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Australian Radiation Laboratory

The Radiological Status of the Monte Bello Islands; May 1983

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ABSTRACT

The results of a radiological survey of the Monte Bello Islands, performed in May 1983, are presented. The radiation environments of the sites (ground zeros) of the two atomic weapons tests conducted over land, in 1956, on Trimouille Island and Alpha Island are described. The radiation fields at both ground zero locations are now relatively low, and present no health risk to the casual visitor. The radiation field on the southern and central parts of Trimouille Island, adjacent and downwind of the first atomic weapons test offshore, on HMS Plym, in 1952 is also described. The southern part of Trimouille Island is essentially free of radioactive contamination, whereas in the central part of the island the fallout pattern from this test is evident. For the first time, this fallout area has been reasonably accurately defined.

Radioactive metal fragments, containing the ^{60}Co radionuclide, were observed in large numbers scattered throughout the central part of Trimouille Island. The radioactive content of this metal, which originates from HMS Plym, was typically 6 kBq/kg. A number of soil samples from the two ground zero locations, and from central and southern Trimouille Island, were collected and analysed for radionuclide concentrations. As well, samples of oysters were obtained from three sites on Trimouille Island. There was no significant radioactive contamination of the oyster flesh or shells.

INTRODUCTION

The first full-scale field trial in the British program for developing nuclear weapons was performed at the Monte Bello Islands in Western Australia in 1952, in an operation code-named HURRICANE. The Islands, and their location off the coast of Western Australia, are shown in the maps of Figures 1 and 2.

In all, three full-scale tests of nuclear weapons were carried out at the Islands. In Operation HURRICANE, one weapon was exploded on a ship, HMS Plym, moored 600 m off the coast of Trimouille I., and in Operation MOSAIC in 1956, two weapons were exploded on towers over land at sites (ground zeros) on Trimouille I. and Alpha I. These ground zeros are identified as G1 and G2 respectively. Details of these tests are presented elsewhere (Moroney and Cooper, 1982). No other trials related to weapons development were conducted at the Islands.

As at other nuclear weapon test sites, the residual radioactive contamination at the Islands comprises activation products in soil that was irradiated by neutrons from the explosions together with close-in fallout around and downwind of the explosion ground zeros.

The radiological status of the Islands has been assessed on several occasions following the cessation of nuclear weapons testing in mid-1956. The results of previous surveys during the period 1962 to 1978 have been published (Cooper and Hartley, 1979; Cooper and Duggleby, 1980; Moroney and Cooper, 1982) and evaluated in terms of possible detriment to health of visitors to the Islands (AIRAC, 1979). The most recent publication summarised all available data on the external radiation environment of the Islands from 1962 to 1978 (Moroney and Cooper, 1982). At the end of this period there remained three areas with residual radioactive contamination and in which the external radiation field exceeded background levels. These areas were the immediate environs of the ground zeros on Alpha I. and Trimouille I. and the region in the central part of Trimouille I. adjacent to the position at which HMS Plym was moored.

Access to the former atomic test sites on the Monte Bello Islands has been controlled by the Commonwealth under Defence legislation since the tests were conducted. In accordance with the policy of the Commonwealth Government, that the Islands be transferred to the control of the Government of Western Australia, the Minister for National Development and Energy in July, 1982 requested a report on the current levels of residual radioactive contamination on the Islands. At this time the Government of Western Australia was developing management plans which were to accommodate the dual objectives of conservation and resource development, and was invited to nominate representatives to co-operate with Commonwealth scientists in conducting a radiological survey.

Previous radiological surveys of the Islands during the period 1962 to 1978 were planned using estimates and predictions of the environmental radiation field by the United Kingdom Atomic Weapons Research Establishment (UKAWRE) as a basis. However, it is only recently that the precise co-ordinates of the location of HMS Plym at the time of the first test in 1952 have been made available. The actual position of HMS Plym was approximately 2 km south of the position assumed in the previous surveys. Radiological data from those surveys have recently been reassessed in terms of the correct position of HMS Plym (Moroney and Cooper, 1982). Due to lack of knowledge about the position of HMS Plym, the possibility remained that, in the previous surveys, the extent of radioactive contamination in the central and southern regions of Trimouille I. was not adequately investigated. Therefore, one of the major aims of the present survey was to perform an extensive broadscale examination of the environmental radiation field in this region.

A further aim of the present study was to examine changes to the external radiation environments of the ground-zero locations on Alpha I. and Trimouille I. since the previous 1978 survey. Such changes will have occurred as a result of both natural decay of radionuclides and of a work program designed to clean-up these areas. This was performed by Army personnel on behalf of the Department of National Development in 1979 (DND & E, 1980).

THE PRESENT SURVEY

The survey was performed at the Monte Bello Islands over three full days, 24 - 26 May 1983 inclusive.

Monitoring of the environmental gamma-radiation fields at the two ground-zero sites, and in the central and southern regions of Trimouille I., was performed by use of two Studsvik Gammameter Model 2414A meters with Studsvik Model 5315B detectors. These instruments had been individually calibrated over the relevant energy range, and average calibration factors have been applied to the results presented in this report. Readings from the two instruments were compared from time to time in the field, and both instruments performed without malfunction. A background level of 0.03 μSv/h was determined with both instruments over water some distance from the Islands.

