SURVEY OF RADIOACTIVITY IN SEDIMENTS IN THE VICINITY OF NAVAL ESTABLISHMENTS IN THE UK

BY: DR. PAUL JOHNSTON
GREENPEACE RESEARCH FELLOW
QUEEN MARY COLLEGE
UNIVERSITY OF LONDON

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INTRODUCTION

Levels of artificial radionuclides have been recorded in a number of matrices around the UK coastline and published by the Ministry of Agriculture, Fisheries and Food in a series of Aquatic Environment Monitoring Reports (see e.g. MAFF 1988). These surveys are largely designed to assess public exposure to radiation and as such rely upon the concept of "critical groups" backed by ongoing studies of the behaviour of radioactive materials in the wider environment.

Monitoring of radioactivity is carried out around a number of Naval Bases in the UK which discharge radioactive liquid wastes. Two of these establishments, Devonport and Rosyth have now been privatised. Together with the British base at Faslane and the US base at Holy Loch these discharge what are described as "liquid wastes containing small quantities of radioactivity". The critical pathway is considered to be through occupancy, by the public, of intertidal areas while the critical groups range from dredgermen, boatyard workers and baitdiggers to the less specific group described as "local community" around Holy Loch (MAFF 1988). There are a number of possible drawbacks to the MAFF approach.

The MAFF monitoring includes a determination of gamma radiation exposure in situ (including that due to natural sources) and the measurement of individual artificial nuclides. The results for a number of samples taken over an "integrating" period of a year are published as an average figure with a correction applied for radio decay functions. The frequency of sampling in any given area "reflects the resolution (which affects the accuracy) judged to be necessary in the assessment of dose and is largely governed by the radiological importance" (MAFF 1988). The rationale behind this is that the use of the highest observed but unsustained level would not provide a realistic basis for comparison with recommended limits. The maximum number of sediment samples used in the averaging for 1987 is 9 for Rosyth. Devonport was averaged over 6 samples, Faslane over 4 and Holy Loch over 2.

It is notable that such arithmetic means are published without any supporting statistical measure of variation such as the measurement of range, standard error of the mean or standard deviation about the mean all or any of which would allow assessment of the relationship between the arithmetic mean and the highest levels recorded. The provision of such a statistic is highly desirable since the arithmetic mean of samples will effectively "dilute" the effect of an anomalously high value. The masking of anomalous values in this way may cause underestimation of the doses received by statistical "outliers" of the critical group under consideration. In the case of the MAFF data, mean values are based on so few samples that a good case could be made for the full publication of results. In the case of Holy Loch where only two samples per year are used in the derivation of the published value serious doubts must exist as to the degree to which this regime is likely to provide an accurate basis for radiological assessment.

A further drawback to the critical group approach arises from the monitoring strategy itself in that it does not consider full ecosystem effects but only pathways of human exposure. The amounts af radionuclides discharged from these establishments are known but their fate is not. The sequestration of radioactive contaminants by intertidal sediments such as those officially monitored is likely to be somewhat different from that of subtidal sediments which tend to be less disturbed by wave and tidal action. It is tacitly assumed that discharged nuclides are homogenously dispersed, but this assumption needs verification on a comprehensive local basis.

The survey described here was carried out during the summer of 1988 around five naval bases involved in the maintenance of nuclear submarines or the handling of nuclear weapons. The survey sought to investigate the levels of radionuclides present in the subtidal sediments around each of the bases and in particular those isotopes discharged as a result of maintenance and servicing of nuclear powered vessels.

MATERIALS AND METHODS

Samples of subtidal sediments were obtained in the vicinity of Rosyth, Faslane, Holyloch, Devonport and Portsmouth dockyards. In most cases a 0.1 square metre Day grab was used but where water was too shallow to permit the use of a large vessel, a 10cm Ekman grab was deployed from an inflatable. Samples of sediment were taken from above the redox horizon evenly over the undisturbed sediment surface within the large grab. In the case of the small grab the full contents were retained. Due to operating difficulties at Faslane, samples obtained at three locations were bulked and divided. The divided portions were supplied to the base personnel. Samples were also divided in the case of Devonport dockyard. At Holy Loch, personnel from the base were observed taking their own sediment samples using a hand held grab. This differed from the Day grab in that it could not be expected to produce a sample with an undisturbed vertical profile.

In each case, sediment samples were transferred to polythene bottles and transported to the analysing laboratory at St Bartholomews Hospital Medical School, London. Analysis for gamma emitting isotopes was carried out using a gamma spectrometer fitted with a germanium detector. Detection limits were about 2 to 3 Bq/kg dry weight of sediment. The counter was calibrated against a series of radionuclide standards traceable to a National Physical Laboratory standard.

RESULTS

The results of the sediment analyses are presented in Tables 1-5. MAFF and other data for comparison are given in Table 6. Sample locations, fixed using satellite navigation equipment calibrated against fixed chart positions at each site are shown on the maps comprising Figures 1-5. Analytical measurements are given as a count in Bq/kg dry weight +- the standard error of the count.

