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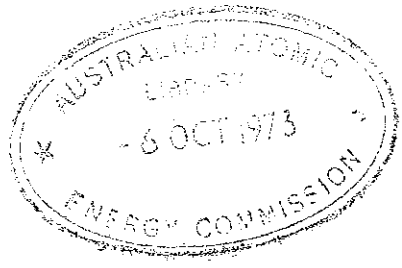

AUSTRALIAN ATOMIC ENERGY COMMISSION

RESEARCH ESTABLISHMENT
LUCAS HEIGHTS

ENVIRONMENTAL SURVEY AT THE AAEC RESEARCH ESTABLISHMENT, LUCAS HEIGHTS

RESULTS FOR PERIOD AUGUST 1970 - DECEMBER 1971

by

A. DUDAITIS

May 1973

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ABSTRACT

This report tabulates the results of the environmental survey at Lucas Heights for the period August 1970 to December 1971 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 for the period August 1970 to December 1971. The rationale for the programme and synopsis of results for the period 1965-1970 have been reported by Watson (1972).

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. 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 7 refer to samples collected from the Woronora estuary and Table 8 refers to milk samples from the terrestrial environment which show no trace of radioactivity from airborne waste arising from the Research Establishment. Table 9 refers to samples taken from the closed solid waste burial ground (Station T 1, one mile from the Research Establishment) while Table 10 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

4.1 Woronora Estuary

The results for estuarine water, oysters, fish and beach sand are summarised in Table 13 where the average results for the period are expressed as fractions of the derived maximum permissible concentrations listed. The results for 1965 to 1970 are included for comparison.

The isotopes detected were the same as were found in previous years with the exception of Caesium-137 which is no longer detected 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. Gross alpha and gross beta activities in beach sand samples, attributed to natural activity, were generally the same as in previous years at three thousandths and four thousandths of the derived maximum permissible concentrations.

Dosimeters placed on the bottom sand at the discharge point showed measurable results (Table 12 and Figure 3) and these levels are attributed to waste discharge operations. Cook and Dudaitis (1970) established that levels of gross alpha and gross beta activity bottom sands at 1.5 miles are not

significantly different from those in beach sand samples in areas removed from possible influence by site operation and are attributed to natural activity.

Water samples taken from 3.6 miles above the discharge point showed no significant changes from previous years.

Zostera (Table 7) showed the same activity concentrations as in previous years with cobalt-60 the only gamma emitter detected. This activity is attributed to site operations. There are no identifiable human exposure routes for Zostera and hence no derived maximum permissible concentrations.

4.2 Terrestrial Samples Related to Possible Airborne Waste

The radioisotopes found in grass and milk samples (Tables 8, 9, 10, 11) are all attributable to the expected activity from weapons test fallout and from natural activity. (The lower limit of detection of iodine-131 in milk (Table 8) 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. The figures are comparable to previous years.

4.3 Other Terrestrial Samples

Samples from the closed solid waste burial ground are listed in Table 9. Vegetation taken from the nearest point to the actual buried waste showed the presence of cobalt-60 and short lived mixed fission products. Water from boreholes in the burial ground showed only trace levels of cobalt-60.

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 a line of five borehole sampling sites (designated A to E) is maintained just outside the northern perimeter of the burial ground. Water samples from these holes contain alpha activity from a near equilibrium (i.e. naturally occurring) uranium series.

Soil and vegetation samples taken along the length of the effluent pipeline from the site to the Woronora estuary (Table 10) show activities which do not vary significantly from those obtained in previous years.

5. RADIOLOGICAL SIGNIFICANCE OF THE RESULTS

The results have been used to calculate the maximum potential doses to individual members of the local population from ingestion of oysters, fish or milk, or by the other exposure pathways which were taken into account in setting discharge limits. These are given in Table 14.

Maximum whole-body doses from the ingestion of tritium and zinc-65, attributable to operations at the Research Establishment, are 0.02 and 0.05 millirem per year respectively. The total annual dose for a hypothetical individual who consumes 70 g each of local oysters and fish, and swims daily at

the discharge point, is 0.08 millirem. This is less than one five-thousandth of the maximum permissible dose limits for members of the public (ICRP 1966).

The traces of activity reported in other samples give no exposure to man. The activity in milk is attributable to fallout and the beach sand activity is natural. For comparison, whole-body dose from natural background radiation, internal and external, is of the order of 100 millirem per year.

6. SUMMARY

During the period August 1970 to December 1971 no radioactivity attributable to aerial dispersion from the Research Establishment was detected in the environment.

In the Woronora estuary a number of radioisotopes were detected other than those that occur naturally or in weapons test fallout, or in quantities in excess of natural or fallout concentrations. 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 soild and vegetation samples taken along the liquid effluent pipeline.

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 borehole 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

The author wishes to acknowledge the assistance of Mr. N.F. Conway in the preparation of this report and the assistance received from members of Health and Safety Division and Chemical Technology Division in the collection, processing and chemical and radiochemical analysis of samples.

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ENVIRONMENTAL SURVEY RESULTS

AUGUST 1970 - DECEMBER 1971

TABLES 1-14

NOTE: Upper limits shown in Tables 3-13 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 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	EO.8,E4.0	Quarterly	Caught by seine net.	Whole fish ashed.
Beach Sand	EO.8,E3.7	Six Monthly	Taken by scoop from top 2 in. in the inter-tidal region.	Fraction between 60 and 120 mesh B.S.S. removed after ashing.
Estuary Water	E3.6	Weekly	From surface by bucket.	Distilled for tritium.
Zostera	E1.0,E1.5 E2.9,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
Milk	T3.1	Monthly	Obtained from bulk milk supplies.	Gamma spectrometry of whole milk for iodine-131.
Vege-tation	T1	Six Monthly	Cut by hand clippers.	Whole unwashed vege-tation is ashed.
Ground Water	T1	Six Monthly	Boreholes pump-ed 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 T2	Six Monthly Six Monthly	Taken in bucket.	As for ground water (Distilled for tritium.)