Radiation measurements were made at 1 m above ground-level, and the values reported at each of the locations shown in Figures 3 - 5 are averages of five readings, one at the centre and four evenly spaced on a circle of radius 1 m about the centre.

Soil samples were obtained from the sites described in Tables 1 and 2, and were ground and homogenised and sealed in packs of a standard geometry for analysis by high-resolution gamma-ray spectrometry. Oyster samples were obtained from Cocoa Beach (50 oysters), north end of Main Beach (36 oysters), and from rocks near to G1 (40 oysters) on Trimouille I. These were separated into flesh and shells, and the former was freeze-dried and the latter were ashed at 500°C before being sealed in packs of standard geometry for analysis by gamma-ray spectrometry.

The concentrations of gamma-emitting radionuclides in the soil and oyster samples were determined by high-resolution gamma-ray spectrometry. The spectrometry system consists of a lithium-drifted germanium detector (Ortec model VIP10), the output of which is fed via a preamplifier, amplifier and analog-to-digital converter (Nuclear Data ND 570) to a Nuclear Data model 6600 data acquisition, control and processing computer. The spectrometer was calibrated for efficiency with a standard source of pitchblende (New Brunswick Laboratory) in a silica matrix, presented in the geometry used for the soil and oyster samples.

Activities were calculated from the areas of full-energy spectral peaks for gamma-rays, corrected for background and continuum effects. All spectral peaks of statistical significance were considered. The estimated uncertainties in the activities, given in parentheses in the Tables, are expressed as estimated standard deviations of the mean. They were determined from counting statistics or, where statistically valid, from the scatter of individual estimates of the activity.

RADIATION ENVIRONMENT OF G1 ON TRIMOUILLE I.

The effects of the work program performed in 1979, to remove radioactive debris and soil from the ground-zero area, and to replace removed material with fresh soil, are apparent in the very significant decrease (from 18 μSv/h in 1978 to 1.3 μSv/h in 1983) in the radiation field at the immediate ground-zero location. Radiation levels radiating out from the ground zero (Figure 3) are decreased by a factor of ca. 1/2 to 1/3 due to both natural decay and the results of the work program. Apart from the south-west direction, radiation levels more than 100 m from the ground zero are all less than 0.20 μSv/h.

RADIATION ENVIRONMENT OF G2 ON ALPHA I.

Again the effects of the work program of 1979 to reduce radiation levels at the immediate ground-zero location are seen to have been successful. The level of 30 μSv/h at G2 in 1978 has been reduced to 1.7 μSv/h in 1983. Natural decay accounts for radiation field levels in 1983 of ca. 1/2 those observed in 1978 (Figure 4). This reduction is consistent with the decay of the main neutron-induced radionuclides ^{60}Co and ^{152}Eu. No obvious effects of weathering were apparent in this area.

The radiation field at ground zero on Alpha I. is still considerably higher than that on Trimouille I., and even at a radius of 200 m levels are considerably in excess of 0.2 μSv/h.

RADIATION ENVIRONMENT OF CENTRAL AND SOUTHERN TRIMOUILLE I.

The fallout on Trimouille I. from the test performed on HMS Plym is seen (Figure 5) to occur in a broadly north-west direction from the position at which HMS Plym was moored at the time. The radiation field on the southern part of Trimouille I., including that part immediately adjacent to HMS Plym (Cocoa Beach area), was found to be very low (less than 0.1 μSv/h, Figure 5). This confirms that the southern part of Trimouille I. is essentially free of radioactive contamination. However, the radiation levels on the Island in the area extending inland from the middle of Main Beach to its northern extremity exceeded the levels predicted (0.2 - 0.5 μSv/h) from the 1978 survey (Moroney and Cooper, 1982). The predictions of levels in this area were based on a paucity of measurements from this region, a situation which arose from the assumed (incorrect) position of HMS Plym in the earlier surveys.

RADIONUCLIDES IN SOIL

The concentration and distribution of radionuclides in soil at the Islands had been well-established by the analysis of a large number of soil samples from the 1972 and 1978 surveys. Additional samples were collected during this present survey for comparison with previous results and to identify which radionuclides give rise to the external radiation field in the region of Main Beach, the area suspected of being contaminated by close-in fallout from the test on HMS Plym.

The content of gamma-emitting radionuclides in soil from sites close to G1 and G2 are presented in Table 1 together with data obtained from sites nearby in 1972 and 1978. The principal contaminants of the soil are unchanged, namely ^{60}Co, ^{137}Cs, ^{152}Eu and weapon-related material, ^{239}Pu and ^{241}Am. The concentrations of neutron-induced radionuclides are generally consistent with previous results. However, for a particular site, there are significant differences between the data from the three surveys for fission-products and ^{241}Am which cannot be explained by natural decay of the radionuclides with time. Most probable explanations are the considerable variability at a site due to the discrete particulate nature of close-in fallout and the instability of the loose sandy soil, particularly in the vicinity of the ground zero on Trimouille I.

