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RESEARCH ESTABLISHMENT
LUCAS HEIGHTS

ENVIRONMENTAL SURVEY AT THE A.A.E.C. RESEARCH ESTABLISHMENT, LUCAS HEIGHTS RESULTS FOR 1969

by

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ABSTRACT

This third supplement to AAEC/E151, 'Results of the Lucas Heights Biological Survey, December 1959 to December 1964', tabulates the results of the environmental survey during 1969 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.

CONTENTS

1. INTRODUCTION

This report gives results obtained from samples collected for the environmental survey programme at Lucas Heights during 1969. It continues the tabulation of results reported by Giles and Stockdale (1966). Cook, Dudaitis and Giles (1969). and Cook and Dudaitis (1970). 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. During the year the sampling frequency for bottom sand at the discharge point was increased to once per month and sampling of fresh water 0 3 miles above the discharge point at the same frequency was added to the programme. 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. During the year the frequency of milk samples from Menai (Station T3 1, three miles from the Research Establishment) was increased to once per month and samples were analysed for radioiodine. in order to monitor uptake of possible discharges of iodine-131 in airborne waste from operations by Isotope Production Section.

3. TABULATION OF RESULTS

Tables 3 to 11 refer to samples collected from the Woronora estuary and Tables 12 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 T1. one mile from the Research Establishment) while Table 17 refers to samples taken along the route of the effluent pipe line (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 18, where the annual average results are expressed as fractions of the derived maximum permissible concentrations (Fry 1966); the results for 1965, 1966, 1967 and 1968 are included for comparison.

The isotopes detected were the same as were found in previous years. The figures for tritium in water, zinc-65 in oysters and cobalt-60 and caesium-137 in fish were all less than one thousandth of the derived maximum permissible concentrations. Positive results for strontium-90 in oyster flesh have not been obtained and as in previous years the limit is less than two thousandths of the derived maximum permissible level. Strontium-90 in whole fish averaged 0.007 pCi/g fresh weight or under one hundredth of the derived maximum permissible concentration. Gross alpha and gross beta activities in beach sand samples, attributed to natural activity, were of the same order as in previous years at respectively three thousandths and one thousandth of the derived maximum permissible concentrations.

Bottom sand samples (Table 6) are taken at the discharge point and 1.5 miles downstream. Compared with the 1 5 mile samples the discharge point samples showed significantly greater levels of gross alpha activity. gross beta activity. strontium-90. cobalt-60, caesium-137 and gamma emitters in the thorium-232 decay chain. These are attributed to waste discharge operations. The levels of gross alpha and gross beta activity at 1 5 miles were not significantly different from those in beach sand samples and are attributed to natural activity.

The variations, with time, of the activity of bottom sand samples may be genuine or may be due to inhomogeneity of deposition at the discharge point. The latter is illustrated by Figure 3 which shows the results of a survey using a gamma radiation detector, carried out on 27th March 1969. The detector was a waterproof 1 inch diameter by 1 inch thick sodium iodide crystal and photomultiplier. Measurements were made at 4 metre intervals with the crystal resting on the bottom. Subsequent laboratory measurements of the response of the detector to point sources on a plane surface

under water showed that for plane sources of cobalt-60 and caesium-137 each of strength 1 μCi/metre^2 and with the detector in contact with the plane the respective responses would be 60 and 40 counts/second. Although these figures are not directly applicable to the readings obtained on the estuary bed, owing to the unevenness of the bottom and the penetration of activity into the mass of bottom sand, approximations suggest that there is reasonable agreement between the detector readings and the measured activity levels. For example, the count rate in the neighbourhood of the discharge point was of the order of 100 counts/second and this corresponds to about 2 μCi/metre^2 of either cobalt-60 or caesium-137. Observed levels were of the order of 50 pCi of cobalt-60 per gram dry weight in bottom sand, which at 2 μCi/metre^2 corresponds to an effective sand thickness of 4 grams/cm^2. This is a reasonable figure.

Fresh water from above the discharge point (Table 8) showed traces of caesium-137, which is attributed to fallout, and some gross beta activity, attributed to natural activity, and no other detectable activity. These measurements were made to obtain information on fallout and the work will not be continued.

Zostera, Table 10, showed cobalt-60 as in previous years. Concentrations dropped by a factor of 10 for every 2.5 miles of estuary length. There are no identifiable human exposure routes associated with this material and hence no derived maximum permissible concentrations. The observed concentrations were of the same order or less than the natural activity of potassium in the material.

The miscellaneous samples, Table 11, were crabs. Those taken from the discharge point, Station E0, showed detectable cobalt-60 at low levels but no other activity. Crabs from a sandbank 4 miles from the discharge point showed no detectable activity.

4.2 Terrestrial Samples Relating to Possible Airborne Waste

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

Results for three-monthly milk samples (Table 13a) are summarised in Table 19 which gives the annual average strontium-90 and caesium-137 contents with comparative results for 1965 to 1968 and also compares the figures with derived maximum permissible concentrations (Bryant 1966). The figures for 1969 showed an increase over those for 1968. This is attributed more to increased rainfall (for example, 3881 points at station T0 (Table 14) during 1969, compared with 1291 points for 1968 (Cook and Dudaitis 1970)), than to increased amounts of activity from atmospheric weapons test fallout.

4.3 Other Terrestrial Samples

Samples from the solid waste burial ground are listed in Table 15 Vegetation samples showed only weapons test fallout gamma emitters and alpha and beta activity attributed to natural sources. Water samples from the bore holes showed variable amounts of gross alpha and beta activity and of beryllium, the variations with position are reasonably constant with time. Two out of three samples from sampling hole OS3, which is nearest to actual buried waste, showed cobalt-60 and an unidentified gamma emitter or emitters which have gamma energies of 0.5 and 1.85 MeV. The actual levels are low (corresponding to less than one thousandth of the non-occupational maximum permissible concentration in drinking water for cobalt-60 (ICRP 1960)).