TABLE 3 - WORONORA SAMPLES - OYSTER FLESH, 1971

Station	Date	Radioactivity, pCi/g Fresh Weight			K ppm
		Gross Alpha	Gross Beta (Less ^{40}K)	^{65}Zn	
E4.4	5. 8.70	0.25	0.55	0.36	2800
	30.10.70	0.11	0.44	0.28	2400
	2. 2.71	0.20	0.58	0.30	3600
	18. 5.71	0.25	0.27	0.42	1900
	20. 9.71	0.30	0.38	0.36	2600
Average		0.22	0.44	0.34	
E5.8	12.10.70	0.27	0.75	0.16	2500
	14.12.70	0.15	0.39	0.15	2600
	18. 5.71	0.30	0.49	0.19	2000
	26. 8.71	0.16	0.42	0.03	2800
Average		0.22	0.51	0.13	
Hawkesbury River (H.R.)	14.12.70	0.08	0.28	-	1900
	18. 5.71	0.21	0.08	-	2700
	20. 8.71	0.22	0.23	-	2900
Average		0.17	0.20	-	
Oyster Shell Composite	18.5-20.9.71	0.64	0.37	-	300
			Derived m.p.c.	1000	
E4.4			Fraction of m.p.c.	3×10^{-4}	
E5.8				1×10^{-4}	
H.R.				-	
Oyster Shell Composite				-	

TABLE 4 - WORONORA SAMPLES - WHOLE FISH, 1971

Station	Date	Radioactivity, pCi/g Fresh Weight				K ppm
		Gross Alpha	Gross Beta (Less ^{40}K)	^{137}Cs	^{60}Co	
E0.8 Mullet	13. 8.70	0.16	0.10	-	trace	2900
"	11.11.71	0.16	0.23	-	trace	3100
Bream	11.11.71	0.24	0.43	-	0.12	3000
Tailor	11.11.71	0.20	0.17	-	-	3600
Average		0.19	0.23	-		
E4.0 Mullet	20. 8.70	0.50	0.22	-	-	2800
"	28. 1.71	0.40	0.68	-	-	3100
"	4. 3.71	0.68	0.83	-	-	3100
"	3.12.71	0.56	0.28	-	-	3300
Blackfish	28. 1.71	0.45	0.73	-	-	5500
"	4. 3.71	0.42	0.51	-	trace	3000
"	3.12.71	0.34	0.32	-	-	3300
Eel	4. 3.71	0.01	0.13	-	-	2000
"	3.12.71	0.02	0.07	0.02	-	2700
Average		0.38	0.42			
		Derived m.p.c.		200	500	
E0.8		Fraction of m.p.c.		-	-	
E4.0		Fraction of m.p.c.		-	-	

TABLE 5 - WORONORA SAMPLES - BEACH SAND, 1971

Station	Date	Radioactivity, pCi/g Dry Weight				K ppm
		Gross Alpha	Gross Beta (Less ^{40}K)	^{60}Co	^{232}Th+ dtrs	
E0.8	26. 1.71	25	1	0.06	trace	360
	15. 7.71	4	1	0.42	trace	200
Average		20	1	0.24		
E3.7	26. 1.71	5	1	-	-	470
	15. 7.71	1	1	-	-	300
Average		3	1	-	-	
Derived m.p.c.		3000	2500	500	-	
Average Fraction of m.p.c.		0.003	0.0004	<0.0005	-	

TABLE 6 - WORONORA SAMPLES - TRITIUM IN SURFACE WATER AT STATION E3.6, 1971

Date	Tritium pCi/ml	Date	Tritium pCi/ml	Date	Tritium pCi/ml
7. 8.70	2	12. 2.71	1	13. 8.71	6
14. 8.70	1	19. 2.71	2	20. 8.71	6
21. 8.70	2	26. 2.71	1	27. 8.71	3
28. 8.70	1	8. 3.71	1	3. 9.71	4
4. 9.70	1	12. 3.71	1	14. 9.71	5
11. 9.70	1	19. 3.71	2	17. 9.71	1
18. 9.70	1	26. 3.71	1	24. 9.71	1
25. 9.70	1	2. 4.71	1	1.10.71	1
2.10.70	1	8. 4.71	1	8.10.71	2
9.10.70	2	16. 4.71	1	15.10.71	1
16.10.70	1	23. 4.71	2	22.10.71	1
23.10.70	1	30. 4.71	2	29.10.71	2
30.10.70	1	7. 5.71	4	5.11.71	2
6.11.70	1	14. 5.71	1	12.11.71	4
13.11.70	1	21. 5.71	1	22.11.71	3
20.11.70	1	31. 5.71	3	26.11.71	1
27.11.70	3	4. 6.71	3	6.12.71	1
4.12.70	3	11. 6.71	1	10.12.71	5
11.12.70	1	18. 6.71	3	17.12.71	3
18.12.70	1	25. 6.71	3	24.12.71	2
23.12.70	1	2. 7.71	1	31.12.71	1
8. 1.71	1	12. 7.71	3	Average	2
15. 1.71	1	16. 7.71	3	Derived mpc = 3×10^{4} pCi/ml	
22. 1.71	1	23. 7.71	3		
29. 1.71	1	30. 7.71	6	Average Fraction of mpc	
5. 2.71	1	6. 8.71	5	= 7×10^{-5}	

TABLE 7 - WORONORA SAMPLES - ZOSTERA, 1971

Station	Date	Radioactivity, pCi/g Fresh Weight				
		Gross Alpha	Gross Beta (Less ^{40}K)	Gamma Emitters		
				^{60}Co	0.5 MeV	$^{95}Zr+^{95}Nb$
E1.0	14. 8.70	0.8	1.6	3.0	trace	trace
	27. 1.71	1.8	3.5	4.1	"	"
	6. 5.71	1.6	0.7	2.1	"	"
	15. 7.71	1.0	2.0	4.2	"	"
	28.10.71	0.8	1.6	2.1	0.1	0.2
Average		1.2	1.9	3.1		
E1.5	27. 1.71	1.9	3.3	2.5	trace	trace
	6. 5.71	1.6	1.9	1.2	"	"
	28.10.71	1.0	1.4	1.6	0.1	0.2
Average		1.5	2.2	1.8		
E2.9	27. 1.71	1.2	0.6	0.4	trace	trace
	6. 5.71	0.9	0.4	trace	"	"
	28.10.71	1.9	1.4	0.3	0.1	0.1
Average		1.3	0.8	0.3		
E4.4	27. 1.71	0.9	0.9	0.1	trace	trace
	6. 5.71	0.8	0.5	0.3	"	"
	15. 7.71	1.0	1.8	0.3	0.3	0.8
	28.10.71	1.3	1.2	0.1	0.1	0.1
Average		1.0	1.1	0.2		
E5.8	27. 1.71	0.8	0.1	trace	trace	trace
	6. 5.71	0.5	0.8	"	"	"
	29.10.71	1.5	1.3	"	0.1	0.1
Average		0.9	0.7			

