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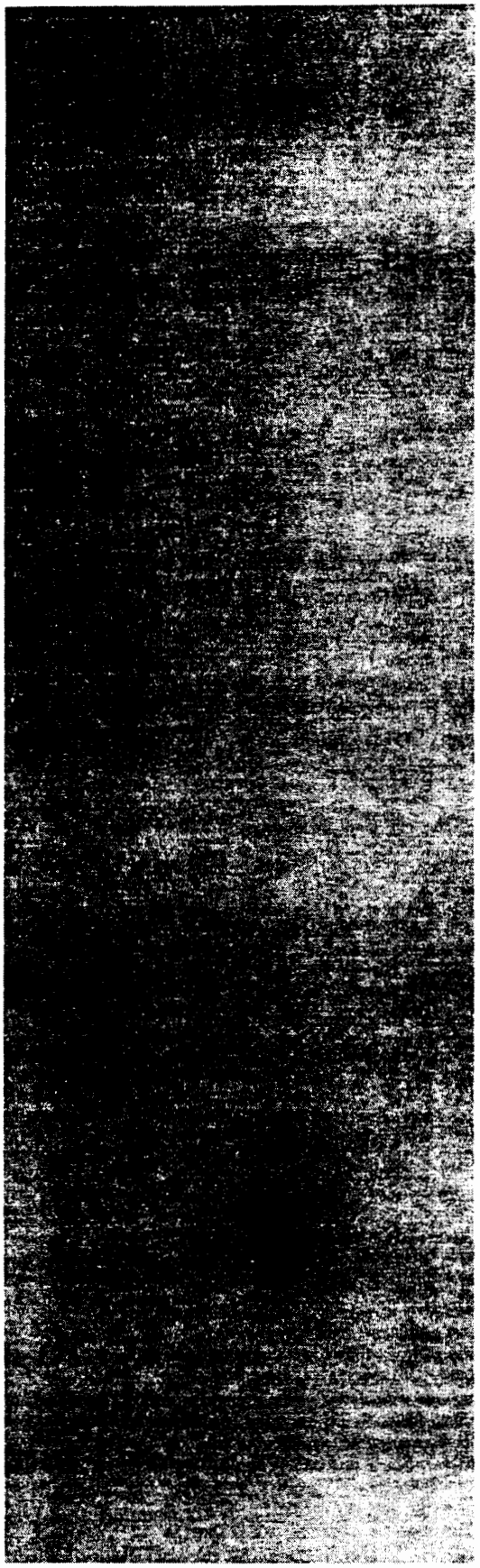

Area G Perimeter Surface-Soil and Single-Stage Water Sampling

Environmental Surveillance for Fiscal Year 95

Group: ESH-19

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Group: ESH-19

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Acronyms and Abbreviations

cpm	counts per minute
CST	Chemical Science and Technology Division, LANL
EPA	Environmental Protection Agency
ER	Environmental Restoration Project, LANL
ESH	Environment, Safety, and Health Division, LANL
FIDLER	field instrument for detection of low-energy radiation
FIMAD	Facility for Information Management and Display
FY	fiscal year
HAZWOPER	hazardous waste operations
ICPMS	inductively coupled plasma mass spectral (analysis)
keV	kiloelectron volts (10^3 electron volts)
KPA	kinetic phosphorescence analysis
LANL	Los Alamos National Laboratory
MDA	material disposal area
μg	microgram (10^{-6} grams)
μmhos	micromhos (10^{-6} ohms^{-1}, a measure of conductance)
μm	micrometer (10^{-6} meters)
NAD	North American Datum
OU	Operable Unit
pCi	picocurie (10^{-12} curies)
RAS	radioactivity/alpha spectroscopy
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
ROI	(spectral) region of interest
SOP	standard operating procedure
SW	solid waste
TA	technical area
TRU	transuranic (waste)
TWISP	Transuranic Waste Inspectable Storage Project
WILD	brand-name surveying station
WSS	Waste Site Studies

AREA G PERIMETER SURFACE SOIL AND SINGLE-STAGE WATER SAMPLING

Environmental Surveillance for Fiscal Year 95

Group: ESH-19

by

Marquis Childs and Ron Conrad

ABSTRACT

ESH-19 personnel collected soil and single-stage water samples around the perimeter of Area G at Los Alamos National Laboratory (LANL) during FY 95 to characterize possible radionuclide movement out of Area G through surface water and entrained sediment runoff. Soil samples were analyzed for tritium, total uranium, isotopic plutonium, americium-241, and cesium-137. The single-stage water samples were analyzed for tritium and plutonium isotopes. All radiochemical data was compared with analogous samples collected during FY 93 and 94 and reported in LA-12986 and LA-13165-PR.

Six surface soils were also submitted for metal analyses. These data were included with similar data generated for soil samples collected during FY 94 and compared with metals in background samples collected at the Area G expansion area.

Elevated levels of tritium (as high as 105,000 pCi/L) were found in perimeter soil samples during FY 95. Five single-stage water runoff samples (out of a total of 131 collected) had a tritium activity greater than 1000 pCi/L. The tritium concentrations in soils were substantially lower than those found during corresponding sampling accomplished in FY 94, but similar to tritium levels in soils collected during FY 93. Although we propose two major subsurface-to-surface tritium migration mechanisms, we do not know how well these surface sample tritium data reflect the true Area G near-surface soil tritium distribution.

For soil samples, the average plutonium-238 activity was 0.539 pCi/g, whereas for plutonium-239 the average activity was 0.343 pCi/g. The locations of elevated plutonium readings in soil samples were consistent with the history of plutonium disposal at Area G, which was also reflected in the americium-241 results. Americium-241 on soils had a mean concentration of 0.202 pCi/g. Cesium-137 activities in soils had a wide distribution and ranged from 0.02 to 1.76 pCi/g. The uranium soil concentrations had an average value of 2.67 μg/g and were uniformly distributed around Area G.

Of the ten metals analyzed on six perimeter soils collected around Area G, all were within the baseline concentrations for metals established from the soil sampling done in the undisturbed Area G expansion grid.

Baseline or local background concentrations for future disposal operations were established for metals and radionuclides by a sampling program conducted in the proposed Area G expansion area during FY 93 and 94.

Considering the amount of low level radioactive waste that has been disposed of at Area G, there is evidence of only low concentrations of radionuclides on perimeter surface soils. Consequently, little radioactivity is leaving the confines of Area G via the surface water runoff pathway.

EXECUTIVE SUMMARY

Area G, in Technical Area 54, has been the principal facility at Los Alamos National Laboratory for the storage and disposal of low-level, solid mixed, and transuranic (TRU) radioactive waste since 1957. Our investigation during FY 95 focused on defining whether surface water has moved contaminated sediments out of the Area G site perimeter. Soil samples were analyzed for tritium, total uranium, isotopic plutonium, americium-241, and cesium-137. Ten metals—silver, arsenic, barium, beryllium, cadmium, chromium, mercury, nickel, lead and antimony—were analyzed on soils using standard analytical chemistry techniques (EPA SW-846). Filtered-water fractions from single-stage collectors were analyzed for tritium. Filtered-sediment fractions of the single-stage samples were analyzed for isotopic plutonium only.

Elevated levels of tritium (as high as 90,500 pCi/L) in soil were found for sampling locations adjacent to the tritium burial shafts located on the south-central perimeter of Area G. Additionally, tritium concentrations in soil as high as 105,000 pCi/L were detected adjacent to the TRU pads in the northeast corner of Area G. The majority of soil samples collected from sampling points surrounding the TRU pads and extending to the west were elevated in tritium concentration. During FY 95, five single-stage water samples (out of a total of 131) had tritium concentrations greater than 1000 pCi/L, with the highest value measured at 10,900 pCi/L. The highest tritium readings in runoff water were from locations adjacent to the tritium shafts. Two primary mechanisms, vapor-phase transport and capillary action, may allow tritium to move from the subsurface to surface soils. Tritium's residence time in surface soils is unknown, and we do not know how well our sample results reflect tritium's actual distribution (surface and subsurface) at Area G.

The uranium on soil concentrations ranged from 1.62–4.86 μg/g, with an average value of 2.67 ± 0.57 μg/g. Plutonium-238 activities ranged from 0.001–10.7 pCi/g, with an average of 0.54 ± 1.75 pCi/g. Plutonium-239 activities in soils ranged from 0.002 to 6.29 pCi/g, with an average of 0.343 ± 0.913 pCi/g. The total activities for plutonium-238 and -239 isotopes ranged from 0.003–11.9 pCi/g, with an average of 0.88 ± 2.13 pCi/g. The locations of elevated plutonium readings were consistent with the history of plutonium disposal at Area G; the sampling stations adjacent to the TRU pads and the oldest disposal pits had the highest plutonium levels for both surface soil and single-stage sediment fraction samples. The two areas of elevated americium-241 activity reflected the elevated activities found for plutonium; the average value for Am-241 on soils was 0.202 ± 0.289 pCi/g. Cesium-137 activities in soils had a wide distribution and ranged from 0.02–1.76 pCi/g, with an average value of 0.31 ± 0.35 pCi/g. There was no perimeter area where soil concentrations of Cs-137 were significantly elevated.

For the ten metals in soil analyzed, there were no apparent elevated concentrations over the metal in soil concentrations measured in the baseline soils collected from the proposed Area G expansion area located immediately west of the active part of Area G.

1.0 INTRODUCTION

Area G or Material Disposal Area (MDA) G, in Technical Area 54 (TA-54), has been the principal facility at Los Alamos National Laboratory (LANL or the Laboratory) for the storage and disposal of low-level, solid mixed, and TRU radioactive waste since 1957 (see Figure 1). From the standpoint of the surrounding environment, an important question is whether there has been an impact outside of Area G due to the disposal and storage operations that have taken place within Area G. One aspect of this question is whether contamination associated with surface soil within Area G somehow migrates off-site. The two most likely pathways (ignoring the improbable groundwater pathway) for spread of contaminants from Area G surface sediments are airborne dispersion of particulate matter or gases and off-site movement of contaminated sediments and/or dissolved chemical compounds by surface water runoff.

This environmental surveillance investigation was carried out, in part, to ensure ongoing compliance with DOE Order 5400.1, "General Environmental Protection Program" (June 1990), and DOE Order 5820.2A, "Radioactive Waste Management" (September 1988), and to satisfy recent criticisms from the Nuclear Facility Defense Safety Board on the scarcity of formal environmental surveillance activities at Area G.

Our investigation focuses principally on defining the potential pathway for the transport of contaminated sediment and storm water or other precipitation out of Area G. Extensive surface soil and storm-water-runoff sampling was initiated in FY 93 around the perimeter of Area G and continued during FY 94 and FY 95. Sampling locations were intentionally selected to best indicate whether contaminants were moving off-site via these pathways; thus, these sampling locations should be considered as locations most sensitive to possible contaminant migration outside of Area G. The data collected during FY 95 can be used to

1. determine whether there has been movement of contaminants out of the site;

2. compare with baseline concentrations of constituents on soils sampled in an undisturbed area of TA-54 proposed for the expansion of Area G disposal operations;

3. compare with baseline concentrations established at the same locations during the FY 93 sampling and to define contaminants of potential concern (COPCs) and locales for future Area G surveillance efforts; and

4. assist Area G Waste Management personnel attempts to engineer techniques to prevent off-site movement of contaminants by either indicating areas of concern or assessing effectiveness of engineering fixes already in place to preclude off-site movement of contaminants.

