.}$$

Skin Dose from Contact with Beach Sand

A gross beta activity level of 2500 pCi/g dry weight in beach sands is estimated to give an annual dose of up to 3 rem for a contact time of 15 hours per week (Fry 1966). Hence the observed level of 2 pCi/g will give an annual dose for the assumed contact time of up to

$$3 \times 10^{3} \times 2/2500 \quad 2.4 \text{ mrem.}$$

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APPENDIX (continued)

TABLE A.2

OTHER RADIOACTIVITY IN LOCAL FOODSTUFFS

Foodstuff	Radioisotope	Concentration, maximum annual average, pCi/g Fresh Weight
Oysters	tritium (1)	3 (2)
	zinc-65	0.07
Fish	tritium (1)	12 (3)
	cobalt-60	0.08 (4)
	caesium-137	0.04 (4)
Milk	caesium-137	0.008

Notes: (1) Tritium in oysters and fish is assumed to be in equilibrium with tritium in water.

(2) Average tritium concentration is assumed to be that in water at 3.6 miles from the discharge point.

(3) Average tritium concentration is assumed to be that in water at 1.5 miles from the discharge point.

(4) These levels have been corrected for the difference between flesh and whole fish concentrations (Cook, Dudaitis and Giles 1969).

TABLE A.3

POSSIBLE DOSES FROM CONTINUOUS INGESTION OF FOODSTUFFS AT THE CONCENTRATIONS OF TABLE A.2

Foodstuff	Consumption Assumed	Annual Dose	Critical Organ	Isotope
Oysters	70 g/day	0.005 mrem	Whole body	tritium
		0.01 mrem	Whole body	zinc-65
Fish	70 g/day	0.02 mrem	Whole body	tritium
		0.1 mrem	Lower large intestine	cobalt-60
		0.04 mrem	Whole body	caesium-137
Milk	0.5 l/day	0.06 mrem	Whole body	caesium-137

ENVIRONMENTAL SURVEY RESULTS – 1968

TABLES 1 – 20

Note: Upper limits shown in Tables 3 – 19 are at the 95 percent 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 and not the average of all the upper limits.

TABLE 1

DETAILS OF COLLECTION AND PREPARATION OF ESTUARINE SAMPLES

Sample Type	Station	Collection Frequency	Collection Details	Special Steps in Preparation
Estuary Water	E0.0 E1.5 E3.6, E5.0	Weekly Weekly Weekly	From surface by bucket	Boiled to dryness and then ashed for gross alpha and beta. Distilled for tritium
Oyster Flesh	E4.4 E5.8 Control	Quarterly Quarterly Quarterly	Obtained from commercial leases	Opened by commercial openers. Liquid is removed by placing on a sieve for five minutes
Beach Sands	E0.8 E2.9 E3.7	Quarterly Quarterly Quarterly	Taken by scoop from the top 2 in. of sand in the intertidal region	Fraction between 60 and 120 mesh B.S.S. is removed for α counting after ashing
Bottom Sands	E0.0 E1.5	Quarterly Quarterly	Taken by pump	As for beach sand
Blackfish	E0.8 E4.0	Half Yearly Half Yearly	Caught by Seine net	Whole fish ashed
Mullet	E0.8 E4.0	Half Yearly Half Yearly	As above	As above
Crabs	E4.0	Half Yearly	Taken by hand from the inter-tidal region	Whole crab ashed
Riverweed (Zostera)	E1.0 E1.5 E2.9 E4.4 E5.8	Quarterly Quarterly Quarterly Quarterly Quarterly (if available)	Pulled from bottom by rake or hand	Ashed

TABLE 2

DETAILS OF COLLECTION AND PREPARATION OF TERRESTRIAL SAMPLES

Sample Type	Station	Collection Frequency	Collection Details	Special Steps in Preparation
Rainwater	T0 T11 T32	Quarterly Quarterly Quarterly	Collected in polythene pots having a funnel diameter of 10 in. 50 ml of A.R. HNO_3, 50 mg Cs^{++} and 50 mg of Sr^{++} are added as carrier	The water is passed through 200 ml of Amberlite IRC 120 resin which is then ashed
Grass	T0 T1.2 T11 T32	Quarterly Quarterly Quarterly Quarterly	The grass is cut by rotary mower or hand clippers to within 1 in. of the ground	Whole unwashed grass is ashed
Milk	T3.1 T11 T32	Quarterly Quarterly Quarterly	Milk is obtained from bulk milk supplies	Whole milk is ashed
Vegetables	T4.1	Yearly	Bought from small market gardens	Whole vegetables are ashed