The analytical results for sampling sites in the central and southern regions of Trimouille I. are given in Table 2. The external radiation field in the area from Main Beach to Beaver Hill is due, almost entirely, to ^{137}Cs in the upper layers of the soil. As expected, ^{241}Am was also detected in the soil from these sites which indicates that surface contamination in this area includes low levels of plutonium. The only other contaminant which is present in significant quantities in soil from this region is ^{60}Co. This radionuclide probably occurs as a result of neutron activation of the metal components of HMS Plym followed by vaporisation of some of this material and dispersion with the radioactive plume from the test.

Although radiation dose-rates did not exceed background in the area of Trimouille I. south of Main Beach, confirming the absence of contamination, it was of interest to analyse soil sampled from the closest point (Cocoa Beach) to the mooring location of HMS Plym for, in particular, neutron activation products. Analytical data for soil sampled at Cocoa Beach are given in Table 2 and although ^{137}Cs, ^{60}Co and ^{152}Eu were detected in surface soil the concentrations are of no significance.

ANALYSIS OF OYSTERS

The concentrations of gamma-emitting radionuclides in oyster flesh and shell samples from three sites on Trimouille I. are given in Table 3. In accord with previously published analyses of marine species (AIRAC, 1979; Cooper and Hartley, 1979) trace quantities of radioactive contaminants, particularly ^{60}Co, were found in oyster flesh taken from each site. The levels of contamination are considered to be quite insignificant and to represent no hazard to health. For example, the maximum concentrations of ^{60}Co and ^{137}Cs in the oysters were 1.0(1) and 1.7(1) Bq/kg (from Table 3). With reference to data in a recent publication of the International Commission for Radiological Protection (ICRP, 1979) the estimated annual dose equivalent that would result from the consumption of 10 kg of oyster flesh per year containing these levels of contamination is 0.3 μSv. By comparison the natural external radiation background in uncontaminated areas of the Islands was approximately 0.05 μSv/h. Continuous exposure at this level would result in an annual dose equivalent of 0.4 mSv.

RADIOACTIVE DEBRIS

The presence of radioactive metal fragments on both Trimouille I. and Alpha I. has been observed during previous surveys and surface dose rates in excess of 100 μG/h were reported for many of the fragments (Moroney and Cooper, 1982). Likewise a significant observation of the present survey was the very large number of metal fragments ranging in mass from less than one kilogram to several hundred. Most pieces encountered had surface dose rates in excess of their surroundings. On Trimouille I. the radioactive fragments were generally scattered throughout the central part of the Island, in a broad band across the Island from Main Beach to beyond Beaver Hill in the north. Isolated pieces were found inland from Cocoa Beach. For example, measurements of a number of pieces of metal plate in the Main Beach area gave surface dose rates in the range 1 - 17 μG/h.

Analysis of several fragments by high-resolution gamma-ray spectrometry showed that the radioactivity in the metal is due entirely to ^{60}Co. This radionuclide is formed by neutron activation of trace quantities of the stable isotope ^{59}Co during the nuclear explosion. The radioactive content of ^{60}Co in a representative piece of metal was determined to be 6 kBq/kg. It can be assumed that the ^{60}Co is uniformly distributed throughout the metal so that 6 MBq/tonne (160 μCi/tonne) is a reasonable estimate for the specific activity of ^{60}Co in the metal fragments throughout the central region of Trimouille I. Clearly the location of the radioactive metal fragments in this region, and the presence of ^{60}Co in the metal, indicate that this debris originates from HMS Plym. Under certain circumstances such as the unrestricted removal of material by souvenir hunters, the larger metal fragments could represent a potential radiation hazard. Depending on the nature of future management regimes consideration should therefore be given to the collection and burial of the radioactive metal.

ACKNOWLEDGEMENTS

We are very grateful to Mr Bill Daniels of the Commonwealth Department of Resources and Energy for his assistance in the planning and execution of the survey and for helpful discussions. We also thank Mr S Hoogerwaard, Mr J Carver, Mr J Dols and Mr T Britton, crew of the 'Armstrong Creek', whose diverse skills and local knowledge were invaluable to the survey.

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Table 1. Radionuclide concentrations in soil from sites in the vicinity of the ground zeros on Alpha I. and Trimouille I.