COMMENTS

1) Rosyth Naval Dockyard (Sampled: 12 July 1988)

Sediment samples taken in the vicinity of Rosyth showed the presence of Cs-137 up to a maximum value of 83.3 +- 6.0 Bq/kg of sediment (Table 1 & Figure 1). In addition, one sample showed the presence of Cs-134 and Ag-110 at relatively low levels. No evidence of Co-60 was found although Wheaton 1988 and MAFF 1988 report low levels of this isotope. The ratio of Cs-137:Cs-134 in sample number 7 is 7.6:1 indicating that it is unlikely to have arisen entirely from the Chernobyl accident. MAFF 1988 attribute the levels of radiocaesium in the vicinity of this base to discharges from the Sellafield reprocessing plant and report an overall 1987 value of 51 Bq/kg of Cs-137 with a Cs-137:Cs134 ratio of 7.8:1. This may be regarded as consistent with the values reported here. The value for sample No. 10 which was taken some distance down the Forth Estuary of a similar sediment type to that found close to the base showed a level of 57.0 +- 5.0 Bq/kg Cs-137. The general comparability of this value with those closer to the base suggests that the major origin of radiocaesium is external to the Forth Estuary system. This however may be an over simplification since the sample point at 56 02.02N, 3.06.68W is undoubtedly subject to deposition of material suspended at points further inland.

Permission to obtain samples of sediment from the dock basin where the decommissioned nuclear submarine HMS Dreadnought is laid up was denied. In connexion with this it is worth noting that the samples containing the highest levels of Cs-137 and traces of other isotopes were 5,6 and 7. Samples 5 & 6 were taken from immediately outside the lock gates in a regularly dredged area. Sample 7 was taken from an area subject to redeposition of suspended materials. Similarly the sample described by Wheaton (1988) as containing Cs-134 and Co-60 was taken in the region of Limekilns upstream of the main basin retaining wall and an area subject to likely redeposition of materials suspended by tidal influence. It is possible therefore that the sediments of the Main Basin are considerably contaminated, a view given credence by the identification of dredgermen as the critical group at Rosyth. Samples of these sediments should be made available for independent analysis.

Faslane Naval Base (Sampled: 20 July 1988)

At Faslane the critical group is stated to be boatyard workers. A preliminary survey of intertidal sediments (Wheaton 1988) gave values in broad agreement with the MAFF (1988) averaged values for 1987 although levels of Cs-137 are generally much lower in sediments sampled by Wheaton (1988). The survey found one anomalous value of Cs-137 in a soil/rootmat sample which in his opinion was not attributable to Chernobyl fallout.

Levels of Cs-137 recorded here from subtidal sediment samples were between 4 and 5 times that recorded as an averaged value of four samples for 1987 by MAFF (1988). The MAFF published value moreover, apart from a slight rise recorded in 1986 (MAFF 1987) seems to be of a series showing a continuing downward trend, possibly as a result of declining discharges from Sellafield. Cs-134 was recorded at up to twice the level published by the Ministry. The ratio Cs-137:Cs-134 for the subtidal sediments is between 18 and 26:1. This rules out Chernobyl radiation as a source though not Sellafield discharges. The levels recorded are not consistent however with expected values at this distance from the reprocessing plant unless there was a huge increase in discharges over the previous year. Similarly, Hunterston power station seems an unlikely source on the basis of previously published discharge levels.

Levels of Co-60 in the subtidal sediments exceed the averaged value for intertidal sediments by a factor of up to 8 times. As with Cs-137, the highest values of Co-60 were determined from the composite sample obtained close to the submarine berths at Faslane, which was divided with the base personnel at the time of sampling. Finally, levels of Sb-125 exceeded published values by up to 15 times although this is of marginal significance given the low counts and relatively large standard error values obtained for this radioisotope.

In the case of Co-60 and Sb-125 it is worth noting that the arithmetic means taken over all sampling sites were 34.6 and 13.96 Bq/kg respectively. The distribution of these nuclides was fairly patchy and they were below detection limits at some sites. This serves to illustrate that averaging of spatially separated results may misrepresent the true radiological significance of discharged isotopes. Such treatment of temporally separated sample results would also be prone to the same effect. A true assessment of the situation therefore would require a much extended sampling programme comprising more sampling sites with more samples taken each year at each site. The use of a mere 4 sediment samples per annum is inadequate.

Holy Loch Naval Base (Sampled: 21 July 1988)

Levels of Cs-137 recorded were between 2 and 9 times the value published by MAFF (1988). The Cs-137:Cs-134 ratio was between 10 and 30:1 indicating that Chernobyl fallout was not the source. Further, the overall levels were much higher than would be expected from Sellafield discharges alone. This indicates a local origin for these nuclides. The consistently elevated levels of Cs-137 at Holy Loch and Faslane with an apparent gradient suggesting Faslane as the source may be misleading. A low recorded Cs-137 value towards the mouth of Holy Loch at site No.1 (Table 3) suggests that radiocaesium has been directly introduced to the Loch. This of course may simply be a further example of "patchiness" in the distribution. There is evidence, too of within sample variation for the activation product Co-60 in Holy Loch sediments as evidenced by its detection in one of the replicate subsamples of sample 5 but not in the other. In contrast, Cs-137 and Cs-134 values are in good agreement. This suggests that activation products may be discharged in the form of relatively large particulates. Current survey methodology using average readings does not adequately evaluate the potential effects of such particulates.

Levels of Co-60 found in the subtidal sediments of Holy Loch appear somewhat higher than those at Faslane, and are on average some 9 times higher than those recorded by MAFF (1988). Sb-125 was detected in three subtidal sediment samples in contrast to MAFF surveys where it has not been recorded since reporting of the isotope began in 1987 (MAFF 1987). This is further evidence that the use of intertidal sediments for monitoring for the purposes of exposure assessment seriously misrepresents the true loading of radionuclides to the system.