TABLE 3

WORONORA SAMPLES – OYSTER FLESH 1968

Station	Date	Radioactivity, pCi/g Fresh Weight					K	Ca	Be
		Gross Alpha	Gross Beta (less K-40)	Sr-90	Gamma Emitters Zn-65	Gamma Emitters 0.5[a] MeV	ppm	ppm	ppm
E4 4	12. 1 68	0 3	0.5	0.001	0.06	trace	3100	1700	0.002
	23. 4 68	0.2	< 0.5	< 0.002	0.09	–	2900	4300	0.002
	2. 9 68	0.1	0.5	0 003	0.07	0 02	2600	3700	0.002
Average		0 2	< 0.4	0.002	0.07	< 0 01			
E5 8	9 4 68	0 5	< 0 5	< 0 002	–	–	3200	2800	0.001
	26 6.68	0.2	< 0 5	< 0 001	–	–	2600	5400	0.001
	19.11.68	0.1	< 0 5	0 001	–	0 02	3200	2800	0.002
Average		0 3	< 0.4	0 002	–	< 0.01			
Hawkesbury River (H R)	15 1 68	0 3	< 0 5	0 002	–	trace	3300	1500	0.002
	9. 4 68	0 5	0 5	0 002	–	–	2000	5400	0 002
	2 7 68	0 3	0 3	< 0 001	–	–	2300	3600	0 004
	26 9 68	0 2	< 0 5	0 001	–	0 03	3300	3100	0.001
	10 12 68	0 1	< 0 5	0.002	–	0.03	3000	2600	0.004
Average		0.3	< 0 3	< 0.002	–	0.01			
	Derived m.p.c.			1	1000	100[b]			
	Fractions of m p.c.								
E4.4				0.002	7×10^{-5}	$< 10^{-4}$			
E5.8				< 0 002	–	$< 10^{-4}$			
H.R.				0 002	–	10^{-4}			

(a) Amongst the gamma-ray peaks detected by gamma spectrometry in the environmental samples are two which do not uniquely determine specific isotopes. These are at approximately 0.14 MeV, which could be either Ce-141 (0.146 MeV, 32.5 day half-life), Ce-144 (0.134 MeV, 255 day half-life) or Ba-140 (0.16 MeV, 12.8 day half-life) and at approximately 0.50 MeV, which could be either Be-7 (0.48 MeV, 53 day half-life), Ru-103 (0.50 MeV, 40 day half-life) or Ru-106 (0.51 MeV, 1.0 year half-life). Where these gamma rays have been detected they have generally been recorded as such and not attributed to specific isotopes, and the unit pCi/g refers to the disintegrations per gram emitting a gamma photon of the energy quoted. Be-7 is a cosmic ray produced atmospheric activation product; the remainder are fission products. Ba-140 can be inferred from the presence of its daughter La-140.

(b) Assumed all Ru-106 as being the most restrictive of Be-7, Ru-103 and Ru-106.

TABLE 4

WORONORA SAMPLES – WHOLE FISH 1968

Station	Date	Radioactivity, pCi/g Fresh Weight				K	Ca	Be
		Gross Alpha	Gross Beta (less K-40)	Sr-90	Gamma Emitters	ppm	ppm	ppm
E0.8 Mullet	8.4.68	0.9	1.9	0.02	0.5 Co-60 0.08 Cs-137 trace 0.5 MeV trace 0.14 MeV	2600	10000	0.02
" "	24.6.68	0.4	< 0.4	0.004	trace Co-60	2200	8700	0.001
" "	4.9.68	0.1	< 0.5	0.007	0.15 Co-60	3200	14000	0.002
E0.8 Blackfish	8.4.68	0.7	2.0	0.008	1.0 Co-60 trace Cs-137	1400	10000	0.004
E0.8 Bream	8.4.68	0.3	0.4	0.03	0.25 Co-60 0.06 Cs-137	3300	15000	–
Average		0.5	0.9	0.013	0.4 Co-60 0.03 Cs-137			
E4.0 Mullet	3.4.68	0.8	0.7	0.004	trace Th-232+dtrs	3000	10000	0.03
" "	10.9.68	0.1	< 0.5	0.007	–	3200	14000	0.01
E4.0 Blackfish	3.4.68	0.6	0.4	0.003	–	3100	13000	0.02
E4.0 Eel	3.4.68	0.1	0.2	0.004	0.3 Cs-137	3000	4600	–
" "	10.9.68	0.1	0.4	0.006	–	2500	5900	0.006
Average		0.3	0.4	0.005	0.06 Cs-137			
E4.4 Mullet	3.4.68	0.4	0.8	< 0.004	trace Th-232+dtrs	2800	12000	0.02
E4.4 Blackfish	3.4.68	0.6	0.5	< 0.003	" "	3100	9000	0.02
	Derived m.p.c.			1	500 Co-60 200 Cs-137			
E0.8	Fraction of m.p.c.			0.013	8×10^{-4} Co-60 2×10^{-4} Cs-137			
E4.0				0.005	3×10^{-4} Cs-137			
E4.4				< 0.004	–			