TABLE 8 - TERRESTRIAL SAMPLES - MILK, 1971

Station	Date	Radioactivity, pCi/g Fresh Weight	
		^{137}Cs	^{131}I
T3 (Menai)	10. 8.70	0.01	-
	8. 9.70	0.01	-
	13.10.70	0.06	-
	18.11.70	0.03	-
	17.12.70	0.03	-
	15. 1.71	0.03	-
	16. 2.71	0.03	-
	16. 3.71	0.03	-
	20. 4.71	0.04	-
	20. 5.71	0.02	-
	15. 6.71	0.04	-
	20. 7.71	0.02	trace
	17. 8.71	0.03	-
	16. 9.71	0.02	-
	19.10.71	0.03	-
	9.11.71	0.03	-
	16.12.71	0.01	-
Average		0.03	

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

TABLE 9 - TERRESTRIAL SAMPLES - SOLID WASTE BURIAL GROUND, 1971

Location	Sample	Date	Radioactivity, pCi/g Fresh Weight				K ppm
			Gross Alpha	Gross Beta[a] (Less ^{40}K)	Gamma Emitters		
Trench Nos. 39-40	Acacia	11. 8.70	0.5	3.1	0.4 0.8	0.5 MeV $^{95}Zr+^{95}Nb$	1900
Trench Nos. 70-71	Acacia	11. 8.70	0.3	38.5	0.4 0.7 1.2	0.5 MeV $^{95}Zr+^{95}Nb$ ^{60}Co	800
Trench Nos. 70-71 (centre)	Acacia	11. 8.70	0.4	8.7	0.3 0.9 trace	0.5 MeV $^{95}Zr+^{95}Nb$ ^{60}Co	700
Trench Nos. 72-73	Acacia	11. 8.70	0.3	11.8	0.6 1.1 1.8	0.5 MeV $^{95}Zr+^{95}Nb$ ^{60}Co	3700
Near Bore OS3	Gum Leaves	11. 8.70	0.4	2.8	0.7 1.1	0.5 MeV ^{95}Zr ^{95}Nb	1600
Trench Nos. 70-71	Acacia	22. 2.71	0.2	28.1	0.2 0.8 1.3	0.5 MeV $^{95}Zr+^{95}Nb$ ^{60}Co	3200
Trench Nos. 70-71 (centre)	Acacia	22. 2.71	0.1	7.5	trace 0.7 0.2	0.5 MeV $^{95}Zr+^{95}Nb$ ^{60}Co	3900
Trench Nos. 71-72	Acacia	22. 2.71	0.2	4.9	0.4 2.2 trace	0.5 MeV $^{95}Zr+^{95}Nb$ ^{60}Co	3700
Trench Near 73	Tree Leaves	22. 2.71	0.7	7.4	0.3 1.8 trace	0.5 MeV $^{95}Zr+^{95}Nb$ ^{60}Co	2000
Trench No. 73 (North)	Tree Leaves	22. 2.71	0.3	4.9	0.2 trace 1.0 trace	0.5 MeV ^{137}Cs $^{95}Zr+^{95}Nb$ ^{60}Co	3600
Trench 71-72	Grass	6. 9.71	1.4	49.0	1.5 5.0 10.6 trace	0.5 MeV $^{95}Zr+^{95}Nb$ ^{60}Co ^{232}Th+dtrs	3000
Trench 70-71	Acacia	6. 9.71	0.3	41.4	0.8 2.2 0.7	0.5 MeV $^{95}Zr+^{95}Nb$ ^{60}Co	3300

TABLE 9 (Cont'd)

Location	Sample	Date	Radioactivity, pCi/g Fresh Weight			K ppm
			Gross Alpha	Gross Beta[(a)] (Less ^{40}K)	Gamma Emitters	
Trench 70-71 (centre)	Acacia	6. 9.71	0.2	8.3	0.2 0.5 MeV 1.8 $^{95}Zr+^{95}Nb$ trace ^{60}Co	4100
Trench 72 (west)	Acacia	6. 9.71	0.3	8.5	0.7 0.5 MeV 3.2 $^{95}Zr+^{95}Nb$ 0.1 ^{60}Co	2600
Trench 58-59	Tree Leaves	6. 9.71	0.4	7.6	0.6 0.5 MeV 3.1 $^{95}Zr+^{95}Nb$	2600

Location	Sample	Date	Radioactivity, pCi/Litre			K ppm
			Gross Alpha	Gross Beta[(a)] (Less ^{40}K)	Gamma Emitters	
Bore Hole OS2	Ground Water	11. 8.70	5.1	5.6	-	
" " OS3	" "	"	3.8	17.7	trace ^{60}Co	
" " A	" "	"	9.0	6.2	-	
" " B	" "	"	16.0	8.9	-	
" " C	" "	"	11.7	6.4	-	
" " D	" "	"	18.5	9.4	-	
" " E	" "	"	10.5	8.7	-	
" " OS3	" "	16.10.70	1.7	7.8	trace ^{60}Co	
" " A	" "	"	6.3	6.4	-	
" " B	" "	"	11.1	8.8	-	
" " C	" "	"	16.0	8.5	-	
" " D	" "	"	11.0	6.0	-	
" " E	" "	"	18.5	12.4	-	
" " A	" "	22.12.70	0.2	7.8	-	
" " B	" "	"	15.4	10.0	trace ^{238}U series	
" " C	" "	"	7.3	5.9	" " "	
" " D	" "	"	40.9	17.4	" " "	
" " E	" "	"	0.8	11.7	-	
" " OS3	" "	26. 1.71	0.4	73.4	2.1 0.5 MeV trace $^{95}Zr+^{95}Nb$ trace ^{60}Co	
" " A	" "	"	4.2	10.1	-	
" " B	" "	"	6.4	7.3	trace ^{238}U series	
" " C	" "	"	3.2	6.0	" " "	
" " D	" "	"	17.8	13.9	" " "	
" " E	" "	"	12.3	10.6	" " "	
" " A	" "	22. 2.71	0.3	8.3	-	
" " B	" "	"	15.7	8.4	-	
" " C	" "	"	2.6	5.8	-	
" " D	" "	"	40.8	24.9	trace ^{238}U series	
" " E	" "	"	18.1	11.5	" " "	

(a) Including ^{40}K for water results; excluding it for vegetation.