Devonport Naval Dockyard (Sampled 28 July 1988)

Only Cs-137 was detected in the samples of sediment taken in the vicinity of Devonport dockyard. The values are comparable with, though slightly higher than, values published by MAFF. The recorded values, nonetheless, are consistent with atmospheric fallout and are not significant radiologically. It is possible that the low recorded levels are a reflection of the complex sediment water interactions and rapid dispersion in the turbid Tamar estuary (Uncles et al. 1987).

Portsmouth Naval Dockyard (Sampled 2 August 1988)

Portsmouth Dockyard is not monitored as part of the MAFF Naval Establishment monitoring scheme although a certain amount of monitoring takes place in the vicinity in connection with the discharge of radioactive material from the UK Atomic Energy Authority establishment at Winfrith.

The sediment samples taken at sites 1, 2 & 2a showed no radio-isotope levels above detection limits. Samples taken further inside the harbour showed detectable levels of radio caesium isotopes and of activation products. In particular appreciable levels of Co-60 were detected. Since activation isotopes are a significant component of the discharge from the Winfrith establishment it seems most likely that those detected in Portsmouth harbour originated from the UKAEA plant. The apparent elevation of radioisotopes in sediments from the inner harbour as compared to those from the main channel and the harbour mouth is most probably a function of the extensive areas of fine sediment in the inner harbour acting as a sequestrator of the radio-isotopes rather than evidence of them originating within the dockyard. The possibility of input from naval vessels directly into the harbour cannot, however, be excluded. An intriguing aspect of the local authority run Hampshire, Dorset and Isle of Wight radiation monitoring programme (Anon. 1988 a, b & c) are the elevated levels of Co-60 described for the South and Eastern Isle of Wight and general area of the Solent as compared to those obtained closer to the Winfrith plant. Results obtained by the Institution of Naval Medecine for the Solent area, which are at present confidential, should be made public. Efforts should be made generally to establish the precise source of the Co-60 found in Portsmouth harbour.

CONCLUSION AND RECCOMENDATIONS

1) Subtidal sediments sampled in the vicinity of naval establishments proved to be useful indicators of radio-active discharges although the levels found are not of radiological significance according to parameters set by the NRPB (1987).

2) In the case of Rosyth, Devonport and Portsmouth the levels of artificial radionuclides found were broadly in agreement with published figures. It should be noted that in the case of Rosyth samples were not taken of sediments within the dock basin which are likely to be the most contaminated. The same is true of Devonport, although in this case the hydrodynamic properties of the estuary are likely to result in rapid dispersion of introduced contaminants.

3) Levels of artificial radio-nuclides at Holy Loch and Faslane were found to be elevated to levels well above those expected from data published by MAFF. It seems likely that these high levels resulted from operational discharges of nuclear powered vessels.

4) In view of these results, it would appear that the current MAFF monitoring strategy is inadequate and should be reappraised with a view to extending its scope. Alternatively, a local authority monitoring programme could be implemented. This would have that advantage of perceived independence in the public view.

REFERENCES

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(mimeo 32pp)

Anon (1988 b)
Hampshire, Dorset and Isle of Wight radiation monitoring programme. Results: November 1987- January 1988
(mimeo 14pp)

Anon (1988 c)
Hampshire, Dorset and Isle of Wight radiation monitoring programme. Results: February 1988- April 1988
(mimeo 32pp)

Anon (1988 d)
Hampshire, Dorset and Isle of Wight radiation monitoring programme. Annual Report August 1987-July 1988
(mimeo 50pp)

MAFF (1987)
Radioactivity in surface and coastal waters of the British Isles, 1986
Aquatic Environment Monitoring Report No: 18 (Lowestoft), 62pp

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Radioactivity in surface and coastal waters of the British Isles, 1986
Aquatic Environment Monitoring Report No: 19 (Lowestoft), 67pp

NRPB (1987)
Revised general derived limits for radioisotopes of strontium, iodine, Caesium, plutonium, americium and curium. Report: NRPB-GS8, HMSO, London, 45pp

