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Environmental Surveillance of Low-Level Radioactive-Waste-Management Areas At Los Alamos During 1987

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Cover photo: *View of Area G, the Laboratory's low-level radioactive-waste-management site.*

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ENVIRONMENTAL SURVEILLANCE OF LOW-LEVEL RADIOACTIVE-WASTE-MANAGEMENT AREAS AT LOS ALAMOS DURING 1987

by

Environmental Protection Group (HSE-8)
Environmental Science Group (HSE-12)
Waste Management Group (HSE-7)

ABSTRACT

This report presents the 1987 results of environmental monitoring of 1 active and 12 inactive low-level, radioactive-waste-management sites at Los Alamos National Laboratory. Results are presented for monitoring of radionuclides in air, surface water, ground water, soils and sediments, and vegetation, as well as for monitoring of external penetrating radiation. Regional and site information is evaluated to place the site-specific information into perspective. The waste-management-site surveillance program is designed to evaluate the containment performance of active and inactive sites, measure potential discharges from the sites, and evaluate potential doses received from these discharges.

Although some radiological parameters are elevated in association with waste-management sites, none exceeds limits for protection of the general public at off-site locations. During 1987, waste-management activities contributed less than 2% of the maximum off-site dose attributable to Laboratory operations; this dose level remained less than Radiation Protection Standards set by the U.S. Department of Energy. Airborne doses to the public from waste operations were less than 0.1% of the standard established by the U.S. Environmental Protection Agency for the air pathway.

I. INTRODUCTION

The Laboratory maintains an ongoing environmental surveillance program as required by U.S. Department of Energy (DOE) orders (Environmental Surveillance Group 1988). The surveillance program maintains routine monitoring stations for radiation and radioactive materials at locations on Laboratory lands and in the surrounding environment. The goal of this program is to provide ongoing assessments of releases from overall Laboratory operations into surrounding environmental media, such as air, ground waters, surface waters, and soil.

In addition to overall surveillance activities at the Laboratory, routine monitoring is carried out at 1 active and 12 inactive low-level, radioactive-waste-management areas under contract to the DOE's Defense Waste Operations Office (Environmental Science Group 1986, 1987). This program is carried out to ensure ongoing compliance with DOE order 5820.2A, "Radioactive Waste Management" (September 1988). The goal of radioactive-waste-area surveillance is to assess the performance of these areas in containing residual radioactive materials within their boundaries. This program consists of (1) routine surveys of management

areas to assess year-to-year integrity of the sites, and (2) detailed surveys of one or two sites each year to provide more-detailed knowledge about each site over a several-year cycle (Hansen et al. 1980).

The purpose of this report is to detail the activities of the waste-management-area surveillance program during 1987 and to integrate the information derived in 1987 with that from previous years and with overall surveillance results at the Laboratory and in surrounding regions.

II. SITE DESCRIPTIONS

The 1 active low-level radioactive-waste-management area (Area G) and the 12 inactive areas are identified in Fig. 1. The following descriptions provide general background information on each area. More-detailed information can be found in Rogers (1977), Walker et al. (1981), Wenzel et al. (1986), and the U.S. Department of Energy (1988).

A. Area A

Radioactive-waste-management Area A is located at Technical Area (TA)-21, DP Site. The area consists of five pits and two storage tanks. Waste solutions of plutonium and americium were stored in the tanks but were removed in 1983. The tanks presently contain a few centimeters of semisolid precipitate. Several small pits, which were used from 1944 to 1947, are believed to hold solid waste that originally contained polonium (now decayed away), trace beta-gamma activity, and trace alpha activity (probably plutonium). A larger pit, in use from 1969 to 1978, contains debris from the decommissioning of several buildings at TA-21. Additionally, drums of radioactive iodide were stored on the surface until 1960. Residual radioactive iodide from leaking drums would have decayed away by now. In 1985, the area was regraded to improve drainage, surface contamination was removed, and the area was revegetated.

B. Area B

This area is located immediately to the west of TA-21. The number of pits in Area B cannot be determined from the information currently available. Wastes consisted principally of solids originally containing plutonium, polonium, uranium, americium, curium, and actinium. At least one truck contaminated with fission products from the Trinity test is buried here. At the east end, several small trenches were used for nonradioactive chemical disposal. Part of the west end of the area has been covered with asphalt and is now leased to the county of Los Alamos for rental of storage space to the public. In 1982, the eastern portion was cleared of vegetation, re-covered with compact fill and soil, and reseeded.

C. Area C

Area C is located on the north side of Pajarito Road, south of the waste-management site (TA–50). It was opened in 1948 and consists of 6 pits for radioactive waste, 1 for chemical waste, and 107 shafts. Disposal in the pits ended in 1964; disposal in the shafts ended in 1969. Types of waste buried at Area C include depleted uranium chips, building debris from decommissioning TA-1 and TA-10, routine waste containing radionuclides, and sludge from liquid-waste treatment. Plutonium-contaminated sodium loops from TA–35 were deposited in several shafts. Uranium powders and hydrides have been deposited in the area, including some materials containing plutonium. Nonradioactive materials in the chemical pit include pyrophoric metals, hydrides and powders, sealed vessels containing sodium/potassium alloys or compressed gases, and equipment not suitable for salvage or deposition in municipal or radioactive-waste dumps. In 1984, a new cover was placed on portions of the site containing buried wastes, and the area was reseeded.

D. Area D

This area is located at TA-33, HP Site, on the eastern point of a mesa overlooking the Rio Grande. The area consists of two concrete line shafts approximately 14 m deep. Offset from the bottom of each shaft is an octagonal room that was used for experiments with weapons components. The principal radiological contaminant was ^{210}Po (now decayed to near zero), although residual beryllium and depleted uranium may also be present in small amounts. The shafts were used once each during 1948, and one was used again during 1952.

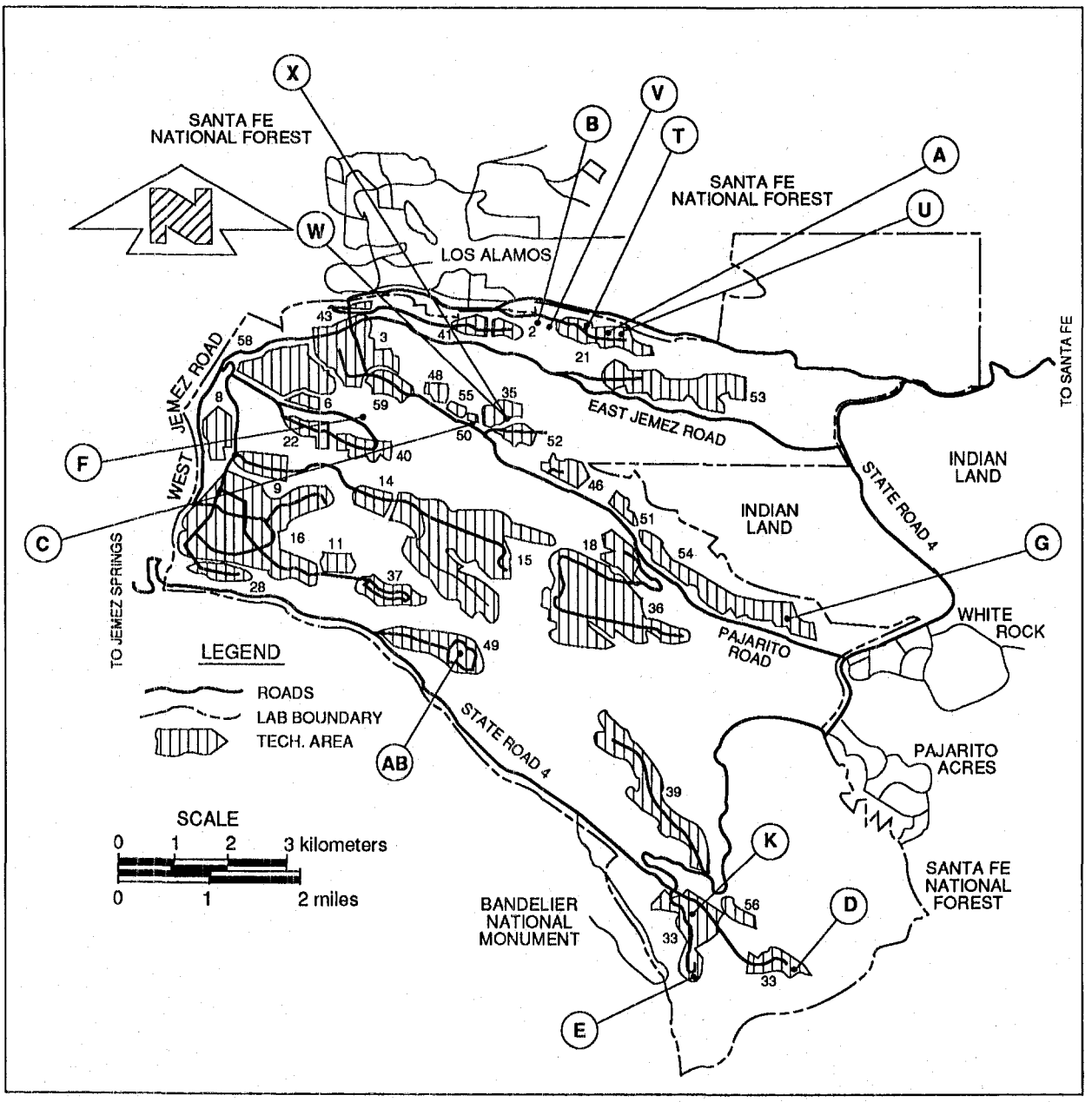


Fig. 1. Location of technical areas and radioactive-materials disposal areas at Los Alamos National Laboratory.

E. Area E

This area is also located at TA-33 on the southernmost mesa point. The area probably originally contained ^{210}Po (now decayed away) and uranium. The area apparently consists of six pits and one test shaft; the latter was used for experimenting with weapons components. Beryllium may also be present. Some subsidence has occurred around the shaft.

F. Area F

Area F is located on Two-Mile Mesa, east of TA-6. It is believed that two pits are present at the area, but

their locations are not accurately known. The area was opened in 1946 for disposal of unsalvageable materials potentially containing depleted uranium, high explosives, primacord, and ^{137}Cs.

G. Area G

Area G is located at TA-54 on the east end of Mesita del Buey, north of Pajarito Road. This currently active area is the radioactive-solid-waste burial and storage site for the Laboratory. The area was established in 1957 to receive low-level radioactive waste. It has a fenced area of 255 000 m^2 (63 acres) devoted to waste disposal. Early records did not identify the total activity disposed of at the site, although isotopic composition of the waste was noted. Since about 1970, records have been maintained for all aspects of the wastes handled here. From 1971 to 1983, materials containing transuranic (TRU) radionuclides of more than 10 nCi/g (100 nCi/g for ^{238}Pu) were placed in retrievable storage. Since 1983, the DOE limit for all retrievable TRU waste has been 100 nCi/g. In addition to TRU waste, the main radionuclides in waste deposited here have been tritium, uranium, and a variety of fission and activation products. In recent years, 50 000 to 70 000 Ci/year of tritium have been buried in Area G. Wastes containing asbestos and polychlorinated biphenyls (PCBs) have also been placed here under a permit from the U.S. Environmental Protection Agency. Asbestos has been regularly buried at the site.

H. Area K

This area contains one or two small sump pits located at TA-33 north of building 86. It is believed that these pits served a large sink that was used to maintain and repair an old tritium transfer pump. The principal radionuclide of concern here is tritium, with uranium possibly present. No other constituents are known to discharge to the sumps.

I. Area T

This area consists of four absorption beds at TA-21 that received untreated liquid waste generated during plutonium processing from 1945 to 1952. Between 1952 and 1967, infrequent discharges occurred from the liquid-waste processing at building 35. After that time, batch americium wastes from new treatment facilities were mixed with cement and pumped down shafts between two of the absorption beds. Beginning in 1975, TRU wastes were mixed with cement and pumped into corrugated metal-pipe sections that were stored between two rows of absorption pits. These pipes were moved to Area G in 1986.

J. Area U

Area U is also located at TA-21 and contains two absorption beds similar to those at Area T. These beds were used for the disposal of liquid waste between 1945 and 1968. The principal radionuclide in these wastes was polonium, which has since decayed away. Several curies of ^{227}Ac were also discharged to the beds. The area has been partially excavated, backfilled, and recapped with uncontaminated soil materials.

K. Area V

Also located at TA-21, Area V contained three absorption beds that received liquid waste generated by laundry operations from 1945 to 1961. An estimated 3 Ci of ^{89}Sr, ^{140}Ba, and ^{140}La have decayed to undetectable limits after discharge to the beds. Small quantities of ^{90}Sr and ^{239}Pu were also discharged. The area was recapped in 1985.

L. Area W

Area W consists of two vertical stainless steel tubes located at TA-35, Ten Site. The tubes contain 220 to 290 kg of sodium metal and sodium/potassium alloy that were used as a coolant for an experimental reactor. These materials contain small, but unknown, amounts of ^{239}Pu, as well as ^{137}Cs. The reactor was shut down in 1963, and shorter-lived fission products have decayed away. The tops of the pipe were entombed in 1979.

M. Area X

This area is also located at TA-35 and contains the reactor pressure vessel of another experimental reactor, as well as associated piping and the remains of a pump pit. The reactor used a phosphoric acid/uranium

solution as fuel. The fuel was removed in 1959. Currently the area is paved, and a permanent surface marker designates the location of the vessel.

N. Area AB

Area AB is located at TA-49, north of State Route 4 on the southern boundary of the Laboratory. It consists of a series of shafts, 30 to 120 ft deep, located within four experimental areas. The area was used for subsurface hydronuclear experiments from 1959 to 1961. Totals of about 40 kg of plutonium, 93 kg of enriched uranium, and at least 82 kg of depleted uranium were used in the experiments. Less than 1 mCi of fission products is expected to be present. Beryllium and lead are also present as a result of the experiments.

III. METEOROLOGY

A. Waste Management Area G

A 10.5-m meteorological tower is located in the northeastern section of Area G. The parameters measured and the tower heights where the measurements were taken are presented in Table 1. Fifteen-minute-averaged data are recorded by a data-acquisition system. A 24-hour summary is also recorded, which includes measurements of maximum and minimum temperatures, relative humidity, maximum wind gusts, average wind speed, total solar radiation, and total precipitation.

Precipitation at Area G was higher than normal during 1987 (Table 2). Heavier-than-average snowfall in January, February, and December, as well as heavy thundershowers in May and August, produced an annual precipitation of 36.55 cm for the year. One-third of the annual precipitation fell during August thunderstorms—a single storm on August 25 produced 2.69 cm of rain. Monthly temperatures (Table 3) were colder than normal during the months having above-normal precipitation, yielding an annual temperature slightly below normal. Dry weather during September and October produced temperatures above normal. The coldest temperature, −19.5°C, was recorded in the early hours of December 27, a calm clear night following snowfall on December 24 and 25. The highest temperature, 32.7°C, was recorded on June 24.

Wind roses for Area G are presented in Fig. 2(a)–(c). The predominant wind direction [Fig. 2(a)] is from the south-southwest, reflecting the channeling and diurnal heating effect of the Rio Grande Valley. Frequent occurrences of weak, synoptic-scale pressure gradients allow differential solar heating of the terrain surrounding Los Alamos to produce a large diurnal variation of winds at the site.

The daytime wind rose [Fig. 2(b)] shows a maximum frequency of occurrence from the south-southwest, indicating wind flow up the Rio Grande Valley. This wind flow occurs from midmorning through the evening. A secondary maximum is present from the north-northeast through northeast. These are

Table 1. Meteorological Measurements at Radioactive-Waste-Management Areas G and C.

	Height of Measurement (m)	
Parameters	**Area G**	**Area C**
Wind	1.2, 3.5, 10.5	11.5, 23, 46, 92
Velocity		
Direction		
Standard deviation		
Temperature	0.1, 1.2, 10.5	11.5, 23, 46, 92
Solar radiation	3.5	
Relative humidity	1.2	
Precipitation	1.2	

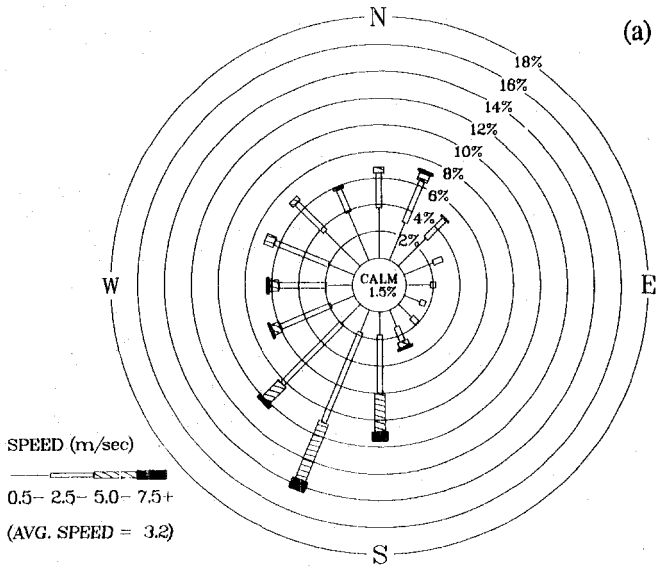
Table 2. Precipitation at Radioactive-Waste-Management Areas G and C During 1987.

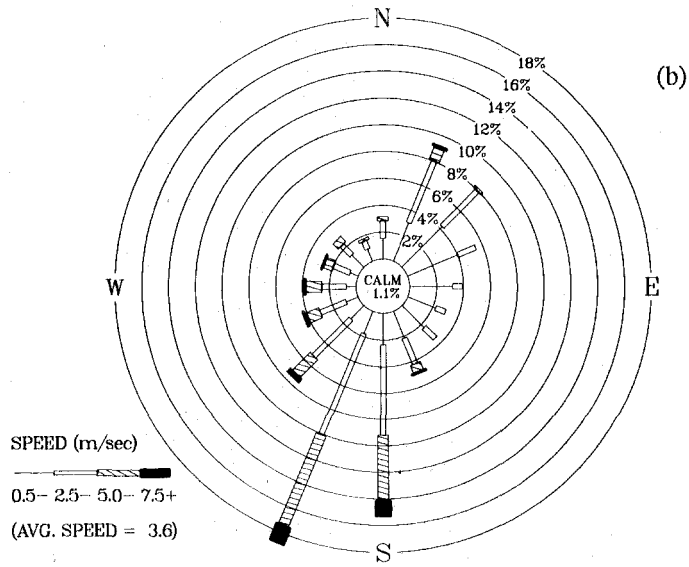
	Area G		Area C	
	1987 cm (in.)	Normal[a] cm (in.)	1987[b] cm (in.)	Normal[c] cm (in.)
January	2.39 (0.94)	1.63 (0.64)	5.55 (2.19)	1.94 (0.77)
February	3.48 (1.37)	1.30 (0.51)	6.36 (2.50)	1.55 (0.61)
March	0.76 (0.30)	1.93 (0.76)	2.01 (0.79)	2.31 (0.91)
April	1.09 (0.43)	1.65 (0.65)	2.49 (0.98)	1.97 (0.77)
May	3.91 (1.54)	2.16 (0.85)	6.47 (2.55)	2.58 (1.02)
June	1.63 (0.64)	2.13 (0.84)	6.15 (2.42)	2.56 (1.01)
July	3.51 (1.38)	6.05 (2.38)	3.13 (1.23)	7.27 (2.86)
August	12.09 (4.76)	7.49 (2.95)	9.81 (3.86)	8.98 (3.54)
September	1.57 (0.62)	3.10 (1.22)	3.93 (1.55)	3.73 (1.47)
October	1.09 (0.43)	2.90 (1.14)	1.12 (0.44)	3.47 (1.37)
November	2.39 (0.94)	1.83 (0.72)	3.36 (1.32)	2.19 (0.86)
December	2.64 (1.04)	1.83 (0.72)	3.61 (1.42)	2.19 (0.86)
Total	36.55 (14.39)	33.99 (13.38)	54.0 (21.26)	40.76 (16.05)

[a]Estimated as 75% of the 30-year normal precipitation at TA-59.
[b]Estimated as 90% of the 1987 precipitation at TA-59.
[c]Estimated as 90% of the 30-year normal precipitation at TA-59.

Table 3. Average Daily Maximum and Minimum Temperatures at Area G and TA-59 During 1987.