Location	Survey	Soil Sample Depth in mm (no. of samples)	Radionuclide Concentration in soil Bq/kg at collection						
			Fission Product		Neutron-induced Radionuclide				Weapon - Related
			^{137}Cs 30.2y	^{155}Eu 4.9y	^{60}Co 5.27y	^{133}Ba 10.7y	^{152}Eu 13.0y	^{154}Eu 8.5y	^{241}Am 4.33y
Trimouille G.Z. 50m W G1	1972	0 - 80 (1)	4800 (70)	1850 (40)	3070 (60)	n.r.	740 (30)	n.r.	750 (7)
	1978	0 - 80 (4)	381 (54)	124 (14)	138 (16)	n.r.	300 (30)	n.r.	60 (11)
	1983	0 - 80 (3)	2290 (170)	610 (150)	580 (580)	103 (17)	540 (130)	39(12)	360 (70)
		80 - 160 (1)	1680 (10)	375 (6)	267 (3)	75 (3)	1200 (80)	69(10)	182 (3)
		160 - 240 (1)	300 (4)	16 (5)	104 (2)	12 (1)	1160 (60)	58(9)	12 (2)
Trimouille G.Z 25m SW G1	1983	0 - 80 (3)	2720 (1750)	405 (375)	2330 (160)	63 (39)	830 (380)	66(30)	248 (220)
		80 - 160 (1)	396 (7)	-	82 (3)	-	2250 (13)	140(16)	-
		160 - 240 (1)	69 (2)	-	60 (1)	1 (1)	1770 (9)	81(14)	-
Alpha G.Z 50m E G2	1972	0 - 80 (1)	11600 (80)	1500 (50)	5500 (70)	n.r.	40000 (100)	n.r.	500 (40)
	1978	0 - 80 (3)	1700 (3800)	4550 (130)	2900 (1500)	n.r.	39500 (4300)	n.r.	1300 (100)
	1983	0 - 80 (3)	1600 (400)	200 (20)	1700 (200)	20 (4)	22000 (3400)	95(210)	66 (16)
		80 - 160 (1)	52 (9)	-	1530 (10)	-	26200 (1700)	1250(30)	-
		160 - 240 (1)	34 (5)	19 (12)	852 (6)	11 (3)	14300 (900)	600(70)	-
Alpha G.Z 50m NW G2	1972	0 - 80 (1)	3660 (80)	1060 (90)	3900 (80)	n.r.	36600 (160)	n.r.	455 (82)
	1978	0 - 80 (3)	1320 (590)	444 (82)	3760 (610)	n.r.	48450 (8500)	n.r.	n.r.
	1983	0 - 80 (3)	1020(2020)	590(950)	2470(390)	14(12)	26600(2400)	1330(140)	212(381)
		80 - 160 (1)	773 (7)	240 (10)	1810 (10)	26 (4)	26600 (150)	1180(140)	24 (8)
		160 - 240 (1)	248 (6)	81 (12)	1510 (10)	11 (3)	18600 (100)	790(90)	-
Alpha G.Z 75m SW G2	1983	0 - 80 (3)	11600 (3000)	6400 (2100)	2950 (400)	270 (84)	19900 (1150)	1100(90)	1680 (800)

(a) 'n.r.' indicates that the radionuclide concentration was not reported.

(b) '-' indicates that the radionuclide was not detected.

(c) The estimated standard deviations of the activities are given in parentheses. When only one sample was analysed at a particular location and soil depth the standard deviation is based solely upon counting statistics whereas for three or more samples per site the standard deviation represents the dispersion in radionuclide concentration between samples at that location.

(d) Data for the 1972 and 1978 surveys is taken from Cooper and Duggleby, 1980.

Table 2. Radionuclide concentrations in soil from sites in the central and southern regions of Trimouille I.

Location	Survey	Soil sample Depth in mm (no. of samples)	Radionuclide Concentration in soil Bq/kg at collection						
			Fission Product		Neutron-induced radionuclide				Weapon-related
			^{137}Cs 30.2y	^{155}Eu 4.9y	^{60}Co 5.27y	^{133}Ba 10.7y	^{152}Eu 13.0y	^{154}Eu 3.5y	^{241}Am 4.33y
Trimouille I near Red Beacon	1972	0 - 80 (1)	8700 (40)	425 (12)	618 (14)	n.r.	-	n.r.	200 (10)
	1983	0 - 80 (3)	5600 (3200)	295 (181)	330 (150)	54 (22)	-	-	220 (90)
		80 - 160 (1)	8720 (10)	134 (6)	139 (2)	124 (7)	-	-	73 (3)
		160 - 240 (1)	395 (3)	16 (2)	143 (6)	20 (2)	-	-	7 (1)
Trimouille I Main Beach area Survey point F1	1983	0 - 80 (3)	3840 (1080)	281 (84)	434 (144)	74 (17)	-	-	162 (57)
		80 - 160 (1)	131 (2)	-	-	-	-	-	-
		160 - 240 (1)	143 (2)	7.6 (1.6)	9 (1)	2.5 (5)	-	-	4 (1)
Trimouille I Main Beach area Survey point F2	1983	0 - 80 (3)	2070 (600)	213 (32)	342 (63)	72 (9)	4 (2)		137 (26)
		80 - 160 (1)	419 (3)	22 (2)	27 (1)	10 (1)	-	-	10 (1)
		160 - 240 (1)	220 (2)	-	-	-	-	-	-
Trimouille I South of Cocoa Beach	1983	0 - 80 (3)	10 (4)	-	0.5 (3)	-	2 (3)	-	-
		80 - 160 (1)	-	-	-	-	4 (2)	-	-
		160 - 240 (1)	-	-	-	-	3 (2)	-	-

(a) 'n.r.' indicates that the radionuclide concentrations was not reported.

(b) '-' indicates that the radionuclide was not detected.

(c) The estimated standard deviations of the activities are given in parentheses. When only one sample was analysed for a particular site and depth the standard deviation is based upon counting statistics whereas for 3 or more samples per site the standard deviation represents the dispersion in radionuclide concentration between samples at that location.

(d) Data for the 1972 and 1978 surveys is taken from the reference, Cooper and Duggleby, 1980.