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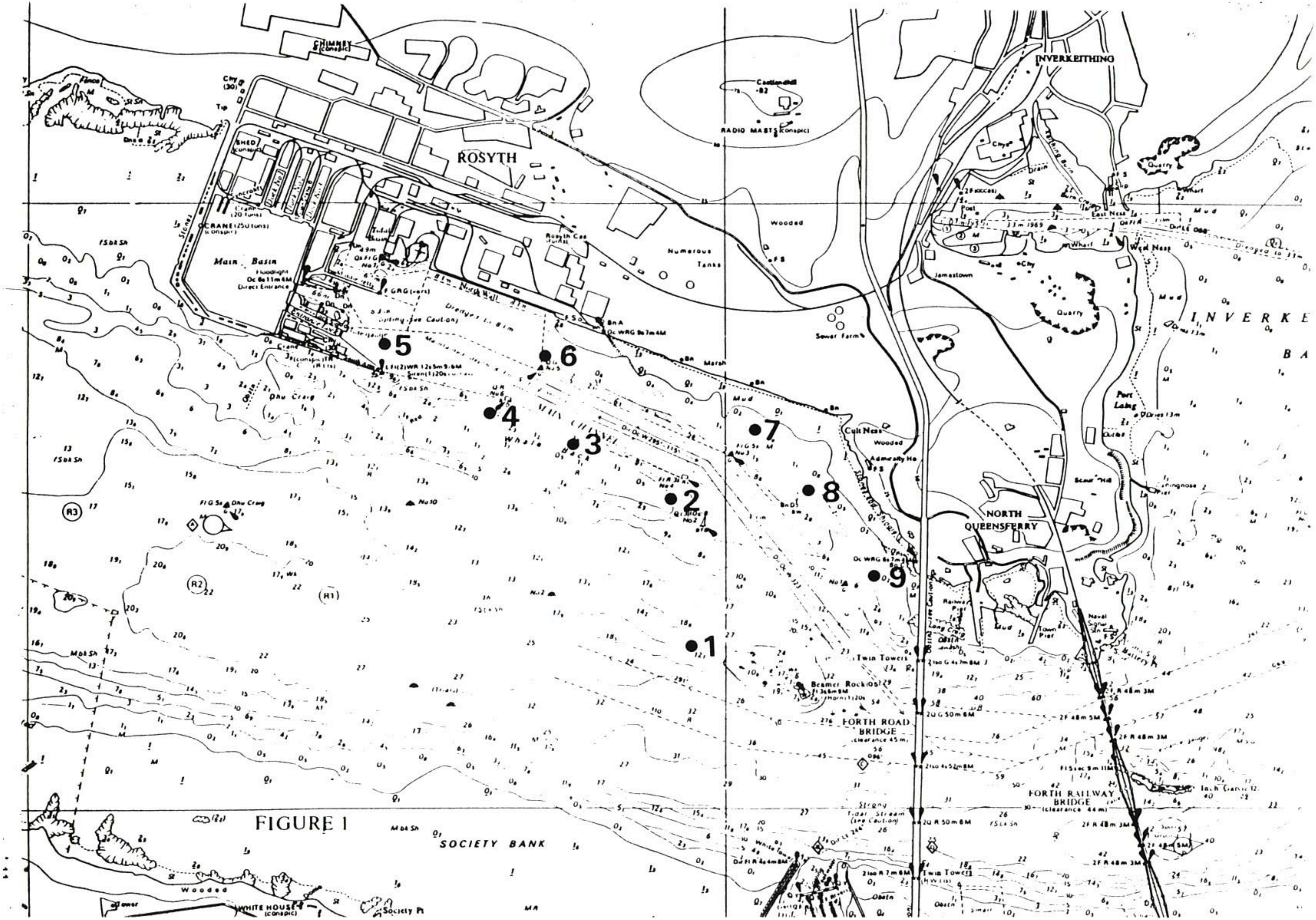
Continental Shelf Res. 7 (11/12): 1489-1493

Wheaton, R. (1988)
Report to Greenpeace UK of initial surveys for radioactivity around U.K. Naval Bases which accommodate nuclear submarines. (Edinburgh Radiation Consultants, June 1988), 16pp

SAMPLE	137 Cs	134 Cs	110m Ag	54 Mn	125 Sb	60 Co
Rosyth						
1	66.3+-4.7	-	-	-	-	-
2	33.6+-3.8	-	-	-	-	-
3	16.7+-3.0	-	-	-	-	-
4	42.6+-4.4	-	-	-	-	-
5	83.3+-6.0	-	-	-	-	-
6	73.0+-5.8	-	-	-	-	-
7	75.3+-3.4	9.8+-2.4	3.6+-2.8	-	-	-
8	60.4+-4.4	-	-	-	-	-
9	8.8+-1.4	-	-	-	-	-
10	57.0+-5.0	-	-	-	-	-

TABLE 1: Concentrations of radionuclides in sediments in the vicinity of Rosyth Naval Dockyard. Sampling sites are shown in Figure 1. All values are in Bq/kg dry weight of sediment. Sample No. 10 was taken from a subtidal mudbank at position 56 02.02N, 3 06.68W and is not shown on the chart.


ROSYTH
INVERKEITHING
NORTH QUEENSFERRY
FORTH ROAD BRIDGE
FORTH RAILWAY BRIDGE
SOCIETY BANK
CHIMNEY (conspic)
RADIO MASTS (conspic)
WHITE HOUSE (conspic)
Main Basin
Numerous Tanks
Wooded
Sewer Farms
Jamestown
Quarry
Mud
Marsh
Cult Ness
Admiralty Ho
Port Laing
Twin Towers
Beamer Rock
Dhu Craig
Society Pt
1
2
3
4
5
6
7
8
9
FIGURE 1

SAMPLE	137 Cs	134 Cs	110m Ag	54 Mn	125 Sb	60 Co
Faslane						
1	647+-17	34.6+-4.2	-	-	25.6+-18.2	-
2	625+-16	32.6+-6.7	-	-	-	24.5+-4.2
3	564+-16	26.6+-3.8	-	-	-	44.4+-5.7
4	565+-5	30.8+-2.5	-	-	12.2+-7.4	19.1+-2.6
5	481+-15	18.5+-3.5	-	-	46.0+-30	-
C **	657+-10	30.5+-4.3	-	-	-	120.0+-8.0

TABLE 2: Concentrations of radionuclides in sediments in the vicinity o' Faslane Naval Dockyard. Sampling sites are shown in Figure 2. All value: are in Bq/kg dry weight of sediment. ** C was a composite sample from material taken opposite berth numbers 1,3 & 6.

