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NEVADA TEST SITE
RADIONUCLIDE INVENTORY AND DISTRIBUTION PROGRAM: REPORT #4. AREAS 18 AND 20

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ABSTRACT

As part of the Radionuclide Inventory and Distribution Program on the Nevada Test Site, *in situ* measurements of gamma-emitting radionuclides were made at more than 600 locations in six regions near ground zeros in Areas 18 and 20. In addition, several soil samples were collected from each region and analyzed to determine inverse relaxation lengths and radionuclide ratios. Analysis of the data from Area 20 led to estimated inventories of 23 Ci of ^{241}Am, 30 Ci of ^{238}Pu, 41 Ci of ^{239,240}Pu, 18 Ci of ^{60}Co, 6.4 Ci of ^{137}Cs, 6.0 Ci of ^{90}Sr, 17 Ci of ^{152}Eu, 19 Ci of ^{154}Eu, and 6.6 Ci of ^{155}Eu. For Area 18, the estimated inventories were 27 Ci of ^{241}Am, 4.9 Ci of ^{238}Pu, 150 Ci of ^{239,240}Pu, 1.3 Ci of ^{60}Co, 4.9 Ci of ^{137}Cs, 13 Ci of ^{90}Sr, 2.1 Ci of ^{152}Eu, 1.3 Ci of ^{154}Eu, and 1.4 Ci of ^{155}Eu. The locations of the measurements in Area 18 were chosen by importance sampling, which permits the calculation of an estimate of the sampling error. Maps of radionuclide distributions were also generated for all regions except the area near the Palanquin and Cabriolet ground zeros.

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SECTION 1
INTRODUCTION

The goal of the Radionuclide Inventory and Distribution Program (RIDP) is to assess the amount of radioactivity in the surface soil of the Nevada Test Site (NTS). The project's initial effort was in Yucca Flat, where most of the above-ground testing of nuclear weapons at the NTS has taken place, and the first three RIDP reports (McArthur and Kordas, 1983, 1985; McArthur and Mead, 1987) presented the results from that area. This report presents the results from six regions in Areas 18 and 20 in the northwest corner of the NTS.

The previous reports have described in detail the methods used by the RIDP. A brief summary of those methods will be given in the next few paragraphs.

Because of the large area of the NTS and the limited time available for completion of the RIDP, only those regions with substantial levels of radioactive contamination can be studied intensively. The contaminated portions of Areas 18 and 20 were identified by an aerial survey conducted by EG&G in October and November 1980. The report of that survey (Feimster, 1985) gives contour maps of both exposure rates and net count rates of ^{137}Cs (in Area 18) and ^{60}Co (in Area 20). The count rates are considered better indicators of man-made contamination, and those maps were used as the basis for choosing the locations of the *in situ* measurements and soil samples.

Measurements of gamma radiation by *in situ* spectrometry provide the data for estimating radionuclide inventories and distributions. The procedures for making these measurements were essentially the same as those used in Yucca Flat. However, a completely different method for selecting the locations of the *in situ* measurements was used in Area 18, as described in Section 4.

Soil samples are collected and analyzed for two reasons: To determine the distribution of radioactivity with depth in the soil (more specifically, to determine the inverse relaxation lengths needed to analyze the *in situ* spectra) and to measure the concentrations of important radionuclides that are not usually detectable by the *in situ* system. Samples collected as part of the RIDP are usually taken in a vertical profile of four increments to a total sampling depth of 15 cm. Each sample is oven-dried, homogenized with a ball mill,

and sieved through a 10-mesh screen. All measurements of radioactivity are made on the fine fraction.

Two of the regions covered in this report (Cabriolet/Palanquin in Area 20 and Little Feller II in Area 18) were studied previously by researchers of the Nevada Applied Ecology Group (NAEG) (Howard *et al.*, 1985; Howard and Fuller, 1987). From 1976 through 1982, several hundred soil samples from those sites were collected and analyzed by methods similar to those used in the RIDP, and the collection of more samples for the RIDP seemed unnecessary. The soil data for these regions were therefore obtained from NAEG samples.

Appendix A gives the locations, REECo library numbers, and original designations of the soil samples. The original designations enable the *in situ* measurement results from the same locations to be retrieved from the NAEG/RIDP database; no such designations exist for the NAEG samples because they were not collected at *in situ* measurement points. Also, the locations of these samples were determined by surveyors instead of by the microwave ranging system used by the RIDP.

The results of the gamma-spectrometric analyses of the soil samples are given in Appendix B. The RIDP samples were counted on a gamma-ray spectrometer at the REECo Analytical Laboratory, and the resulting spectra were then analyzed at LLNL using the GAMANAL program (Gunnink and Niday, 1971). The results for the NAEG samples were obtained earlier by REECo, Los Alamos National Laboratory, or TMA/Norcal. The methods by which inverse relaxation lengths were determined from these results are discussed in Section 2.

In addition, aliquots of the top increment from 29 samples (18 RIDP samples and 11 NAEG samples retrieved from the REECo Soils Library) were sent to TMA/Norcal, where they were analyzed by gamma spectrometry for ^{137}Cs and other radionuclides, by chemical separation and alpha-spectrometry for ^{241}Am, ^{238}Pu, and $^{239,240}Pu$, and by chemical separation and beta-spectrometry for ^{90}Sr. The results are presented in Table C-2 of Appendix C, which describes the quality assurance program for the soil analyses. Ratios of $^{238}Pu/^{241}Am$, $^{239,240}Pu/^{241}Am$, and $^{90}Sr/^{137}Cs$ computed from these data were used to infer inventories of plutonium and strontium from the estimated ^{241}Am and ^{137}Cs inventories.

Other parameters used in analyzing the *in situ* spectra were an air density of 0.001204 g/cm^3, a wet soil density of 1.5 g/cm^3, and a soil moisture content of 10 percent.

The mass attenuation coefficients for all energies of interest were obtained by interpolation from Beck *et al.* (1972). Several representative values are shown below.

Energy:	cm^2/g air	soil
60 keV	0.177	0.248
662 keV	0.0770	0.0781
1,332 keV	0.0550	0.0558

SECTION 2
DETERMINATION OF INVERSE RELAXATION LENGTHS

As discussed in McArthur and Kordas (1983), the interpretation of the *in situ* gamma-ray measurements to determine actual soil activities requires a knowledge of the distribution of the significant radionuclides as a function of depth in the soil. In most cases, the depth distribution of man-made radionuclides at the NTS can be described in terms of an inverse relaxation length (α) associated with an exponential depth dependence (Anspaugh, 1976).

Part of the input required for the GAMANAL analysis of the *in situ* measurements is an appropriate α value for each radionuclide. These values are determined from the gamma-spectrometric analysis of the soil samples by first calculating separate α values for each sample, then selecting representative values for each radionuclide in each region.

CALCULATION OF α VALUES

The procedures used in calculating inverse relaxation lengths were described in McArthur and Mead (1987), but some slight modifications have been made since. The revised procedure is summarized below.

First, recall that the GAMANAL analysis of a gamma-ray spectrum provides an activity value (in pCi/g) and a standard deviation (in percent) for each radionuclide of interest. The standard deviation is based largely on counting statistics, with some modification depending on photopeak energies. It does not reflect other sources of error, such as variations in the height of the sample in the bottle due to density differences; while such errors may be the dominant errors in individual high-activity measurements, they are generally less than 10 percent and are not of primary significance in terms of the overall RIDP accuracy objectives. GAMANAL also computes upper limit values for radionuclides whose peaks are searched for but not found.

As before, the activity values from GAMANAL are used to compute the parameter I_i, the activity (in pCi/cm^2) in a column of the sample from level i. The index i usually takes one of the values a (the top increment), b, c, or d (the bottom increment).

For the assumed exponential decrease in activity with depth, the inverse relaxation length α in cm^{-1} and the percent standard deviation in α (%SDα) are calculated from one of three pairs of expressions:

$$\alpha = 0.4 \ln(I_a/I_b) \quad (1)$$

$$SD\alpha = .004\sqrt{(\%SD\ I_a)^2 + (\%SD\ I_b)^2} \quad (2)$$

$$\alpha = 0.2 \ln[(I_a + I_b)/I_c] \quad (3)$$

$$SD\alpha = .002\sqrt{[\%SD(I_a + I_b)]^2 + (\%SD\ I_c)^2} \quad (4)$$

$$\alpha = -0.2 \ln[0.5(\sqrt{1+4R} - 1)] \quad (5)$$

$$SD\alpha = 0.4SDR/(1 + 4R - \sqrt{1+4R}) \quad (6)$$

where $R = (I_c + I_d)/(I_a + I_b)$ and SDR is the standard deviation of R.

The following rules are used to determine which expressions to use. They are basically just a reorganization and rewording of the previous rules, but Rule 2 does specify a different pair of expressions than it specified before. The rules are applied independently for each radionuclide of interest.

- Rule 1. If soil sample "d" yields a "proper value" for I_d (a measured value above the detection limit, not an upper limit value), use expressions (5) and (6). Otherwise, go to Rule 2.

- Rule 2. If sample "c" yields a proper value for I_c, use expressions (5) and (6) with I_d equal to the upper limit value for sample "d." Otherwise, go to Rule 3.

- Rule 3. If sample "b" yields a proper value for I_b, use expressions (3) and (4) with I_c equal to the upper limit value for sample "c." Otherwise, go to Rule 4.

- Rule 4. If sample "a" yields a proper value for I_a, use expressions (1) and (2) with I_b equal to the upper limit value for sample "b." Otherwise, do not calculate an α value for that radionuclide at that sampling location.

- Rule 5. If a calculated α value is less than 0.05, set $\alpha = 0.05$ and indicate with a footnote that soil sampling did not extend deep enough.

The new method of selection differs from that previously described in that it results in the calculation of an α value based on the activity in levels down to the deepest soil

sample in which measurable activity is found plus the upper limit value for the activity in the next deeper level. This approach was used so an α value would be calculated for those cases in which shallow sample activity levels fell below detection limits while deeper samples showed measurable activities. Additionally, in those cases where shallow sample activities were measurable but one or more deeper samples gave upper limit values, the first such deeper-level limit value for the activity was included in the calculation. This treatment provides an α value that better reflects the depth of penetration of the radionuclide.

SELECTION OF REPRESENTATIVE α VALUES

In many areas, the measured α values fall naturally into two groups. The smaller α values (roughly 0.05 to 0.2 cm^{-1}) represent points where radioactive materials extend deeper into the soil. (An α value of 0.1 cm^{-1}, for example, indicates that half of the activity has penetrated more than 7 cm of soil.) This group of α values is generally associated with radionuclide depth distributions found within roughly a quarter-mile of a GZ, and a region of low α values is therefore called a "GZ region." (Note the distinction between the term "GZ region" as defined here and the term "GZ area," a generic term referring to an entire area where measurements were made, e.g., the Schooner area.) While GZ regions are defined primarily by the presence of comparatively deep soil activities, they are also associated with, and sometimes partially defined by, higher values of the exposure rate measurements made routinely at the *in situ* measurement points. The remaining regions of interest (outside the GZ regions) are those characterized by the larger α values representative of soil activities concentrated nearer the surface.

For each of the principal man-made radionuclides, in each GZ and non-GZ region and in each study area, a representative α value was determined by calculating a geometric mean value of the measured α values. When the geometric mean values for different nuclides agreed within their standard deviations, an overall geometric mean value for the entire set of radionuclides was determined. Geometric rather than arithmetic means were used because the distributions of α values for the various radionuclides were described better by a log-normal distribution than by a normal distribution.

SECTION 3
AREA 20

IN SITU MEASUREMENTS

Three above-ground nuclear tests were conducted in Area 20:

Event	Nevada Grid Coordinates	Date
Palanquin	E541638 N921074	14 April 1965
Cabriolet	E544287 N921252	26 January 1968
Schooner	E529301 N944011	8 December 1968

The ^{60}Co count rates from the aerial survey (Figure 1) show the extent of contamination from these events. Figure 1 was used to define two general areas, called "Schooner" and "Cabriolet," within which *in situ* measurements were made from July through November 1983. Note that the aerial survey extended beyond the boundary of Area 20, which is shown in Figure 1 as a faint dashed line, and included part of the Nellis Air Force Range north and west of the NTS. Because the RIDP is concerned only with radioactivity on the NTS, and because access to the Air Force Range north of the NTS is restricted for safety reasons, measurements were confined to the region within the NTS even though contamination from the Schooner event clearly extends off-site.

The patterns for the *in situ* measurements were similar to those used in Yucca Flat, with grids ranging from 250 to 1,500 feet depending on the levels of radioactivity shown by the aerial survey. Because of the naturally rugged terrain and the many large boulders ejected from the three craters, the measurement vehicles could not reach many of the preselected points. Figures 2 and 3 show both the original sampling plans for the Schooner and Cabriolet areas and the actual locations at which *in situ* measurements were made.

Several points in the Cabriolet area were originally measured at incorrect locations because of an error in recording the position of one of the microwave transponders. Included among these are the southernmost nine points and the eight points in the northern part of the region that are not on the sampling grid. The measurement results at these

points are reported here, but they have not been used in estimating radionuclide inventories.

Because much of the area near the Schooner GZ was inaccessible to the regular *in situ* system, additional measurements were taken there with two hand-held exposure-rate meters, a Bicron and a Ludlum as described in McArthur and Mead (1987). The meters were "calibrated" by taking readings at seven points at which radionuclide concentrations had been determined by *in situ* measurements. Table 1 shows the ratios of the *in situ* measurements of six radionuclides to the exposure rates measured by the Bicron meter. The mean values of these ratios, together with similar values for the Ludlum meter, were used as calibration factors to infer activity levels from exposure-rate data at 35 previously unmeasured grid points, shown in Figure 4.

TABLE 1. RATIOS OF *IN SITU* MEASUREMENTS TO EXPOSURE RATE READINGS FOR THE BICRON METER

	Ratio					
Original Point	^{241}Am	^{60}Co	^{137}Cs	^{152}Eu	^{154}Eu	^{155}Eu
14	3.5	5.8	2.7	4.8	6.5	---
20	5.7	9.4	2.2	10.3	13.7	3.5
41	1.0	4.5	---	4.8	5.3	1.1
43	3.9	8.4	---	14.6	18.7	4.3
46	7.3	12.3	---	20.7	26.8	7.6
50	1.8	7.7	---	11.5	14.7	3.1
54	4.6	9.6	1.6	13.9	18.9	4.8
Mean	4.0	8.2	2.2	11.5	14.9	4.1
Standard error	0.82	0.98	0.32	2.1	2.8	0.88

In an effort to approximate the wide field of view of the elevated *in situ* detectors, five readings were taken at each location with each meter: one at the grid point of interest and four at points 30 feet north, east, south, and west of the grid point. Locations were determined with a transit and tape measure. The five readings for each meter at each grid point were generally within 10 to 20 percent of the mean value. Evidently the limited field of view of the hand-held meters, as used, did not introduce serious errors.

The overall validity of the hand-held measurements can be inferred from the standard errors of the means given in Table 1. The variations in ratios (calibration factors)

are believed to be a result of differences in the spectral composition of the soil activities (the relative amounts of the various radionuclides).

SOIL SAMPLES

The locations of the soil samples are shown in Figures 4 and 5. Table 2 gives the inverse relaxation lengths (α) calculated from the data in Appendix B. The actual values of α used in GAMANAL were 0.4 cm^{-1} for points in the Cabriolet area, 0.1 cm^{-1} for points in the Schooner GZ region, and 0.6 cm^{-1} for the other Schooner points. For reasons of clarity, the Schooner GZ region is not explicitly shown in Figure 4; it includes all the *in situ* measurement points in estimation region a and the two westernmost points in region b.

TABLE 2. CALCULATED INVERSE RELAXATION LENGTHS FROM AREA 20

Point	Inverse relaxation length and standard deviation (cm^{-1})									
	^{60}Co		^{137}Cs		^{152}Eu		^{155}Eu		^{241}Am	
Schooner										
1	0.79	0.33	0.82	0.33	1.3	0.13	----*		1.1	0.29
2	0.68	0.16	0.58	0.21	1.9	0.13	1.4	0.14	1.7	0.14
3	1.1	0.26	0.78	0.31	1.0	0.33	0.54	0.34	0.88	0.36
4	0.73	0.076	0.49	0.21	0.73	0.046	1.5	0.14	0.76	0.43
5	0.65	0.089	0.64	0.28	0.59	0.037	0.60	0.34	0.74	0.36
6	0.58	0.14	0.52	0.16	0.57	0.33	0.21	0.35	1.4	0.21
7	0.56	0.33	0.66	0.33	0.33	0.34	----		0.63	0.33
8	0.85	0.26	0.55	0.26	0.71	0.33	0.66	0.14	0.39	0.81
65	0.12	0.003	0.10	0.016	0.17	0.004	0.19	0.015	0.12	0.035
66	0.10	0.004	0.12	0.015	0.086	0.003	0.086	0.014	0.11	0.045
67	0.82	0.33	0.76	0.33	0.68	0.33	0.44	0.36	1.4	0.15
Cabriolet										
52	----		0.25	0.036	----		----		0.05	--†
53	0.25	0.032	0.37	0.020	----		----		0.28	0.018
54	0.39	0.010	0.46	0.019	0.25	0.036	----		0.51	0.011
55	0.77	0.016	0.87	0.021	0.95	0.032	----		0.86	0.017
56	0.41	0.036	0.32	0.010	----		----		0.39	0.011
57	0.91	0.028	0.77	0.029	----		----		0.19	0.019
58	----		0.41	0.036	----		----		0.45	0.016
59	0.46	0.036	0.38	0.036	----		----		0.53	0.017
60	0.44	0.036	0.39	0.036	----		----		0.38	0.015
61	0.52	0.015	0.49	0.036	0.31	0.037	----		0.48	0.013
62	0.33	0.036	0.33	0.036	----		----		0.27	0.016
63	0.24	0.023	0.22	0.031	----		----		0.25	0.031
64	0.05	--	0.37	0.031	0.60	0.044	----		0.47	0.039

*Value could not be calculated because of insufficient data.
†Values of 0.05 with no standard deviation are estimates used where the sample was not deep enough.

Table 3 gives the radionuclide ratios computed from the data in Appendix C. These numbers are averages of the ratios in two or more aliquots analyzed from each sample.

DATA ANALYSIS

The results of the *in situ* measurements and the supplementary measurements in the Schooner area are shown in Figures 6 through 19. Values shown as "n.d." (not detected) were reported as upper limit values by GAMANAL. Upper limit values were calculated

TABLE 3. RADIONUCLIDE RATIOS IN SOIL SAMPLES FROM AREA 20

Point	$^{239,240}Pu/^{241}Am$	$^{238}Pu/^{241}Am$	$^{90}Sr/^{137}Cs$
Schooner			
3	0.78	1.8	0.90
5	0.68	1.9	0.77
8	0.76	1.6	0.68
65	0.62	1.6	1.1
66	0.62	1.4	1.3
average	0.69	1.7	0.95
Palanquin			
55	2.7	0.38	1.3
57	2.7	0.65	0.95
61	2.4	1.1	0.93
54	2.5	1.6	0.55
average	2.6	0.93	0.93
Cabriolet			
58	1.0	2.3	1.5
56	0.79	1.6	0.59
average	0.90	1.95	1.0

for the six nuclides (^{60}Co, ^{137}Cs, ^{152}Eu, ^{154}Eu, ^{155}Eu, and ^{241}Am) which commonly appeared in measurable quantities in the *in situ* spectra. Three other nuclides (^{101}Rh, ^{102m}Rh, and ^{125}Sb) were detected and measured at a few locations within the Cabriolet area. Upper limit values were not calculated for these, as their presence had not been anticipated, and they were not widely distributed. Hence, these radionuclides are listed as "not reported" at some locations in Figures 18 and 19.

Inventory estimates were obtained by first dividing the areas into regions of approximately constant sampling density, as shown in Figures 4 and 5. The average of the *in situ* measurements in each region was then computed and multiplied by the area of the region to give an inventory estimate for that region.

The results are shown in Table 4. Many of the data for all radionuclides except ^{137}Cs are upper limit values, and estimates in Table 4 that are based largely on upper limit values are marked with an asterisk. Such estimates are likely to be overestimates of the inventory in a region, but they are usually an insignificant part of the total inventory for an entire GZ area.

Estimates of plutonium and strontium inventories were derived from the average ratios in Table 3. In the Cabriolet area, the Cabriolet values were used in region e and the Palanquin values were used in the other five regions.

Distribution maps of the important radionuclides in the Schooner area are shown in Figures 20 through 25. These maps were produced by using the BLUEPACK kriging package (Delfiner *et al.*, 1976) to interpolate the values on a 500-foot grid of points

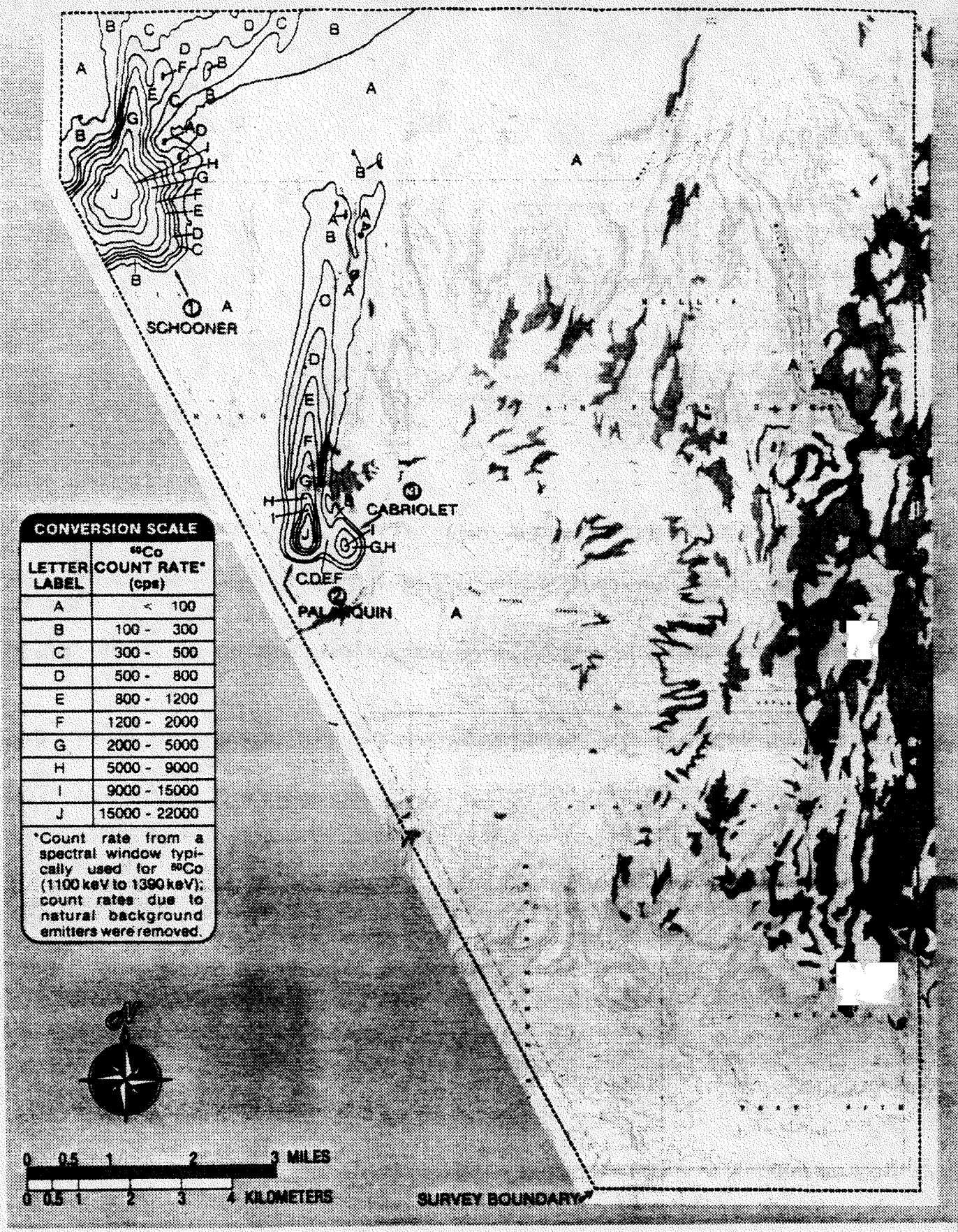
TABLE 4. INVENTORY ESTIMATES FOR AREA 20

Region		Area ($ft^2 \times 10^6$)	Radionuclide Inventory (Ci) ^{241}Am	^{238}Pu	$^{239,240}Pu$	^{60}Co	^{137}Cs	^{90}Sr	^{152}Eu	^{154}Eu	^{155}Eu
Schooner	a	2.74	6.3	11.	4.3	5.4	.40	.38	7.9	10.	3.0
	b	2.50	1.2	2.0	.83	.98	.11	.10	1.2	1.5	.44
	c	2.25	.14	.24	.097	.15	.039	.037	.22	.29	.095
	d	29.28	.31*	.53	.21	.23*	.25	.24	.42*	.50*	.26*
	e	9.65	1.4	2.4	.97	2.9	.75	.71	4.1	5.2	1.4
Total		46.42	9.4	16.	6.4	9.7	1.5	1.5	14.	17.	5.2
Cabriolet	a	72.00	1.0	.93	2.6	.48	1.1	1.0	.48*	.46*	.60*
	b	32.00	.70	.65	1.8	.37	.55	.51	.22*	.17*	.28*
	c	12.25	1.3	1.2	3.4	.84	.57	.53	.28	.13	.14*
	d	4.38	10.	9.4	26.	6.6	2.4	2.2	2.2	.86	.36
	e	3.00	.58	1.1	.52	.12	.14	.14	.040	.032	.034*
	f	2.31	.30	.28	.78	.054	.15	.14	.036	.027*	.025*
Total		125.94	14.	14.	35.	8.5	4.9	4.5	3.3	1.7	1.4

*These estimates are based largely on upper limit values.

covering the region of interest. The resulting array of values was checked to ensure that it was consistent with the actual data, then used as input to the NCAR subroutine CONREC (Wright, 1977), which was used to draw a contour map. Finally, the contour map was digitized and redrawn to give the final figure.

This procedure did not give acceptable contours when applied to the Cabriolet data. A 500-foot grid of interpolated values missed much of the detail near the GZs, where concentrations can change by two orders of magnitude or more over that distance. On the other hand, a 250-foot grid gave an array of nearly 2,500 values which was prohibitively costly to check and run through the contouring program. In all cases, the interpolation program gave nonsensical results when it tried to extrapolate into the large regions where no data could be collected. Because the contours can be inferred quite well from the data plots (Figures 12 through 19), no further attempts to produce computer-drawn contour maps for the Cabriolet area were made. (The NAEG report by Gilbert *et al.* [1987] gives estimated distributions of $^{239,240}Pu$ and ^{241}Am and ^{90}Sr based on data from soil samples.)



CONVERSION SCALE	
LETTER LABEL	^{60}Co COUNT RATE* (cps)
A	< 100
B	100 - 300
C	300 - 500
D	500 - 800
E	800 - 1200
F	1200 - 2000
G	2000 - 5000
H	5000 - 9000
I	9000 - 15000
J	15000 - 22000

*Count rate from a spectral window typically used for ^{60}Co (1100 keV to 1390 keV); count rates due to natural background emitters were removed.

Figure 1. Man-made contamination in Area 20 as indicated by ^{60}Co count rates from an aerial survey (from Feimster, 1985).

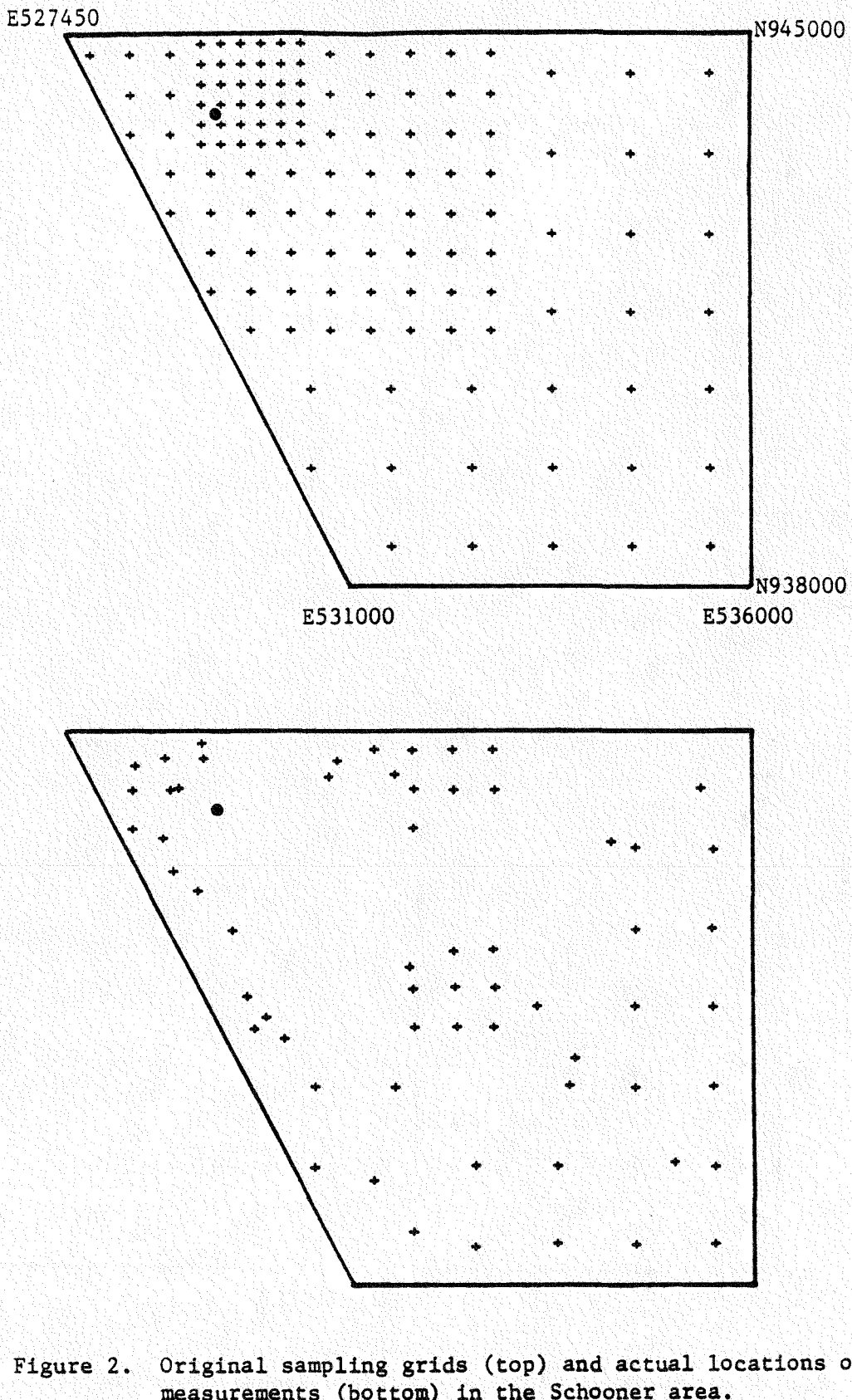


Figure 2. Original sampling grids (top) and actual locations of in situ measurements (bottom) in the Schooner area.

● = ground zero

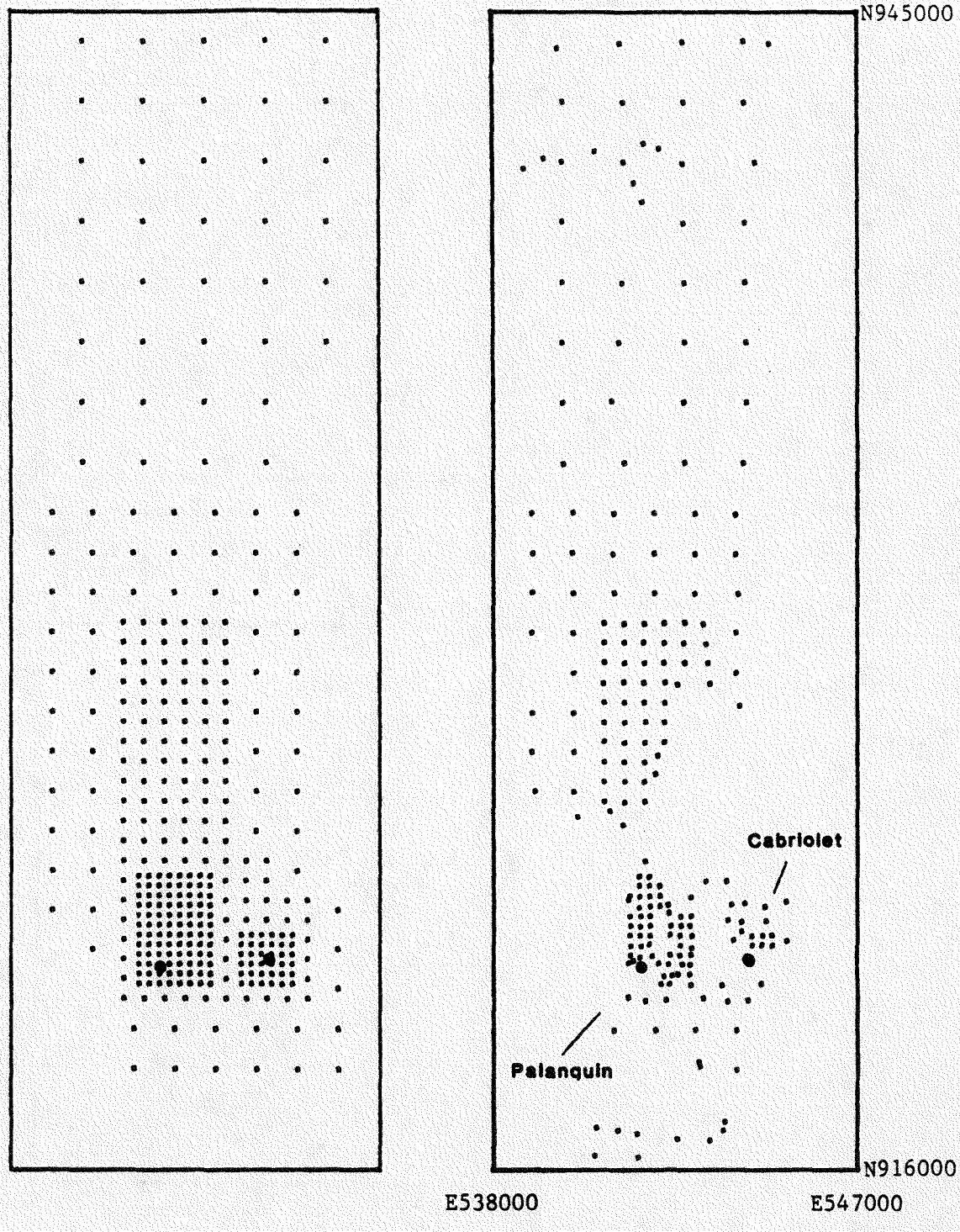


Figure 3. Original sampling grids (left) and actual locations of <u>in situ</u> measurements (right) in the Cabriolet area.

● = ground zero

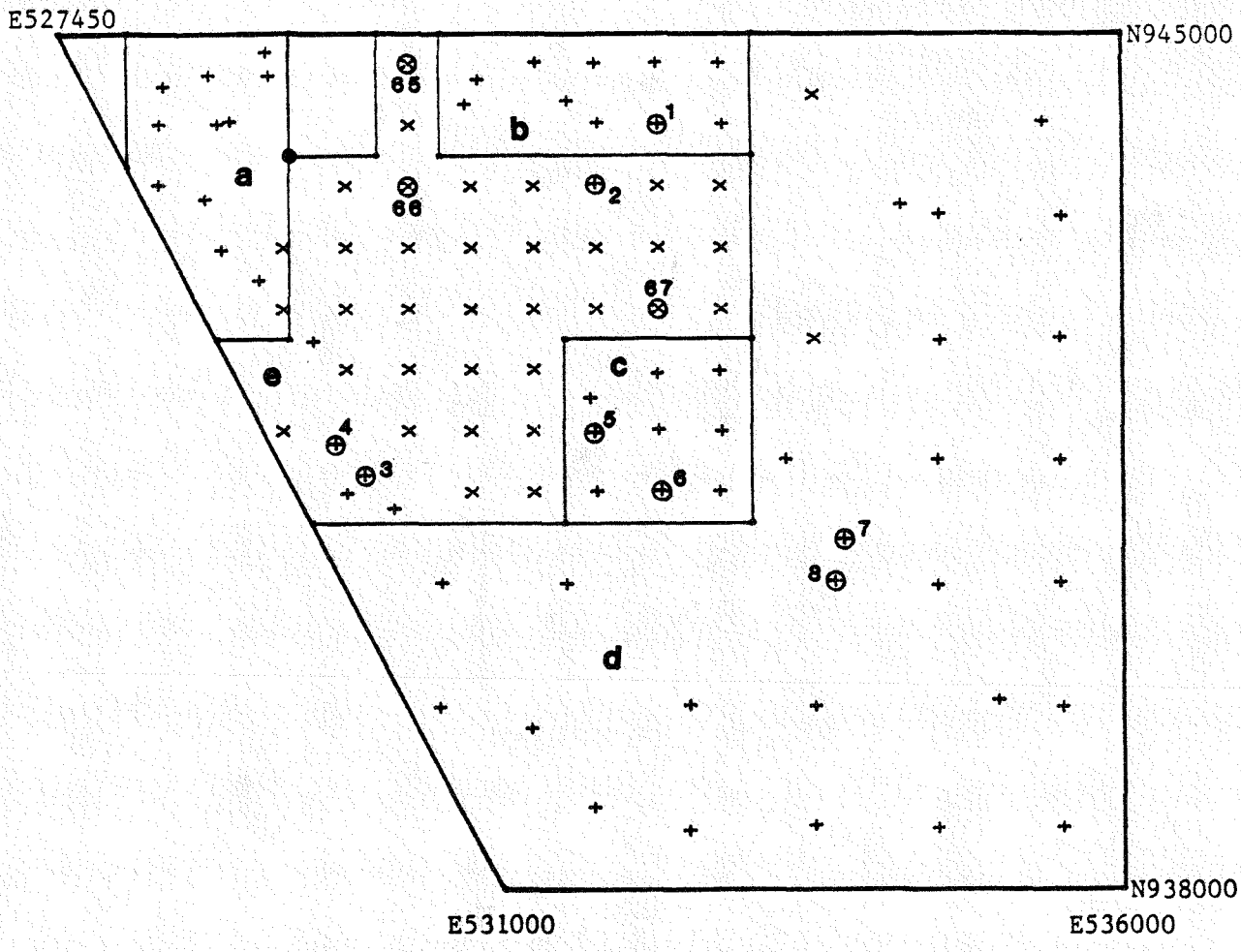


Figure 4. Locations of supplementary measurements, soil samples, and estimation regions in the Schooner area.

● = ground zero
\+ = location of in situ measurement
x = location of supplementary measurement
⊕ or ⊗ = location of soil sample

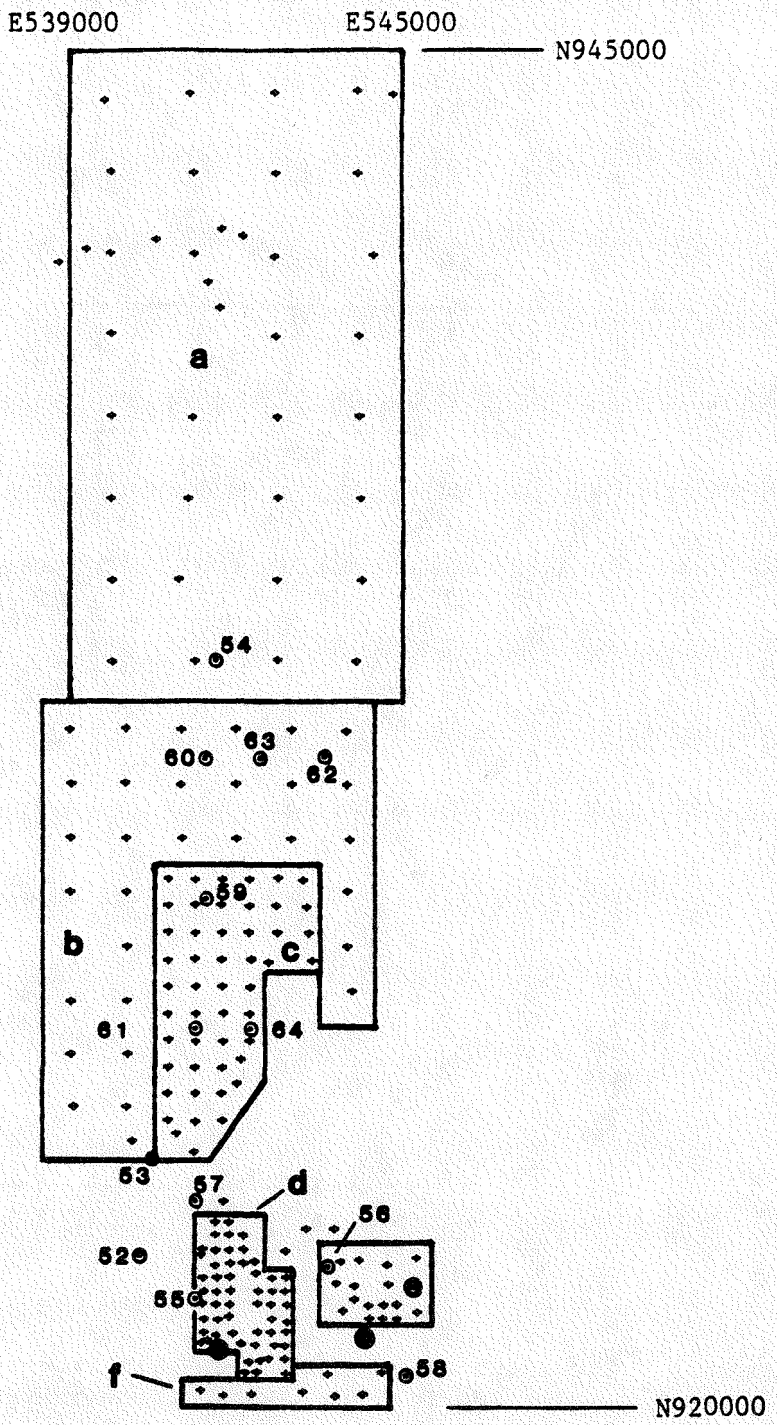


Figure 5. Locations of soil samples and estimation regions in the Cabriolet area.

● = ground zero
+ = location of in situ measurement
⊙ = location of soil sample

^{241}Am (nCi/m^2)			
0	n.d.	5	2,000-3,000
+	<100	6	3,000-6,100
1	100-200	7	16,000-20,000
2	200-500	8	20,000-30,000
3	500-1,000	9	30,000-38,500
4	1,000-2,000		

● = ground zero

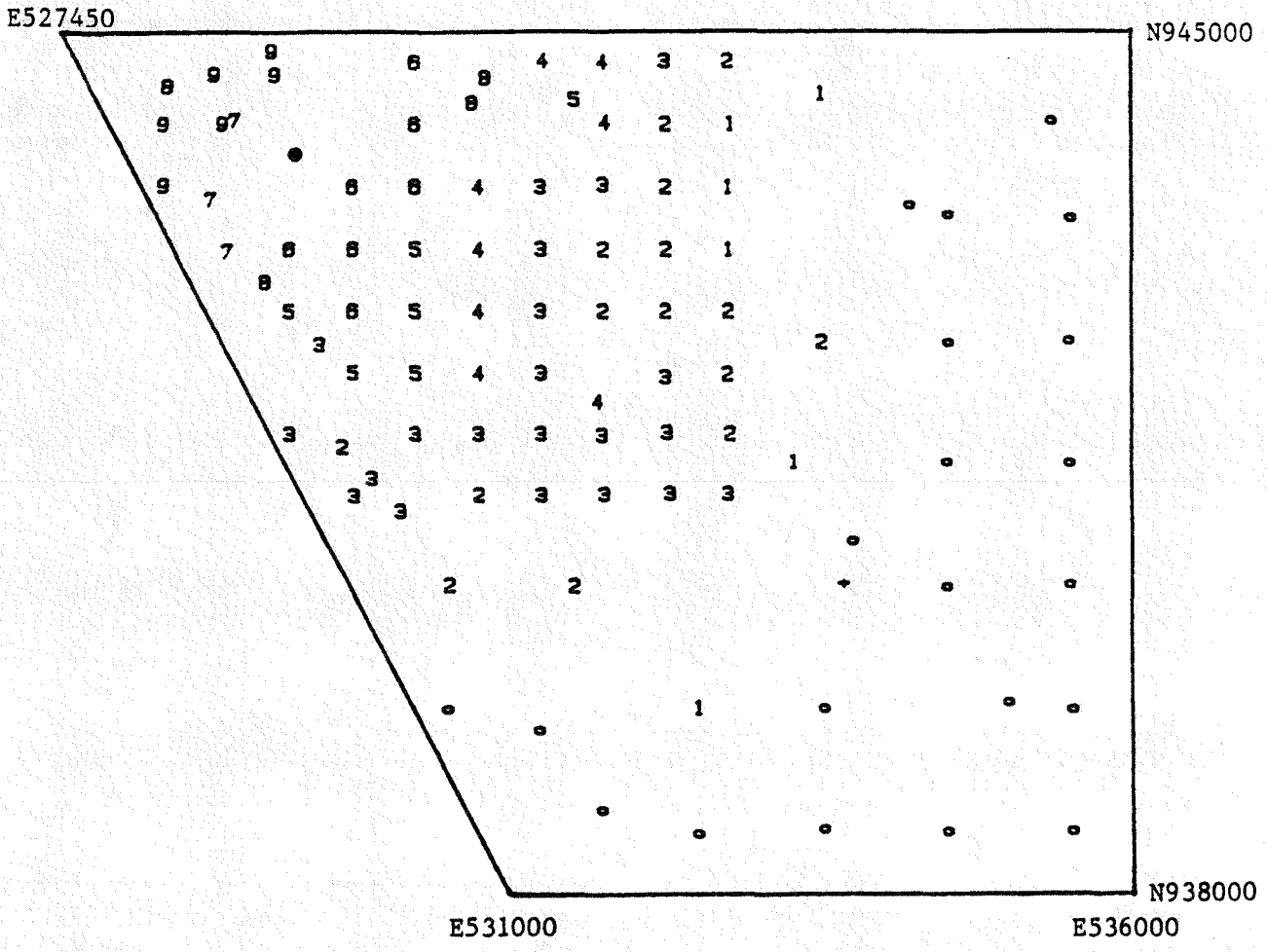


Figure 6. Measured ^{241}Am activities in the Schooner area.