	Area G		TA-59			
	1987		1987		Normal	
	Maximum °C (°F)	Minimum °C (°F)	Maximum °C (°F)	Minimum °C (°F)	Maximum °C (°F)	Minimum °C (°F)
January	2.7 (36.8)	−8.6 (16.6)	2.8 (37.1)	−8.2 (17.2)	4.3 (39.7)	−7.5 (18.5)
February	5.6 (41.9)	−5.3 (22.4)	5.2 (41.3)	−5.8 (21.6)	6.1 (43.0)	−5.8 (21.5)
March	9.8 (49.6)	−3.7 (25.3)	8.8 (47.9)	−4.7 (35.7)	9.3 (48.7)	−3.1 (26.5)
April	16.8 (62.2)	1.3 (34.3)	16.1 (61.0)	0.8 (33.5)	14.2 (57.6)	0.9 (33.7)
May	20.6 (69.1)	5.1 (41.2)	18.6 (65.4)	4.7 (40.5)	19.4 (67.0)	6.0 (42.8)
June	27.1 (80.9)	11.0 (51.9)	25.9 (78.6)	10.5 (50.9)	25.4 (77.8)	11.3 (52.4)
July	29.4 (84.9)	13.5 (56.3)	27.7 (81.9)	13.2 (55.8)	26.9 (80.4)	13.4 (56.1)
August	25.6 (78.0)	12.1 (53.8)	24.1 (75.3)	11.8 (53.3)	25.2 (77.4)	12.4 (54.3)
September	23.1 (73.6)	8.2 (46.8)	21.4 (70.5)	8.3 (46.9)	22.3 (72.1)	9.1 (48.4)
October	20.0 (68.0)	4.0 (39.3)	19.1 (66.4)	4.9 (40.8)	16.7 (62.0)	3.7 (38.7)
November	9.2 (48.5)	−3.4 (26.0)	8.9 (48.0)	−2.7 (27.2)	9.3 (48.7)	−2.7 (37.9)
December	2.9 (37.1)	−8.5 (16.7)	2.6 (36.7)	−7.9 (17.8)	5.9 (41.4)	−6.5 (20.3)
Average	16.1 (60.9)	2.1 (35.9)	15.0 (59.3)	2.1 (35.8)	15.3 (59.6)	2.6 (36.7)





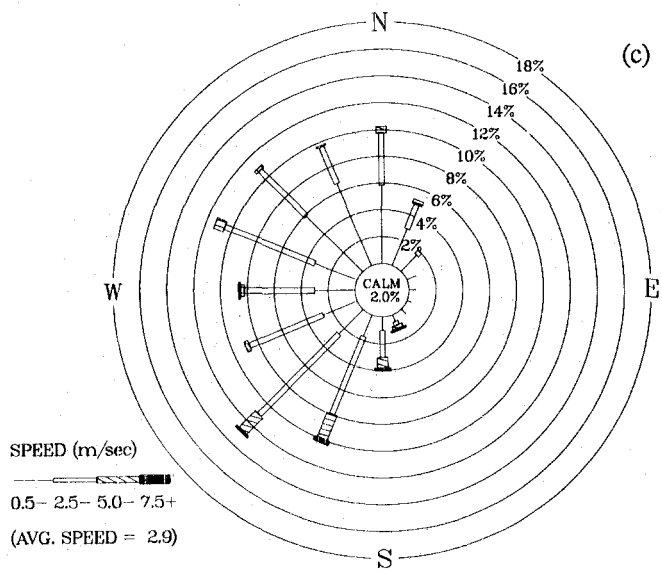


Fig. 2(a)–(c). Wind roses for Area G (TA-54) during 1987 for (a) total time (24 hours), (b) daytime, and (c) nighttime.

down-valley drainage winds that develop over the Rio Grande during the night and continue past sunrise because of thermal inertia. At night [Fig. 2(c)], the predominant winds are light winds flowing down the Pajarito Plateau, which slopes from the west-northwest and northwest to the east-southeast and southeast.

Los Alamos is a light-wind site; the annual average wind speed at Area G is 3.2 m/s, with 40% of wind speeds less than 2.5 m/s. High wind speeds are observed in the spring months when large-scale, low-pressure systems move out of the Rocky Mountains onto the Great Plains. Wind gusts up to 31 m/s have been recorded during these storms.

B. Waste Management Area C

A 92-m meteorological tower is located in Area C. The meteorological variables measured and the tower heights where measurements are taken are presented in Table 1. As at the Area G tower, 15-minute-averaged data and a 24-hour summary are recorded. Precipitation and surface (1 m above ground level) temperatures were not measured at Area C. However, measurements at TA-59, 1500 m to the west, provide estimates of temperatures and precipitation at Area C.

Precipitation at Area C also was higher than normal during 1987 (Table 2). Record snows fell during January and February (180 and 120 cm, respectively, at TA-59), and heavy snow fell during December (91 cm at TA-59), making 1987 the year with the most snow on record (452 cm). Higher-than-average precipitation also occurred during May and June; one thunderstorm on June 7 produced 5.48 cm of rain at TA-59. Annual average maximum and minimum temperatures (Table 3) were colder than normal, primarily because of cold, wet weather in January, February, and December. Temperatures in these months were offset by warm, dry weather in September and October. The highest temperature recorded during the year was 31.1°C on June 24. The coldest temperature (−19.4°C) occurred on January 18.

Wind roses for Area C are presented in Fig. 3(a)–(c). The predominant wind directions at Area C are from the south through the northwest. These directions reflect (1) the channeling effect of the Rio Grande Valley, and (2) the diurnal wind cycle caused by differential solar heating of the terrain surrounding Los Alamos.

The daytime wind rose [Fig. 3(b)] shows a maximum frequency of occurrence of winds from the south, indicating wind flow up the Rio Grande Valley. Light winds (with speeds less than 2.5 m/s) from the east and southeast represent winds moving up the slope of the Pajarito Plateau in the morning hours. The northeast winds are nighttime drainage winds flowing down the Rio Grande Valley, which persist past sunrise because of thermal inertia.

The dominant aspect of the nighttime wind rose [Fig. 3(c)] is the west-northwest wind. This represents a drainage wind off the Jemez Mountains down across the Pajarito Plateau, which slopes from the west-northwest to east-southeast.

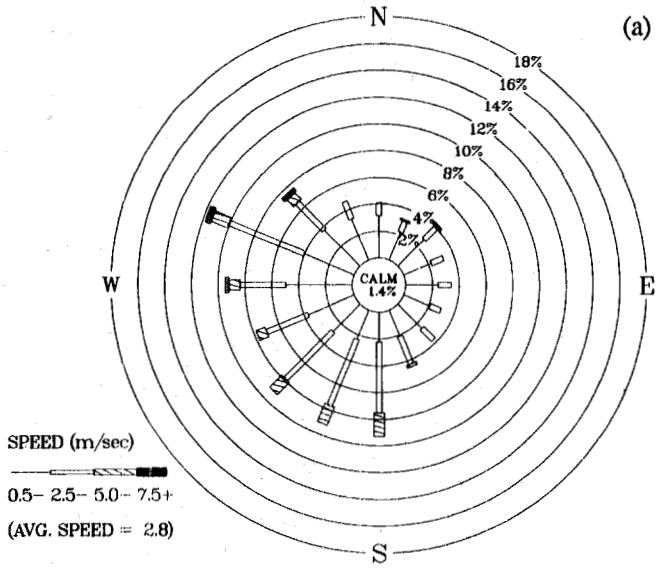
IV. SAMPLING AND ANALYTICAL METHODOLOGY

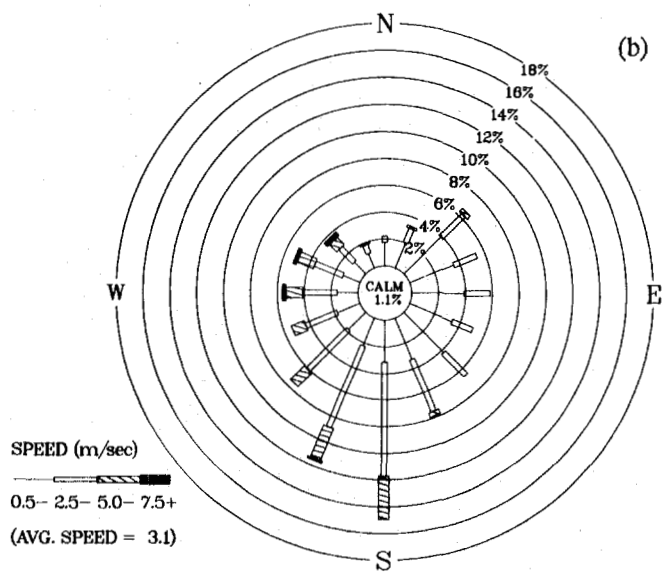
Samples for the low-level, radioactive-waste-area surveillance program are collected from several media, including air, ground and surface waters, soil and sediment, and vegetation. External penetrating radiation is also monitored. This sampling is carried out as an adjunct to the routine, site-wide sampling program. Sampling locations are situated where residual radionuclides from the waste areas are expected to be mobilized. Sampling and analytical procedures follow those carried out for the site-wide sampling operations (Environmental Surveillance Group 1987, 1988; Health and Environmental Chemistry Group 1987, 1988).

V. AIR MONITORING

Since 1984, six air-monitoring stations have been maintained at TA-54 at the active radioactive-waste management site Area G (Fig. 4). Station 31 is a replicate of station 22. These six stations are operated in the same manner as the air-monitoring stations in the Laboratory's routine surveillance program (Environmental Surveillance Group 1987, 1988). Samples are collected and analyzed monthly for tritium and quarterly for total uranium, ^{238}Pu, $^{239,240}Pu$, and ^{241}Am.

Concentrations of airborne radionuclides at Area G tended to be higher than those found in off-site stations within 4 km of the Laboratory boundary (off-site stations are called perimeter stations in the Environmental Surveillance Group report, Table G-4 [1988]).





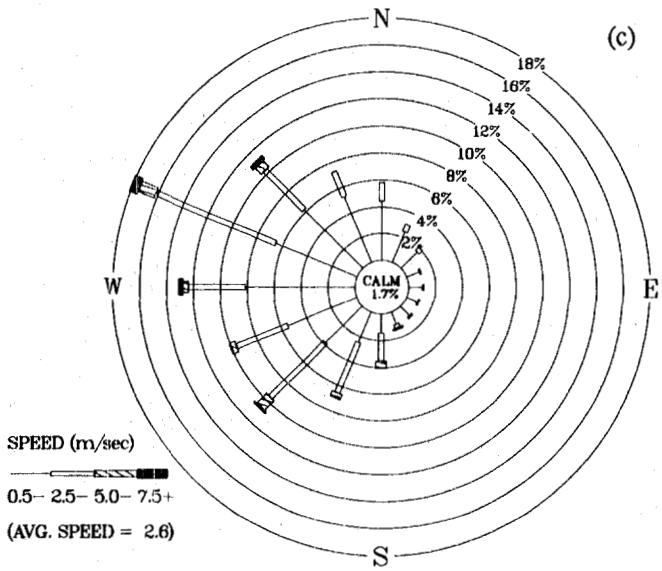


Fig. 3(a)–(c). Wind roses for Area C (TA-50) during 1987 for (a) total time (24 hours), (b) daytime, and (c) nighttime.

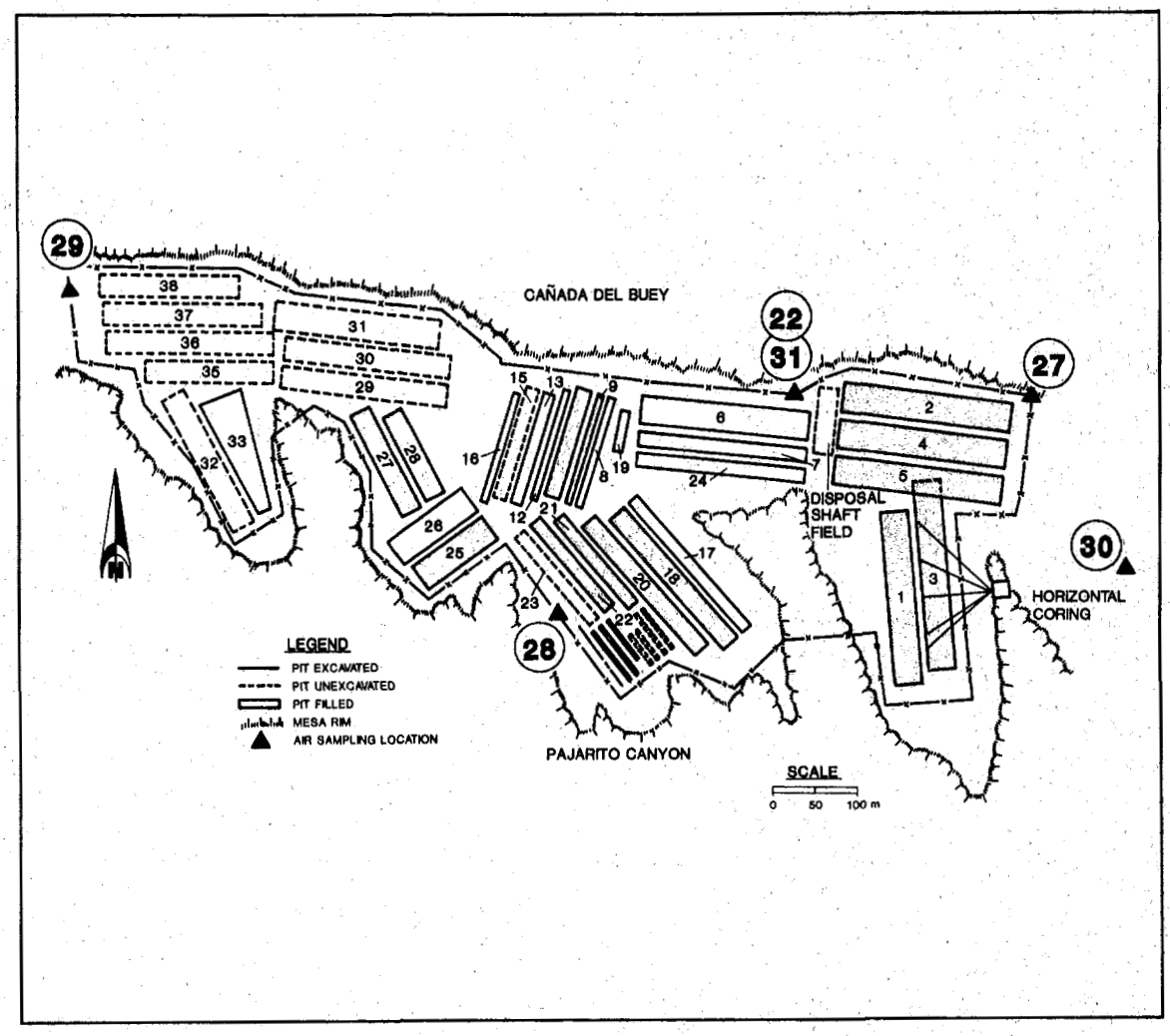


Fig. 4. Active radioactive-waste-management site at Area G (TA-54).

However, the differences were only statistically significant at one or two stations within Area G for a given radionuclide (Tables 4–8).

Concentrations of airborne tritium were significantly higher at station 28 than at off-site (perimeter) stations (Table 4). Tritium concentrations at this station were also significantly higher than those found at other stations at Area G. A similar trend was found in 1985 and 1986 (Environmental Science Group 1986, Table 6; 1987, Table 14). Station 28 is adjacent to the pits and shafts located near the south-central boundary of Area G (Fig. 4). The shafts are used for burial of high concentrations of tritium as tritiated water. This material is generated from exhaust air cleaning at Laboratory tritium-work facilities. This waste is packaged in drums before burial.

Airborne concentrations of uranium tended to be higher along the northern boundary of Area G (stations 22, 27, 29, and 31). However, significant differences from off-site (perimeter) stations occurred only at stations 22 and 29 (Table 5). The concentrations of airborne transuranics also tended to be higher at the four stations located on the northern perimeter of Area G. A similar trend was found in 1985 and 1986 (Environmental Science Group 1986, Table 6; 1987, Table 14). Plutonium-238 concentrations at station 27 were significantly higher than those at all off-site (perimeter) stations (Table 6), and concentrations of

$^{239,240}Pu$ at stations 22 and 31 were significantly higher than at some, but not all, perimeter stations (Table 7). Prevailing daytime winds at Area G are from the south to southwest [Fig. 2(b)]. Hence, the stations on the northern boundary of the area are downwind from the radioactive-waste handling and storage activities and probably have higher dust loading than other stations.

The sampling stations at Area G are located well within the boundaries of the Laboratory. DOE order

Table 4. Average Concentrations (10^{-12} μCi/mL) of Tritiated Water in Air Samples from Laboratory Perimeter, Area G, and Area AB Stations During 1987.

Station	No. of Samples	Mean	Standard Deviation
Perimeter [a]			
4	12	12	17
5	12	9.4	11
6	12	9.0	6.9
7	12	27	42
8	12	11	9.0
9	11	2.9	2.8
10	12	8.9	8.2
11	12	27	39
12	12	7.7	15
13	12	0.63	3.0
14	12	4.4	3.8
Group summary	131	11	20
Area G			
22	12	32	36
27	12	26	30
28	12	200[b]	170
29	11	10	21
30	11	37	97
31	12	26	38
Group summary	70	56	100
Area AB			
23	12	18	46
32	3	4.7	—
Group summary	15	15	42

[a]Data are from the Environmental Surveillance Group (1988).

[b]Significantly different from data from perimeter stations and other stations at Area G (one-way analysis of variance, Student-Newman-Keuls test [Norusis 1987; SPSS, Inc., 1988]).

5480.1A sets forth Concentration Guidelines for airborne radionuclide concentrations for lands under DOE control. The measured concentrations of radionuclides at Area G in 1987 were less than 0.1% of the

Table 5. Average Concentrations (pg/m^3) of Total Uranium in Air Samples from Laboratory Perimeter, Area G, and Area AB Stations During 1987.

Station	No. of Samples	Mean	Standard Deviation
Perimeter [a]			
4	4	36	8.9
5	4	21	5.0
6	4	37	8.4
7	4	29	4.5
8	4	50	17
9	4	28	11
10	4	52	13
11	4	42	19
12	4	28	3.7
13	4	20	6.0
14	4	11	5.6
Group summary	44	33	14
Area G			
22	4	54	24
27	4	76[b]	33
28	4	34	12
29	4	100[c]	58
30	4	27	9.2
31	4	49	20
Group summary	24	57	37
Area AB			
23	4	20	6.8
32	1	27	—
Group Summary	5	22	6.6

[a]Data are from the Environmental Surveillance Group (1988).

[b]Significantly different from data from perimeter stations 5, 9, 13, and 14 (one-way analysis of variance, Student-Newman-Keuls test [Norusis 1987; SPSS, Inc., 1988]).

[c]Significantly different from data from perimeter stations and stations 22, 28, 30, and 31 at Area G (one-way analysis of variance, Student-Newman-Keuls test [Norusis 1987; SPSS, Inc., 1988]).

applicable guidelines. Measurements of airborne radionuclide concentrations in off-site areas, not controlled by DOE, indicated that the Laboratory's waste-management operations were not contributing to airborne concentrations in excess of off-site guidelines for DOE operations (Environmental Surveillance Group 1988, Tables G-7 through G-10).

The Laboratory's routine surveillance program also maintains an air-monitoring station at TA-49, less than

Table 6. Average Concentrations (10^{-18} μCi/mL) of ^{238}Pu in Air Samples from Laboratory Perimeter, Area G, and Area AB Stations During 1987.

Station	No. of Samples	Mean	Standard Deviation
Perimeter [a]			
4	3	1.0	1.4
5	3	0.42	0.065
6	4	0.62	0.91
7	3	0.00	0.00
8	4	0.50	0.34
9	4	0.21	0.24
10	4	0.042	0.085
11	4	1.1	1.2
12	4	0.13	0.11
13	4	0.23	0.36
14	4	0.28	0.11
Group summary	41	0.41	0.66
Area G			
22	4	3.2	2.2
27	4	210[b]	140
28	4	1.3	1.0
29	4	7.2	13
30	4	0.72	0.51
31	4	2.1	1.0
Group summary	24	37	92
Area AB			
23	4	0.42	0.38
32	1	0.0	—
Group summary	5	0.34	0.38

[a]Data are from the Environmental Surveillance Group (1988).

[b]Significantly different from data from perimeter stations and other stations at Area G (one-way analysis of variance, Student-Newman-Keuls test [Norusis 1987; SPSS, Inc., 1988]).

Table 7. Average Concentrations (10^{-18} μCi/mL) of $^{239,240}Pu$ in Air Samples from Laboratory Perimeter, Area G, and Area AB Stations During 1987.

Station	No. of Samples	Mean	Standard Deviation
Perimeter [a]			
4	3	0.61	0.64
5	3	0.67	0.17
6	4	1.5	1.6
7	3	0.25	0.26
8	4	1.2	0.65
9	4	1.2	0.63
10	4	2.1	1.0
11	4	0.62	0.59
12	4	0.49	0.24
13	4	0.52	0.38
14	4	0.26	0.21
Group summary	41	0.90	0.86
Area G			
22	4	14[b]	16
27	4	11	12
28	4	0.70	0.27
29	4	3.5	1.7
30	4	0.78	0.89
31	4	16[c]	13
Group summary	24	7.6	11
Area AB			
23	4	0.55	0.13
32	1	32	—
Group summary	5	6.8	14

[a]Data are from the Environmental Surveillance Group (1988).

[b]Significantly different from data from perimeter stations 6 and 10 (one-way analysis of variance, Student-Newman-Keuls test [Norusis 1987; SPSS, Inc., 1988]).

[c]Significantly different from data from perimeter stations 6 and 8–14 and Area G stations 27–30 (one-way analysis of variance, Student-Newman-Keuls test [Norusis 1987; SPSS, Inc., 1988]).

a kilometer south of Area AB. In addition, for the last quarter of 1987, an air-sampling station (32) was installed about 30 m further northeast of the northeastern corner of Area AB. The 1987 results from these

Table 8. Average Concentrations (10^{-18} µCi/mL) of ^{241}Am in Air Samples from Laboratory Perimeter, Area G, and Area AB Stations During 1987.

Station	No. of Samples	Mean	Standard Deviation
Perimeter [a]			
6	3	1.1	0.71
8	1	1.7	
9	3	1.0	0.70
12	4	0.85	0.34
Group summary	11	1.0	0.54
Area G			
22	4	9.5	11
31	4	5.8	6.4
Group summary	8	7.7	8.7
Area AB			
23	4	1.2	0.90
32	1	1.3	—
Group summary	5	1.3	0.82

[a]Data are from the Environmental Surveillance Group (1988).

stations are shown in Tables 4–8. With the exception of ^{239,240}Pu, radionuclide concentrations in air samples from TA-49 varied in the range exhibited by samples taken from perimeter stations. The one quarterly sample collected northeast of Area B exhibited a higher concentration of ^{239,240}Pu than that found in perimeter samples. This may be correlated with the known higher concentrations in surface soil in that corner of Area AB (Purtymun and Stoker 1987).

The concentrations of radionuclides in air samples from TA-49 were well below DOE Concentration Guides for on-site areas. The maximum proportion of measured concentration (32×10^{-18} µCi/mL of ^{239,240}Pu) to guide (2×10^{-12} µCi/mL) for any radionuclide was <<0.1%. At off-site sample locations in the vicinity, concentrations were also well within appropriate guidelines (Environmental Surveillance Group 1988, Tables G-7 through G-10).