TABLE 9 (Cont'd)

Location	Sample	Date	Radioactivity, pCi/Litre			K ppm
			Gross Alpha	Gross Beta (Less ^{40}K) (a)	Gamma Emitters	
Bore Hole BH1	Ground Water	22. 2.71	2.5	6.8	-	
" " BH2	" "	"	2.0	3.5	-	
" " BH3	" "	"	1.4	8.1	-	
" " BH10	" "	"	33.4	17.2	trace ^{232}Th+dtrs	
" " OS3	" "	"	2.3	75.6	trace ^{60}Co	
" " OS1	" "	24. 3.71	1.1	5.1	-	
" " OS2	" "	"	2.1	6.6	-	
" " BH4	" "	"	0.6	3.8	-	
" " BH5	" "	"	1.7	2.8	-	
" " BH6	" "	"	1.1	2.7	-	
" " A	" "	6. 9.71	1.0	6.3	-	
" " B	" "	"	11.7	7.5	trace ^{238}U series	
" " C	" "	"	1.1	7.7	-	
" " D	" "	"	50.2	19.5	trace ^{238}U series	
" " E	" "	"	31.9	15.3	" " "	
" " BH1	" "	7. 9.71	9.5	10.5	-	
" " BH2	" "	"	9.2	8.4	-	
" " BH3	" "	"	4.0	4.8	-	
" " BH4	" "	"	3.5	4.5	-	
" " BH5	" "	"	0.6	3.2	-	
" " BH6	" "	"	7.7	4.9	-	
" " BH10	" "	"	0.8	3.4	-	
" " OS1	" "	"	1.0	3.6	-	
" " OS2	" "	"	0.4	4.5	-	
" " OS3	" "	"	2.8	13.4	0.2 0.5 MeV trace ^{60}Co	

(a) Including ^{40}K for water results; excluding it for vegetation.

TABLE 10 - TERRESTRIAL SAMPLES - EFFLUENT PIPELINE, 1971

Location	Sample	Date	Radioactivity, pCi/g Fresh Weight					K ppm
			Gross Alpha	Gross Beta (Less ^{40}K)	^{3}H	Gamma Emitters		
Near Scour Valve No. 4(a)	Soil	4.11.70	12.8	10.3		trace trace	^{60}Co ^{232}Th+dtrs	1400
Near Scour Valve No. 4(a)	Water	4.11.70			<1.0			
Under Joint Above Scour Valve No. 5	Soil	4.11.70	155.9	244.6		312.6 331.9 trace	^{60}Co ^{137}Cs ^{232}Th+dtrs	700
Below Joint Above Scour Valve No. 5	Soil	4.11.70	53.2	84.8		83.6 30.1 trace	^{60}Co ^{137}Cs ^{232}Th+dtrs	900
Below Joint Above Scour Valve No. 5	Fern	4.11.70	1.0	9.2		0.6 1.1 2.5 trace	0.5 MeV ^{137}Cs $^{95}Zr+^{95}Nb$ ^{60}Co	4800
Near Scour Valve No.5	Sand	4.11.70	6.9	6.3		trace trace trace	^{60}Co ^{137}Cs ^{232}Th+dtrs	200
Near Scour Valve No.1	Sand	7. 6.71	3.2	2.3		trace	^{232}Th+dtrs	900
Near Scour Valve No.1	Water	7. 6.71			5.3			
Near Scour Valve No.4	Soil	8. 6.71	11.1	5.3		trace	^{232}Th+dtrs	5700
Near Scour Valve No.4	Gymea Lily	8. 6.71	1.0	0.2		0.1 trace	^{137}Cs ^{60}Co	4400
Under Joint Above Scour Valve No. 5	Soil	8. 6.71	137.9	210.6		309.9 461.1 trace	^{137}Cs ^{60}Co ^{232}Th+dtrs	2100
Below Joint Above Scour Valve No. 5	Soil	8. 6.71	74.3	89.5		66.5 102.3 trace	^{137}Cs ^{60}Co ^{232}Th+dtrs	3500
Below Joint Above Scour Valve No. 5	Fern	8. 6.71	3.5	0.6		trace 0.3 0.1	0.5 MeV ^{137}Cs ^{60}Co	3500
Near Scour Valve No.1	Sand	27.10.71	3.1	2.0				200
Near Scour Valve No.1	Water	27.10.71			8.5	-		

TABLE 10 (Cont'd)

Location	Sample	Date	Radioactivity, pCi/g Fresh Weight					K ppm
			Gross Alpha	Gross Beta (Less ^{40}K)	^{3}H	Gamma Emitters		
Near Scour Valve No.1	Tree Leaves	27.10.71	1.7	5.6		0.3 1.7	0.5 MeV $^{95}Zr+^{95}Nb$	2800
Near Scour Valve No.4	Soil	1.11.71	22.1	10.8		0.6 trace trace	^{60}Co ^{137}Cs ^{232}Th+dtrs	1200
Near Scour Valve No.4	Gymea Lily	1.11.71	0.2	2.3		0.2 0.7 trace	0.5 MeV $^{95}Zr+^{95}Nb$ ^{232}Th+dtrs	5200
Under Joint Above Scour Valve No. 5	Soil	1.11.71	27.3	47.0		28.2 39.7 trace	^{137}Cs ^{60}Co ^{232}Th+dtrs	1500
Below Joint Above Scour Valve No. 5	Soil	1.11.71	20.7	15.1		1.3 3.8 trace	^{137}Cs ^{60}Co ^{232}Th+dtrs	2700
Below Joint Above Scour Valve No. 5	Fern	1.11.71	1.5	20.0		1.3 5.2 0.1	0.5 MeV $^{95}Zr+^{95}Nb$ ^{60}Co	4200
Near Scour Valve No.5	Sand	1.11.71	12.7	9.0		1.3 0.5 trace	^{137}Cs ^{60}Co ^{232}Th+dtrs	1300