TABLE 5

WORONORA SAMPLES – BEACH SAND 1968

Station	Date	Radioactivity, pCi/g Dry Weight		K	Be
		Gross Alpha	Gross Beta (less K-40)	ppm	ppm
E0.8	19. 1.68	6	2	600	0.15
	22. 3.68	5	1	300	0.09
	28. 6.68	4	4	410	0.21
	18.10.68	13	2	360	<0.02
Average		7	2		
E2.9	19. 1.68	7	2	400	0.17
	22. 3.68	3	1	300	0.12
	28. 6.68	4	2	420	0.11
	18.10.68	6	4	450	0.10
Average		5	2		
E3.7	19. 1.68	2	<1	1100	0.20
	22. 3.68	5	1	400	0.11
	28. 6.68	4	2	540	0.17
	18.10.68	5	3	340	0.14
Average		4	2		
Derived m.p.c.		3000	2500		
Average fraction of m.p.c.		0.002	0.0008		

TABLE 6

WORONORA SAMPLES – BOTTOM SAND 1968

Station	Date	Radioactivity, pCi/g Dry Weight				K	Ba
		Gross Alpha	Gross Beta (less K-40)	Sr-90	Gamma Emitters	ppm	ppm
E0	31. 1.68	4	5	0.04	20 Co-60 0.5 Cs-137 2.5 0.14 MeV	790	0.14
	23. 5.68	21	17	0.11	13 Co-60 1.0 Cs-137 0.5 0.14 MeV	1400	0.45
	27. 9.68	55	40	0.50	60 Co-60 trace Cs-137 trace Th-232 + dtrs	940	1.1
Average		27	20	0.21	30 Co-60 0.5 Cs-137		
E1.5	19. 1.68	6	1	0.006	–	800	0.17
	22. 3.68	6	1	0.002	–	300	0.09
	28. 6.68	9	< 1	0.004	–	590	0.07
	18.10.68	4	3	0.002	–	350	0.02
Average		6	1	0.003	–		

TABLE 7

WORONORA SAMPLES – WATER FROM DISCHARGE POINT (E0) AND FROM TOLOFIN (E1.5) 1968)

Station	Radioactivity, pCi/ml (Annual Averages)	
	Gross Alpha	Gross Beta (less K-40)
E0	< 0.04	< 0.06
E1.5	< 0.05	< 0.06

Note: No positive results were obtained during the year, so individual results are not tabulated.

TABLE 8

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

Date	Radioactivity, pCi/ml				H-3
	Gross Alpha	Gross Beta (incl. K-40)	Gamma Emitters		
27. 9.68	< 0.005	0.005	–		< 2
16.12.68	< 0.003	0.003	trace	0.14 MeV	< 2
			trace	0.5 MeV	
			trace	Zr + Nb-95	

TABLE 9

WORONORA SAMPLES – TRITIUM IN SURFACE WATER

Date	Tritium, pCi/ml				Date	Tritium, pCi/ml			
	Station E0	Station E1.5	Station E3.6	Station E5.0		Station E0	Station E1.5	Station E3.6	Station E5.0
15. 1.68	14	15			29. 7.68	3	6	2	2
19. 1.68	20	12			2. 8.68	7	6	4	2
26. 1.68	15	14			9. 8.68	6	6	2	< 2
2. 2.68	42	35			16. 8.68	8	5	< 2	< 2
9. 2.68	40	38			23. 8.68	7	5	2	< 2
16. 2.68	40				30. 8.68	24	21	8	4
23. 2.68	36				6. 9.68	9	9	7	7
4. 3.68	6	2			13. 9.68	19	7	7	5
8. 3.68	7				20. 9.68	5	2	3	2
22. 3.68	6	11			27. 9.68	2		< 2	
29. 3.68	7	7			4.10.68	5		< 2	
5. 4.68	10	5			11.10.68	6		< 2	
12. 4.68	9	5			18.10.68	5	5	< 2	< 2
19. 4.68	190	14			28.10.68	13	4	< 2	< 2
29. 4.68	50	35			1.11.68	11	5	< 2	< 2
3. 5.68	37	28			8.11.68	40	5	< 2	< 2
10. 5.68	30	28			15.11.68	35	17	< 2	< 2
17. 5.68	13	17			22.11.68	22	7	< 2	< 2
24. 5.68	24	22			29.11.68	26	12	9	< 2
31. 5.68	16	9			6.12.68	13	7	< 2	< 2
7. 6.68	13	8			16.12.68	12	10	3	< 2
14. 6.68	8	8			20.12.68	11	7	< 2	< 2
21. 6.68	10	9							
28. 6.68	17	23			Average	20	12	3	2
5. 7.68	15	14							
9. 7.68			16	11	Average fraction of m.p.c. (a)				
19. 7.68	19	16	9	6		7×10^{-4}	4×10^{-4}	1×10^{-4}	7×10^{-5}