The miscellaneous terrestrial samples in Table 16 were associated with drainage from the burial ground (see Table 15) and the Research Establishment site. Sub-surface water from the burial ground is expected to drain into Mill Creek (see Figure 2). For this reason sand and water samples were taken from the creek for background information and the results showed natural activity and a trace of fallout caesium-137.

The creek water samples taken around the perimeter of the Research Establishment site all contained tritium. These creeks normally have little flow. The tritium levels are up to one thousandth of the derived maximum permissible concentration for the Woronora estuary. The creek

near Building 9 drains into the creek near the Main Gate, which mainly drains the northern and western sides of the site, including the HIFAR area. This creek joins Mill Creek (see Figure 2) and eventually runs into the Georges River. The creek opposite the South Gate drains the eastern side of the site, including the waste disposal area, and runs into the Woronora River.

Table 17 lists results obtained from soil and vegetation samples along the length of the effluent pipe-line from the site to the Woronora estuary. The results are not significantly different from those obtained in 1968 (Cook and Dudaitis 1970).

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 other possible exposure routes has been made using the same assumptions as for the 1968 results (Cook and Dudaitis 1970). The results are summarised in Table 20. Whole body doses from tritium, cobalt-60, zinc-64 and caesium-137 attributable to Research Establishment operations were each of the order of 0.01 millirem per year and cumulatively could amount to 0.05 millirem per year for the hypothetical person consuming an average of 70 grams each of oysters and fish per day and swimming daily at the discharge point. This is one ten thousandth of the maximum permissible dose limit for members of the public (ICRP 1966). In addition such a person would experience a dose to the lower large intestine of 0.06 millirem per year from cobalt-60 in fish. This is less than one ten thousandth of the maximum permissible dose limit.

Doses due to weapons test fallout ingested in diet are estimated to be 8 mrem per year to rapidly growing bone from strontium-90 (children aged 1 to 2 years) and 0.1 millirem per year whole body dose from caesium-137.

Regular contact with beach sands could give up to 3 millirem per year to skin from natural beta activity (assuming 15 hours exposure per week (Fry 1966)).

Whole body dose from all natural radiation, internal and external, would be of the order of 100 millirem per year, although measurements which would allow an exact determination for the local area have not been made.

6. SUMMARY

During 1969 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 discharges of low level liquid effluent. Those found were tritium (as water), cobalt-60 (in fish, zostera and crabs and bottom sand from the discharge point), strontium-90 (in bottom sand at the discharge point and possibly in fish), caesium-137 (in bottom sand at the discharge point and in fish) and traces of thorium-232 daughters and gross alpha 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 the bore-hole nearest to buried material.

Levels of activity attributable to Research Establishment operations were similar to those recorded in 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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TABLES 1 – 20

Note: Upper limits shown in Tables 3 – 18 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. Dashes indicate that no activity was detected and blank spaces 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 seive 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
Crabs	E4.0	Quarterly	Taken by hand from intertidal sand bank	Whole crabs ashed

TABLE 2

DETAILS OF COLLECTION AND PREPARATION OF TERRESTRIAL SAMPLES

Sample	Stations	Collection Frequency	Collection Details	Special Steps in Preparation
Grass	T0 T1.2 T32	Quarterly Quarterly Quarterly	Cut by rotary mower or hand clippers to within 1 in. of the ground	Whole unwashed grass is ashed
Milk	T3.1	Monthly	Obtained from bulk milk supplies	Gamma spectrometry of whole milk for iodine-131. Whole milk ashed for other assays
Rain	T0	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 Sr^{++} 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
Ground Water	T1	Six Monthly	Bore holes pumped out, allowed to refill, sample taken from bottom	Boiled to dryness, ashed
Creek Water	T0 T2	Six Monthly Six Monthly	Taken in bucket	Boiled to dryness, ashed (distilled for tritium)

TABLE 3

WORONORA SAMPLES – OYSTER FLESH, 1969

Station	Date 1969	Radioactivity, pCi/g Fresh Weight				K ppm	Ca ppm	Be ppm
		Gross Alpha	Gross Beta (less K-40)	Sr-90	Zn-65			
E4.4	10.3	0.1	< 0.7	< 0.004	0.02	2700	2100	0.001
	28.4	0.1	< 0.5	< 0.001	0.02	2900	1900	0.002
	4.8	< 0.1	0.9	< 0.001	0.08	2500	1400	0.001
	3.11	0.2	0.8	< 0.001	0.09	2200	1400	0.001
Average		0.1	0.5	< 0.002	0.05			
E5.8	12.2	0.2	< 0.6	0.002	–	3700	2700	0.003
	30.4	0.1	< 0.5	< 0.004	0.08	3000	2000	0.003
	10.7	0.1	< 0.4	< 0.001	0.04	2500	900	0.001
	3.11	0.1	1.0	< 0.001	0.05	2100	3000	0.002
Average		0.1	< 0.5	< 0.002	0.04			
Hawkesbury River (H.R.)	30.4	0.1	< 0.4	< 0.003	–	2500	4100	0.006
	11.7	0.2	0.3	< 0.001	–	1600	1600	0.003
	3.11	0.1	< 0.5	< 0.001	–	2600	3900	0.003
Average		0.1	0.3	< 0.002	–			
Oyster Shell Composite	12.2–30.4	0.8	0.6	< 0.036	–	300	36300	0.029
	10.7–3.11	0.6	0.4	< 0.036	–	310	35800	0.039
Average		0.7	0.5	< 0.036	–			
	Derived m.p.c.			1	1000			
E4.4	Fraction of m.p.c.			< 0.002	5×10^{-5}			
E5.8				< 0.002	4×10^{-5}			
H.R.				< 0.002	–			
Oyster Shell Composite					–			