^{60}Co (nCi/m^2)

0	n.d.	5	5,000-10,000
+	<100	6	10,000-15,000
1	100-500	7	15,000-20,000
2	500-1,000	8	20,000-25,000
3	1,000-2,000	9	25,000-30,000
4	2,000-5,000	x	33,450

● = ground zero

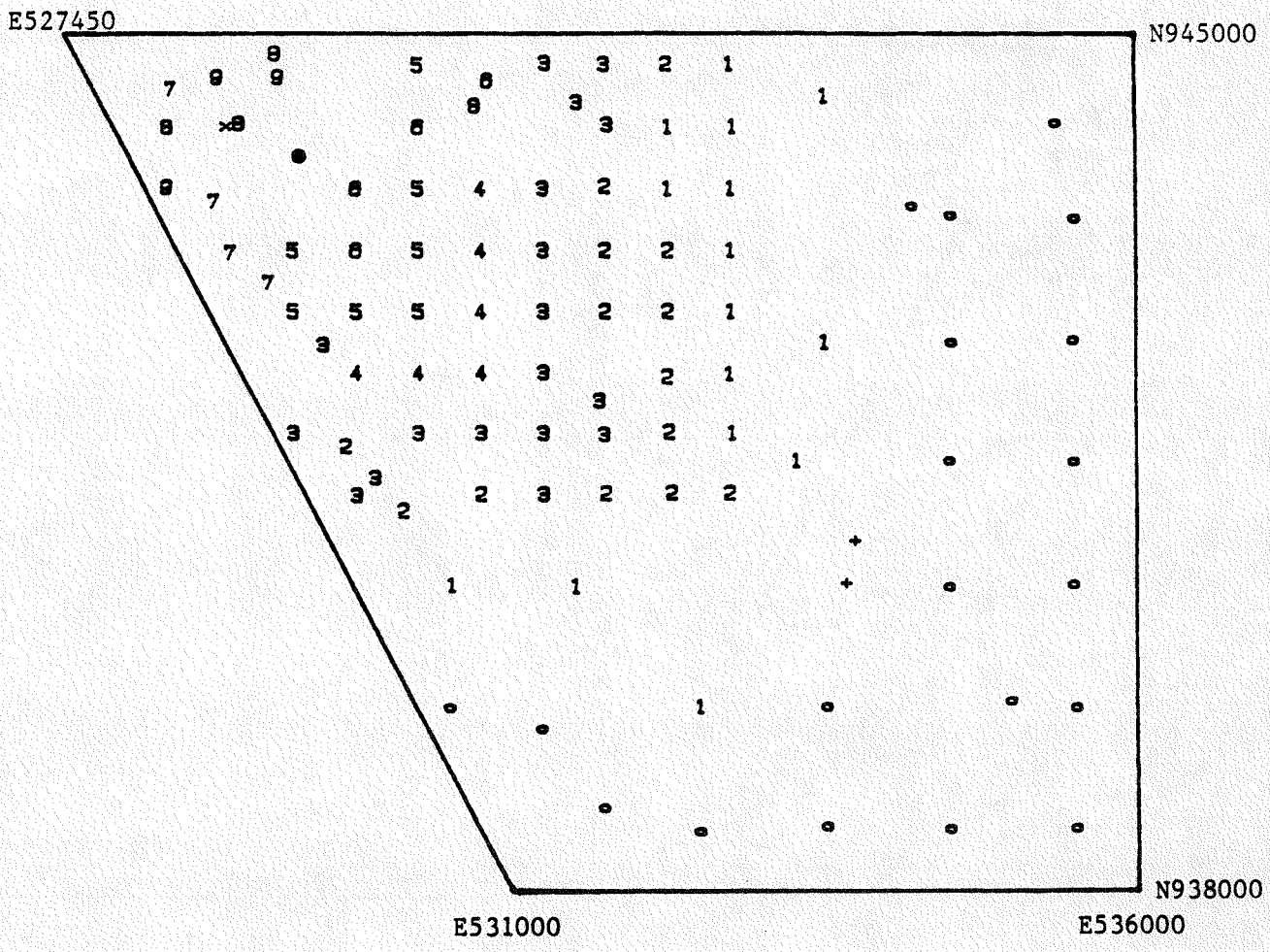


Figure 7. Measured ^{60}Co activities in the Schooner area.

^{137}Cs	(nCi/m^2)		
0	n.d.	5	1,000-1,500
+	<100	6	1,500-2,000
1	100-200	7	2,000-2,500
2	200-300	8	2,500-3,000
3	300-500	9	3,000-3,400
4	500-1,000		

● = ground zero

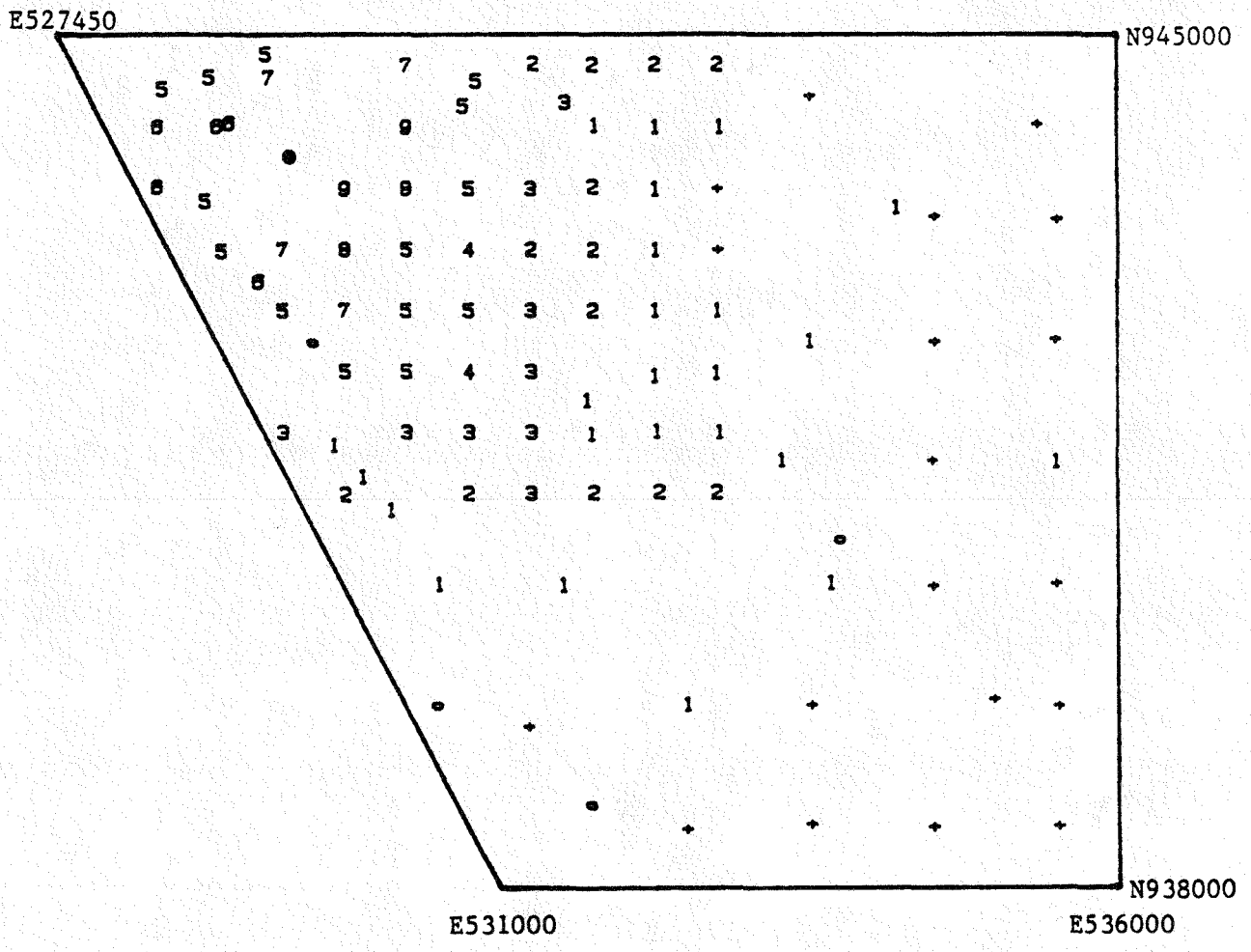


Figure 8. Measured ^{137}Cs activities in the Schooner area.

^{152}Eu (nCi/m^2)

0	n.d.	6	10,000-15,000
+	<100	7	15,000-20,000
1	100-500	8	20,000-30,000
2	500-1,000	9	30,000-40,000
3	1,000-2,000	x	40,000-50,000
4	2,000-5,000	*	50,300
5	5,000-10,000		

● = ground zero

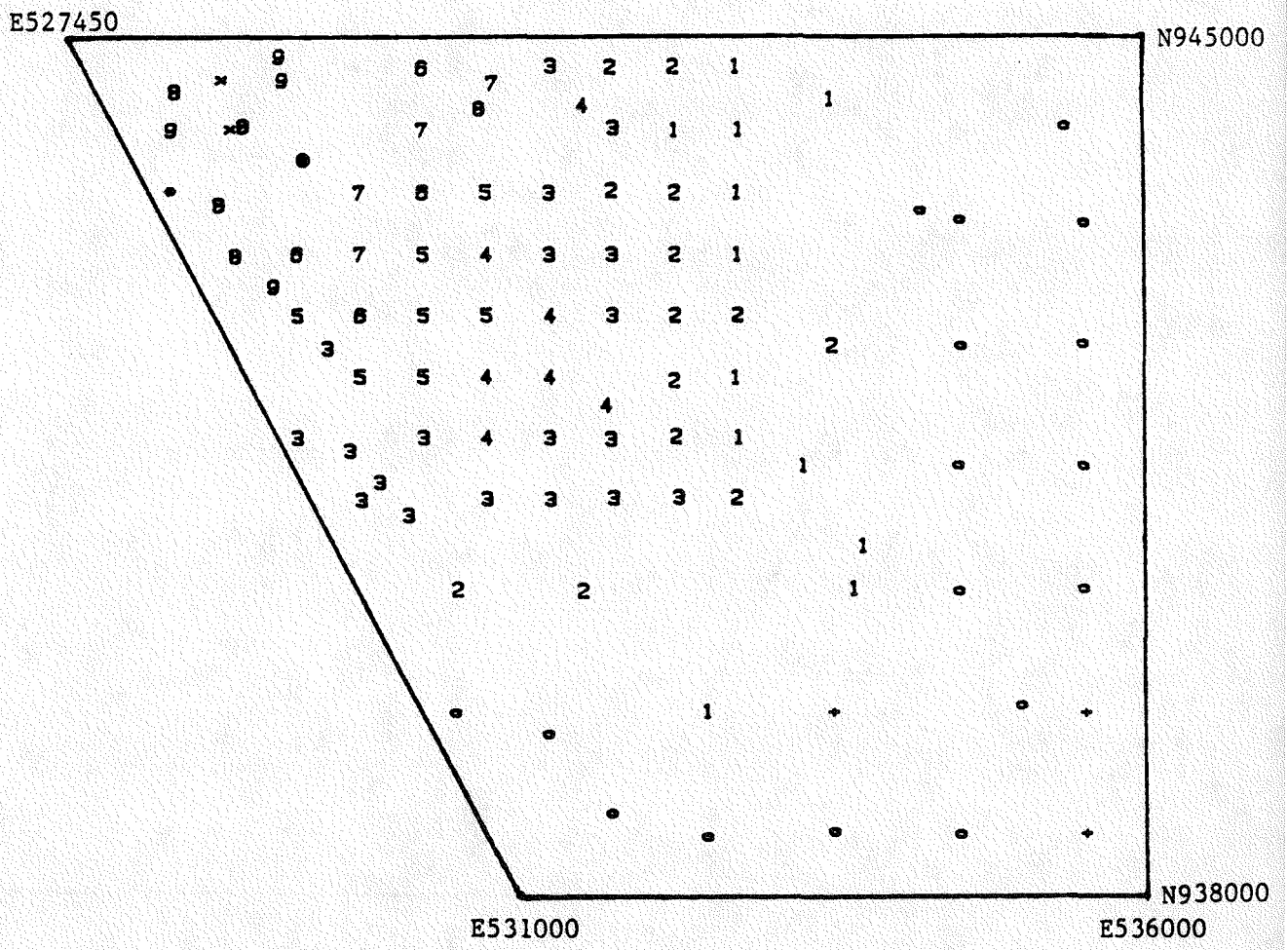


Figure 9. Measured ^{152}Eu activities in the Schooner area.

^{154}Eu	(nCi/m^2)		
0	n.d.	6	10,000-20,000
+	<100	7	20,000-30,000
1	100-500	8	30,000-40,000
2	500-1,000	9	40,000-50,000
3	1,000-2,000	x	50,000-60,000
4	2,000-5,000	*	63,750
5	5,000-10,000		

● = ground zero

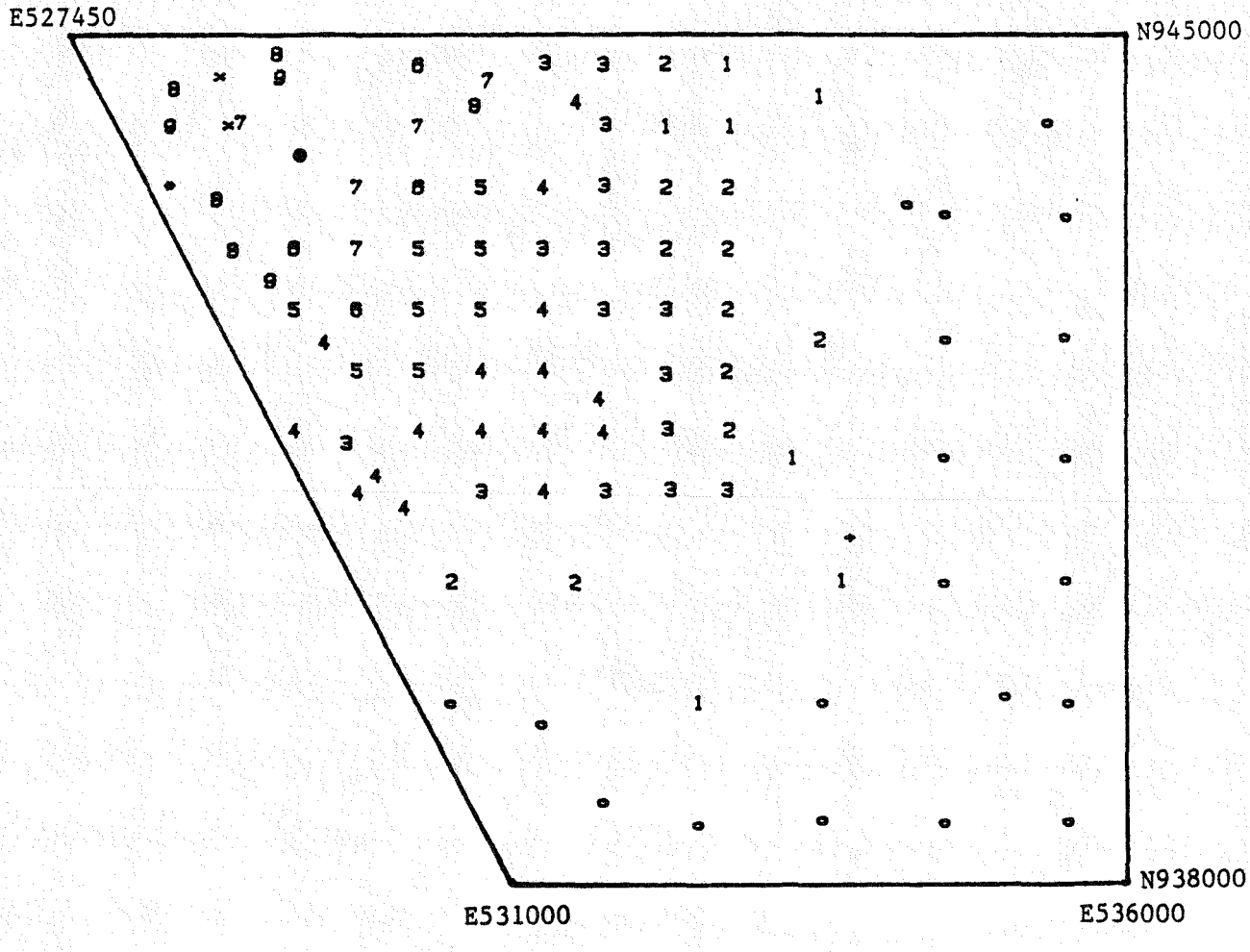


Figure 10. Measured ^{154}Eu activities in the Schooner area.

^{155}Eu (nCi/m^2)			
0	n.d.	5	5,000-7,000
+	<100	6	7,000-10,000
1	100-500	7	10,000-15,000
2	500-1,000	8	15,000-20,000
3	1,000-3,000		
4	3,000-5,000		

● = ground zero

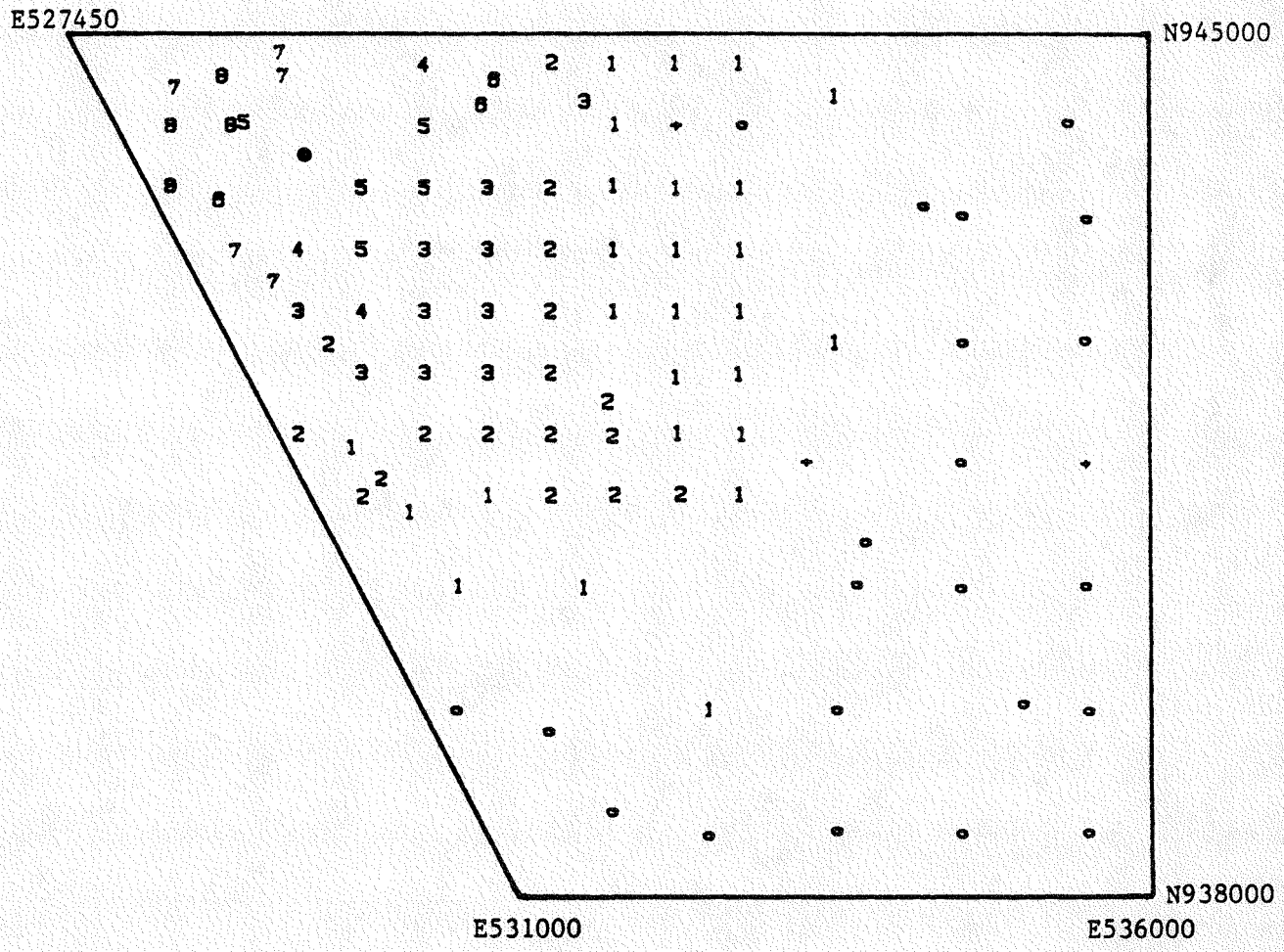


Figure 11. Measured ^{155}Eu activities in the Schooner area.

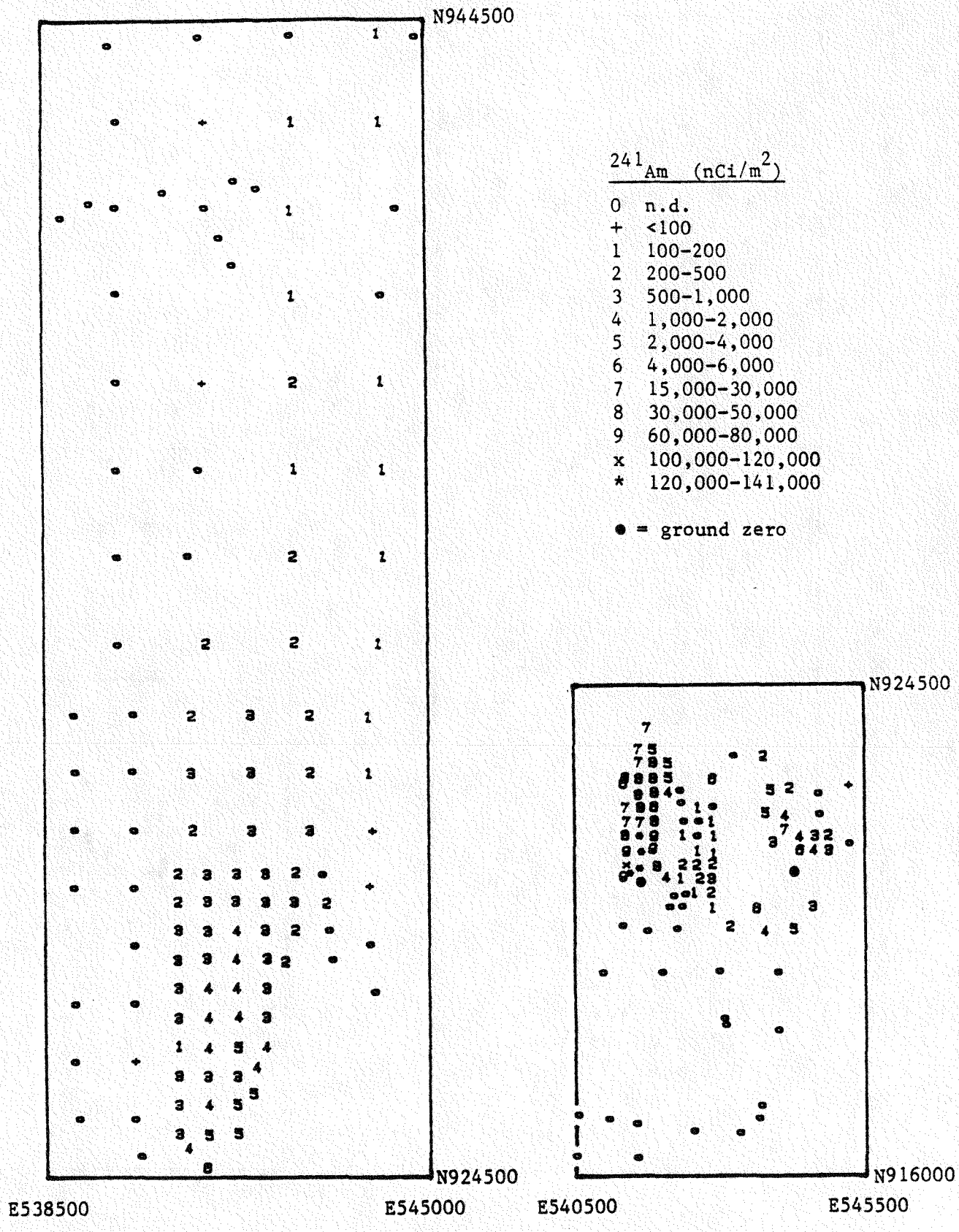


Figure 12. Measured ^{241}Am activities in the Cabriolet area.

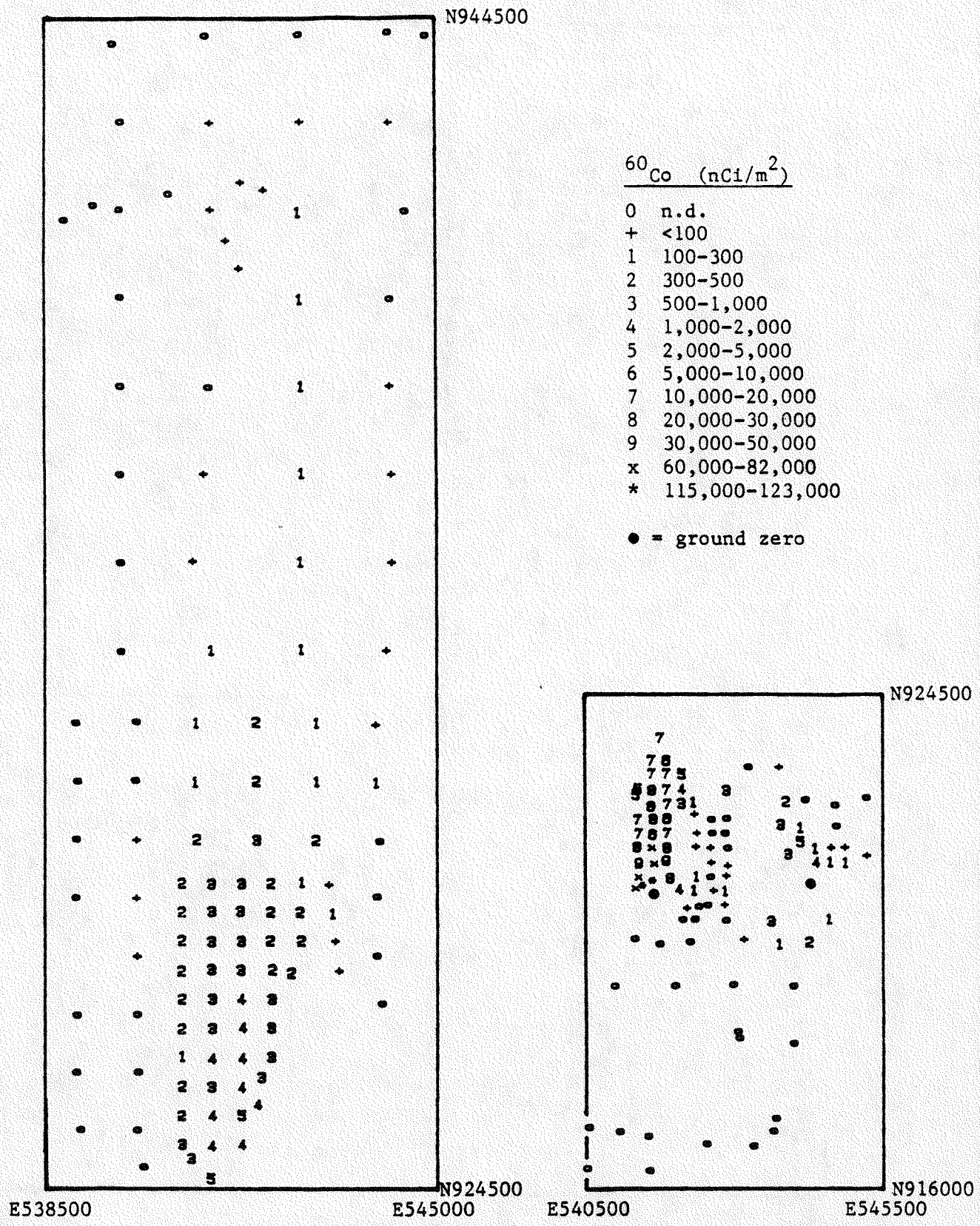


Figure 13. Measured ^{60}Co activities in the Cabriolet area.

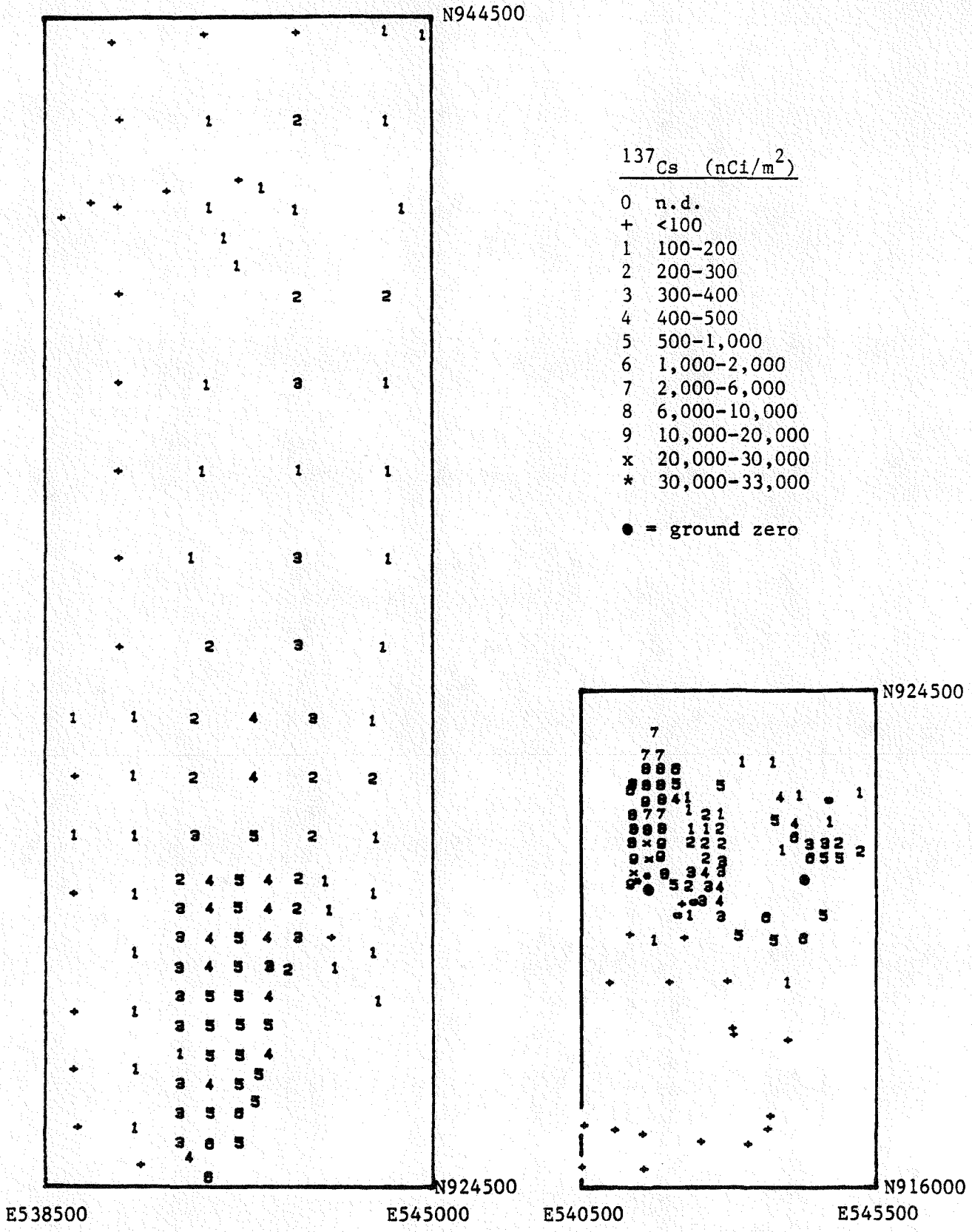


Figure 14. Measured ^{137}Cs activities in the Cabriolet area.

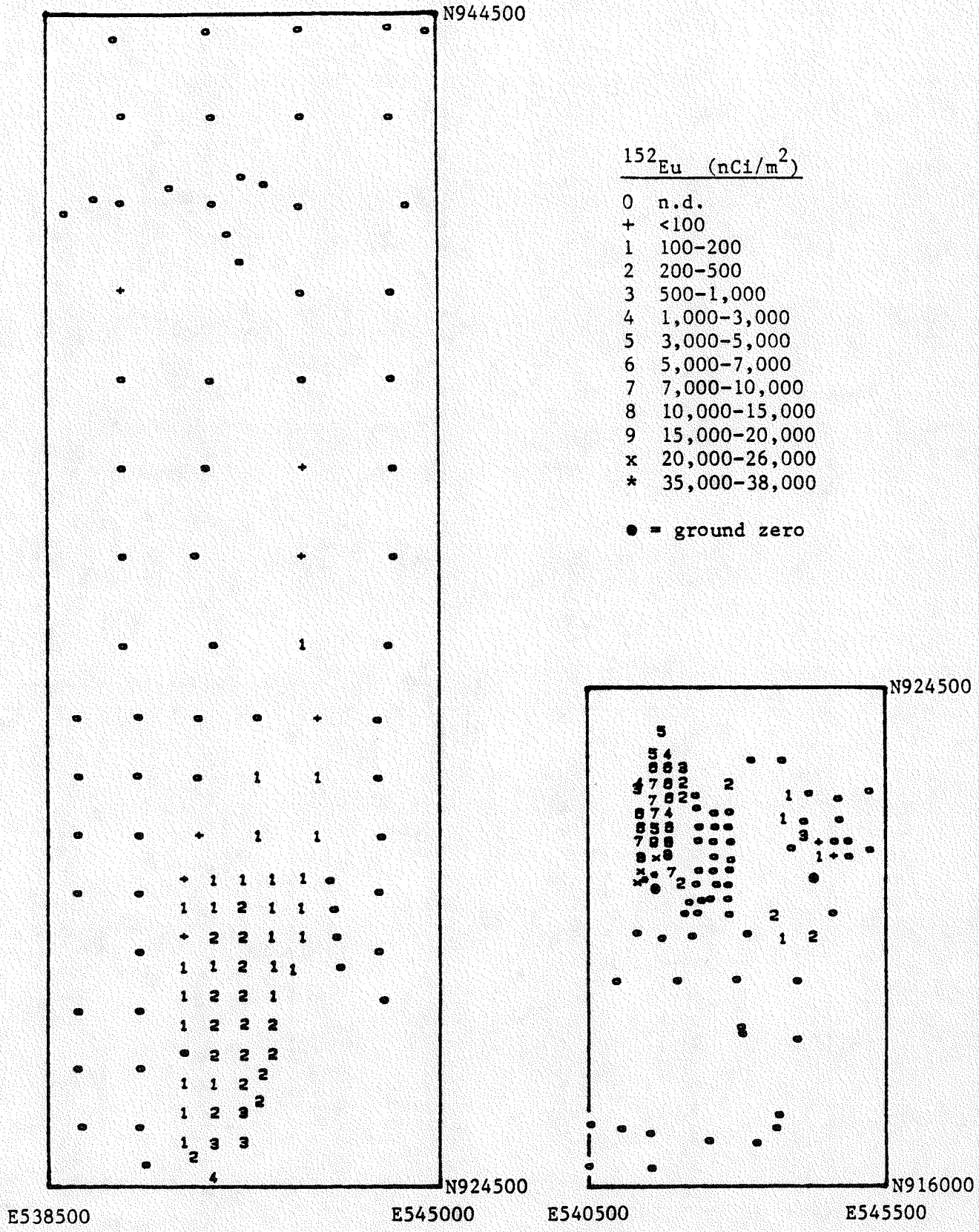


Figure 15. Measured ^{152}Eu activities in the Cabriolet area.

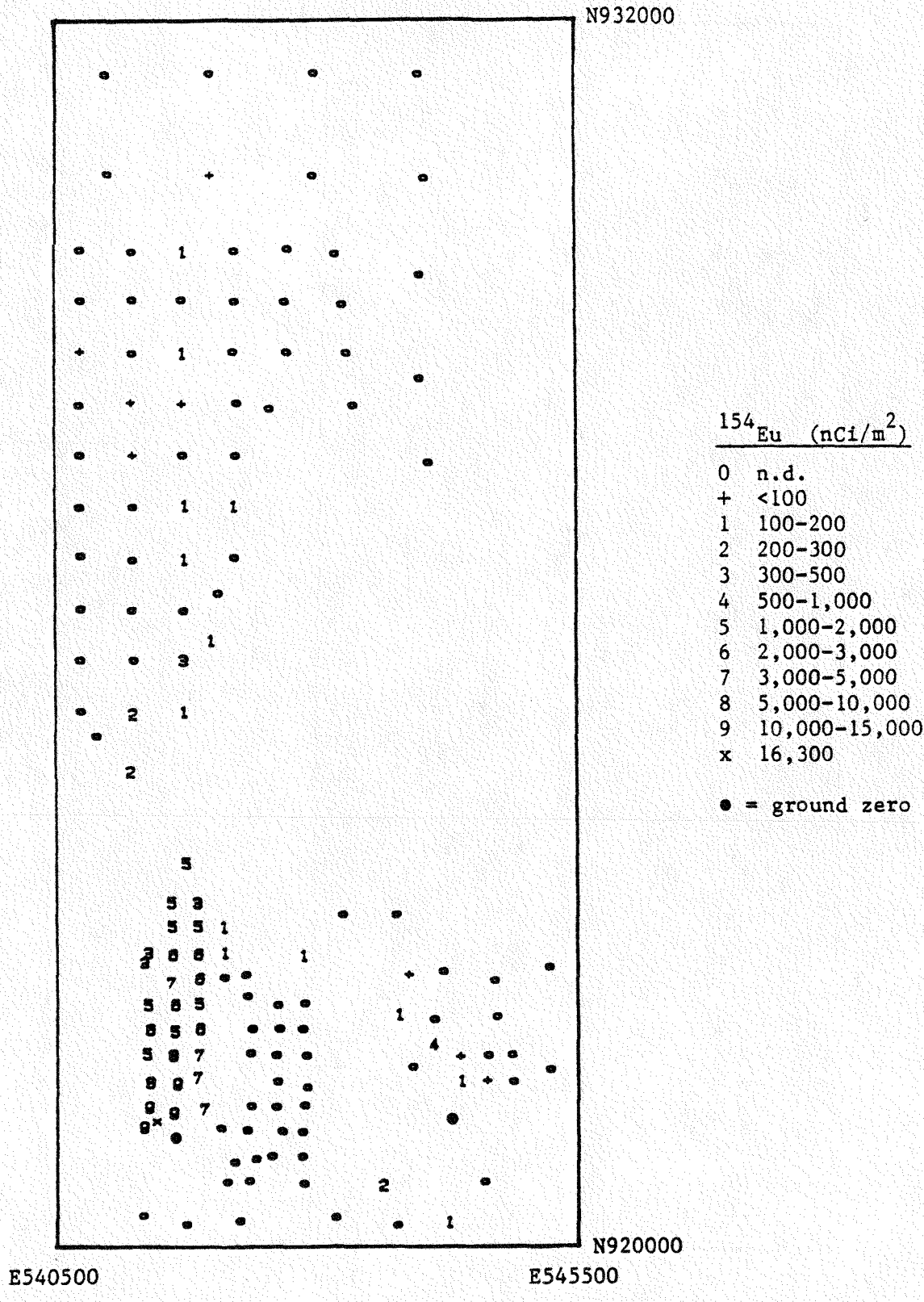


Figure 16. Measured ^{154}Eu activities in the Cabriolet area.

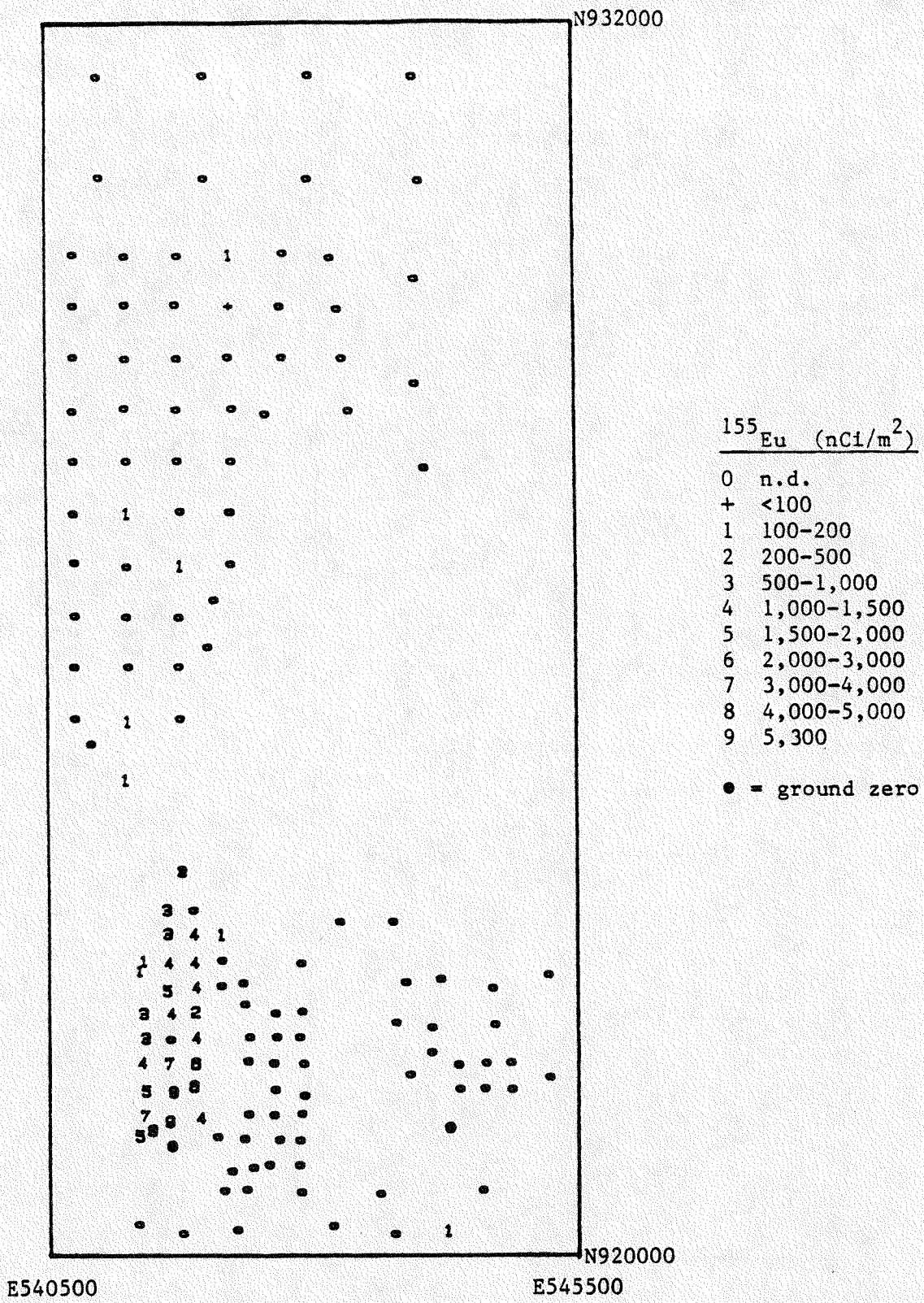


Figure 17. Measured ^{155}Eu activities in the Cabriolet area.