(a) Derived m.p.c. = 3×10^{4} pCi/ml

TABLE 10

WORONORA SAMPLES – ZOSTERA 1968

Station	Date	Radioactivity, pCi/g Fresh Weight				
		Gross Alpha	Gross Beta (less K-40)	Gamma Emitters		
				Co-60	0.5 MeV	Zr + Nb-95
E1.0	13. 1.68	2	1.1	4	trace	trace
	8. 5.68	3	1.6	4	–	–
Average		3	1.3	4	–	–
E1.5	31. 1.68	1	0.3	3	trace	trace
	8. 5.68	2	2.0	2	–	–
	3. 9.68(a)	1	5.6	25	–	–
Average		1	2.6	10		
E2.9	31. 1.68	2	0.3	0.4	trace	trace
	8. 5.68	2	1.0	0.4	–	–
Average		2	0.6	0.4		
E4.4	31. 1.68	2	0.9	trace	trace	trace
	8. 5.68	2	0.8	trace	–	–
Average		2	0.8			
E5.8	31. 1.68	3	0.4	–	trace	trace
	8. 5.68	1	0.4	–	–	–
Average		2	0.4			

(a) During the latter part of 1968 there was very little zostera available in the estuary and this one sample at 1.5 miles from the discharge point was the only one taken. (The beds recovered at the end of the year).

TABLE 11

WORONORA SAMPLES – MISCELLANEOUS 1968

Station	Sample	Date	Radioactivity, pCi/g Fresh Weight			K	Ca	Be
			Gross Alpha	Gross Beta (less K-40)	Gamma Emitters	ppm	ppm	ppm
E4.4	Crabs	24. 1.68	1.5	0.8	–	2200	38000	0.03
E4.0	"	20. 5.68	1.4	1.1	–	2000	38000	0.01

TABLE 12

TERRESTRIAL SAMPLES – GRASS 1968

Station	Date	Radioactivity, pCi/g Fresh Weight					K	Ca
		Gross Alpha	Gross Beta (less K-40)	Sr-90	Gamma Emitters		ppm	ppm
T0	30. 1.68	0.5	<1.2	0.1	<0.1	0.14 MeV	6700	1500
					0.2	0.5 MeV		
					0.2	Zr + Nb-95		
	2. 5.68	0.4	< 2.2	0.1	0.3	0.5 MeV	13000	2500
					trace	Zr + Nb-95		
	1. 8.68	1.5	3.1	0.2	0.2	0.14 MeV	4800	2300
					0.5	0.5 MeV		
					0.8	Zr + Nb-95		
	4.11.68	2.1	12.0	0.6	0.8	0.14 MeV	4800	4500
					1.4	0.5 MeV		
					7.6	Zr + Nb-95		
T1.2	20. 2.68	0.3	< 2.0	0.1			13200	1800
	2. 5.68	0.2	< 1.2	< 0.1			6700	400
	1. 8.68	0.5	< 1.2	< 0.1			6800	2000
	4 11.68	1.5	0.8	< 0.1			4500	1500
T1.1	25. 1.68	0.3	1.4	0.1			4600	1600
	10. 4.68	0.3	5.6	0.1			23700	4100
	11. 7.68	1.0	1.3	0.1			5000	2500
	30.10.68	1.3	5.5	0.3			6500	3500
T32	23. 1.68	1.5	1.5	0.2	0.1	0.14 MeV	5000	1400
					0.3	0.5 MeV		
					0.3	Zr + Nb-95		
	18. 4.68	0.5	< 1.0	0.1	0.8	0.5 MeV	5500	600
					trace	Cs-137		
	4. 7.68	4.0	3.1	0.4	0.3	0.5 MeV	5700	2500
					0.3	Cs-137		
	31.10.68	0.3	< 1.2	0.1	0.1	0.14 MeV	6500	900
					0.1	0.5 MeV		
					0.7	Zr + Nb-95		