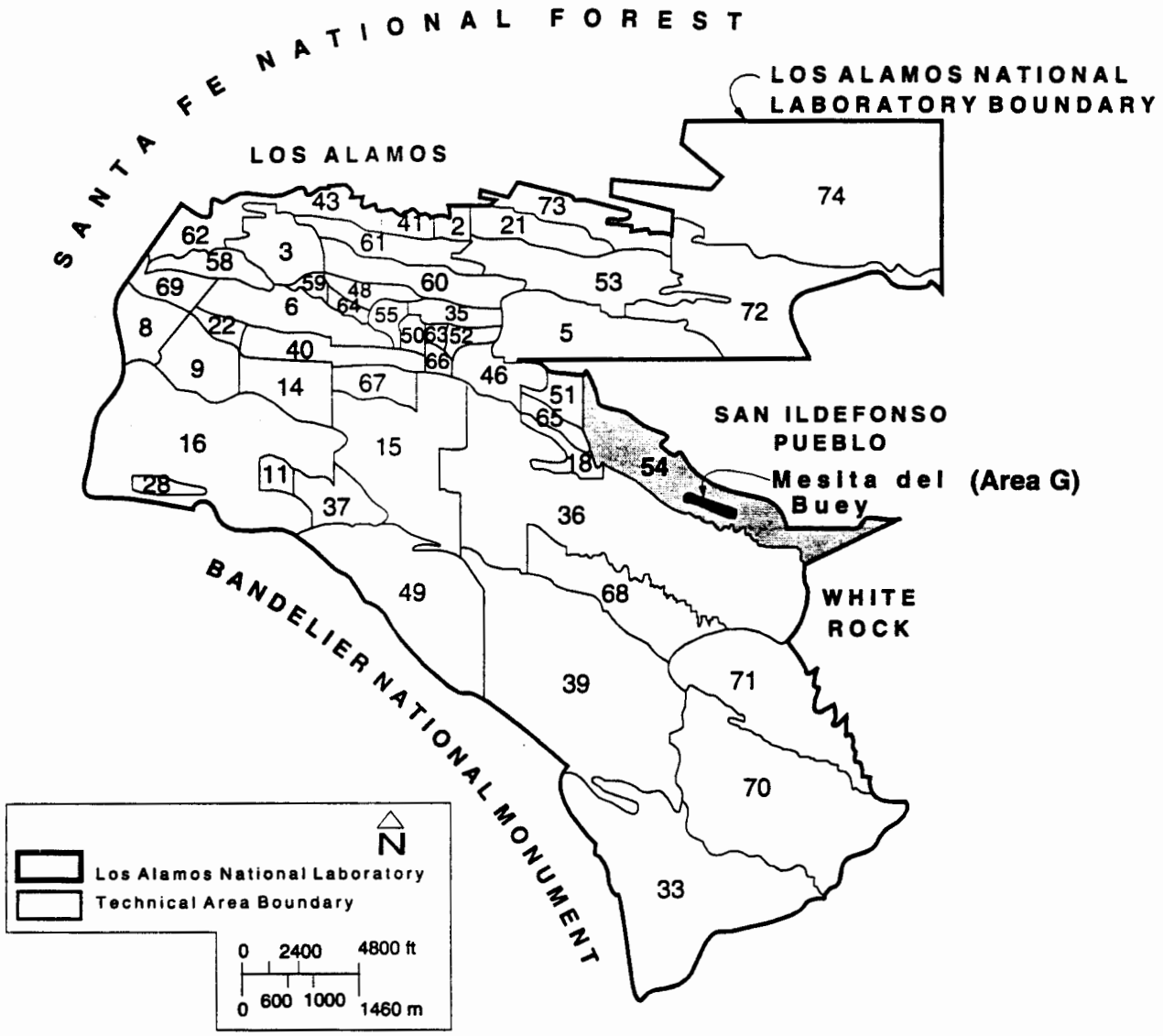

Figure 1: Location of TA-54 and Area G at Los Alamos National Laboratory. The 74 technical areas (TAs) of the Laboratory are shown here, with TA-54 located south of San Ildefonso Indian Reservation property. Area G (shaded in gray) runs along Mesita del Buey and parallels Pajarito Road.

The expansion area sites that were sampled in FY 94 and 95 are located where no radioactive-waste disposal has occurred and in an location where Waste Management operations are expected to develop in the future. In FY 94 a regular 100 × 100 foot grid was established in this area, just west of the old Area G gate (the area west of the shaded yellow expanse in Figure 2). The analytical data from 54 samples collected in this area will serve as baseline or preoperational concentrations for constituents of interest when disposal operations are initiated in this expansion area. This information is also presented in this paper to serve as one benchmark against which perimeter soil and water constituent concentrations will be compared.

3.0 HEALTH AND SAFETY TRAINING FOR WSS PERSONNEL

All field work on this project was performed by members of the Waste Site Studies (WSS) team from the Environmental Safety and Health Division's Hazardous and Solid Waste Group (ESH-19). Each member of the team has received and is up-to-date with all the requisite health and safety training required to perform environmental sampling at Area G. This training includes HAZWOPER (Hazardous Worker Operations), Rad Worker and General Employment Training. All field work was done following the guidelines of the WSS site-specific Health and Safety Plan (HASP) for Area G.

All members of the team also received radiation support personnel training, which allowed them to competently operate the ESP-1 beta/gamma and Model 139 alpha meters and to perform routine frisking and radiation screening operations.

In addition, each team member watched the Area G site-specific training video, was aware of the potential hazards associated with this sampling project, was apprised of the health and safety rules and guidelines under which Area G employees operate, and performed field duties according to the Area G in-house health and safety protocols. Each WSS team member formally checked in and out of Area G daily if the work was within Area G. Work outside the fence at Area G did not require formal check-in but entailed complying with the same health and safety protocols as required within Area G. Each field task was performed using the buddy system; at no time did team members undertake a task at Area G without another team member being present. Finally, all team members were also enrolled in an annual LANL medical surveillance program.

Sediment movement out of Area G via the surface water pathway is important because this is a major mechanism for disseminating nongaseous contaminants from the surface of Area G to outlying areas. Contamination of the ground surface of Area G (and formation of the surface soil source term for surface water runoff) may have resulted from

1. dispersion of material from active pits by natural phenomena and other anthropic activities;

2. movement of contaminated sediments off the TRU pads or other storage or disposal areas by wind, surface water runoff, mass wasting, or anthropic activities;

3. capillary action or vapor movement of buried, radioactive contaminants in pits and shafts to the surface;

4. inadvertent spills or discharges from facilities or vehicles handling contaminated materials;

5. dispersion of contaminants from trucks carrying waste into Area G; or

6. transport of contaminants or contaminated materials from inactive pits, shafts, or pads to the surface by burrowing animals, vegetation, or anthropic activities.

Radioactive surface soil contamination has been documented within the confines of Area G, and it is important to determine if these contaminants are moving off the mesa top to areas where the public may be exposed or to where there may be a detrimental impact to the environment.

To this end, an extensive perimeter sampling network has been established at Area G (Figure 2, inside back cover pocket).

2.0 OBJECTIVES OF INVESTIGATION

The objectives of these investigations are to

1. define those perimeter locations at Area G where concentrations of radioactive contaminants are expected to be elevated in surface soils or in established surface-water-runoff channels. The latter are established by walking the site and detecting the small channels that are formed by surface water runoff originating in Area G;

2. quantify the levels of radioactive and RCRA regulated metal contaminants in surface soils at Area G and compare to baseline levels from surface soil samples taken in adjacent, nonimpacted locations;

3. provide contaminant concentration data that can be compared with analogous baseline data collected in FY 93; and

4. document whether contaminants (either dissolved in water or associated with sediments) are moving off-site through surface water runoff and compare to contaminant concentrations on samples collected from adjacent areas where disposal operations have not occurred.

Enhanced Area G perimeter surveillance is taking place on an annual basis in order to provide an up-to-date picture of existing radioactive (and other constituent) contamination in perimeter surface soils and surface water runoff. Ultimately, any measurable impacts on unimpacted adjacent areas can be documented by comparing these data with those from future surveillance efforts.

2.1 Areal and Temporal Extent

The investigation to define off-site migration of contaminants via the surface water pathway is limited to the near mesa top perimeter outside the fence of Area G, the hillsides directly below Area G, and one major drainage within the disposal area itself. Surface soil sampling stations and single-stage water samplers were installed in small arroyos or rivulets incised into the hillsides around the perimeter of Area G. The single-stage locations are designed to sample runoff either on the mesa top (just outside the fence line) or at points before the runoff enters the bottom of either of the two adjoining canyons, Cañada del Buey or Pajarito Canyon. This micro-scale surface water runoff sampling complements the macro-scale storm water runoff compliance sampling performed by the Water Quality and Hydrology Group (ESH-18) of the Environmental Safety and Health Division.

This study is not intended to define potential contamination in the environment downstream from Area G. The sediments in the canyon bottoms, surface water, and ground water from wells located downstream from Area G are all monitored on an annual basis by ESH-18.

Based on available funding, this investigation will be performed yearly with annual reports being prepared to compare contemporary with historical data.

2.2 Data Needs

The data needs for the FY 95 perimeter surveillance study are

1. surface soil samples (0–6 in. deep) from existing runoff pathways located just outside the Area G perimeter fence and analyses of these samples for those constituents listed in Section 5.3; and

2. surface water-runoff samples collected with single-stage samplers from minor runoff pathways that were estimated to have significant runoff volumes originating in Area G and analyses of these surface water-runoff samples for constituents listed in Section 5.2.

4.0 FIELD INVESTIGATION METHODS

Accepted techniques were used to identify and certify sampling locations, install sampling equipment, take samples, and make measurements on these samples. A summary of field protocols is found in the following sections.

4.1 Land Survey

A WILD-brand electronic-theodolite complete surveying station was used in the field. This equipment was used and field data were collected employing WILDsoft 2000 software for data reduction. Bill Kopp, a LANL technical staff member and professional engineer registered in the state of New Mexico, supervised all of the surveying for this project.

At all of the sampling locations (coordinates referenced to NAD 1983), an aluminum stake was emplaced to memorialize the position.

The unique sampling locations on the perimeter of Area G were coded as G-##-#. The first two numbers after "G" in the sequence refer to one of seventy permanent survey monuments, each of which is identified by a piece of rebar driven into the ground and tagged with an aluminum cap marked with the location number. These 70 monuments were originally installed in 1991 as part of the old A411 material disposal area (MDA) low-energy gamma (FIDLER) study to characterize potential movement of radioactive contaminants off-site. FIDLER readings are still taken on an annual basis at each of these 70 locations; the data collected in FY 95 are found in Appendix A of this report. For the perimeter surveillance study, the soil and single-stage sampling sites were numbered in reference to these 70 permanent, surveyed locations. For instance, two soil or combination soil/single-stage sampling sites are sited near monument MDA-24. These locations are identified by aluminum stakes with numbered tags G-24-1 and G-24-2.

The expansion area soil sampling 100 × 100 foot grid was also memorialized by surveying in the locations. At each location, a four foot aluminum stake was pounded into the ground. Numbered brass tags attached to the stake describe the locations with the notation, G-X-##. The gridded locations are numbered consecutively from G-X-1 through G-X-55, excluding point G-X-7 which is sited off the edge of the mesa top.

On the map depicting the perimeter and expansion area surveillance locations (Figure 2), soil-sample points are in orange, single-stage water sample points are in blue, and the combination points where both surface soil and single-stage samples are collected are depicted in green. The expansion area grid points are represented by purple numbers. All sampling locations depicted in Figure 2 may not have been sampled in FY 95. This map was prepared by Doug Walther of the LANL Facility for Information Management and Display (FIMAD) team.

4.2 Field Techniques

The following standard sampling and instrument procedures, adopted by the WSS team to collect soil and water samples and to make associated measurements, were used during this investigation:

SOP Number	Title
LANL-ER-SOP-01.02	Sample Containers and Preservation
LANL-ER-SOP-03.01	Land Surveying Procedures
LANL-ER-SOP-06.09	Spade and Scoop Method for Collection of Soil Samples
LANL-ER-SOP-06.29	Single-Stage Sampling for Surface Water Runoff
LANL-ER-SOP-10.04	MCA-465/FIDLER Instrument System
LANL-ESH-8-008	General Field Work
DOE GJ/TMC-07(83), UC-70A	"Procedures for Field Chemical Analyses of Water Samples," by Nic Korte and Dennis Ealey

Before soil samples were collected, 1 minute counts were made at the soil surface to define surface soil beta/gamma activity. These readings were made with an Eberline ESP-1 beta/gamma meter equipped with a pancake probe. The beta/gamma measurements were taken principally to define any potential radioactive hazards at sampling points. A typical soil-background level taken with the ESP-1 counter at Area G was 300 cpm.

4.3 Chain-of-Custody Procedure

In addition to the above SOPs, we followed procedure LANL-ESH-8-002, "Chain-of-Custody for Environmental Samples." In this project, each sample was handled under standard chain-of-custody procedures, using traceable forms, transfer signatures, and custody tape. Every sample was always kept within sight of one of the WSS team members or locked in a room or cooler to which only the WSS team members had keys. All samples requiring analytical chemistry services were delivered to the Sample Receiving Facility of the Chemical Science and Technology Division (Group 3 or CST-3), located at SM-59-1, TA-59. CST-3 personnel took formal custody of the samples at that time. All FY 95 samples were analyzed on-site at LANL.

5.0 SAMPLE ANALYSIS

The analytical chemistry data for samples referred to in this report are found in Tables 1–5.