TABLE 4

WORONORA SAMPLES – WHOLE FISH, 1969

Station	Date 1969	Radioactivity, pCi/g Fresh Weight				K ppm	Ca ppm	Be ppm
		Gross Alpha	Gross Beta (less K-40)	Sr-90	Gamma Emitters			
E0.8 Mullet	12.3	0.6	< 0.5	0.010	0.2 Co-60	2800	13000	0.009
" (small)	26.5	0.2	< 0.5	0.007	trace Cs-137 trace Co-60	3000	11000	0.003
" (big)	26.5	0.1	< 0.6	0.014	–	3300	15000	0.003
"	24.9	0.2	< 0.5	0.005	trace Co-60	3000	10000	0.004
"	5.11	0.4	0.9	0.009	trace Co-60	2100	12000	0.001
E0.8 Blackfish	12.3	0.7	< 0.6	0.007	0.8 Co-60	3200	11000	0.011
"	24.9	0.7	1.1	0.009	0.7 Co-60	3100	9500	0.012
E0.8 Eel	12.3	< 0.1	< 0.4	0.003	trace Cs-137 trace Co-60	2500	3900	0.001
"	24.9	< 0.1	< 0.5	0.017	0.1 Cs-137 0.06 Co-60	3200	35800	0.039
Average		< 0.3	0.4	0.007	0.01 Cs-137 0.2 Co-60			
E4.0 Mullet	5.2	0.8	< 0.5	0.011	–	3000	14000	0.017
"	21.5	0.4	< 0.5	0.007	–	3100	12000	0.014
"	29.9	0.5	< 0.6	0.009	–	3500	11000	0.020
"	12.12	0.3	< 0.5	0.011	–	3100	11000	0.009
Blackfish	5.2	0.6	< 0.6	0.003	–	3700	11000	0.017
"	21.5	0.2	< 0.5	0.008	trace Co-60	2700	9500	0.008
"	29.9	0.4	< 0.5	0.005	–	3500	8000	0.026
"	12.12	0.5	0.6	0.009	trace Co-60	3200	10000	0.020
Leatherjacket	5.2	0.2	< 0.5	0.003	–	2800	11000	0.009
Average		0.4	< 0.4	0.007				
	Derived m.p.c.			1	500 Co-60 200 Cs-137			
E0 8	Fraction of m.p.c.			0.007	4×10^{-4} Co-60			
E0.4				0.007	–			

TABLE 5

WORONORA SAMPLES – BEACH SAND, 1969

Station	Date 1969	Radioactivity, pCi/g Dry Weight		K ppm	Be ppm
		Gross Alpha	Gross Beta (less K-40)		
E0.8	12.3	15	4	440	0.04
	25.6	7	< 1	270	0.01
	30.9	6	2	470	0.34
	5.12	17	< 1	380	0.13
Average		11	1.5		
E2.9	12.3	12	6	390	0.08
	25.6	1	< 1	200	0.03
	30.9	7	3	420	0.38
	5.12	6	3	300	0.17
Average		6	3		
E3.7	12.3	6	2	280	0.08
	25.6	2	< 1	250	0.10
	30.9	20	5	530	0.58
	5.12	7	2	400	0.17
Average		9	2		
Derived m.p.c.		3000	2500		
Average fraction of m.p.c.		0.003	0.001		

TABLE 6

WORONORA SAMPLES – BOTTOM SAND, 1969

Station	Date 1969	Radioactivity, pCi/g Dry Weight				K ppm	Be ppm
		Gross Alpha	Gross Beta (less K-40)	Sr-90	Gamma Emitters		
E0	7.3	29	52	0.27	trace Cs-137 66 Co-60	3500	1.21
	18.4	76	39	0.39	trace Cs-137 45 Co-60	1100	1.89
	29.5	14	24	0.29	trace Cs-137 30 Co-60	5400	0.21
	25.6	55	46	0.16	trace Cs-137 56 Co-60	790	0.69
	25.7	32	49	0.12	trace Cs-137 67 Co-60 trace Th-232 + dtrs	1100	0.52
	10.9	57	61	0.20	trace Cs-137 64 Co-60 trace Th-232 + dtrs	650	0.77
	3.10	84	58	0.16	trace Cs-137 78 Co-60 trace Th-232 + dtrs	950	0.98
	7.11	49	38	0.20	37 Co-60	300	0.33
	21.11	34	18	0.05	24 Co-60	400	0.57
	5.12	30	24	0.04	41 Co-60	290	0.29
Average		46	41	0.19	51 Co-60		
E1.5	12.3	8	2	0.01	trace Co-60	400	0.07
	25.6	7	1	0.01	trace Co-60	350	0.02
	30.9	10	5	0.01	trace Th-232 + dtrs	520	0.32
	5.12	10	1	0.01	–	280	0.10
Average		9	2	0.01			

TABLE 7

WORONORA SAMPLES – WATER FROM DISCHARGE POINT (E0)

AND FROM TOLOFIN (E1.5), 1969

Station	Radioactivity, pCi/ml (Annual Averages)	
	Gross Alpha	Gross Beta (less K-40)
E0	< 0.02	< 0.03
E1.5	< 0.03	< 0.04

TABLE 8

WORONORA SAMPLES – FRESH WATER FROM ABOVE CAUSEWAY,

0.3 MILES ABOVE DISCHARGE POINT

Date 1969	Radioactivity, pCi/ml			H-3
	Gross Alpha	Gross Beta (less K-40)	Gamma Emitters	
26. 3	< 0.003	0.005	–	
10.4	< 0.002	0.004	–	<1
8.5	< 0.003	0.004	trace Cs-137	<1
5.6	< 0.002	< 0.003	0.001 Cs-137	<1
7.7	< 0.002	0.003	–	
11.8	< 0.002	0.003	–	
15.9	< 0.002	0.002	0.002 Cs-137	
8.10	< 0.002	0.003	–	
10.11	< 0.001	0.003	–	<1
8.12	< 0.001	0.003	–	<1