TABLE 13

TERRESTRIAL SAMPLES – MILK 1968

Station	Date	Radioactivity, pCi/g Fresh Weight				K	Ca
		Gross Alpha	Gross Beta (less K-40)	Cs-137	Sr-90	ppm	ppm
T3	23. 1.68	< 0.01	< 0.3	0.012	0.005	1600	1100
	5. 4.68	< 0.02	< 0.3	0.010	0.003	1800	1100
	26. 7.68	< 0.02	< 0.2	0.003	0.007	800	1800
	18.11.68	0.02	< 0.3	0.006	0.006	2100	900
T11	25. 1.68	< 0.02	< 0.3	0.005	0.002	1400	1100
	10. 4.68	< 0.02	< 0.3	0.004	0.002	1700	1000
	11. 7.68	< 0.02	< 0.3	0.007	0.007	1700	1100
	30.10.68	< 0.01	< 0.3	0.001	0.002	1700	800
T32	23. 1.68	< 0.01	< 0.3	0.012	0.003	1800	1000
	18. 4.68	< 0.02	< 0.3	0.005	0.004	2100	1000
	4. 7.68	< 0.02	< 0.3	0.005	0.003	1800	1100
	31.10.68	< 0.02	< 0.3	0.003	0.004	1900	1100
Averages							
T3				0.008	0.005		
T11 and T12				0.005	0.003		
Fractions of derived m.p.c.[a]							
T3				0.0004	0.006		
T11 and T32				0.0002	0.004		

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

TABLE 14

TERRESTRIAL SAMPLES – RAIN 1968

Station	Collection Period	Rainfall in Period (points)	Radioactivity, pCi/m²/day						
			Gross Alpha	Gross Beta	Sr-90	Cs-137	14 MeV	0.5 MeV	Zr+Nb-95
T0	30. 1.68 – 4. 5.68	462			0.5	1.4			
	5. 4.68 – 8. 7.68	502	1.5	6	1.0	2.7	–	–	–
	8. 7.68 – 4.11.68	327	2.1	21		trace	3.7	3.8	14.0
T11	25. 1.68 – 10. 4.68	390			1.2	3.4			
	10. 4.68 – 11. 7.68	429	0.8	1	<0.4	1.4	–	–	–
	11. 7.68 – 30.10.68	209	1.7	12		trace	1.4	1.9	9.2
T32	23. 1.68 – 18. 4.68	403			1.5	2.7			
	18. 4.68 – 4. 7.68	431	<0.7	1	0.4	2.7	–	–	–
	4. 7.68 – 31.10.68	170	1.6	7		0.2	3.6	16	16

TABLE 15

TERRESTRIAL SAMPLES – MISCELLANEOUS 1968

Station	Sample	Date	Radioactivity, pCi/g Fresh Weight				K	Be
			Gross Alpha	Gross Beta (less K-40)	Gamma Emitters		ppm	ppm
T4.1	Beans	11. 4.68	0.02	0.5			2800	–
T0 (South)	Acacia	8. 8.68	0 3	4.0	0 6	0.14 MeV	3000	0.005
					0.9	0.5 MeV		
					2.0	Zr + Nb-95		
T0 (South)	Gymea Lily	8. 8 68	0.3	1 0	0 05	0.14 MeV	3500	0.002
					0.07	0 5 MeV		
					0.24	Zr + Nb-95		

TABLE 16

TERRESTRIAL SAMPLES – SOLID WASTE BURIAL GROUND 1968

Location	Sample	Date	Radioactivity, pCi/g Fresh Weight Gross Alpha	Gross Beta (a)	Gamma Emitters		K ppm	Be ppm
North	Acacia	22. 1.68	0.2	0.8	0.02	0.14 MeV	2800	0.01
					0.1	0.5 MeV		
					0.2	Zr + Nb-95		
Centre	Acacia	22. 1.68	0.5	0.8	0.03	0.14 MeV	2600	0.01
					0.2	0.5 MeV		
					0.4	Zr + Nb-95		
North	Grass(b)	22. 1.68	1.5	3.7	0.08	0.14 MeV	2100	0.03
					0.5	0.5 MeV		
					1.0	Zr + Nb-95		
North	Acacia	7. 8.68	0.4	3.4	0.6	0.14 MeV	3300	0.01
					0.8	0.5 MeV		
					1.8	Zr + Nb-95		
Centre	Acacia	7. 8.68	0.3	5.3	0.9	0.14 MeV	3500	0.01
					1.3	0.5 MeV		
					3.0	Zr + Nb-95		
			pCi per litre					µg/1
Bore Hole 1	Ground Water	22. 1.68	<1	1.5	–			
" " 5	" "	"	<1	0.5	–			
" " 8	" "	"	1	1.5	–			
" " 10	" "	"	3	4	–			
" " SH	" "	"	2	1.5	–			
" " 1	" "	7. 8.68	<15	3	–			0.05
" " 5	" "	"	35	23	–			0.02
" " 7	" "	"	<15	7	–			0.04
" " 10	" "	"	20	20	–			0.7
" " SH	" "	"	<15	13	–			0.03
" " 5	" "	17. 9.68						0.01
" " 7	" "	"						0.07
" " 10	" "	"						0.9
" " SH	" "	"						0.06