5.1 Water Samples—pH and Conductivity Measurements

The single-stage water samples were collected in 1-gal. polyethylene bottles. The bottles were collected as soon as possible after a storm event and brought back to TA-59, where temperature, pH, and specific conductivity measurements were made (Korte, 1983). The pH and specific conductivity results are found in Table 2.

5.2 Requested Analytical Services

5.2.1 Surface Soil Samples

The following analytical services were requested for soil samples taken during FY 95:

1. isotopic plutonium by radioactivity/alpha spectroscopy (RAS),
2. total uranium by kinetic phosphorescence analysis (KPA) or inductively coupled plasma spectrograph (ICP),
3. tritium by distillation of soil moisture and scintillation counting,
4. cesium-137 and americium-241 by gamma spectroscopy,
5. percent moisture by gravimetric methods, and
6. metals extracted by EPA SW-846 Method 3050 followed by appropriate ICP or atomic absorption (AA) analytical techniques.

5.2.2 Single-Stage Water Samples

For each water sample, we requested that the sample first be filtered through a 0.45-μm filter and separated into a water fraction and a sediment fraction. The following analyses were then requested:

<u>Water fraction</u>

- tritium

<u>Sediment fraction</u>

- Isotopic plutonium (for the majority but not all samples)

Table 1: FY 95 TA-54 Area G (OU 1148) Perimeter Soil Data (Sample locations can be found in Figures 2 through 9. Please note that negative values sometimes result from counting statistics when average background activities are subtracted from gross analytical results.)

Sample Location	Collection Date	% Water	^{3}H pCi/L	^{241}Am pCi/g	^{137}Cs pCi/g	Total U (µg/g)	^{238}Pu pCi/g	^{239}Pu pCi/g	Total Pu pCi/g
G-5-1	7/25/95	4.47	100	-0.12	1.76	4.86	0.004	0.085	0.089
G-5-2	7/25/95	2.86	400	0.09	0.88	3.89	0.056	0.06	0.116
G-6-1	7/25/95	1.9	200	-0.03	0.05	2.52	0.000	0.003	0.003
G-7-1	7/25/95	4.12	200	0.02	0.25	2.84	0.001	0.009	0.01
G-8-1	7/25/95	3.62	100	0.01	0.15	2.13	0.001	0.007	0.008
G-8-2	7/25/95	2.08	300	0.15	0.45	2.33	0.004	0.021	0.025
G-29-1	7/25/95	1.89	43300	-0.15	0.07	2.98	0.059	0.022	0.081
G-29-2	7/25/95	1.23	60000	0	0.28	2.55	0.053	0.028	0.081
G-29-3	7/25/95	1	90500	0.01	0.23	2.57	0.012	0.014	0.026
G-30-1	7/25/95	0.94	83600	0.07	0.03	1.6	0.007	0.005	0.012
G-31-1	7/25/95	5.87	33700	-0.02	0.88	3.31	0.035	0.079	0.114
G-31-2	7/25/95	1.82	71900	0	0.02	2.06	0.013	0.02	0.033
G-31-3	7/25/95	1.51	69100	0.05	0.1	1.99	0.003	0.004	0.007
G-32-1	7/25/95	1.38	32100	0.11	0.02	1.66	0.006	0.009	0.015
G-32-2	7/25/95	2.25	24300	0.05	0.03	3.24	0.011	0.067	0.078
G-32-3	7/25/95	1.89	16100	0.03	0.19	2.67	0.034	0.021	0.055
G-34-4	7/25/95	2.49	4500	0	0.15	3.02	0.029	0.034	0.063
G-34-5	7/25/95	2.02	5000	0.23	0.05	2.63	0.008	0.007	0.015
G-34-7	7/25/95	3.45	2300	0.19	0.03	2.21	0.006	0.003	0.009
G-34-9	7/25/95	3.22	3100	0.07	0.32	3.1	0.017	0.071	0.088
G-34-10	7/25/95	5.84	1700	0.12	0.14	2.21	0.028	0.199	0.227
G-34-13	7/25/95	2.26	3400	0.01	0.09	2.19	0.212	0.023	0.235
G-38-2	7/25/95	6.32	15100	0.14	0.25	2.75	0.078	1.132	1.21
G-39-1	7/25/95	3.78	1800	0.03	0.11	1.62	0.445	0.231	0.676
G-39-2	7/25/95	0.77	2900	0.08	0.02	2.18	0.085	0.114	0.199
G-40-1	7/25/95	1.64	1600	0.09	0.16	2.1	1.309	0.169	1.478
G-40-2	7/25/95	2.95	1700	0.22	0.34	2.66	1.731	0.267	1.998
G-41-2	7/25/95	3.85	500	0.14	0.22	2.44	2.182	0.206	2.388
G-42-1	7/25/95	1.21	1600	0.08	0.27	3	1.420	0.736	2.156
G-42-6	7/25/95	5.98	1700	0.08	0.03	2.86	0.120	6.29	6.41

(continued)

Table 1 (continued): FY 95 TA-54 Area G (OU 1148) Perimeter Soil Data (Sample locations can be found in Figures 2 through 9. Please note that negative values sometimes result from counting statistics when average background activities are subtracted from gross analytical results.)

Sample Location	Collection Date	% Water	^{3}H pCi/L	^{241}Am pCi/g	^{137}Cs pCi/g	Total U (µg/g)	^{238}Pu pCi/g	^{239}Pu pCi/g	Total Pu pCi/g
G-43-1	7/25/95	2.19	7200	0.4	0.46	2.95	0.277	0.558	0.835
G-44-2	7/25/95	3.44	5000	0.97	0.42	2.88	0.626	0.942	1.568
G-45-4	7/25/95	3.45	14000	0.74	0.35	2.47	0.964	1.301	2.265
G-45-5	7/25/95	4.18	3600	0.69	0.33	2.25	0.303	0.378	0.681
G-45-6	7/25/95	3.27	105000	0.12	0.08	2.42	0.231	0.151	0.382
G-45-7	7/25/95	5.38	35700	0.63	0.68	3.09	10.700	1.2	11.9
G-46-1	7/25/95	19	1900	0.34	1.1	3.07	7.760	1.06	8.82
G-46-2	7/25/95	3.84	2500	0.92	0.33	2.57	1.971	0.825	2.796
G-47-1	7/25/95	3.22	1300	0.89	0.47	2.39	0.111	2.477	2.588
G-49-1	7/25/95	6.92	1200	0.61	0.14	2.11	0.044	0.342	0.386
G-49-2	7/25/95	5.73	1100	0.42	0.13	2.61	0.022	0.092	0.114
G-50-1	7/25/95	3.47	2600	0.3	0.19	2.93	0.062	0.211	0.273
G-50-2	7/25/95	3.21	1700	0.67	0.03	2.52	0.038	0.048	0.086
G-52-1	7/25/95	1.51	1400	0.9	0.35	2.91	0.014	0.025	0.039
G-52-2	7/25/95	2.01	1160	0.32	0.16	1.97	0.005	0.012	0.017
G-52-3	7/25/95	1.39	1900	0.51	0.37	2.49	0.028	0.035	0.063
G-53-1	7/25/95	6.29	300	0.01	0.5	2.39	0.010	0.02	0.03
G-53-2	7/25/95	5.72	3800	0.49	0.42	2.78	0.019	0.023	0.042
G-54-1	7/25/95	5.56	400	-0.01	0.44	2.7	0.016	0.025	0.041
G-54-2	7/25/95	4.46	600	0.04	0.35	2.95	0.009	0.035	0.044
G-55-1	7/25/95	5.71	300	-0.03	0.11	2.49	0.004	0.015	0.019
G-57-1	7/25/95	4.47	200	0.02	1.63	4.19	0.011	0.093	0.104
G-58-1	7/25/95	3.76	2200	0.01	0.18	2.36	0.025	0.033	0.058
G-59-1	7/25/95	3.23	200	0.02	0.02	3.51	0.004	0.002	0.006
G-60-1	7/25/95	3.41	200	-0.06	0.16	2.92	0.004	0.009	0.013
G-62-1	7/25/95	4.66	-100	0.06	0.66	3	0.008	0.025	0.033
G-64-1	7/25/95	3.76	200	-0.02	0.4	2.85	0.005	0.011	0.016
G-65-2	7/25/95	4.03	0	0	0.17	2.91	0.004	0.01	0.014

(continued)

Table 1 (continued): FY 95 TA-54 Area G (OU 1148) Perimeter Soil Data (Sample locations can be found in Figures 2 through 9. Please note that negative values sometimes result from counting statistics when average background activities are subtracted from gross analytical results.)

	% Water	^{3}H pCi/L	^{241}Am pCi/g	^{137}Cs pCi/g	Total U (µg/g)	^{238}Pu pCi/g	^{239}Pu pCi/g	Total Pu pCi/g
Statistics:								
Mean	3.653	13248	0.202	0.314	2.670	0.539	0.343	0.882
Median	3.425	1850	0.080	0.205	2.620	0.027	0.035	0.081
Std. Dev.	2.605	25270	0.289	0.350	0.575	1.753	0.913	2.126
Max	19.000	105000	0.970	1.630	4.190	10.700	6.290	11.900
Min	0.770	-100	-0.150	0.020	1.600	0.000	0.002	0.003

Table 2: FY 95 TA-54 Area G (OU 1148) Water Fraction Data from Single-Stage Samplers (Sample locations can be found in Figures 2 through 9. Please note that negative values sometimes result from counting statistics when average background activities are subtracted from gross analytical results.)

Sample Location	Sample Date	^3H pCi/L	pH	Conductivity µmhos
G-5-1	5/30/95	-100	7.64	35
G-5-2	5/30/95	-100	7.76	20
G-5-2	7/11/95	0.0	7.69	46
G-6-1	7/18/95	0.0	6.31	25
G-6-1	9/11/95	0.0	7.26	110
G-8-2	5/30/95	-300	7.68	30
G-9-1	6/27/95	-200	6.97	37
G-9-1	7/11/95	-200	6.91	40
G-10-2	5/30/95	0.0	7.68	25
G-11-1	5/30/95	-100	7.28	110
G-12-1	5/30/95	100	7.48	50
G-12-1	7/11/95	-300	6.77	47
G-12-1	7/18/95	300	6.51	5
G-12-2	9/11/95	-100	6.88	100
G-12-3	5/30/95	-200	7.57	30
G-13-1	6/27/95	-200	6.48	139
G-13-1	7/11/95	-600	6.45	113
G-13-2	7/11/95	-300	6.69	81
G-13-2	8/15/95	100	8.38	30
G-13-3	5/30/95	-200	7.58	25
G-13-3	9/11/95	-100	7.14	47
G-13-4	6/27/95	-500	6.69	178
G-13-4	7/11/95	-300	6.61	184
G-13-4	8/15/95	300	7.69	10
G-13-5	6/27/95	200	6.78	200
G-13-5	8/15/95	100	8.31	110

(ANP = analysis not performed)

(continued)

Table 2 (continued): FY 95 TA-54 Area G (OU 1148) Water Fraction Data from Single-Stage Samplers (Sample locations can be found in Figures 2 through 9. Please note that negative values sometimes result from counting statistics when average background activities are subtracted from gross analytical results.)

Sample Location	Sample Date	^3H pCi/L	pH	Conductivity µmhos
G-13-5	9/11/95	0.0	7.79	125
G-13-6	9/11/95	100	6.71	23
G-13-7	6/27/95	-300	6.86	38
G-13-7	9/11/95	100	7.11	65
G-13-8	7/27/95	-200	6.66	150
G-13-8	9/11/95	0.0	7.76	145
G-13-9	9/11/95	200	7.59	140
G-14-1	6/27/95	-200	6.87	132
G-14-1	8/15/95	100	8.25	145
G-15-1	5/30/95	-100	6.81	500
G-15-1	6/27/95	-300	6.93	100
G-15-1	7/11/95	0.0	6.74	121
G-18-2	8/30/95	300	7.75	48
G-19-1	5/30/95	100	7.34	90
G-19-1	7/18/95	100	6.8	39
G-19-2	7/11/95	-400	6.93	24
G-19-2	8/15/95	100	7.38	190
G-21-1	7/11/95	-400	6.67	213
G-21-1	9/11/95	0.0	8.60	75
G-21-2	6/27/95	-200	7.11	101
G-21-2	7/11/95	-300	6.86	120
G-21-2	7/18/95	0.0	8.38	50
G-22-1	5/30/95	-200	7.47	50
G-22-1	9/11/95	-100	7.32	100
G-24-1	5/30/95	-300	7.75	15
G-28-1	9/11/95	500	6.80	32

(ANP = analysis not performed)

(continued)

Table 2 (continued): FY 95 TA-54 Area G (OU 1148) Water Fraction Data from Single-Stage Samplers (Sample locations can be found in Figures 2 through 9. Please note that negative values sometimes result from counting statistics when average background activities are subtracted from gross analytical results.)