TABLE 9

WORONORA SAMPLES – TRITIUM IN SURFACE WATER

Date 1969	Tritium, pCi/ml				Date 1969	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
3.1	25	7	2	3	4.7	1	4	4	3
14.1	10	10	4	2	11.7	1	3	4	< 1
17.1	16	9	4	1	18.7	< 1	2	1	<1
24.1	13	9	3	1	25.7	3	3	5	<1
31.1	12	9	2	3	1.8	1	2	< 1	<1
7.2	20	6	2	3	8.8	1	3	<1	<1
14.2	1	2	3	1	15.8	3	3	3	1
21.2	6	2	< 1	<1	22.8	30	9	2	2
28.2	2	2	< 1	< 1	29.8	5	4	1	<1
7.3	3	2	< 1	1	5.9	1	< 1	<1	
17.3	2	3	2	< 1	12.9	< 1	< 1	< 1	<1
21.3	2	2	5	< 1	19.9	< 1	4	3	<1
28.3	5	8	2	1	26.9	1	< 1	< 1	<1
3.4	10	3	< 1	<1	3.10	2	4	< 1	<1
11.4	8	2	5	< 1	10.10	< 1	4	2	<1
18.4	< 1	< 1	< 1	< 1	17.10	2	5	< 1	<1
24.4	< 1	1	1	2	24.10	< 1	3	3	<1
2.5	2	3	< 1	2	31.10	< 1	< 1	2	<1
9.5	2	3	2	2	7.11	< 1	< 1	1	<1
16.5	2	2	< 1	2	14.11[a]				
23.5	3	1	2	< 1	21.11	< 1	< 1	< 1	<1
29.5	2	3	3	< 1	28.11	< 1	< 1	< 1	<1
6.6	< 1	1	2	2	5.12	6	4	< 1	<1
13.6	2	2	4	2	12.12	3	2	< 1	<1
20.6	1	2	< 1	1	19.12	6	6	< 1	< 1
27.6	1	1	< 1	<1					
					Average	5	3	2	1
Average fraction of m.p.c.[b]									
	2×10^{-4}	1×10^{-4}	7×10^{-5}	3×10^{-5}					

(a) River in flood, no sampling possible

(b) Derived m.p.c. = 3×10^{4} pCi/ml

TABLE 10

WORONORA SAMPLES – ZOSTERA, 1969

Station	Date 1969	Radioactivity, pCi/g Fresh Weight				
		Gross Alpha	Gross Beta (less K-40)	Gamma Emitters		
				Co-60	0.5 MeV	Zr÷Nb-95
E0.8	12.3	1.4	3.5	10.5	–	–
E1.0	11.3	2.9	2.7	12.2	–	–
	13.5	2.4	2.3	3.2	–	–
	10.7	1.2	1.0	4.5	–	trace
	4.11	1.4	3.9	1.6	–	–
Average		2.0	2.5	5.4		
E1.5	11.3	2.8	2.1	4.5	–	–
	13.5	2.3	2.0	2.0	–	–
	10.7	1.4	3.0	3.9	–	trace
	4.11	1.3	2.9	1.3	–	–
Average		2.0	2.5	2.9		
E4.4	11.3	1.1	0.6	0.5	–	–
	13.5	1.6	1.5	trace	–	–
	10.7	2.9	5.4	0.3	–	trace
	4.11	1.0	2.9	trace	–	–
Average		1.7	2.6	0.2		
E5.8	11.3	0.7	0.6	trace	–	–
	13.5	2.1	1.6	trace	–	–
	4.11	0.9	2.4	0.1	–	–
Average		1.2	1.5	< 0.1	–	–

TABLE 11

WORONORA SAMPLES – MISCELLANEOUS, 1969

Station	Sample	Date 1969	Radioactivity, pCi/g Fresh Weight			K ppm	Ca ppm	Be ppm
			Gross Alpha	Gross Beta (less K-40)	Gamma Emitters			
E0	Crabs	11.4	1.3	2.8	6 Co-60	1900	42000	0.02
E4.0	Crabs	13.3	0.7	0.6	–	2200	42000	0.01
		25.6	0.8	0.3	–	2100	35000	0.03
		7.10	1.6	0.7		2200	39000	0.02
		19.12	1.3	1.1	–	1900	33200	0.02

TABLE 12

TERRESTRIAL SAMPLES – GRASS, 1969

Station	Date 1969	Radioactivity, pCi/g Fresh Weight					K ppm	Ca ppm
		Gross Alpha	Gross Beta (less K-40)	Sr-90	Gamma Emitters			
T0	10.3	0.2	1.0	0.08	0.1	0.14 MeV	7500	1000
					0.1	0.5 MeV		
					0.4	Zr + Nb-95		
	30.4	0.3	1.5	0.11	0.1	0.14 MeV	3500	1400
					0.2	0.5 MeV		
					0.4	Zr + Nb-95		
	21.7	0.2	2.5	0.18	0.1	0.14 MeV	5200	1600
					0.2	0.5 MeV		
					0.5	Zr + Nb-95		
	16.10	0.3	1.5	0.12	0.05	0.14 MeV	5300	1200
					0.05	0.5 MeV		
					0.1	Zr + Nb-95		
T1.2	20.3	0.3	1.0	0.07			5200	1200
	24.4	0.5	2.0	0.08			5000	1200
	21.7	0.2	1.0	0.08			4700	900
	16.10	0.3	2.0	0.06			4300	1700
T32	18.2	0.7	9.5	0.36	0.4	0.14 MeV	6500	1200
					0.8	0.5 MeV		
					4.2	Zr + Nb-95		
	23.4	0.3	1.5	0.16	0.1	0.14 MeV	6600	1700
					0.1	0.5 MeV		
					0.4	Zr + Nb-95		
	24.7	0.3	2.5	0.23	0.05	0.14 MeV	6500	1300
					0.2	0.5 MeV		
					0.5	Zr + Nb-95		
	13.10	0.1	1.0	0.13	0.05	0.14 MeV	3500	700
					0.05	0.5 MeV		
					0.1	Zr + Nb-95		