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

TABLE 11 - TERRESTRIAL SAMPLES - MISCELLANEOUS, 1971

Station	Sample	Date	Radioactivity, pCi/g Fresh Weight					K ppm
			Gross Alpha	Gross Beta (Less ^{40}K)	^{3}H	Gamma Emitters		
RE Stormwater Outlet Near South Gate	Sand	8. 9.70	48.6	100.4		3.3 1.2 12.3 4.3 25.0 trace	0.39 MeV 0.5 MeV ^{137}Cs $^{95}Zr+^{95}Nb$ ^{60}Co $^{232}Th+dtrs$	500
RE Stormwater Outlet Near South Gate	Sand	26.11.70	34.7	19.5		trace trace 1.9 3.0 4.9 trace	0.39 MeV 0.5 MeV ^{137}Cs $^{95}Zr+^{95}Nb$ ^{60}Co $^{232}Th+dtrs$	500
RE Stormwater Outlet Near South Gate	Sand	23.12.70	48.1	17.1		1.8 1.5 3.6 trace	^{137}Cs $^{95}Zr+^{95}Nb$ ^{60}Co $^{232}Th+dtrs$	700
RE Stormwater Outlet Near South Gate	Sand	18. 1.71	107.9	61.2		0.6 7.2 2.6 17.1 trace	0.39 MeV ^{137}Cs $^{95}Zr+^{95}Nb$ ^{60}Co $^{232}Th+dtrs$	400
RE Stormwater Outlet Near South Gate	Sand	7. 6.71	24.2	25.6		trace 4.6 9.7	0.39 MeV ^{137}Cs ^{60}Co	800
RE Stormwater Outlet Near South Gate	Sand	1.11.71	96.6	82.6		17.7 38.4 trace	^{137}Cs ^{60}Co $^{232}Th+dtrs$	800
RE Stormwater Outlet Near South Gate	Reeds	8. 9.70	3.4	2.5		0.5 0.1 0.3 0.5 1.7 trace	0.39 MeV 0.5 MeV ^{137}Cs $^{95}Zr+^{95}Nb$ ^{60}Co $^{232}Th+dtrs$	1500
RE Stormwater Outlet Near South Gate, 60 ft away from it.	Sand	8. 9.70	39.3	98.1		2.8 1.7 15.4 8.1 31.8	0.39 MeV 0.5 MeV ^{137}Cs $^{95}Zr+^{95}dtrs$ ^{60}Co	400

TABLE 11 (Cont'd)

Station	Sample	Date	Radioactivity, pCi/g Fresh Weight					K ppm
			Gross Alpha	Gross Beta (Less ^{40}K)	^{3}H	Gamma Emitters		
RE Stormwater Outlet Near South Gate, 60 ft away from it.	Sand	26.11.70	35.8	59.1		1.8 trace 6.5 2.2 11.0 trace	0.39 MeV 0.5 MeV ^{137}Cs $^{95}Zr+^{95}Nb$ ^{60}Co ^{232}Th+dtrs	200
RE Stormwater Outlet Near South Gate, 60 ft away from it.	Sand	23.12.70	107.1	34.3		trace trace 4.5 1.9 7.3 trace	0.39 MeV 0.5 MeV ^{137}Cs $^{95}Zr+^{95}Nb$ ^{60}Co ^{232}Th+dtrs	300
RE Stormwater Outlet Near South Gate, 60 ft away from it.	Sand	18. 1.71	59.1	23.1		0.9 2.9 trace 5.7 trace	0.3 MeV ^{137}Cs $^{95}Zr+^{95}Nb$ ^{60}Co ^{232}Th+dtrs	600
RE Stormwater Outlet Near South Gate, 60 ft away from it.	Sand	7. 6.71	4.0	4.6		-		600
RE Stormwater Outlet Near South Gate, 60 ft away from it.	Sand	1.11.71	22.9	27.0		3.6 4.4 6.8 trace	^{137}Cs ^{54}Mn ^{60}Co ^{232}Th+dtrs	900
RE Stormwater Outlet Near South Gate, 60 ft away from it.	Grass	8. 9.70	3.2	3.8		0.2 0.6 0.9 1.9	0.5 MeV ^{137}Cs $^{95}Zr+^{95}Nb$ ^{60}Co	6100
RE Stormwater Outlet Near South Gate, 60 ft away from it.	Grass	26.11.70	15.1	5.6		0.1 0.1 1.0 16.3 26.8 trace	0.39 MeV 0.5 MeV ^{137}Cs $^{95}Zr+^{95}Nb$ ^{60}Co ^{232}Th+dtrs	9200
RE Stormwater Outlet Near South Gate, 60 ft away from it.	Grass	23.12.70	19.4	12.3		trace 0.3 0.8 1.3 2.8 trace	0.39 MeV 0.5 MeV ^{137}Cs $^{95}Zr+^{95}Nb$ ^{60}Co ^{232}Th+dtrs	5700

TABLE 11 (Cont'd)

Station	Sample	Date	Radioactivity, pCi/g Fresh Weight					K ppm
			Gross Alpha	Gross Beta (Less ^{40}K)	^{3}H	Gamma Emitters		
RE Stormwater Outlet Near South Gate, 60 ft away from it.	Grass	18. 1.71	5.2	6.3		0.3 0.4 1.5 1.3 trace	0.5 MeV ^{137}Cs $^{95}Zr+^{95}Nb$ ^{60}Co $^{232}Th+dtrs$	6600
RE Stormwater Outlet Near South Gate, 60 ft away from it.	Grass	7. 6.71	4.0	4.7		trace 0.7 0.8 2.0 trace	0.5 MeV ^{137}Cs $^{95}Zr+^{95}Nb$ ^{60}Co $^{232}Th+dtrs$	5300
RE Stormwater Outlet Near South Gate, 60 ft away from it.	Grass	1.11.71	0.8	2.5		0.1 0.3 0.5 0.5 trace	0.5 MeV ^{137}Cs $^{95}Zr+^{95}Nb$ ^{60}Co $^{232}Th+dtrs$	6200
RE Stormwater Outlet Near South Gate, 1250 ft away from it.	Sand	11. 9.71	3.0	5.8		0.5 trace	^{60}Co $^{232}Th+dtrs$	300
RE Stormwater Outlet Near South Gate, 1250 ft. away from it.	Sand	26.11.70	6.0	8.4		trace	$^{232}Th+dtrs$	400
RE Stormwater Outlet Near South Gate, 1250 ft away from it.	Sand	23.12.70	16.8	5.2		-		300
RE Stormwater Outlet Near South Gate, 1250 ft away from it.	Sand	18. 1.71	9.4	2.3		-		500
RE Stormwater Outlet Near South Gate, 1250 ft away from it.		7. 6.71	3.2	2.3		-		900
RE Stormwater Outlet Near South Gate, 1250 ft away from it.		27.10.71	3.1	2.0		-		200