Sample Location	Sample Date	^3H pCi/L	pH	Conductivity µmhos
G-28-3	5/30/95	-100	7.64	30
G-28-3	9/11/95	300	6.99	85
G-28-4	8/23/95	700	6.72	54
G-29-2	5/30/95	800	7.66	30
G-29-2	8/15/95	10900	7.25	175
G-30-1	5/30/95	300	7.53	55
G-30-1	8/15/95	1800	7.78	92
G-31-2	8/15/95	2500	7.83	139
G-31-3	7/11/95	300	6.43	203
G-31-3	8/15/95	500	7.81	195
G-31-4	8/23/95	700	6.54	40
G-31-5	8/23/95	1900	6.45	80
G-34-11	7/18/95	200	11.87	10
G-34-1	5/30/95	-100	7.80	10
G-34-2	7/11/95	-200	6.35	60
G-34-2	5/30/95	-200	7.64	30
G-34-3	8/15/95	400	6.85	49
G-34-4	9/11/95	0.0	6.88	47
G-34-6	8/15/95	100	7.00	ANP
G-34-8	7/18/95	200	5.95	30
G-34-8	8/15/95	0.0	7.30	ANP
G-34-10	8/15/95	100	7.20	ANP
G-34-11	8/15/95	200	7.45	ANP
G-34-12	7/18/95	200	6.34	50
G-34-12	8/15/95	100	7.01	ANP
G-36-1	5/30/95	-100	7.36	105

(ANP = analysis not performed)

(continued)

Table 2 (continued): FY 95 TA-54 Area G (OU 1148) Water Fraction Data from Single-Stage Samplers (Sample locations can be found in Figures 2 through 9. Please note that negative values sometimes result from counting statistics when average background activities are subtracted from gross analytical results.)

Sample Location	Sample Date	^3H pCi/L	pH	Conductivity µmhos
G-36-1	6/27/95	-300	7.05	150
G-39-3	8/30/95	400	7.05	58
G-39-4	7/18/95	400	7.42	125
G-39-4	8/30/95	200	7.13	80
G-41-1	7/18/95	200	6.88	241
G-41-3	7/18/95	200	6.55	18
G-41-3	8/22/95	200	7.50	100
G-41-3	7/5/95	-300	6.55	40
G-41-4	7/5/95	-100	6.57	38
G-41-5	8/30/95	300	7.48	32
G-41-5	8/30/95	0.0	7.08	85
G-41-5	7/18/95	400	6.41	29
G-42-2	7/5/95	-100	6.65	23
G-42-3	7/5/95	-400	ANP	30
G-42-5	8/30/95	0.0	7.79	50
G-43-3	8/22/95	300	7.13	52
G-43-4	8/30/95	200	7.39	29
G-44-2	8/22/95	400	7.23	95
G-44-2	7/5/95	-100	5.96	42
G-44-3	8/22/95	500	6.98	55
G-44-4	9/12/95	300	ANP	ANP
G-44-5	9/12/95	300	ANP	ANP
G-44-6	8/15/95	400	6.80	ANP
G-45-2	7/5/95	-200	6.07	51
G-45-2	8/22/95	300	7.33	99
G-45-3	8/15/95	300	7.25	ANP

(ANP = analysis not performed)

(continued)

Table 2 (continued): FY 95 TA-54 Area G (OU 1148) Water Fraction Data from Single-Stage Samplers (Sample locations can be found in Figures 2 through 9. Please note that negative values sometimes result from counting statistics when average background activities are subtracted from gross analytical results.)

Sample Location	Sample Date	^3H pCi/L	pH	Conductivity µmhos
G-46-5	9/12/95	500	ANP	ANP
G-47-2	8/22/95	100	7.09	42
G-47-3	8/15/95	200	7.00	ANP
G-47-3	8/30/95	400	7.60	26
G-48-4	9/12/95	200	ANP	ANP
G-49-2	7/18/95	-100	7.09	150
G-49-2	7/5/95	-100	6.84	195
G-49-3	7/5/95	-100	7.07	171
G-50-1	8/15/95	-100	7.80	13
G-50-3	8/30/95	100	7.04	210
G-51-1	8/22/95	-300	7.20	28
G-51-3	8/22/95	0.0	6.95	42
G-51-4	7/18/95	4500	6.52	50
G-52-5	9/12/95	400	ANP	ANP
G-53-3	8/30/95	0.0	7.24	30
G-54-3	9/12/95	300	ANP	ANP
G-55-2	7/5/95	-200	5.58	25
G-56-1	8/22/95	100	6.77	10
G-56-3	8/22/95	100	6.64	50
G-56-3	7/5/95	-100	6.03	31
G-56-4	8/30/95	400	7.78	13
G-57-3	9/12/95	400	ANP	ANP
G-58-1	8/22/95	100	6.72	40
G-58-2	9/12/95	300	ANP	ANP
G-59-1	8/15/95	-100	7.96	10
G-60-1	9/12/95	-100	ANP	ANP
G-65-1	9/12/95	400	ANP	ANP

(ANP = analysis not performed)

5.2.3 Laboratory Soil-Sample Preparation

Before the CST-9 soil analyses for radionuclides (excepting tritium), the soils were first dried overnight at 100°C and then sieved through a number 12 Tyler sieve to remove large-sized particles and foreign matter (twigs, grass, etc.). When these dried soil (or the sediment-fraction of the single-stage water sample) samples were analyzed for plutonium or uranium, these radionuclides were first extracted from the dried soils by a hot nitric acid/hydrofluoric acid leaching procedure that effectively dissolves the entire sample. Standard CST analytical chemistry procedures were then followed for separating, plating, and counting radionuclides.

For tritium analyses on soils, the soil moisture is distilled from the soil. This soil moisture is analyzed for tritium by scintillation counting.

Before soils were analyzed for metals, they were dried at temperatures between 100 and 150°F for 4–12 hours and, subsequently, milled for one hour in a shaker mill. The soils were then digested before metal analysis according to EPA SW-846 Method 3050 (hot nitric acid digestion).

6.0 EXPANSION AREA BASELINE STUDY

An approximately ten acre site directly west of active Area G has been identified as the location for the development of Waste Management disposal operations. Baseline surface soil and water chemistry data have been collected to define the ambient conditions before any operations are initiated in this area. This baseline data will not only be used in the future to define any impacts from the active operations that will be taking place in this area, but will serve in this study as baseline or local background for comparison to perimeter soil and surface water runoff samples collected during FY 95 in the active part of Area G. A summary of the expansion area analytical chemistry data is found in Table 5. This data is used in box plots presented in Appendix B.

7.0 PERIMETER SOIL-SAMPLE RESULTS FOR CONSTITUENTS OF INTEREST

Figures 3–10 illustrate the distribution of radionuclides in surface soil and storm water runoff samples collected on the perimeter of Area G. A discussion of individual constituents is found below.

7.1 Tritium

The analytical radiochemistry results for the soil and single-stage samples are presented in Tables 1 and 2. Figures 3 and 4 depict the perimeter and expansion area tritium distributions for the soil tritium and single-stage water samples. Appendix B contains box plots depicting the distribution of tritium concentration on surface soils collected around the Area G perimeter in FY 93, 94, and 95 and

compares tritium distributions with data from soil samples collected in the expansion area in FY 94 and 95 (period used to collect samples and establish baseline).

The tritium values for the water samples collected at a particular sampling station, as depicted in Figure 4, may be an average of several measurements if a separate sample was collected after individual storm events.

From the perimeter soil sampling (those samples taken from locations in minor drainages into which sediments are expected to be carried and water to flow during a storm event), it is shown that there is elevated tritium activity in perimeter surface soils collected around the entire active portion of Area G. The tritium concentrations in soils collected in FY 95 are, by-and-large, lower than analogous samples collected in FY 94 and are more similar to samples collected in FY 93 (see box plots comparing relative concentration distributions in Appendix B). Tritium on soil samples collected adjacent to the TRU pads and the tritium disposal shafts are most highly elevated over baseline. In Figure 3, one can see elevated levels of tritium (as high as 105,000 pCi/L) in soil from sampling locations between monuments G-42 and G-51. These locations are along the northern edge of the TRU pads and adjacent to one set of tritium disposal shafts; they extend along the fence line to the west some 600 feet. To the east and south of the TRU pads (between monuments G-34 and G-41), the soil samples also show moderately elevated tritium activity. One isolated soil sample, G-38-02, on the perimeter at the south edge of the TRU pads had a relatively high tritium concentration (15,100 pCi/L). This particular soil sample also had elevated tritium concentrations during the FY 93 and 94 sampling campaigns.

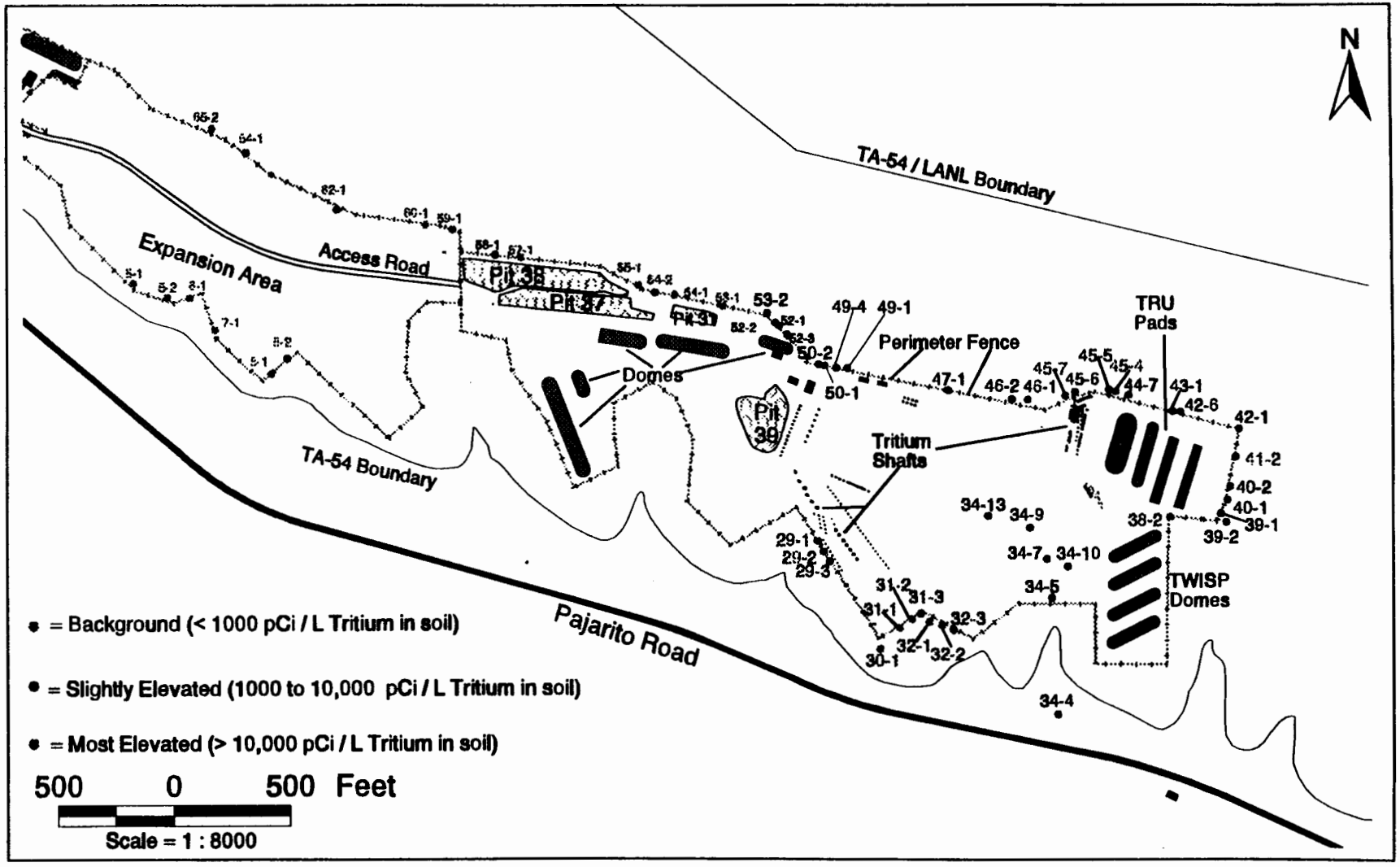

Figure 3: Tritium soil-sample locations and analytical results at Area G. The number is the sample location identification number, and the color represents its tritium concentration range (in picocuries per liter). There are three categories in the tritium concentration range: background (green), slightly elevated (blue), and most elevated (red). All the significant Area G landmarks and features are identified on the figure.