TABLE 13a

TERRESTRIAL SAMPLES – MILK, 1969

Station	Date 1969	Radioactivity, pCi/g Fresh Weight				K ppm	Ca ppm
		Gross Alpha	Gross Beta (less K-40)	Cs-137	Sr-90		
T3.1	26.2	0.01	0.3	0.013	0.010	1800	1100
	30.4	0.01	0.4	0.009	0.008	2200	1400
	29.7	0.01	0.4	0.011	0.011	1400	1300
	13.10	0.01	0.2	0.020	0.013	1300	1300
T32	18.2	0.01	0.3	0.008	0.005	1700	1000
	23.4	0.01	0.3	0.007	0.005	1600	1000
	24.7	0.02	0.3	0.003	0.003	1900	1100
	13.10	0.02	0.3	0.010	0.004	1500	1000
Averages							
T3.1				0.013	0.010		
T32				0.007	0.004		
Fractions of derived m.p.c.(a)							
T3.1				0.0004	0.010		
T32				0.0002	0.005		

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

TABLE 13b

TERRESTRIAL SAMPLES – MILK (FOR RADIOIODINE)

Station	Date 1969	Radioactivity, pCi/g Fresh Weight	
		Cs-137	I-131
T3 (Menai)	21.2	0.009	–
	9.3	0.008	–
	7.5	0.008	–
	17.6	0.010	–
	29.7	0.013	–
	12.8	–	–
	16.9	0.012	–
	9.10	0.009	–
	12.11	0.015	–
	10.12	0.008	–
Average		0.009	

Note: Minimum detectable level for iodine-131 in milk is 0.3 pCi/g fresh weight (0.3 nCi/litre)

TABLE 14

TERRESTRIAL SAMPLES – RAIN, 1969

Station	Date 1969	Rainfall (points)	Radioactivity, pCi/m²/day						
			Gross Alpha	Gross Beta	Sr-90	Cs-137	0.14MeV	0.5 MeV	Zr+Nb-95
T0	10.3	1270	4	100	4		2	2	37
	30.4	1102	2	45	3	4	2	5	18
	21.7	579	1	35	2	3	1	2	4
	16.10	930	1	60	4	6	3	3	5
T32	18.2	1511	2	40	3	2	1	1	18
	23.4	1083	4	55	1	0.5	3	5	35
	24.7	362	2	23	2	2	0.5	2	3
	13.10	666	1	40	4	4	2	1	3

TABLE 15

TERRESTRIAL SAMPLES – SOLID WASTE BURIAL GROUND, 1969

Location	Sample	Date 1969	Radioactivity, pCi/g Fresh Weight			K ppm	Be ppm
			Gross Alpha	Gross Beta (a)	Gamma Emitters		
Bore Hole 1	Acacia	22.4	0.2	7	0.15 0.14 MeV 1.2 0.5 MeV 1.2 Zr+Nb-95	2700	0.01
Centre	"	"	0.1	2	0.06 0.14 MeV 0.08 0.5 MeV 0.4 Zr+ Nb-95	3900	0.01
Bore Hole 10	Grass	"	3.5	6	0.15 0.14 MeV 0.35 0.5 MeV 1.25 Zr+Nb-95	3600	
Bore Hole 1	Acacia	19.9	0.1		0.15 0.14 MeV 0.08 0.5 MeV 0.35 Zr+Nb-95		
Centre	"	"	0.1		0.2 0.14 MeV 0.04 0.5 MeV 0.3 Zr+Nb-95		
Bore Hole 10	Grass	"	0.7	8	0.3 0.14 MeV 0.3 0.5 MeV 0.7 Zr+Nb-95	3000	
			pCi/litre				μg/l
Bore Hole 1	Ground Water	28.4	6	6	–		0.20
" " 2	" "	"	2	3	–		0.18
" " 3	" "	"	2	10	–		0.12
" " 4	" "	"	2	3	–		0.06
" " 5	" "	"	2	2	–		0.08
" " 6	" "	"	6	9	–		0.20
" " 10	" "	"	28	15	trace Th-232+dtrs		0.50
" " OS1	" "	"	< 1	17	45 Cs-137		0.04
" " OS2	" "	"	1	5	–		0.06
" " OS3	" "	"	6	33	4.5 0.5 MeV 5 Co-60 2 1.85 MeV		0.10
" " 10	" "	23.6	34	16	trace Th-232+dtrs		0.52
" " OS1	" "	"	1	4	–		0.16
" " OS3	" "	"	7	16	–		0.09
" " 4	" "	17.9	2	6	–		0.10
" " 1	" "	18.9	14	14	–		0.01
" " 2	" "	"	3	4	–		0.05
" " 3	" "	"	4	16	–		0.02
" " 5	" "	"	11	7	–		0.03
" " 10	" "	"	32	18	trace Th-232+dtrs		0.60
" " OS1	" "	"	< 2	5	–		0.03
" " OS2	" "	"	4	6	–		0.04
" " OS3	" "	"	3	70	4.0 0.5 MeV 3.5 Co-60 1.5 1.85 MeV		0.06
" " 6	" "	19.9	4	6			0.04

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

TABLE 16

TERRESTRIAL SAMPLES – MISCELLANEOUS 1969

Station	Sample	Date 1969	Radioactivity, pCi/g Fresh Weight				K ppm	Be ppm
			Gross Alpha	Gross Beta (less K-40)	Gamma Emitters	H-3		
Mill Creek, T2	Sand	2.1	21	4	trace Cs-137		600	0.33
"	"	14.5	9	3	–		400	0.08
"	"	17.9	26	2	–		300	0.09
			pCi/litre			nCi/ℓ		μg/ℓ
Mill Creek, T2	Water	2.1	< 7	9				
"	"	14.5	2	5				< 0.05
Creek near Main Gate	Water	6.3				35		
" "	"	23.6				18		
Creek near Bld. 9	Water	6.3				3		
" "	"	23.6				3.0		
Creek opposite South Gate	Water	6.3				6.0		
" " "	"	3.6				7		
" " "	"	15.9				2		
" " "	"	14.10				1.0		
Near South Gate under pipeline	Water	3.6				230		
" " " "	"	14.10				11		