(a) including K-40 for water results, excluding it for vegetation

(b) dry grass collected. Results are as pCi/g Dry Weight

TABLE 17

TERRESTRIAL SAMPLES – EFFLUENT PIPELINE 1968

Location	Date	Sample	Radioactivity, pCi/g Fresh Weight					K ppm
			Gross Alpha	Gross Beta (less K-40)	H-3	Gamma Emitters		
Near Scour Valve No. 1	18. 1.68	Acacia	0.08	< 0.5		0.01	0.14 MeV	2700
						0.09	0.5 MeV	
						0.2	Zr + Nb-95	
Near Scour Valve No. 1	3.10.68	Acacia	0.2	2.4		0.2	0.14 MeV	3600
						0.2	0.5 MeV	
						1.9	Zr + Nb-95	
Near Scour Valve No. 5	4.10.68	Acacia	0.35	2.0		0.2	0.14 MeV	2900
						0.2	0.5 MeV	
						1.3	Zr + Nb-95	
Near Scour Valve No. 4	4.10.68	Gymea Lily	0.2	1.3		0.1	0.14 MeV	4400
						0.08	0.5 MeV	
						0.8	Zr + Nb-95	
Near Site South Gate	22. 4.68	Sand	8	4.5			–	1100
Near Site South Gate	3.10.68	Sand	8	22		trace	0.14 MeV	500
						trace	0.5 MeV	
						1.8	Cs-137	
Near Scour Valve No. 1	3.10.68	Sand	11	10		trace	0.14 MeV	500
						trace	0.5 MeV	
						1.5	Cs-137	
2nd joint from River	3.10.68	Soil	6	7		1.5	Cs-137	700
Joint above Scour Valve No. 5	4.10.68	Soil	470	600		250	Cs-137	1800
						1000	Co-60	
Near Scour Valve No. 4	4.10.68	Soil	30	30		2.5	Cs-137	1100
						9	Co-60	
			pCi/litre	pCi/litre	pCi/ml			
Near Site South Gate	22. 4.68	Creek Water	< 0.6	0.6				
" "	22.10.68	Creek Water	< 1.6	3.8	5			

TABLE 18

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
Water	H-3,30 nCi/ml				
E0			8×10^{-4}	2×10^{-4}	7×10^{-4}
E1.5			4×10^{-4}	3×10^{-4}	4×10^{-4}
E3.6					1×10^{-4}
E5.0					7×10^{-5}
Oyster Flesh	Zn-65,1000 pCi/g				
E4.4		1×10^{-4}	2×10^{-4}	1×10^{-4}	7×10^{-5}
E5.8		2×10^{-5}	1×10^{-5}	–	–
Hawkesbury		–	–	–	–
	Sr-90,1 pCi/g				
E4.4		1×10^{-3}	$< 1 \times 10^{-3}$	$< 2 \times 10^{-3}$	$< 2 \times 10^{-3}$
E5.8		$< 1 \times 10^{-3}$	$< 2 \times 10^{-3}$	$< 2 \times 10^{-3}$	$< 1 \times 10^{-3}$
Hawkesbury		1×10^{-3}	$< 1 \times 10^{-3}$	$< 1 \times 10^{-3}$	$< 2 \times 10^{-3}$
Fish (Averages of all samples)	Co-60 500 pCi/g	–	2×10^{-4}	1×10^{-4}	4×10^{-4}
	Sr-90 1 pCi/g	3×10^{-2}	9×10^{-3}	8×10^{-3}	8×10^{-3}
	Cs-137 200 pCi/g	–	–	5×10^{-5}	2×10^{-4}
Beach Sand (Average of all samples)	Gross Alpha 3000 pCi/g	1×10^{-3}	2×10^{-3}	1×10^{-3}	2×10^{-3}
	Gross Beta 2500 pCi/g	1×10^{-3}	5×10^{-4}	5×10^{-4}	8×10^{-4}