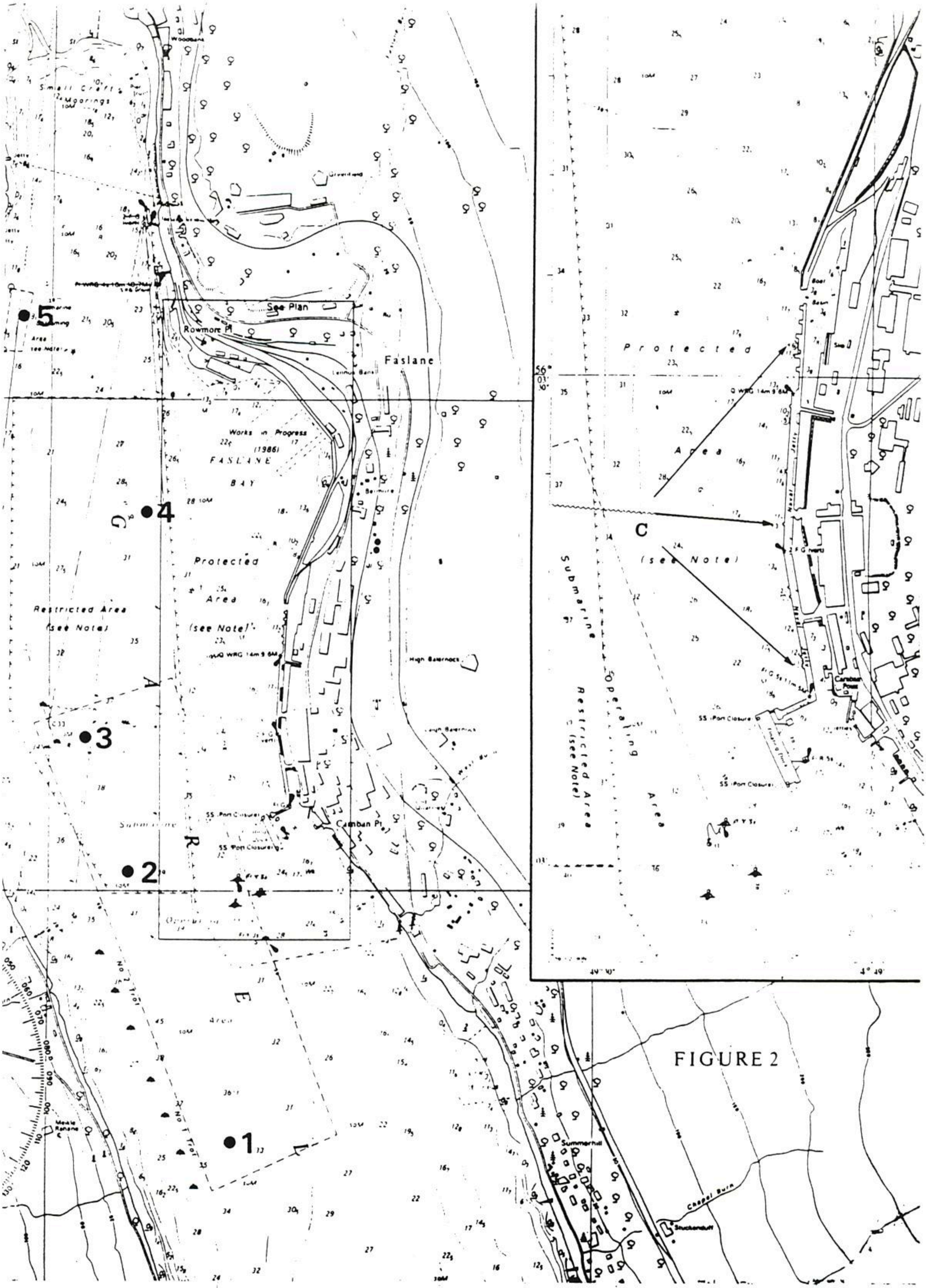

Woodbank
Small Craft Moorings
See Plan
Rowmore Pt
Faslane
Works in Progress (1986)
FASLANE BAY
Protected Area (see Note)
Restricted Area (see Note)
High Balernock
Camban Pt
SS (Port Closure)
Meikle Rahane
Summerhill
Stuckenduff
Chapel Burn
Protected Area
C
(see Note)
Submarine Operating Area
Restricted Area (see Note)
1
2
3
4
5

FIGURE 2

SAMPLE	^{137}Cs	^{134}Cs	^{110m}Ag	^{54}Mn	^{125}Sb	^{60}Co
Holy Loch						
1	116+-6	-	-	-	-	-
2	405+-4	15.2+-1.8	-	-	8.8+-7.2	63.7+-3.2
3	410+-13	-	-	-	60.8+-28	53.0+-4.8
4	462+-13	29.9+-3.7	-	-	-	68.5+-6.7
5	440+-13	38.3+-7.7	-	-	-	-
**	440+-13	37.5+-4.5	-	-	-	47.2+-5.6
6	421+-12	-	-			61.1+-6.2
7	448+-2	15.7+-0.8	-		11.5+-1.4	49.0+-1.7

TABLE 3: Concentrations of radionuclides in sediments in the vicinity o Holy Loch Naval Dockyard. Sampling sites are shown in Figure 3. All value are in Bq/kg dry weight of sediment. **Denotes a replicate subsample fron sample 5. In addition, most samples from this site contained levels of europium-155 just below the minimum quotable level.