TABLE 17

TERRESTRIAL SAMPLES – EFFLUENT PIPELINE, 1969

Location	Date 1969	Sample	Radioactivity, pCi/g Fresh Weight					K ppm
			Gross Alpha	Gross Beta (less K-40)	H-3	Gamma Emitters		
Near joint above Scour Valve No. 5 (a)	20.5	Fern	4	21		3.5 13	Co-60 Cs-137	4200
"	15.10	"	2	13		1.5 1.5	Co.60 Cs-137	6800
Near Scour Valve No. 4	20.5	Gymea Lily	0.1	0.5		0.15	Zr + Nb-95	6200
"	15.10	"	0.1	0.9		trace trace trace	Co-60 Cs-137 Zr + Nb-95	6100
Near Scour Valve No. 1	3.6	Acacia	0.1	2		0.11 0.03 0.4	0.14 MeV 0.5 MeV Zr + Nb-95	3100
"	14.10	"	0.3	4		0.25	Cs-137	2400
Under joint above Scour Valve No. 5	20.5	Soil	32	470		600 150	Co-60 Cs-137	1800
Below joint above Scour Valve No. 5	20.5	"	220	400		550 170	Co-60 Cs-137	2200
Near Scour Valve No. 4	20.5	"	18	6		–		800
Second joint	14.10	"	11	8		trace	Th-232+dtrs	1100
Under joint above Scour Valve No. 5	15.10	"	460	400		570 160	Co-60 Cs-137	1400
Below joint above Scour Valve No. 5	15.10	"	240	240		330 70	Co-60 Cs-137	1800
Near Scour Valve No. 1	3.6	Sand	14	2.5		–		490
Near Site South Gate	3.6	"	11	9		–		850
Near Scour Valve No. 1	14.10	"	11	6		–		590
Near Site South Gate	14.10	"	30	6		–		300
Near Scour Valve No. 4	15.10	"	23	15		–		1400
Near Scour Valve No. 5	15.10	"	14	7		trace 0.7	Co-60 Cs-137	480

(a) There are 6 scour valves along the length of the pipe line from the Research Establishment to the discharge point in the Woronora estuary, numbered from the site.

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	1969
Water	H-3, 30 nCi/ml					
E0			2×10^{-4}	8×10^{-4}	7×10^{-4}	2×10^{-4}
E1.5			4×10^{-4}	3×10^{-4}	4×10^{-4}	1×10^{-4}
E3.6					1×10^{-4}	7×10^{-5}
E5.0					7×10^{-5}	3×10^{-5}
Oyster Flesh	Zn-65,1000 pCi/g					
E4.4		1×10^{-4}	2×10^{-4}	1×10^{-4}	1×10^{-4}	5×10^{-5}
E5.8		2×10^{-5}	1×10^{-5}	–	–	4×10^{-5}
Hawkesbury		–	–	–	–	–
	Sr-90, 1 pCi/g					
E4.4		$< 1 \times 10^{-3}$	$< 1 \times 10^{-3}$	$< 2 \times 10^{-3}$	$< 2 \times 10^{-3}$	$< 2 \times 10^{-3}$
E5.8		$< 1 \times 10^{-3}$	$< 2 \times 10^{-3}$	$< 2 \times 10^{-3}$	$< 1 \times 10^{-3}$	$< 2 \times 10^{-3}$
Hawkesbury		1×10^{-3}	$< 1 \times 10^{-3}$	$< 1 \times 10^{-3}$	$< 2 \times 10^{-3}$	$< 2 \times 10^{-3}$
Fish	Co-60,500 pCi/g	–	2×10^{-4}	1×10^{-4}	4×10^{-4}	2×10^{-4}
(Averages of all Samples)	Sr-90, 1 pCi/g	3×10^{-2}	9×10^{-3}	8×10^{-3}	8×10^{-3}	7×10^{-3}
	Cs-137,200 pCi/g	–	–	5×10^{-5}	2×10^{-4}	3×10^{-5}
Beach Sand	Gross Alpha					
(Averages of all Samples)	3000 pCi/g	1×10^{-3}	2×10^{-3}	1×10^{-3}	2×10^{-3}	3×10^{-3}
	Gross Beta					
	2500 pCi/g	1×10^{-3}	5×10^{-4}	5×10^{-4}	8×10^{-4}	$< 1 \times 10^{-3}$

(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	1969	1965	1966	1967	1968	1969
T3.1 (Menai)	15	7	7	4	8.5	27	15	18	5	8.5
T11 (Campbelltown)[b]	5	3.5	3.5	3		11	5	10	3	
T32 (Richmond)	6	3.5	3.5	3	4	14	8	11	3	4.5
	Fractions of Derived m.p.c.[a]									
T3.1	2×10^{-3}	9×10^{-3}	9×10^{-3}	6×10^{-3}	1×10^{-2}	1×10^{-3}	8×10^{-4}	9×10^{-4}	3×10^{-4}	4×10^{-4}
T11[b]	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}	5×10^{-3}	8×10^{-4}	4×10^{-4}	6×10^{-4}	2×10^{-4}	2×10^{-4}

(a) Derived maximum permissible concenttations (Bryant 1966)

Sr-90 0.8 nCi/gCa

Cs-137 20 nCi/g K

(b) Sampling discontinued as from January, 1969

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	0.004	Whole Body
	Zinc-65	Ingestion	0.008	Whole Body
Fish	Tritium	Ingestion	0.006	Whole Body
	Caesium-137	Ingestion	0.007	Whole Body
	Cobalt-60	Ingestion	0.005	Whole Body
	"	"	0.06	Lower Large Intestine
Milk	Strontium-90	Ingestion	8	Growing Bone (children)
	Caesium-137	Ingestion	0.1	Whole Body
Estuary water	Tritium	Daily swimming at Discharge Point	0.015	Whole Body
Beach sand	Gross Beta Activity	Regular Contact	3	Skin