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

TABLE 19

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 Sr-90/g Ca				pCi Cs-137/g K			
	1965	1966	1967	1968	1965	1966	1967	1968
T3 (Menai)	15	7	7	4	27	15	18	5
T11 (Campbelltown)	5	3.5	3.5	3	11	5	10	3
T32 (Richmond)	6	3.5	3.5	3	14	8	11	3
	Fractions of derived m.p.c. [a]							
T3	2×10^{-2}	9×10^{-3}	9×10^{-3}	6×10^{-3}	1×10^{-3}	8×10^{-4}	9×10^{-4}	3×10^{-4}
T11	6×10^{-3}	4×10^{-3}	4×10^{-3}	4×10^{-3}	7×10^{-4}	3×10^{-4}	5×10^{-4}	2×10^{-4}
T32	7×10^{-3}	4×10^{-3}	4×10^{-3}	4×10^{-3}	8×10^{-4}	4×10^{-4}	6×10^{-4}	2×10^{-4}

(a) Derived maximum permissible concentrations (Bryant 1966)

Sr-90 0.8 nCi/g Ca

Cs-137 20 nCi/g K

TABLE 20

POSSIBLE DOSES TO 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	Ingestion	0.005	Whole Body
	Zinc-65	Ingestion	0.01	Whole Body
Fish	Tritium	Ingestion	0.02	Whole Body
	Cobalt-60		0.1	Lower Large Intestine
	Caesium-137		0.04	Whole Body
Milk	Strontium-90	Ingestion	4	Growing Bone (Children)
	Caesium-137	Ingestion	0.06	Whole Body
Estuary	Tritium	Daily Swimming at Discharge Point	0.1	Whole Body
Beach Sand	Gross Beta Activity	Contact	2	Skin

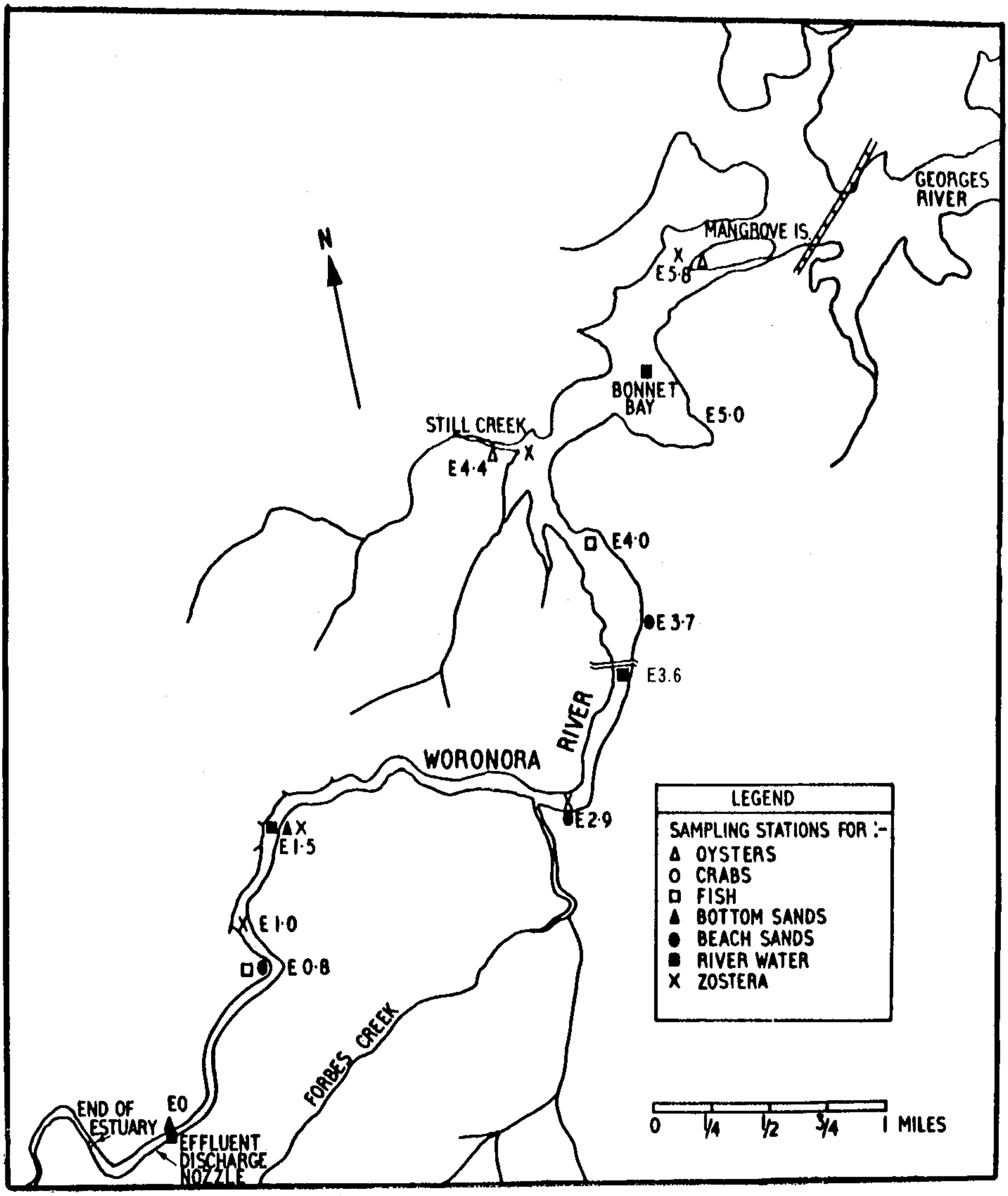

FIGURE 1. WORONORA ESTUARY SAMPLING STATIONS (1968)