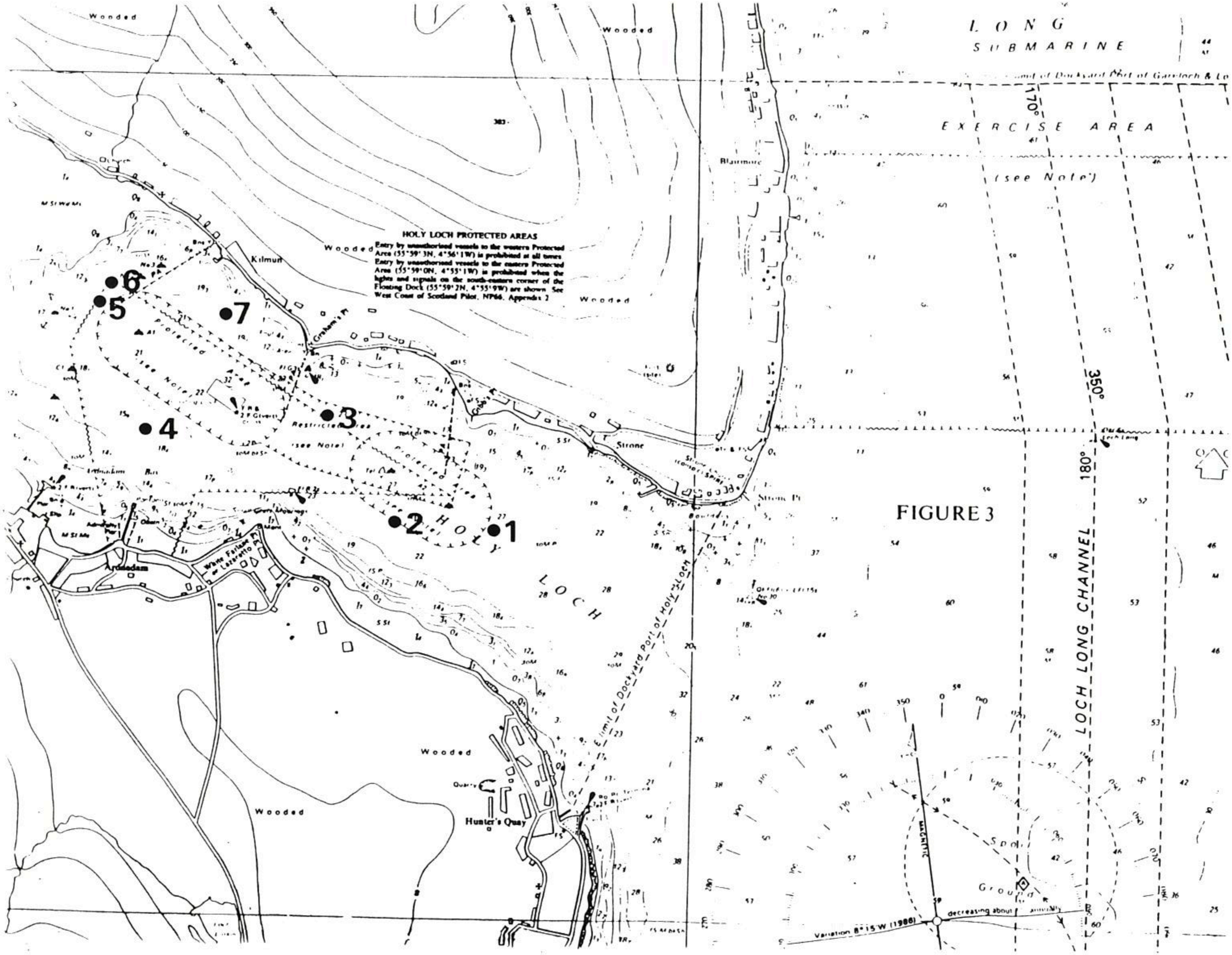

HOLY LOCH PROTECTED AREAS
Entry by unauthorised vessels to the western Protected Area (55°59'3N, 4°56'1W) is prohibited at all times.
Entry by unauthorised vessels to the eastern Protected Area (55°59'0N, 4°55'1W) is prohibited when the lights and signals on the south-eastern corner of the Floating Dock (55°59'2N, 4°55'9W) are shown. See West Coast of Scotland Pilot, NP66, Appendix 2
1
2
3
4
5
6
7
HOLY
LOCH
Kilmun
Graham's Pt
Strone
Strone Pt
Blairmore
Ardnadam
Hunter's Quay
Quarry
Wooded
Restricted Area
(see Note)
Protected
E limit of Dockyard Port of Holy Loch
LONG
SUBMARINE
EXERCISE AREA
(see Note)
LOCH LONG CHANNEL
170°
350°
180°
Spoil Ground
MAGNETIC
Variation 8°15'W (1986) decreasing about annually

FIGURE 3

SAMPLE	137 Cs	134 Cs	110m Ag	54 Mn	125 Sb	60 Co
Devonport						
1	10.6+-2.9	-	-	-	-	-
2	17.1+-2.4	-	-	-	-	-
3	19.4+-2.6	-	-	-	-	-
4	16.4+-2.4	-	-	-	-	-
5	7.9+-1.2	-	-	-	-	-
6	-	-	-	-	-	-
7	6.7+-2.5	-	-	-	-	-
8	-	-	-	-	-	-
9	-	-	-	-	-	-
10	14.3+-3.4	-	-	-	-	-

TABLE 4: Concentrations of radionuclides in sediments in the vicinity of Devonport Naval Dockyard. Sampling sites are shown in Figure 4. All values are in Bq/kg dry weight of sediment.