VI. EXTERNAL-PENETRATING-RADIATION MONITORING

A network of 92 thermoluminescent dosimeter (TLD) locations monitors external-penetrating-radiation levels at the low-level radioactive-waste-management areas. These waste-management areas are controlled-access areas and are not accessible to the general public. Active and inactive waste areas are monitored for external penetrating radiation with arrays of TLDs (Table 9). Averages at all sites except Area X were higher than perimeter average values. However, the ranges at most sites largely overlapped the range of values found at perimeter and regional stations (Table 9). The extremes at Area G, the active radioactive-waste area, and Area T, an inactive waste area, have been noted in previous years (Environmental Science Group 1986, 1987). These are the results of past and present radioactive-waste-management

Table 9. Doses (mrem) Measured by TLDs at Radioactive-Waste-Management Areas During 1987.

Area	Number of TLDs	Mean	Minimum	Maximum
A	5	118	112	121
B	14	118	107	126
C	10	116	104	149
E	4	119	113	125
F	4	108	102	111
G	27	132	111	174
T	7	133	109	198
U	4	115	112	119
V	4	117	111	122
W	2	110	107	113
X	1	91	—	—
AB	10	106	96	114
Perimeter stations	12	103	85	122

activities. Elevated levels at Area G result from ongoing handling and storage of radioactive wastes before burial. A holding tank for radioactive liquid wastes and for buried wastes from past operations results in the high measurements at Area T.

VII. SURFACE RUN-OFF MONITORING

Surface run-off and sediment in drainages are routinely monitored at two materials disposal areas, Area G and Area AB. During 1987, the Area G samples for radiochemical analysis were lost, and results cannot be reported here (Environmental Surveillance Group 1988).

Table 10 presents the results of radiochemical analysis of sediment samples from 12 stations located in drainages of Area AB. In 1987, above-background concentrations of ^{239}Pu were found at station A-3 (Fig. 5). This station has exhibited this pattern in the past (Purtymun and Stoker 1987). The station is down gradient from the former radiochemistry laboratory at TA-49 and is in an area known to have residual surface concentrations of plutonium resulting from activities in 1960. Concentrations of other radionuclides in these sediments are within the range of background levels or are only slightly elevated (Table 10).

Three run-off events were sampled in drainages from Area AB during 1987 (Tables 11 and 12). Concentrations of radionuclides were within the range of background, indicating that no detectable transport of radionuclides from Area AB is occurring. This is further supported by data from analyses of bed sediments and run-off in the lower sections of Water Canyon, which receives the drainage from Area AB to the north (Table 12). All downstream analyses were within the range of upstream background.

VIII. GROUND-WATER MONITORING

Monitoring of deep and shallow ground waters is carried out as part of the routine, site-wide surveillance program (Environmental Surveillance Group 1988). Measurable amounts of radioactivity have been found in shallow aquifers in several canyons. This residual radioactivity is attributable principally to past and present discharges of liquid effluents with residual radionuclides into Acid–Pueblo, DP–Los Alamos, Sandia, and Mortandad canyons. Lesser contributions

Table 10. Radionuclides in Sediment from Area AB, TA-49, During 1987.[a]

Station	^{137}Cs (pCi/g)	Total Uranium (μg/g)	^{238}Pu (10^{-3} pCi/g)	$^{239,240}Pu$ (10^{-3} pCi/g)
A-1	0.08	2.3	4	3
A-2	0.22	3.7	1	4
A-3	0.29	4.7	1	83
A-4	0.16	3.4	1	6
A-4A	0.23	3.4	1	8
A-5	0.39	3.4	0	16
A-6	0.14	3.5	0	1
A-7	0.37	3.9	2	16
A-8	0.17	3.4	−1	4
A-9	0.09	2.9	0	2
A-10	0.45	3.7	5	14
A-11	0.57	2.6	2	10
Regional background[b]	0.44	4.4	6	23

[a]Data are from the Environmental Surveillance Group (1988), Table G-68.

[b]Data are from Purtymun et al. (1988). Background is presented as the 97.5 percentile of background samples taken by Purtymun et al., that is, $\bar{x} \pm 2s$.

may be due to run-off from Areas A, B, T, U, and V into DP–Los Alamos canyons and from Area C into Mortandad Canyon. The shallow aquifer in Pajarito Canyon is unaffected by Laboratory operations, including those at Area G to the north.

The deep aquifer has shown no measurable radioactivity above background (Environmental Surveillance Group 1988). Three deep test wells are located at or near Area AB (Fig. 5). Samples from these wells in 1987 and previous years contained no radionuclides above background (Environmental Surveillance Group 1988, Purtymun and Stoker 1987).

IX. DOSE ASSESSMENT

Monitoring data from several radioactive-waste-management areas indicate the presence of radionuclides on and near the ground surface, both within and outside the perimeter fence (Environmental Science Group 1986, 1987, and this report). However, the measured levels are low. Dose estimates to members of the public, based on the monitoring data from the waste sites and general Laboratory areas, were made for 1987 and are reported in the annual "Environmental Surveillance Report" (Environmental Surveillance Group 1988).

In 1987, the DOE's Radiation Protection Standard for the general public was 100 mrem/year total effective dose equivalent (50-year commitment) from all pathways of exposure and from all operations, including waste handling. In addition to the DOE's Radiation Protection Standard governing doses from all pathways, doses from the air pathway are required by the U.S. Environmental Protection Agency (EPA) to not exceed 25 mrem/year to the whole body and 75 mrem/year to any organ. In September 1988, DOE order 5820.2A

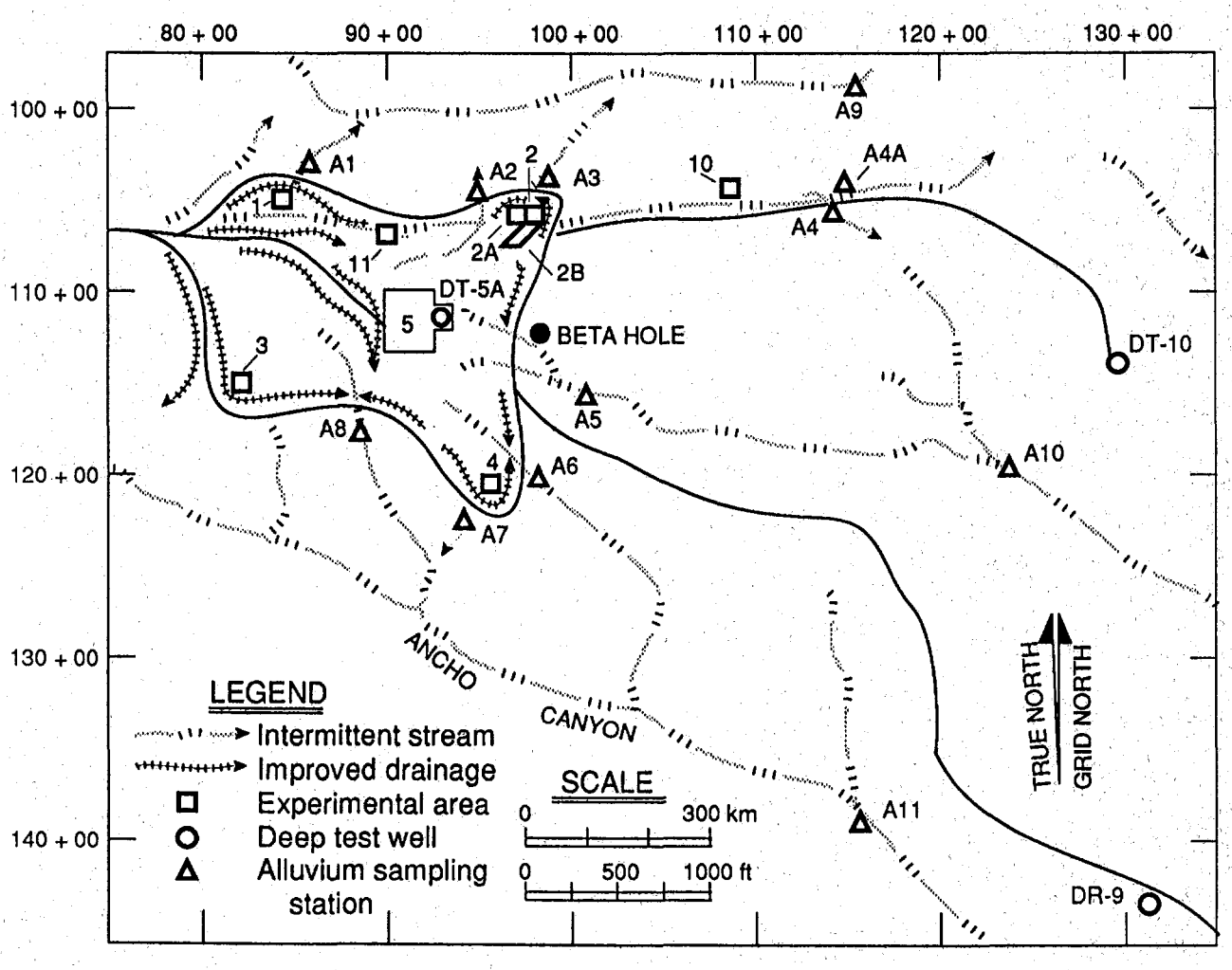


Fig. 5. Location of experimental areas and test wells at TA-49.

established a limit of 25 mrem/year total effective dose to the general public exposed to releases resulting from waste handling and disposal operations.

Based on the inhalation pathway and the air-monitoring data, the maximum 50-year dose commitment (effective dose equivalent) to the public resulting from waste operations is <0.02 mrem/year. This effective dose equivalent is <0.02% of the DOE's 1987 Radiation Protection Standard of 100 mrem/year from all pathways, <0.02% of EPA's standard for the air pathway, and <0.01% of DOE's 1988 standard for waste-handling operations.

Possible 50-year dose commitments via ingestion in 1987 that could have resulted from Laboratory operations (including waste management) were estimated to be 0.07 mrem/year and 0.03 mrem/year (effective dose equivalent) from ingestion of produce and fish, respectively. These doses sum to about 0.1% of the DOE's 100 mrem/year (effective dose equivalent) 1987 standard for all operations and all pathways, including ingestion (Environmental Surveillance Group 1988). Doses attributable to waste-management operations would be some fraction of these doses. There is currently no evidence of any radionuclides in drinking water that could be attributable to Laboratory (and waste) operations.

Doses to the public from external exposure resulting from waste-management operations is estimated to be <0.01 mrem/year.

Table 11. Plutonium in Run-Off Solution from Area AB and Lower Water Canyon During 1987.[a]

Location	^{238}Pu (10^{-12} pCi/mL)	$^{239,240}Pu$ (10^{-12} pCi/mL)
Area AB		
A-1	7	10
A-1	−8	0
A-2	−57	0
A-5	−9	33
A-5	8	25
A-5	11	−4
A-8	0	0
A-8	21	5
Water Canyon at State Route 4	−17	33
	0	24
	10	−10
	18	4
	0	−4
	4	−4
	0	9
	15	−15
Background	30	26

[a]Data are from the Environmental Surveillance Group (1988).

Table 12. Plutonium in Run-Off Suspended Sediment from Area AB and Lower Water Canyon During 1987.[a]

Location	^{238}Pu (10^{-3} pCi/mL)	$^{239,240}Pu$ (10^{-3} pCi/mL)
Area AB		
A-1	0	27
A-1	−4	48
A-2	1	2
A-5	0	7
A-5	0	6
A-5	4	24
A-8	1	1
A-8	0	28
Water Canyon at State Route 4	0	0
	18	−62
	−12	24
	4	4
	342	770
	0	58
	66	66
	28	56
Background	135	830

[a]Data are from the Environmental Surveillance Group (1988).

The cumulative dose from waste-management operations at the Laboratory is estimated to be 0.12 mrem/year, or 0.12% of the DOE's 1987 standard of 100 mrem/year for all pathways from all operations and <0.5% of DOE's 1988 standard for all pathways from waste-management operations alone.

This total effective dose equivalent from all pathways of 0.12 mrem/year due to waste-management operations is <<0.1% of the 327 mrem/year natural background radiation (whole-body radiation and radon) estimated to be received by residents of Los Alamos during 1987 and is 0.2% of the 53 mrem/year average per capita effective dose equivalent received by the population from medical and dental procedures (Environmental Surveillance Group 1988). The 1987 maximum-exposed individual effective dose equivalent from all Laboratory operations (including waste management) from all pathways was 6.1 mrem, or 6.1% of the DOE's Radiation Protection Standard of 100 mrem/year. More than 95% of this dose was due to

the operations of the Los Alamos Meson Physics Facility (Environmental Surveillance Group 1988).

X. INTENSIVE SURVEY OF WASTE-MANAGEMENT SITE, AREA AB, TA-49

A. Uranium

Average concentrations of uranium in soil ranged from about 2.8 to 4.2 µg/g at areas that were sampled in 1987 (Table 13). These means were higher than regional background, but ranges in each area overlapped greatly with regional background ranges. The Kruskal-Wallis (Norusis 1987; SPSS, Inc., 1988) nonparametric analysis of variance indicated that statistically significant differences existed among the sampled areas and regional background. The maximum concentrations of uranium in soil tended to be located in the northwestern quadrant of Area 11 (Figs. 6–8).

Concentrations of uranium in vegetation were not well correlated with those found in soil (Table 14). Highest concentrations in vegetation (a mean of 6.8 µg/g ash) were found at Area 2A, whereas soil concentrations were at maximum levels in Area 11. Area 11 had the lowest mean concentration (0.4 µg/g ash) of the areas sampled for vegetation. Maximum concentrations in vegetation tended to be located in the southwestern corner of Area 2A.

The ratio of ^{235}U to ^{238}U varied considerably, both in soils and in vegetation (Table 15). Natural uranium contains an isotopic ratio of about 0.007 of ^{235}U to ^{238}U. Measured isotopic ratios varied around this value for both vegetation and soils, although samples of

Table 13. Summary of Radionuclide Concentrations in Soil at TA-49.

Radionuclide	Area 2	Area 2A	Area 2B	Area 3	Area 11	Background
^{137}Cs (pCi/g)						
Mean	1.00	0.58	0.54	0.46	0.38	0.44
Std dev	1.00	0.30	0.40	0.36	0.30	0.33
N	20	23	22	42	20	64
Total Uranium (µg/g)						
Mean	3.1	3.2	2.8	3.6	4.1	2.4
Std dev	0.35	0.55	0.55	0.81	1.73	0.54
N	20	25	22	42	20	34
^{238}Pu (pCi/g)						
Mean	0.031	0.011	0.003	0.003	0.140	0.001
Std dev	0.116	0.020	0.004	0.003	0.542	0.002
N	20	25	21	42	20	76
$^{239/240}Pu$ (pCi/g)						
Mean	2.25	0.366	0.054	0.015	7.52	0.007
Std dev	9.16	0.932	0.086	0.009	26.9	0.009
N	20	25	21	42	20	76
^{241}Am (pCi/g)						
Mean	2.80	0.142	0.041	0.027	1.39	0.007
Std dev	12.0	0.222	0.048	0.034	4.96	0.007
N	20	25	22	42	20	8

vegetation tended to be about 10% lower and samples from Area 11 tended to be about 10% higher. The small mass of ash submitted for analysis (<10 g) contributed to the variability. Some samples exhibited ratios near 0.003 (Table 15), characteristic of depleted uranium. It does not appear that enriched uranium from the experiments conducted here contributed significantly to uranium concentrations in soils or vegetation in the areas sampled.

B. Plutonium and Americium

Nonparametric statistical comparisons of mean concentrations of plutonium and americium in soils and vegetation indicated that there were significant differences. Soil concentrations tended to be higher at TA-49 than at regional stations (Table 13). Areas 2 and 11 had the highest concentrations of transuranics in soils. Although mean concentrations were higher than regional background at the other areas, the ranges strongly overlapped with the ranges found at background stations. The highest concentrations of transuranics were found at the northeasternmost station in Area 2 and at two stations in Area 11 (Figs. 9–17). The station at Area 2 was located on gopher-disturbed ground 2–3 m northeast of an asphalt pad that was laid down in 1961. In 1960, cuttings from an experimental hole inadvertently brought up residual contamination from an earlier experiment. The area was cleaned to levels below those measurable by then-available instrumentation, and the materials were returned to the hole. About 2 m of compacted aggregate and 1–2 m of asphalt were used to cover the area. The two stations at Area 11 are associated with a contaminated drain field

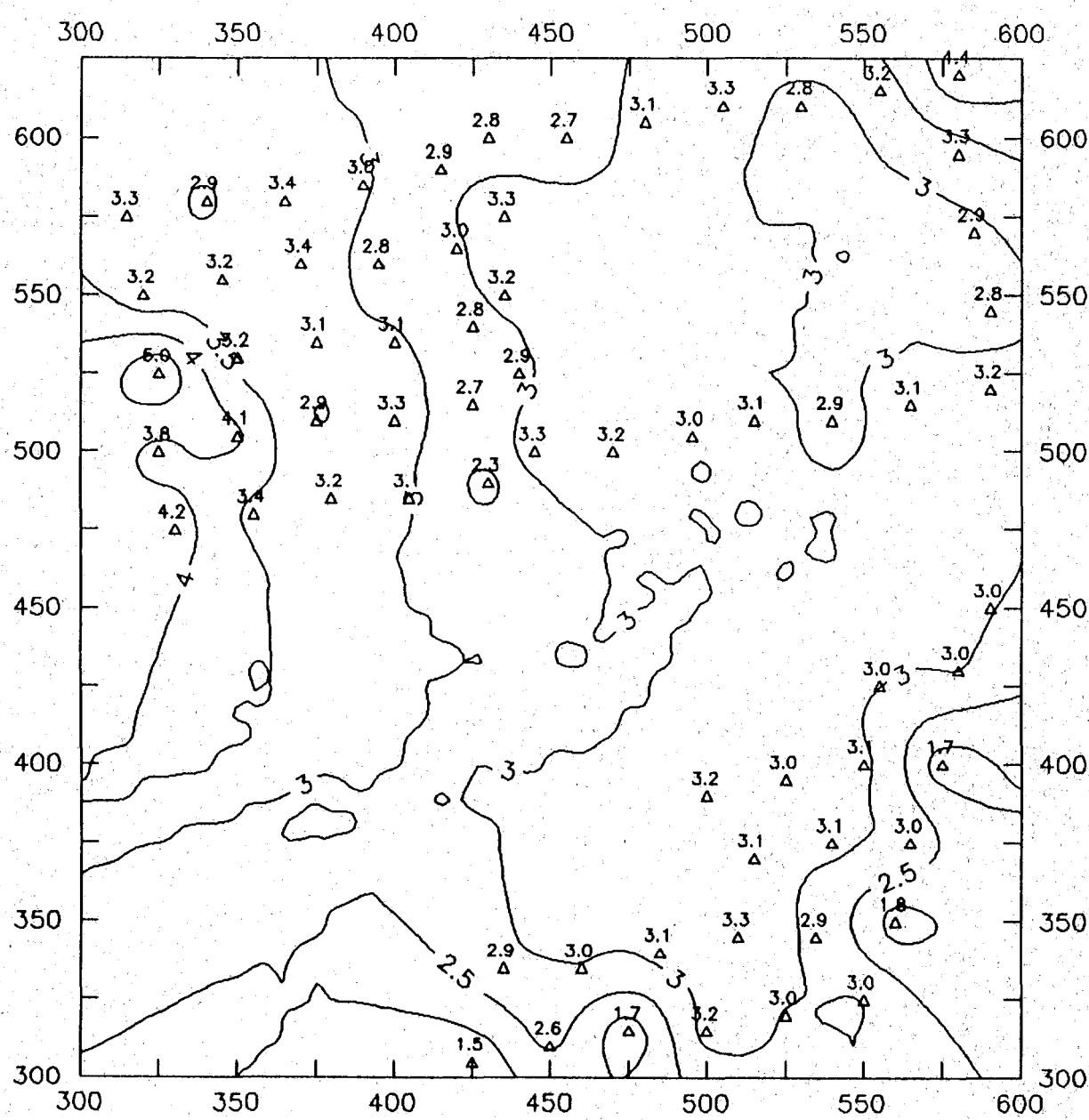
Table 14. Summary of Radionuclide Concentrations in Vegetation at TA-49.

Radionuclide	Area 2	Area 2A	Area 3	Area 11
^{137}Cs (pCi/g ash)				
Mean	0.22	0.76	1.53	1.17
Std dev	0.57	0.92	1.32	0.73
N	19	25	42	19
Total Uranium (μg/g ash)				
Mean	0.49	6.80	1.38	0.44
Std dev	0.40	3.38	0.71	0.26
N	20	25	42	20
^{238}Pu (pCi/g ash)				
Mean	0.0235	0.0006	0.009	0.0008
Std dev	0.1028	0.0008	0.0010	0.0011
N	20	25	43?	20
$^{239/240}Pu$ (pCi/g ash)				
Mean	1.2687	0.0025	0.0048	0.0461
Std dev	5.5046	0.0021	0.0028	0.0653
N	19	25	42	20
^{241}Am (pCi/g ash)				
(pCi/g ash)				
Mean	0.2202	0.2343	0.0887	0.1641
Std dev	0.3179	0.2011	0.0955	0.1922
N	20	26?	42	20

remaining after decommissioning. The residual plutonium found in 1987 in these two areas probably contributes to the run-off concentrations seen in previous years (Tables 11 and 12, Purtymun and Stoker 1987). For activity concentrations in vegetation, only ^{239}Pu concentrations exhibited significant differences among areas (Table 14).

C. Cesium

Statistical analysis revealed slight differences among mean concentrations of ^{137}Cs in soils at TA-49. Area 2 had the most elevated levels (Table 13), with a mean concentration of about twice regional background. The highest levels of cesium were found along



(a)

Fig. 6(a) and (b). Uranium (mg/g) in soil from Areas 2, 2A, and 2B. Grid units are in feet relative to New Mexico State plane coordinates E485 000 and N1 755 000.

the northern boundary of Area 2 (Figs. 18–20). Activity concentrations in vegetation exhibited a different pattern, with highest concentrations occurring in Area 3 (Table 14).