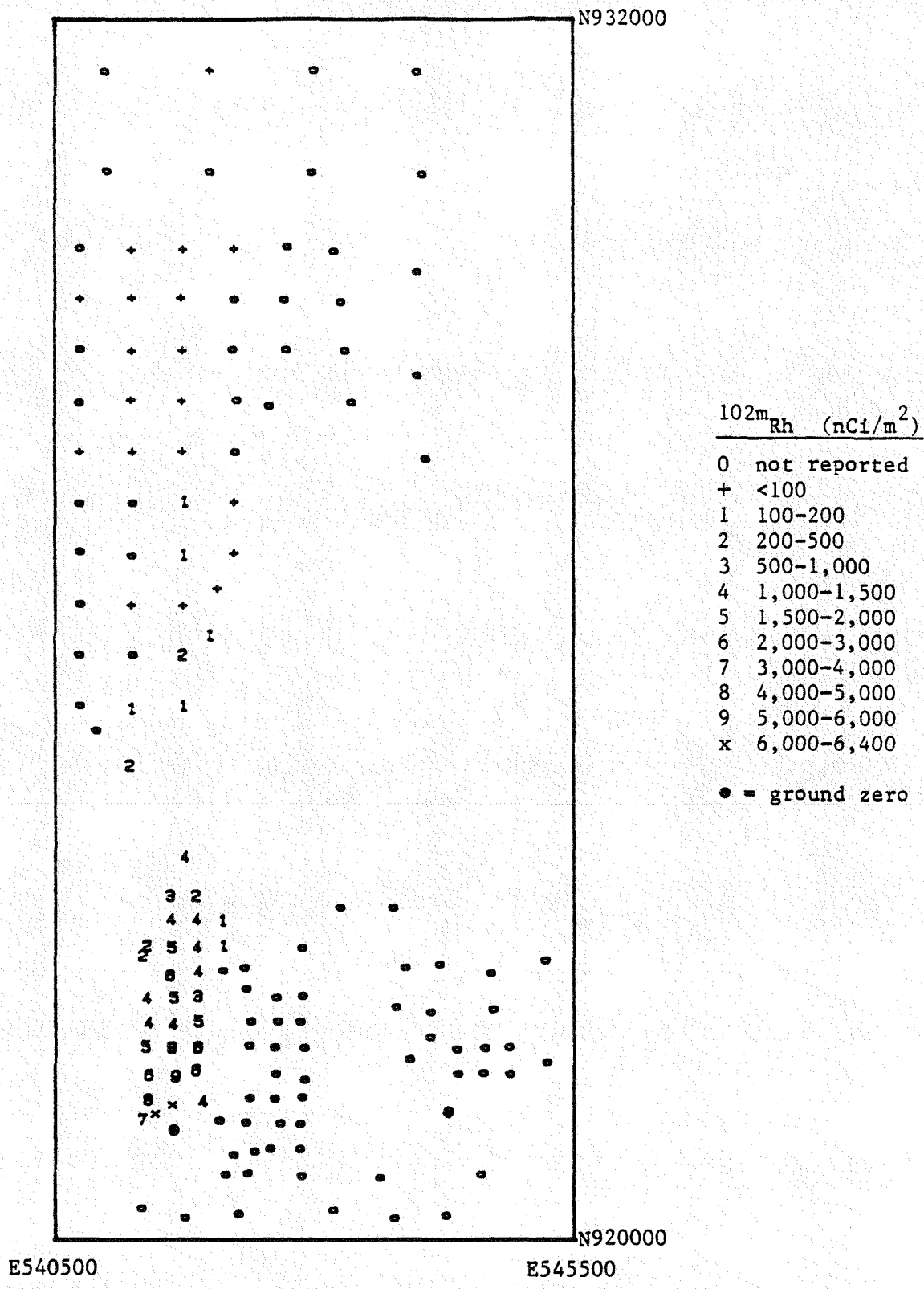


Figure 18. Measured ^{102m}Rh activities in the Cabriolet area.

^{101}Rh (nCi/m^2)	
0	not reported
+	<100
2	200-260
3	300-350

^{125}Sb (nCi/m^2)	
0	not reported
6	650-670
7	790
9	920
x	1,000-1,300
*	1,560

● = Palanquin ground zero

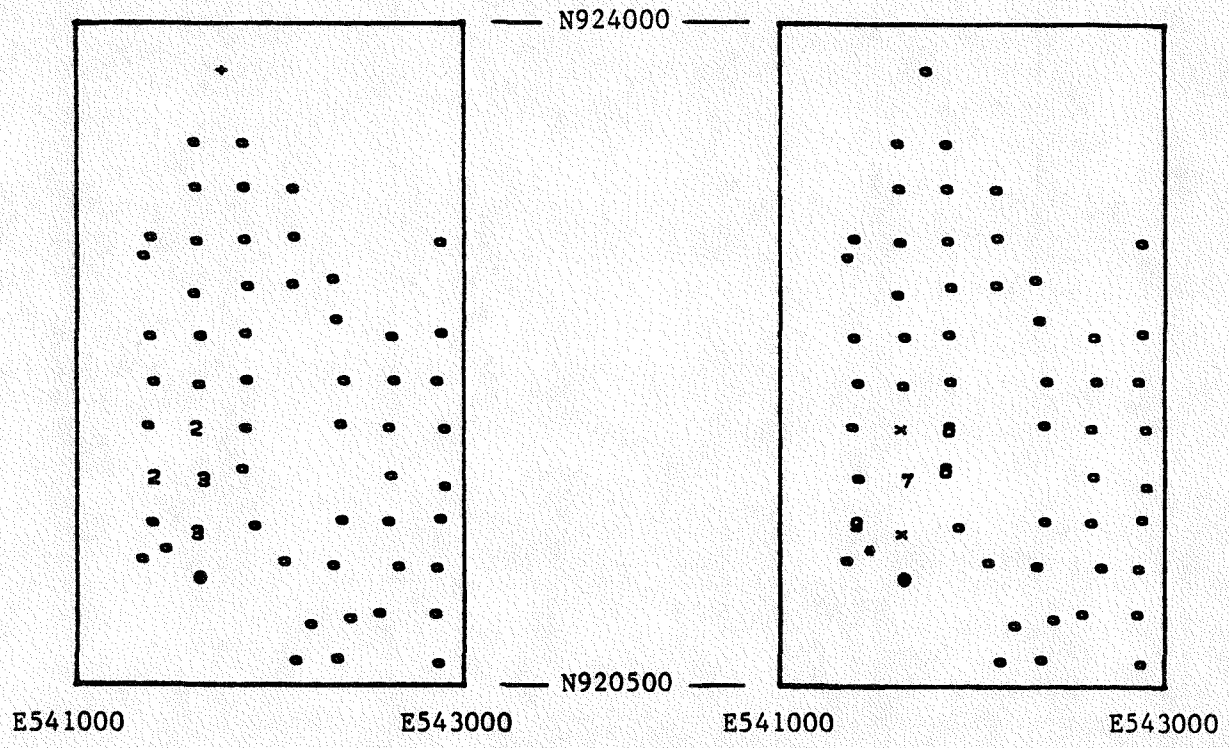


Figure 19. Measured ^{101}Rh and ^{125}Sb activities in the Cabriolet area.

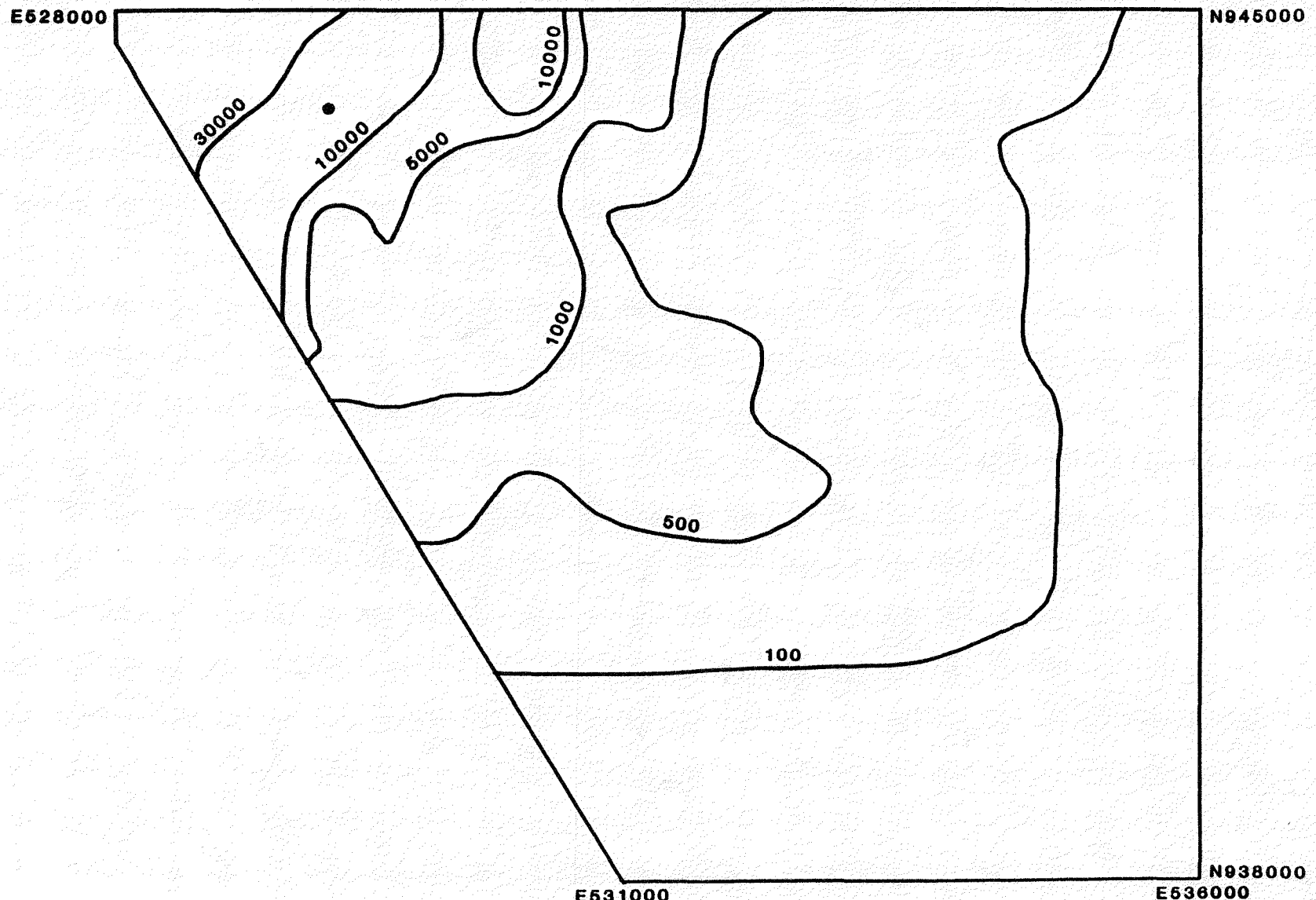


Figure 20. Distribution of ^{241}Am (nCi/m^2) in the Schooner area.

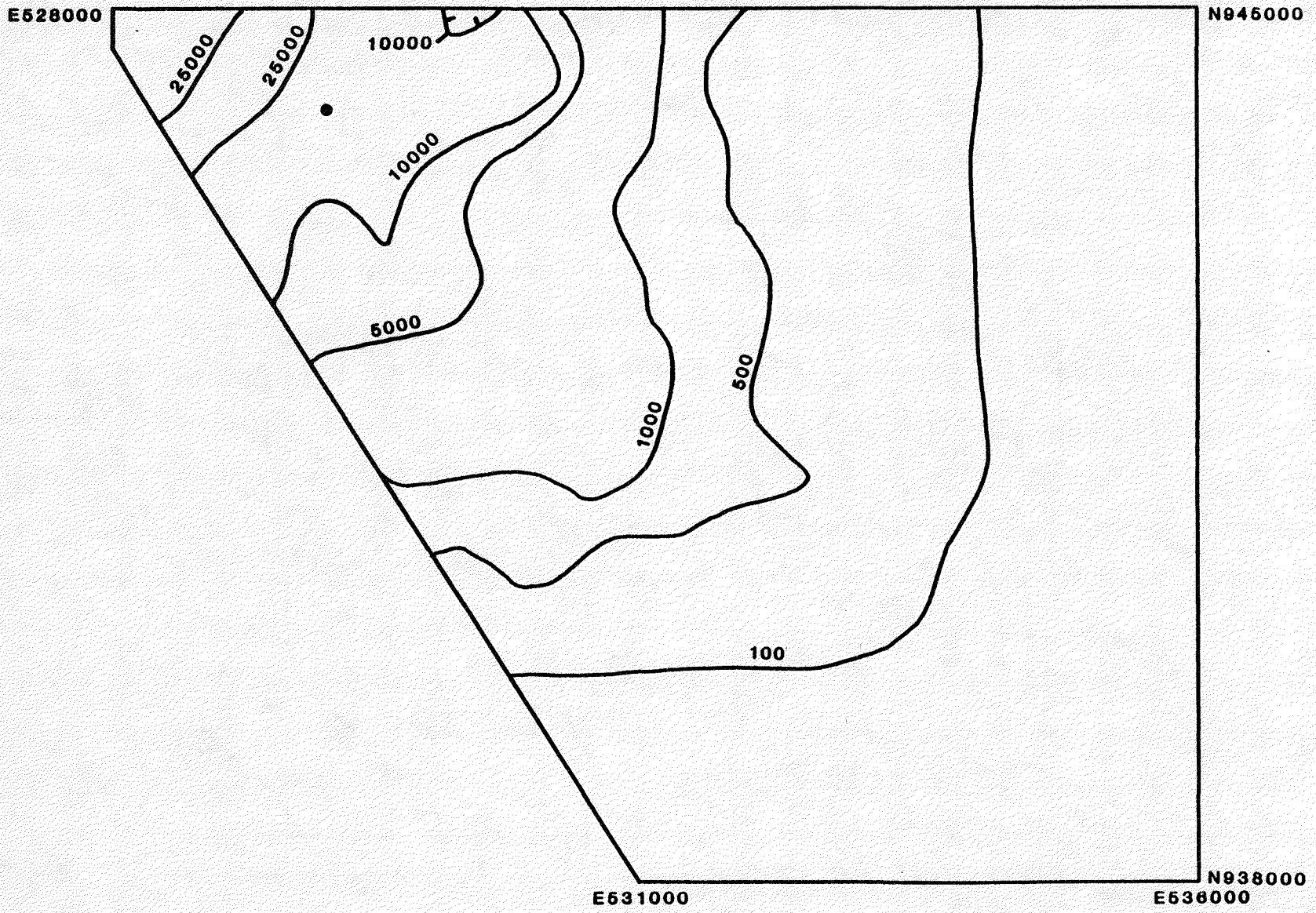


Figure 21. Distribution of ^{60}Co (nCi/m^2) in the Schooner area.

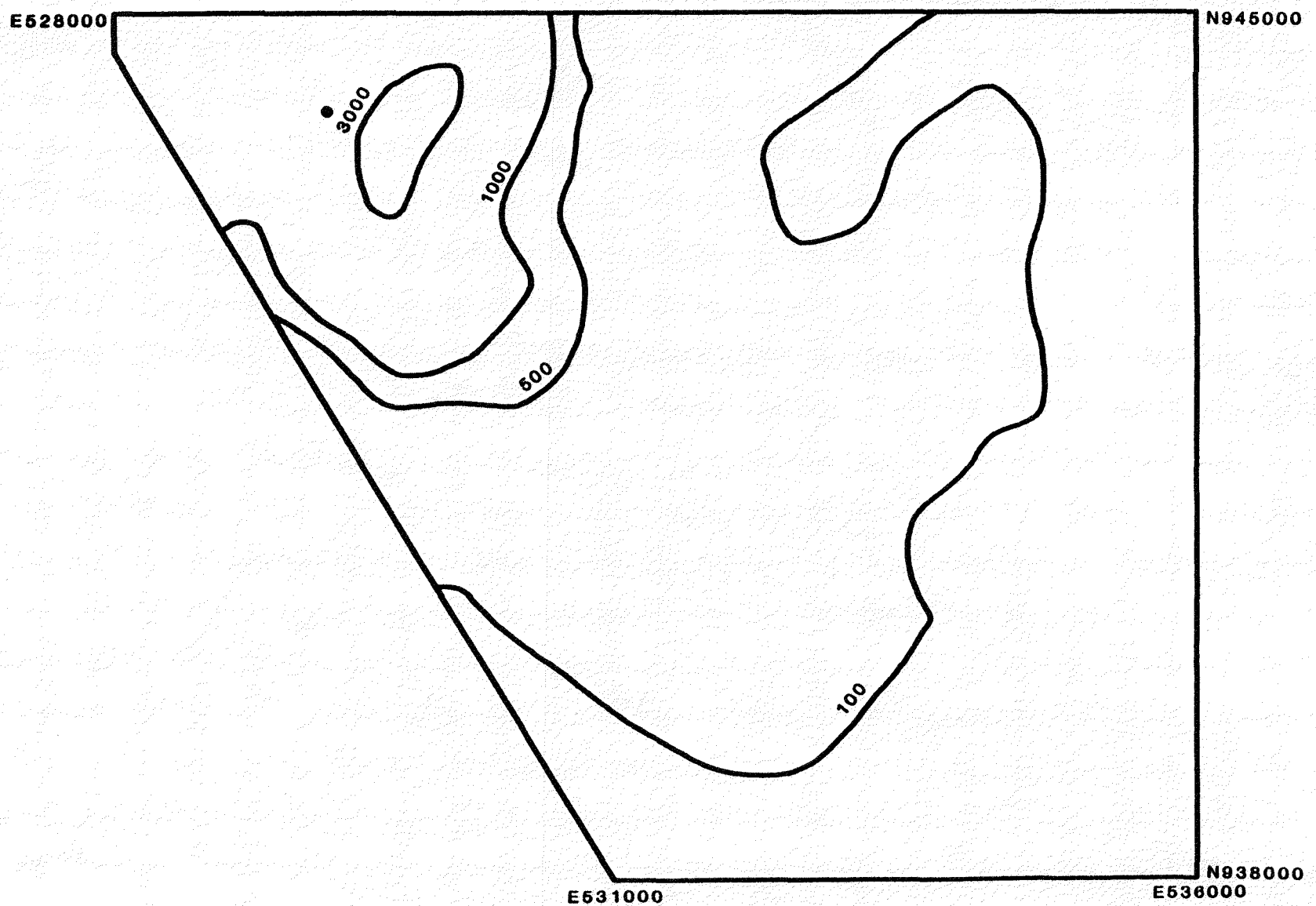


Figure 22. Distribution of ^{137}Cs (nCi/m^2) in the Schooner area.

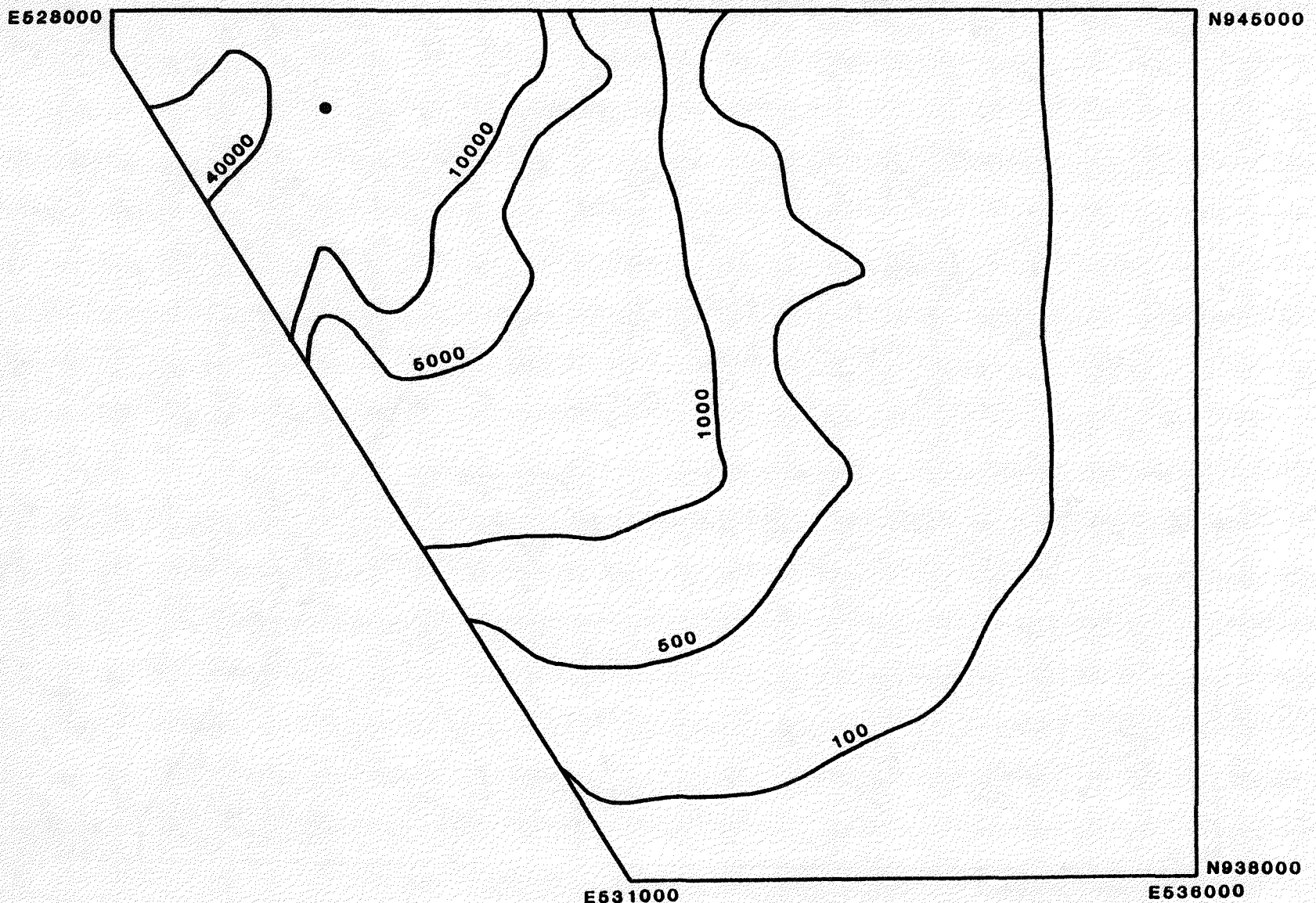


Figure 23. Distribution of ^{152}Eu (nCi/m^2) in the Schooner area.

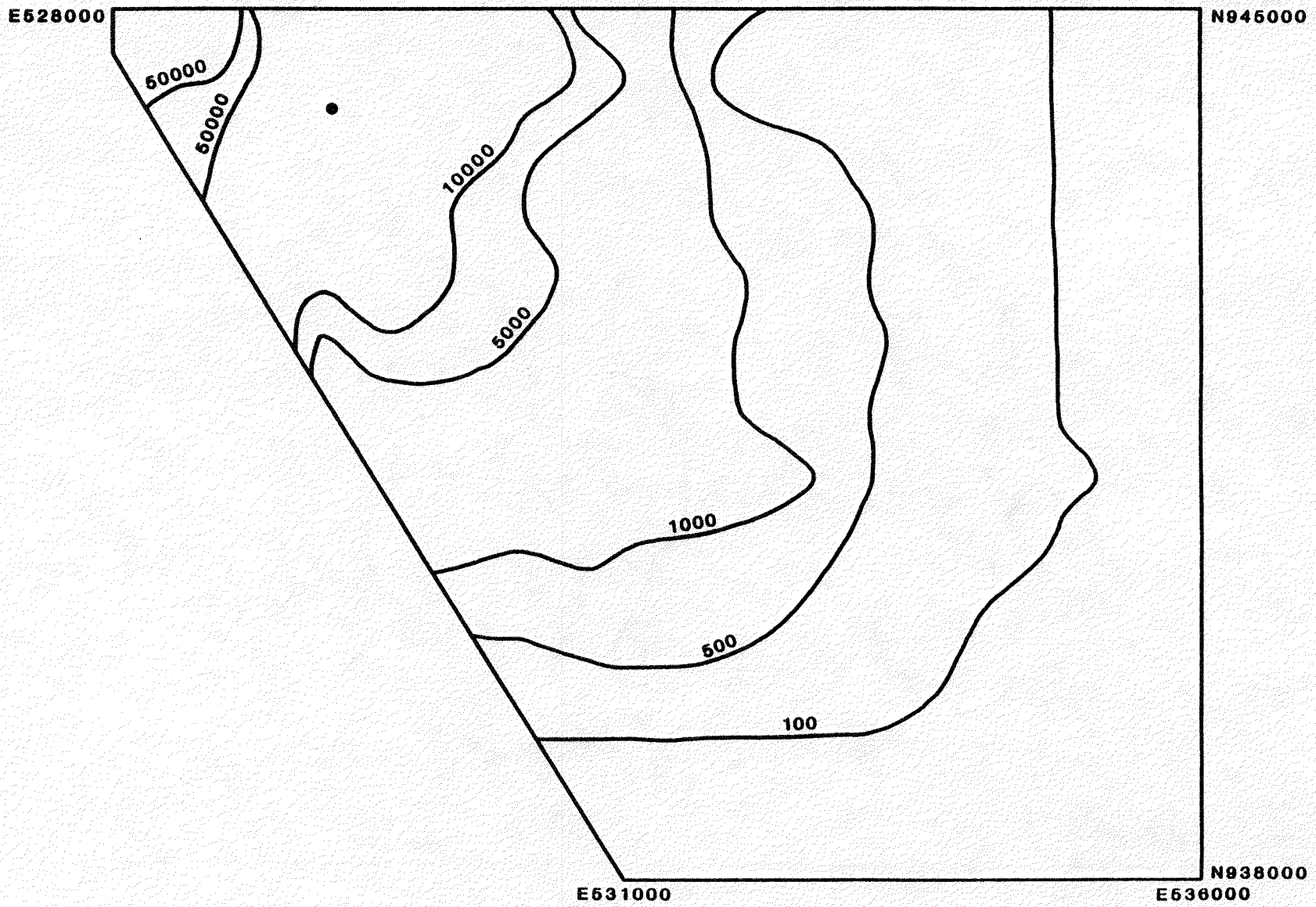


Figure 24. Distribution of ^{154}Eu (nCi/m^2) in the Schooner area.

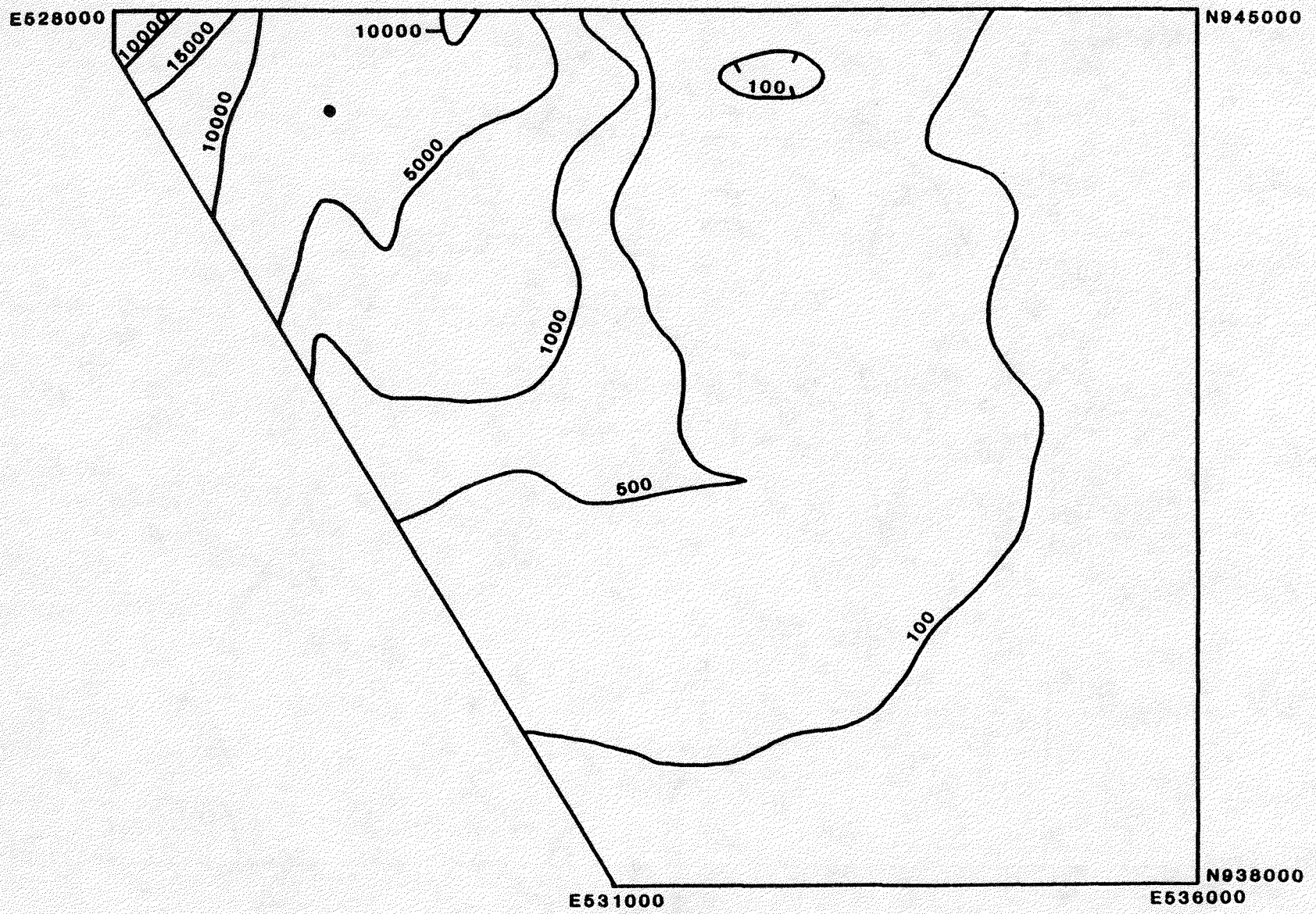


Figure 25. Distribution of ^{155}Eu (nCi/m^2) in the Schooner area.

SECTION 4
AREA 18

IN SITU MEASUREMENTS

The results of the aerial survey of Area 18, shown in Figure 26, show substantial levels of man-made contamination near the GZs of four nuclear tests:

Event	Location	Date
Danny Boy	E587978 N859537	5 March 1962
Johnie Boy*	E597267 N863642	11 July 1962
Little Feller I	E601880 N859076	17 July 1962
Little Feller II	E606067 N862569	7 July 1962

The results also show a large region of low contamination in the northeastern part of Area 18, apparently from radioactivity that drifted westward from Yucca Flat. *In situ* measurements were made in this area in conjunction with the later RIDP investigation of Area 17, and those results will be presented in a future report. Measurements in the four GZ areas were made between November 1983 and June 1984.

In the previous RIDP studies (Yucca Flat and Area 20), the *in situ* measurements were made on grids of points, with the grid spacing smaller in the regions where the aerial survey showed contamination levels to be high and changing rapidly. Such patterns are intuitively better than a uniform spacing of points for determining radionuclide distributions, and a computer simulation study (McArthur, 1987) has shown that they give more precise, although slightly biased, estimates of radionuclide inventories than do regular grids. The chief drawback of any grid-based arrangement of points is that because only one point is chosen at random, there is no straightforward way to compute an estimate of the sampling error.

The plan at the start of the RIDP was to use the geostatistical method called kriging to estimate both radionuclide inventories and sampling variability. However, the radio-

*The proper spelling of the name of this event seems to be an open question, with "Johnnie Boy" and "Johnny Boy" also being used. The version used everywhere in this report except in Figure 26 is the "official" version used in NVO-209, "Announced United States Nuclear Tests, July 1945 through December 1981."

nuclide distributions typically encountered on the NTS, with very high levels of radioactivity localized around a few ground zeros, represent an extreme departure from the stationary distribution assumed in the derivation of kriging. Kriging was used to estimate inventories from the early RIDP data, but the results were viewed with some suspicion and were accepted only to the extent that they could be confirmed by other methods (McArthur and Kordas, 1983 and 1985). Unfortunately, there was no way to check whether the kriging variance was a reasonable estimate of the variability of the inventory estimates.

In the simulation study referred to above, the kriging estimates of inventories had a bias of about 10 percent, providing additional evidence that the kriging results from the RIDP data were reasonable. However, the kriging variance differed by more than an order of magnitude from the true sampling error. Because of the resulting lack of confidence in the variance estimates, kriging was abandoned as a method for estimating inventories for the RIDP (it is still used as an interpolant for producing the distribution maps).

The investigation of the validity of kriging with the RIDP data was accompanied by a search for other methods of estimating inventories that would give a valid estimate of sampling variability. The measurement patterns for the four GZs in Area 18 were produced by one such method based on the statistical principle of importance sampling. The technical details of importance sampling, also called "sampling with probability proportional to size," are available in books such as Cochran (1977, pp. 250–255); the discussion here will concentrate on the application of the method to the Little Feller I ground zero area. (Throughout this section, the word "sampling" refers to the selection of the locations for *in situ* measurements from the large number of possible locations in an area. It is not related to the soil samples referred to elsewhere.)

THEORY OF IMPORTANCE SAMPLING

To estimate reliably the variability of the inventory estimates from sample to sample, it is necessary that the sample be selected at random. The easiest way to do this is by simple random sampling, where each possible measurement location has the same probability of being selected as every other location. Simple random samples allow the calculation of unbiased estimates of both the inventory and the sampling error, but with a distribution having very high values in a small part of the whole area, the sampling error can be unacceptably large.

Importance sampling is similar to simple random sampling in that the locations are chosen at random. With importance sampling, however, all points do not have the same selection probability. Instead, the points having the highest values have a higher probabil-

ity of being chosen. This concentrates the sampling in the region of greatest interest while preserving the randomness needed to assess the sampling variability.

In somewhat simplified mathematical terms, let x be a point in the area within which a radionuclide inventory is to be estimated, let Z(x) be the radionuclide activity at that point, and let p(x) be the probability that point x is selected in the sample of points to be measured. Define the function

$$Y(x) = Z(x)/p(x).$$

Then it can be shown that for a sample of points x_i, i=1,...,n, the average of the $Y(x_i)$,

$$\overline{Y} = \frac{1}{n}\sum_{i=1}^{n} Y(x_i)$$

is an unbiased estimate of the inventory, and that

$$s^2_{\overline{Y}} = \frac{1}{n(n-1)}\sum_{i=1}^{n} [Y(x_i) - \overline{Y}]^2$$

is an estimate of the sampling variance of $\overline{Y}$.

Since $\overline{Y}$ is an average of values of Z/p, its sampling variance will be small if Z/p is nearly constant. If Z/p is constant, then the variance of $Y(x_i)$ and $\overline{Y}$ is zero, but this requires that the inventory (the quantity to be estimated) be known beforehand. The practical implication is that it is desirable to sample from a probability distribution that mimics the distribution of Z as closely as possible.

APPLICATION TO LITTLE FELLER I

Figure 26 shows how Z (the activity of ^{137}Cs in this case) is distributed near the Little Feller I ground zero. Ideally, one would like to model such a distribution with a smooth function such as a polynomial and then to use that function as a probability distribution, but in general this is mathematically intractable. Instead, the distribution was approximated by a step function, a much cruder approximation but one which allows samples to be drawn relatively easily.

The first step was to define the area of interest and superimpose over it a 100-foot grid of measurement points. The grid of points ensures that the measurements will be at least 100 feet apart: Because of the large field of view of the detector, measurements

taken closer together would cover part of the same area and would therefore not be independent. It also reduces the population of possible measurement points from an infinite one to a finite one. Next, regions of the grid were defined to correspond roughly with the aerial survey contours. These regions are shown with the contours and grid in Figure 27.

Finally, the definitions of the contour levels were used to estimate the relative average activity in each region. This led to the function

h = 1 for all points in region A
= 2.4 for all points in region B
= 4 for all points in region C,

which is a rough approximation to the surface represented by the ^{137}Cs contours.

The measurement points were selected in two steps. First a region was chosen at random with probability proportional to the volume under h in each region (0.32 for region A, 0.42 for region B, and 0.26 for region C). Then one of the points in the selected region was chosen at random, with all points having the same probability. Thus one of the 327 points in region A had probability (0.32)x(1/327) = 0.00097 of being selected. The corresponding probabilities for regions B and C were 0.0023 and 0.0039. If simple random sampling had been used, the probability of each region would be proportional to its area (0.57, 0.31, and 0.12 respectively) instead of its volume, and every point would have the same probability of being selected (1/576 = 0.0017) regardless of which region it was in.

A sample of 25 measurement points was selected for the Little Feller I area by this method. Because of the random nature of the selection, there remained some fairly large areas within which no measurements were to be made. This was considered undesirable from the standpoint of estimating radionuclide distribution patterns, so five non-random points from these areas were added to the sample. The data from these points were not used in estimating inventories, but they were part of the data file used in estimating distributions. The final sampling plan is shown in Figure 28.

The sampling plans for the other three GZs were produced in a similar manner. The Johnie Boy area was split into two regions, one of high activity near the GZ and one of low activity north of the GZ, and a 500-foot grid was used instead of a 100-foot grid in the northern region. The sampling plans for these four areas, with the aerial survey con-

tours and the selection regions, are shown in Figures 29 through 32. The selection probabilities are given below:

Area	Selection Region	Probability
Little Feller I	a	0.0097
	b	0.0023
	c	0.0039
Little Feller II	a	0.00057
	b	0.0014
	c	0.0023
Johnie Boy - GZ	a	0.00014
	b	0.00028
	c	0.00056
	d	0.00083
	e	0.0014
Johnie Boy - North	a	0.0030
	b	0.0043
Danny Boy	a	0.00015
	b	0.00030
	c	0.00076
	d	0.0030

An additional 10 points were measured on a grid north of the Little Feller I GZ area because the exposure rate contours from the aerial survey showed a plume extending in that direction.

SOIL SAMPLES

Figures 33 through 35 show the locations of the soil samples, while Table 5 gives the inverse relaxation lengths (α) calculated from the data in Appendix B. The inverse relaxation length values used in GAMANAL were 0.05 cm^{-1} for all points in the Danny Boy GZ region, 0.1 cm^{-1} in the other GZ regions, 0.5 cm^{-1} for the other Little Feller points, 0.4 cm^{-1} for the other Johnie Boy points, and 0.3 cm^{-1} for the other Danny Boy points. Table 6 gives the computed radionuclide ratios.

DATA ANALYSIS

Figures 36 through 52 show the results of the *in situ* measurements. Only upper limit values were reported for ^{154}Eu at both of the Little Feller GZs. The only measurable ^{241}Am values in the Johnie Boy area were clearly part of a plume from Little Feller I, and these points are shown in Figure 36.

TABLE 5. CALCULATED INVERSE RELAXATION LENGTHS FROM AREA 18

Point	Inverse relaxation length and standard deviation (cm^{-1})									
	^{60}Co		^{137}Cs		^{152}Eu		^{155}Eu		^{241}Am	
Johnie Boy										
9	0.64	0.15	0.68	0.28	0.60	0.33	0.26	0.15	1.3	0.16
10	0.14	0.008	0.13	0.010	0.095	0.018	----*		----	
11	1.1	0.31	0.91	0.053	0.90	0.33	0.51	0.34	----	
12	0.29	0.027	0.24	0.036	0.28	0.004	0.26	0.032	----	
13	0.36	0.002	0.33	0.004	0.23	0.003	0.28	0.021	----	
14	0.69	0.33	0.71	0.067	0.15	0.048	0.59	0.15	0.05	--†
15	0.51	0.010	0.61	0.011	0.16	0.003	1.0	0.14	----	
16	0.57	0.004	0.53	0.004	0.28	0.003	1.0	0.34	----	
17	0.42	0.005	0.46	0.010	0.13	0.003	0.33	0.34	----	
18	0.10	0.014	0.61	0.24	0.05	--	----		----	
19	0.40	0.13	0.27	0.007	0.17	0.009	0.27	0.35	----	
20	0.88	0.14	0.45	0.34	----		----		----	
21	0.05	--	0.05	--	0.05	--	----		----	
22	0.39	0.017	0.35	0.051	0.13	0.008	0.69	0.15	----	
Little Feller I										
23	0.31	0.18	0.35	0.34	----		----		0.37	0.18
24	----		1.2	0.15	----		----		----	
25	----		0.10	0.013	----		0.22	0.47	0.11	0.023
26	0.54	0.15	0.81	0.33	0.05	--	----		0.35	0.20
27	0.05	--	0.12	0.015	0.05	--	----		1.2	0.38
28	0.53	0.34	0.68	0.015	0.33	0.064	0.54	0.36	0.63	0.12
29	0.87	0.16	0.33	0.032	----		0.05	--	0.05	--
30	----		0.54	0.34	----		0.05	--	----	
31	----		0.27	0.086	----		----		0.17	0.22
Little Feller II										
43	----		0.05	--	----		----		0.16	0.050
44	0.05	--	0.05	--	----		0.17	0.13	0.05	--
45	0.054	0.019	0.17	0.006	0.05	--	0.28	0.13	0.23	0.005
46	0.05	--	0.84	0.10	0.05	--	----		0.44	0.019
47	0.05	--	0.30	0.019	0.05	--	0.50	0.11	0.43	0.044
48	0.05	--	0.92	0.10	0.05	--	0.42	0.11	0.72	0.036
49	0.13	0.025	0.61	0.036	0.21	0.024	0.32	0.037	0.73	0.015
50	----		0.41	0.051	----		0.17	0.058	0.21	0.055
51	0.66	0.10	0.59	0.036	0.53	0.10	0.72	0.10	0.82	0.021
Danny Boy										
32	----		0.69	0.34	----		----		----	
33	0.17	0.16	0.37	0.21	----		----		----	
34	0.43	0.18	0.27	0.022	----		----		0.47	0.45
35	0.32	0.36	0.38	0.026	----		----		0.51	0.34
36	0.05	--	0.05	--	0.083	0.004	0.05	--	0.093	0.031
37	0.21	0.32	0.20	0.014	0.98	0.14	----		0.22	0.042
38	0.05	--	0.05	--	0.05	--	0.057	0.050	0.087	0.011
39	0.11	0.002	0.10	0.001	0.11	0.003	0.092	0.013	0.12	0.017
40	0.05	--	0.05	--	0.05	--	----		0.05	--
41	0.28	0.016	0.05	--	0.28	0.12	0.19	0.56	0.56	0.39
42	0.39	0.36	0.34	0.14	0.17	0.35	----		0.46	0.59

*Value could not be calculated because of insufficient data.

†Values of 0.05 with no standard deviation are estimates used when the sample was not deep enough.

The computed inventory estimates and their standard deviations are given in Table 7. The standard deviations of the estimates from the grid north of the Little Feller I GZ were assumed to be zero when computing the standard deviation of the total. It must be emphasized that these standard deviations are a measure only of the sampling variability, that is, the variability to be expected among estimates from repeated samples selected by the same method. Other sources of error, such as the error in the measurements of radionuclide activities at each location, are not taken into account.

TABLE 6. RADIONUCLIDE RATIOS IN SOIL SAMPLES FROM AREA 18

Point	$^{238,240}Pu/^{241}Am$	$^{238}Pu/^{241}Am$	$^{90}Sr/^{137}Cs$
Johnie Boy			
9	8.4	2.0	5.0
11	16.	2.4	5.7
12	13.	2.1	5.0
13	9.8	1.5	6.2
16	9.2	1.3	4.1
average	11.	1.9	5.2
Danny Boy			
36	3.2	0.15	0.56
38	4.2	0.11	0.54
39	4.2	0.096	0.83
40	4.3	0.13	0.64
41	4.0	0.11	0.60
average	4.0	0.12	0.63
Little Feller I			
27	6.3	0.12	1.6
28	4.6	0.084	1.9
31	5.9	0.13	2.0
average	5.6	0.11	1.8
Little Feller II			
45	7.1	0.19	1.9
47	5.3	0.11	1.8
48	6.2	0.12	2.1
49	5.1	0.093	2.0
51	5.2	0.097	2.4
average	5.8	0.12	2.0

TABLE 7. INVENTORY ESTIMATES FOR AREA 18

Region	Area ($ft^2 \times 10^6$)	Radionuclide Inventory ± Sampling S.D. (Ci)							
		^{241}Am	^{238}Pu	$^{238,240}Pu$	^{60}Co	^{137}Cs	^{90}Sr	^{152}Eu	^{154}Eu	^{155}Eu
Little Feller I										
GZ area	5.76	5.2±1.9	.57±.21	29.±11.	.29±.16*	.12±.018	.22±.032	.039±.0041*	.024±.0026*	.058±.0066*
N of GZ	10.	.83	.091	4.6	.011*	.15	.27	.046*	.033*	.079*
Little Feller II	9.36	13.±4.6	1.6±.55	75.±27.	.034±.0027*	.26±.029	.52±.058	.10±.0078*	.10±.0088*	.11±.0077*
Johnie Boy										
GZ area	79.	.61±.029*	1.2±.055	6.7±.32	.26±.015	1.1±.071	5.7±.37	.60±.036	.64±.035	.58±.024
N of GZ	32.	.35±.025*	.67±.048	3.9±.28	.50±.092*	1.0±.10	5.2±.52	.78±.091*	.41±.027*	.35±.020*
Danny Boy	24.64	6.6±1.3	.79+.16	26.±5.2	.20±.037	2.3±.29	1.4±.18	.53±.073	.13±.010	.27±.019*
Total	160.76	27.±5.1	4.9±.61	150.±30.	1.3±.19	4.9±.32	13.±.67	2.1±.12	1.3±.046	1.4±.038

*These estimates are based largely on upper limit values.

It should also be noted that these four GZ areas in Area 18 are the only places where importance sampling was used by the RIDP. The method relies on quantitative information from the aerial surveys, and such information was not available for the GZs visited by the RIDP measurement teams after June 1984. Subsequent RIDP studies therefore used the same kind of grid-based sampling as used previously.

Figures 53 through 65 show the estimated distributions of important radionuclides in the four GZ areas. These maps were produced in the same manner as those for the Schooner area, except that the interpolated points for ^{60}Co in the Danny Boy area were on a 250-foot grid instead of the 500-foot grid used for all the other maps. Some of the contours extend into areas within which no *in situ* measurements were made, and these should be used with caution. This is especially true for the westward extension of the ^{241}Am plume from Little Feller I in Figure 53, and for the immediate vicinity of the Danny Boy GZ as well. Note also that substantial ^{241}Am contamination clearly extends north of the region measured at Little Feller II.