TABLE 11 (Cont'd)

Station	Sample	Date	Radioactivity, pCi/g Fresh Weight					K ppm
			Gross Alpha	Gross Beta (Less ^{40}K)	^{3}H	Gamma Emitters		
Junction Mill Crk., and Barden Crk.	Sand	16. 2.71	54.4	2.6		-		300
Junction Mill Crk., and Barden Crk.	Water	16. 2.71			<1.0	-		
Stormwater Outlet Outside RE Safety Fence;								
Opp. Strassman Cres.	Sand	17. 8.71	8.5	21.2		1.2 trace 3.5 trace trace	0.5 MeV ^{137}Cs $^{95}Zr+^{95}Nb$ ^{60}Co ^{232}Th+dtrs	900
Opp. Strassman Cres.	Water	17.8.71			3.5			
Opp. Bld. 23	Sand	17. 8.71	10.5	15.3		trace trace trace 3.4 trace	0.5 MeV ^{137}Cs $^{95}Zr+^{95}Nb$ ^{60}Co ^{232}Th+dtrs	500
Opp. Bld. 23	Water	17. 8.71			5.2			
Opp. Fermi St.	Sand	17. 8.71	5.3	12.4		trace trace 2.1 trace	0.5 MeV ^{137}Cs $^{95}Zr+^{95}Nb$ ^{232}Th+dtrs	1200
Opp. Fermi St.	Water	17. 8.71			5.0			
Clay Pit near Burial Ground:								
(a)	Ground Water	2. 9.71	27.2	24.6		trace	^{238}U series	
(b)	"	"	15.4	23.1		"	"	
(c)	"	"	2.0	11.3		"	"	
Creek Near Main Gate	Water	30. 7.71			1.0			
Creek Near Bld. 9	Water	30. 7.71			2.0			
Creek Opp. South Gate	Water	30. 7.71			22.8			
Drain Opp. Fermi St.	Water	30. 7.71			19.3			

TABLE 12 - RESULTS OF 'LiF - TEFLON DOSIMETERS' RADIATION DOSE READINGS ON BED OF WORONORA ESTUARY AT THE DISCHARGE POINT

Location of Dosimeters (Fig. 3)	Dose in rems from 14.8.70 to 23.9.71
No. 1	NIL
2	0.006
3	0.026
4	0.183
5	NIL
6	NIL
7	0.016
9	0.006
10	NIL
11	NIL
12	NIL

TABLE 13 - WORONORA SAMPLES - ANNUAL AVERAGES EXPRESSED AS FRACTIONS OF THE DERIVED MAXIMUM PERMISSIBLE CONCENTRATIONS[(a)]

Sample	Radioisotope and m.p.c.	Fractions of m.p.c.						
		1965	1966	1967	1968	1969	1970	1971
Water	^{3}H, 30nCi/ml							
EO			$2x10^{-4}$	$8x10^{-4}$	$7x10^{-4}$	$2x10^{-4}$	$5x10^{-4}$	
E1.5			$4x10^{-4}$	$3x10^{-4}$	$4x10^{-4}$	$1x10^{-4}$	$4x10^{-4}$	
E3.6					$1x10^{-4}$	$7x10^{-5}$	$2x10^{-4}$	$7x10^{-5}$
E5.0					$7x10^{-5}$	$3x10^{-5}$	$1x10^{-4}$	
Oyster Flesh	^{65}Zn, 1000pCi/g							
E4.4		$1x10^{-4}$	$2x10^{-4}$	$1x10^{-4}$	$1x10^{-4}$	$5x10^{-5}$	$2x10^{-4}$	$3x10^{-4}$
E5.8		$2x10^{-5}$	$1x10^{-5}$	-	-	$4x10^{-5}$	$8x10^{-5}$	$1x10^{-4}$
Hawkesbury		-	-	-	-	-	-	-
	^{90}Sr, 1pCi/g							
E4.4		$<1x10^{-3}$	$<1x10^{-3}$	$<2x10^{-3}$	$<2x10^{-3}$	$<2x10^{-3}$	$<3x10^{-3}$	
E5.8		$<1x10^{-3}$	$<2x10^{-3}$	$<2x10^{-3}$	$<1x10^{-3}$	$<2x10^{-3}$	$<1x10^{-3}$	
Hawkesbury		$1x10^{-3}$	$<1x10^{-3}$	$<1x10^{-3}$	$<2x10^{-3}$	$<2x10^{-3}$	$<1x10^{-3}$	
Fish (Average of all samples)	^{60}Co, 500pCi/g	-	$2x10^{-4}$	$1x10^{-4}$	$4x10^{-4}$	$2x10^{-4}$	-	-
	^{90}Sr, 1pCi/g	$3x10^{-2}$	$9x10^{-3}$	$9x10^{-3}$	$8x10^{-3}$	$7x10^{-3}$	$<6x10^{-3}$	-
	^{137}Cs, 200pCi/g	-	-	$5x10^{-5}$	$2x10^{-4}$	$3x10^{-5}$	-	-
Beach Sand (Average of all samples)	Gross Alpha 3000pCi/g	$1x10^{-3}$	$2x10^{-3}$	$1x10^{-3}$	$2x10^{-3}$	$3x10^{-3}$	$3x10^{-3}$	$3x10^{-3}$
	Gross Beta 2500pCi/g	$1x10^{-3}$	$5x10^{-4}$	$5x10^{-4}$	$8x10^{-4}$	$<1x10^{-3}$	$1x10^{-3}$	$4x10^{-4}$