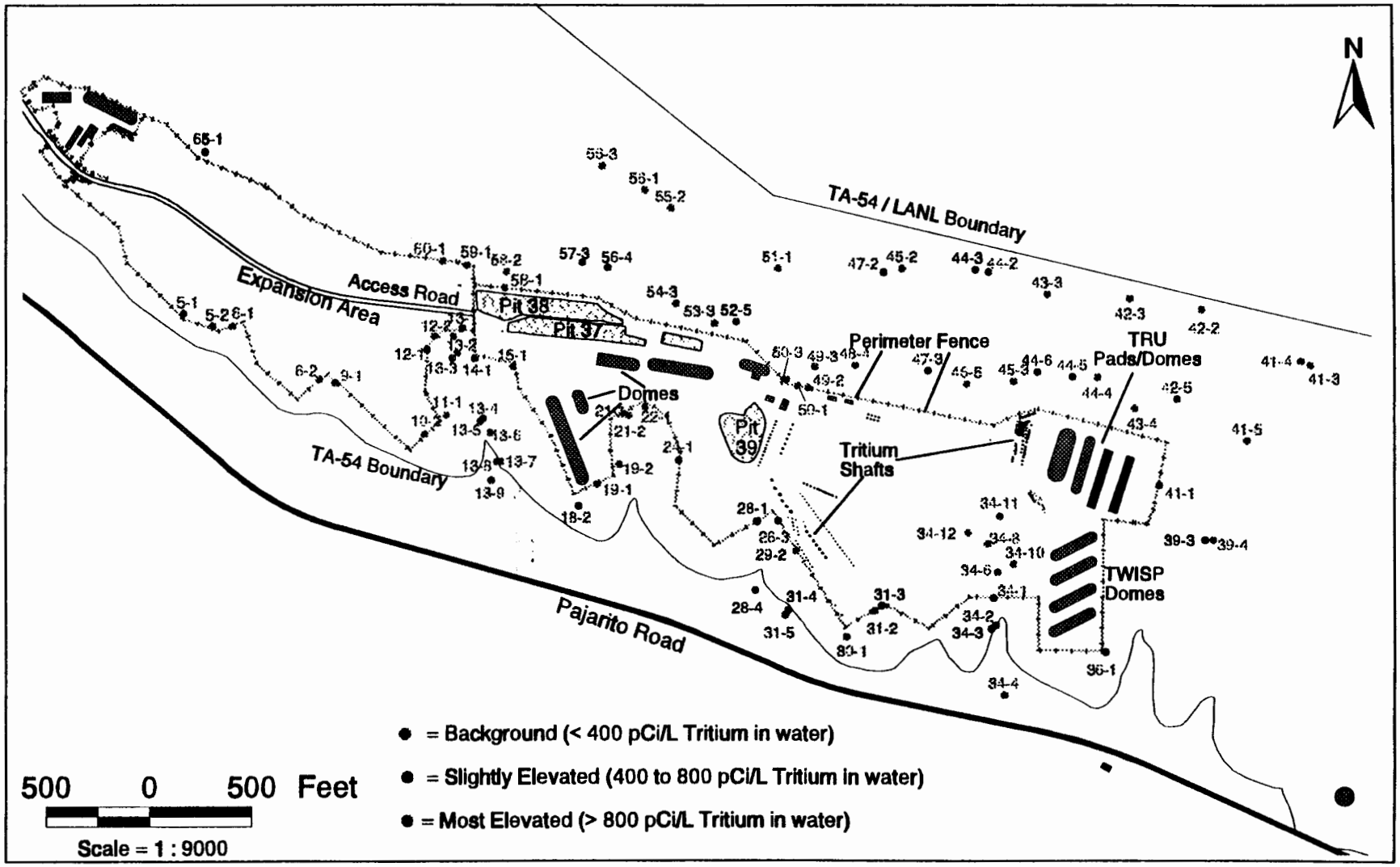

Figure 4: Tritium analytical results for the filtered-water fraction from single-stage samples at Area G. The number is the sample location identification number, and the color represents the tritium concentration range (in picocuries per liter). There are three categories in the tritium concentration range: background (green), slightly elevated (blue), and most elevated (red). All the significant Area G landmarks and features are identified on the figure.

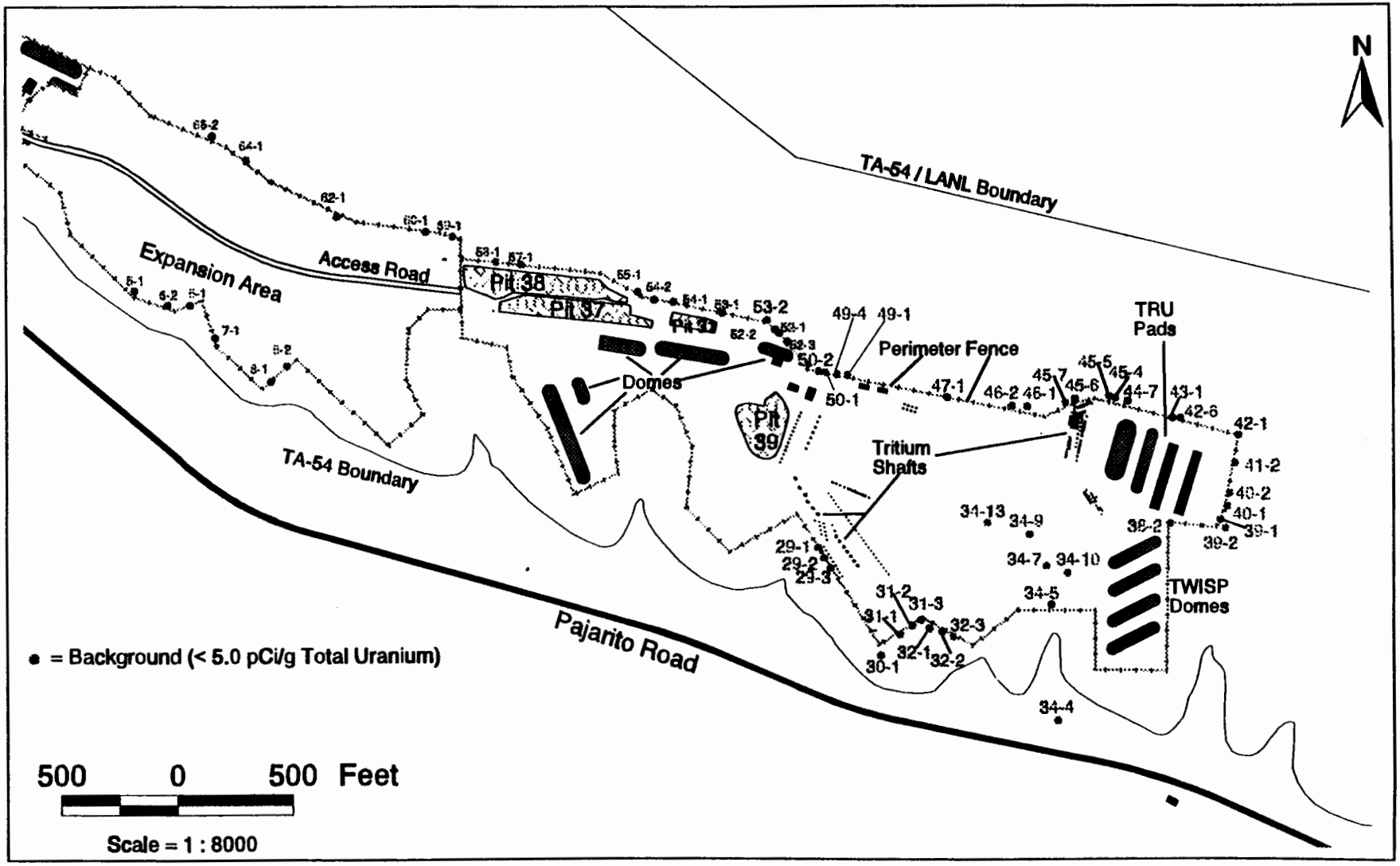

Figure 5: Uranium soil-sample locations and analytical results at Area G. The number is the sample location identification number, and the color represents the uranium concentration range (in micrograms per gram). There are three categories in the uranium concentration range: background (green), slightly elevated (blue), and most elevated (red). The uranium results all fall in the background range. All the significant Area G landmarks and features are identified on the figure.

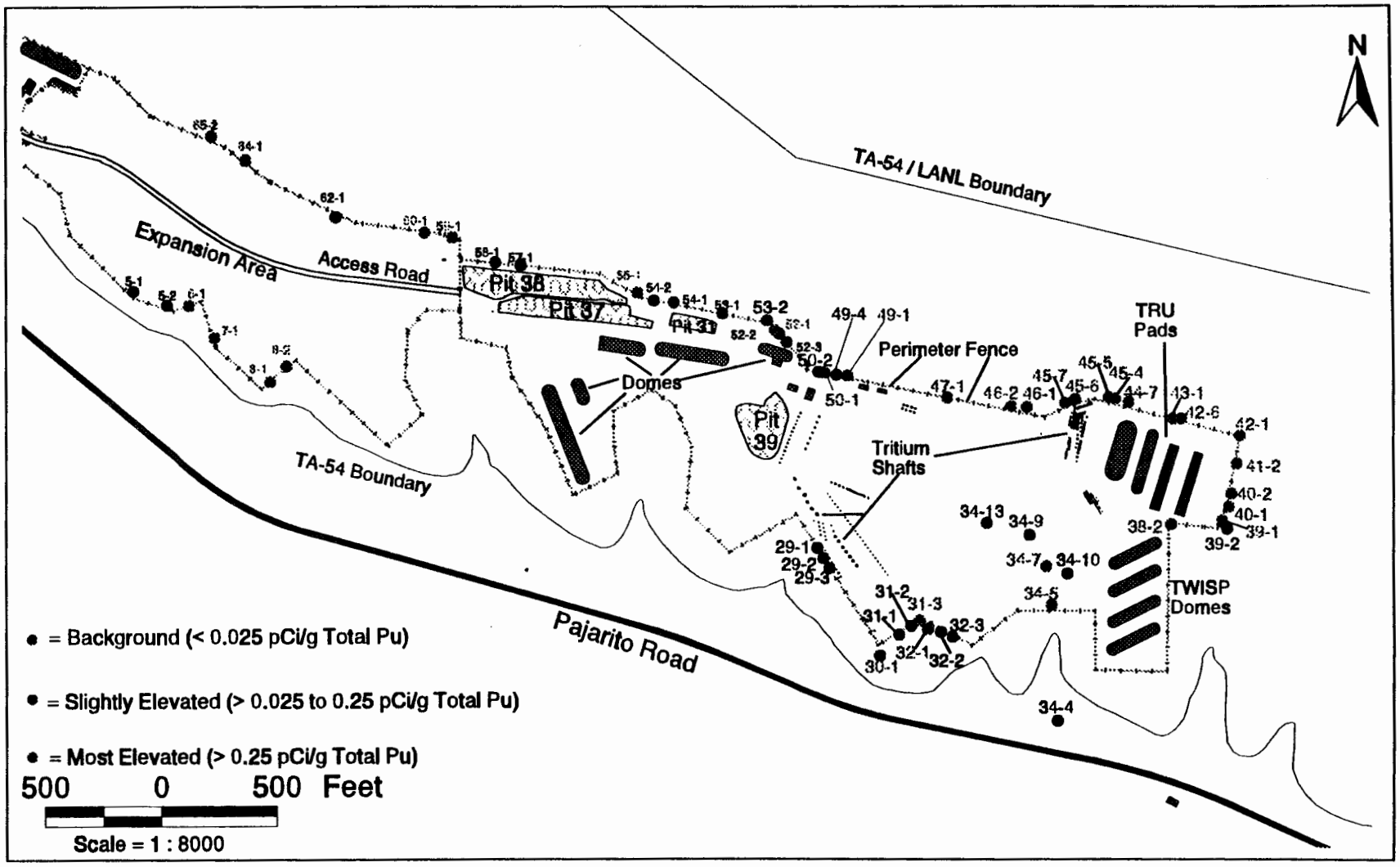

Figure 6: Total isotopic plutonium soil-sample locations and analytical results at Area G. Color coding at each sampling location indicates whether total plutonium in soil from this location was background or below, slightly elevated above background, or most elevated above background. Several Area G landmarks are outlined and labeled for orientation: the perimeter fence line, active pits 37, 38, and 39, the expansion area to the west, and the transuranic waste pads (TRU Pads) and the Transuranic Waste Inspectable Storage Project (TWISP) to the east.