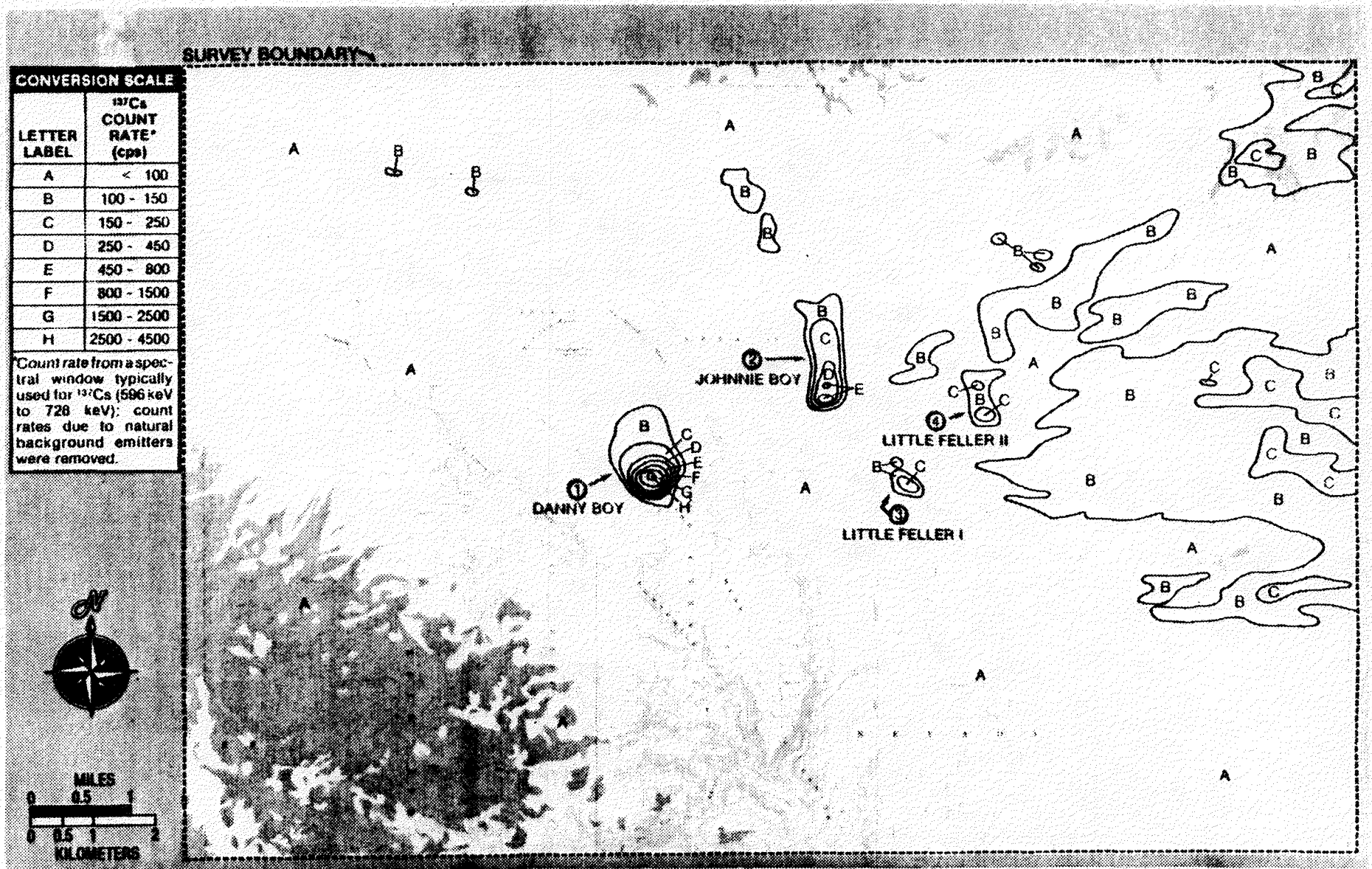


Figure 26. Man-made contamination in Area 18 as indicated by ^{137}Cs count rates from an aerial survey (from Feimster, 1985).

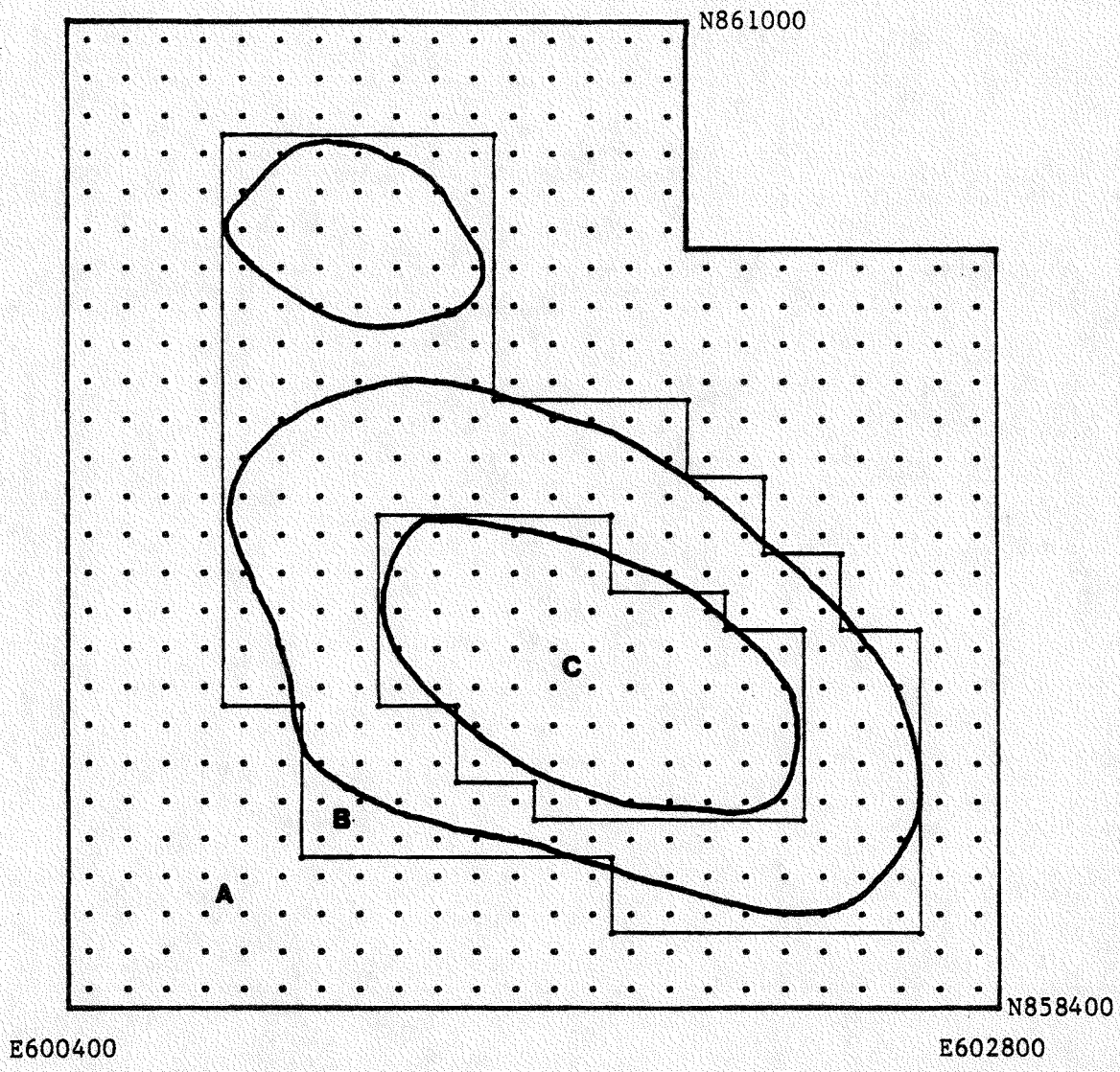


Figure 27. Contours from the aerial survey of the Little Feller I area and regions used in selecting a sample from the grid of possible in situ measurement locations.

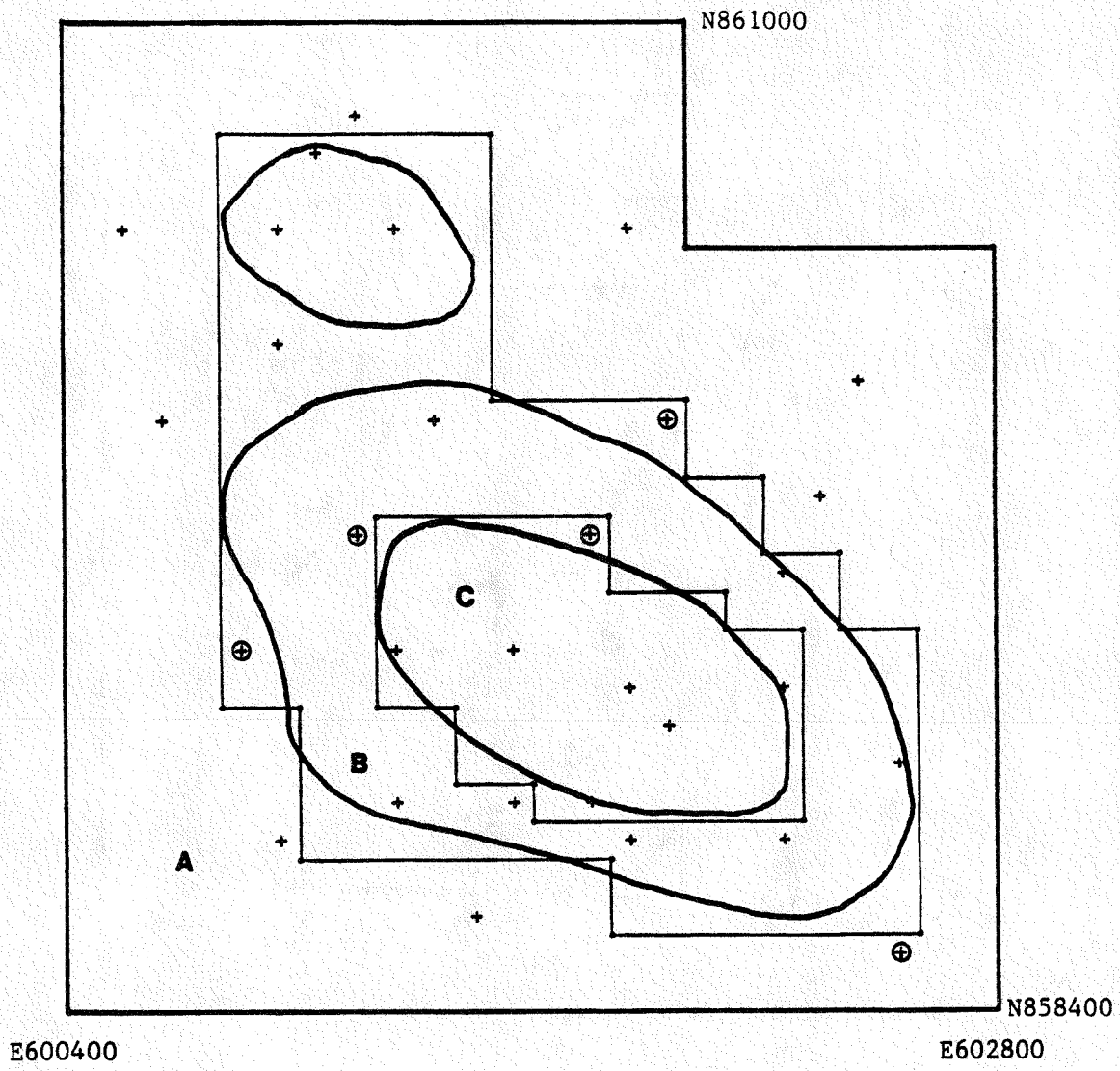


Figure 28. Locations chosen for in situ measurements in the Little Feller I area, with the aerial survey contours and the selection regions.

+ = randomly-chosen point
⊕ = additional point

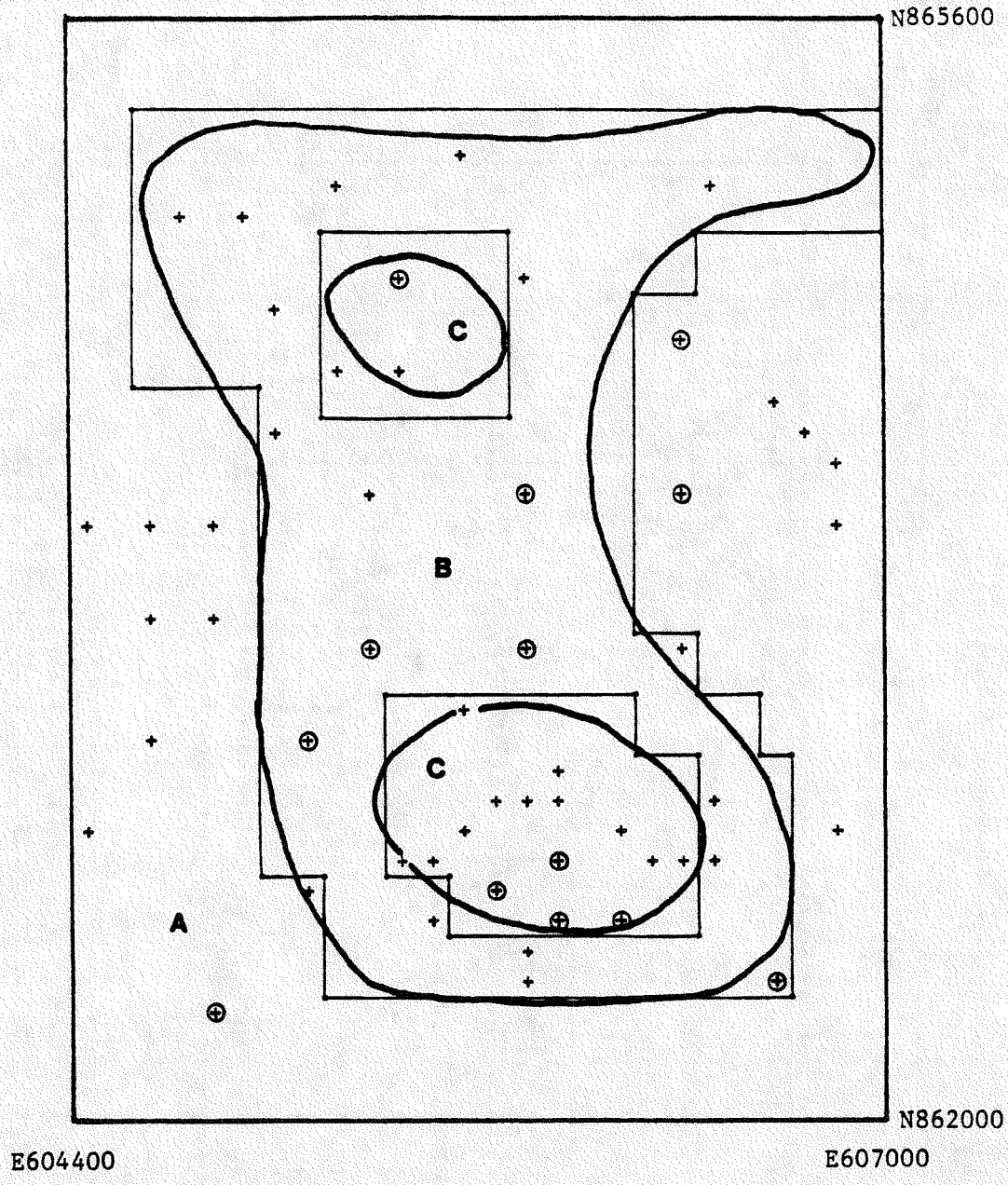


Figure 29. Locations chosen for <u>in situ</u> measurements in the Little Feller II area, with the aerial survey contours and the selection regions.

+ = randomly-chosen point
⊕ = additional point

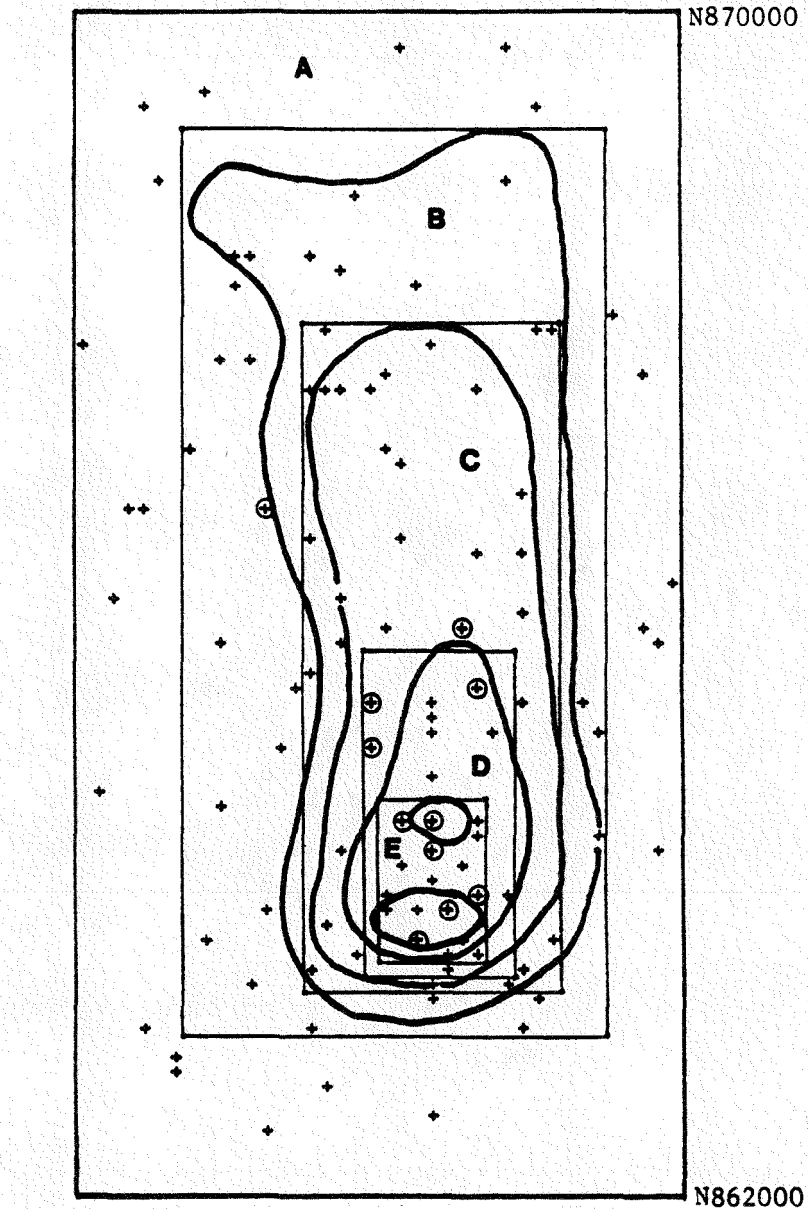


Figure 30. Locations chosen for <u>in situ</u> measurements in the Johnie Boy GZ area, with the aerial survey contours and the selection regions.

+ = randomly-chosen point
⊕ = additional point

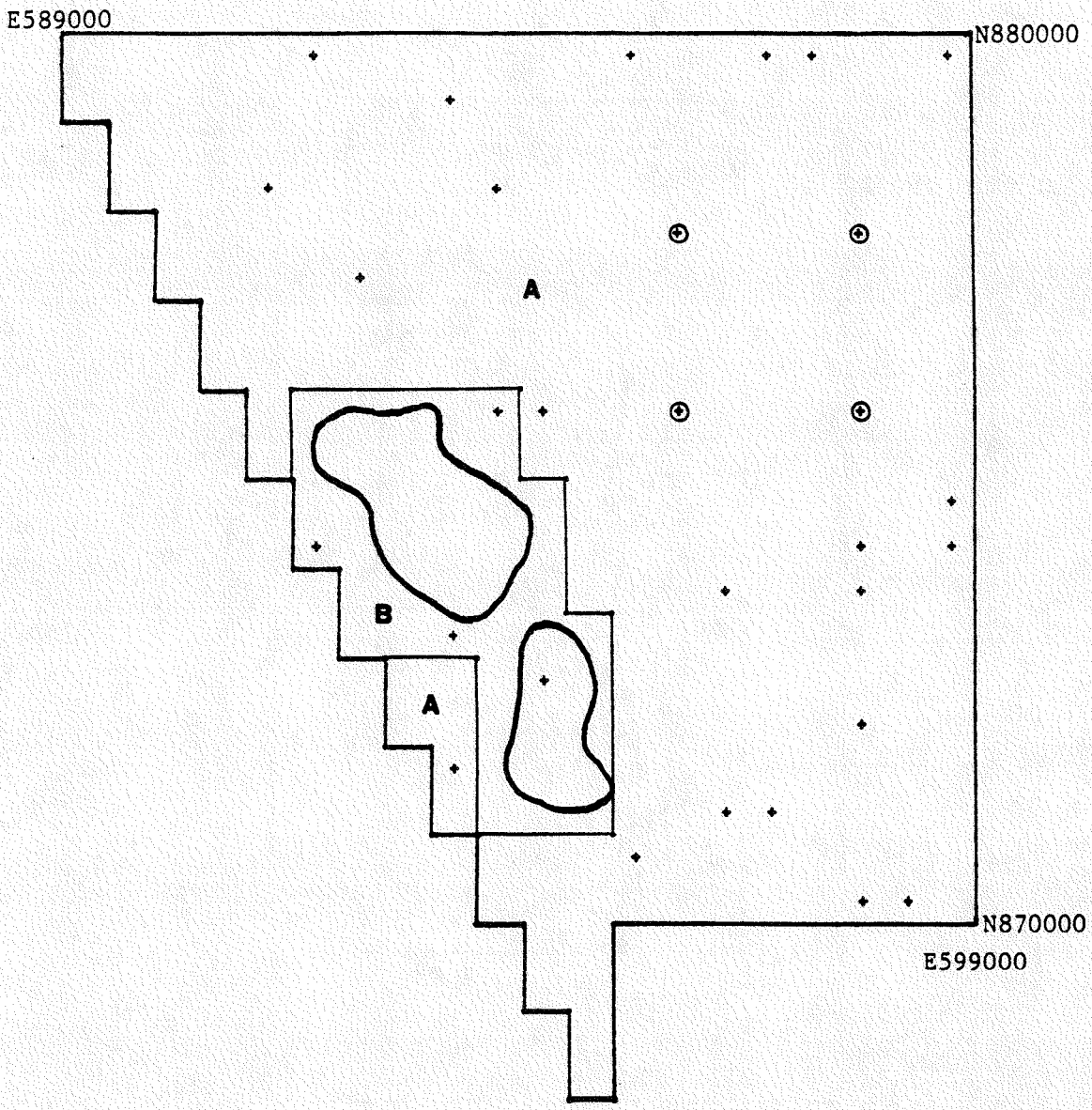


Figure 31. Locations chosen for <u>in situ</u> measurements in the region north of the Johnie Boy GZ, with the aerial survey contours and selection regions.

+ = randomly-chosen point
⊕ = additional point

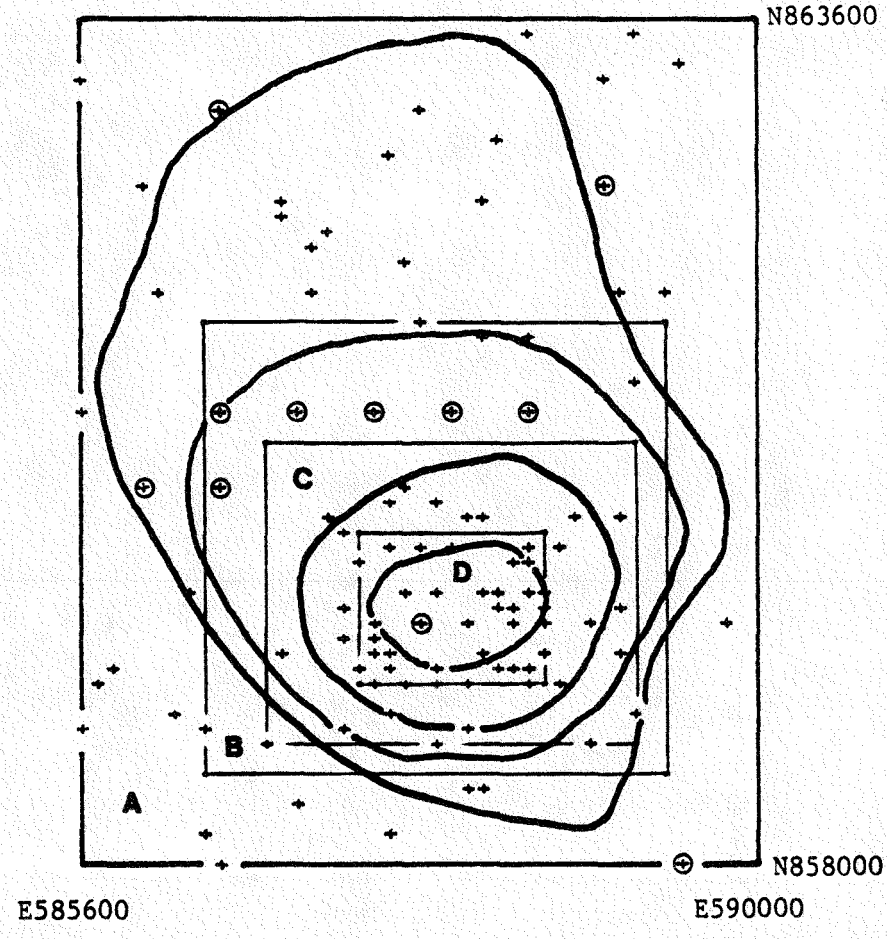


Figure 32. Locations chosen for <u>in situ</u> measurements in the Danny Boy area, with the aerial survey contours and the selection regions.

+ = randomly-chosen point
⊕ = additional point

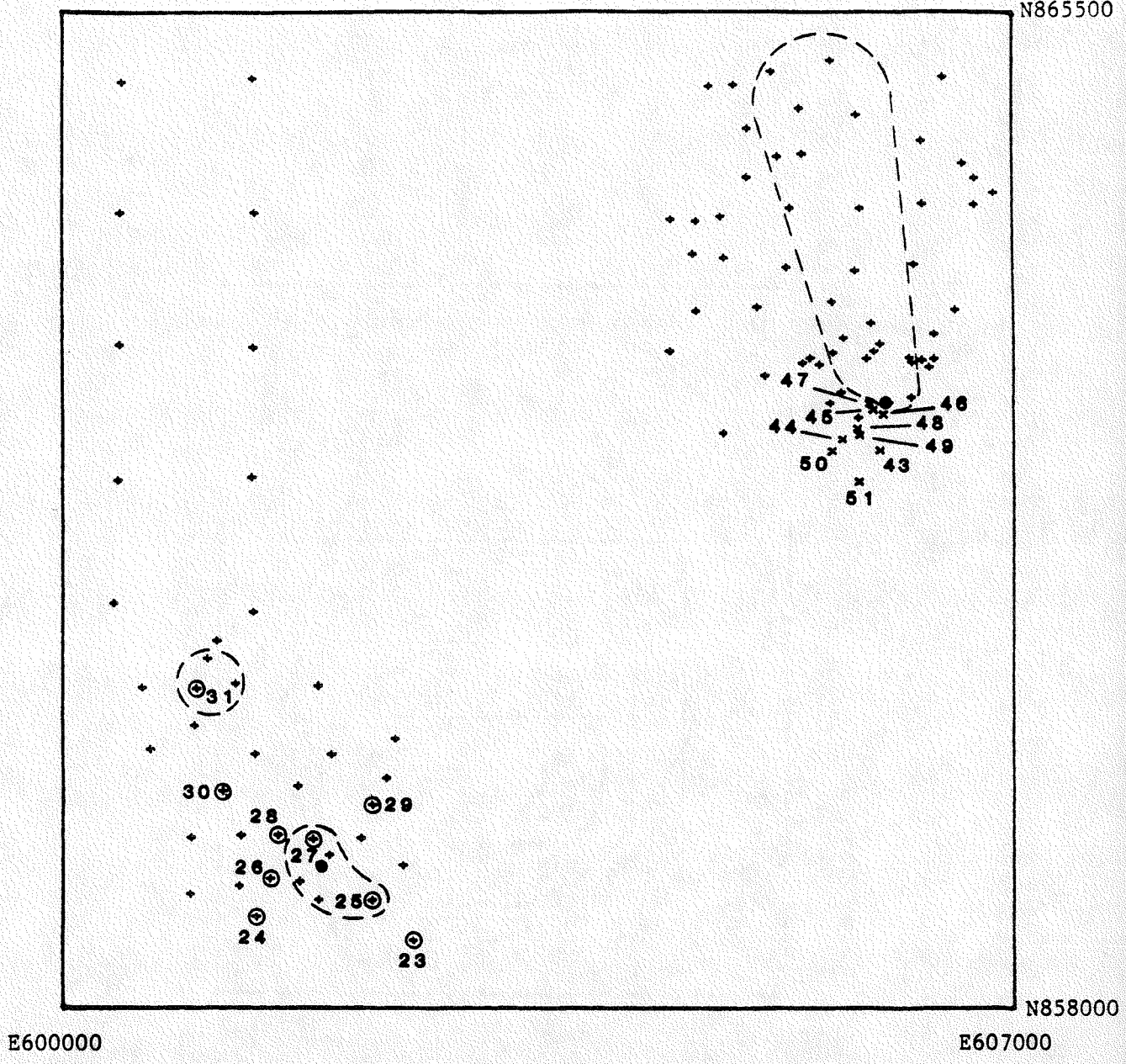


Figure 33. Locations of soil samples in the Little Feller areas. The dashed lines enclose the GZ regions defined for choosing inverse relaxation lengths.

● = ground zero
+ = location of in situ measurement
⊕ = location of RIDP soil sample
x = location of NAEG soil sample

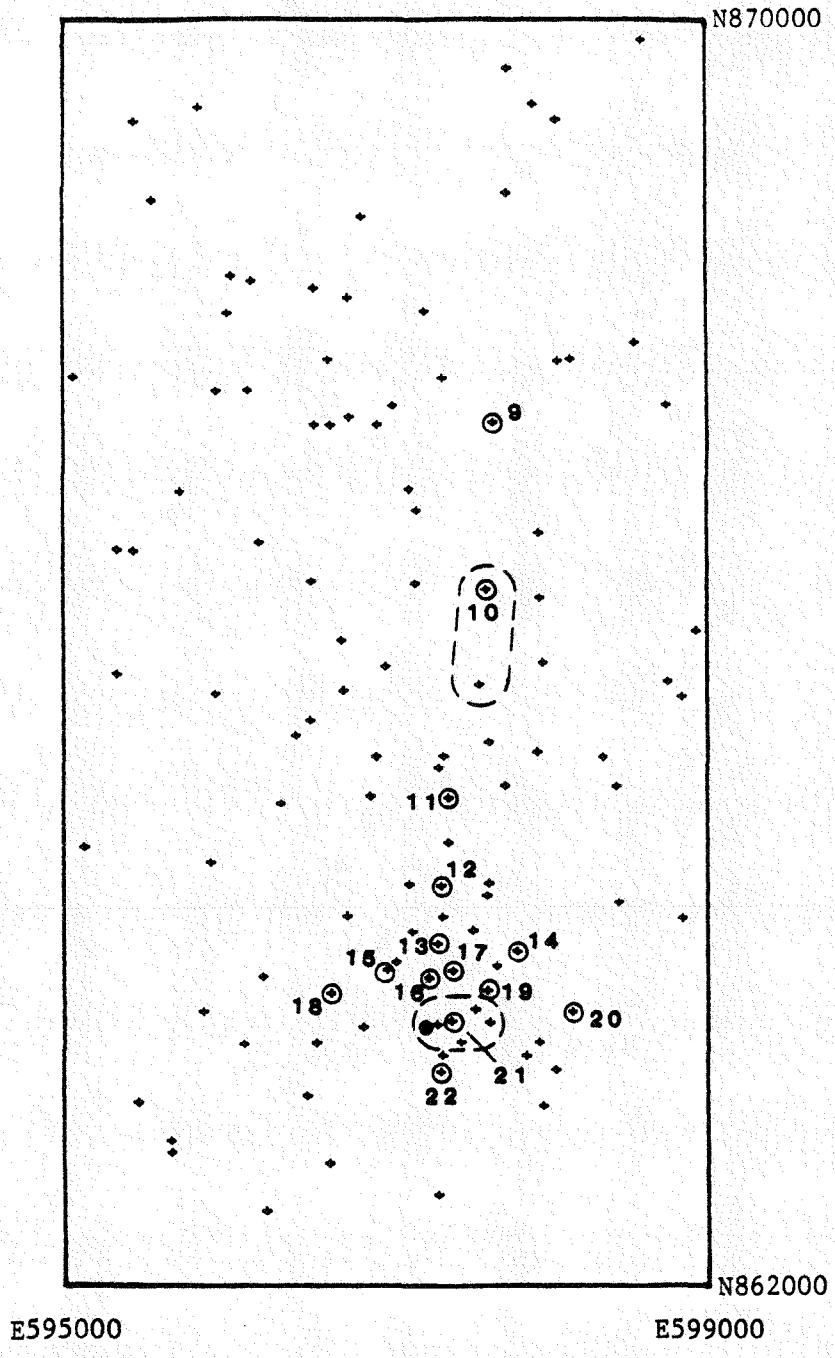


Figure 34. Locations of soil samples in the Johnie Boy GZ area. The dashed lines enclose the GZ region defined for choosing inverse relaxation lengths.

● = ground zero
+ = location of in situ measurement
⊕ = location of soil sample

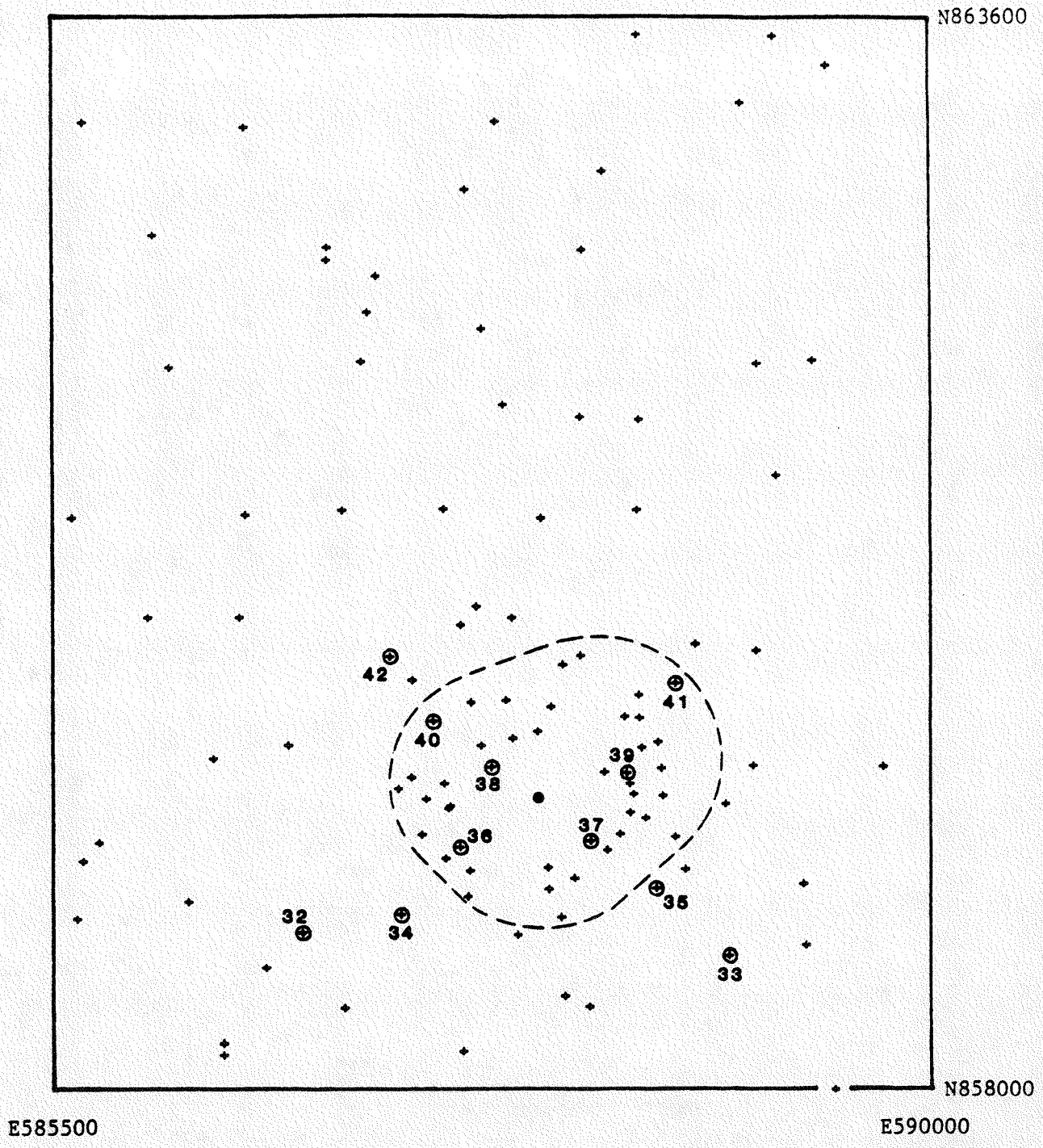


Figure 35. Locations of soil samples in the Danny Boy area. The dashed line encloses the GZ region defined for choosing inverse relaxation lengths.

● = ground zero
+ = location of <u>in situ</u> measurement
⊕ = location of soil sample

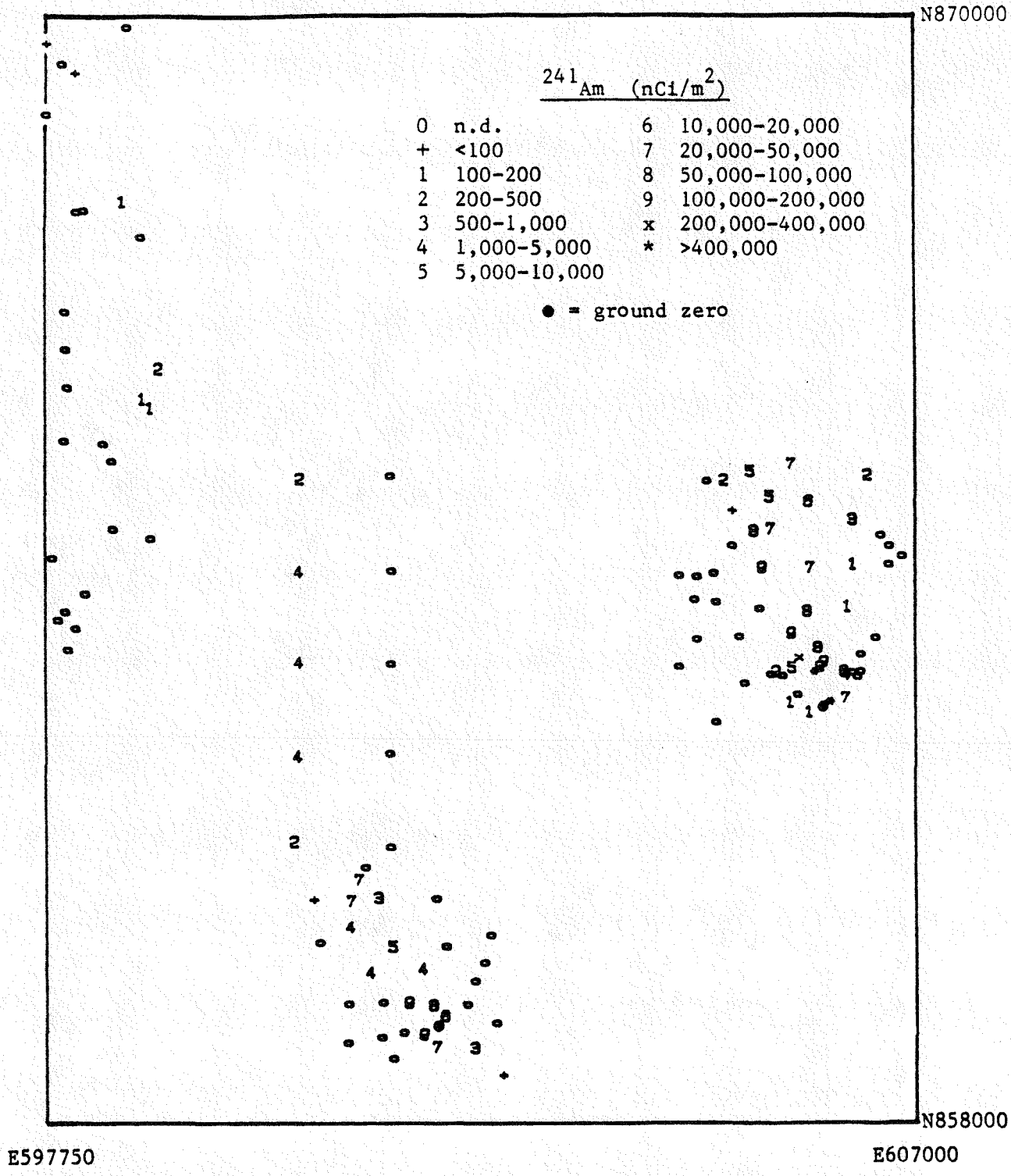


Figure 36. Measured ^{241}Am activities in the Little Feller areas.

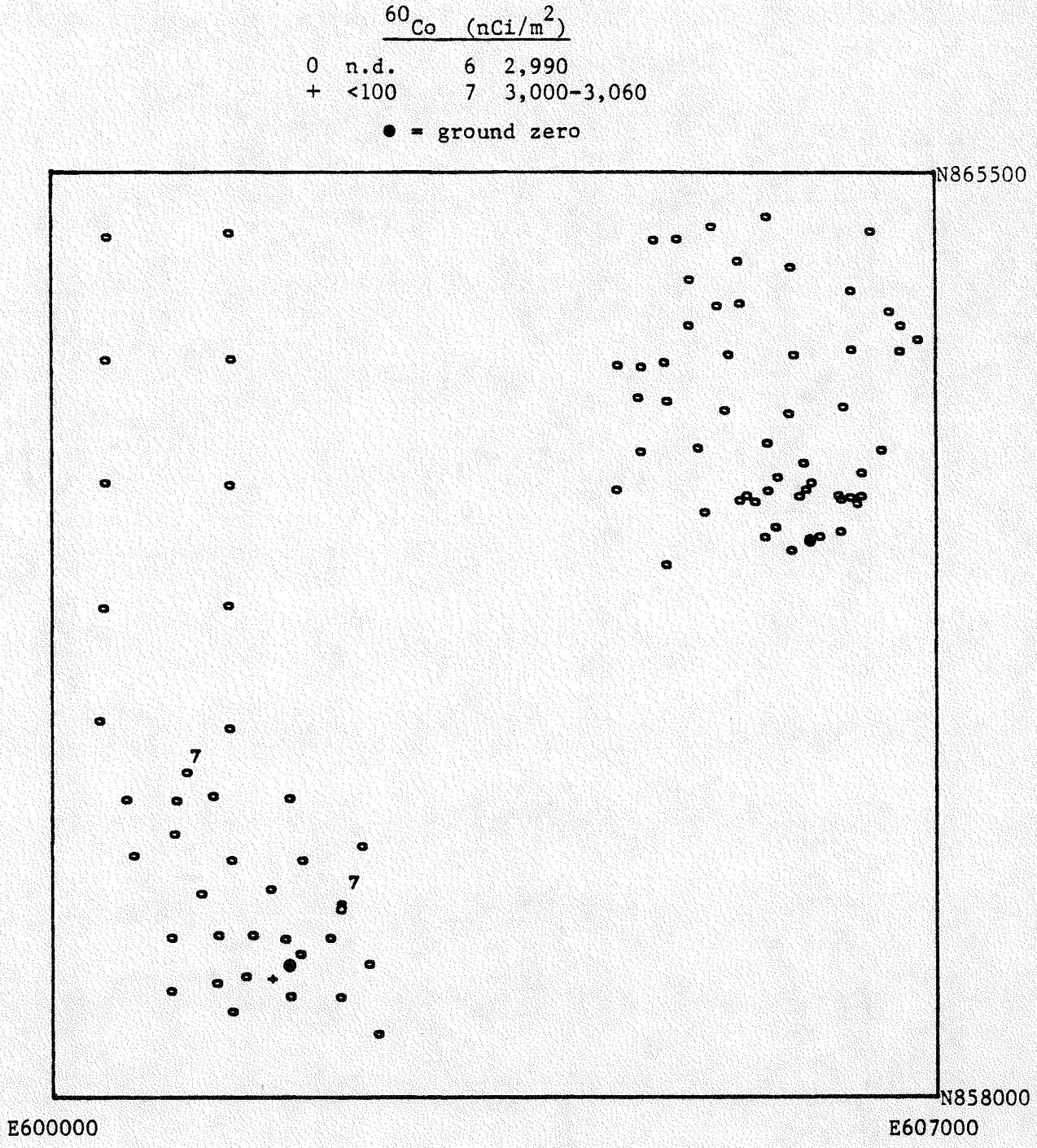


Figure 37. Measured ^{60}Co activities in the Little Feller areas.