Table 3. The concentrations of gamma-ray emitting radionuclides in oysters from the Monte Bello Islands collected in May, 1983

Sample location	Type	Radionuclide concentration in mBq/g fresh weight ^{40}K	^{60}Co	^{133}Ba	^{137}Cs	^{152}Eu	^{226}Ra
Cocoa Beach	Flesh	78(3)	0.4(1)	ND	ND	ND	ND
	Shell	ND	0.3(2)	ND	ND	ND	ND
Main Beach	Flesh	70(7)	0.4(1)	ND	ND	ND	ND
	Shell	5(3)	ND	ND	ND	ND	ND
Trimouille G1	Flesh	74(3)	1.0(1)	ND	1.7(1)	ND	ND
	Shell	1.0(6)	0.3(2)	0.2(1)	ND	ND	ND

(a) The average fresh weights of flesh/oyster are 2.3, 3.2 and 3.2 g for locations Cocoa Beach, Main Beach and Trimouille G1 respectively. Average fresh weights of shell/oyster are 11.2, 11.2 and 18.4 g respectively.

(b) The estimated standard deviations of the activities are given in parentheses.

(c) ND indicates that the radionuclide was not detected.

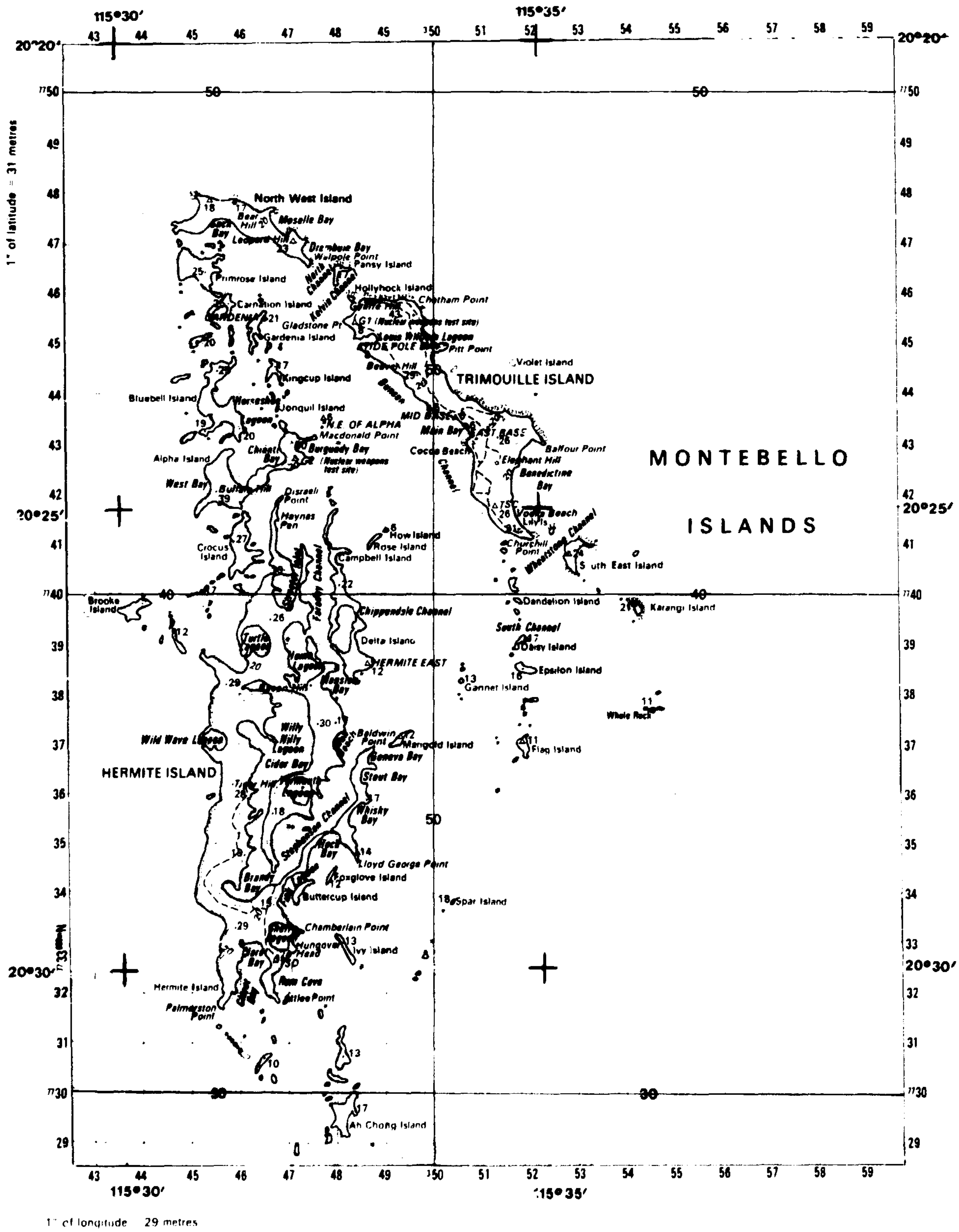

Figure 1 The Monte Bello Islands

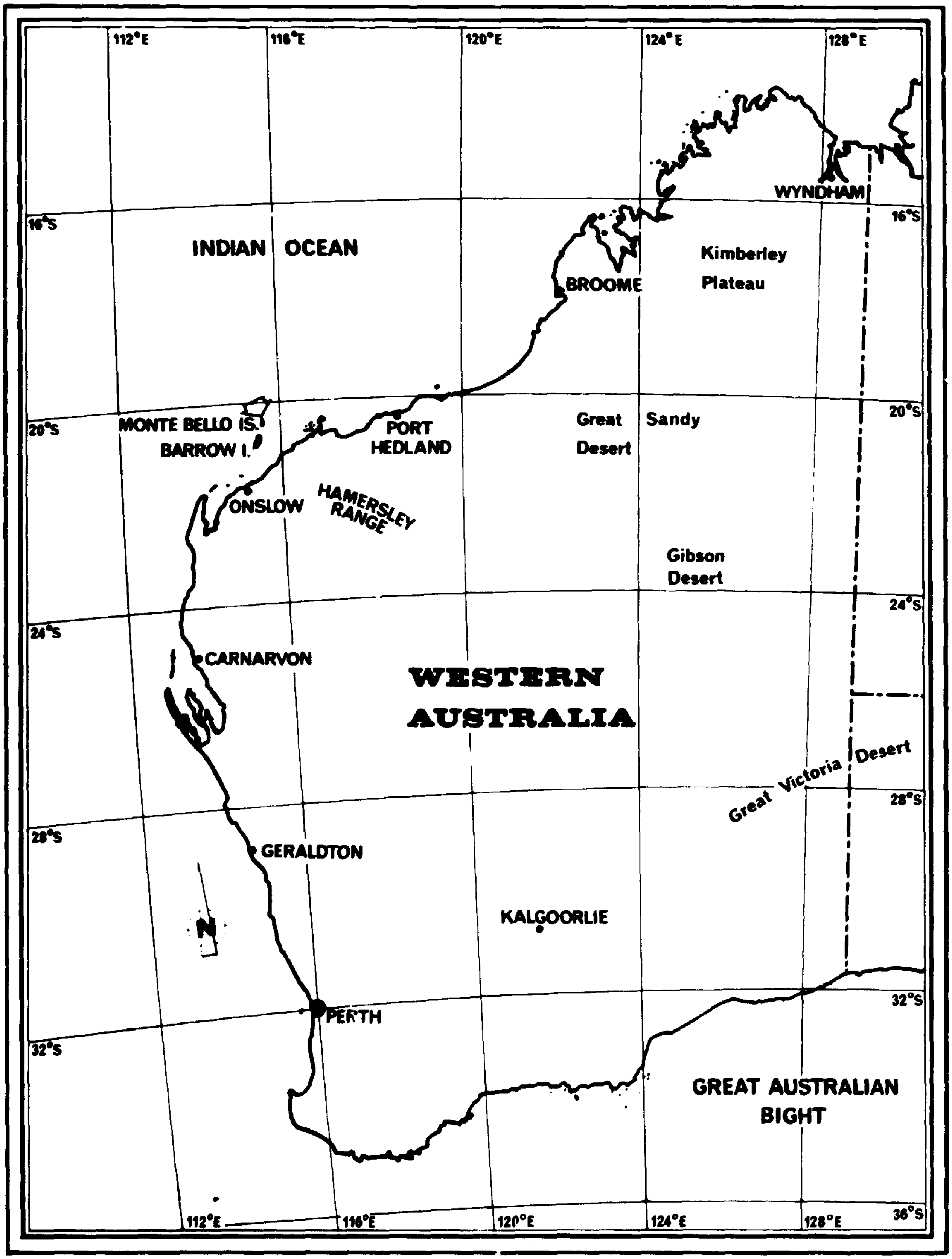

Figure 2 Location of the Monte Bello Islands off the north-west coast of Western Australia.