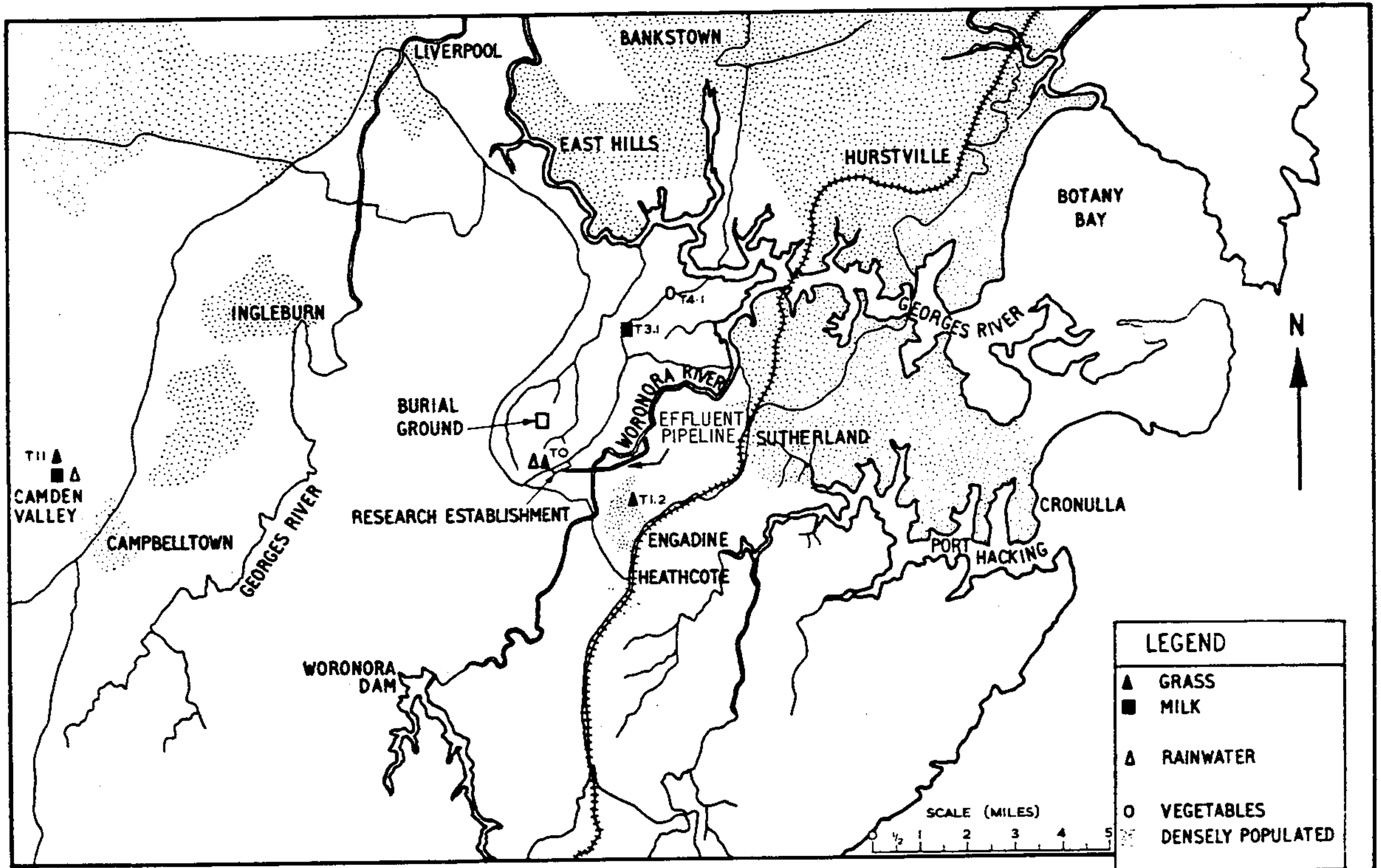

FIGURE 2. TERRESTRIAL SAMPLING STATIONS (1968)