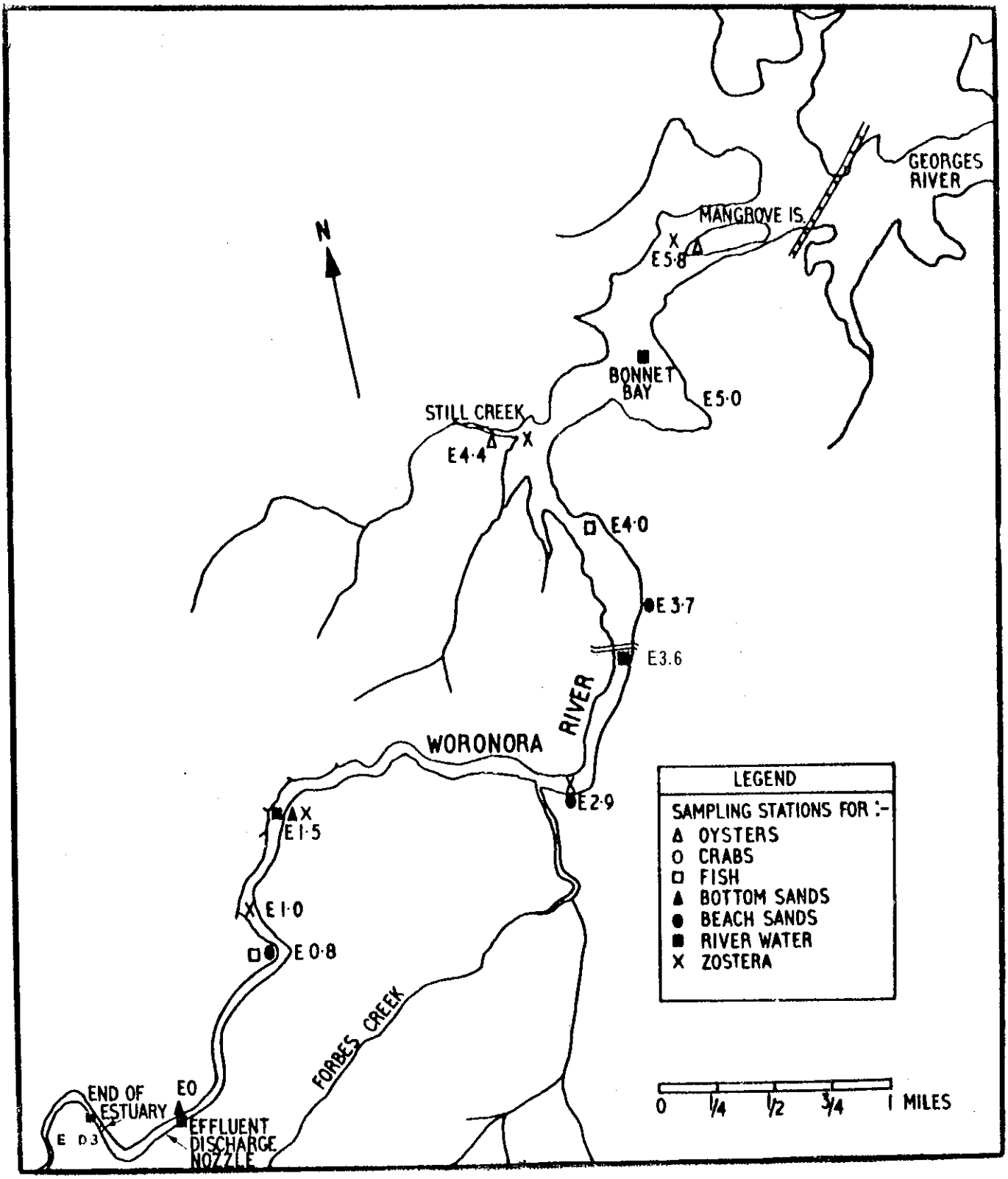

FIGURE 1. WORONORA ESTUARY SAMPLING STATIONS (1969)