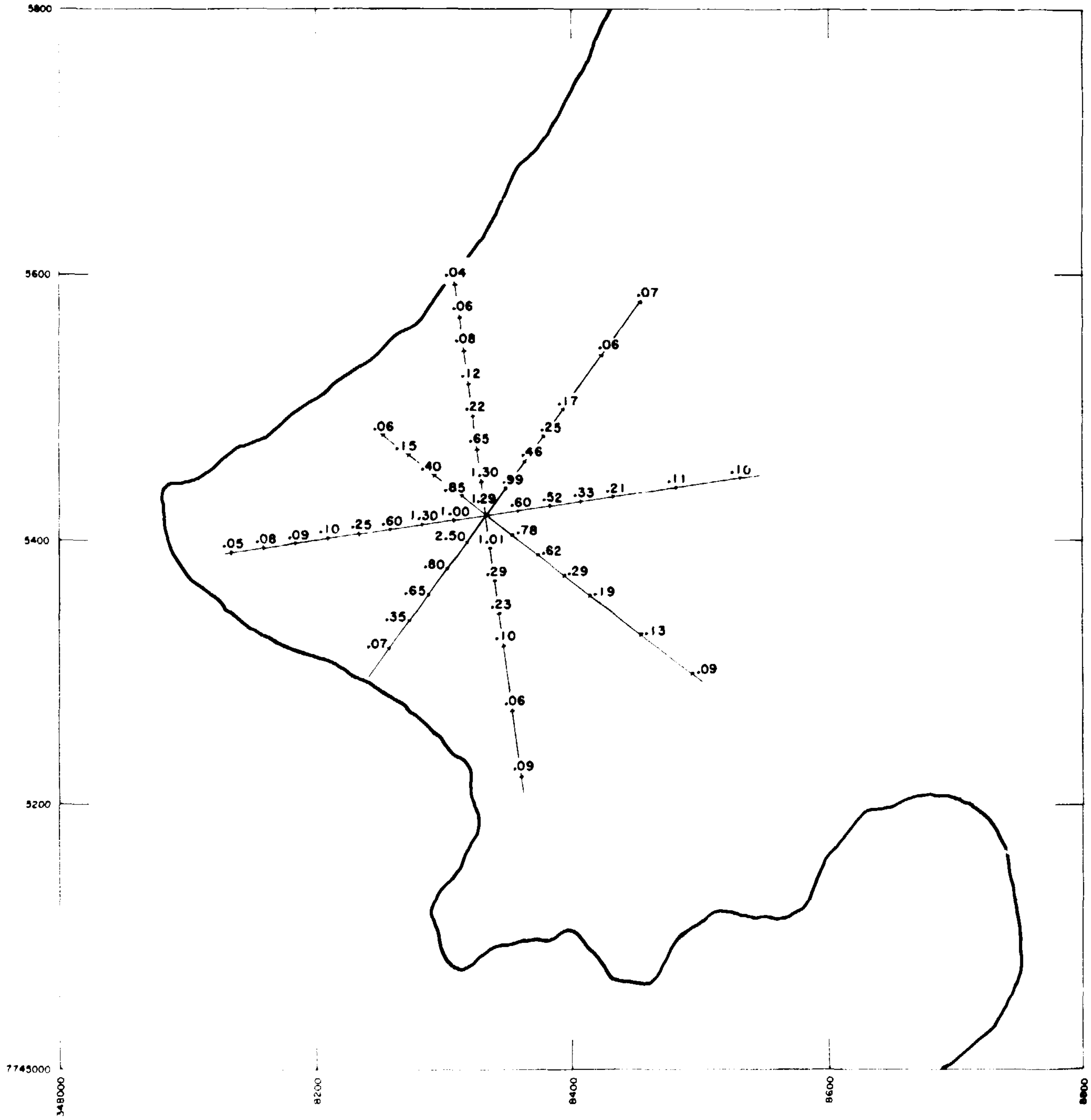

Figure 3. Radiation dose-rate (μSv/h) in the grid survey at G1 on Trimouille I. in May, 1983