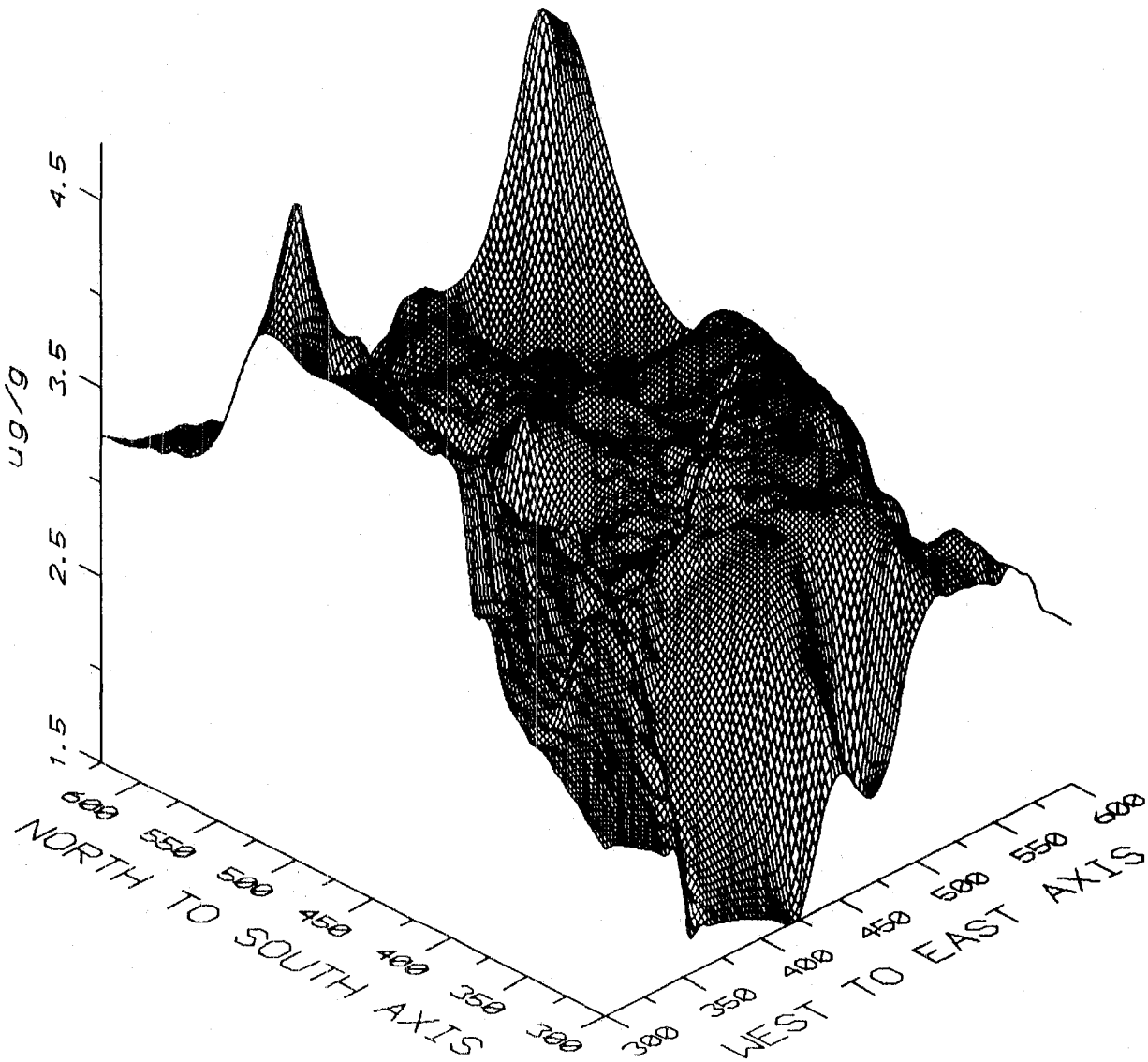


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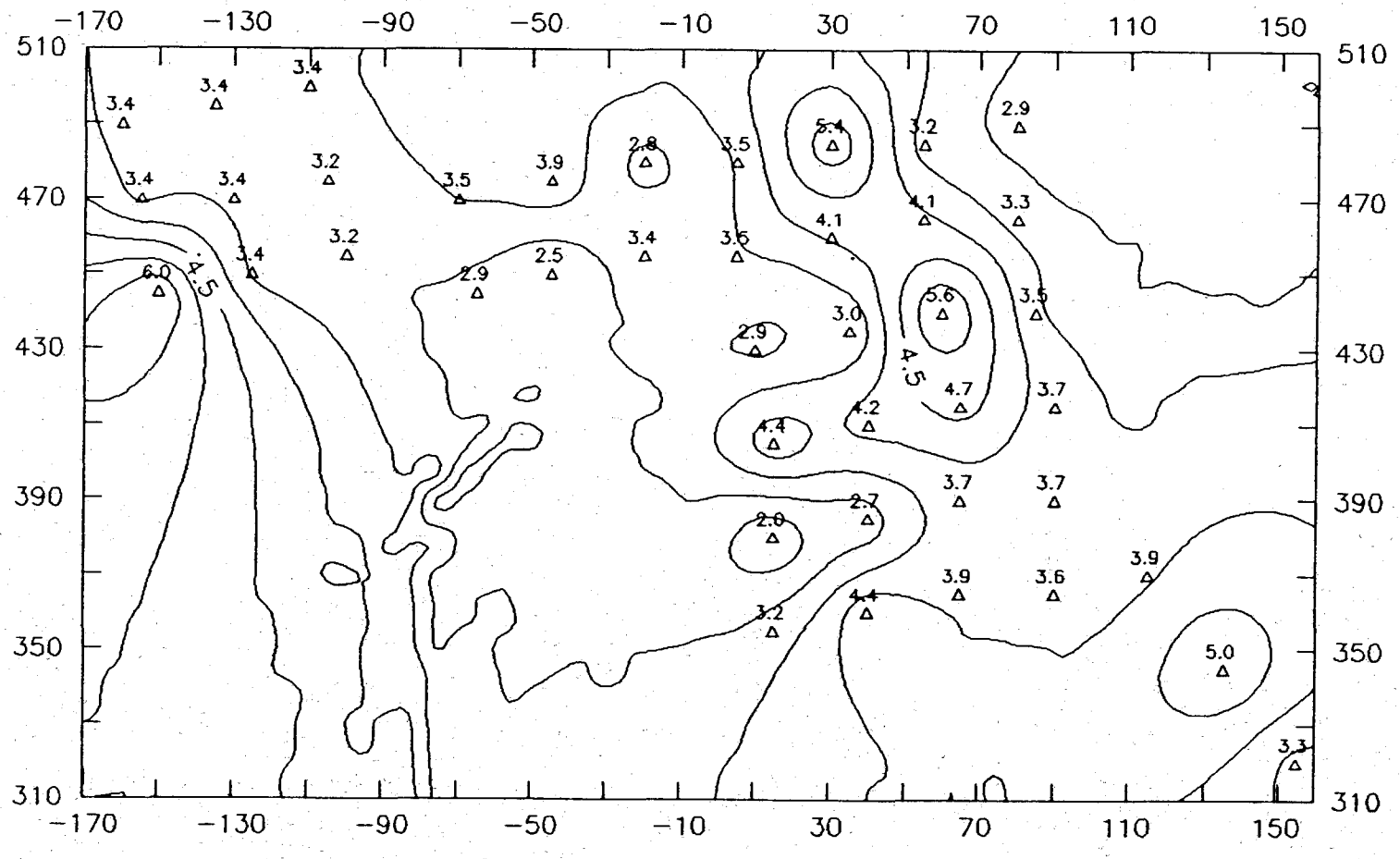
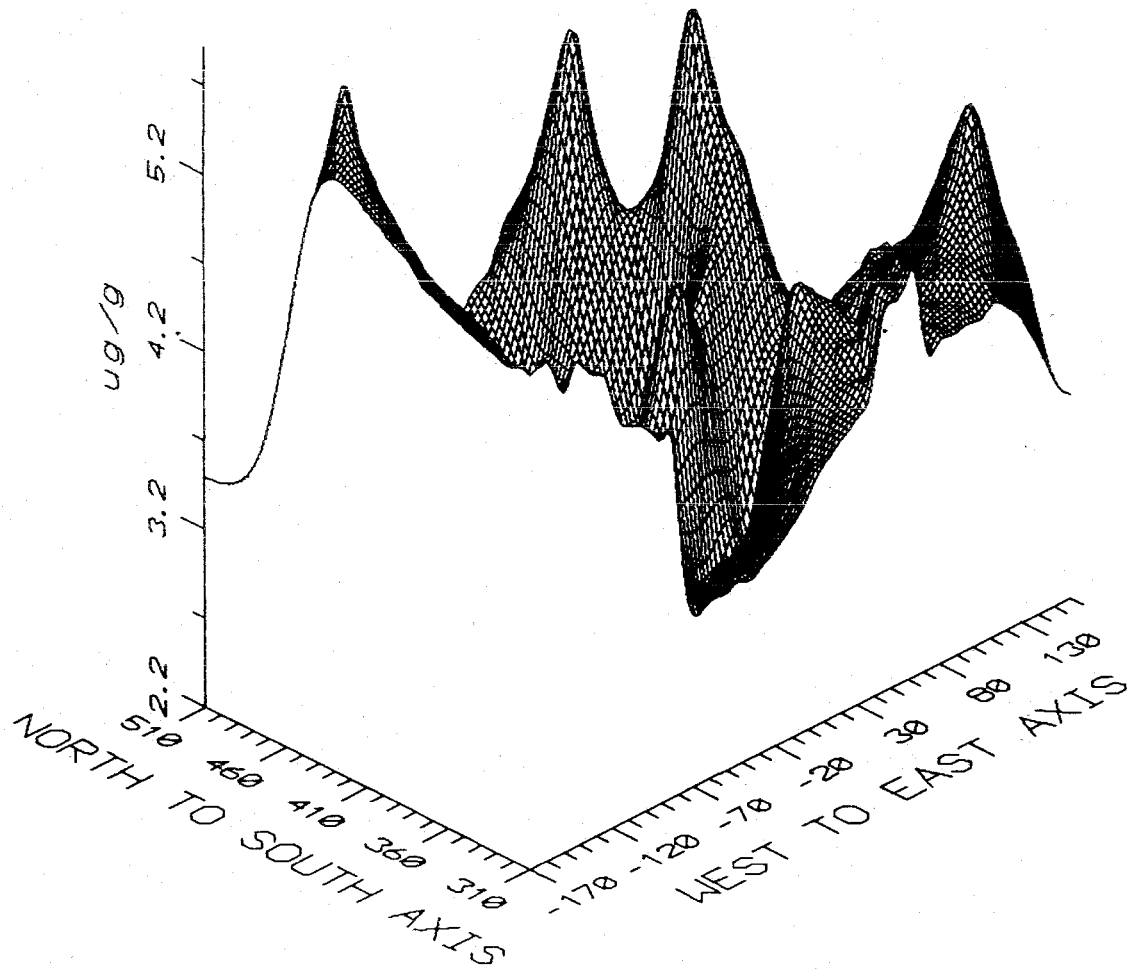
Fig. 6 (Continued)



(a)

Fig. 7(a) and (b). Uranium (mg/g) in soil from Area 3. Grid units are in feet relative to New Mexico State plane coordinates E485 000 and N1 755 000.



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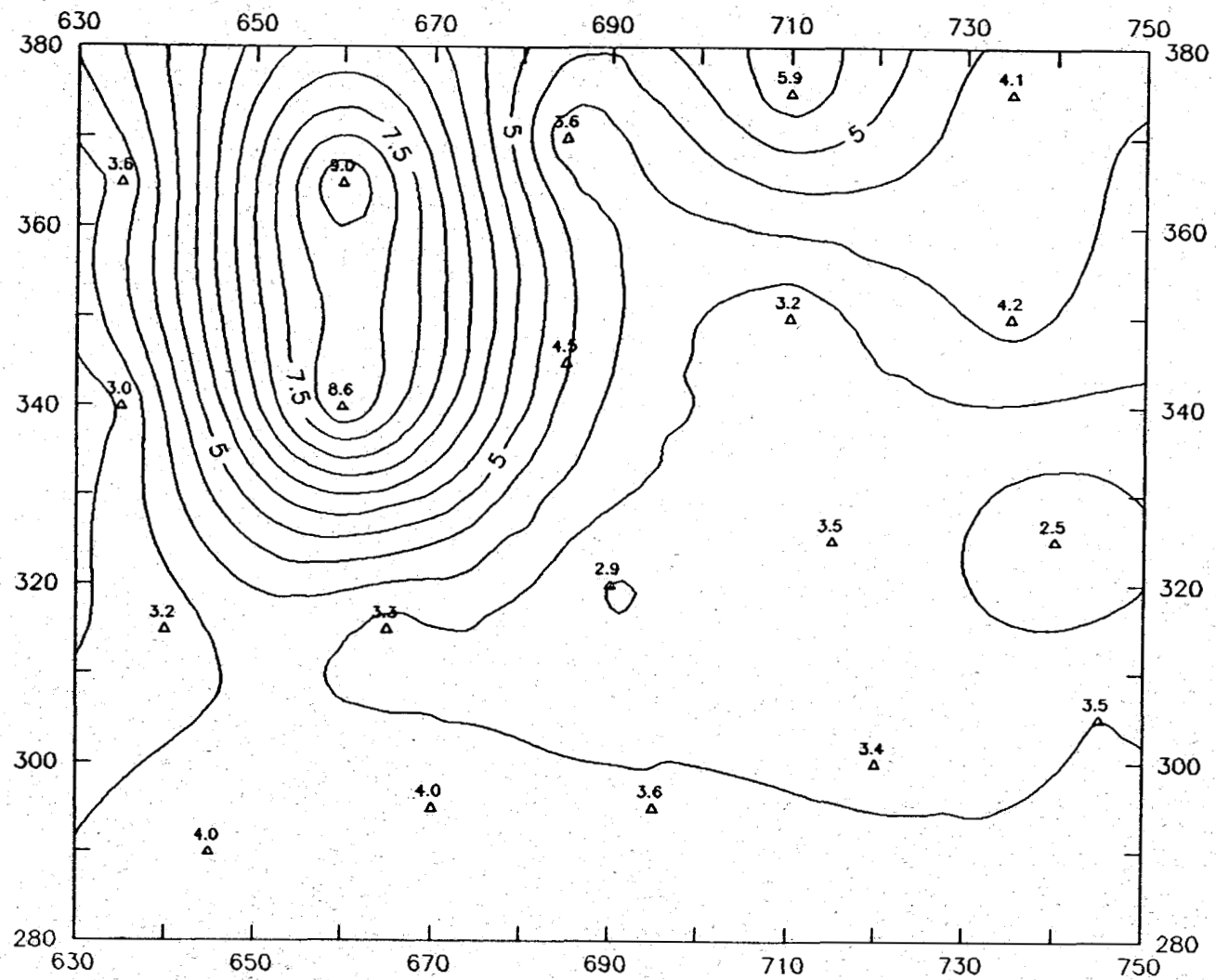
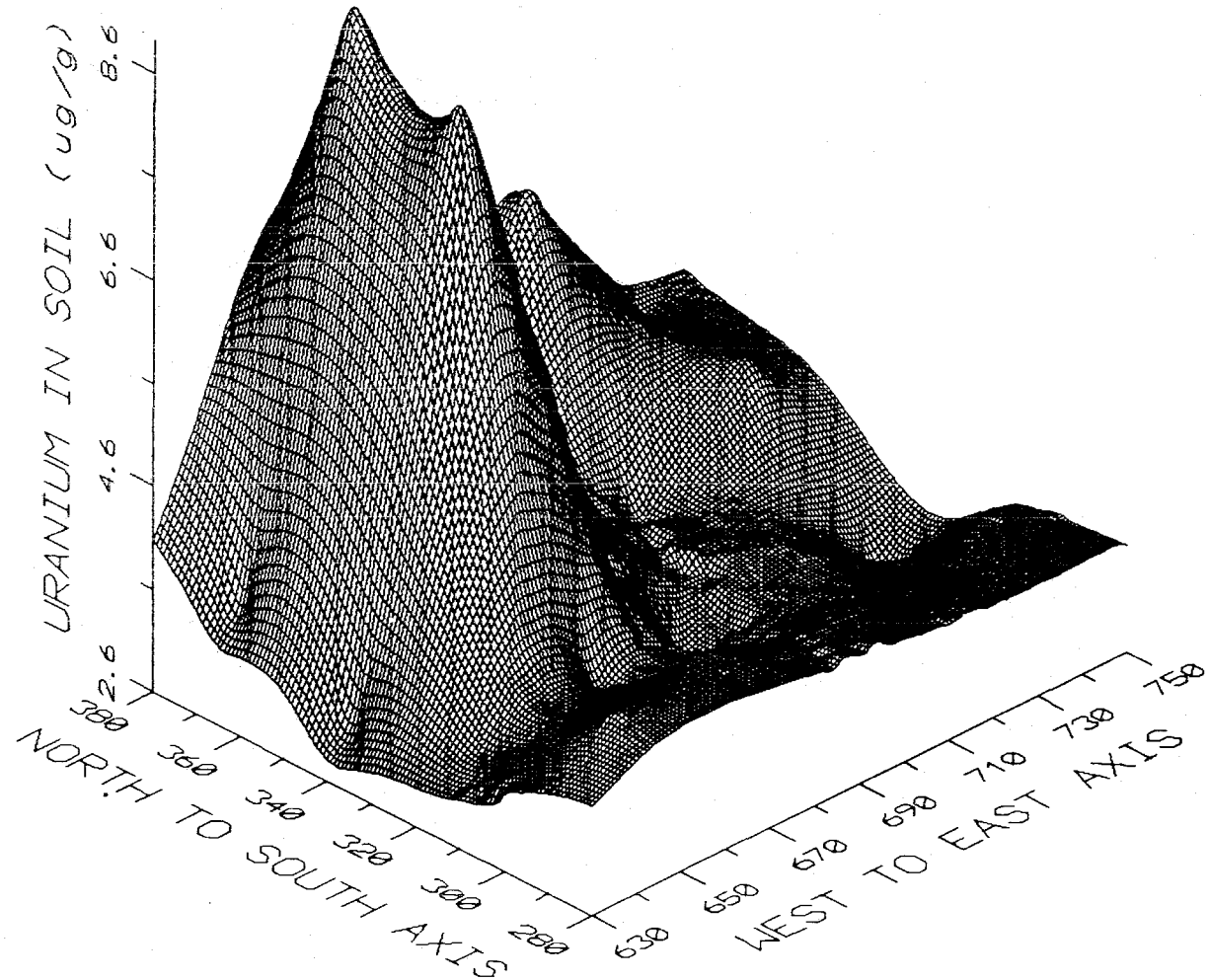


(a)

Fig. 8(a) and (b). Uranium (μg/g) in soil from Area 11. Grid units are in feet relative to New Mexico State plane coordinates E484 000 and N1 755 000.