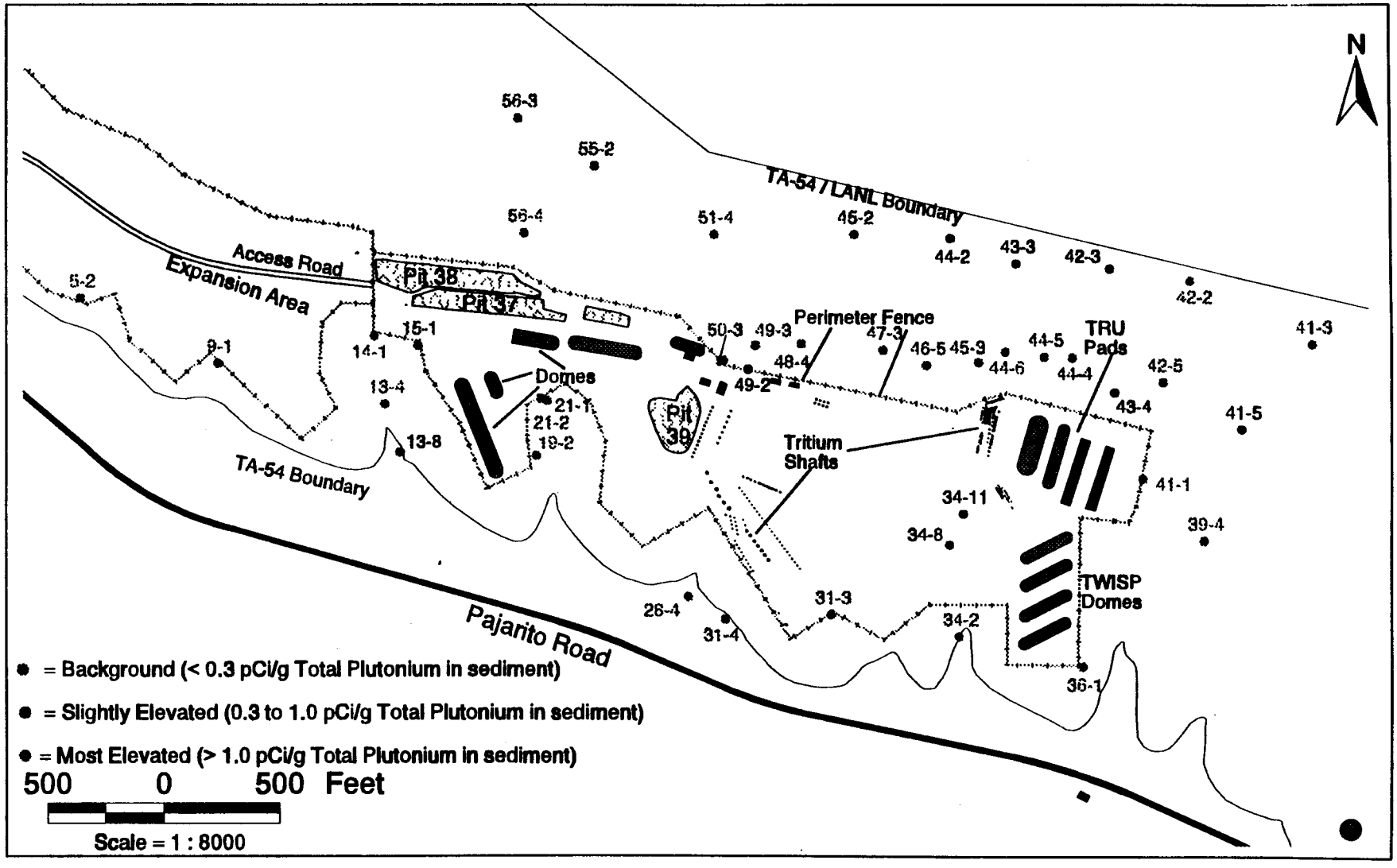

Figure 7: Total isotopic plutonium single-stage sample locations and analytical results for sediment fraction at Area G. The color represents the plutonium concentration range (in pCi/g). There are three categories in in the plutonium concentration range: background (green), slightly elevated (blue), and most elevated (red). All the significant Area G landmarks and features are identified on the figure.

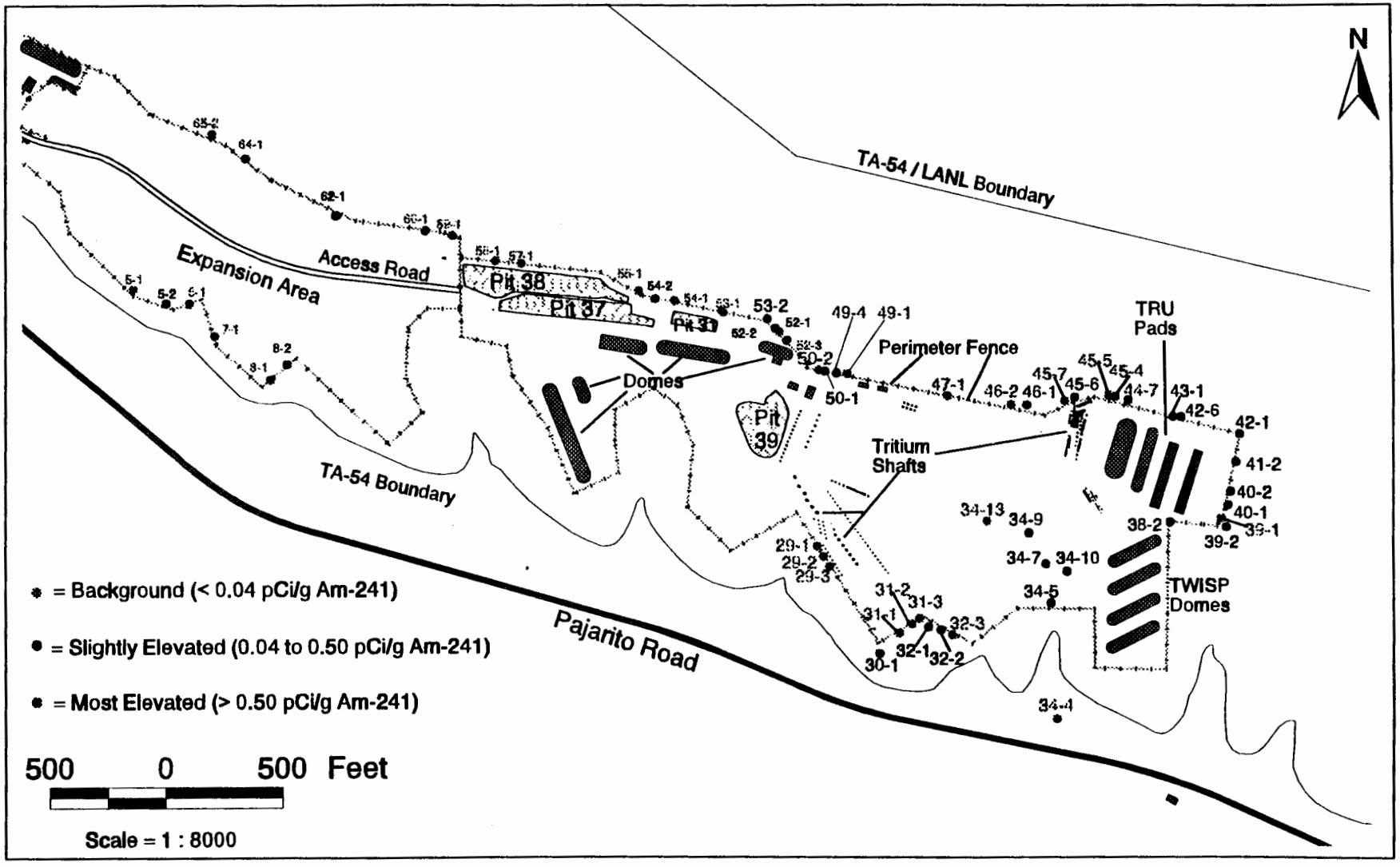

Figure 8: Americium-241 soil-sample locations and analytical results at Area G. The color represents the americium concentration range (in pCi/g). There are three categories in the americium concentration range: background (green), slightly elevated (blue), and most elevated (red). All the significant Area G landmarks and features are identified on the figure.

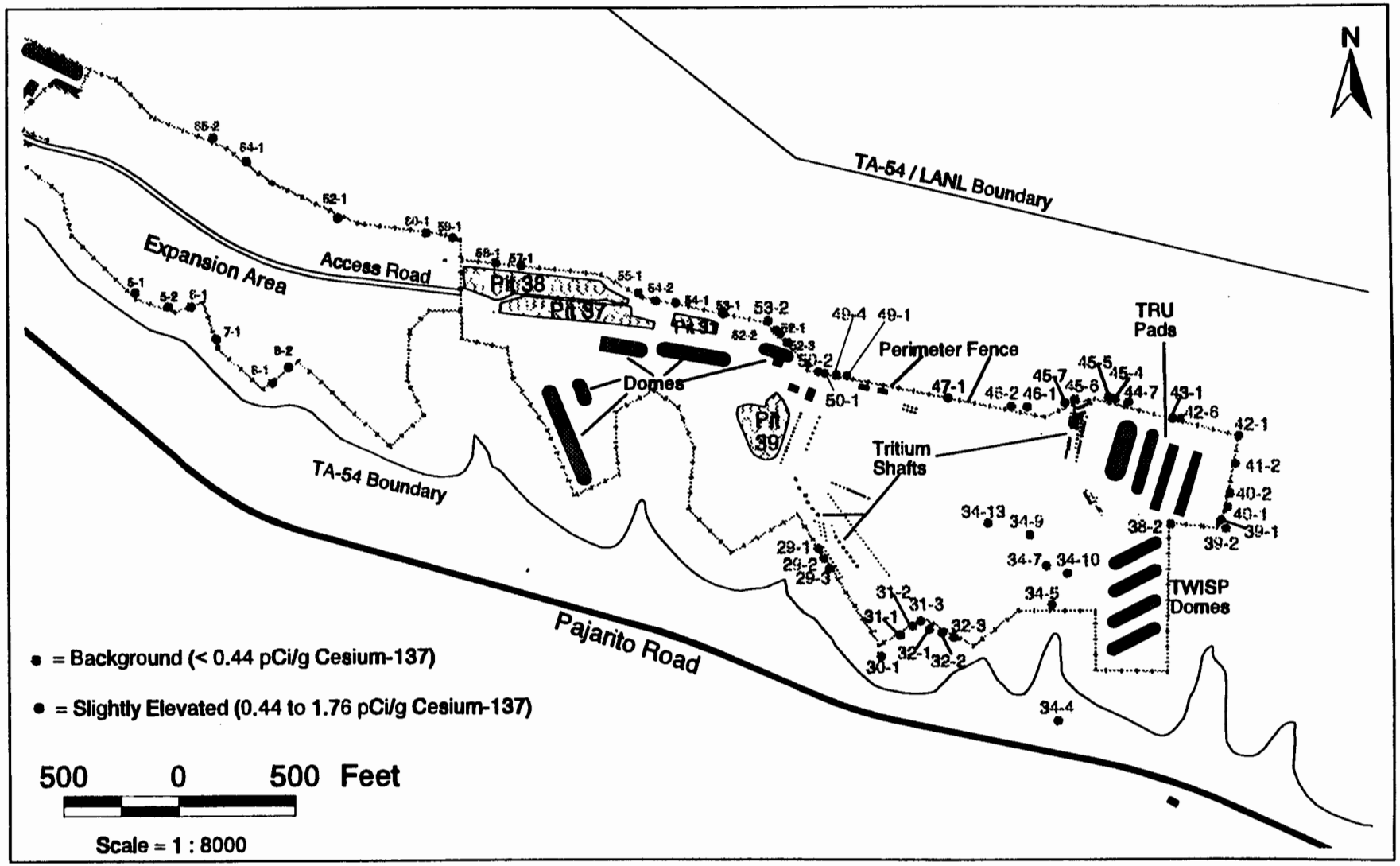

Figure 9: Cesium-137 soil-sample locations and analytical results at Area G. The color represents the cesium concentration range (in pCi/g). There are three categories in cesium concentration range: background (green), slightly elevated (blue), and most elevated (red). All the significant Area G landmarks and features are identified on the figure.