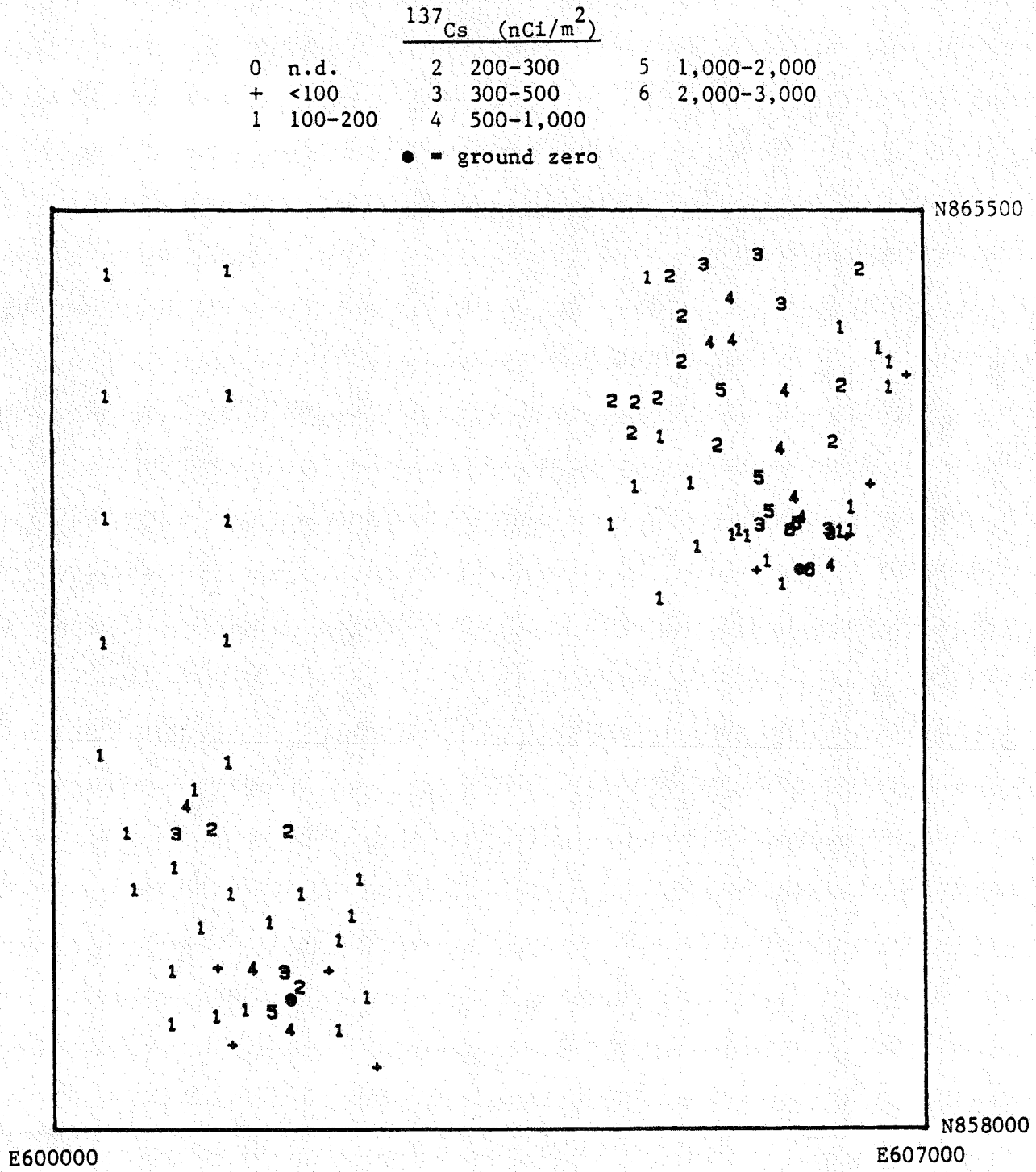


Figure 38. Measured ^{137}Cs activities in the Little Feller areas.

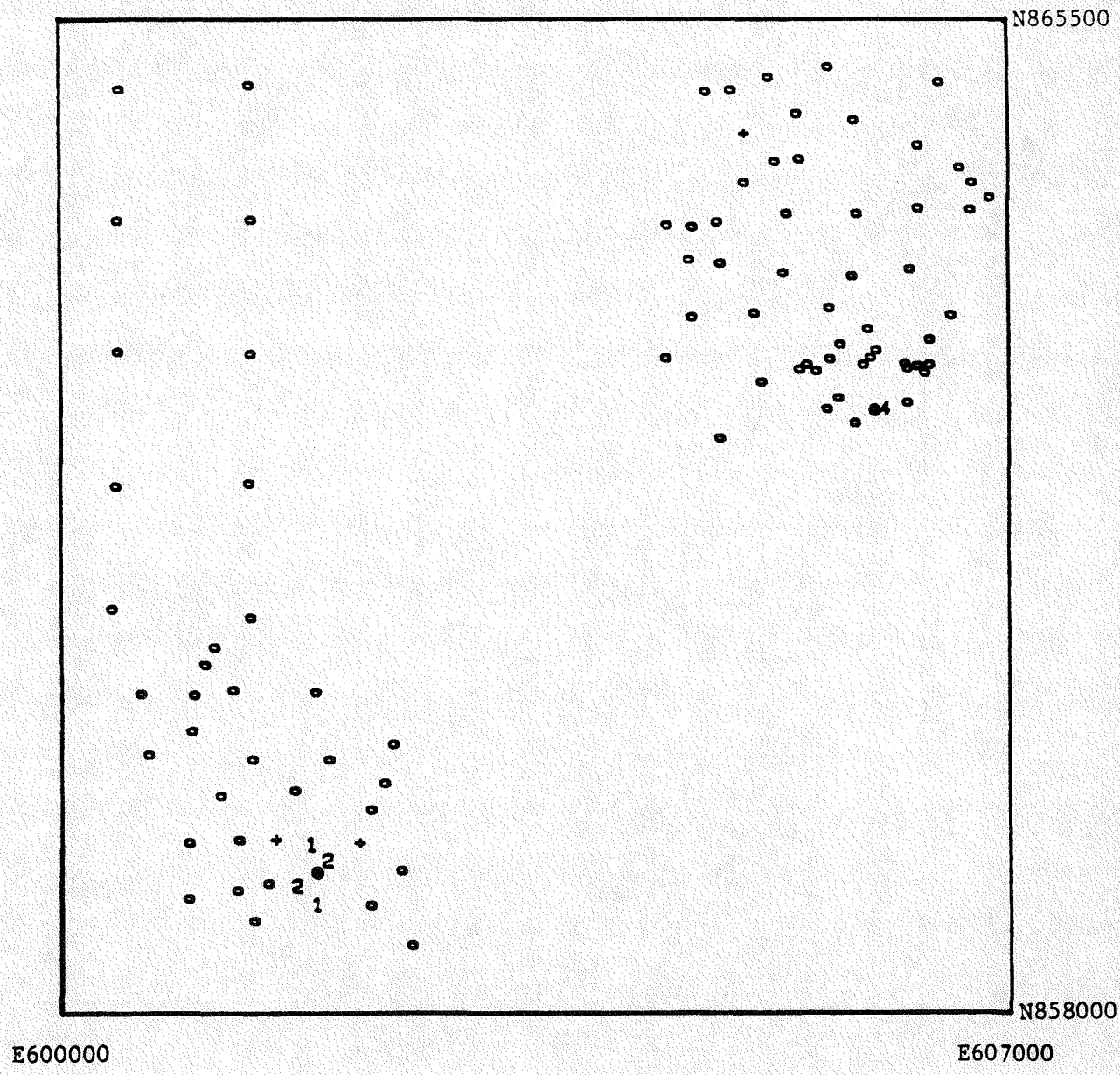


Figure 39. Measured ^{152}Eu activities in the Little Feller areas.

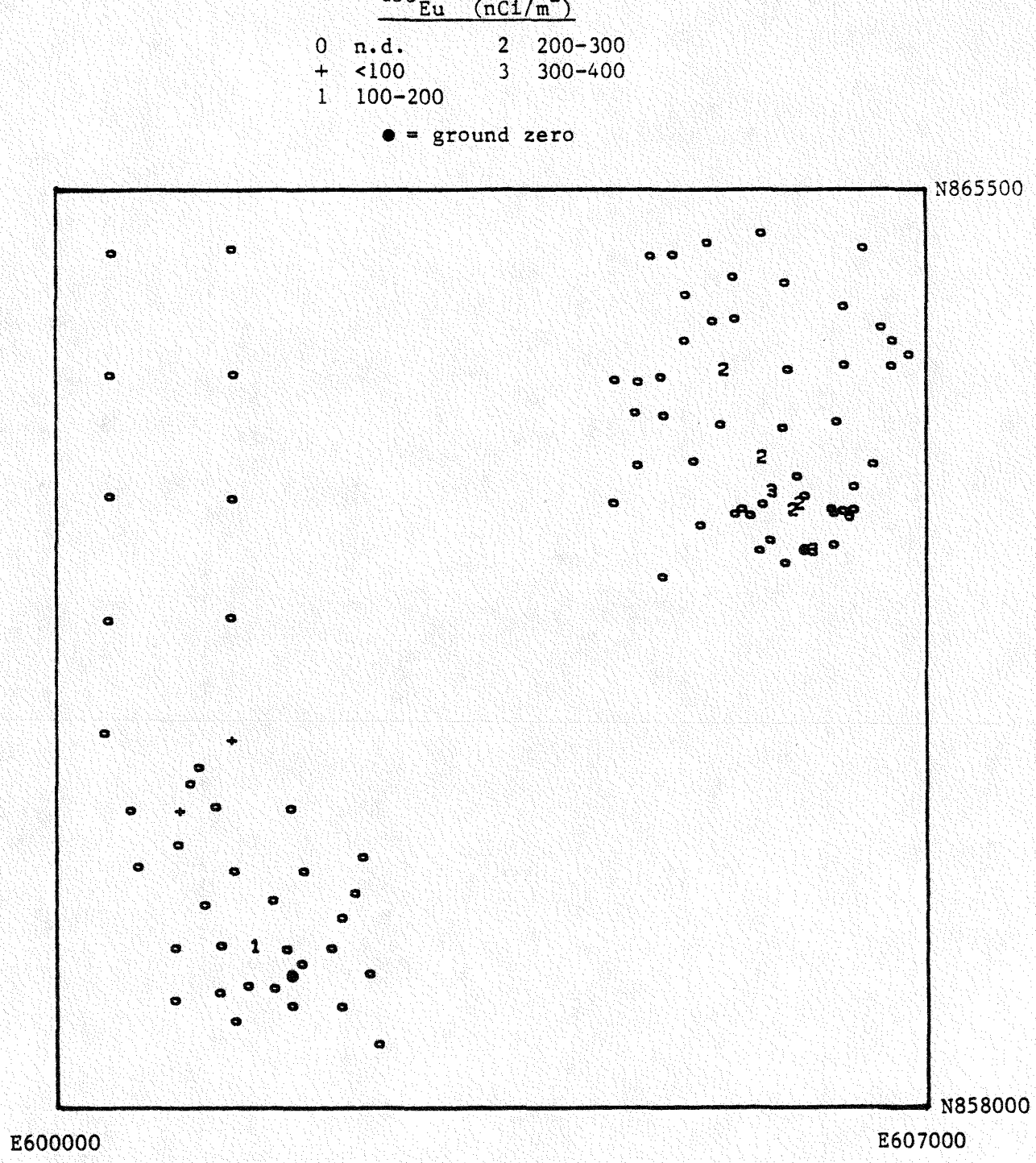


Figure 40. Measured ^{155}Eu activities in the Little Feller areas.

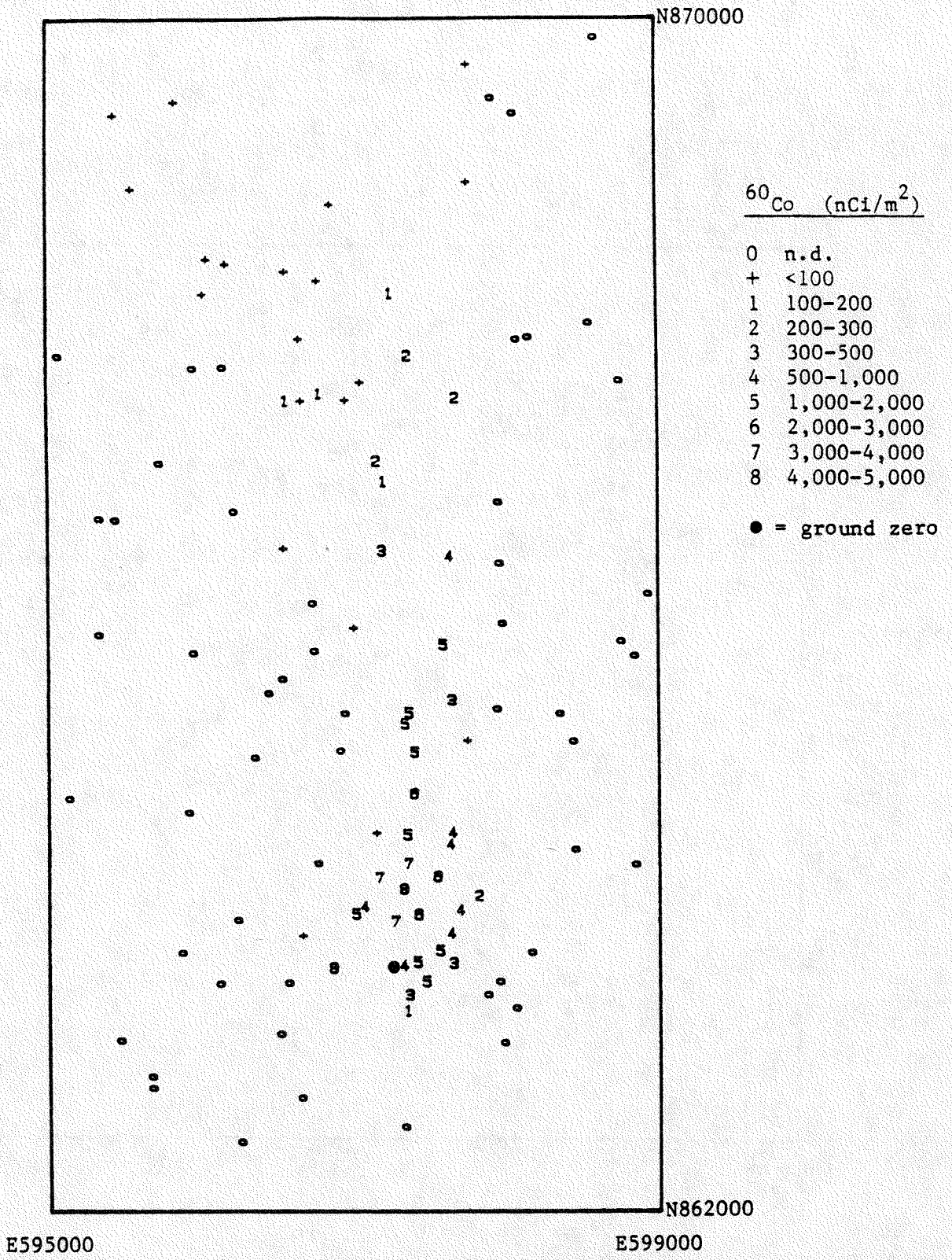


Figure 41. Measured ^{60}Co activities in the Johnie Boy GZ area.

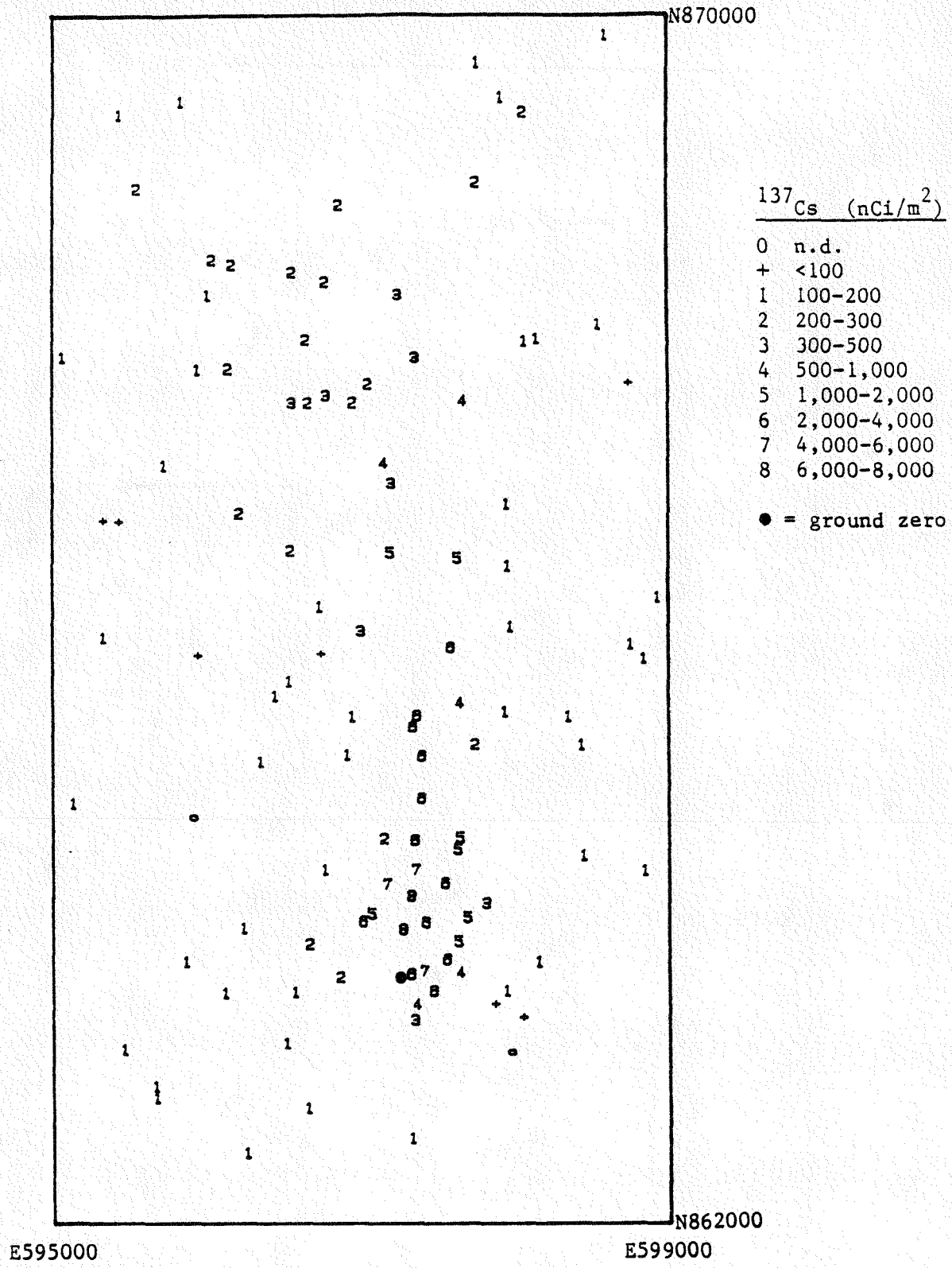


Figure 42. Measured ^{137}Cs activities in the Johnie Boy GZ area.

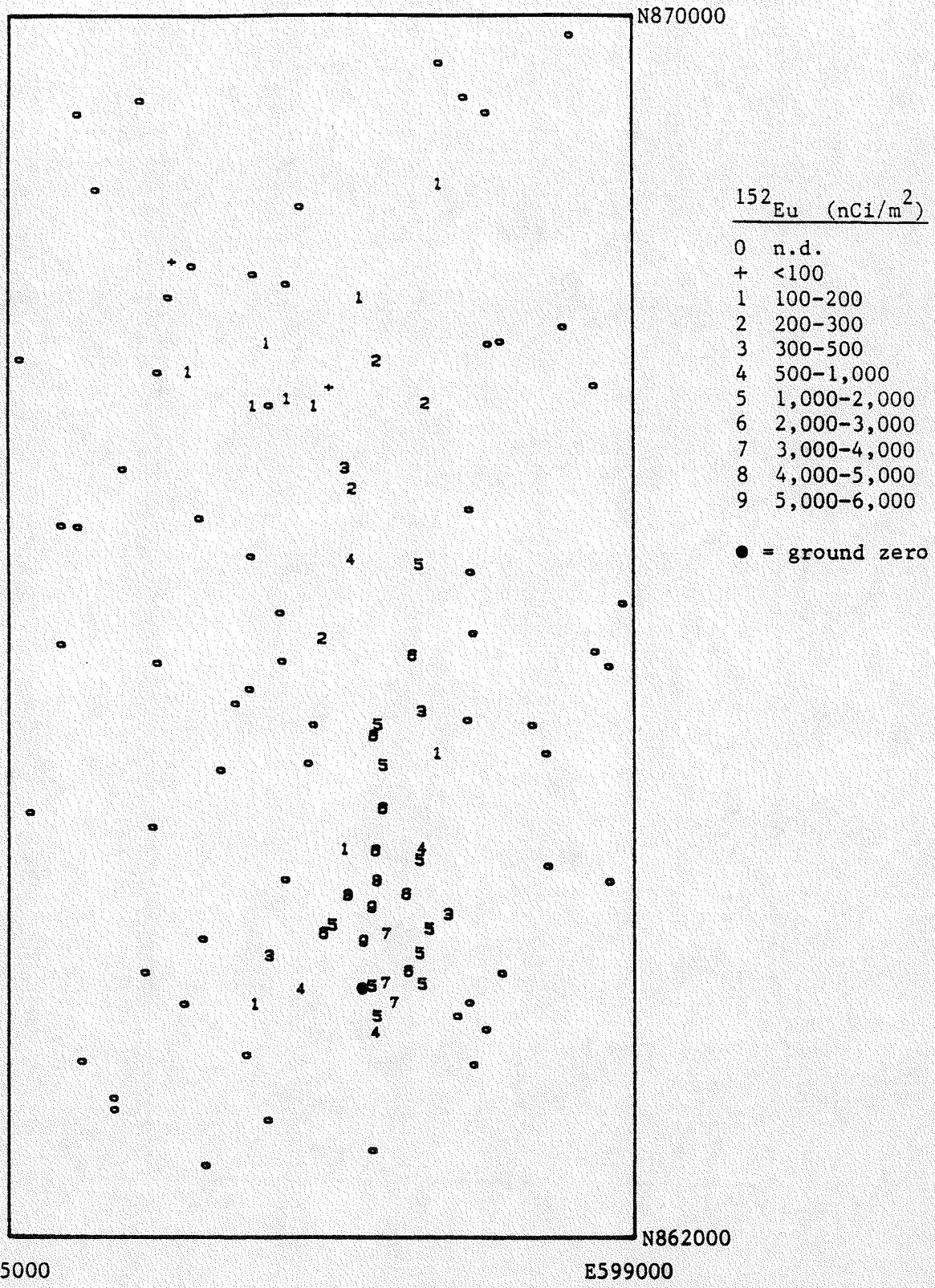


Figure 43. Measured ^{152}Eu activities in the Johnie Boy GZ area.

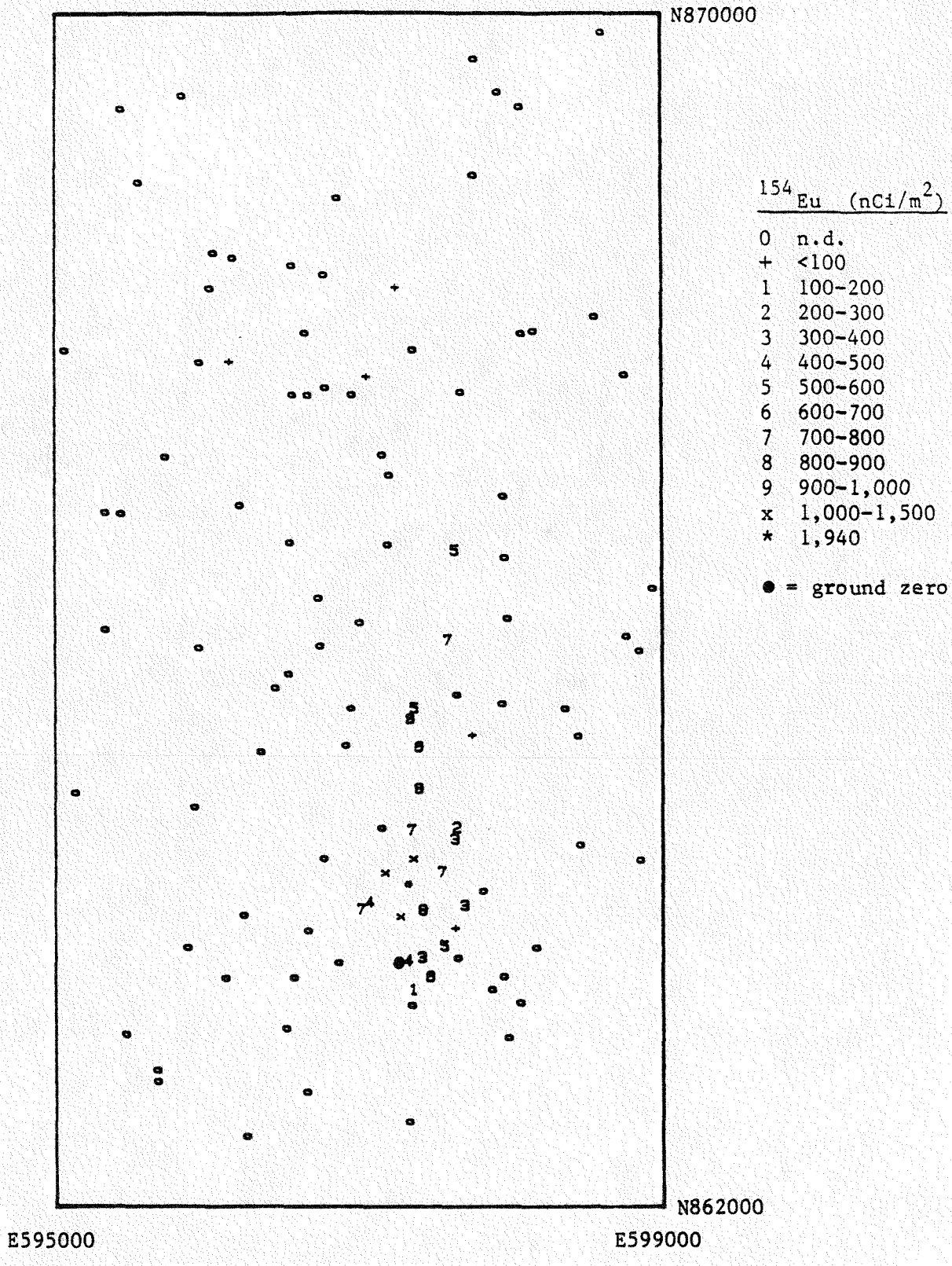


Figure 44. Measured ^{154}Eu activities in the Johnie Boy GZ area.

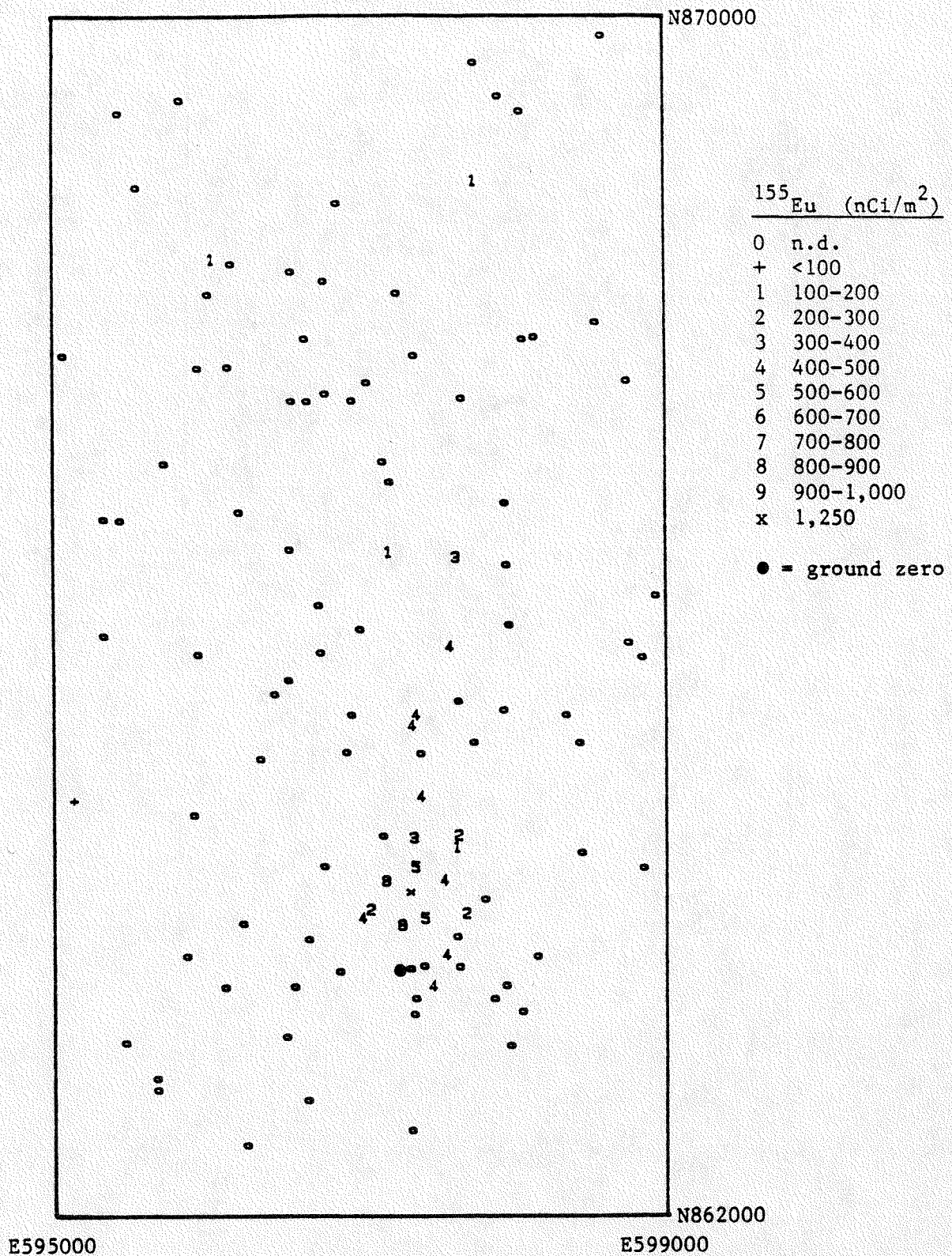


Figure 45. Measured ^{155}Eu activities in the Johnie Boy GZ area.

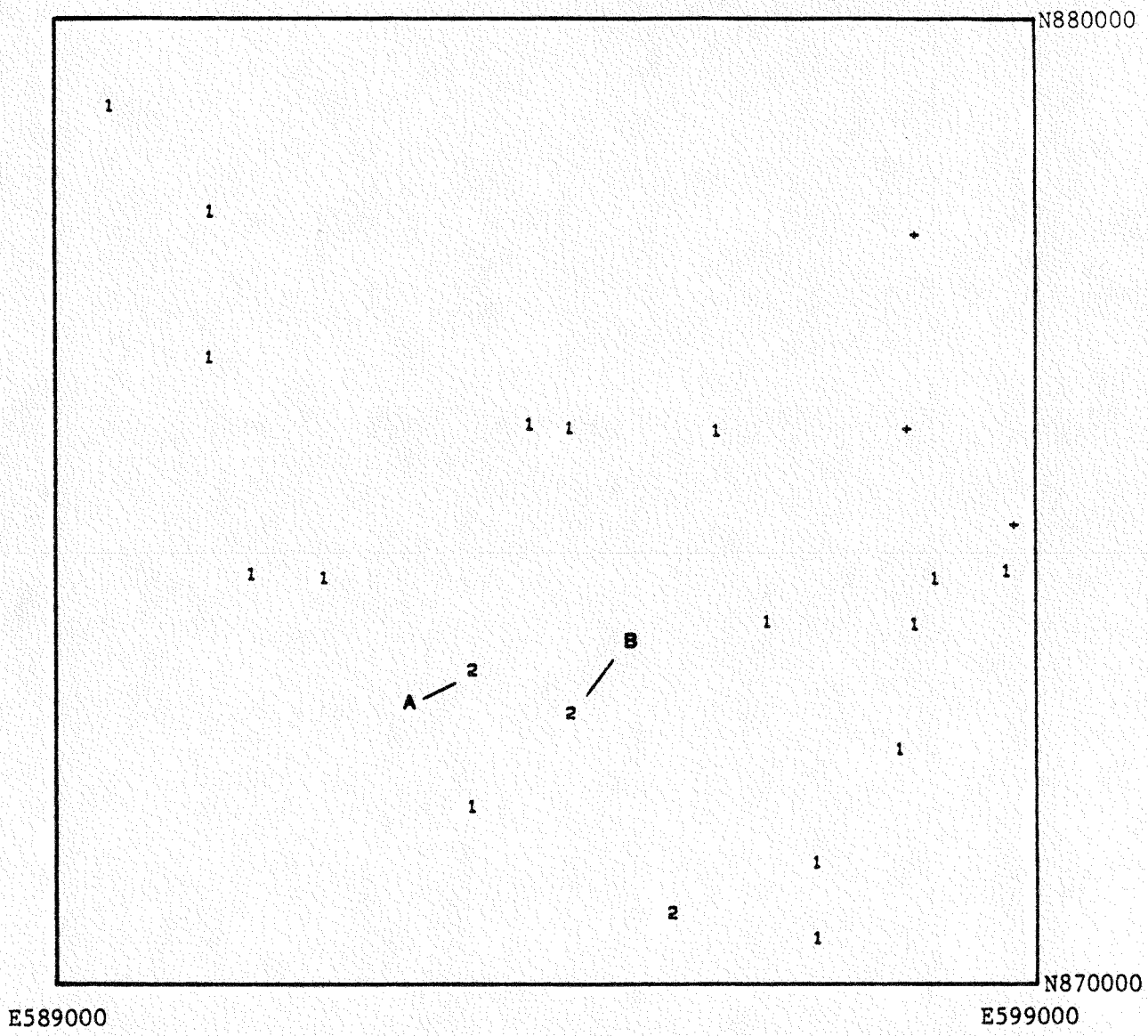


Figure 46. Measured ^{137}Cs activities north of the Johnie Boy GZ area. The only other measurements in this region which exceeded the upper limit value were 70 nCi/m^2 of Cobalt-60 at points A and B and 200 nCi/m^2 of Europium-152 at point B.

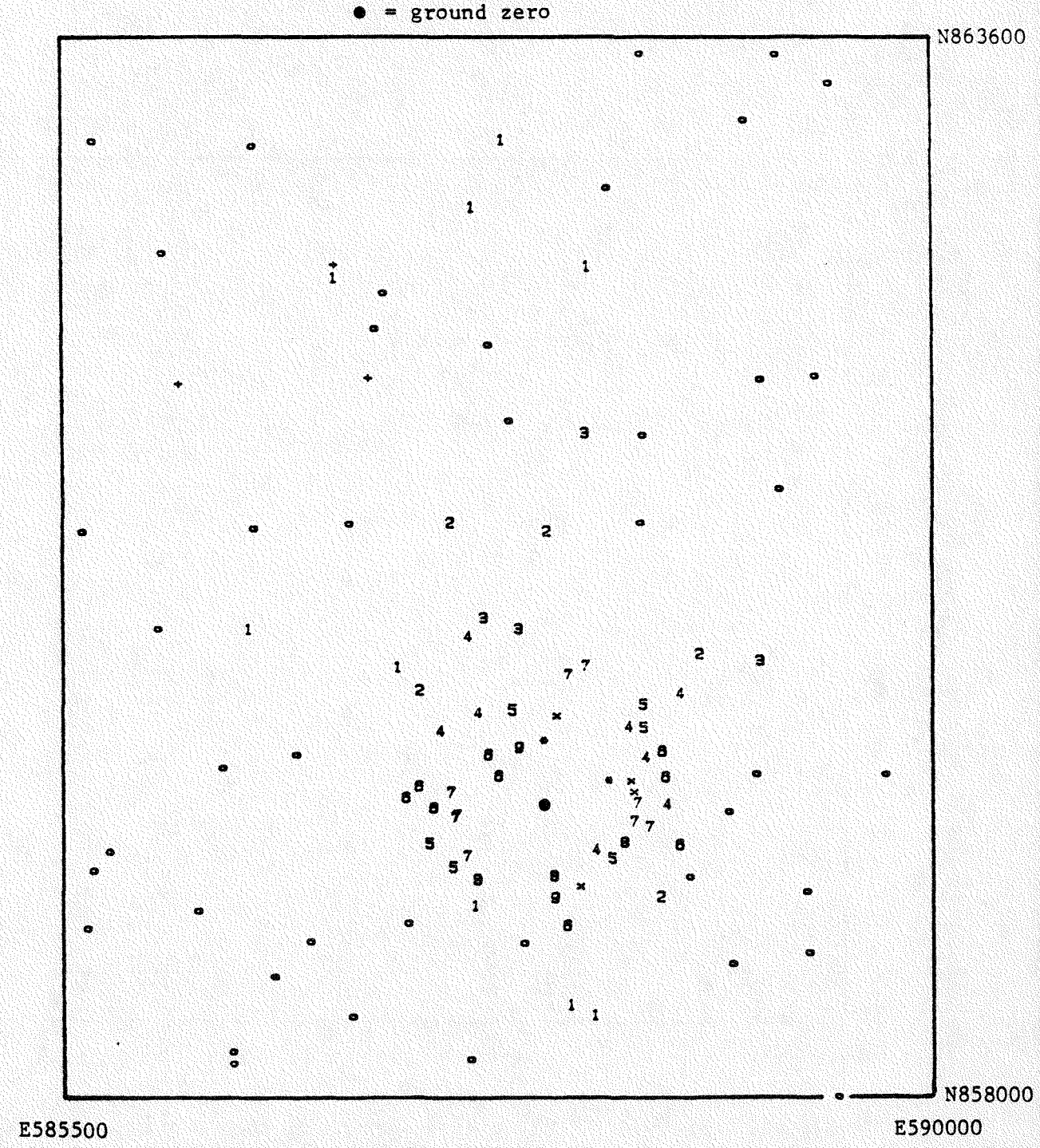


Figure 47. Measured ^{241}Am activities in the Danny Boy area.

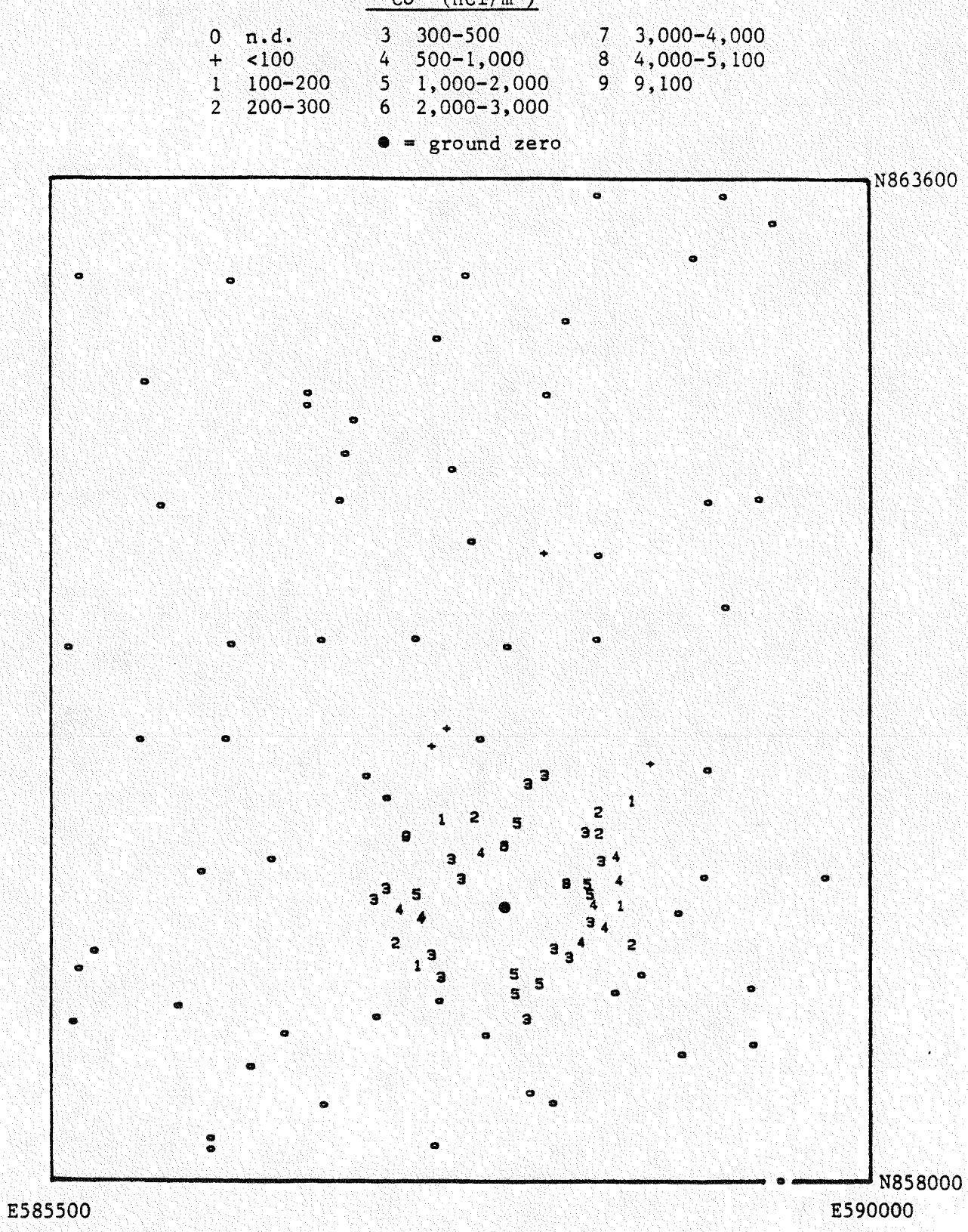


Figure 48. Measured ^{60}Co activities in the Danny Boy area.

^{137}Cs (nCi/m^2)

0	n.d.	4	500-1,000	8	8,000-10,000
+	<100	5	1,000-2,500	9	10,000-15,500
1	100-200	6	3,000-5,000	x	20,000-26,000
2	200-300	7	5,000-8,000	*	35,000
3	300-500	● = ground zero			

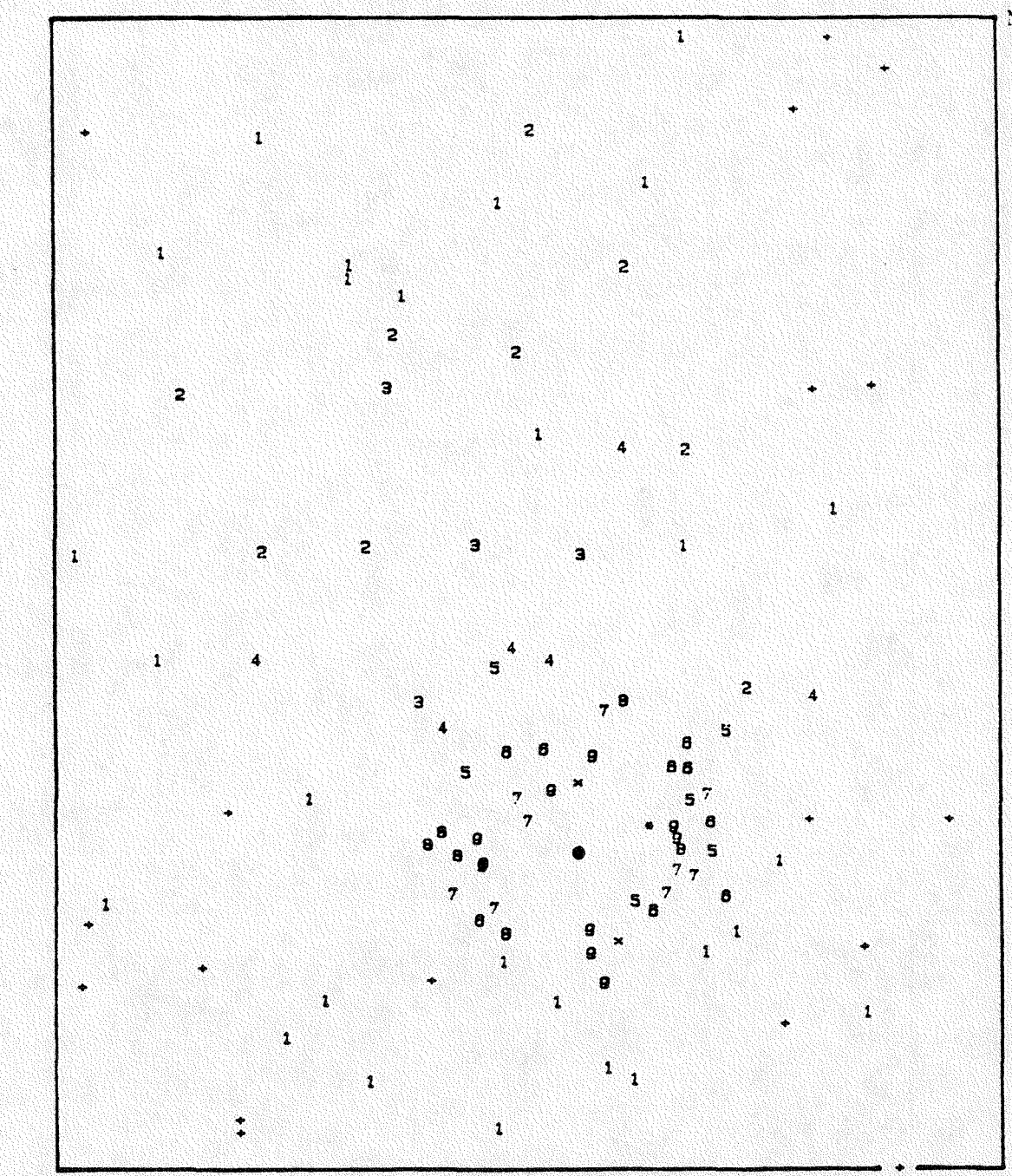


Figure 49. Measured ^{137}Cs activities in the Danny Boy area.