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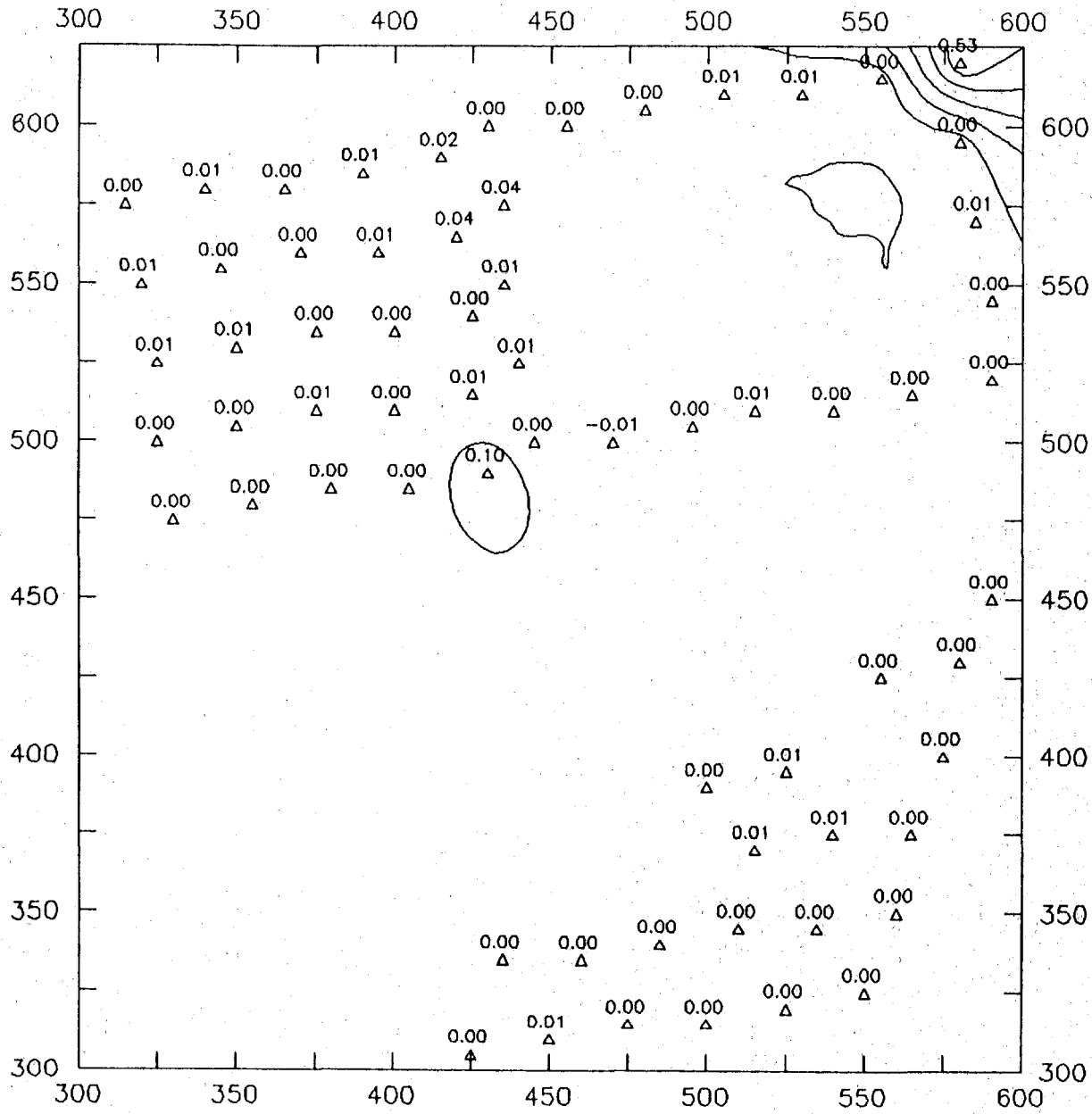
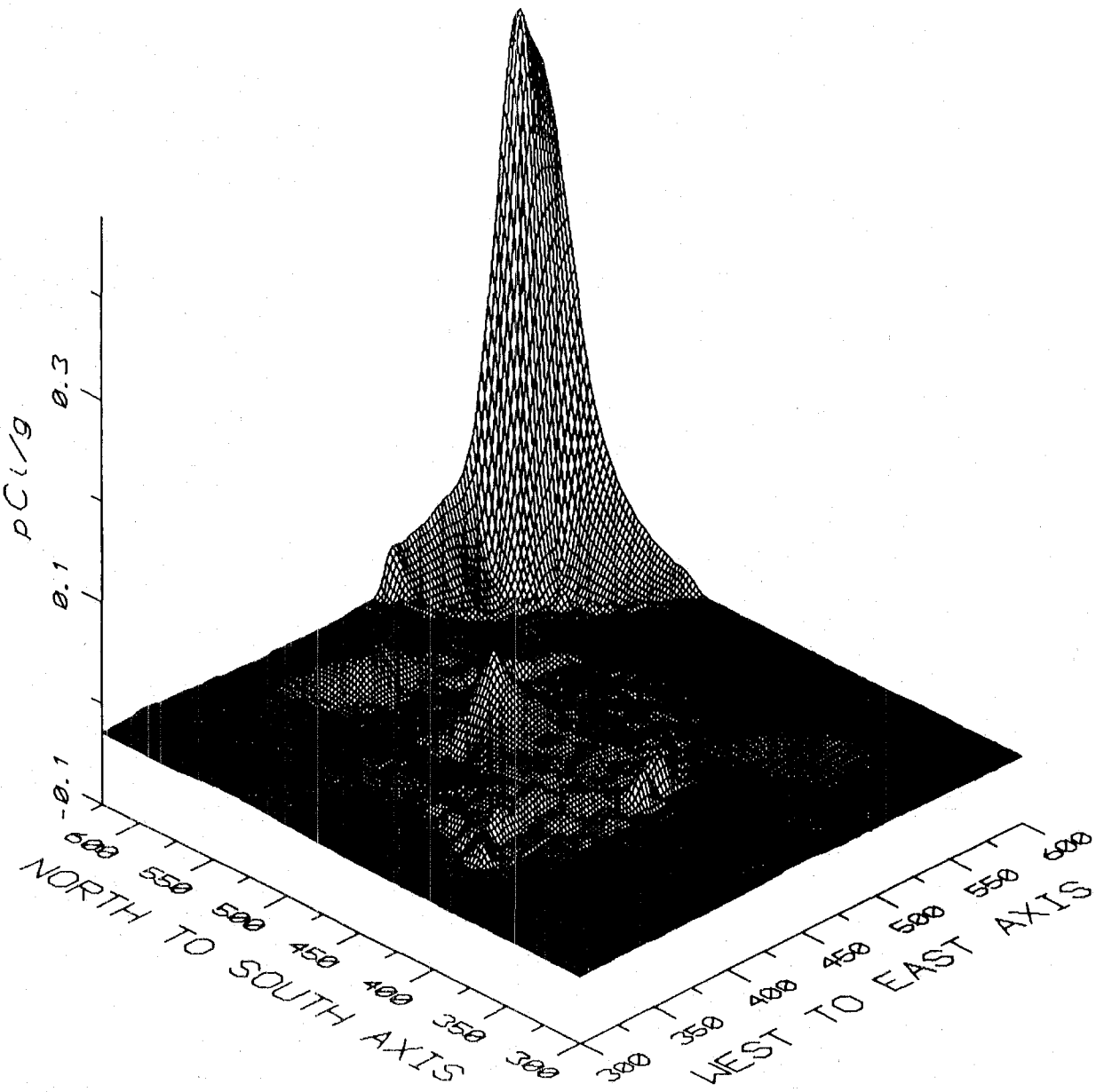


(a)

Fig. 9(a) and (b). Plutonium-238 (pCi/g) in soil from Areas 2, 2A, and 2B. Grid units are in feet relative to New Mexico State plane coordinates E485 000 and N1 755 000.



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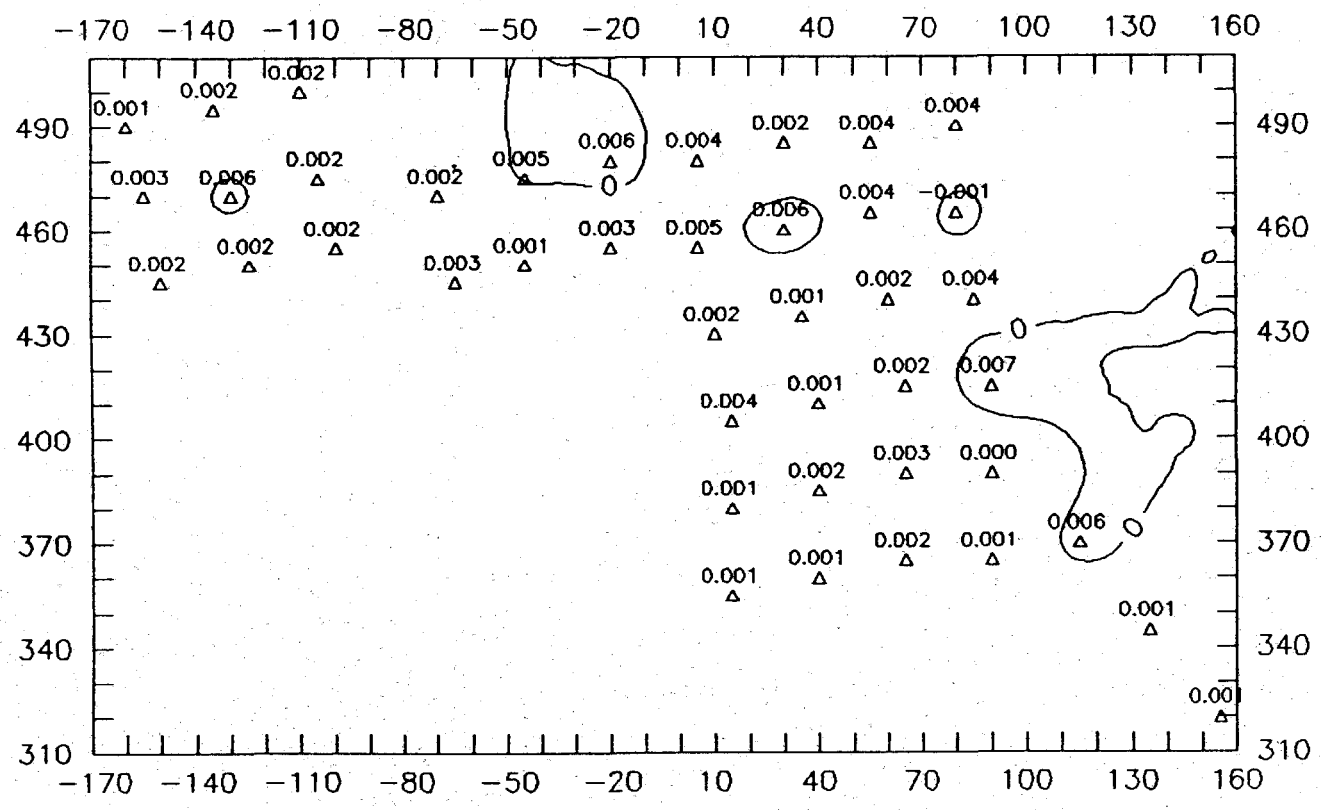
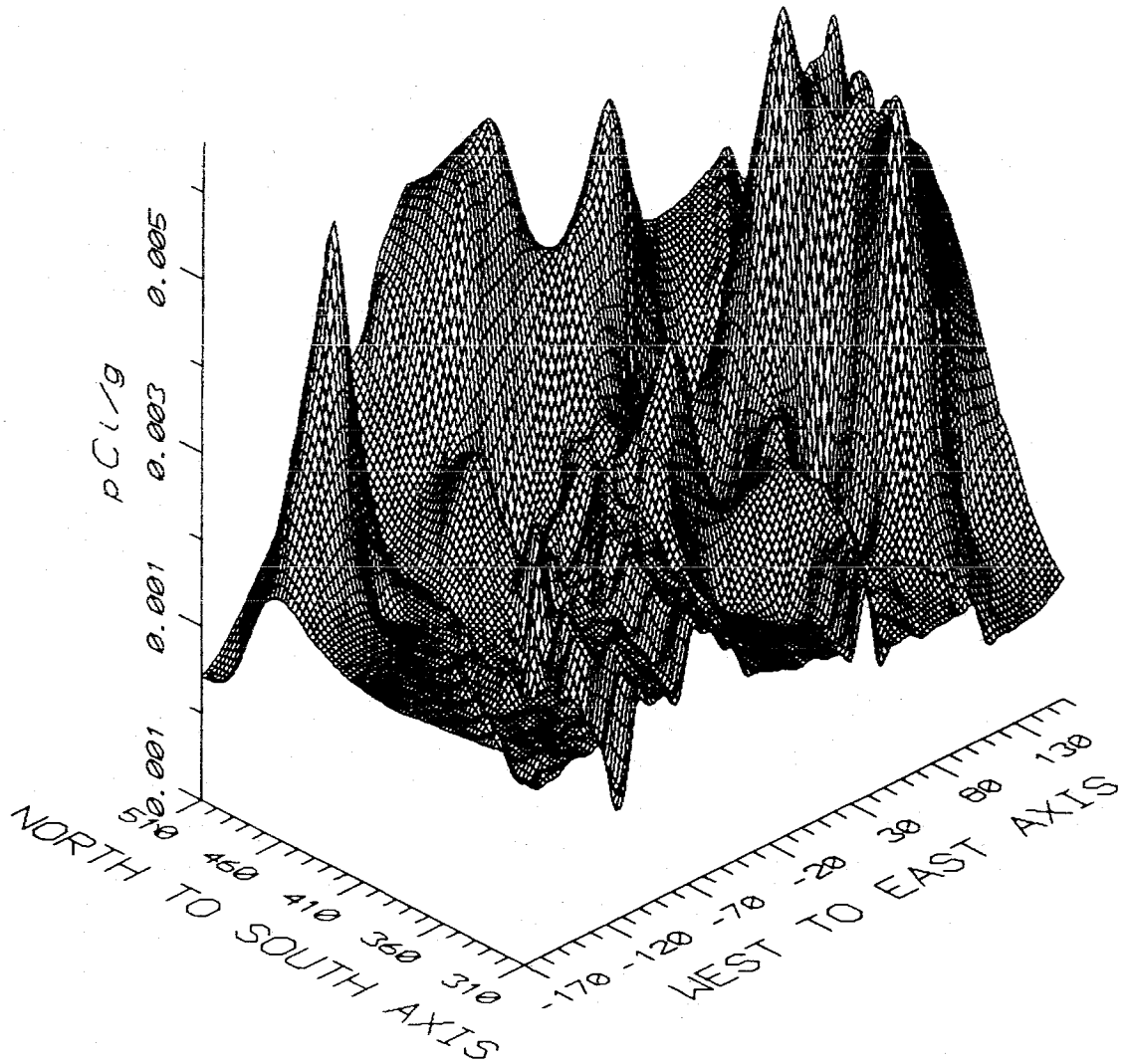


(a)

Fig. 10(a) and (b). Plutonium-238 (pCi/g) in soil from Area 3. Grid units are in feet relative to New Mexico State plane coordinates E485 000 and N1 755 000.



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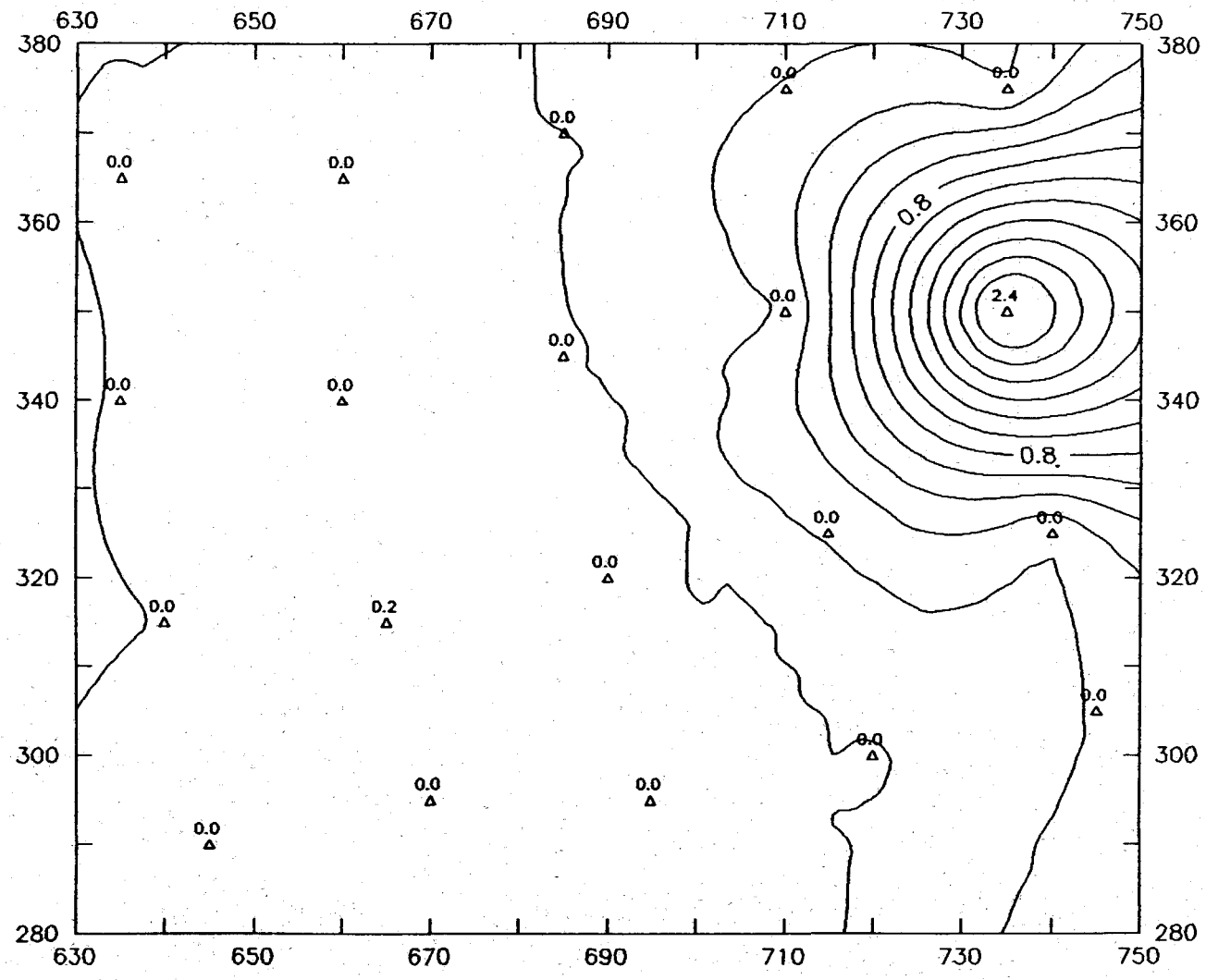
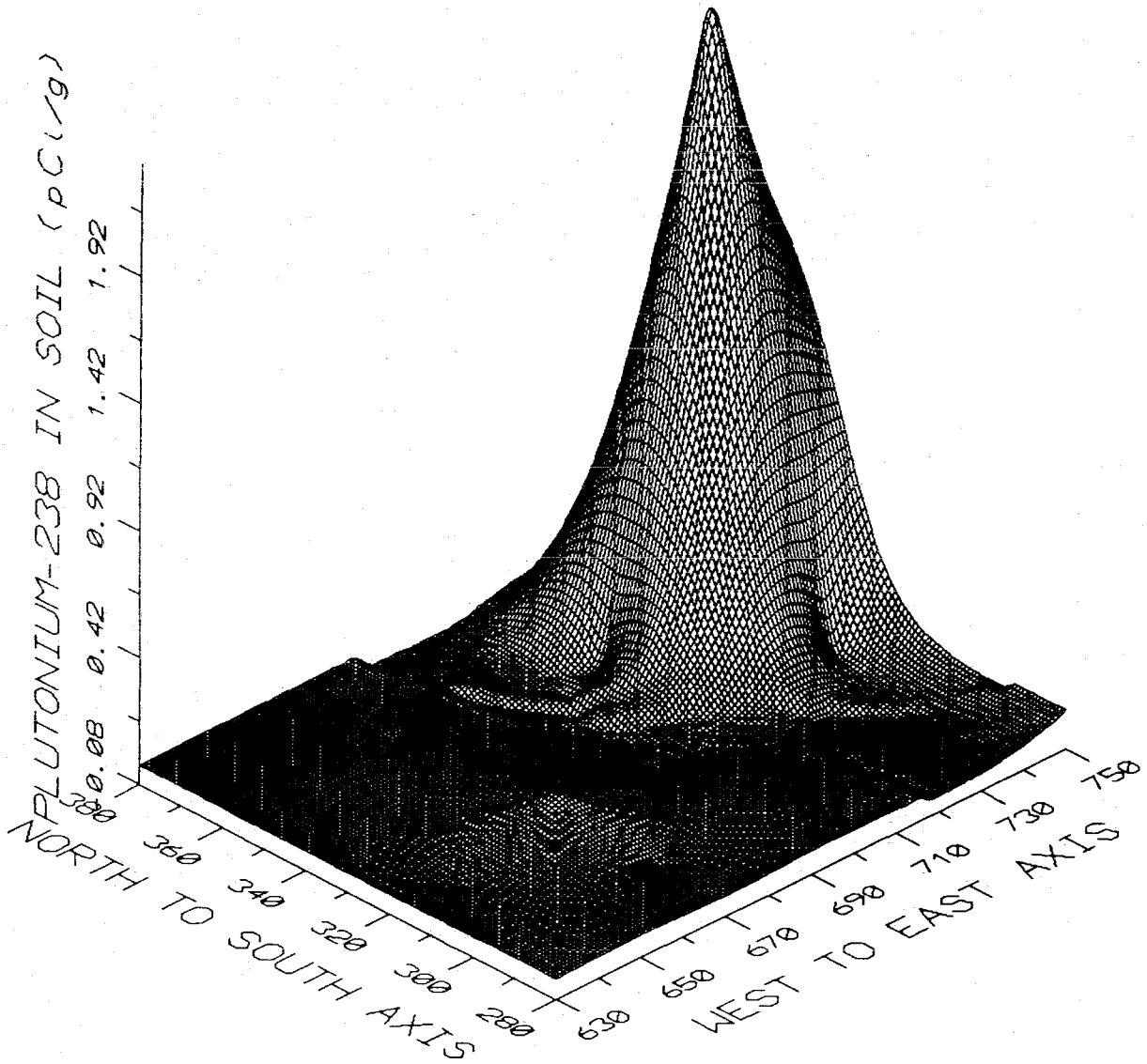


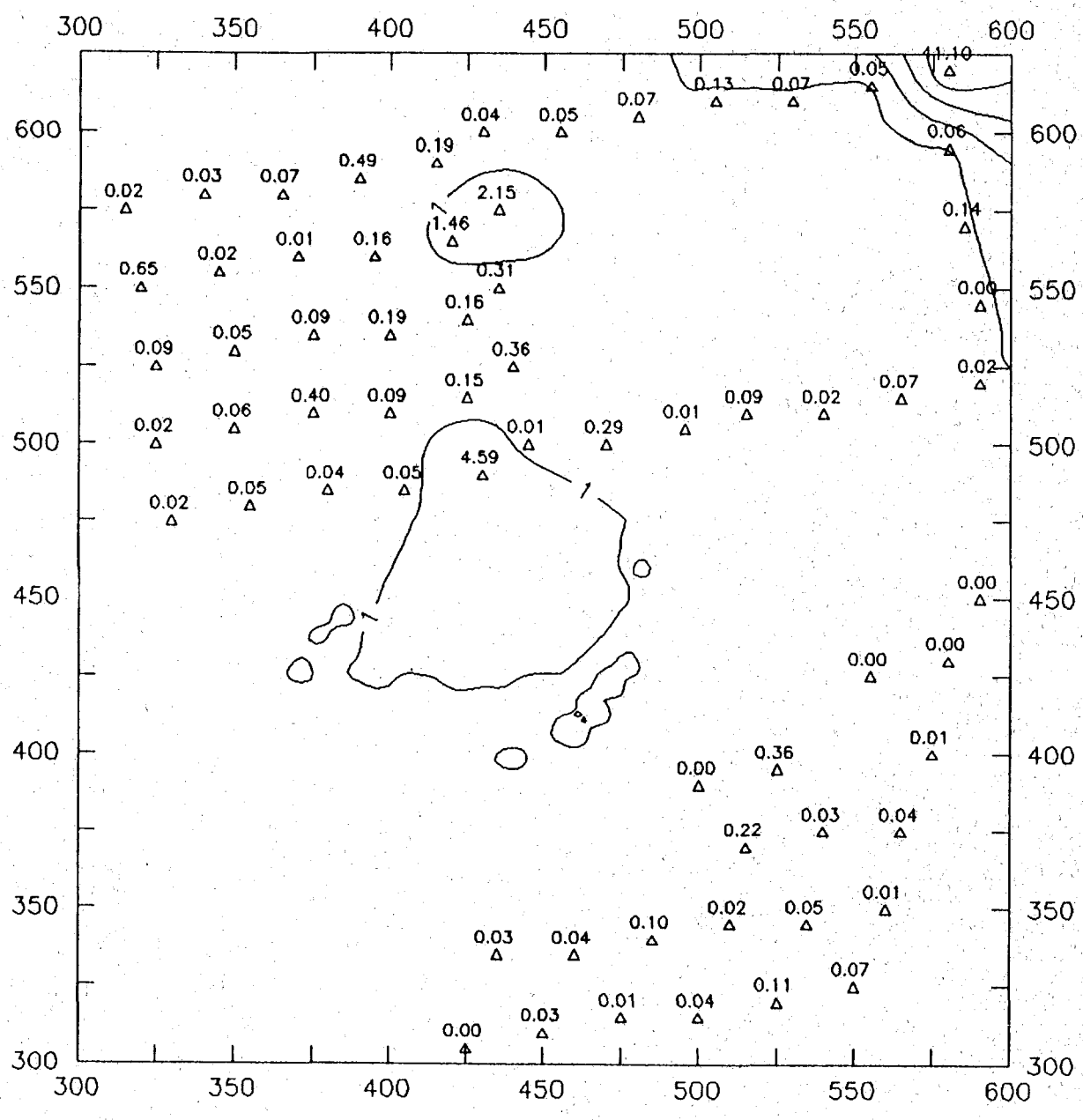
(a)

Fig. 11(a) and (b). Plutonium-238 (pCi/g) in soil from Area 11. Grid units are in feet relative to New Mexico State plane coordinates E484 000 and N1 755 000.