The locale for the most-elevated perimeter soil tritium concentrations in FY 95 is adjacent to a second series of tritium disposal shafts located on the Pajarito Canyon side of Area G and encompasses sample series G-27–32. Soil samples collected from this area in FY 95 had tritium activities as high as 90,500 pCi/L. Figure 10 is a scatter plot depicting the soil tritium concentrations at analogous locations for the years FY 93, 94, and 95. This figure indicates that the localized regions of elevated tritium concentrations on the perimeter of Area G were the same during these years, but tritium concentrations for FY 94 were generally higher than the tritium activities from equivalent samples collected in FY 93 and 95. The significance of year-to-year measured tritium soil concentrations (and runoff water concentrations) will be discussed.

Storm-water runoff (single-stage) samples were also collected in the majority of those locations where perimeter soil samples were taken. We collected 131 water samples by the single-stage-sampler method during FY 95 (at many sampling stations, collections were made on several dates). The analytical chemistry data for these samples are presented in Table 2. Only the water fractions of the single-stage samples were analyzed for tritium. The tritium activity of 76% of the samples ranged from reported values of –600 to 400 pCi/L. Although the detection limit for tritium analyzed by this method is 300 pCi/L, the counting statistics may generate values that are less than the detection limit, and sometimes even negative values may be reported. We consider the activity range of –600 to 400 pCi/L to be the baseline tritium concentration range for surface water runoff at Area G.

Five single-stage water samples collected in FY 95 had tritium concentrations over 1000 pCi/L, and one single-stage water sample (from the tritium shaft area), sample G-29-2, had a tritium activity measured at 10,900 pCi/L. Multiple samples (collected after different storm events) from the same station, especially those collected from the tritium shaft area, illustrate how the tritium concentrations can vary depending on the most recent "weather" extant at Area G (see Table 2). The hypothesis for this variability is discussed by the authors below.

Tritium results for surface soils or single-stage samplers is that they reflect the surface soil environment only at the time of the soil sampling or the storm event (single-stage samples). The ambient conditions at a particular location is one factor that will determine the concentration and availability of tritium at the time a sample is taken. When precipitation falls, soil-surface water interactions are generally limited to the top few inches of surface soils. At that time, tritium concentrations in the surface soil stratum could be altered by the precipitation resulting in

1. entrainment in water of available tritium by water running off of a particular location, or

2. erosion away of tritium-bound sediments.

It is known that on soil, tritium is incorporated into the associated water that is termed "soil moisture." When the laboratory prepares a soil sample for tritium analysis, soil moisture is distilled out of a weighed sample of soil. The tritium measured in the distilled-off water is deemed to represent the tritium content of the soil and is reported as activity per liter of soil moisture. If it had recently rained before the sampling event or if the soil came from a location that was naturally damp (e.g., an area shaded from the sun) or where anthropic activities (such as a water truck spraying on the ground surface) had impacted the soil, this added water to the natural soil moisture would cause a dilution of the tritium concentration on that soil that had a source resulting from disposal of tritium at Area G. Figures 4 and 10 illustrate the manifestation of this hypothesis. In FY 93, 94, and 95, the geographical regions of baseline, slightly elevated, and most elevated tritium concentrations on soils are the same. However, the absolute concentrations of tritium measured on soil during those three years are shown to be generally different.

By minimizing the period of time taken for the collection of all the samples and purposefully collecting samples during dry periods, one can hopefully eliminate most of the local environmental impacts discussed above. Ambient air data collected at Area G indicates a greater flux of tritium is escaping the ground surface during the hotter months of the year. The assumption can be made based on this fact: even the time of day when collection of soils occurs can be a factor in the tritium concentration on soil.

7.2 Uranium

Total uranium analysis data (Table 1) are reported as the mass of uranium present in a soil sample (μg uranium per gram of soil). For the 58 perimeter soil samples analyzed in FY 95, the uranium concentrations ranged from 1.6–4.9 μg/g. The average value for total uranium in perimeter soils was 2.68 ± 0.57 μg/g. The geographic distribution for these soil uranium readings is depicted in Figure 5. The total uranium in perimeter surface soils is similar to data from analogous samples collected in FY 93. The uranium in soil concentrations reported for FY 94 data are biased higher than the soil uranium values reported in FY 93 and 95 (see box plot in Appendix B). One reason for this apparent difference in total uranium concentrations is that the samples analyzed in FY 93 and 95 were done in-house by the KPA method while the FY 94 samples were done by an outside laboratory by the ICPMS method. Obviously, there is a positive bias when measuring total uranium with the ICPMS method with respect to the KPA method.

Uranium concentrations were not analyzed in the sediment or water fractions of the single-stage samples during FY 95 since the analogous data collected during FY 93 illustrated no significant distribution of uranium on the sediment fraction or water fraction collected in the single-stage runoff samples. This, in fact, is to be expected since the perimeter soils on the mesa top that would serve as the source term for sediments (or dissolved uranium) collected in the single-stage sample bottles have no obvious or significant uranium distribution.

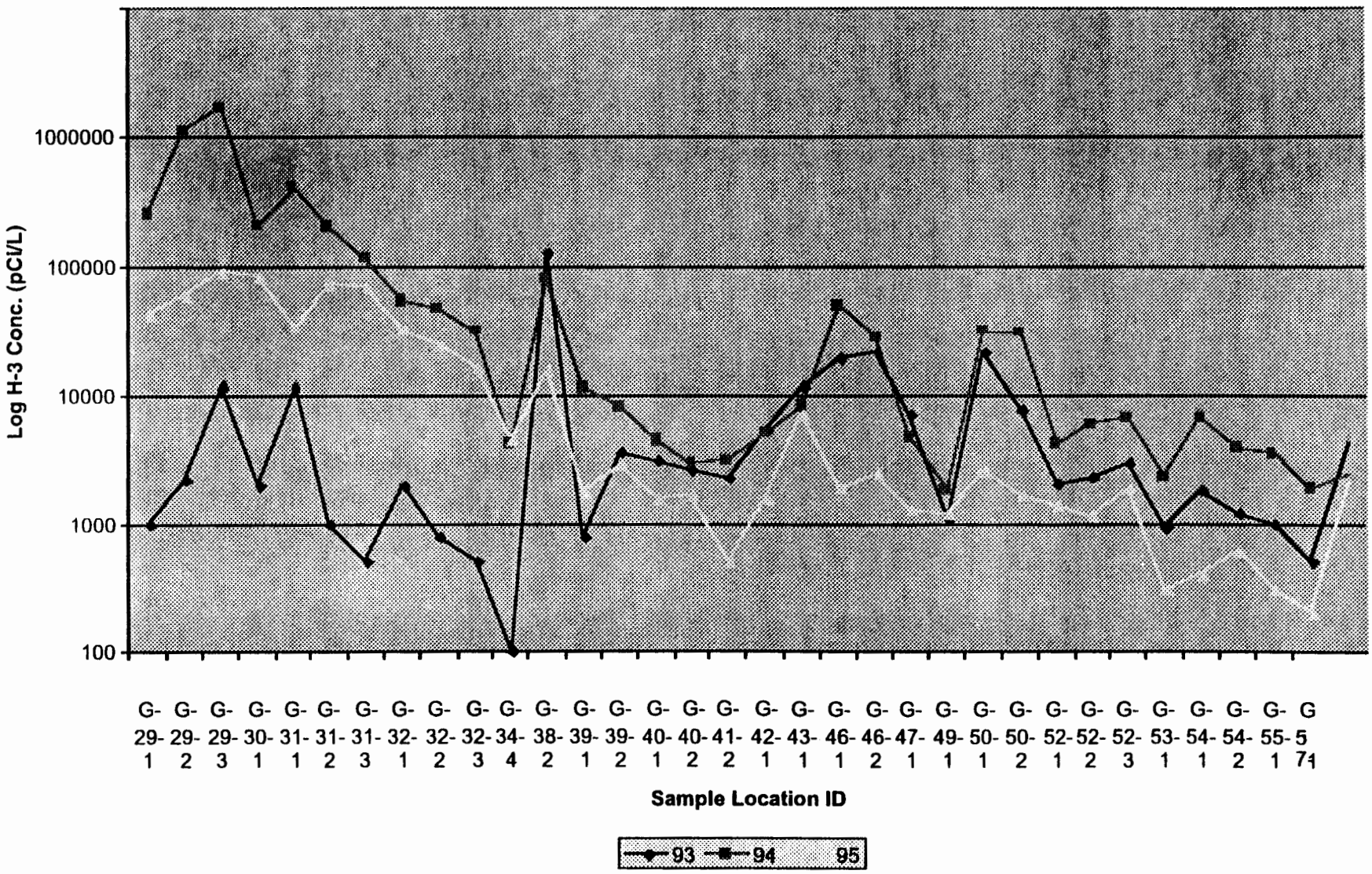

Figure 10: Scatter plot of Area G perimeter soil FY 95 vs. FY 93 and FY 94 soil tritium concentrations.

7.3 Plutonium Isotopes

During the FY 95 perimeter surface soil sampling campaign, 58 perimeter soil samples were analyzed for isotopic plutonium (plutonium-238, -239, and -240). Plutonium-239 and -240 are reported as the sum of the activity of these two isotopes, but hereafter they will be referred to only as plutonium-239. The plutonium soil data are presented in Table 1. The plutonium-238 activities range from 0.0 pCi/g to 10.7 pCi/g. The average plutonium-238 activity is 0.54 ± 1.75 pCi/g. The mean value is far above the median value because several samples have elevated plutonium concentrations and the frequency distribution plot is positively skewed. For plutonium-239, activities range from 0.002–6.29 pCi/g. The mean plutonium-239 activity is 0.343 ± 0.91 pCi/g. The plutonium-239 data is also positively skewed, with the median plutonium-239 value being lower than the mean concentration. For convenience, the sum of the plutonium isotope activity "total" for each sample is also presented in Table 1 (box plots of the total plutonium distribution on perimeter and expansion area surface soils collected in FY 93, 94, and 95 are presented in Appendix B). In Figure 6, total plutonium isotope relative activity in perimeter soils is plotted by location. Figure 6 shows that perimeter surface soils increase slightly in plutonium activity as one moves from the west of Area G (with little or no history of waste disposal or storage activity) to the east (where waste disposal or storage occurred). The highest total plutonium activities are associated with the TRU pads and the vicinity of the lower-numbered inactive disposal pits (location series G-38 to 46), with elevated readings also found to the west of the TRU pads along the northern edge of Area G up through location series G-50. There are other elevated plutonium readings from sites scattered around the perimeter, but these sites are found predominantly in the eastern half of Area G.

The single-stage samples collected during FY 95 were separated into a water fraction and a sediment fraction. Isotopic plutonium analyses were run on the sediment fraction. These data are included in Table 3 and depicted in Figure 7. The locations of single-stage samples where the sediment fractions contain elevated levels of plutonium reflect the areas where soils are also elevated in plutonium—that is, in the vicinity of the TRU pads.

7.4 Americium-241

Americium-241 is normally found with plutonium in soils because it is a direct radioactive decay product of plutonium. Corroboration of plutonium distribution in soils is possible by using the attendant americium-241 analytical results. Table 1 includes the soil americium-241 results, whereas Figure 8 depicts the geographic distribution of the americium-241 readings (box plots depicting the americium-241 distribution in surface soils collected at perimeter and expansion area locations in FY 93, 94, and 95 can be found in Appendix B). The americium-241 values for perimeter soils varied from not detectable to 0.97 pCi/g. The mean americium-241 concentration in soils was 0.20 ± 0.29 pCi/g. An area with elevated americium-241 soil levels was found adjacent to the TRU pads in the area of series G-43 to 52. This location of elevated americium-241 reflects the elevated activities of plutonium in soils reported in section 7.3 (compare Figures 6 and 8).

Table 3: FY 95 TA-54 Area G (OU 1148) sediment fraction data from single-stage samplers. Listed here are the plutonium concentrations in sediment filtered from the single-stage water samples.