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

TABLE 14 - 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	0.01	Whole Body
	Zinc-65	Ingestion	0.05	Whole Body
Fish	Tritium	Ingestion	0.01	Whole Body
	Caesium-137	Ingestion	trace	Whole Body
	Cobalt-60	Ingestion	trace	Whole Body
	Cobalt-60	Ingestion	trace	Lower Large Intestine
Milk	Caesium-137	Ingestion	0.3	Whole Body
Estuary Water	Tritium	Daily Swimming at Discharge Point	0.01	Whole Body
Beach Sand	Gross Beta Activity	Regular Contact	1.0	Skin

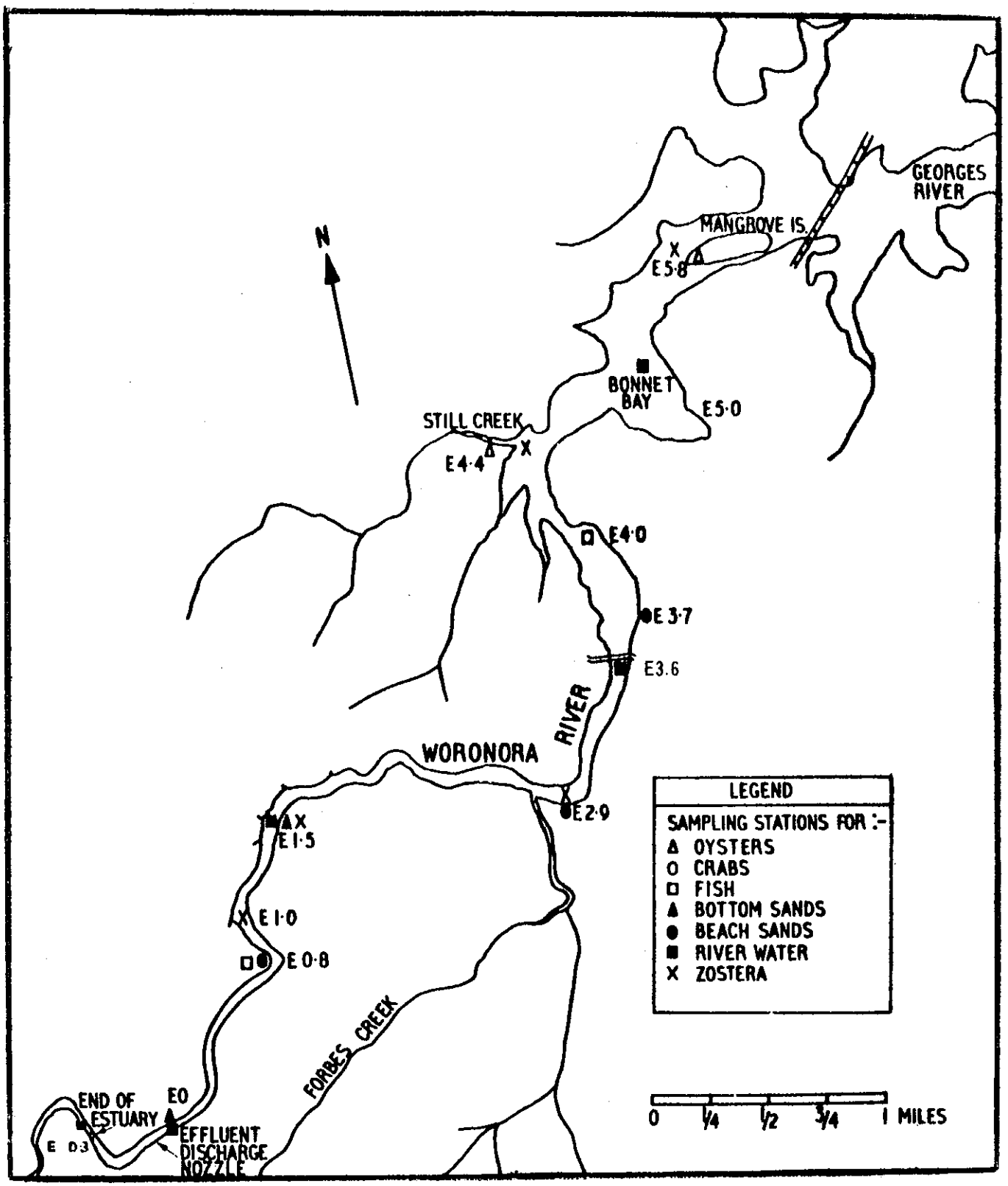

FIGURE 1. WORONORA ESTUARY SAMPLING STATIONS (1971)