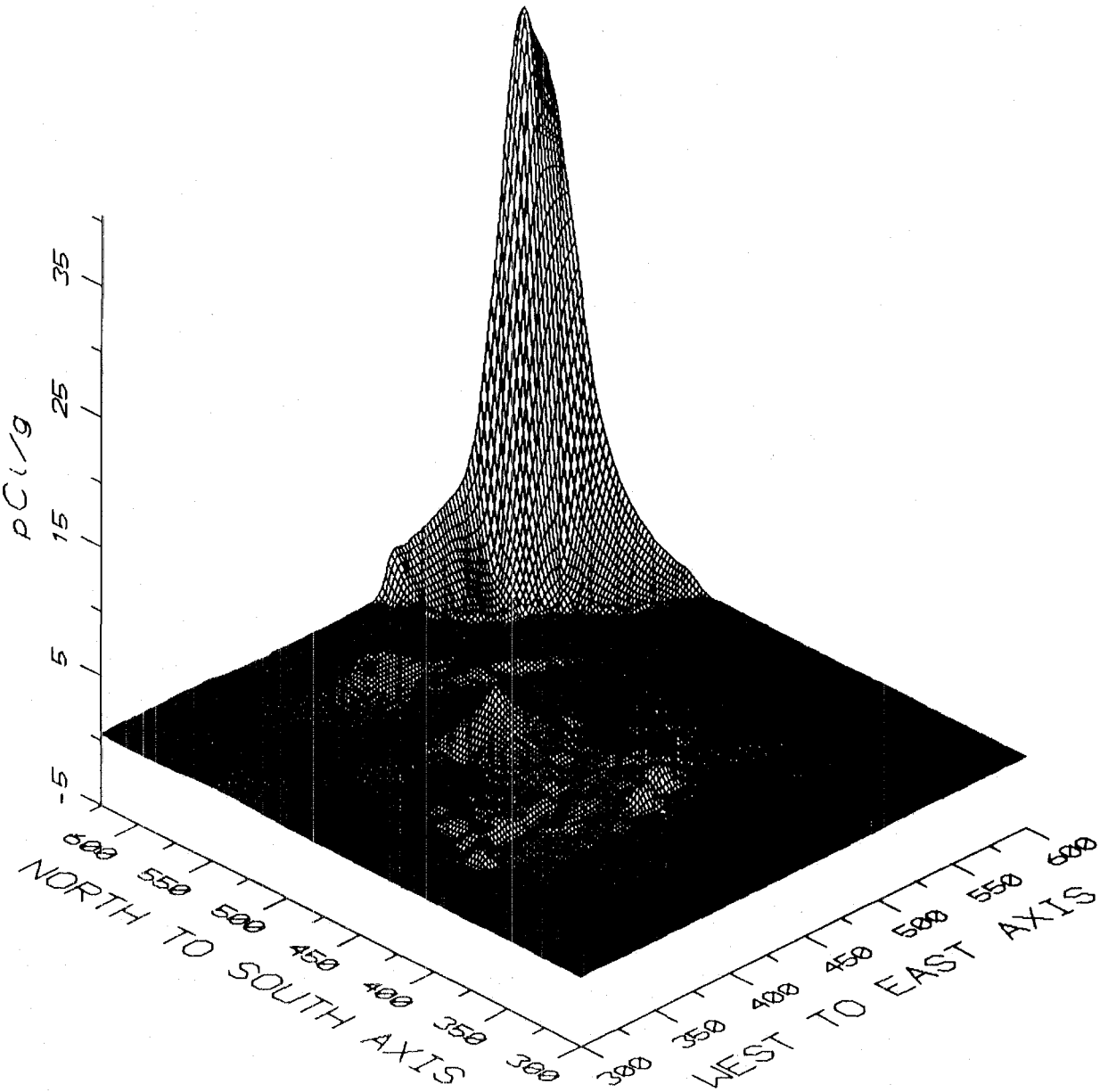
(b)

Fig. 11 (Continued)



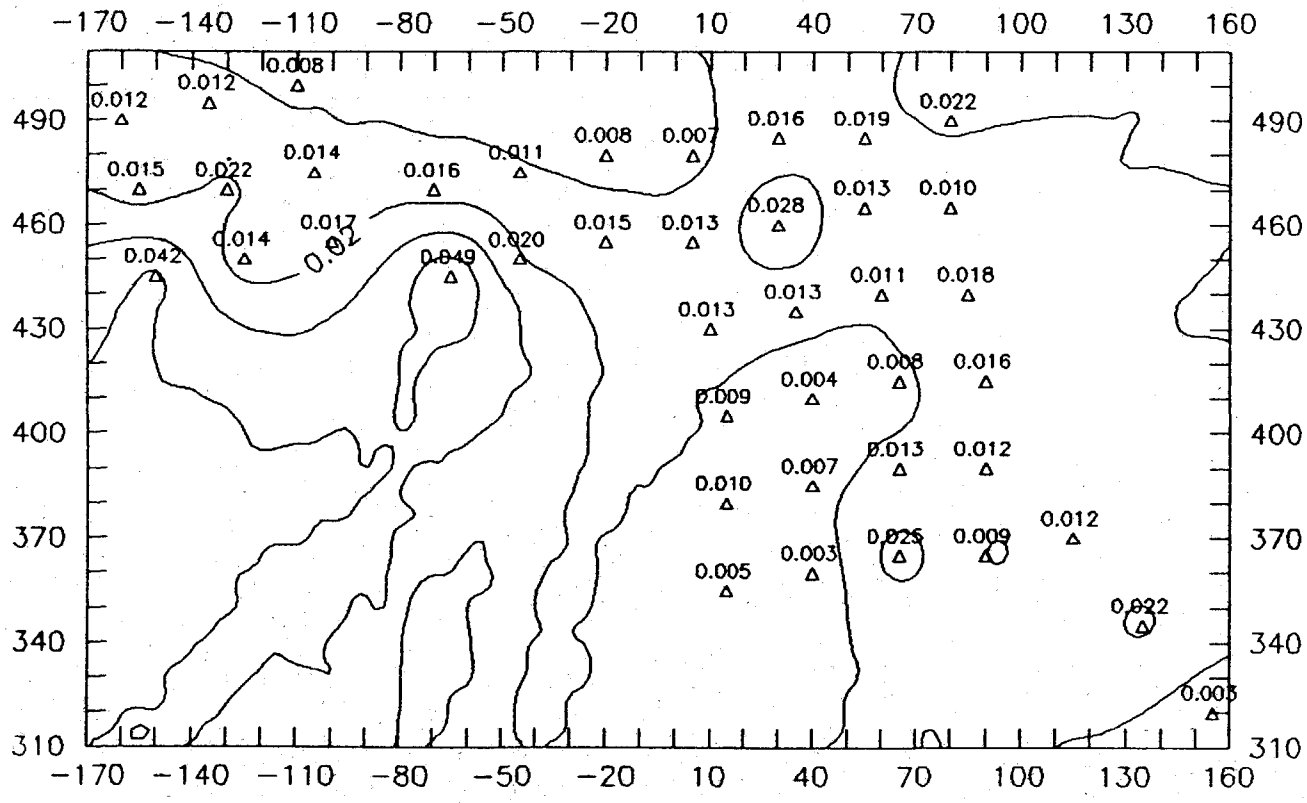
(a)

Fig. 12(a) and (b). Plutonium-239 (pCi/g) from Areas 2, 2A, and 2B. Grid units are in feet relative to New Mexico State plane coordinates E485 000 and N1 755 000.



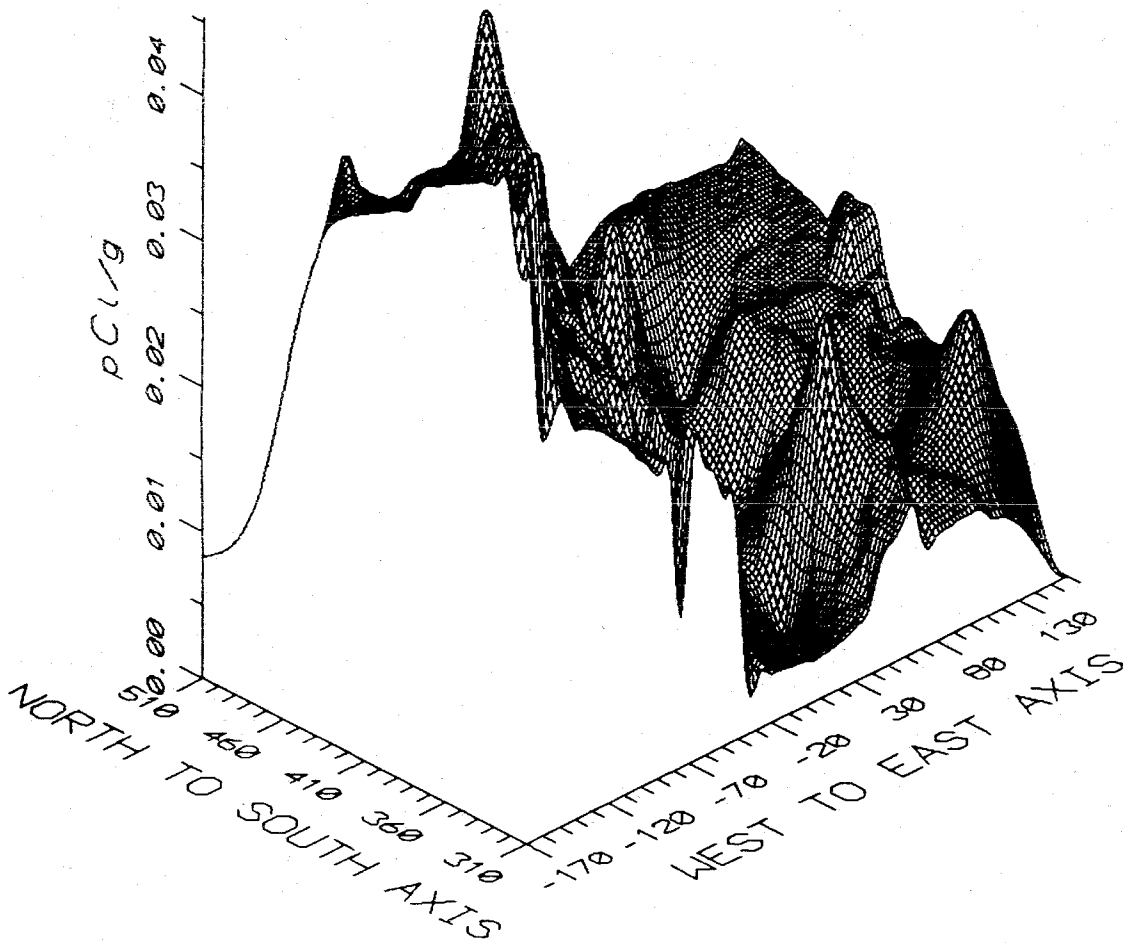
(b)

Fig. 12 (Continued)



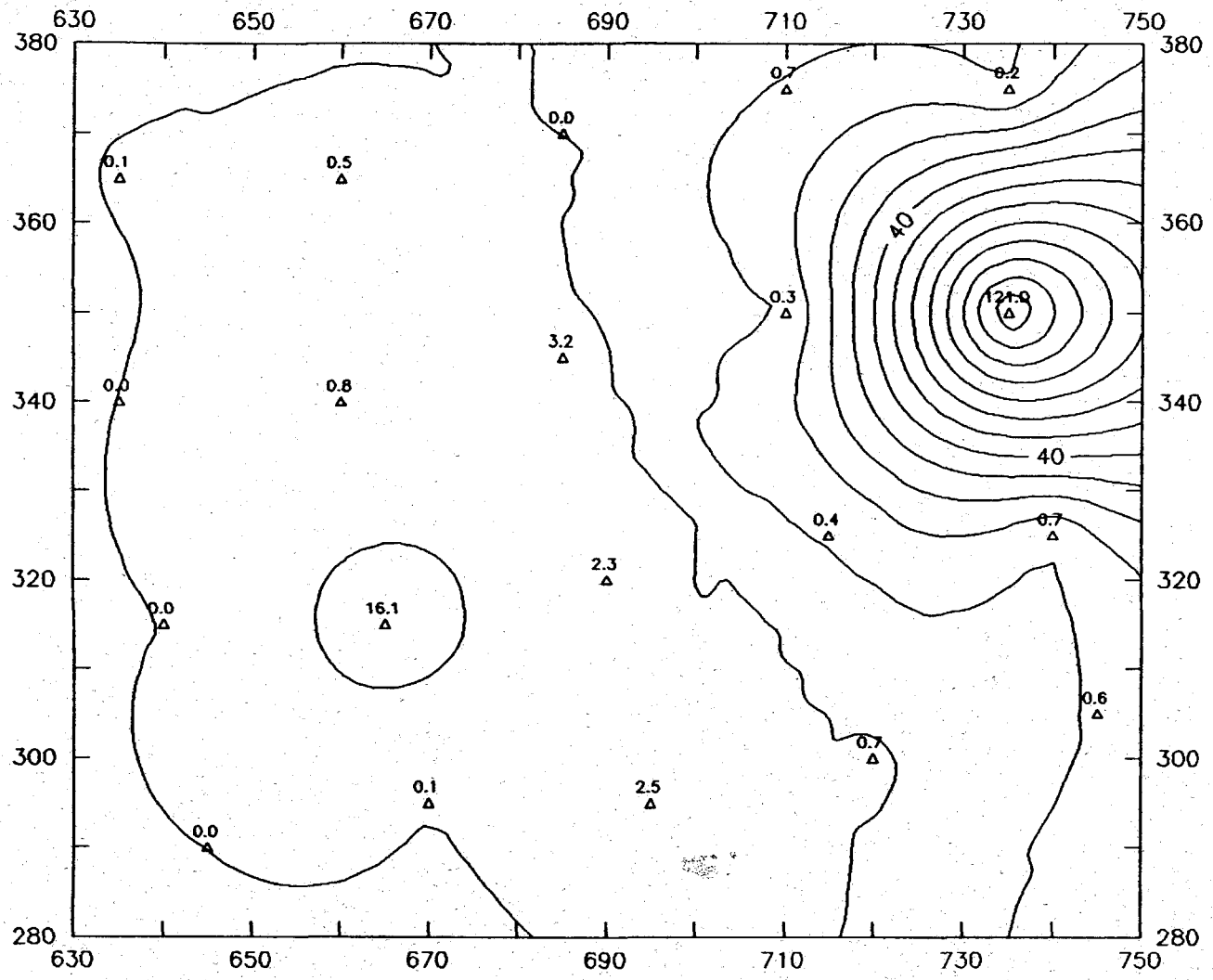
(a)

Fig. 13(a) and (b). Plutonium-239 (pCi/g) from Area 3. Grid units are in feet relative to New Mexico State plane coordinates E485 000 and N1 755 000.



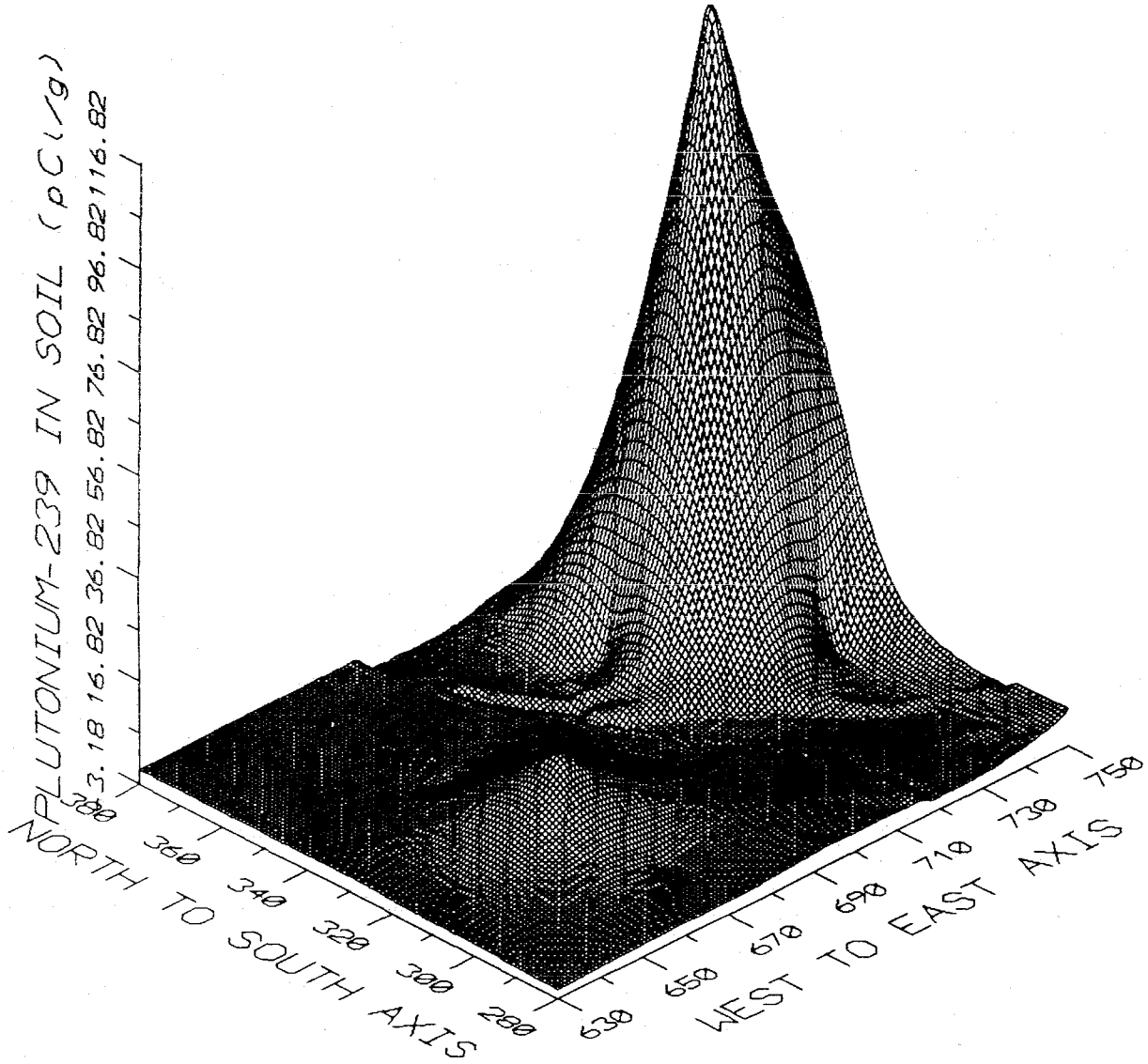
(b)

Fig. 13 (Continued)



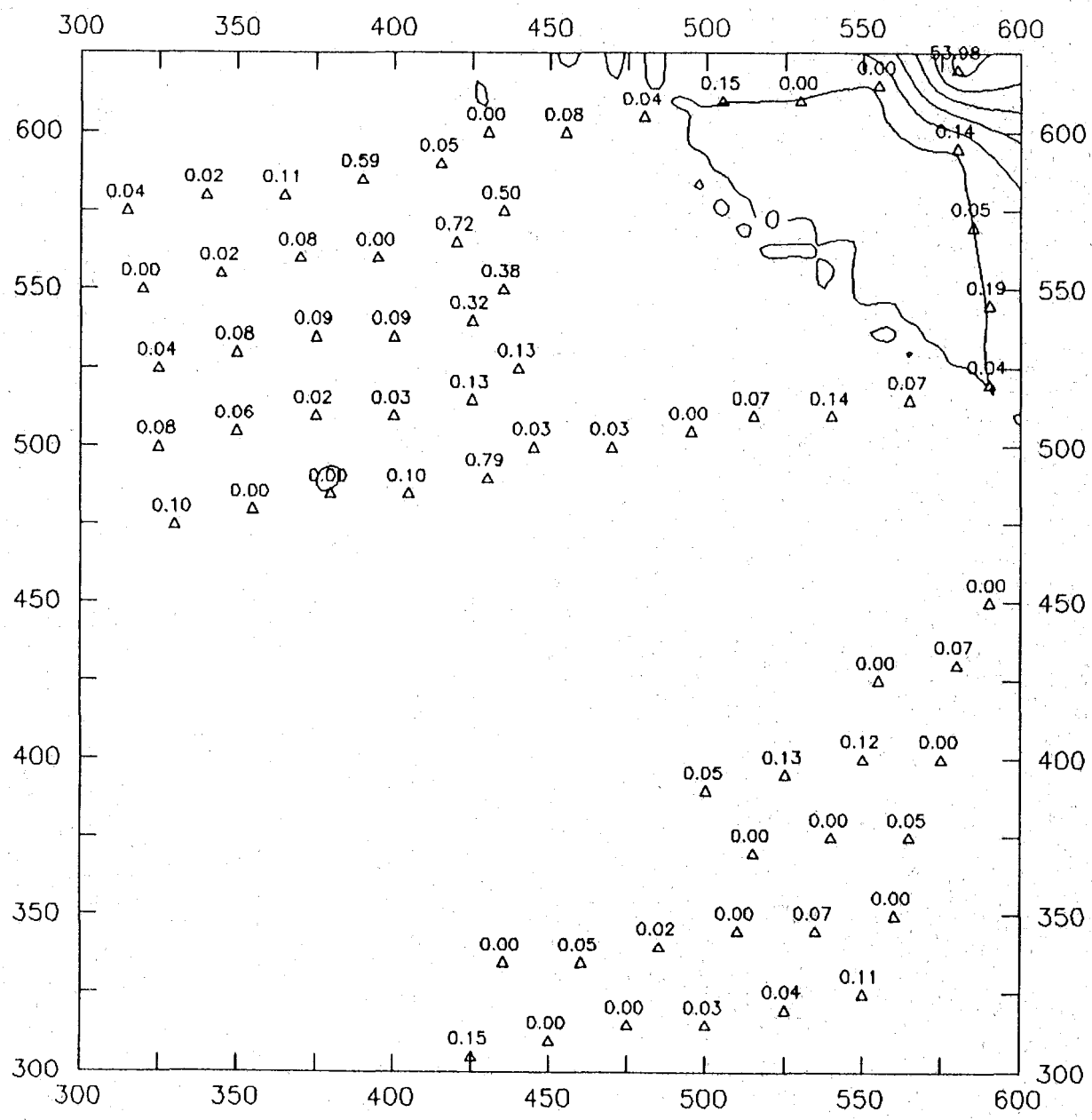
(a)

Fig. 14(a) and (b). Plutonium-239 (pCi/g) in soil from Area 11. Grid units are in feet relative to New Mexico State plane coordinates E484 000 and N1 755 000.