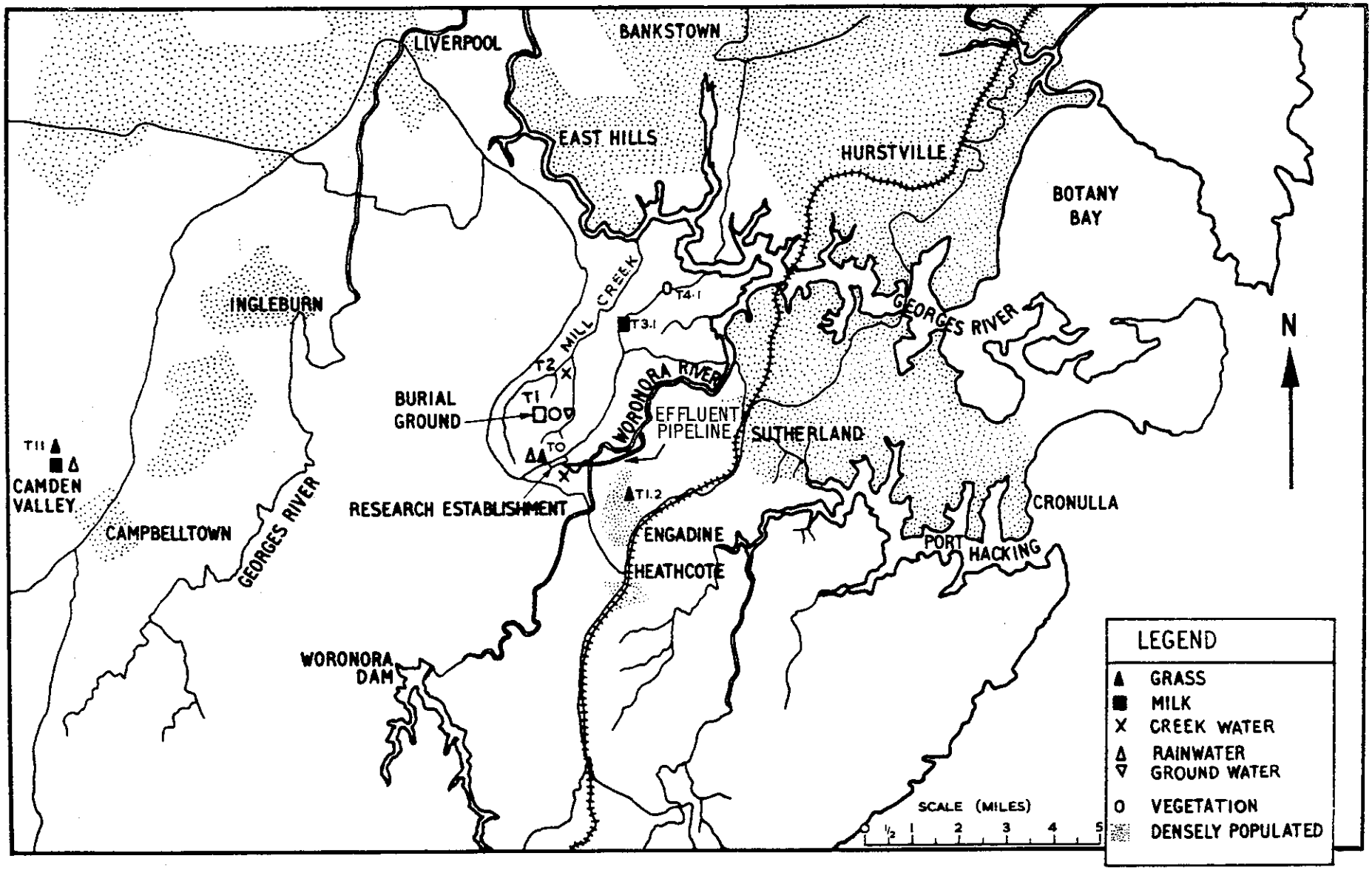

FIGURE 2. TERRESTRIAL SAMPLING STATIONS (1969)

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

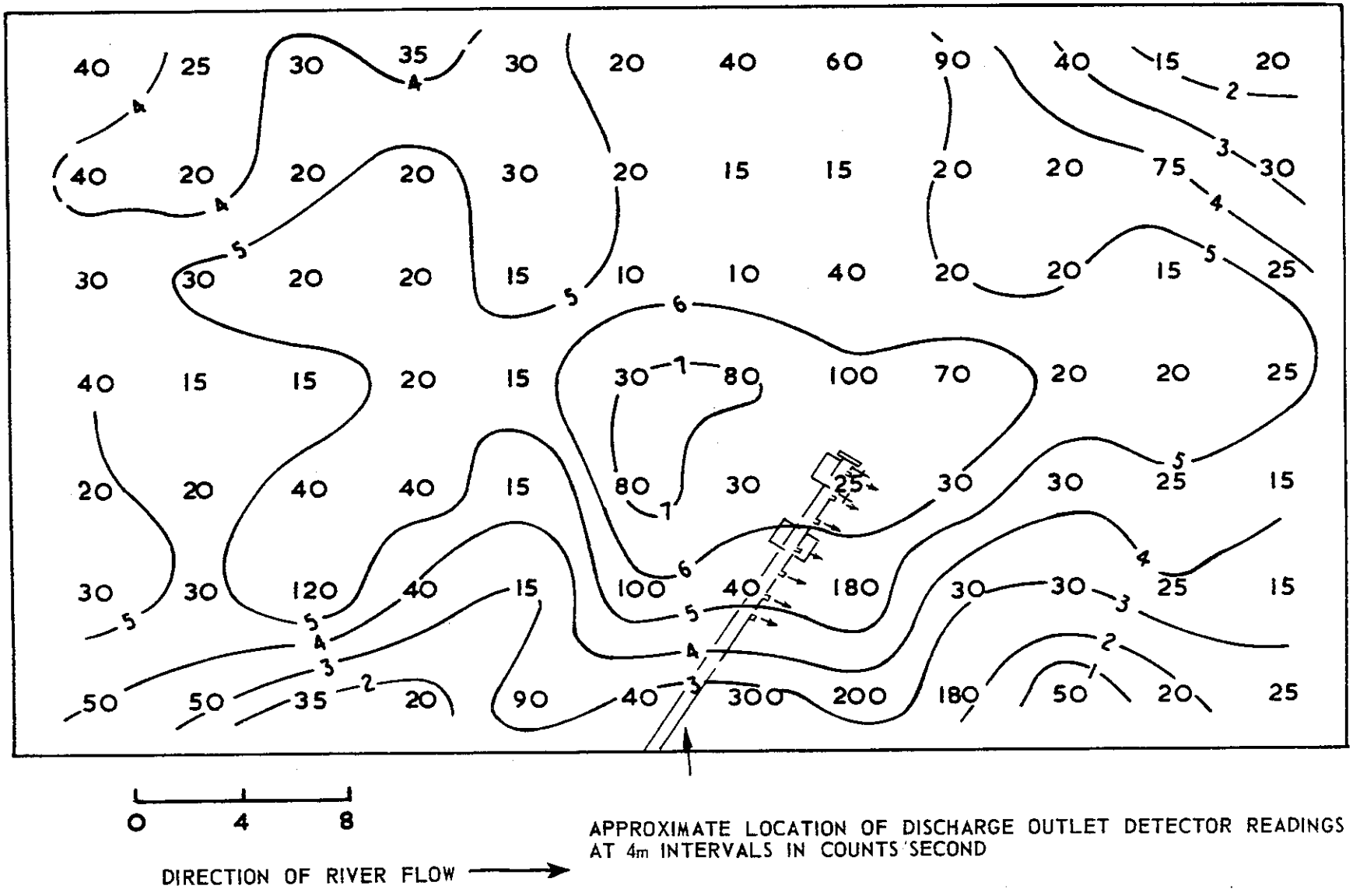

FIGURE 3. GAMMA DETECTOR READINGS ON BED OF WORONORA ESTUARY AT THE DISCHARGE POINT WITH DEPTH CONTOURS IN FEET