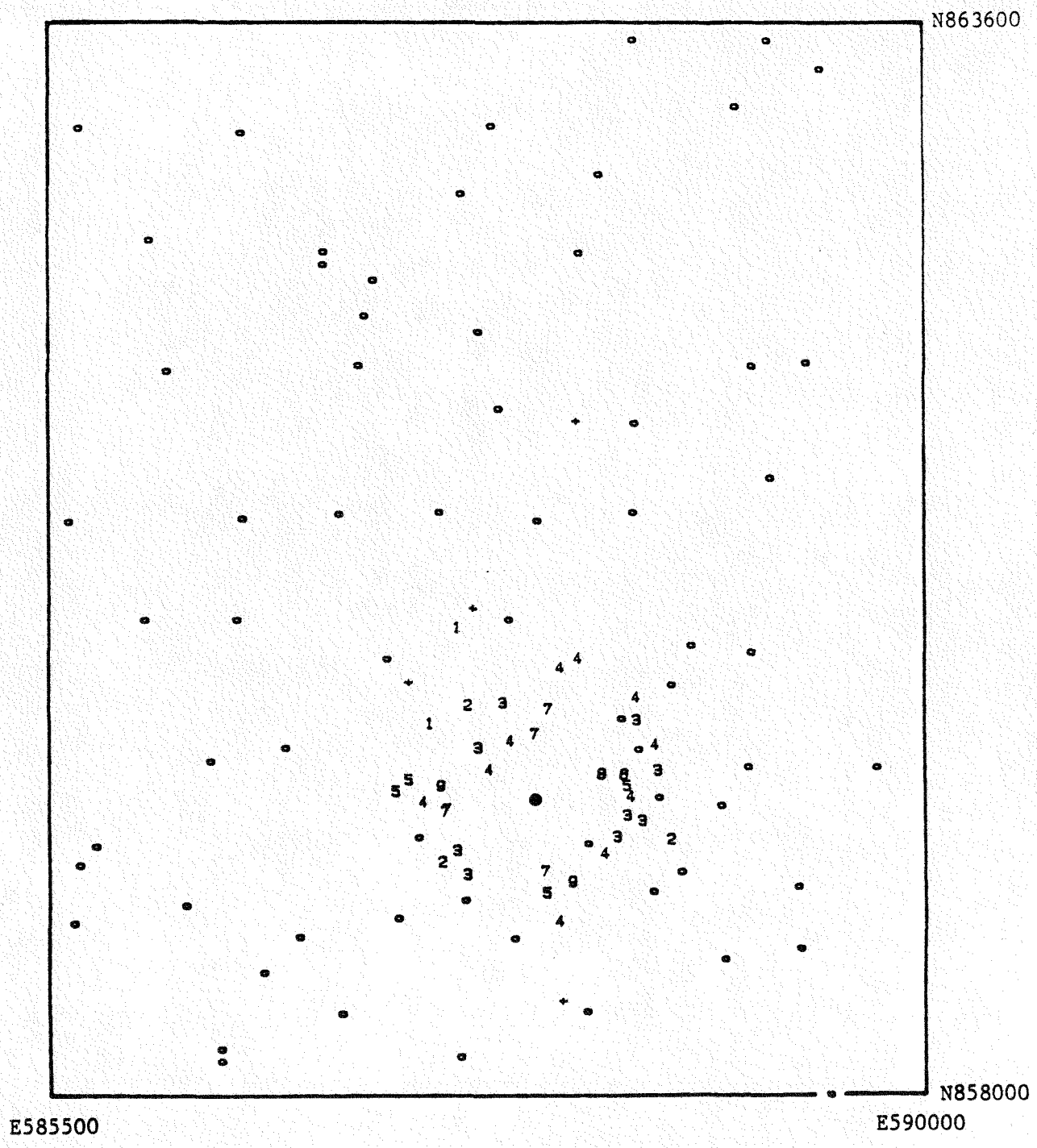


Figure 50. Measured ^{152}Eu activities in the Danny Boy area.

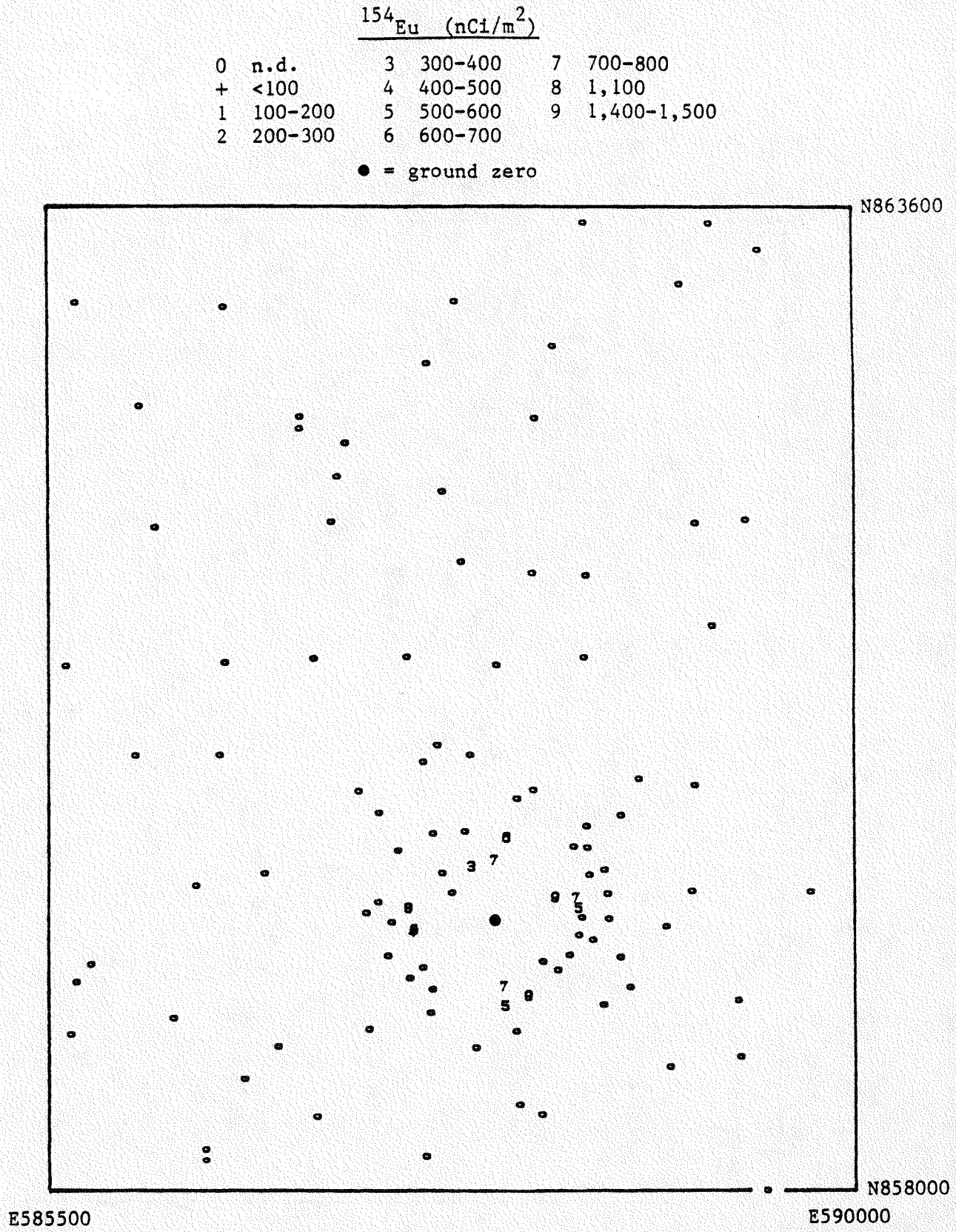


Figure 51. Measured ^{154}activities in the Danny Boy area.

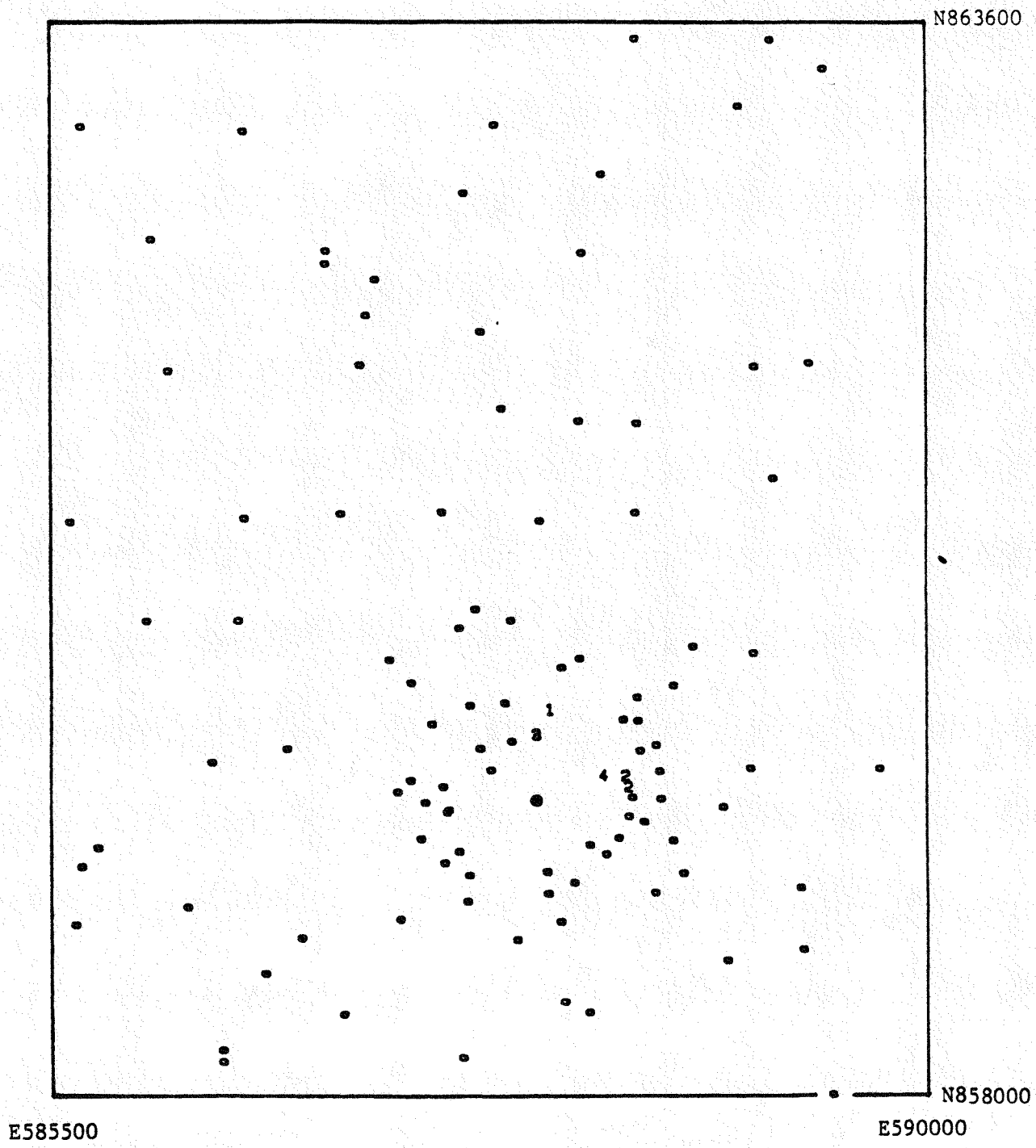


Figure 52. Measured ^{155}Eu activities in the Danny Boy area.

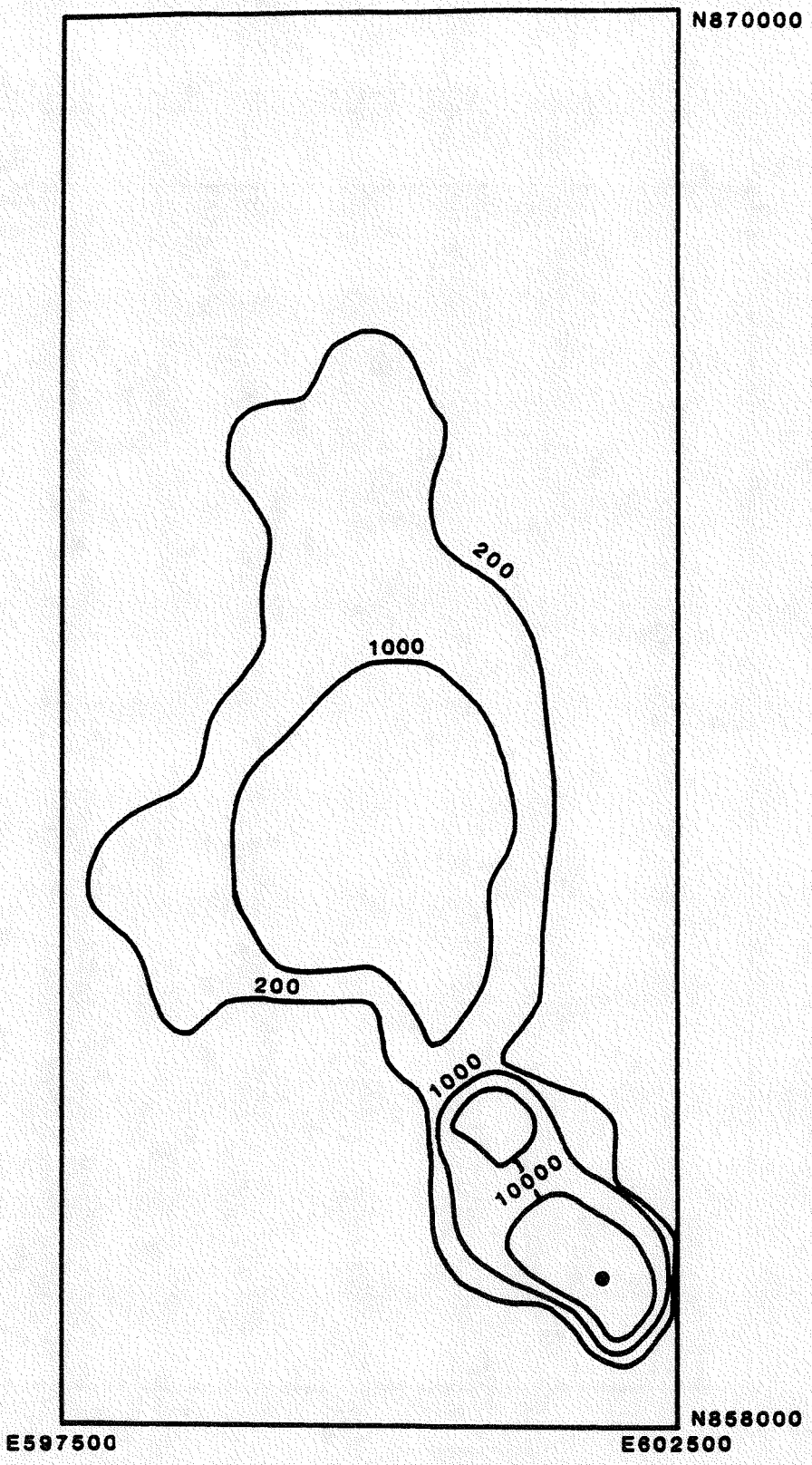


Figure 53. Distribution of ^{241}Am (nCi/m^2) in the Little Feller I area.

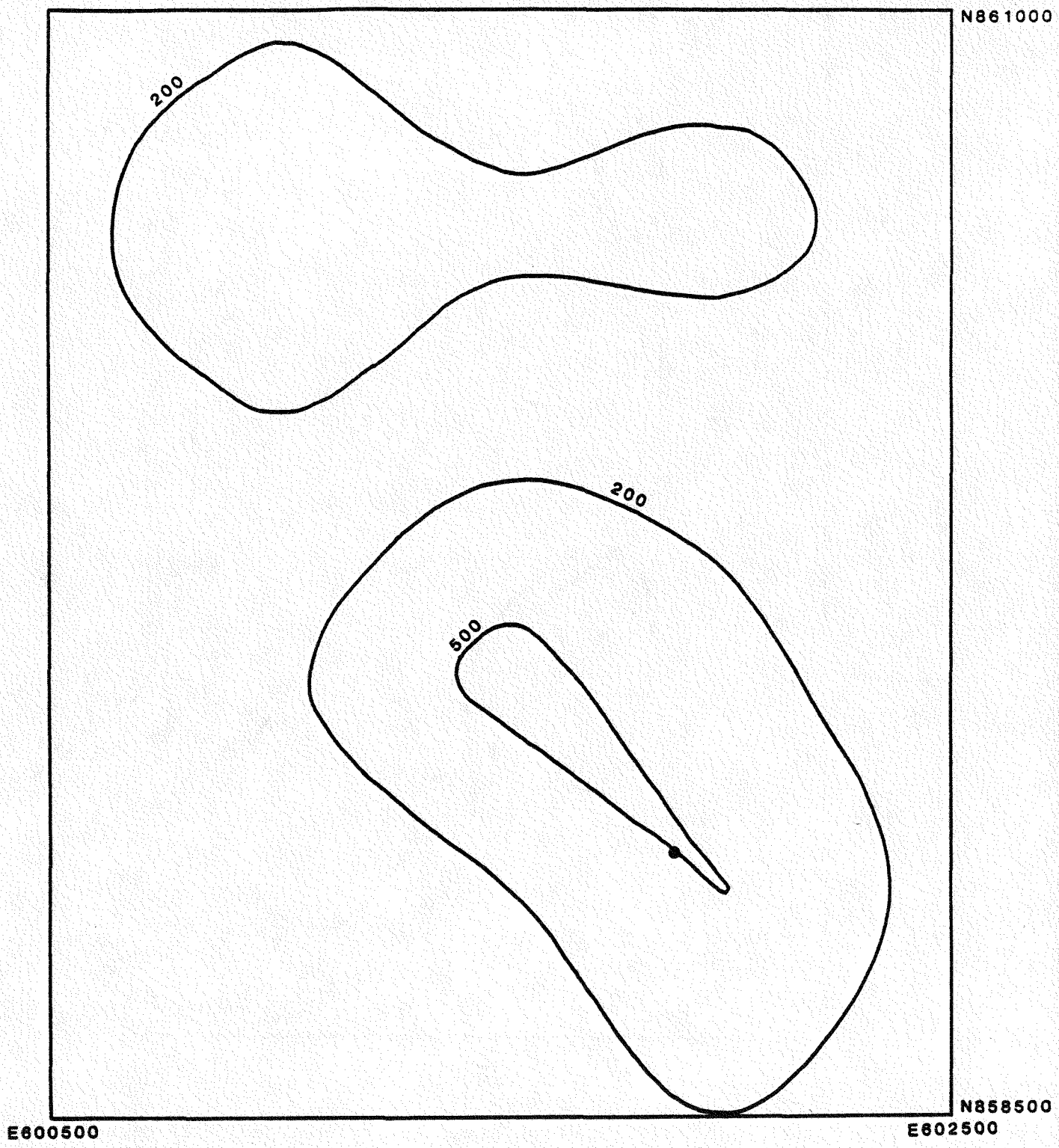


Figure 54. Distribution of ^{137}Cs (nCi/m^2) in the Little Feller I area.

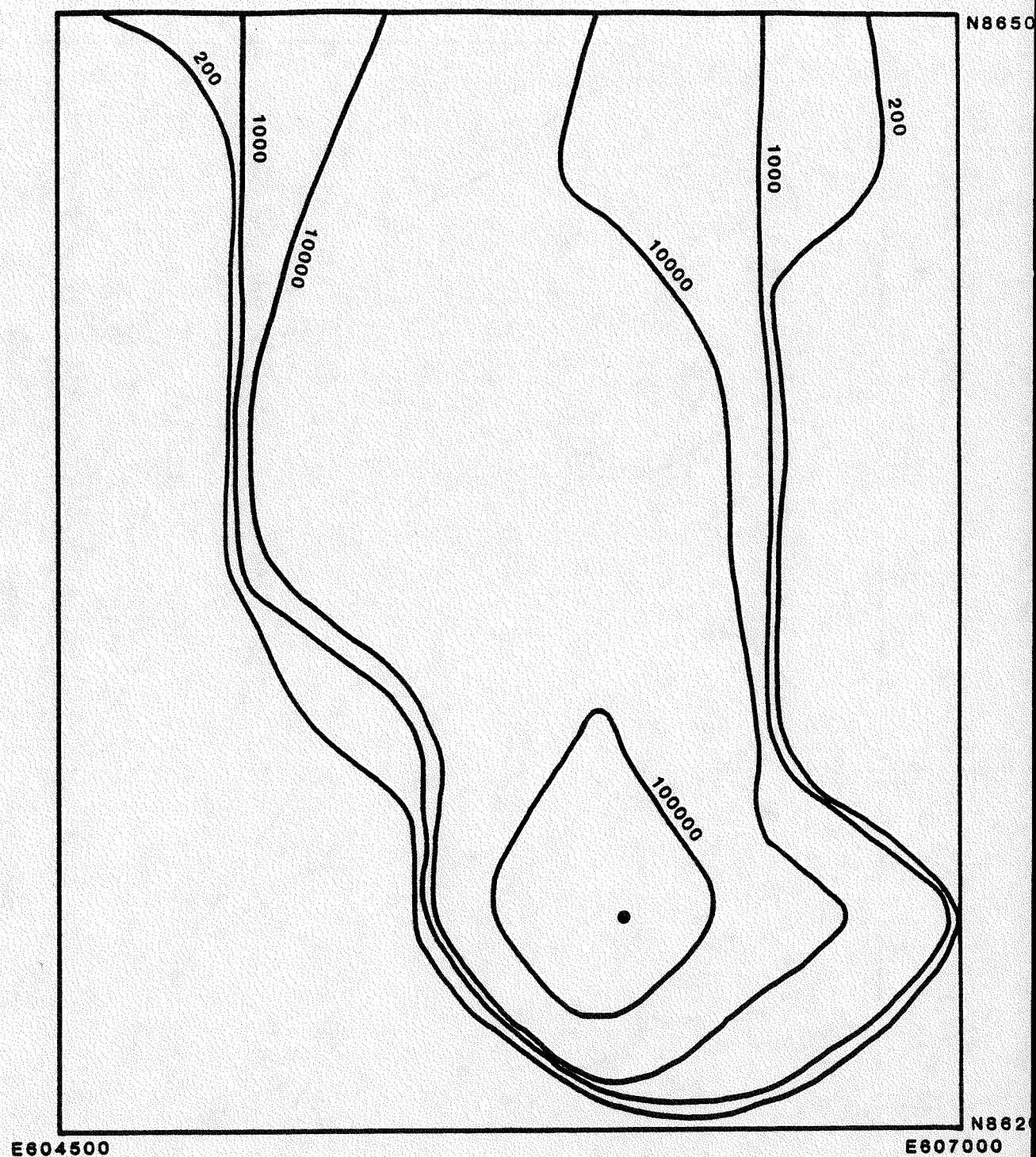


Figure 55. Distribution of ^{241}Am (nCi/m^2) in the Little Feller II area.

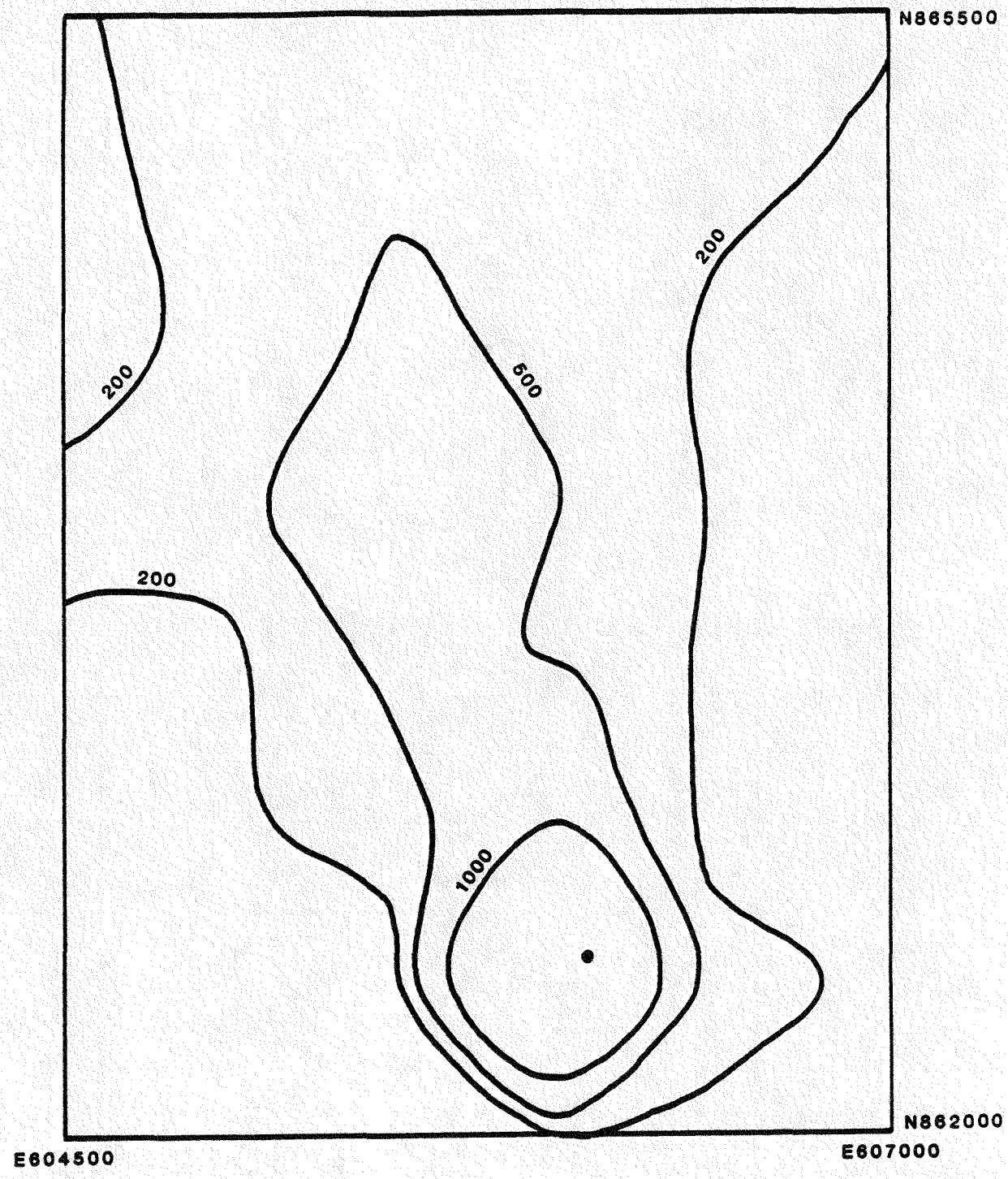


Figure 56. Distribution of ^{137}Cs (nCi/m^2) in the Little Feller II area.

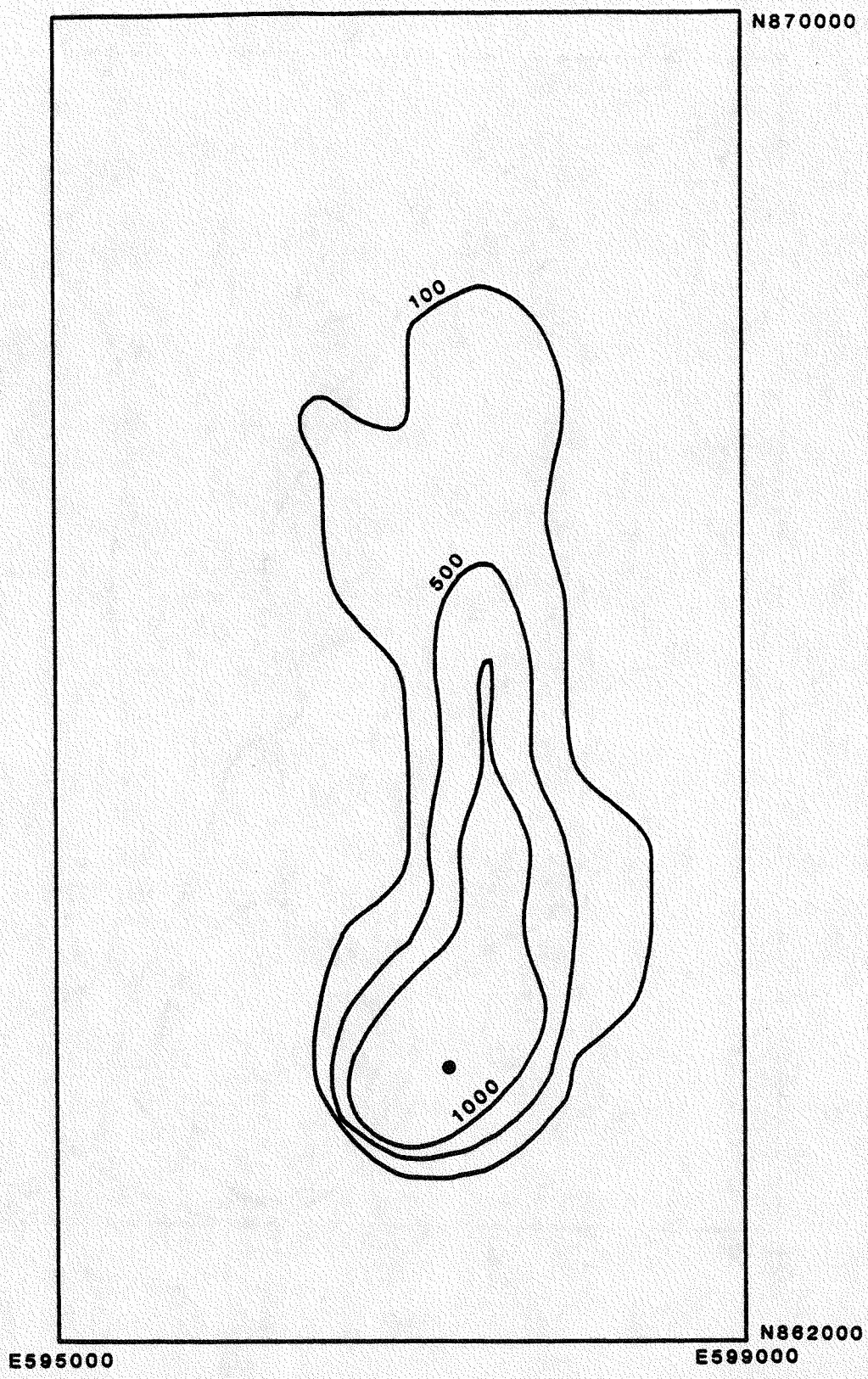


Figure 57. Distribution of ^{60}Co (nCi/m^2) in the Johnie Boy area.

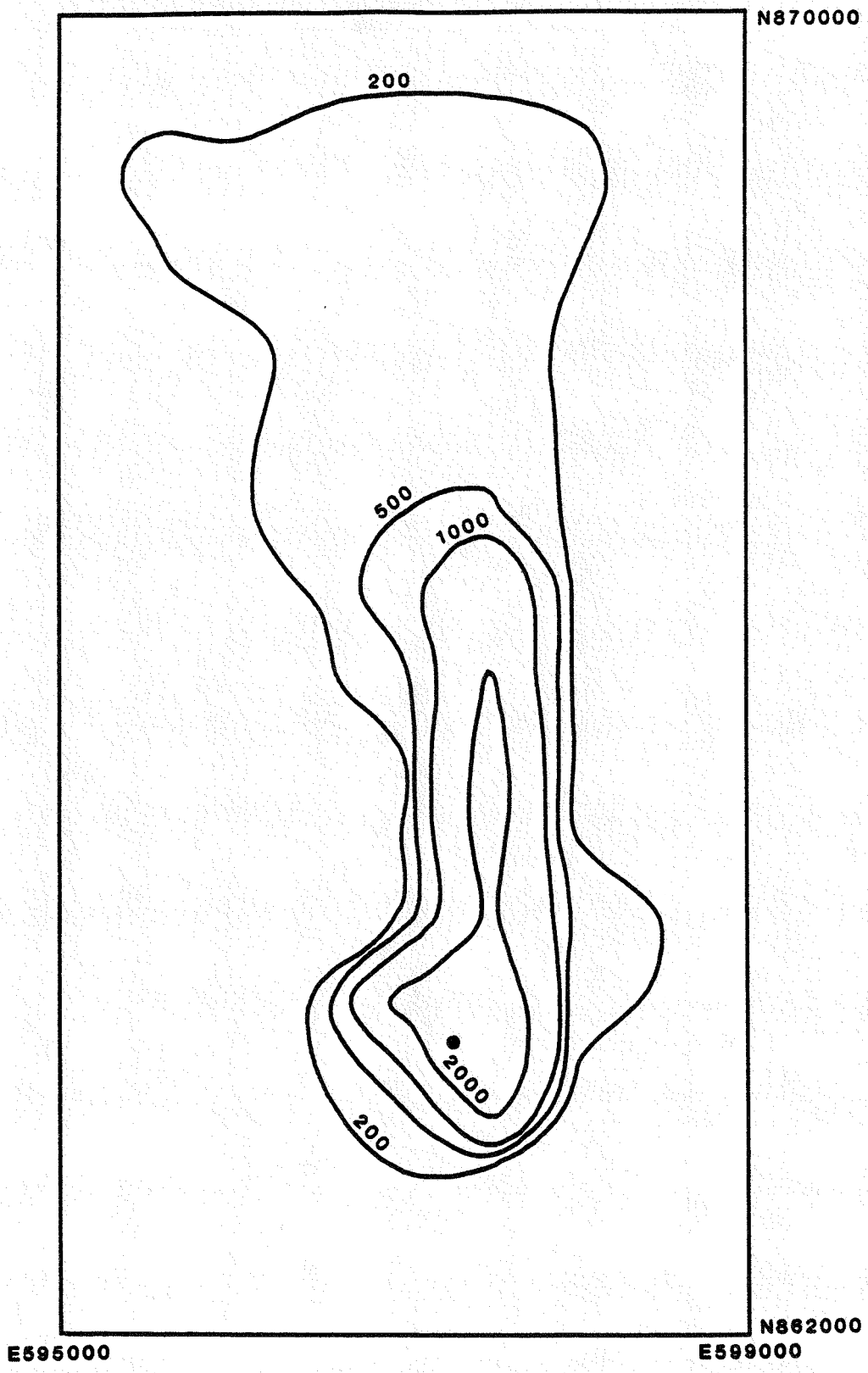


Figure 58. Distribution of ^{137}Cs (nCi/m^2) in the Johnie Boy area.

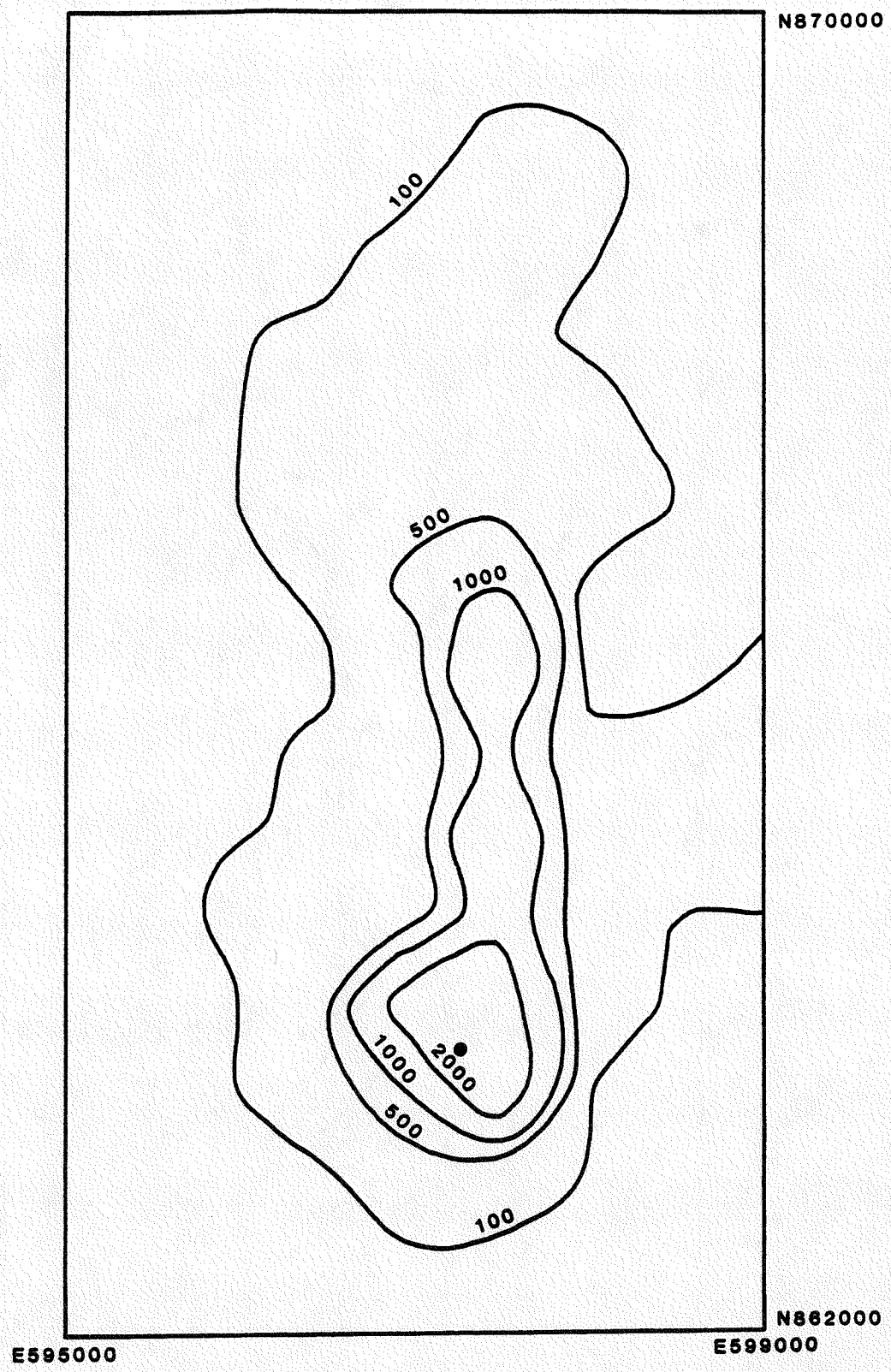


Figure 59. Distribution of ^{152}Eu (nCi/m^2) in the Johnie Boy area.

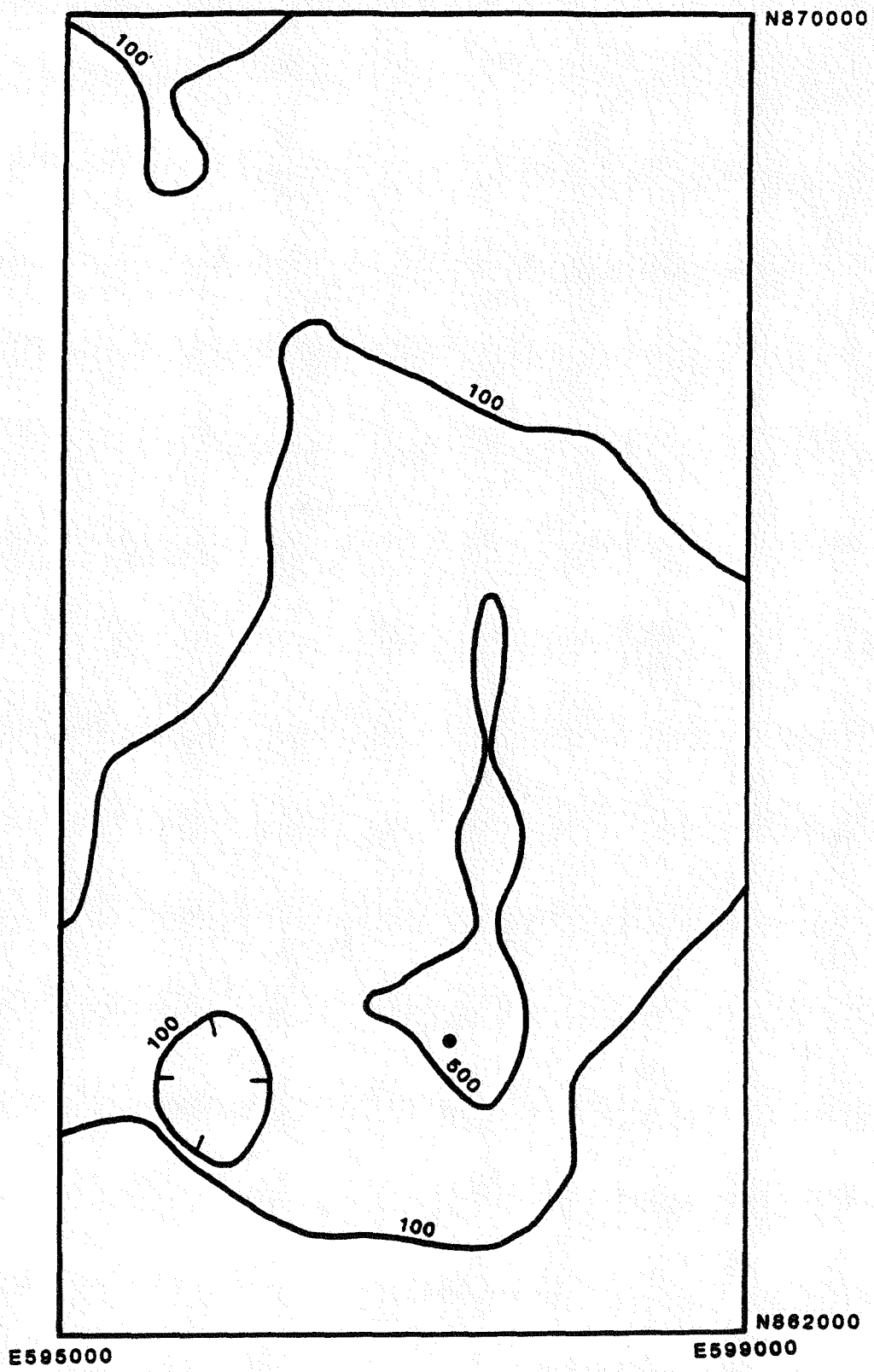


Figure 60. Distribution of ^{154}Eu (nCi/m^2) in the Johnie Boy area.

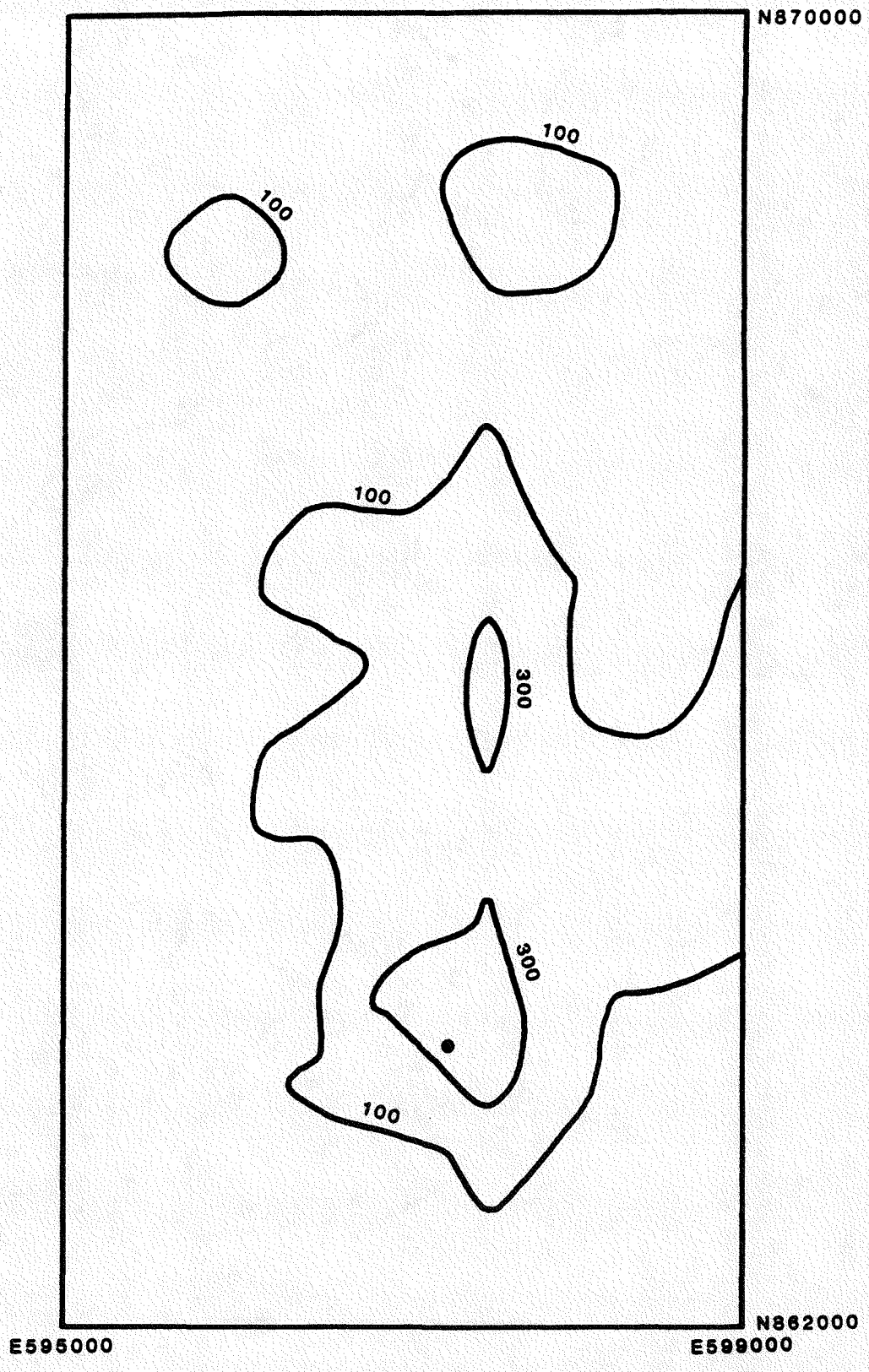


Figure 61. Distribution of ^{155}Eu (nCi/m^2) in the Johnie Boy area.