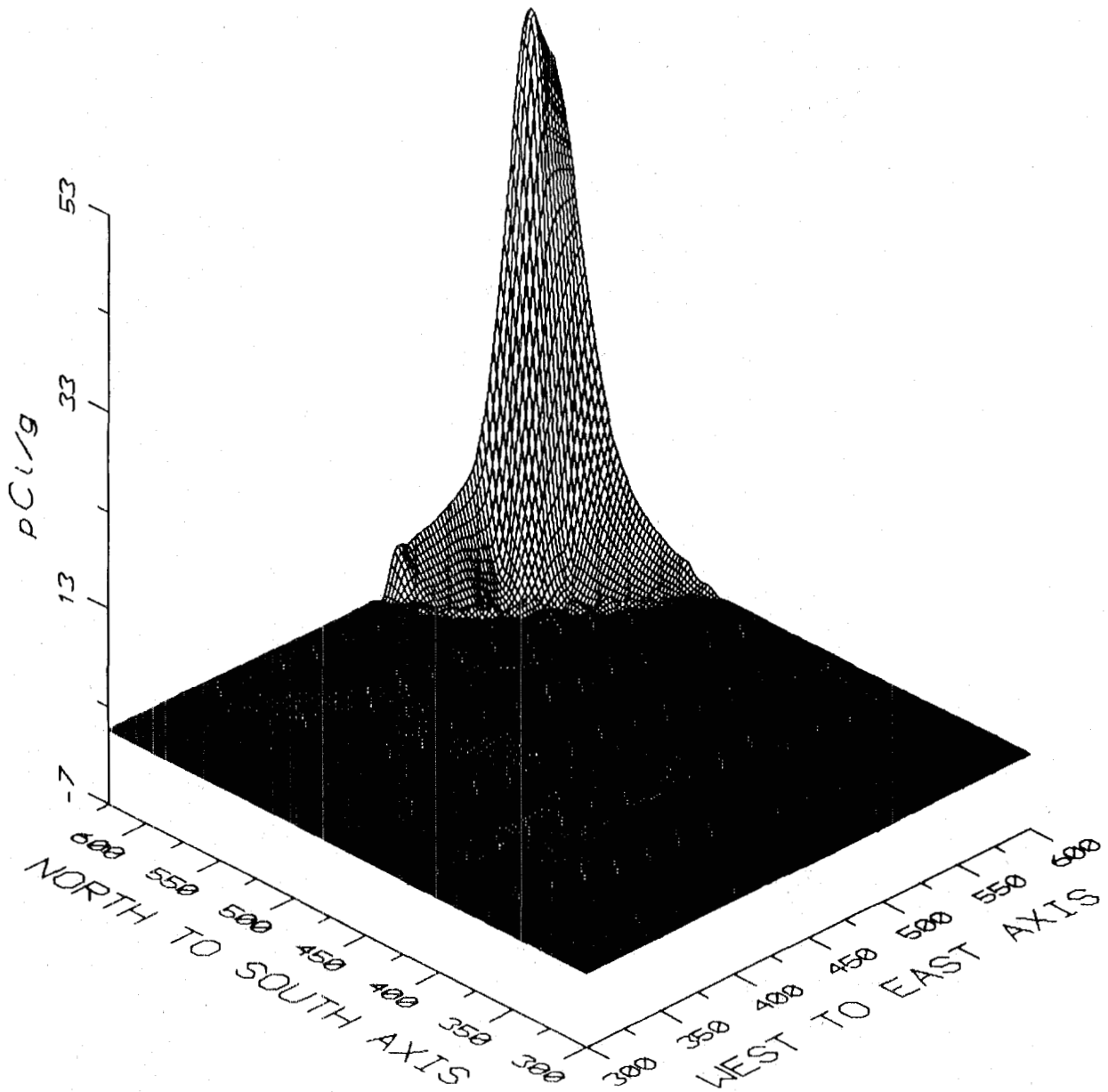
(b)

Fig. 14 (Continued)



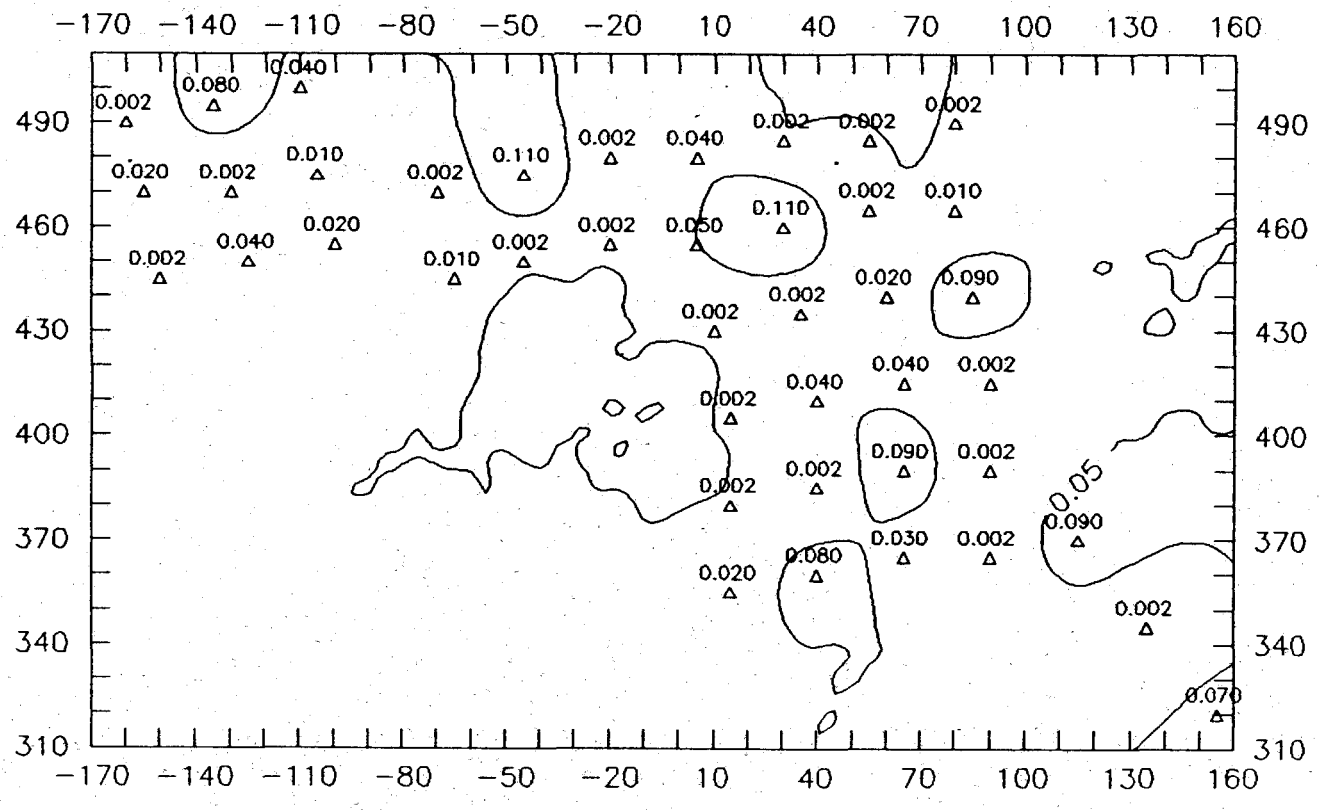
(a)

Fig. 15(a) and (b). Americium-241 (pCi/g) in soil from Areas 2, 2A, and 2B. Grid units are in feet relative to New Mexico State plane coordinates E485 000 and N1 755 000.



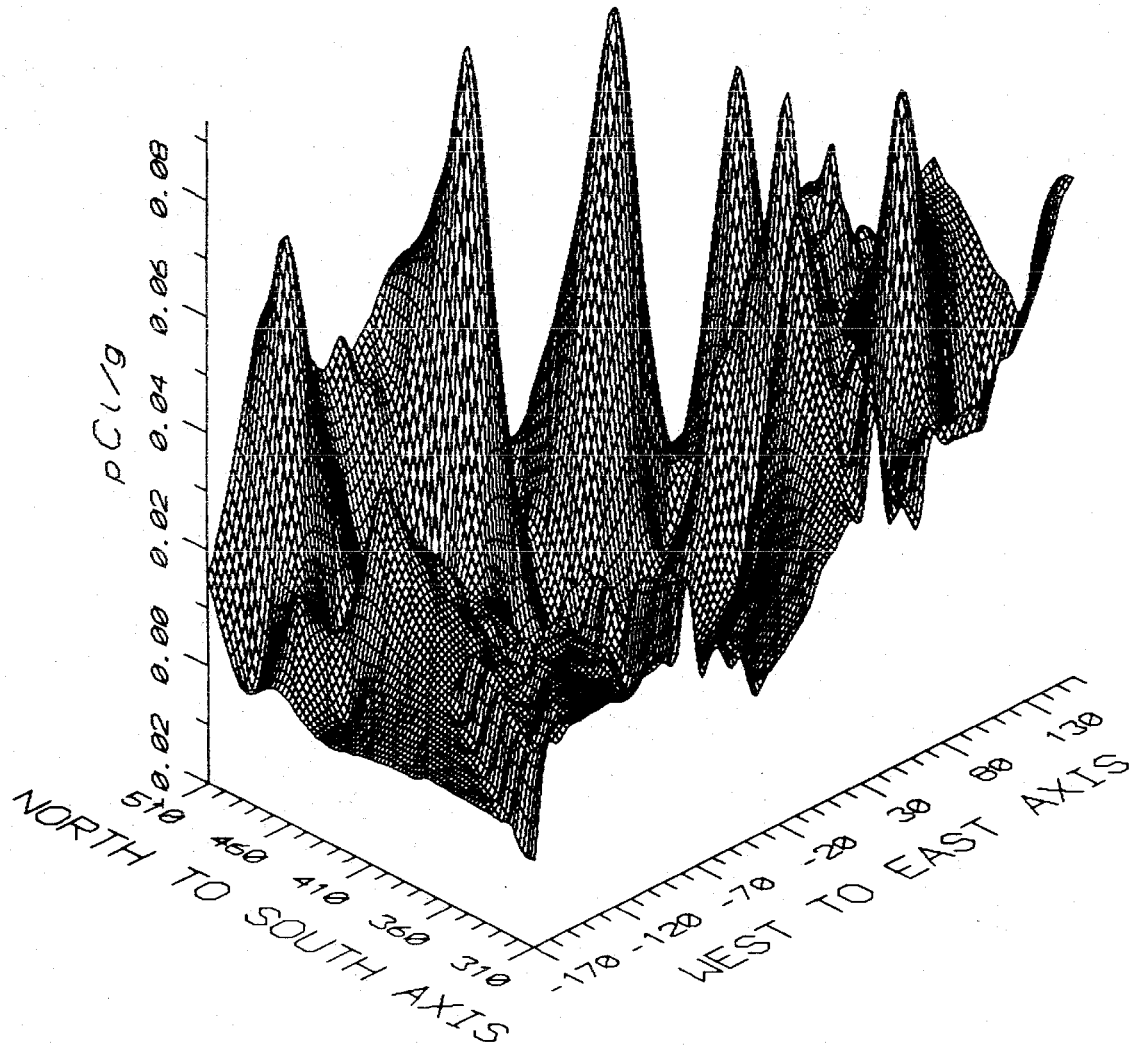
(b)

Fig. 15 (Continued)



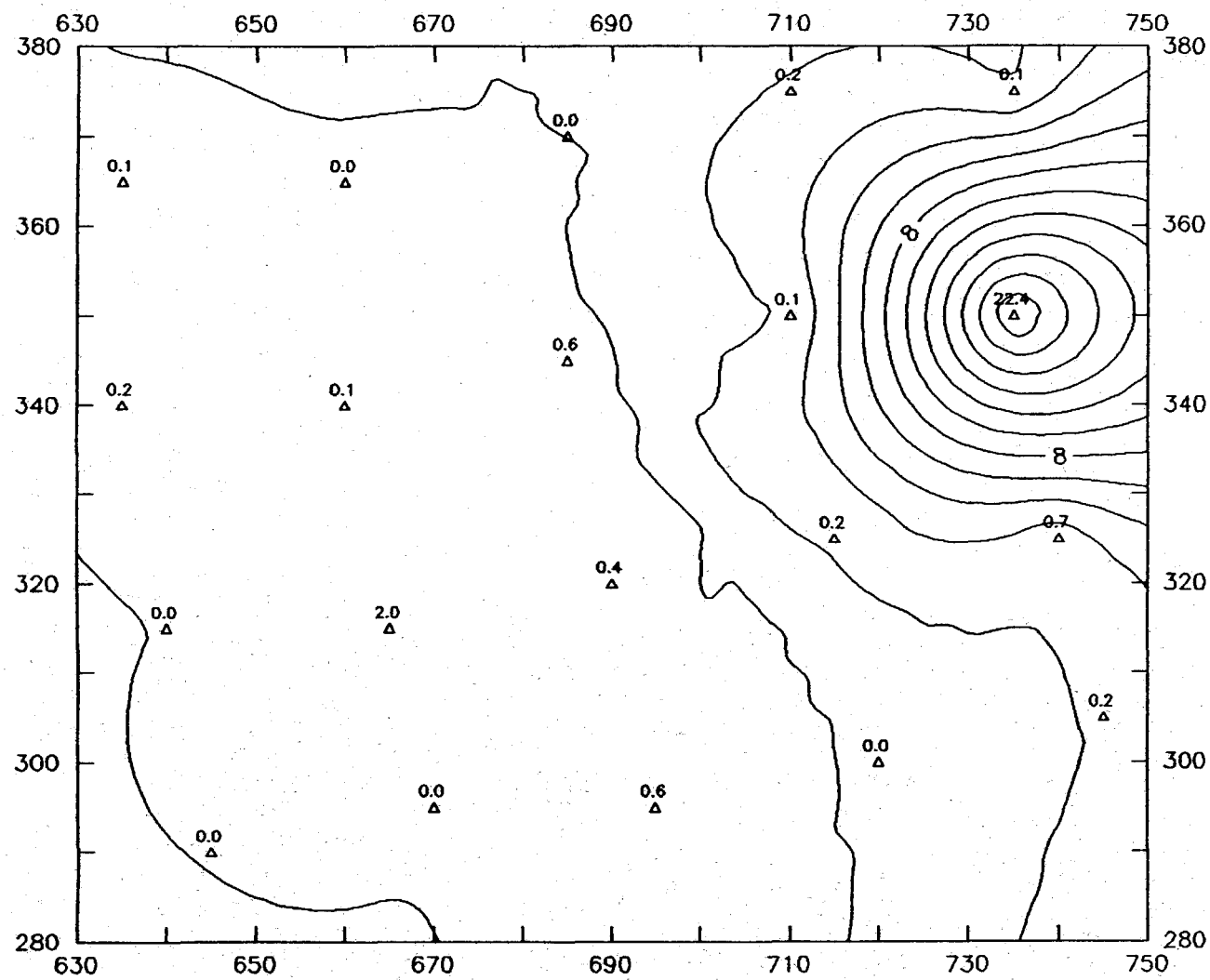
(a)

Fig. 16(a) and (b). Americium-241 (pCi/g) from Area 3. Grid units are in feet relative to New Mexico State plane coordinates E485 000 and N1 755 000.



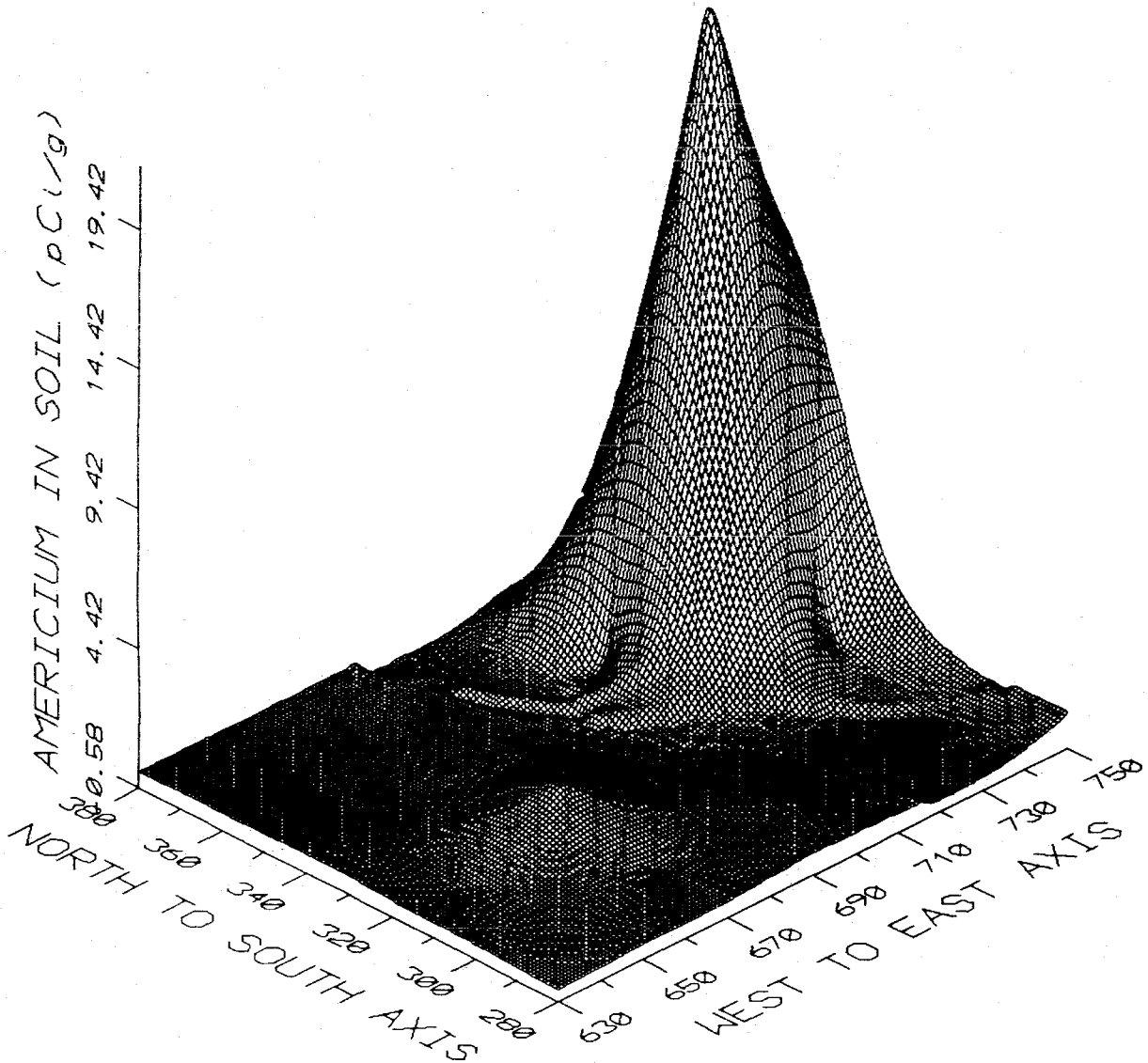
(b)

Fig. 16 (Continued)



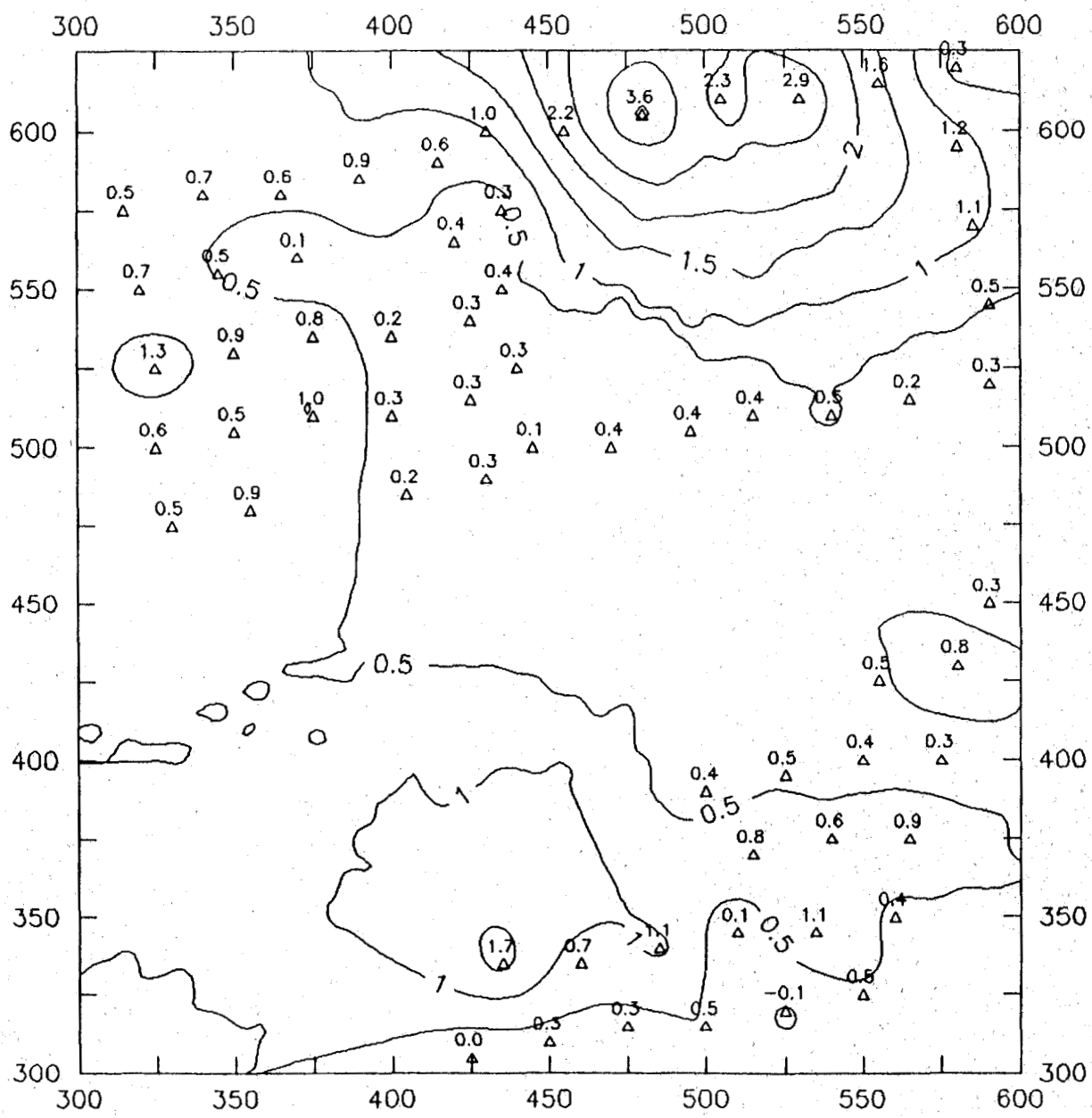
(a)

Fig. 17(a) and (b). Americium-241 (pCi/g) in soil from Area 11. Grid units are in feet relative to New Mexico State plane coordinates E484 000 and N1 755 000.