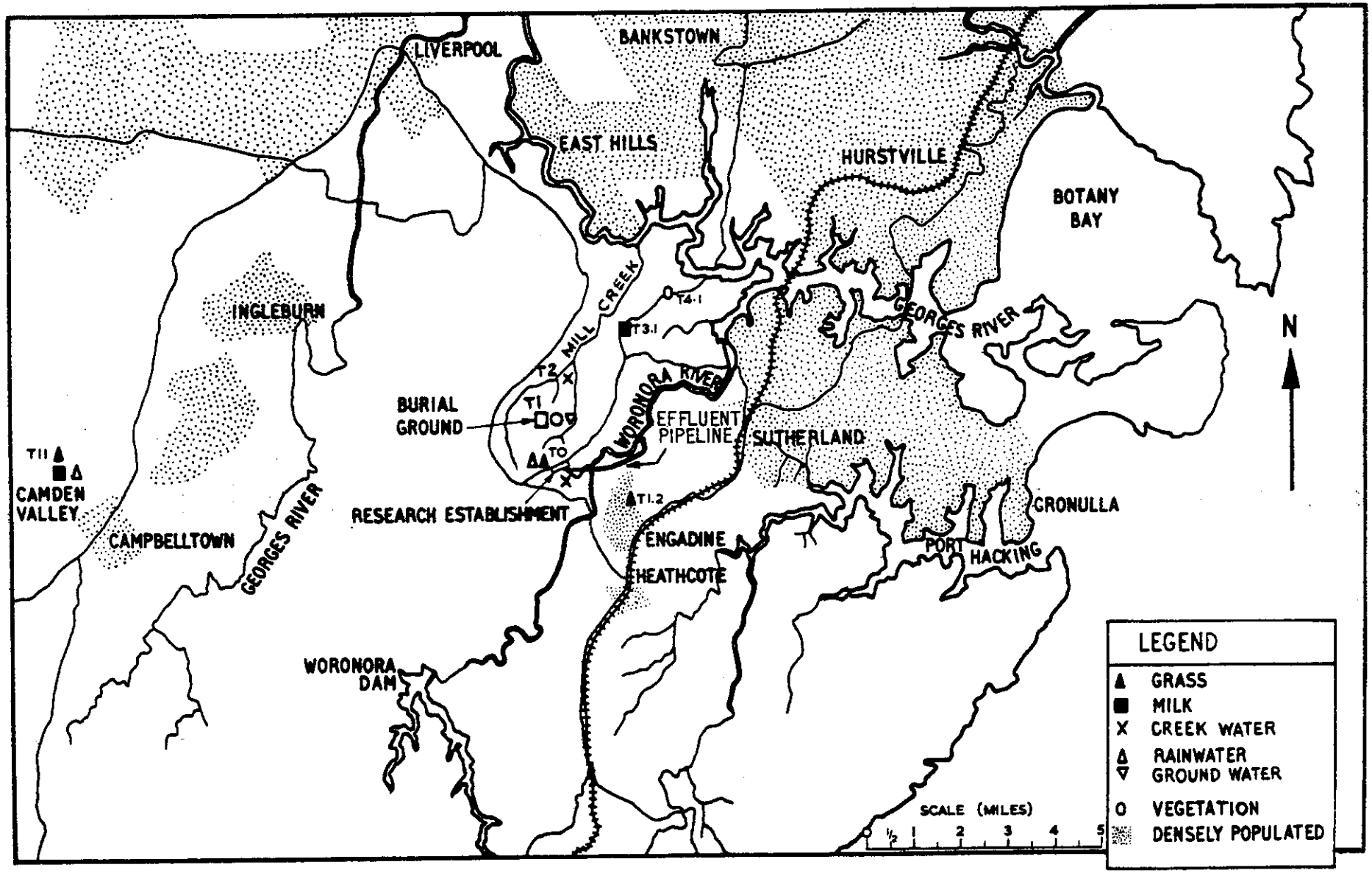

FIGURE 2. TERRESTRIAL SAMPLING STATIONS (1971)

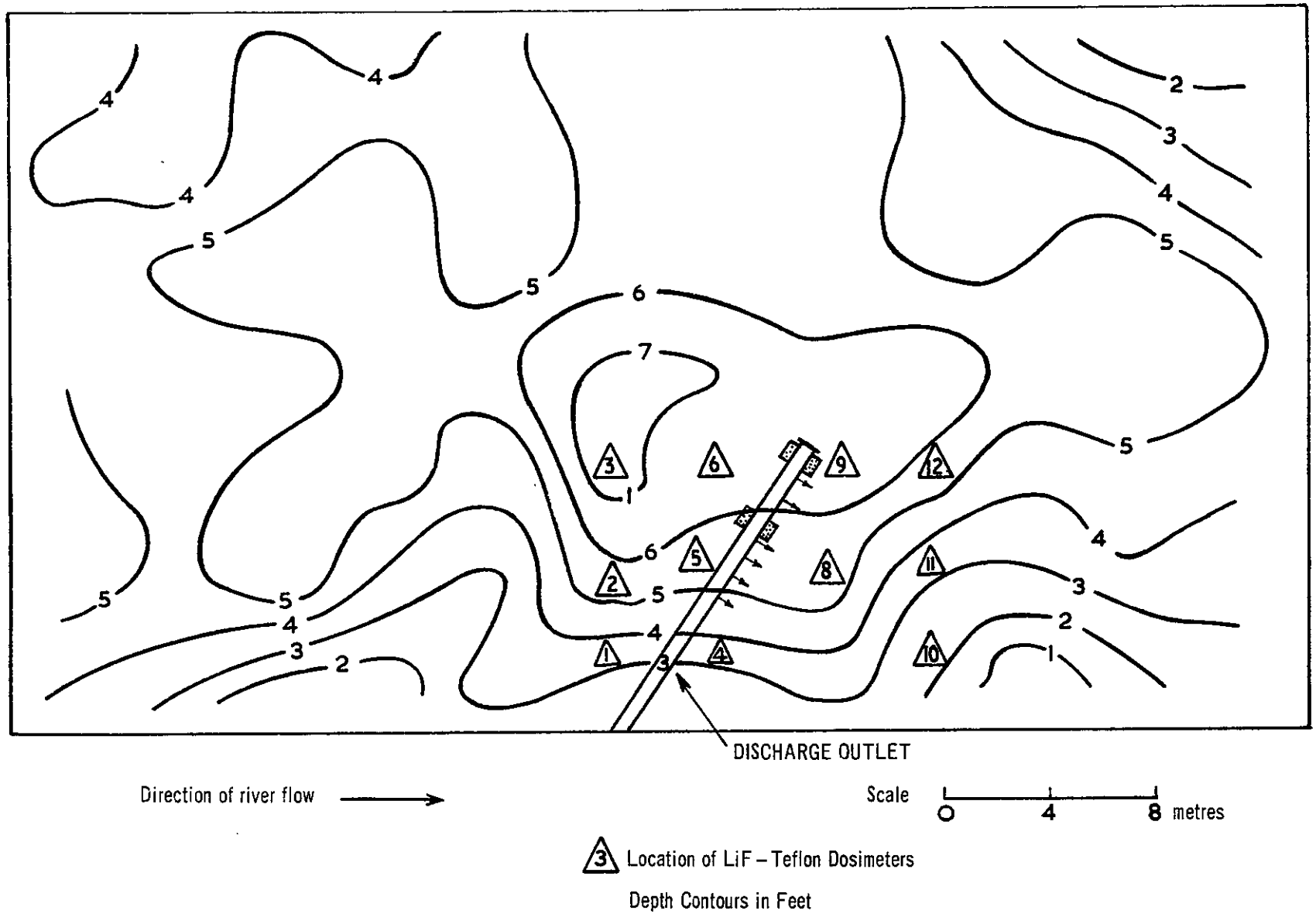

FIGURE 3. LOCATION OF LiF - TEFLON DOSIMETERS ON BED OF WORONORA ESTUARY AT THE DISCHARGE POINT