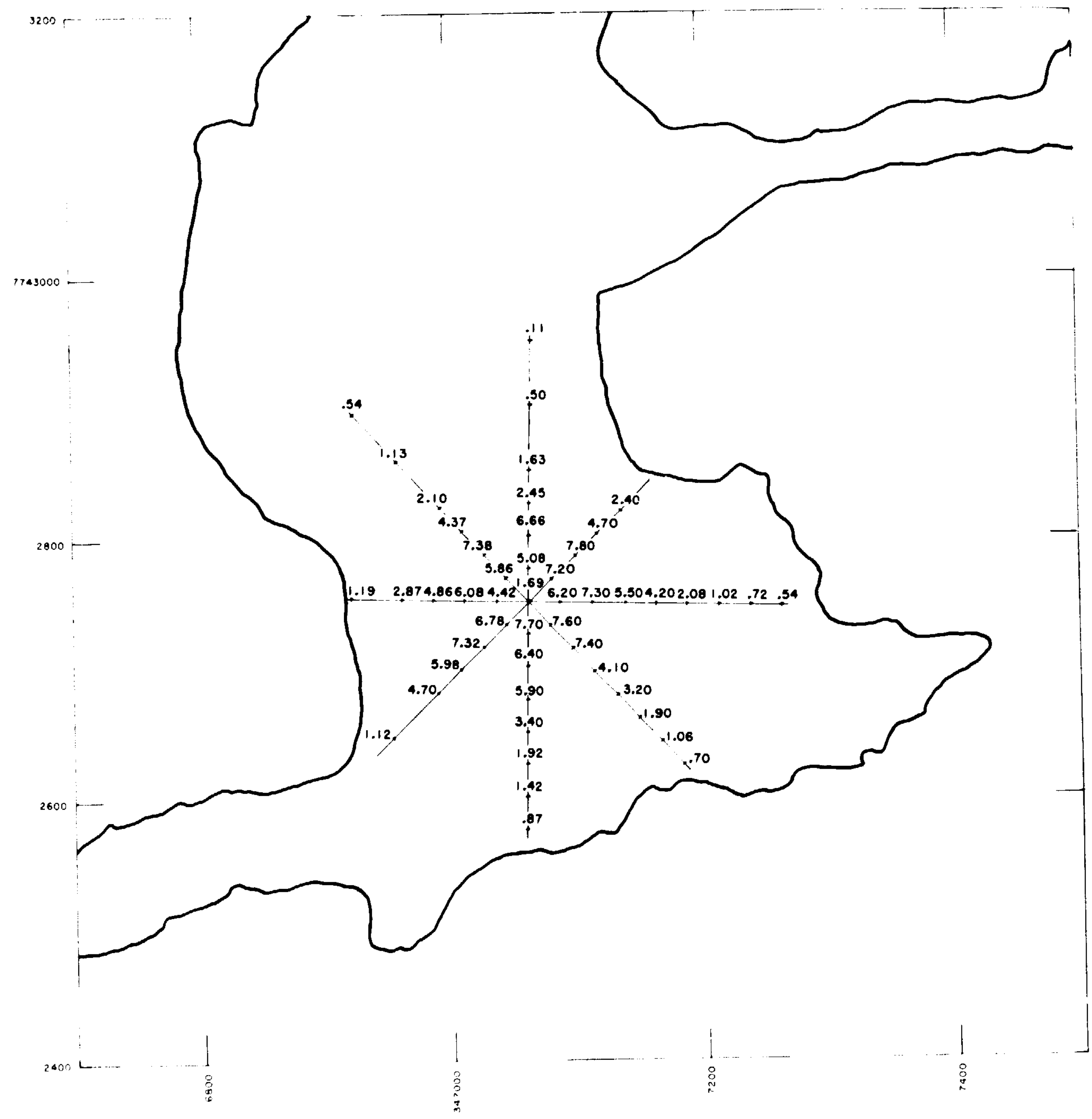

Figure 4. Radiation dose-rate (μSv/h) in the grid survey at G2 on Alpha I. in May, 1983

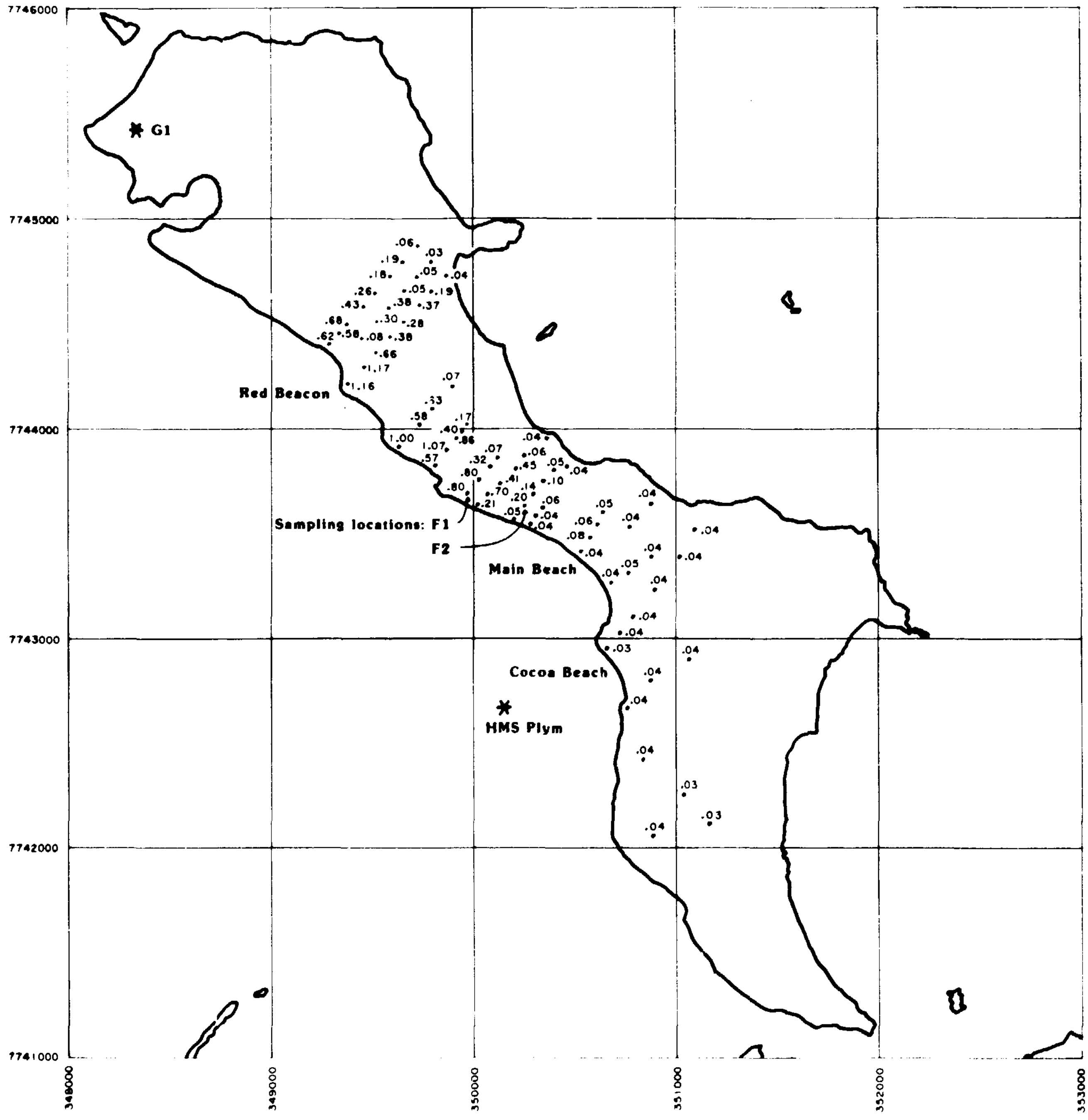

Figure 5. Radiation dose-rate (μSv/h) in the grid survey on Trimouille I. in May, 1983