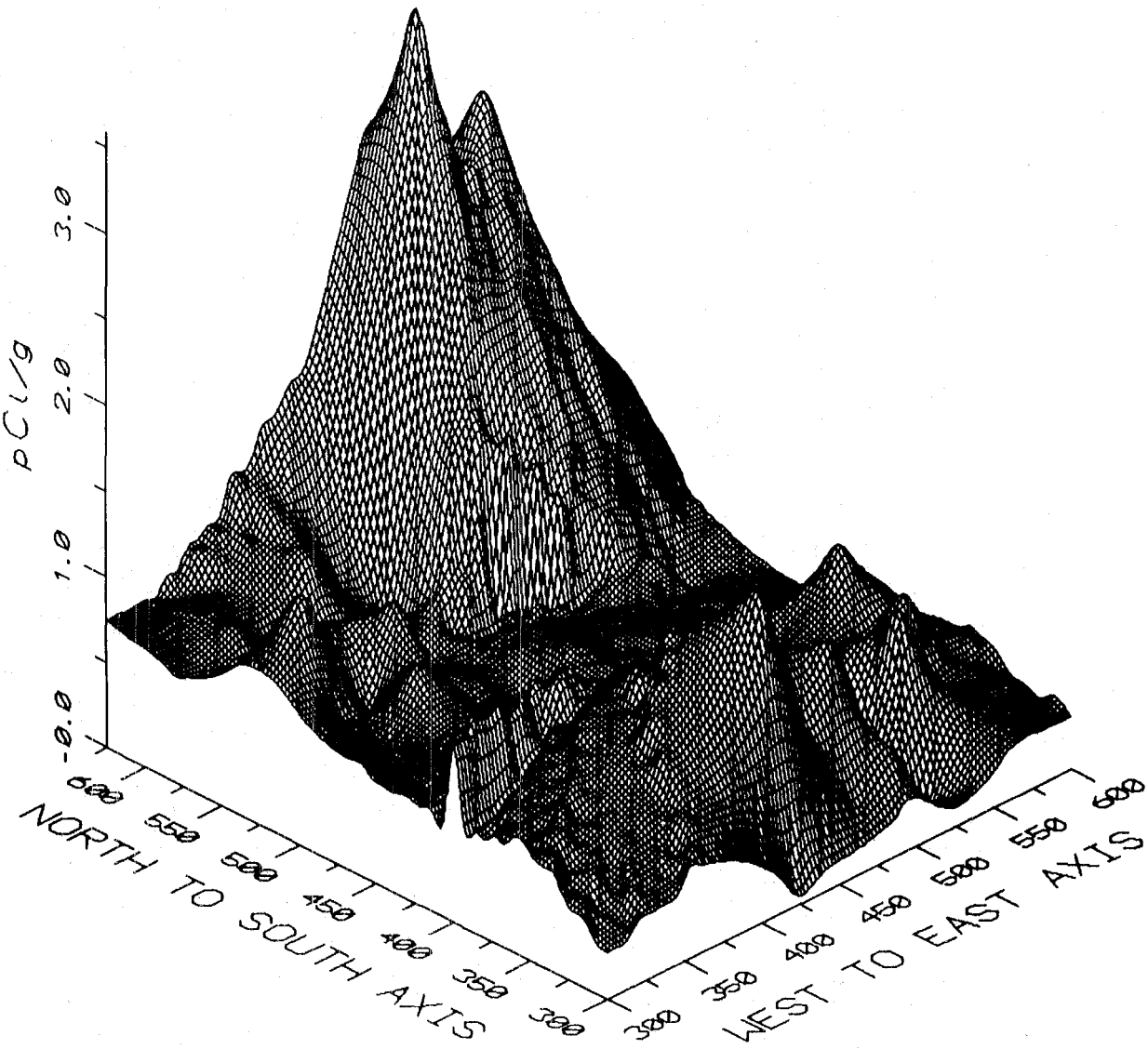
(b)

Fig. 17 (Continued)



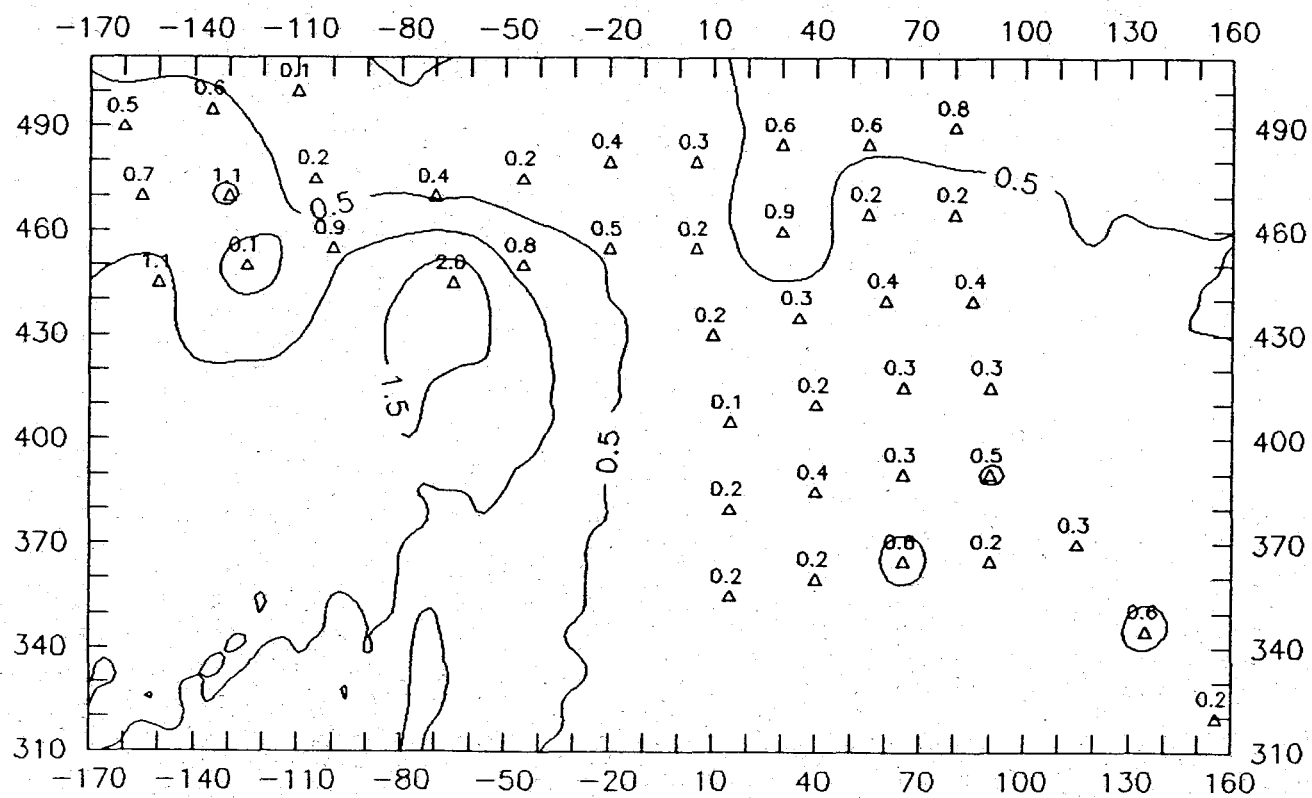
(a)

Fig. 18(a) and (b). Cesium-137 (pCi/g) in soil from Areas 2, 2A, and 2B. Grid units are in feet relative to New Mexico State plane coordinates E485 000 and N1 755 000.



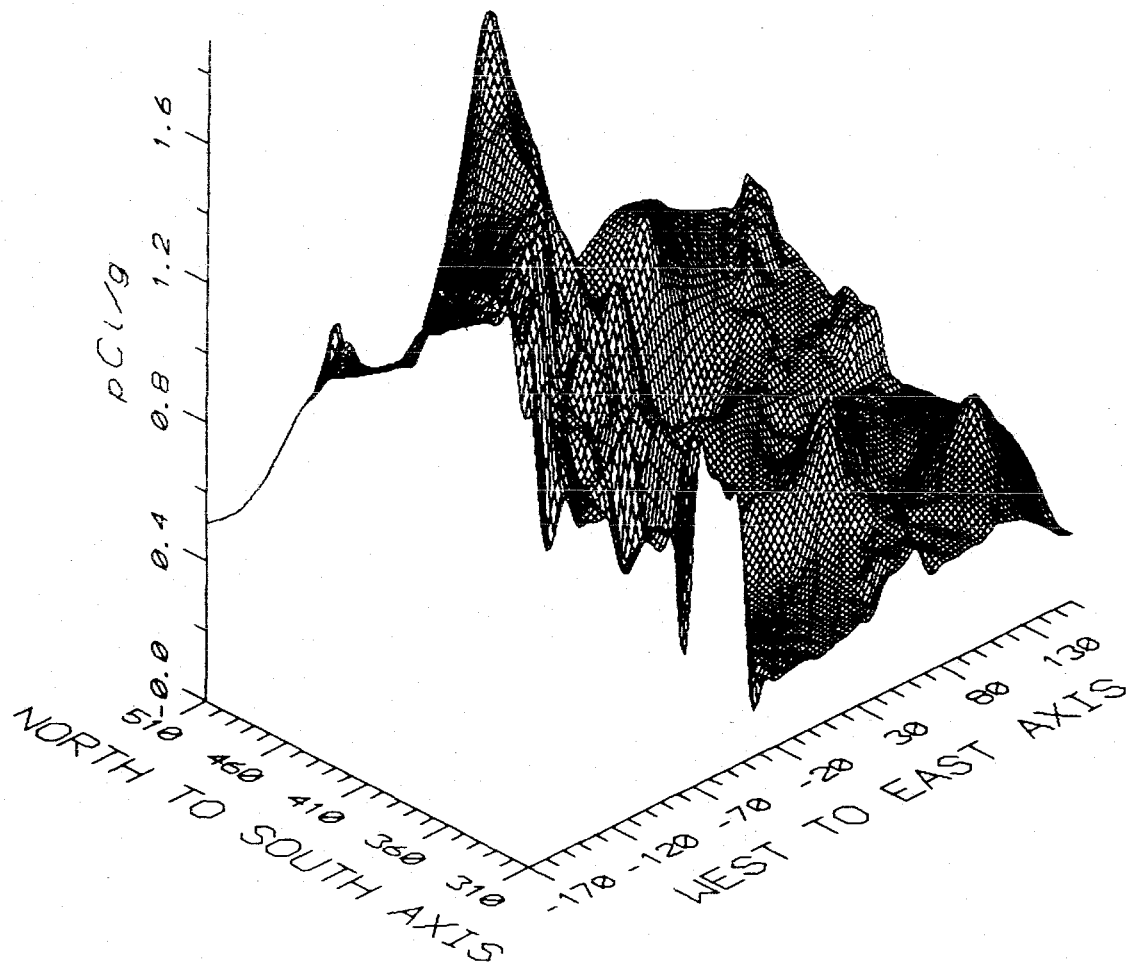
(b)

Fig. 18 (Continued)



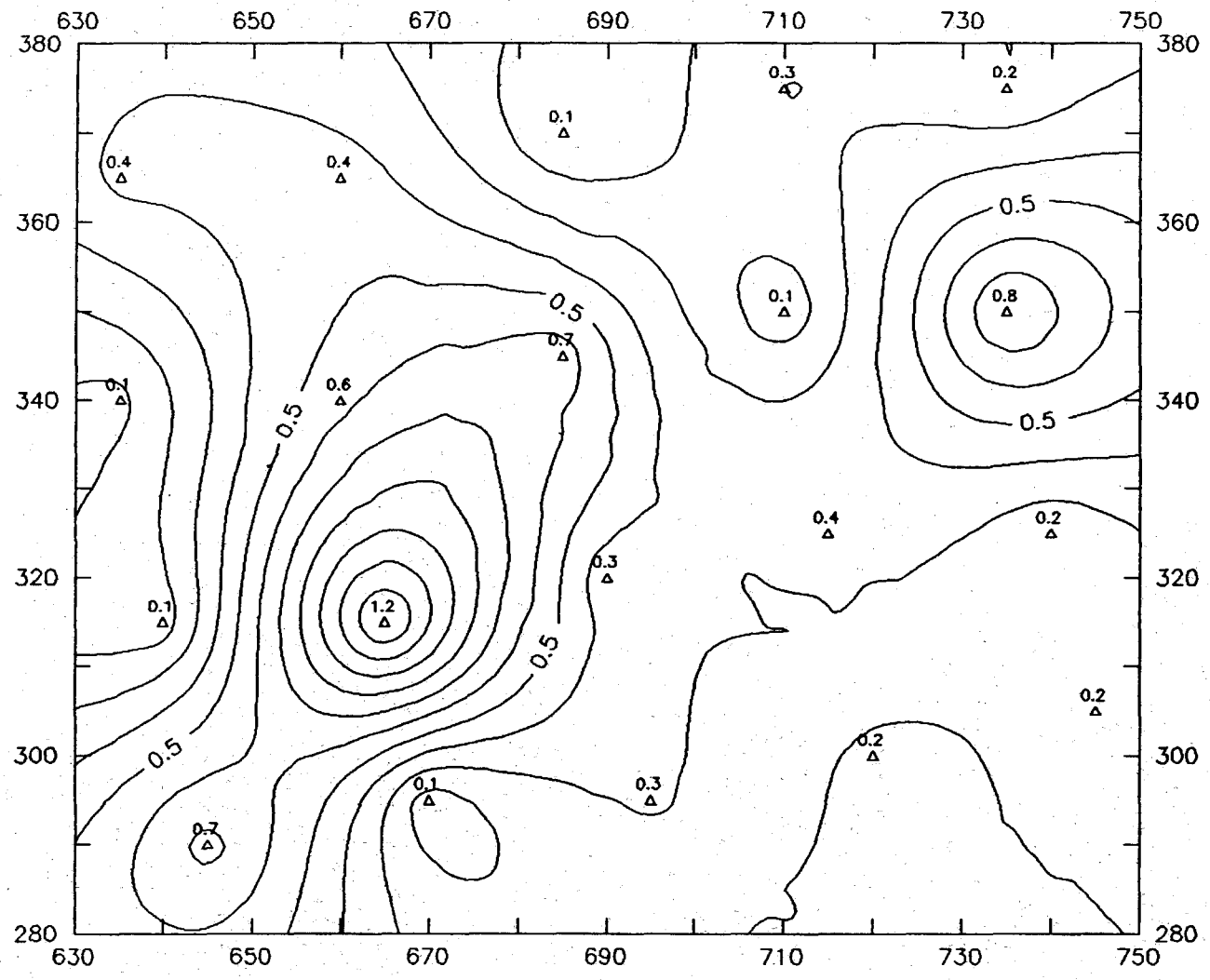
(a)

Fig. 19(a) and (b). Cesium-137 (pCi/g) in soil from Area 3. Grid units are in feet relative to New Mexico State plane coordinates E485 000 and N1 755 000.



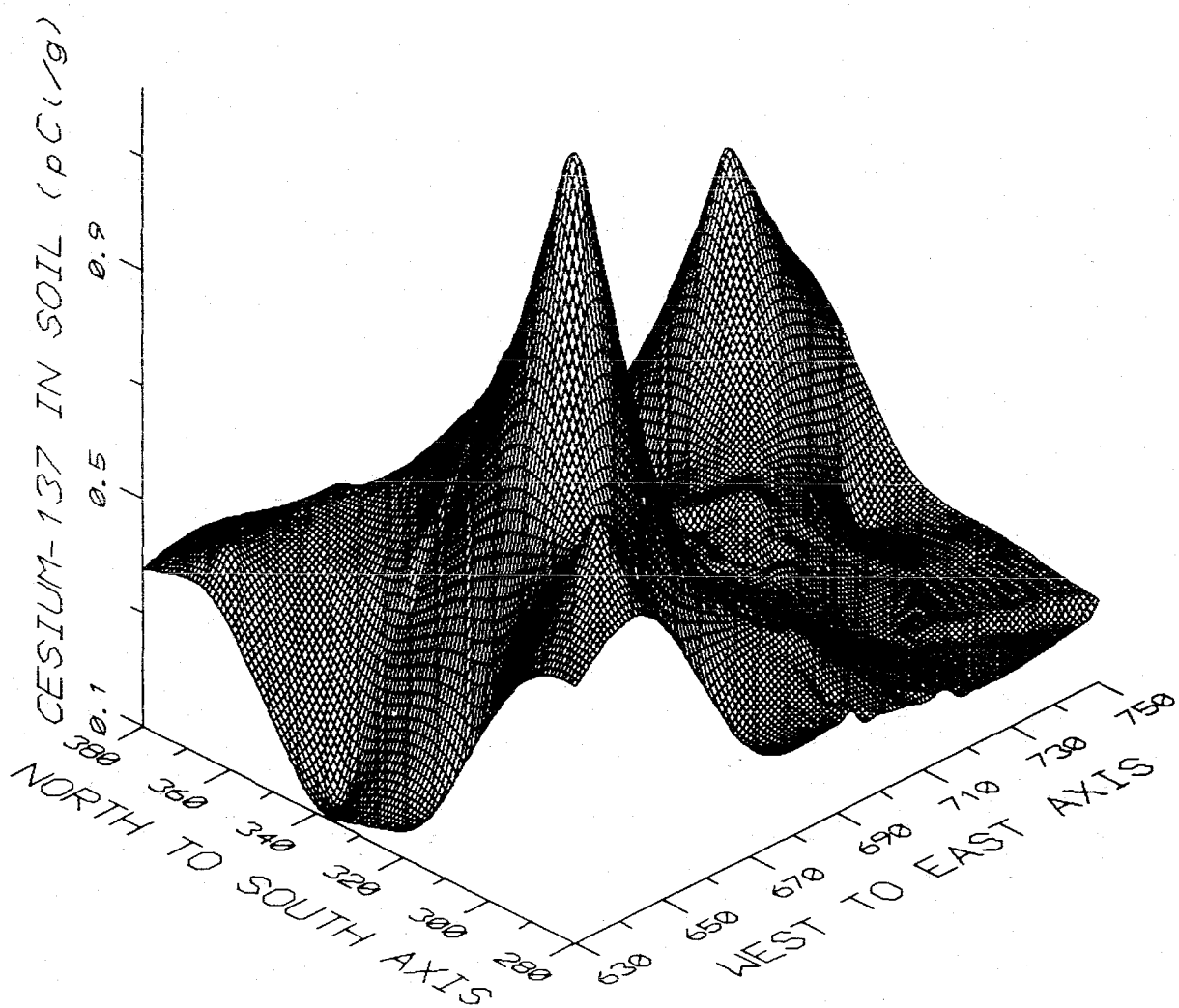
(b)

Fig. 19 (Continued)



(a)

Fig. 20(a) and (b). Cesium-137 (pCi/g) in soil from Area 11. Grid units are in feet relative to New Mexico State plane coordinates E484 000 and N1 755 000.



(b)

Fig. 20 (Continued)

Table 15. Ratio of ^{235}U to ^{238}U in Samples of Soil and Vegetation Collected from Materials Disposal Site Area AB in 1987.

	Area 2	Area 2A	Area 2B	Area 3	Area 11
Soil Samples					
N	16	25	22	41	20
Mean	0.007	0.007	0.007	0.007	0.008
Std dev	0.0008	0.0012	0.0008	0.0009	0.0018
Minimum	0.005	0.002	0.004	0.005	0.006
Maximum	0.008	0.008	0.008	0.009	0.014
Vegetation Samples					
N				39	17
Mean				0.006	0.006
Std dev				0.0012	0.0016
Minimum				0.004	0.003
Maximum				0.008	0.009

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