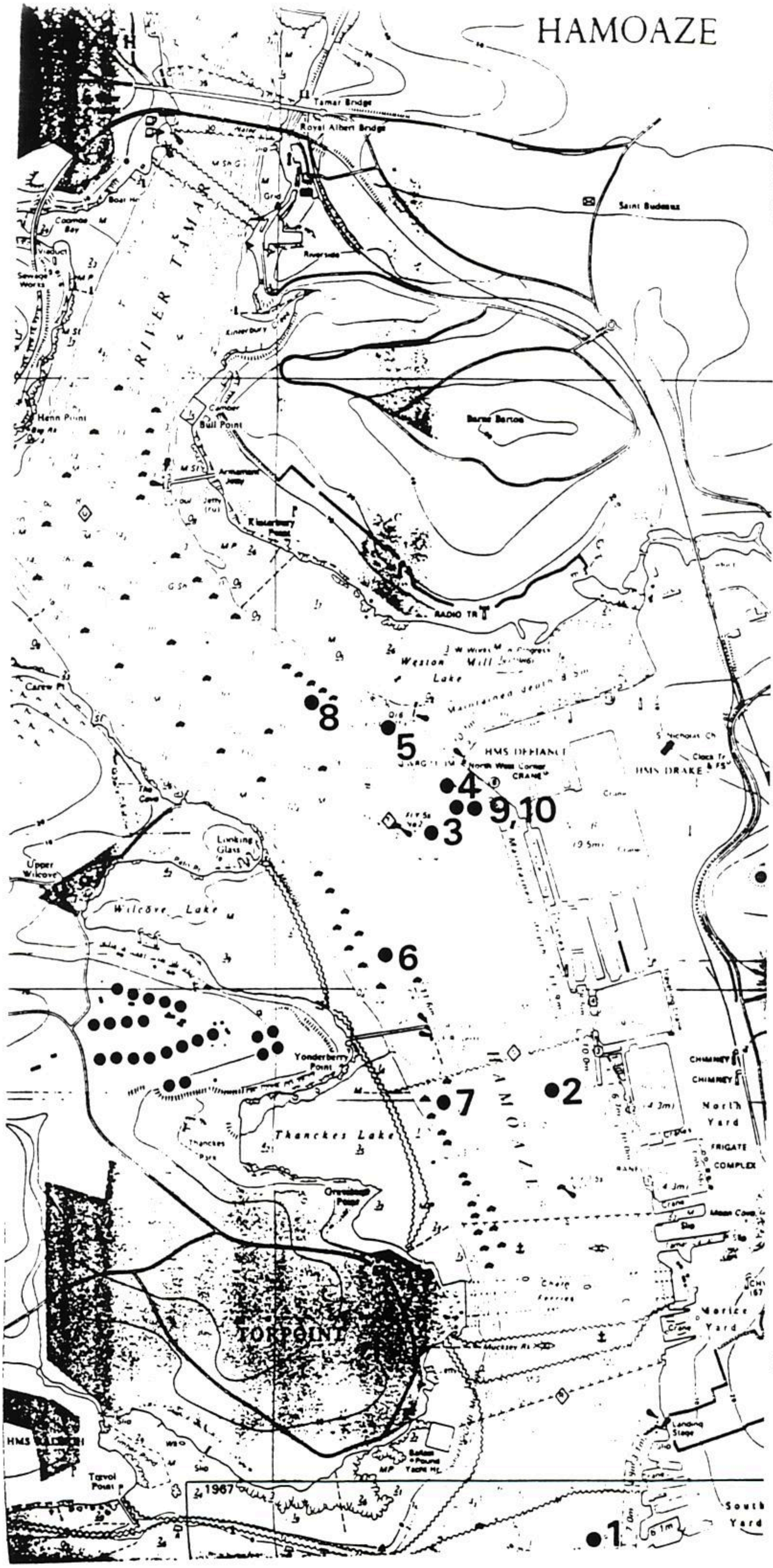
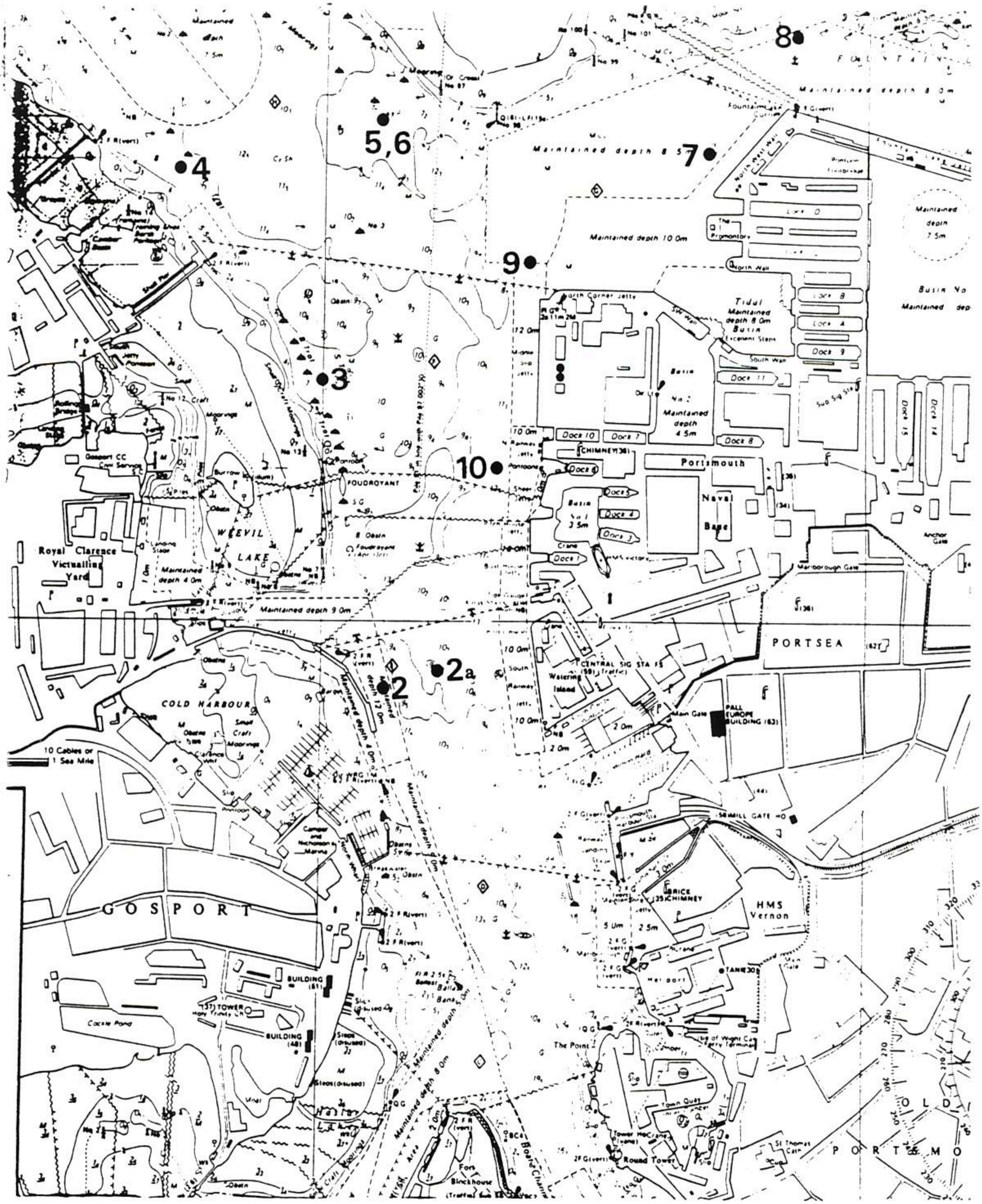