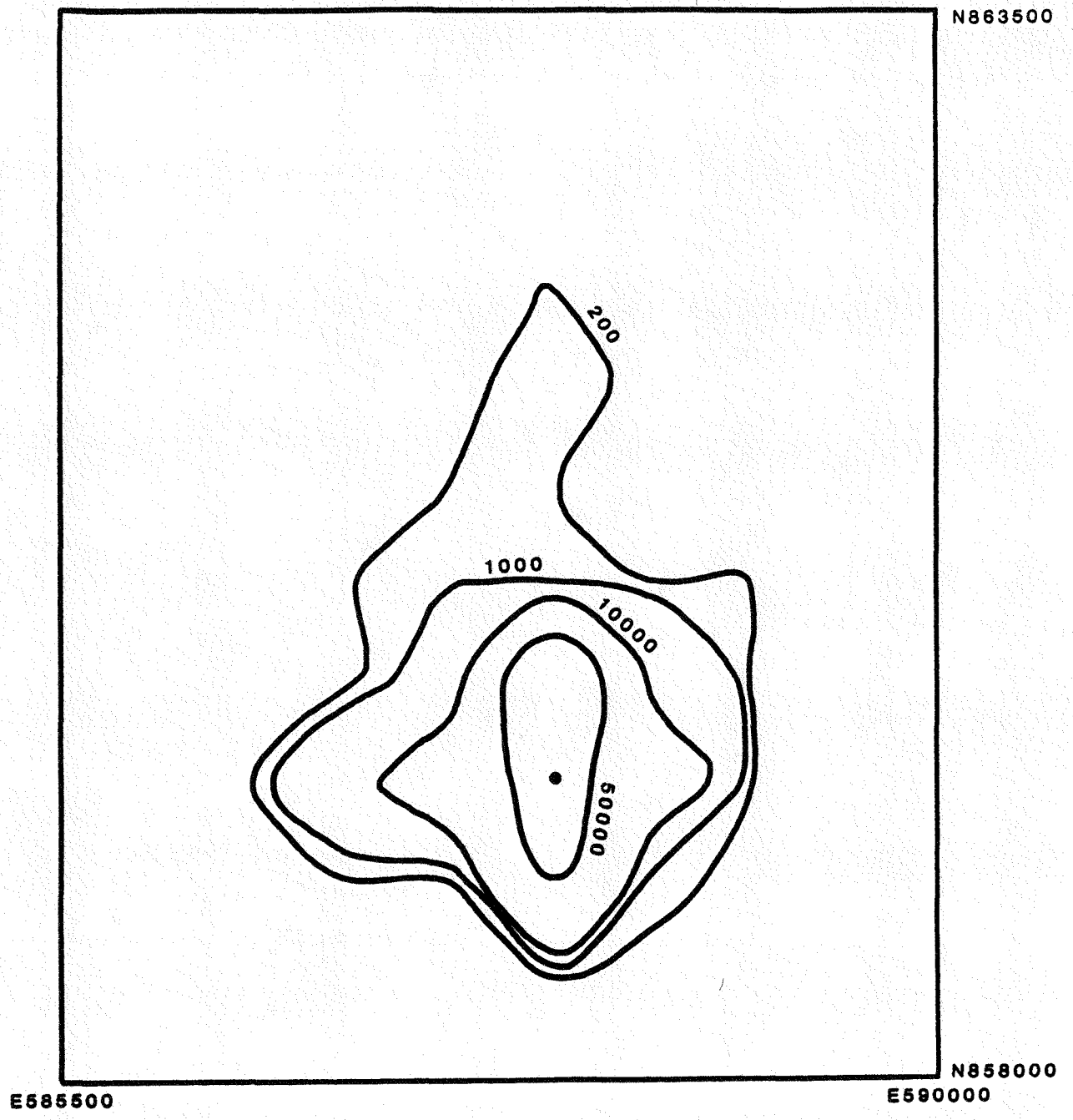


Figure 62. Distribution of ^{241}Am (nCi/m^2) in the Danny Boy area.

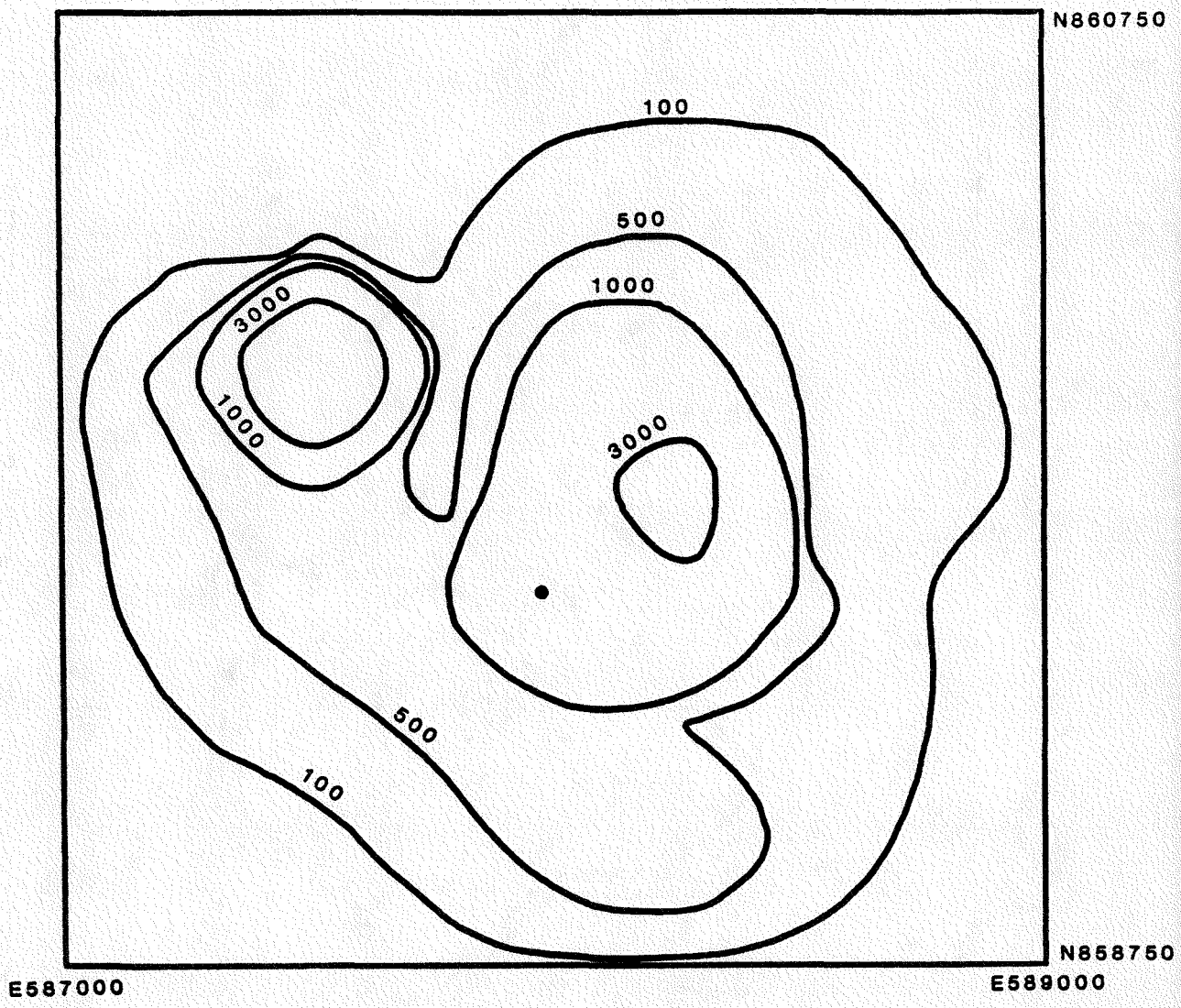


Figure 63. Distribution of ^{60}Co (nCi/m^2) in the Danny Boy area.

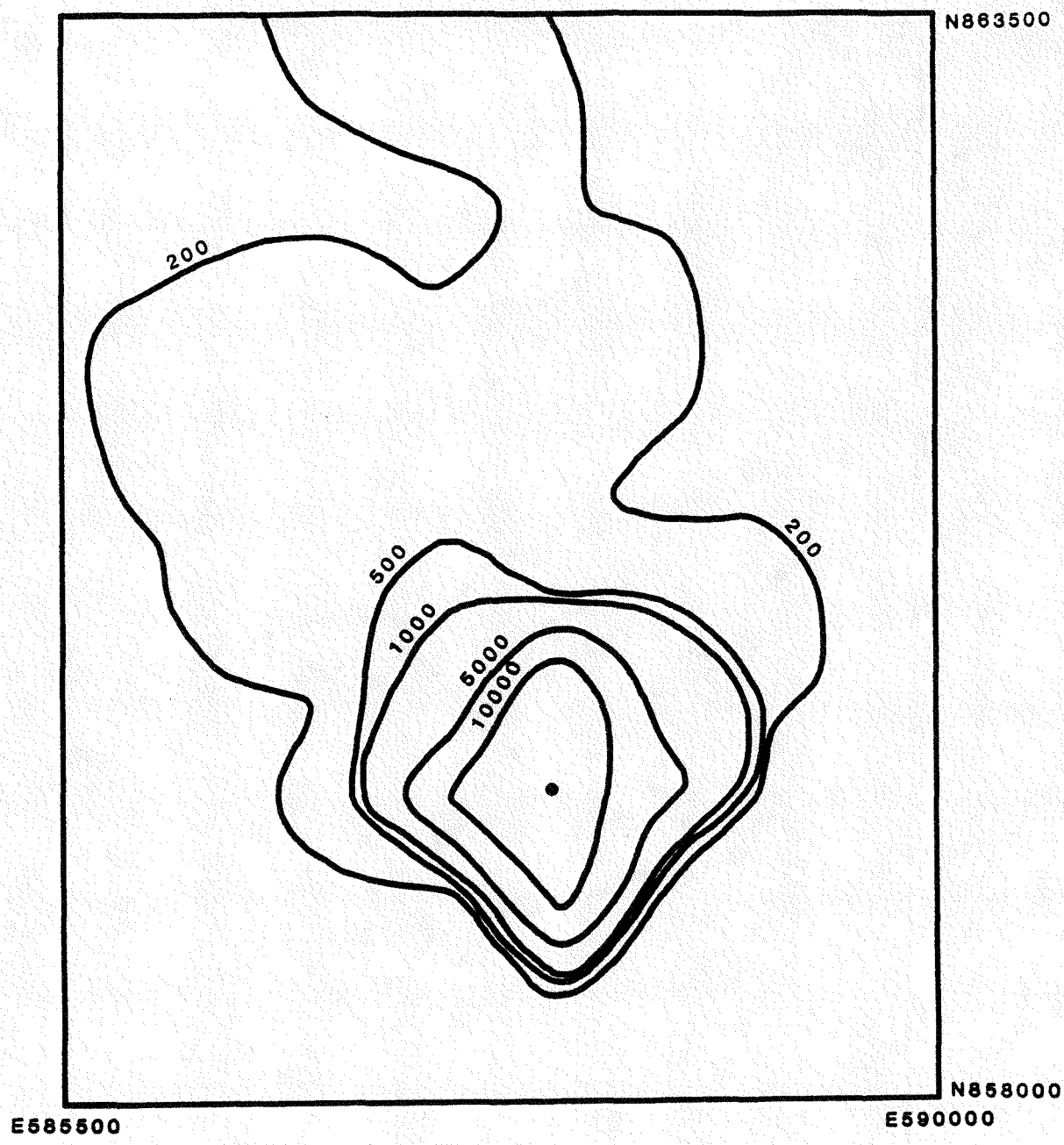


Figure 64. Distribution of ^{137}Cs (nCi/m^2) in the Danny Boy area.

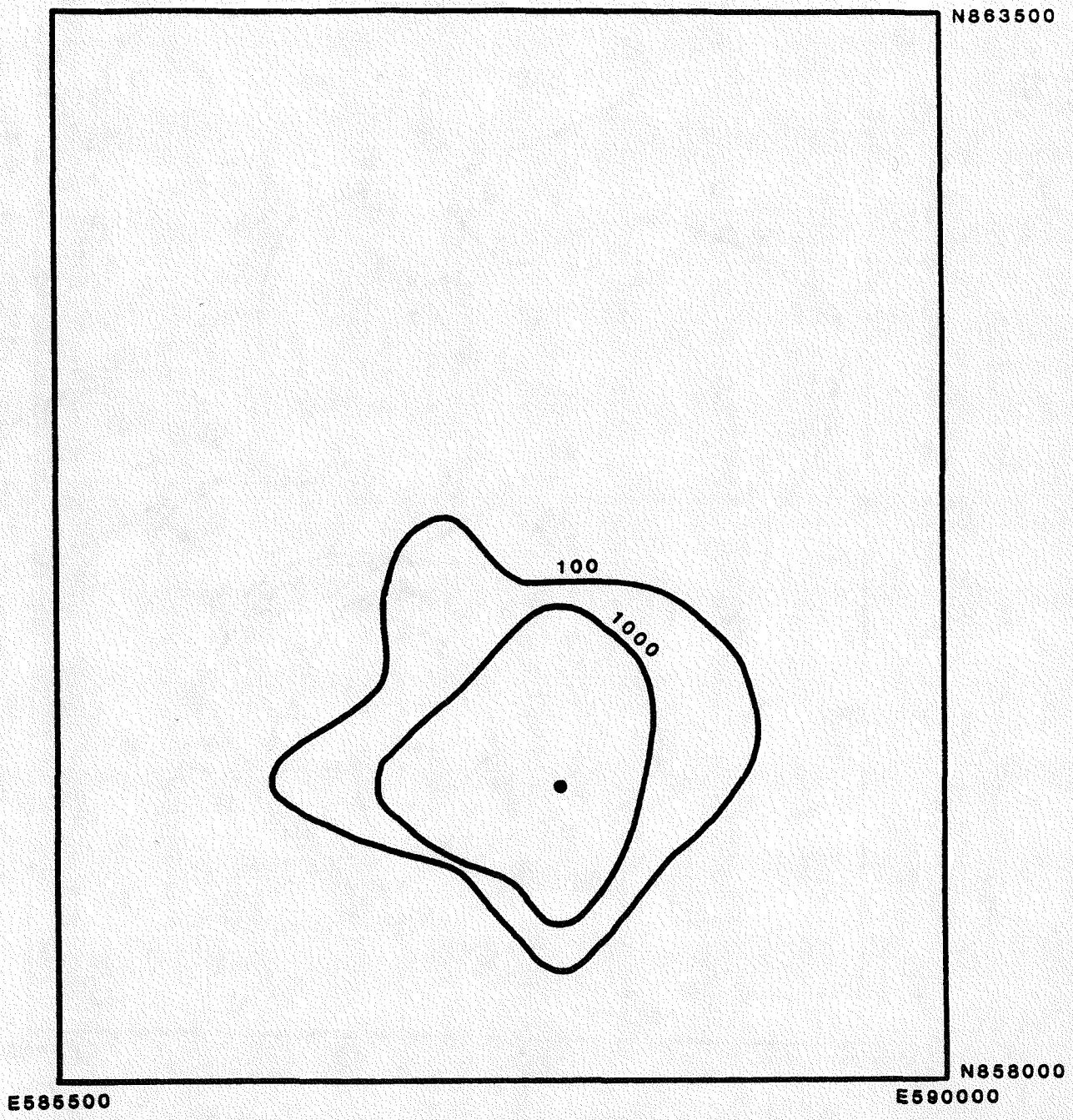


Figure 65. Distribution of ^{152}Eu (nCi/m^2) in the Danny Boy area.

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APPENDIX A
LOCATIONS OF SOIL SAMPLES

APPENDIX A: LOCATIONS OF SOIL SAMPLES

Listed below are the Nevada Grid Coordinates and original designation of each sample location and the library numbers assigned to the samples. Only the event name is given as the original designation for NAEG samples.

Point	Coordinates East	Coordinates North	Original Designation	Library Numbers
1	532251	944253	Schooner 14	20354-357
2	531750	943769	Schooner 20	20358-361
3	529901	941384	Schooner 43	20362-365
4	529667	941644	Schooner 50	20366-369
5	531738	941738	Schooner 54	20370-373
6	532277	941262	Schooner 62	20375-378
7	533741	940867	Schooner 78	20379-382
8	533668	940521	Schooner 79	20383-386
9	597664	867459	Johnie Boy 60	20573-576
10	597623	866408	Johnie Boy 70	20577-580
11	597391	865089	Johnie Boy 90	20581-584
12	597343	864531	Johnie Boy 99	20585-588
13	597319	864165	Johnie Boy 108	20589-592
14	597809	864119	Johnie Boy 111	20594-597
15	597006	863997	Johnie Boy 113	20598-601
16	597265	863946	Johnie Boy 114	20602-605
17	597413	863992	Johnie Boy 115	20606-609
18	596656	863849	Johnie Boy 116	20610-613
19	597625	863867	Johnie Boy 117	20615-618
20	598154	863734	Johnie Boy 121	20619-622
21	597406	863672	Johnie Boy 123	20623-626
22	597340	863349	Johnie Boy 131	20627-630
23	602565	858514	Little Feller I 1	20816-819
24	601405	858694	Little Feller I 2	20820-823
25	602263	858815	Little Feller I 5	20824-827
26	601510	858981	Little Feller I 7	20828-831
27	601826	859281	Little Feller I 11	20832-835
28	601569	859311	Little Feller I 15	20837-840
29	602268	859540	Little Feller I 16	20841-844
30	601162	859645	Little Feller I 17	20845-848
31	600970	860411	Little Feller I 26	20849-852
32	586770	858822	Danny Boy 8	20960-963
33	588958	858702	Danny Boy 10	20964-967
34	587275	858918	Danny Boy 13	20968-971
35	588585	859055	Danny Boy 23	20972-975
36	587579	859269	Danny Boy 27	20976-979
37	588248	859302	Danny Boy 35	20981-984
38	587742	859695	Danny Boy 41	20985-988
39	588434	859665	Danny Boy 56	20989-992
40	587441	859936	Danny Boy 59	20993-996
41	588684	860135	Danny Boy 66	20997-21000
42	587221	860274	Danny Boy 68	21002-005
43	606017	862204	(Little Feller II)	17169-174
44	605742	862289	"	17179-182
45	605967	862509	"	17185-190
46	606042	862474	"	17193-198
47	605941	862557	"	17203-208
48	605852	862369	"	17211-216
49	605867	862319	"	17217-221
50	605667	862199	"	17222-226
51	605867	861969	"	17227-232
52	540238	922774	(Cabriolet)	18643-646
53	540438	924574	"	18650-652
54	541638	933774	"	18660-663
55	541238	921974	"	18238-240
56	543638	922574	"	18241-244
57	541238	923774	"	18245-247
58	545038	920574	"	18261-264
59	541438	929374	"	18272-275
60	541438	931974	"	18276-279
61	541238	926974	"	18280-283
62	543598	932008	"	18284-287
63	542438	931974	"	18288-289
64	542238	926974	"	18290-291
65	530250	944750	Schooner 26a	21292,301,285,297
66	530250	943750	Schooner 26b	21287,290,293,308
67	532250	942750	Schooner 39	21305,298,291,295

APPENDIX B
RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES

APPENDIX B: RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES

The depth increments are: a = 0 – 2.5 cm, b = 2.5 – 5 cm, c = 5 – 10 cm, and d = 10 – 15 cm except at Points 43 through 64 (the NAEG samples), where they are: a = 0 – 5 cm, b = 5 – 10 cm, c = 10 – 15 cm, d = 15 – 20 cm, e = 20 – 25 cm, and f = 25 – 30 cm. Concentration values apply to the natural (wet) soil. Values with 100% error are upper limit values.

Point & increment	Weight (g)			Radionuclide Concentration (pCi/g) and s.d. (%)									
	Wet	Dry	Fine	^{60}Co		^{137}Cs		^{152}Eu		^{155}Eu		^{241}Am	
1 a	419	394	300	2.81e+00	2.3	3.49e+00	3.0	2.61e+00	4.4	1.23e+00	100.0	3.16e+00	64.6
b	428	386	355	9.83e-02	21.2	2.64e-01	16.7	7.71e-02	100.0	2.15e-01	100.0	1.79e-01	100.0
c	876	800	746	2.40e-02	100.0	2.60e-02	100.0	8.59e-02	100.0	1.36e-01	100.0	2.28e-01	100.0
d	830	761	681	2.56e-02	100.0	2.50e-02	100.0	1.53e-01	100.0	2.37e-01	100.0	2.02e-01	100.0
2 a	563	546	296	1.02e+01	1.1	3.89e+00	4.5	1.11e+01	2.3	4.80e+00	7.4	9.98e+00	12.3
b	394	362	339	2.60e-01	8.9	3.00e-01	7.8	8.64e-02	100.0	1.30e-01	100.0	9.86e-02	100.0
c	804	732	712	1.07e-01	15.6	7.10e-02	20.9	9.99e-02	100.0	7.59e-02	100.0	1.08e-01	100.0
d	829	778	372	1.64e-02	100.0	1.38e-02	100.0	8.03e-02	100.0	5.95e-02	100.0	8.74e-02	100.0
3 a	339	326	268	2.08e+01	1.2	5.50e+00	5.4	3.45e+01	1.8	1.37e+01	7.9	1.69e+01	15.3
b	533	509	236	1.86e+00	2.5	1.28e+00	6.2	2.93e+00	3.2	1.48e+00	14.3	1.51e+00	25.4
c	794	720	645	5.25e-02	26.2	6.03e-02	30.3	9.87e-02	100.0	4.28e-01	100.0	1.05e-01	100.0
d	829	730	665	1.45e-02	100.0	1.55e-02	100.0	9.09e-02	100.0	7.27e-02	100.0	1.03e-01	100.0
4 a	418	399	340	1.20e+01	2.4	1.21e+00	13.2	2.00e+01	2.0	7.84e+00	10.3	9.03e+00	14.3
b	397	366	331	7.46e+00	1.2	9.51e-01	11.8	1.32e+01	3.3	2.08e-01	100.0	1.65e+00	155.5
c	792	716	667	2.48e-01	7.4	9.02e-02	18.6	3.66e-01	17.6	5.35e-01	100.0	1.17e-01	100.0
d	792	719	624	1.42e-02	100.0	1.61e-02	100.0	9.00e-02	100.0	7.24e-02	100.0	9.91e-02	100.0
5 a	359	345	216	1.61e+01	1.0	3.82e+00	6.0	2.25e+01	2.0	9.18e+00	9.4	1.16e+01	16.1
b	357	332	304	3.84e+00	1.5	1.48e+00	3.3	5.28e+00	2.4	2.33e+00	10.7	2.58e+00	20.3
c	888	807	782	2.87e-01	8.9	8.28e-02	27.2	4.09e-01	19.0	1.73e-01	100.0	1.30e-01	100.0
d	762	676	647	1.59e-02	100.0	1.70e-02	100.0	4.74e-02	100.0	7.00e-02	100.0	1.04e-01	100.0
6 a	399	378	286	4.97e+00	1.4	3.45e+00	3.9	7.06e+00	2.7	3.06e+00	11.3	4.29e+00	41.2
b	326	295	266	2.35e-01	8.0	3.77e-01	7.2	2.80e-01	21.7	4.35e-01	28.5	1.01e-01	100.0
c	877	787	763	1.17e-01	13.4	1.21e-01	15.3	1.61e-01	100.0	4.59e-01	100.0	1.22e-01	100.0
d	844	752	722	1.63e-02	100.0	1.55e-02	100.0	4.94e-02	100.0	7.66e-02	100.0	1.13e-01	100.0
7 a	369	345	310	9.07e-01	3.3	1.50e+00	2.8	1.12e+00	6.6	6.08e-01	100.0	4.62e-01	76.8
b	386	354	328	1.72e-01	11.4	3.44e-01	8.2	3.01e-01	25.1	3.07e-01	100.0	9.41e-02	100.0
c	952	884	737	3.53e-02	100.0	3.65e-02	100.0	1.15e-01	100.0	3.55e-01	100.0	4.34e-01	100.0
d	757	689	663	3.58e-02	100.0	3.69e-02	100.0	1.09e-01	100.0	3.30e-01	100.0	4.06e-01	100.0

Point & increment	Weight (g)			Radionuclide Concentration (pCi/g) and s.d. (%)									
	Wet	Dry	Fine	^{60}Co		^{137}Cs		^{152}Eu		^{155}Eu		^{241}Am	
8 a	309	247	196	1.50e+01	1.5	9.87e+00	3.7	2.11e+01	2.8	8.26e+00	9.1	5.78e+00	91.1
b	451	381	303	1.76e+00	3.9	2.60e+00	6.1	2.34e+00	7.8	1.03e+00	100.0	1.31e+00	27.7
c	806	654	620	9.96e-02	25.9	3.27e-01	25.5	2.28e-01	100.0	1.65e-01	100.0	4.16e-01	100.0
d	754	608	590	3.66e-02	100.0	4.30e-02	100.0	1.07e-01	100.0	3.22e-01	100.0	3.98e-01	100.0
9 a	236	234	144	5.74e+00	1.4	1.18e+01	1.7	5.86e+00	3.1	1.71e+00	16.4	2.41e+00	21.2
b	500	493	285	7.59e-01	4.2	1.62e+00	5.4	8.67e-01	9.7	4.51e-01	100.0	1.01e-01	100.0
c	683	657	478	1.12e-01	14.9	1.94e-01	27.5	1.16e-01	100.0	1.70e-01	100.0	9.26e-02	100.0
d	622	575	514	1.86e-02	100.0	1.91e-02	100.0	5.35e-02	100.0	1.64e-01	100.0	8.92e-02	100.0
10 a	380	376	338	1.66e+00	2.4	4.08e+00	2.8	1.79e+00	4.8	5.41e-01	100.0	1.12e-01	100.0
b	317	313	280	4.18e-01	10.4	1.26e+00	6.4	6.36e-01	14.4	5.35e-01	100.0	9.68e-02	100.0
c	683	670	636	5.69e-01	4.5	1.43e+00	7.0	1.14e+00	8.5	3.19e-01	100.0	1.14e-01	100.0
d	635	620	507	2.09e-01	9.7	6.28e-01	11.9	1.27e-01	100.0	4.21e-01	100.0	9.45e-02	100.0
11 a	277	275	253	2.07e+01	1.5	3.94e+01	1.1	2.39e+01	1.6	5.37e+00	5.9	2.47e-01	100.0
b	371	368	347	4.16e+00	1.9	7.92e+00	3.3	5.27e+00	3.8	1.25e+00	28.1	2.71e-01	100.0
c	599	591	557	5.56e-02	31.3	1.99e-01	30.7	1.61e-01	100.0	2.50e-01	100.0	1.86e-01	100.0
d	593	564	519	2.15e-02	100.0	5.90e-02	53.5	1.49e-01	100.0	2.37e-01	100.0	1.78e-01	100.0
12 a	345	343	311	2.77e+01	2.6	4.95e+01	3.5	4.04e+01	1.9	7.08e+00	18.5	5.74e-01	100.0
b	310	307	279	2.33e+01	1.2	3.98e+01	3.6	3.35e+01	2.2	6.50e+00	14.9	5.23e-01	100.0
c	685	677	623	5.96e+00	2.2	1.31e+01	2.6	1.07e+-1	1.8	1.93e+00	11.1	3.66e-01	100.0
d	671	655	619	2.52e-02	100.0	2.71e-02	100.0	2.91e-01	26.6	2.64e-01	100.0	1.96e-01	100.0
13 a	215	213	206	3.50e+01	0.8	6.00e+01	1.7	6.06e+01	1.4	1.10e+01	3.9	3.37e-01	100.0
b	325	323	309	3.72e+01	0.8	6.28e+01	2.0	6.02e+01	1.8	1.18e+01	3.3	3.51e-01	100.0
c	707	699	651	7.08e+00	1.3	1.43e+01	2.1	1.75e+01	1.6	2.72e+00	12.4	2.14e-01	100.0
d	600	585	558	1.34e-01	12.9	1.22e-01	14.5	2.25e+00	4.5	8.48e-02	100.0	1.07e-01	100.0
14 a	280	278	256	2.42e+00	4.1	4.67e+00	6.2	2.14e+00	7.2	1.00e+00	15.7	4.55e-01	50.0
b	342	336	315	2.16e-01	15.5	6.20e-01	4.8	6.86e-01	10.2	1.88e-01	100.0	1.31e-01	50.0
c	737	709	697	4.15e-02	100.0	4.27e-02	50.0	5.43e-01	16.7	1.90e-01	100.0	4.16e-01	100.0
d	647	606	593	1.73e-02	100.0	3.48e-02	43.8	2.57e-01	100.0	1.71e-01	100.0	1.01e-01	100.0
15 a	345	343	303	7.69e+00	1.7	1.96e+01	2.3	2.31e+01	1.5	3.59e+00	13.3	2.07e-01	100.0
b	540	536	444	4.58e-01	5.4	1.58e+00	2.6	5.37e+00	2.4	1.83e-01	100.0	1.13e-01	100.0
c	866	856	665	4.01e-01	5.2	5.94e-01	5.5	5.20e+00	2.1	9.92e-02	100.0	1.24e-01	100.0
d	898	879	669	0.	0.0	0.	0.0	3.97e+00	2.9	1.90e-01	100.0	0.	0.0
16 a	251	249	206	4.76e+01	1.3	1.05e+02	1.6	9.25e+01	1.4	1.82e+01	8.0	4.23e-01	100.0
b	297	294	252	1.33e+01	1.0	4.33e+01	2.1	3.31e+01	1.4	5.85e+00	13.0	2.50e-01	100.0
c	609	602	265	1.60e+00	2.7	8.20e+00	2.1	1.47e+01	1.3	1.20e-01	100.0	1.42e-01	100.0
d	482	468	368	1.12e+00	3.1	1.56e+00	3.0	1.19e+01	1.9	4.13e-01	100.0	1.26e-01	100.0

Point & increment	Weight (g)			Radionuclide Concentration (pCi/g) and s.d. (%)									
	Wet	Dry	Fine	^{60}Co		^{137}Cs		^{152}Eu		^{155}Eu		^{241}Am	
17 a	345	343	268	1.64e+01	0.9	2.35e+01	1.0	2.16e+01	1.3	4.68e+00	5.2	2.21e-01	100.0
b	485	481	357	5.29e+00	1.3	1.03e+01	2.0	1.01e+01	1.7	2.05e+00	14.4	1.58e-01	100.0
c	764	745	631	1.01e+00	2.9	1.57e+00	5.1	6.52e+00	2.3	6.01e-01	100.0	1.33e-01	100.0
d	766	736	632	3.54e-01	6.0	1.86e-01	26.1	5.32e+00	2.3	9.55e-02	100.0	1.20e-01	100.0
18 a	310	307	210	5.55e-01	5.3	4.79e+00	2.6	2.34e+00	4.3	6.22e-01	100.0	1.17e-01	100.0
b	427	421	344	2.02e-01	10.4	1.26e+00	5.5	1.75e+00	5.0	7.97e-02	100.0	1.02e-01	100.0
c	826	775	727	1.62e-01	11.7	1.18e-01	24.5	1.86e+00	5.5	9.31e-02	100.0	1.19e-01	100.0
d	788	712	672	1.35e-01	12.4	1.80e-02	100.0	1.27e+00	5.6	8.36e-02	100.0	1.05e-01	100.0
19 a	310	307	297	5.20e+00	21.2	1.22e+01	2.5	1.06e+01	6.0	1.40e+00	16.8	6.21e-01	100.0
b	475	469	366	5.90e+00	3.8	3.68e+00	13.6	7.62e+00	3.3	1.40e+00	17.4	5.88e-01	100.0
c	736	715	633	7.36e-01	7.0	2.67e+00	2.7	3.54e+00	4.7	3.82e-01	100.0	4.85e-01	100.0
d	692	650	624	5.22e-02	100.0	7.34e-02	38.3	2.26e+00	9.3	1.91e-01	100.0	4.22e-01	100.0
20 a	250	246	222	3.03e-01	12.8	2.90e+00	7.6	2.68e-01	100.0	3.54e-01	100.0	3.93e-01	100.0
b	420	413	299	4.21e-02	100.0	1.54e+00	11.1	1.16e-01	100.0	1.75e-01	100.0	4.02e-01	100.0
c	740	699	698	3.79e-02	100.0	2.06e-01	48.8	1.19e-01	100.0	3.69e-01	100.0	4.12e-01	100.0
d	697	626	601	3.31e-02	100.0	3.48e-02	100.0	1.05e-01	100.0	1.65e-01	100.0	3.67e-01	100.0
21 a	209	206	169	2.59e+00	5.0	2.84e+01	1.1	2.12e+01	1.4	3.30e-01	100.0	6.69e-01	100.0
b	361	357	268	3.81e+00	4.6	3.18e+01	1.0	3.15e+01	1.8	3.87e-01	100.0	7.75e-01	100.0
c	731	720	389	4.29e+00	4.3	7.62e+01	1.5	3.67e+01	1.7	4.50e-01	100.0	9.11e-01	100.0
d	666	645	550	1.80e+00	4.8	4.88e+01	1.7	2.13e+01	2.3	3.76e-01	100.0	7.81e-01	100.0
22 a	317	314	274	4.23e+00	7.9	2.38e+00	31.9	9.23e+00	6.5	1.02e+00	17.5	5.66e-01	100.0
b	344	337	277	5.87e-01	4.8	8.00e-01	4.5	4.59e+00	2.8	1.81e-01	100.0	1.07e-01	100.0
c	737	724	469	3.15e-01	8.5	2.02e-01	30.3	3.57e+00	3.8	2.96e-01	100.0	2.03e-01	100.0
d	850	826	476	2.39e-01	11.2	2.54e-01	12.4	2.96e+00	4.2	1.44e-01	100.0	2.00e-01	100.0
23 a	360	358	329	7.18e-02	30.2	9.29e-01	11.2	1.02e-01	100.0	1.57e-01	100.0	9.59e-01	28.8
b	301	299	283	3.24e-02	100.0	5.68e-01	11.3	9.90e-02	100.0	3.15e-01	100.0	3.75e-01	100.0
c	678	668	633	3.62e-02	100.0	1.32e-01	58.6	1.12e-01	100.0	1.78e-01	100.0	4.07e-01	100.0
d	629	609	572	3.18e-02	100.0	3.20e-02	100.0	9.56e-02	100.0	3.10e-01	100.0	3.67e-01	100.0
24 a	364	363	279	3.98e-02	100.0	5.55e-01	15.5	1.89e-01	100.0	1.51e-01	100.0	3.34e-01	100.0
b	429	406	363	3.22e-02	100.0	2.81e-02	100.0	8.41e-02	100.0	2.61e-01	100.0	2.98e-01	100.0
c	719	703	572	1.47e-02	100.0	1.74e-02	100.0	1.05e-01	100.0	1.52e-01	100.0	8.73e-02	100.0
d	596	561	523	1.61e-02	100.0	1.63e-02	100.0	1.03e-01	100.0	1.44e-01	100.0	7.88e-02	100.0
25 a	365	364	337	1.94e-02	100.0	3.29e-01	13.1	1.03e-01	100.0	1.52e-01	100.0	1.17e+00	12.8
b	309	308	279	2.31e-02	100.0	1.16e+00	5.3	1.09e-01	100.0	4.35e-01	20.5	4.42e+00	17.9
c	739	736	350	2.29e-02	100.0	9.76e-01	6.6	1.58e-01	100.0	1.65e-01	100.0	3.89e+00	8.0
d	817	808	599	1.91e-02	100.0	2.65e-01	18.4	1.55e-01	100.0	2.86e-01	100.0	7.37e-01	14.5

Point & increment	Weight (g)			Radionuclide Concentration (pCi/g) and s.d.(%)									
	Wet	Dry	Fine	^{60}Co		^{137}Cs		^{152}Eu		^{155}Eu		^{241}Am	
26 a	292	292	230	1.16e-01	19.9	2.44e+00	4.8	2.17e-01	100.0	1.81e-01	100.0	4.78e-01	37.4
b	367	365	335	2.62e-02	100.0	8.81e-01	9.0	2.21e-01	100.0	2.29e-01	100.0	1.71e-01	100.0
c	651	629	610	2.21e-02	100.0	2.50e-02	100.0	3.85e-01	19.5	1.21e-01	100.0	1.79e-01	100.0
d	535	494	460	2.17e-02	100.0	2.08e-02	100.0	2.50e-01	27.6	2.05e-01	100.0	1.54e-01	100.0
27 a	273	273	208	3.21e-02	50.0	1.65e+00	5.2	4.95e-01	17.6	3.62e-01	100.0	1.24e+02	19.5
b	291	290	242	2.89e-02	50.0	1.21e-01	23.2	7.35e-01	12.2	2.24e-01	100.0	1.14e+00	16.8
c	485	478	435	6.57e-02	28.2	4.25e-01	7.6	6.12e-01	10.2	2.27e-01	100.0	1.70e-01	100.0
d	642	631	533	2.49e-02	100.0	2.63e-01	19.7	6.31e-01	11.4	2.34e-01	100.0	1.74e-01	100.0
28 a	308	307	251	5.19e-01	6.5	4.46e+01	2.0	3.46e+00	7.4	6.41e+00	26.7	4.25e+03	42.9
b	399	398	344	2.54e-01	10.4	2.26e+01	4.9	1.61e+00	9.8	3.87e+00	9.1	2.96e+03	21.6
c	747	739	665	2.53e-02	100.0	1.01e+00	7.0	3.22e-01	24.6	2.94e-01	100.0	1.37e+02	61.5
d	743	719	671	2.26e-02	100.0	8.97e-02	42.0	1.54e-01	100.0	2.60e-01	100.0	1.76e+01	56.7
29 a	240	240	240	8.23e-02	21.3	2.14e+00	4.6	1.15e-01	100.0	2.85e-01	100.0	3.90e-01	22.3
b	358	357	130	2.59e-02	100.0	8.77e-01	8.0	1.15e-01	100.0	1.69e-01	100.0	2.30e-01	51.6
c	742	735	537	1.67e-02	100.0	3.20e-01	17.3	1.13e-01	100.0	1.73e-01	100.0	3.27e-01	41.6
d	524	500	397	1.74e-02	100.0	5.76e-02	66.1	1.03e-01	100.0	2.31e-01	19.2	7.59e-02	100.0
30 a	394	393	362	1.93e-02	100.0	3.35e-01	6.4	1.09e-01	100.0	1.64e-01	100.0	9.15e-02	100.0
b	376	374	353	1.78e-02	100.0	1.91e-01	10.9	5.42e-02	100.0	1.59e-01	100.0	8.79e-02	100.0
c	615	605	549	1.83e-02	100.0	1.83e-02	100.0	5.62e-02	100.0	3.25e-01	100.0	9.11e-02	100.0
d	772	746	510	1.88e-02	100.0	1.81e-02	100.0	1.08e-01	100.0	3.11e-01	23.1	8.77e-02	100.0
31 a	296	295	258	2.44e-02	100.0	2.29e+00	5.3	1.17e-01	100.0	3.91e-01	100.0	1.40e+02	27.0
b	269	268	257	2.28e-02	100.0	7.18e-01	8.5	1.13e-01	100.0	8.68e-02	100.0	4.26e+01	7.4
c	662	653	515	1.92e-02	100.0	4.43e-01	7.3	1.13e-01	100.0	3.42e-01	100.0	4.38e+01	7.4
d	491	476	325	1.52e-02	100.0	1.45e-02	100.0	9.37e-02	100.0	7.20e-02	100.0	7.72e-02	100.0
32 a	368	364	200	3.91e-02	100.0	1.11e+00	10.8	9.89e-02	100.0	3.10e-01	100.0	3.18e-01	100.0
b	254	249	213	4.47e-02	100.0	7.59e-01	7.5	9.54e-02	100.0	3.13e-01	100.0	3.03e-01	100.0
c	716	678	655	1.71e-02	100.0	2.13e-02	100.0	1.21e-01	100.0	1.86e-01	100.0	9.91e-02	100.0
d	468	426	324	2.01e-02	100.0	1.82e-02	100.0	4.89e-02	100.0	7.74e-02	100.0	8.15e-02	100.0
33 a	367	358	246	5.88e-02	23.2	1.53e+00	2.7	9.76e-02	100.0	1.29e-01	100.0	3.67e-01	100.0
b	417	300	292	3.65e-02	100.0	8.04e-01	7.6	9.77e-02	100.0	3.10e-01	100.0	3.17e-01	100.0
c	830	768	678	2.98e-02	100.0	1.57e-01	20.2	1.13e-01	100.0	3.70e-01	100.0	3.79e-01	100.0
d	705	633	595	3.26e-02	100.0	3.62e-02	100.0	1.01e-01	100.0	3.35e-01	100.0	3.49e-01	100.0
34 a	194	191	174	1.00e-01	30.4	2.90e+00	12.2	1.07e-01	100.0	3.32e-01	100.0	1.05e+00	33.0
b	298	291	214	4.26e-02	100.0	1.96e+00	6.2	1.03e-01	100.0	3.15e-01	100.0	1.20e+00	52.0
c	667	627	580	1.47e-02	100.0	5.38e-01	11.2	9.20e-02	100.0	7.71e-02	100.0	9.74e-02	100.0
d	607	555	492	2.22e-02	100.0	2.16e-01	25.0	7.44e-02	100.0	2.38e-01	100.0	1.76e-01	100.0

Point & increment	Weight (g)			Radionuclide Concentration (pCi/g) and s.d.(%)									
	Wet	Dry	Fine	^{60}Co		^{137}Cs		^{152}Eu		^{155}Eu		^{241}Am	
35 a	351	342	286	1.49e-01	15.2	2.92e+00	4.1	4.31e-01	16.8	3.70e-01	100.0	3.23e+00	8.3
b	341	321	268	7.22e-02	27.6	1.98e+00	6.5	2.25e-01	100.0	2.38e-01	100.0	2.56e+00	15.2
c	878	765	722	2.24e-02	100.0	4.20e-01	14.3	8.56e-02	100.0	2.86e-01	100.0	2.18e-01	100.0
36 a	283	277	233	3.39e+00	3.8	3.85e+01	1.9	4.72e+00	5.2	1.77e+00	100.0	1.62e+02	14.6
b	350	335	291	9.64e+00	1.0	1.14e+02	1.1	1.06e+01	1.8	4.24e+00	11.4	3.92e+02	15.3
c	757	707	596	7.40e+00	1.1	1.22e+02	0.7	7.64e+00	2.3	3.67e+00	13.3	2.96e+02	18.0
d	759	695	613	2.10e-02	100.0	8.10e-01	7.4	6.16e-02	100.0	4.73e-01	26.6	1.69e+00	9.8
37 a	318	306	259	2.69e-01	8.2	3.10e+00	3.4	8.83e-01	8.4	3.80e-01	100.0	8.54e+00	19.6
b	267	251	198	4.34e-02	50.0	7.39e-01	7.2	9.87e-02	100.0	3.07e-01	100.0	1.40e+00	36.6
c	736	656	609	5.28e-02	30.4	6.99e-01	8.8	9.01e-02	100.0	1.44e-01	100.0	1.46e+00	24.7
d	699	608	560	2.00e-02	100.0	2.73e-01	19.6	1.15e-01	100.0	1.73e-01	100.0	6.61e-01	26.2
38 a	235	220	180	1.51e+00	2.7	3.75e+01	0.9	5.52e+00	2.1	6.76e-01	14.0	4.85e+01	7.7
b	325	307	240	1.46e+00	3.1	6.00e+01	1.1	5.04e+00	2.6	7.38e-01	16.9	5.48e+01	7.4
c	999	955	458	1.53e+00	3.9	1.16e+02	1.0	5.40e+00	2.3	6.23e-01	27.4	4.22e+01	8.2
d	932	881	498	1.61e+00	2.8	1.52e+02	1.4	6.35e+00	3.3	2.17e-01	100.0	4.13e+01	7.6
39 a	322	310	268	1.62e+01	0.9	9.73e+01	0.8	2.62e+01	1.6	8.16e+00	5.7	6.33e+02	7.7
b	324	310	268	1.56e+01	2.6	1.22e+02	0.8	2.88e+01	2.2	6.26e+00	7.3	6.00e+02	12.7
c	681	640	498	7.90e+00	1.3	6.56e+01	0.8	1.23e+01	2.1	3.50e+00	12.9	2.76e+02	14.6
d	677	625	563	7.88e+00	1.1	5.30e+01	0.8	1.28e+01	2.3	3.99e+00	9.4	2.83e+02	9.6
40 a	238	234	184	4.11e-01	12.0	1.26e+01	4.5	1.30e+00	15.3	6.32e-01	100.0	1.41e+01	37.7
b	309	300	235	4.46e-02	50.0	2.53e+00	6.6	2.73e-01	100.0	3.83e-01	100.0	3.47e+00	20.7
c	716	659	544	2.98e-02	50.0	1.24e-01	30.1	8.62e-02	100.0	2.70e-01	100.0	2.95e-01	50.0
d	624	550	389	1.57e+00	5.0	2.17e+01	1.7	4.27e+00	4.4	8.92e-01	100.0	7.50e+01	17.4
41 a	148	144	115	3.12e+00	4.8	4.91e+01	3.5	8.41e+00	5.3	1.28e+00	100.0	1.14e+02	24.1
b	246	238	195	1.25e+00	6.9	2.05e+01	2.0	2.96e+00	8.2	1.06e+00	27.6	3.97e+01	34.0
c	512	483	422	1.48e-01	19.8	3.50e+00	8.4	3.60e-01	24.0	3.21e-01	100.0	4.49e+00	43.5
d	351	332	239	5.81e-01	9.5	5.72e+02	0.7	1.35e+00	100.0	8.33e-01	100.0	1.87e+00	100.0
42 a	254	246	216	1.53e-01	23.8	5.40e+00	4.9	4.98e-01	25.7	3.63e-01	100.0	2.14e+00	91.8
b	255	240	214	2.83e-01	16.3	1.06e+01	2.0	7.24e-01	11.9	4.67e-01	100.0	4.28e+00	56.8
c	680	638	505	3.46e-02	100.0	1.66e+00	13.5	2.18e-01	100.0	3.41e-01	100.0	3.74e-01	100.0
d	577	521	489	1.58e-02	100.0	1.63e-02	100.0	4.25e-02	100.0	5.85e-02	100.0	1.32e-01	100.0
43 a	571	564	466	4.10e-02	100.0	7.50e-01	32.0	1.40e-01	100.0	1.70e-01	100.0	5.00e-01	100.0
b	396	390	304	4.10e-02	100.0	8.91e-01	27.0	1.40e-01	100.0	1.70e-01	100.0	6.00e-01	50.0
c	454	446	311	4.10e-02	100.0	6.75e-01	34.0	1.40e-01	100.0	1.70e-01	100.0	2.20e-01	100.0
d	358	346	257	4.10e-02	100.0	5.65e-01	40.0	1.40e-01	100.0	1.70e-01	100.0	4.60e-02	100.0
e	481	464	319	4.10e-02	100.0	6.25e-01	37.0	1.40e-01	100.0	1.70e-01	100.0	4.60e-02	100.0
f	440	424	313	4.10e-02	100.0	2.92e-01	64.0	1.40e-01	100.0	1.70e-01	100.0	1.19e+00	43.0

Point & increment	Weight (g)			Radionuclide Concentration (pCi/g) and s.d.(%)									
	Wet	Dry	Fine	^{60}Co		^{137}Cs		^{152}Eu		^{155}Eu		^{241}Am	
44 a	497	489	469	9.49e-02	95.0	1.77e+00	17.0	1.40e-01	100.0	4.07e-01	83.0	5.57e-01	19.0
b	557	550	536	1.49e-01	72.0	1.93e+00	16.0	1.40e-01	100.0	1.70e-01	100.0	1.56e+00	14.0
c	550	543	534	1.41e-01	65.0	2.06e+00	16.0	1.40e-01	100.0	4.78e-01	86.0	1.04e+00	28.0
d	241	239	184	4.10e-02	100.0	7.54e-01	30.0	1.40e-01	100.0	1.70e-01	100.0	2.42e+00	30.0
45 a	482	480	404	5.94e-01	38.0	9.98e+00	10.0	1.34e+00	34.0	7.00e-01	85.0	4.70e+02	18.0
b	510	508	434	5.39e-01	31.0	7.34e+00	10.0	1.28e+00	32.0	1.70e-01	100.0	2.70e+02	21.0
c	702	694	557	3.28e-01	48.0	5.59e+00	11.0	1.42e+00	30.0	1.29e+00	54.0	1.96e+02	19.0
d	629	619	467	3.97e-01	32.0	1.74e+00	17.0	1.49e+00	32.0	1.70e-01	100.0	2.85e+01	9.0
e	725	706	563	4.10e-02	100.0	2.10e-01	76.0	1.60e+00	26.0	1.70e-01	100.0	2.25e+00	16.0
f	733	705	522	4.10e-02	100.0	4.00e-02	100.0	1.55e+00	27.0	1.70e-01	100.0	9.41e-01	22.0
46 a	592	587	508	4.10e-02	100.0	2.35e+00	18.0	1.28e+00	37.0	1.70e-01	100.0	7.70e+01	12.0
b	615	606	457	3.40e-01	51.0	4.00e-02	100.0	2.27e+00	20.0	1.70e-01	100.0	1.12e+00	17.0
c	597	575	435	2.37e-01	92.0	4.00e-02	100.0	1.91e+00	23.0	1.70e-01	100.0	4.75e-01	28.0
d	604	577	480	4.10e-02	100.0	4.00e-02	100.0	1.73e+00	22.0	1.70e-01	100.0	4.40e-02	100.0
e	694	658	525	4.10e-02	100.0	4.00e-02	100.0	1.33e+00	26.0	1.70e-01	100.0	3.30e-02	74.0
f	642	607	493	4.10e-02	100.0	4.00e-02	100.0	1.31e+00	28.0	1.70e-01	100.0	4.60e-02	100.0
47 a	654	647	548	3.96e-01	51.0	8.01e+00	11.0	2.33e+00	21.0	1.96e+00	32.0	4.54e+02	15.0
b	658	650	530	3.51e-01	60.0	2.05e+00	18.0	1.80e+00	24.0	1.70e-01	100.0	3.87e+01	17.0
c	667	656	502	4.10e-02	100.0	4.92e-01	39.0	1.54e+00	26.0	7.21e-01	67.0	6.30e+00	100.0
d	546	532	454	2.87e-01	51.0	4.00e-02	100.0	1.48e+00	27.0	9.06e-01	59.0	8.82e-01	24.0
e	612	593	492	1.72e-01	65.0	4.00e-02	100.0	1.43e+00	26.0	1.70e-01	100.0	3.00e-02	100.0
f	417	402	322	8.80e-02	90.0	4.00e-02	100.0	1.40e-01	100.0	1.70e-01	100.0	4.60e-02	100.0
48 a	605	596	551	3.21e-01	48.0	4.07e+00	13.0	9.71e-01	36.0	1.41e+00	41.0	1.44e+02	15.0
b	875	846	828	1.40e-01	66.0	4.00e-02	100.0	1.16e+00	50.0	1.70e-01	100.0	1.07e-01	32.0
c	628	601	555	1.54e-01	82.0	4.00e-02	100.0	6.29e-01	85.0	5.92e-01	65.0	4.80e-02	100.0
d	862	812	740	1.43e-01	46.0	4.00e-02	100.0	6.07e-01	63.0	1.70e-01	100.0	6.50e-02	100.0
e	720	671	576	4.10e-02	100.0	4.00e-02	100.0	7.99e-01	61.0	1.70e-01	100.0	4.60e-01	100.0
f	522	483	390	4.10e-02	100.0	4.00e-02	100.0	4.62e-01	52.0	1.70e-01	100.0	6.70e-02	100.0
49 a	627	520	444	1.02e+00	28.0	3.76e+01	7.8	4.43e+00	20.0	8.11e+00	18.0	2.44e+03	18.0
b	439	421	368	1.56e-01	73.0	1.13e+00	21.0	5.94e-01	47.0	7.28e-01	64.0	5.31e+01	17.0
c	620	573	514	2.35e-01	46.0	4.00e-02	100.0	1.40e-01	100.0	1.70e-01	100.0	5.93e-01	41.0
d	527	452	354	4.10e-02	100.0	4.00e-02	100.0	4.95e-01	49.0	1.70e-01	100.0	1.05e+00	29.0
e	452	380	290	4.10e-02	100.0	4.00e-02	100.0	2.72e-01	66.0	1.70e-01	100.0	5.50e-02	100.0
50 a	677	672	522	4.10e-02	100.0	1.98e+00	16.0	1.40e-01	100.0	1.70e-01	100.0	2.36e-01	64.0
b	712	695	606	4.10e-02	100.0	1.71e-01	70.0	1.40e-01	100.0	6.22e-01	68.0	1.13e-01	67.0
c	758	723	546	4.10e-02	100.0	4.00e-02	100.0	1.40e-01	100.0	1.70e-01	100.0	4.60e-02	100.0

Point & increment	Weight (g)			Radionuclide Concentration (pCi/g) and s.d.(%)									
	Wet	Dry	Fine	^{60}Co		^{137}Cs		^{152}Eu		^{155}Eu		^{241}Am	
51 a	486	485	371	1.12e+00	25.0	2.83e+01	8.2	2.01e+00	30.0	6.37e+00	21.0	1.38e+03	16.0
b	698	687	542	4.10e-02	100.0	6.94e-01	25.0	1.40e-01	100.0	1.70e-01	100.0	4.57e+01	15.0
c	621	606	490	4.10e-02	100.0	4.00e-02	100.0	1.40e-01	100.0	1.70e-01	100.0	2.75e-01	40.0
d	769	738	615	4.10e-02	100.0	4.00e-02	100.0	1.40e-01	100.0	1.70e-01	100.0	1.15e-01	87.0
e	773	720	647	4.10e-02	100.0	4.00e-02	100.0	1.40e-01	100.0	1.70e-01	100.0	4.60e-02	100.0
f	511	472	417	8.60e-02	95.0	4.00e-02	100.0	3.06e-01	80.0	1.70e-01	100.0	4.60e-02	100.0
52 a	491	484	333	4.10e-02	100.0	9.32e-01	16.0	1.40e-01	100.0	1.70e-01	100.0	4.20e-02	35.0
b	509	485	377	4.10e-02	100.0	1.42e-01	16.0	1.40e-01	100.0	1.70e-01	100.0	2.30e-02	35.0
c	526	501	413	4.10e-02	100.0	4.00e-02	100.0	1.40e-01	100.0	1.70e-01	100.0	1.00e-01	50.0
d	546	523	423	4.10e-02	100.0	4.00e-02	100.0	1.40e-01	100.0	1.70e-01	100.0	8.00e-02	50.0
53 a	477	471	215	1.51e+00	15.0	2.72e+00	9.0	1.40e-01	100.0	1.70e-01	100.0	1.25e+00	10.0
b	448	433	298	2.98e-01	28.0	2.95e-01	18.0	1.40e-01	100.0	1.70e-01	100.0	2.14e-01	15.0
c	588	569	394	4.10e-02	100.0	1.10e-01	25.0	1.40e-01	100.0	1.70e-01	100.0	5.80e-02	25.0
54 a	533	527	298	2.25e+01	5.0	1.45e+01	5.0	4.19e+00	10.0	1.70e-01	100.0	1.13e+01	12.0
b	482	464	370	1.11e+00	17.0	1.03e+00	16.0	2.91e-01	18.0	1.70e-01	100.0	5.36e-01	15.0
c	577	540	454	3.14e-01	18.0	7.50e-02	25.0	1.40e-01	100.0	1.70e-01	100.0	3.00e-02	25.0
d	495	458	393	4.10e-02	100.0	4.00e-02	100.0	1.40e-01	100.0	1.70e-01	100.0	2.20e-02	30.0
55 a	646	622	518	3.20e+02	5.0	1.02e+02	6.0	8.92e+01	10.0	1.70e-01	100.0	2.92e+02	7.0
b	687	655	587	6.49e+00	15.0	1.22e+00	20.0	7.10e-01	30.0	1.70e-01	100.0	3.81e+00	15.0
c	586	567	519	2.68e-01	20.0	4.00e-02	100.0	1.40e-01	100.0	1.70e-01	100.0	1.46e-01	20.0
56 a	601	585	328	4.28e+00	20.0	6.85e+00	16.0	1.40e-01	100.0	1.70e-01	100.0	8.74e+00	15.0
b	645	611	505	8.47e-01	25.0	6.98e-01	20.0	1.40e-01	100.0	1.70e-01	100.0	2.45e+00	15.0
c	613	583	381	4.10e-02	100.0	1.62e-01	20.0	1.40e-01	100.0	1.70e-01	100.0	1.00e-01	25.0
d	506	471	321	4.10e-02	100.0	1.19e-01	20.0	1.40e-01	100.0	1.70e-01	100.0	1.18e-01	25.0
57 a	655	643	475	1.32e+01	13.0	4.68e+00	14.0	1.40e-01	100.0	1.70e-01	100.0	9.55e+00	12.0
b	661	632	490	1.39e-01	25.0	1.00e-01	25.0	1.40e-01	100.0	1.70e-01	100.0	3.64e+00	15.0
c	742	707	498	4.10e-02	100.0	4.00e-02	100.0	1.40e-01	100.0	1.70e-01	100.0	1.45e-01	25.0
58 a	784	773	604	4.10e-02	100.0	4.50e+00	15.0	1.40e-01	100.0	1.70e-01	100.0	2.02e+00	15.0
b	648	618	525	4.10e-02	100.0	2.68e-01	25.0	1.40e-01	100.0	1.70e-01	100.0	8.90e-02	25.0
c	722	679	542	4.10e-02	100.0	4.00e-02	100.0	1.40e-01	100.0	1.70e-01	100.0	6.00e-03	50.0
d	557	510	416	4.10e-02	100.0	4.00e-02	100.0	1.40e-01	100.0	1.70e-01	100.0	1.80e-02	35.0
59 a	752	736	623	8.29e+00	14.0	3.49e+00	15.0	1.40e-01	100.0	1.70e-01	100.0	4.82e+00	15.0
b	728	705	662	4.02e-01	20.0	1.22e-01	25.0	1.40e-01	100.0	1.70e-01	100.0	2.65e-01	25.0
c	741	697	664	4.10e-02	100.0	4.00e-02	100.0	1.40e-01	100.0	1.70e-01	100.0	2.00e-02	35.0
d	489	440	410	4.10e-02	100.0	4.00e-02	100.0	1.40e-01	100.0	1.70e-01	100.0	5.00e-03	50.0

Point & increment	Weight (g)			Radionuclide Concentration (pCi/g) and s.d. (%)									
	Wet	Dry	Fine	^{60}Co		^{137}Cs		^{152}Eu		^{155}Eu		^{241}Am	
60 a	827	600	513	9.41e+00	15.0	5.05e+00	15.0	1.40e-01	100.0	1.70e-01	100.0	4.46e+00	15.0
b	698	652	605	1.47e-01	20.0	1.86e-01	20.0	1.40e-01	100.0	1.70e-01	100.0	1.04e-01	25.0
c	765	737	656	4.10e-02	100.0	4.00e-02	100.0	1.40e-01	100.0	1.70e-01	100.0	2.70e-02	35.0
d	590	560	506	4.10e-02	100.0	4.00e-02	100.0	1.40e-01	100.0	1.70e-01	100.0	4.90e-02	35.0
61 a	705	650	574	2.86e+01	9.0	9.73e+00	11.0	5.41e+00	25.0	1.70e-01	100.0	1.00e+01	12.0
b	731	666	615	1.91e+00	18.0	5.81e-01	34.0	3.32e-01	35.0	1.70e-01	100.0	2.02e+00	15.0
c	708	623	536	1.43e-01	20.0	4.00e-02	100.0	1.40e-01	100.0	1.70e-01	100.0	1.01e-01	25.0
d	559	506	453	4.10e-02	100.0	4.00e-02	100.0	1.40e-01	100.0	1.70e-01	100.0	1.00e-02	40.0
62 a	730	567	532	2.43e+00	18.0	2.34e+00	19.0	1.40e-01	100.0	1.70e-01	100.0	1.44e+00	15.0
b	609	573	545	1.60e-01	20.0	2.14e-01	20.0	1.40e-01	100.0	1.70e-01	100.0	6.90e-02	25.0
c	566	547	516	4.10e-02	100.0	4.00e-02	100.0	1.40e-01	100.0	1.70e-01	100.0	5.60e-02	35.0
d	481	451	426	4.10e-02	100.0	4.00e-02	100.0	1.40e-01	100.0	1.70e-01	100.0	2.50e-02	50.0
63 a	676	640	577	7.21e+00	14.0	3.16e+00	18.0	1.40e-01	100.0	1.70e-01	100.0	3.84e+00	18.0
b	499	476	449	2.04e+00	18.0	9.82e-01	25.0	1.40e-01	100.0	1.70e-01	100.0	1.05e+00	25.0
64 a	703	619	545	1.94e+00	10.0	6.71e+00	13.0	3.86e+00	26.0	1.70e-01	100.0	1.21e+01	21.0
b	749	710	692	1.84e+00	29.0	8.90e-01	28.0	1.64e-01	35.0	1.70e-01	100.0	9.64e-01	33.0
65 a	103	101	99	4.24e+02	1.7	2.28e+01	13.7	7.26e+02	2.7	2.59e+02	8.3	5.74e+02	20.2
b	134	122	116	1.76e+02	0.6	1.36e+01	2.3	2.51e+02	1.5	8.49e+01	9.5	2.68e+02	34.5
c	397	266	258	2.33e+02	1.8	1.49e+01	9.5	3.07e+02	1.7	9.58e+01	8.7	3.25e+02	19.1
d	629	503	446	1.15e+02	2.6	9.49e+00	6.6	1.05e+02	1.9	3.33e+01	8.0	1.75e+02	28.3
66 a	217	197	194	3.07e+02	1.7	2.11e+01	9.6	4.16e+02	1.8	1.34e+02	10.8	4.51e+02	18.9
b	288	261	251	2.48e+02	1.7	1.65e+01	9.9	3.67e+02	1.8	1.14e+02	8.4	3.21e+02	19.7
c	683	623	622	1.97e+02	2.8	1.08e+01	10.0	3.07e+02	1.8	9.64e+01	8.1	2.44e+02	35.8
d	800	563	478	1.01e+02	0.6	6.54e+00	6.8	1.52e+02	1.5	5.10e+01	10.4	1.45e+02	36.0
67 a	391	333	295	3.56e+00	1.8	2.30e+00	4.4	4.89e+00	2.4	1.72e+00	14.0	4.03e+00	19.0
b	401	368	351	1.52e-01	11.8	3.30e-01	6.8	3.46e-01	18.0	4.32e-01	46.4	9.96e-02	100.0
c	978	878	866	2.59e-02	100.0	2.58e-02	100.0	7.54e-02	100.0	1.07e-01	100.0	1.81e-01	100.0
d	889	775	358	2.61e-02	100.0	2.49e-02	100.0	7.45e-02	100.0	1.08e-01	100.0	1.82e-01	100.0

APPENDIX C
RELIABILITY OF SOIL ANALYSES

APPENDIX C: RELIABILITY OF SOIL ANALYSES

by E.H. Essington (Quality Assurance Referee)
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Soil profile samples were analyzed for constituent radionuclides to provide the data necessary for calculating inverse relaxation lengths and the ratios of specific radionuclides in the top increment. A quality assurance (QA) program was conducted along with the sample analyses to test the reliability of the analytical results. The elements of the QA program included interlaboratory comparisons, analysis of blind reference samples, and comparisons of hidden replicate samples.

METHODS

The basic QA procedure has been described by Essington and Mead (1985) and Essington (1987); some modifications were made to accommodate the sample requirements of the contracted analytical laboratory, TMA/Norcal (TMA).

Soil samples were collected from the Schooner site in Area 20 and from the Danny Boy, Johnie Boy, and Little Feller I sites in Area 18. These bulk samples were processed and analyzed according to the procedures described by McArthur and Kordas (1983) to determine inverse relaxation lengths. Aliquots of selected surface samples were analyzed for specific radionuclides to determine ratios used to estimate concentrations of one radionuclide from measured concentrations of another. Samples from Cabriolet in Area 20 and Little Feller II in Area 18 had been collected previously as part of the Nevada Applied Ecology Group program, and profile data generated by that program were used to calculate inverse relaxation lengths. Radionuclide ratios, however, were determined by analysis of new aliquots of those samples.

The Schooner samples were the first set of bulk samples processed under the current QA procedure. Bulk samples for Danny Boy, Johnie Boy, and Little Feller I had been processed and assayed for gamma-ray emitters before the formal QA program began.

The prepared Schooner bulk samples were contained in 500-ml polyethylene bottles labeled with field sampling location numbers. Normally a library number is assigned to each sample upon collection as the permanent sample identifier. The QA procedure, however, requires that library and sample numbers be assigned and applied in such a way

that the identity of the samples and any included replicates or blinds remains unknown to the analyst. The Referee therefore added to each bulk sample bottle a second label with the assigned library and sample numbers, photographed the bottle with both labels, and then removed the field number from the bottle. Appropriate documentation of the field, library, and sample numbers is maintained in the Referee's log book.

Aliquots of two reference soils, designated REF-2 and BKGD, were included with the bulk samples for QA purposes. In addition, hidden replicates of several bulk samples were prepared and included for assay. REECo carried out the spectrometric measurements of the bulk samples and LLNL analyzed the spectra using the GAMANAL program to generate the results presented.

All samples analyzed for the determination of radionuclide ratios were prepared in duplicate from the bulk sample and sent to TMA for analysis. Aliquots ranged from about 20 g to about 100 g depending on the amount of sample available. Attempts were made to prepare the largest aliquot possible (not to exceed about 100 g) while maintaining sufficient library sample for historical purposes. No two aliquots of a specific sample were the same size. In some cases an additional 20-g aliquot was prepared and sent to the Referee's analytical laboratory for an independent check on the reliability of the analyses.

The care taken in preparing representative aliquots included periodic mixing of the bulk sample as the aliquots were drawn, processing of low-level radioactive samples before the more active samples, and complete processing of only one sample at a time. The completed aliquots were labeled only with new sample numbers and were photographed with the original bulk sample to provide a visual cross-reference. The cross-reference information was also documented in the Referee's log book.

TMA analyzed aliquots of the surface profile increments by gamma spectrometry for ^{60}Co, ^{137}Cs, ^{152}Eu, ^{154}Eu, and ^{155}Eu to check the determination of those radionuclides in the bulk sample and to generate part of the data for calculating ^{90}Sr to ^{137}Cs ratios. The same aliquots were analyzed for ^{90}Sr, ^{241}Am, ^{238}Pu, and $^{239,240}Pu$ by chemical separation and alpha spectrometry (beta counting of separated ^{90}Y for ^{90}Sr analysis). These radiochemical data provide a check of the ^{241}Am, initially determined by gamma-counting of the bulk samples, and provide part of the data for calculating ^{90}Sr to ^{137}Cs, ^{238}Pu to ^{241}Am, and $^{239,240}Pu$ to ^{241}Am ratios.

Analytical results were reported directly to the Referee and the Technical Director for evaluation and acceptance. The data were evaluated by comparing replicate results

reported by TMA, comparing gamma-spectrometry and ^{241}Am results reported by TMA with those generated by REECo, and comparing results reported by both laboratories with those reported by the Referee. In addition, results for the blinds were compared to results reported from previous analyses. Results that appeared questionable, either by simple inspection or by failure to pass the replicate screening test (the "3-sigma" test) described by Essington (1987), were reevaluated by the analyst. If no changes were suggested, the results were accepted as the analyst's final declaration.

RESULTS

Some pertinent results of the gamma analyses of the bulk Schooner samples are summarized in Table C-1. Only four samples provided replicates for comparison and only one sample contained sufficient radioactivity to compare the major gamma-emitting radionuclides. Almost all of the other results indicated activities below the detection limit, supporting the contention that cross-contamination of sample aliquots was minimal. Where replicates could be compared, the results indicated acceptable agreement. Acceptable agreement was also found for the multiple measurements of the blind reference sample REF-2, and those measurements are also similar to earlier results from the same material reported by Essington (1987) and summarized at the end of Table C-2. Although this is a small sampling of the bulk gamma analyses, the results do indicate a consistency both in replicate analysis and in tracking the established blinds.

TABLE C-1. GAMMA ANALYSES OF BULK SAMPLES FROM THE SCHOONER AREA

Library No.	Sample No.	Concentration (pCi/g) and s.d. (%), decay-corrected to 1/1/87					
		^{60}Co	^{137}Cs	^{152}Eu	^{154}Eu	^{155}Eu	^{241}Am
L21291	64418	<	<	<	<	<	<
	64445	<	<	<	<	<	<
L21295	64422	<	<	<	<	<	<
	64446	<	<	<	<	<	<
L21299	64426	12.2 (1)	3.24 (6)	11.9 (3)	13.6 (3)	3.20 (12)	25.3 (20)
	64444	12.4 (1)	3.38 (5)	12.2 (3)	13.9 (3)	3.70 (15)	26.0 (18)
L21304	64431	<	<	<	<	0.277 (28)	<
	64447	<	<	<	<	<	<
L21037 (REF-2)							
L21286	64413	31.1 (2)	405. (2)	47.3 (3)	2.54 (16)	20.1 (7)	171. (22)
L21294	64421	30.9 (2)	403. (4)	48.0 (2)	2.55 (14)	20.8 (7)	176. (19)
L21310	64437	31.6 (1)	410. (2)	46.9 (2)	2.68 (10)	20.9 (5)	167. (14)
L21039 (BKGD)							
L21309	64436	<	0.285 (7)	<	<	<	<

TABLE C-2. COMPARISON OF REPLICATE AND INTERLABORATORY ANALYTICAL RESULTS

Library No.	Laboratory	Sample No.	Concentration (pCi/g) and s.d. (%), decay-corrected to 1/1/87								
			^{60}Co	^{137}Cs	^{152}Eu	^{154}Eu	^{155}Eu	^{241}Am†	^{238}Pu	$^{239,240}Pu$	^{90}Sr
L20573	REECo	63322	4.08 (2)	11.1 (2)	4.81 (4)	1.61 (7)	0.943 (17)	0.150 (100)	---	---	---
	TMA	64483	5.10 (5)	12.9 (4)	6.35 (5)	2.44 (11)	1.13 (14)	0.105 (7)	0.218 (6)	0.928 (5)	60.8 (7)
		64493	4.76 (5)	12.6 (4)	6.41 (5)	2.20 (13)	0.567 (22)	0.120 (6)	0.222 (6)	0.958 (5)	65.8 (8)
L20581	REECo	63330	14.7 (2)	37.1 (2)	19.6 (2)	6.21 (4)	2.97 (6)	0.248 (100)	---	---	---
	TMA	64485	16.1 (4)	39.5 (4)	22.8 (4)	7.06 (7)	3.48 (8)	0.112 (6)*	0.217 (5)*+	1.18 (4)*	251. (7)
		64491	15.6 (4)	38.0 (4)	22.7 (4)	7.13 (6)	3.07 (8)	0.041 (10)*	0.115 (6)*+	0.858 (5)*	204. (7)
	Referee	64549	17.0 (6)	41.9 (7)	24.1 (11)	9.03 (14)	3.40 (18)	<	0.290 (5)+	2.33 (2)+	224. (6)
L20585	REECo	63334	19.7 (3)	46.6 (4)	33.1 (2)	9.43 (5)	3.92 (19)	0.574 (100)	---	---	---
	TMA	64486	22.6 (4)	52.5 (4)	38.0 (4)	11.6 (5)	5.03 (6)	0.120 (8)	0.208 (6)	1.44 (5)	273. (7)
		64497	20.5 (4)	47.0 (3)	35.6 (4)	10.5 (5)	4.29 (6)	0.085 (8)	0.209 (6)	1.19 (5)	228. (7)
L20589	REECo	63338	24.9 (1)	56.6 (2)	49.7 (2)	13.9 (4)	6.10 (4)	0.337 (100)	---	---	---
	TMA	64487	27.7 (4)	59.2 (4)	54.3 (4)	17.1 (8)	7.23 (11)	0.141 (7)*	0.310 (7)	1.90 (6)	343. (7)
		64494	26.0 (4)	58.1 (4)	51.7 (4)	16.3 (7)	7.94 (10)	0.298 (36)	0.244 (5)	1.80 (4)	387. (7)
L20602	REECo	63470	33.8 (2)	99.3 (2)	76.0 (2)	23.7 (4)	10.0 (8)	0.423 (100)	---	---	---
	TMA	64488	37.8 (4)	106. (3)	95.0 (4)	29.2 (4)	11.9 (5)	0.150 (6)*	0.299 (6)*	1.98 (5)	468. (7)
		64496	39.4 (4)	108. (3)	96.9 (4)	30.5 (4)	12.3 (5)	0.298 (7)*	0.169 (6)*	1.54 (5)	412. (7)
L20976	REECo	63824	2.41 (4)	36.2 (2)	3.87 (6)	0.684 (21)	0.980 (31)	162. (15)	---	---	---
	TMA	64489	3.14 (8)	45.4 (4)	4.35 (8)	1.10 (21)	1.28 (24)	371. (7)*	70.6 (5)*	759. (4)	27.8 (9)
		64499	3.57 (9)	46.7 (4)	4.09 (9)	<	1.34 (30)	144. (8)*	16.1 (6)*	629. (4)	23.8 (16)
L20985	REECo	63833	1.08 (3)	35.3 (1)	4.53 (3)	0.638 (10)	0.374 (14)	48.7 (8)	---	---	---
	TMA	64490	1.20 (20)	41.9 (4)	5.47 (8)	1.49 (26)	<	51.9 (6)	5.17 (6)	216. (4)	22.8 (7)
		64495	1.28 (16)	42.1 (4)	4.45 (9)	<	<	52.2 (6)	6.36 (7)	219. (4)	22.2 (10)
L20989	REECo	63837	11.6 (1)	91.7 (1)	21.5 (2)	5.05 (5)	4.51 (6)	633. (8)	---	---	---
	TMA	64500	13.1 (4)	97.7 (3)	25.6 (4)	5.94 (7)	5.58 (5)*	672. (7)	70.7 (6)	2920. (4)	91.0 (15)
		64506	12.3 (4)	97.9 (3)	25.8 (4)	6.08 (5)	1.70 (10)*	686. (6)	82.1 (7)	3040. (4)	95.2 (13)
	Referee	64551	13.0 (7)	104. (4)	24.4 (11)	4.96 (22)	3.66 (17)	776. (4)	48.0 (11)+	2920. (5)	61.9 (7)+
L20993	REECo	63841	0.292 (12)	11.9 (5)	1.06 (16)	0.176 (100)	0.349 (33)	16.0 (19)	---	---	---
	TMA	64501	0.177 (38)	5.78 (4)+	0.380 (22)	<	<	5.77 (5)	0.767 (6)	22.9 (6)	4.25 (8)
		64507	<	5.53 (5)+	0.551 (23)	<	0.167 (66)	5.25 (8)	0.699 (7)	24.0 (6)	3.02 (7)
L20997	REECo	63845	2.22 (5)	46.2 (4)	6.90 (6)	0.946 (30)	0.707 (41)	117. (34)	---	---	---
	TMA	64504	1.96 (11)	40.9 (4)	7.12 (7)	<	0.863 (36)	98.2 (6)	10.1 (5)	381. (4)	24.1 (9)
		64511	2.14 (9)	41.4 (4)	6.16 (6)	1.20 (26)	<	99.2 (6)	11.3 (6)	403. (4)	24.9 (9)
L20832	REECo	63602	0.023 (100)	1.56 (6)	0.406 (18)	0.094 (100)	0.200 (90)	129. (19)	---	---	---
	TMA	64502	<	1.49 (9)	0.370 (55)	<	<	68.2 (7)	8.20 (8)	423. (5)	2.25 (15)
		64512	0.219 (68)	1.64 (8)	0.575 (28)	<	<	68.0 (7)	8.09 (8)	433. (4)	2.64 (13)
L20837	REECo	63607	0.369 (7)	42.0 (2)	2.84 (8)	0.130 (100)	3.54 (27)	2680. (21)	---	---	---
	TMA	64505	0.407 (21)	45.4 (4)	3.90 (6)	0.212 (65)	<	13100. (9)+	865. (5)	46900. (5)	86.9 (9)
		64513	0.407 (19)	45.0 (4)	4.90 (7)	<	<	7910. (6)*+	816. (5)	44200. (5)	81.8 (10)
L20849	REECo	63619	0.017 (100)	2.16 (6)	0.096 (100)	0.066 (100)	0.216 (69)	140. (27)	---	---	---
	TMA	64508	<	2.29 (5)*	0.134 (39)	<	0.110 (68)	173. (6)	18.1 (6)	997. (4)	6.27 (9)
		64517	0.099 (57)	4.42 (4)*	0.433 (18)	<	0.549 (19)	139. (6)	20.2 (12)	903. (5)	5.59 (41)
	Referee	64552	<	2.70 (9)	<	<	<	160. (4)	23.8 (5)	857. (5)	<
L17185	TMA	64509	0.233 (20)	7.43 (4)	1.15 (9)	<	<	658. (6)	171. (7)*	4670. (5)	14.2 (17)
		64518	0.187 (29)	7.18 (4)	0.934 (6)	<	1.40 (6)	632. (7)	73.1 (8)*	4490. (4)	13.3 (12)
L17203	TMA	64510	0.088 (64)	5.93 (4)	1.49 (7)	<	1.51 (6)	611. (6)*	65.0 (7)*	3160. (4)*	5.94 (39)
		64519	0.078 (60)	5.81 (4)	1.25 (8)	<	<	942. (4)*	102. (7)	5130. (4)*	15.3 (11)
L17211	TMA	64514	0.074 (32)	3.52 (4)	0.492 (15)	<	0.355 (31)	301. (6)	32.7 (10)	1700. (4)	4.79 (14)*
		64516	0.188 (34)	3.24 (5)	0.614 (14)	<	0.380 (26)	257. (6)	32.0 (9)	1710. (4)	9.34 (28)
L17217	TMA	64515	0.347 (19)	30.6 (4)	3.50 (5)*	<	4.25 (4)	5450. (6)	474. (6)	25800. (5)	58.9 (11)
		64526	0.474 (9)	30.2 (3)	0.485 (14)*	0.154 (70)	3.62 (4)	4440. (5)	461. (5)	24800. (5)	75.6 (20)
	Referee	64553	0.585 (49)	32.4 (6)	2.56 (48)	<	<	4520. (4)	392. (6)	22100. (5)	53.1 (7)

TABLE C-2 (continued)

Library No.	Laboratory	Sample No.	Concentration (pCi/g) and s.d. (%), decay-corrected to 1/1/87								
			^{60}Co	^{137}Cs	^{152}Eu	^{154}Eu	^{155}Eu	^{241}Am†	^{239}Pu	$^{239,240}Pu$	^{90}Sr
L17227	TMA	64521	0.366 (17)	21.6 (4)	1.05 (7)	<	<	3120. (5)	278. (5)	15100. (4)	50.8 (9)
		64529	0.378 (19)	23.0 (4)	1.80 (10)	<	2.79 (5)	2560. (5)	267. (5)	14200. (4)	54.2 (13)
L20362	REECo	62668	12.8 (2)	5.07 (6)	27.6 (2)	28.1 (2)	7.23 (9)	16.9 (16)	---	---	---
	TMA	64522	13.4 (4)	4.98 (4)	23.6 (4)*	36.0 (4)	8.14 (4)	14.6 (6)	29.6 (6)	13.0 (6)	3.91 (7)
		64535	13.6 (4)	5.22 (5)	31.9 (4)*	38.6 (4)	8.80 (4)	17.3 (5)	28.9 (5)	11.4 (5)	5.24 (7)
L20370	REECo	62676	10.1 (1)	3.52 (6)	18.5 (2)	18.2 (3)	5.08 (10)	11.6 (17)	---	---	---
	TMA	64523	11.4 (5)	3.56 (8)	22.0 (4)	25.7 (5)	6.08 (9)	11.2 (10)	21.3 (4)	7.85 (4)	2.80 (8)
		64533	11.9 (4)	4.00 (5)	22.0 (4)	26.8 (4)	6.04 (5)	12.0 (10)	22.4 (5)	7.91 (5)	2.98 (9)
L20383	REECo	62689	9.38 (2)	9.08 (4)	17.3 (3)	19.4 (3)	4.57 (10)	12.0 (24)	---	---	---
	TMA	64524	11.5 (4)	10.9 (4)	20.7 (4)	24.0 (4)	6.16 (5)	12.4 (6)	20.9 (6)	10.3 (6)	6.90 (7)
		64532	10.8 (4)	10.5 (4)	20.3 (4)	23.6 (4)	5.77 (4)	13.5 (6)	21.7 (5)	9.37 (5)	7.71 (7)
L21287	REECo	64414	249. (2)	20.3 (10)	384. (2)	402. (3)	106. (11)	451. (19)	---	---	---
	TMA	64528	285. (4)	24.6 (5)	482. (3)	555. (4)	137. (4)	458. (4)	699. (4)	294. (5)	26.2 (19)
		64537	299. (3)	23.7 (5)	486. (3)	562. (4)	143. (4)	454. (5)	661. (4)	262. (4)	24.9 (30)
	Referee	64554	290. (4)	23.0 (8)	471. (6)	512. (6)	136. (5)	476. (4)	672. (6)	298. (6)	42.6 (7)
L21292	REECo	64419	344. (2)	22.0 (14)	671. (3)	680. (4)	205. (9)	592. (20)	---	---	---
	TMA	64525	390. (4)	24.8 (6)	797. (3)	963. (4)	232. (4)	549. (6)	918. (4)	353. (5)	29.6 (17)
		64534	380. (3)	23.4 (6)	793. (3)	935. (4)	225. (4)	603. (4)	935. (5)	362. (5)	23.0 (11)
L18238	TMA	64530	91.7 (4)	77.7 (3)	53.0 (4)	12.9 (6)	6.98 (5)	259. (5)	97.4 (6)	706. (4)	118. (14)
		64540	96.2 (3)	82.2 (3)	55.2 (4)	13.1 (5)	7.05 (5)	280. (5)	106. (6)	761. (5)	82.6 (8)
L18241	TMA	64531	1.60 (12)	5.59 (6)	<	<	<	8.51 (6)	15.9 (5)	6.10 (5)	3.59 (7)
		64545	1.14 (13)	5.95 (5)	0.335 (56)	0.615 (44)	0.232 (80)	8.77 (6)	12.4 (6)	7.52 (6)	3.15 (7)
L18245	TMA	64538	4.48 (5)	4.17 (5)	1.98 (8)+	<	0.448 (34)	10.2 (6)	7.57 (5)	30.3 (5)	4.40 (8)
		64548	4.10 (5)	4.06 (4)	2.23 (6)+	0.569 (36)	0.542 (15)	11.5 (10)	6.98 (6)	29.3 (6)	3.95 (8)
	Referee	64555	4.64 (13)	4.51 (8)	4.72 (36)	<	<	10.8 (5)	6.53 (4)	29.3 (4)	3.67 (34)
L18261	TMA	64539	0.305 (16)	3.58 (4)	<	<	<	2.26 (5)	4.63 (6)	1.89 (6)*	4.92 (7)
		64546	0.393 (16)	3.65 (4)	<	<	0.137 (41)	2.34 (11)	5.92 (5)	2.72 (5)*	5.85 (7)
L18280	TMA	64541	8.18 (4)	7.44 (4)	3.42 (5)	1.36 (14)	0.478 (25)	17.2 (6)	19.0 (5)	43.0 (5)	6.70 (7)
		64544	8.47 (4)	7.45 (4)	3.64 (5)	1.09 (17)	0.561 (15)	18.4 (6)	20.9 (5)	44.3 (5)	7.15 (7)
L18660	TMA	64543	6.50 (6)	11.7 (4)	2.76 (10)	1.02 (40)	<	12.1 (5)	19.4 (4)	30.6 (4)	6.47 (7)
		64547	6.71 (4)	11.9 (4)	2.72 (6)	1.20 (19)	0.478 (22)	12.3 (7)	20.2 (5)	31.3 (5)	6.42 (7)
L21037	TMA	64484	30.0 (4)	403. (3)	50.1 (4)	3.08 (20)	24.2 (6)	150. (7)	300. (5)	933. (4)	673. (7)
		64498	26.0 (4)*	395. (3)	47.8 (4)	2.46 (26)	25.0 (5)	164. (6)	353. (7)	1060. (6)	736. (7)
		64503	32.3 (4)	429. (3)	52.8 (4)	3.16 (20)	27.0 (4)	153. (7)	328. (7)	934. (6)	652. (8)
		64520	30.2 (4)	394. (3)	53.1 (4)	2.70 (16)	24.2 (4)	174. (8)	319. (5)	1010. (4)	729. (7)
		64527	30.6 (4)	422. (3)	50.7 (4)	2.68 (23)	24.3 (5)	126. (8)	290. (5)	898. (4)	580. (8)
		64536	30.1 (4)	412. (3)	50.9 (4)	2.52 (18)	24.8 (4)	155. (5)	302. (5)	900. (4)	797. (7)
	Referee	64550	31.5 (5)	414. (3)	50.1 (8)	4.47 (33)	25.6 (7)	166. (4)	287. (5)	909. (5)	844. (6)
L21037		‡	30.5 (8)	393. (5)	NR	NR	NR	154. (9)	289. (7)	913. (3)	817. (10)
L21039	TMA	64492	<	0.236 (9)	<	<	<	0.029 (11)*	0.054 (9)	0.180 (7)	0.609 (9)*
		64542	<	0.319 (10)	<	<	<	0.108 (11)*	0.053 (8)	0.193 (6)	0.190 (8)*
L21039		‡	0.3 (25)	0.4 (25)	NR	NR	NR	<	NR	NR	NR

†TMA used chemical separation and alpha spectrometry to determine ^{241}Am; REECo and the Referee used gamma spectrometry.

*TMA value flagged by 3-sigma test of replicate analyses.

+Value flagged when compared to results from the other laboratories.

‡Average of results reported by Essington (1987); "NR" indicates results not reported.

Results of the analysis of selected samples for determination of radionuclide ratios are summarized in Table C-2. This table includes results from the gamma assays of the original bulk samples by REECo and LLNL and results generated by TMA and the Referee from aliquots of the bulk samples.

Evaluation of the results included the 3-sigma screening test. The test flagged a result as questionable if the absolute value of the result minus the mean of the replicates was larger than 3 times the reported standard deviation (error term) for the result as specified by the analytical laboratory. It was applied to results on the assumption that the error term quoted by the analyst for each result is the total analytical error. That is the case for the TMA and Referee results, but the error term reported for the REECo results included only the counting error plus a small energy-dependent factor calculated by the GAMANAL computer code. Total analytical error includes the counting error and errors due to, for example, positioning the sample on the detector, standardization for counter efficiency, and variability in sample density. Consultation with the REECo analytical laboratory indicated that the minimum analytical error, excluding the counting error, was 9% due to sample density variability and 1.4% for ^{137}Cs, 3% for ^{60}Co, ^{152}Eu and ^{154}Eu, and 7% for ^{155}Eu and ^{241}Am due to other sources of variability. Those errors were combined with the counting error reported for each result to give an estimate of the total analytical error which was used in the 3-sigma test of the results.

After a result was flagged or otherwise found to be questionable, the analyst was asked to check for possible transcription errors or other factors that might have caused the result to appear erroneous. The consultation was conducted in such a way that the analyst did not learn the direction or magnitude of the suspected errors or the identity of the replicates or blind samples.

The 3-sigma test was first used to identify questionable results from analysis of replicate samples by TMA. Such results are noted in Table C-2 by (*). The average of the replicates (with the propagated error term) was then compared with the results from REECo or the Referee using the 3-sigma test. Flagged results from that test are noted with (+).

The following are specific examples of TMA replicate results that were flagged and evaluated to determine possible discrepancies. Sample L20976-64489 exhibited much higher ^{241}Am and ^{238}Pu, but only slightly higher $^{239,240}Pu$ and ^{90}Sr, than did its replicate. This same difference between replicates was not observed for the ^{60}Co, ^{137}Cs, or radioeuropium results. The discrepancy in these results is probably not a result of sample

aliquoting error but is likely to be due to analytical problems. This conclusion is supported by the fact that the ratio of ^{238}Pu in the two replicates (4.4) should have been the same as the $^{239,240}Pu$ ratio (1.2) and the ^{241}Am ratio (2.6), which is clearly not the case. Had the ratios been similar one could argue that the difference in replicates was due to the "hot particle problem" (HPP), which is the presence of a limited number of highly radioactive particles in a matrix of particles containing relatively low radioactivity. The HPP can cause a large degree of variability in replicate aliquots.

As another example, the sample L20837 results for ^{241}Am are quite variable whereas the results for plutonium are not. Again this appears to be due to an analytical problem and not to the HPP or to errors in aliquoting the original sample; there is good reason to believe that plutonium and americium will be distributed in radioactive particles in a similar manner. The amount of ^{238}Pu in sample L17185 is not consistent with the amounts of ^{241}Am or $^{239,240}Pu$, again suggesting that analytical problems may be responsible. Americium-241 and plutonium results for L17203 were flagged and are consistent in the differences between replicates. These data are representative of the variability introduced as a consequence of the HPP.

Results for the blind REF-2 sample show one replicate with a low value of ^{60}Co. That value failed the 3-sigma test, but because of the high degree of uniformity among the other values it was not considered a serious discrepancy.

The second test of the data is the comparison by the 3-sigma test of the REECo gamma results from the bulk samples with the results reported on replicate aliquots of the bulk samples by TMA and the few values reported by the Referee. The comparison was made after the bulk gamma results for the shorter-lived radionuclides were corrected for radioactive decay to the same date (1/1/87) used by TMA in reporting the replicate results. The 3-sigma test used adjusted error terms as discussed above. In only two samples were results flagged: ^{152}Eu in sample L18245 and ^{137}Cs in sample L20993. However, the activity levels were low, and experience suggests that in such cases all of the sources of error may not have been taken into consideration.

The third test of the data involves the independent analyses by the Referee of aliquots of a small number of the same samples analyzed by TMA. Except for ^{238}Pu and ^{90}Sr results for sample L20989, the Referee's results compare well with those of TMA; no reason could be found for the noted discrepancies.

As we have suggested previously, the fact that a result is flagged by the 3-sigma test does not indicate that it should be automatically rejected or removed from consideration.

An important example of this observation may be seen in the ^{137}Cs results for sample L20993. The TMA replicate results compare well, and the REECo bulk gamma result appears to be high (using the adjusted REECo analytical error described above), yet the 3-sigma test flagged only the TMA results. Thus, it is clear that the 3-sigma test does not give meaningful results when there are large differences in the errors associated with the individual measurements, and caution must be used in assessing the flagged results; the flagging is only an indication that one or more of the component results in the set should be evaluated before acceptance.

Finally, it is important to emphasize that the soil sample radioactivity parameters used in calculation of ratios and inverse relaxation lengths are averages that are based, in general, on measurements of several samples. For this reason, errors associated with individual analyses tend to be averaged and to produce only small errors in the final results. The variability incurred in the final parameters by this treatment is kept within the prescribed RIDP objectives.

SUMMARY

Based on the QA results of blinds and replicates, the overall data set reported for the samples evaluated appears to be reliable. Caution should be exercised in using those few results that were identified as questionable.

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