HAMOAZE
Tamar Bridge
Royal Albert Bridge
Saint Budeaux
RIVER TAMAR
Riverside
Kinterbury Creek
Barne Barton
Bull Point
Armament Jetty
Kinterbury Point
RADIO TR
Weston Mill Lake
HMS DEFIANCE
HMS DRAKE
St Nicholas Ch
Carew Pt
Looking Glass
Upper Wilcove
Wilcove Lake
Yonderberry Point
Thanckes Lake
HAMOAZE
CHIMNEY
North Yard
FRIGATE COMPLEX
Morice Yard
TORPOINT
Landing Stage
HMS RALEIGH
Tarvol Point
South Yard
1967
1
2
3
4
5
6
7
8
9,10

FIGURE 4

SAMPLE	137 Cs	134 Cs	110m Ag	54 Mn	125 Sb	60 Co
Portsmouth						
1	-	-	-	-	-	-
2	-	-	-	-	-	-
2a	-	-	-	-	-	-
3	6.8+-0.9	-	-	3.0+-1.9	-	39.7+-2.3
4	13.2+-1.9	-	-	-	-	59.0+-5.6
5	-	-	-	-	-	48.0+-5.0
6	-	-	-	-	-	50.4+-5.3
7	14.2+-2.2	-	-	-	-	47.1+-5.5
8	11.4+-3.0	-	-	-	-	46.8+-5.4
9	5.0+-1.2	2.9+-1.0	-	3.5+-2.6	-	48.5+-3.0
10	-	-	-	-	-	33.5+-4.3

TABLE 5: Concentrations of radionuclides in sediments in the vicinity of Portsmouth Naval Dockyard. Sampling sites are shown in Figure 5 with the exception of sample No 1 which was taken in the harbour mouth at 50 47.93N 1 06.16W. Samples 5 & 6 are site replicates. All values are in Bq/kg dry weight of sediment.



8
7
5,6
4
3
9
10
2
2a
Maintained depth 10.0m
Maintained depth 9.0m
Maintained depth 4.0m
Maintained depth 7.5m
Maintained depth 8.0m
Maintained depth 4.5m
Maintained depth 12.0m
Royal Clarence Victualling Yard
WEEVIL LAKE
FOUDROYANT
COLD HARBOUR
GOSPORT
Portsmouth Naval Base
PORTSEA
Tidal Basin
Dock 10
Dock 7
Dock 8
Dock 9
Dock 11
Dock 1
Dock 3
Dock 4
Dock 5
Dock 6
Dock 14
Dock 15
Lock A
Lock B
North Wall
South Wall
North Corner Jetty
The Promontory
CHIMNEY (36)
CENTRAL SIG STA
Watering Island
Main Gate
PALL EUROPE BUILDING (63)
Marlborough Gate
Anchor Gate
Camper and Nicholsons Marina
BUILDING (51)
(57) TOWER Holy Trinity Ch
BUILDING (48)
Cockle Pond
10 Cables or 1 Sea Mile
HMS Vernon
BRICE (35) CHIMNEY
The Point
Round Tower
Fort Blockhouse
St Thomas Cath
PORTSMO
OLD

FIGURE 5

LOCATION	137 Cs	134 Cs	110m Ag	54 Mn	125 Sb	60 Co
Devonport(6)	7.2	0.2	ND	NA	ND	1.5
Faslane (4)	120	15.0	ND	NA	3.1	15
Rosyth (9)	51	7.2	0.1	NA	0.08	1.1
Holy Loch(2)	52	5.2	ND	NA	ND	6.4
Portsmouth(-)	9.3	NG	NG	1.7	NG	27

TABLE 6: Comparative values for concentrations of radionuclides in sediments in the vicinity of naval establishments in the UK. All values quoted are from MAFF (1988) except values for Portsmouth which are those for Haslar Lake given by Anon.(1988d). ND signifies nuclide not detected, NG signifies value not given, probably not analysed. All values are in Bq/kg dry weight of sediment.