Sample Location	Sample Date	^{238}Pu pCi/g	^{239}Pu pCi/g	Total Pu
G-5-2	7/11/95	0.013	0.123	0.136
G-9-1	6/27/95	0.005	0.075	0.08
G-13-4	6/27/95	0.021	0.018	0.039
G-13-8	6/27/95	0.287	0.255	0.542
G-14-1	6/27/95	0.016	0.037	0.053
G-15-1	6/27/95	0.014	0.032	0.046
G-19-2	7/11/95	0.028	0.059	0.087
G-21-1	7/11/95	0.026	0.055	0.081
G-21-2	6/27/95	0.009	0.019	0.028
G-28-4	8/23/95	0.004	0.006	0.01
G-31-3	7/11/95	0.034	0.078	0.112
G-31-4	8/23/95	0.024	0.109	0.133
G-34-2	7/11/95	0.024	0.079	0.103
G-34-8	8/16/95	0.055	0.504	0.559
G-34-11	7/18/95	0.003	0.290	0.293
G-34-11	8/16/95	0.028	0.351	0.379
G-36-1	6/27/95	0.028	0.075	0.103
G-39-4	8/30/95	3.786	0.259	4.045
G-41-1	7/18/95	9.406	2.130	11.536
G-41-3	7/5/95	0.067	0.047	0.114
G-41-3	7/18/95	0.047	0.037	0.084
G-41-3	8/22/95	0.022	0.024	0.046
G-41-5	7/18/95	0.430	0.523	0.953
G-41-5	8/30/95	0.614	0.396	1.01
G-42-2	7/5/95	0.060	0.017	0.077
G-42-3	7/5/95	0.260	0.140	0.4
G-42-5	8/30/95	0.645	0.408	1.053
G-43-3	8/22/95	0.729	0.214	0.943

(continued)

Table 3 (continued): FY 95 TA-54 Area G (OU 1148) sediment fraction data from single-stage samplers. Listed here are the plutonium concentrations in sediment filtered from the single-stage water samples.

Sample Location	Sample Date	^{238}Pu pCi/g	^{239}Pu pCi/g	Total Pu
G-43-4	8/30/95	0.314	0.629	0.943
G-44-2	7/5/95	0.348	0.024	0.372
G-44-4	9/12/95	0.466	0.600	1.066
G-44-5	9/12/95	0.811	0.623	1.434
G-44-6	8/16/95	2.860	0.901	3.761
G-45-2	7/5/95	0.039	0.051	0.09
G-45-3	8/16/95	1.340	0.288	1.628
G-46-5	9/12/95	1.043	1.308	2.351
G-47-3	8/30/95	6.547	0.978	7.525
G-48-4	9/12/95	0.640	0.817	1.457
G-49-2	7/5/95	0.055	0.262	0.317
G-49-2	7/18/95	0.063	0.296	0.359
G-49-3	7/5/95	0.046	0.195	0.241
G-50-3	8/30/95	0.071	0.148	0.219
G-51-4	7/18/95	0.015	0.033	0.048
G-55-2	7/5/95	0.007	0.016	0.023
G-56-3	7/5/95	0.040	0.055	0.095
G-56-4	8/30/95	0.018	0.036	0.054

7.5 Cesium-137

Cesium-137 is another isotope of interest at Area G. All perimeter soils collected were analyzed by gamma spectroscopy for cesium-137, and these data are found in Table 1. Figure 9 illustrates a fairly even distribution of cesium-137 in perimeter surface soils at Area G. Cesium-137 activities in soils range from 0.02 pCi/g to 1.76 pCi/g, with an average concentration in soils of 0.31 ± 0.35 pCi/g.

7.6 Metals

Because little analytical data are available on RCRA-regulated metals in Area G surface soils, we continued a program begun in FY 94 for collection of soil samples for analysis of metals. In FY 95, ten RCRA metals were analyzed on six soil samples collected from the perimeter of Area G. We submitted these six soil samples for EPA SW-846 Method 3050 extraction and metal analyses of Ag, As, Ba, Be, Cd, Cr, Hg, Ni, Pb, and Sb. One change in the particular metals analyzed in FY 95 was the

analysis of antimony (Sb) instead of selenium (Se). Table 4 summarizes the soil metal data. There is no apparent contamination of Area G perimeter surface soils by any of the metals analyzed. Included in the summary table are the mean, median, and standard deviation from the mean for the metals Ba, Cr and Pb. These are the three metals that were analyzed that yielded enough "nondetect" data points to calculate basic statistical parameters. Box plots comparing concentration distributions of these three metals on FY 94 and 95 perimeter soils, as well as soils from the expansion area, are presented in Appendix B of this report.

Table 4: FY 95 TA-54 Area G (OU 1148) Perimeter Soil Metal Results

Sample Location	Collection Date	Ag (µg/g)	As (µg/g)	Ba (µg/g)	Be (µg/g)	Cd (µg/g)	Cr (µg/g)	Hg (µg/g)	Ni (µg/g)	Pb (µg/g)	Sb (µg/g)
G-29-3	7/25/95	5.5	2	53	0.54	<.4	5.6	0.05	<2	8	<.3
G-38-2	7/25/95	<4	2	77	0.53	<.4	6.6	0.04	2.2	9	<.3
G-43-1	7/25/95	<4	2	44	0.38	<.4	4.7	0.05	<2	7	<.3
G-44-2	7/25/95	<4	3	74	0.67	<.4	9.3	0.05	<5	8	<.3
G-45-5	7/25/95	<4	3	70	0.56	<.4	7.7	0.06	<5	10	<.3
G-46-1	7/25/95	4.2	2	47	0.35	<.4	8.6	0.05	<2	9	<.3

8.0 STATISTICAL CONSIDERATIONS

Independent perimeter surface soil data sets are now available for FY 93, 94, and 95 and the Area G expansion area. It is appropriate to compare this information. The comparisons we choose to make are

1. whether the FY 95 Area G perimeter soil chemistry data continue to be statistically different from the expansion area baseline data; and

2. whether the perimeter soil chemistry data collected in FY 94 and 95 are statistically different from the analogous data collected in FY 93 (considered the baseline year for the perimeter soil samples).

It is expected that the soil data for several constituents (in particular, tritium, plutonium, and americium-241) for the perimeter G samples can be shown to be statistically different (that is, constituents will have higher average concentrations) than the soil data collected from the expansion area where disposal operations have not occurred.

On the other hand, a more difficult question is determining whether, for example, the plutonium activity in perimeter soils at Area G is increasing (or decreasing) from year to year. Because concentration changes from year to year are expected to be small, one can use statistical techniques to assist in determining whether there truly are concentration changes of constituents on soil from one year to the next.

In Appendix B, the analytical chemistry data is summarized in box plots to assist in making the two types of comparisons discussed above. The first comparison is to look at the constituents measured on perimeter soils and compare these concentrations with constituent concentrations measured on soil samples collected in the proposed Area G expansion area (defined as background). Surface soil and single-stage water samples were collected in this expansion area during FY 94 and 95.

The second type of statistical assessment is done by comparing the constituent concentrations for FY 94 and 95 with constituent concentrations for FY 93 from analogous locations (for example, by comparing tritium concentrations on soils collected in FY 94 and 95 to tritium concentrations on soils collected in FY 93).

Box plots are used to depict all of the following distributions and to assist in comparing the different data sets. Box plots give information on the median, interquartile range, and skewness; all of which help determine whether a distribution is normal. By placing the box plots on the same scale and in the same figure, we have an immediate impression of the differences and similarities of the distributions we are attempting to compare.

9.0 CONCLUSIONS

In the following paragraphs, the results of the FY 95 perimeter soil and water sampling performed at Area G are discussed.

9.1 Tritium

Tritium has unique chemical properties that distinguish it from most radionuclides. As an isotope of hydrogen, tritium can exchange with the normal hydrogen atoms in compounds such as water. From information gathered at many facilities where tritium is stored, including LANL, we know that tritium can migrate some distance from its place of disposal. Tritium in the surface soils at Los Alamos has a wide distribution resulting from both fallout and Laboratory activities. Disposal of hundreds of thousands of curies of tritium in a series of pits, shafts, or pads occurred at Area G since this facility opened in 1957. A relatively unstable isotope, tritium has a half-life of 12.26 years, during which time half of the tritium transmutes into helium by emitting a low-energy beta particle.

An important question that needs to be addressed is that of the relationship between the tritium found in annual surface soil and water-runoff samples and the true distribution of tritium at the site. One long-term goal of this study is to better define the actual tritium distribution in surface soils (and possibly in the subsurface) at Area G by gathering these tritium concentration data over a period of years.

Except for inadvertent discharges of tritium to the ground surface, the major sources of surface tritium at Area G are tritium contaminated materials that have been disposed of (buried or emplaced) in one or another of the many shafts, pits, and pads at the site. We expect the probability of finding tritium on surface soils at elevated levels to be greatest in the proximity of these sources. Because ground disposal or storage of waste entails subsequent covering by natural tuffaceous material, one important question is, by what pathway does subsurface tritium migrate to the surface, so that it resides in soils and ultimately could be carried off-site? We have postulated two primary mechanisms for tritium transport to the surface: vapor-phase migration and capillary action. Secondary mechanisms would be evapotranspiration, transport to the surface via vegetative growth or burrowing animals, and anthropic activities such as excavation of tritium-contaminated soils, tuff, or waste.

Tritiated water (or other tritiated compounds with elevated vapor pressures) can migrate in the vapor phase from the subsurface to the surface. Upon reaching the surface layer of soils, the question is, does tritium simply vent into the atmosphere or is there a mechanism for it to attenuate with surface soils? Because tritium *is* found on surface soils, there must exist a viable mechanism for attenuation. The only obvious mechanisms for tritiated water vapor migrating upward (or laterally) to attenuate to surface soil sediments are condensation on the surface particles when encountering cooler temperatures (e.g., at night) and/or the tendency of very dry or salt-containing surface soils to temporarily absorb this water vapor.

A second pathway by which tritium could arrive at the surface (and have some residence time) would be capillary action. Capillary action is the phenomenon by which a liquid rises in a tube (or a network of "tubes," as in packed soil) because of the difference in surface tension between the water molecules themselves and between the water molecules and the surface of the tube (or packed soil particles). Unlike water transported via the vapor phase, water transported by capillary action can also carry dissolved compounds. Thus, nonvapor phase tritium that exists as a dissolved chemical species can also migrate upwards to surface soils by capillary action.

By either of these two mechanisms—vapor-phase transport or capillary action—tritium could move from subsurface soils to surface soils. Tritium's residence time in surface soils is unknown because we do not know how the tritium migration rates from subsurface to surface soils compare to the rates of tritium removal from the surface by evaporation or by other mechanisms. We do know from tritium flux studies (where water vapor escaping from the ground surface is captured on silica gel and the

tritium in the water measured) that tritium is escaping in the vapor phase from the ground surface. We also know that more tritium escapes the surface during the hotter months. In addition to evaporation, the mechanisms by which tritium can be removed from surface soils are

1. exchange and runoff with surface water,

2. percolation back into the subsurface after a storm event,

3. air dispersion of surface soil particles (containing tritium) during periods of high winds,

4. evapotranspiration of tritium-containing water by vegetation, and

5. removal of tritium containing materials by human or animal intervention.

These tritium dispersal mechanisms are important because the actual date and time a sample is taken (and concomitant measured tritium concentration) may be impacted by localized environmental effects. For example, during long dry periods one would expect the movement of tritium on subsurface soils to be from the subsurface to the surface, and ultimately away from the surface by one of the mechanisms mentioned above. If soil sampling occurred after a long dry period, the question is, would the tritium in the soil be higher or lower than the average value that would be found for that sampling point if samples were taken every day of the year? ESH-17 ambient air data indicates that tritium escapes the surface more readily during the hot months of the year. Or if soil samples were taken the day after a precipation event, would a lower than representative tritium concentration be expected because some of the tritiated surface sediments were carried off by surface water runoff or because the tritium in the soil moisture was diluted by the rain water? These are difficult questions that may only be answered after many years of quality surface soil sampling.

After three years of systematic soil sampling at Area G, we begin to see a pattern in the distribution of tritium in perimeter soils. By observing the maps of Area G tritium concentrations on soil and surface water runoff (Figures 3 and 4), it is evident from the FY 95 data that there are specific regions of Area G where tritium concentrations are particularly elevated. These regions are predominantly in the area adjacent to the TRU pads (between MDA stations G-42 and 51) and the tritium storage shafts (between MDA stations G-28 and 31). These tritium data, in fact, mirror the soil tritium data collected at the same locations in FY 93 and 94. By observing the scatter plot in Figure 10, one can see that although the absolute tritium concentrations on soil collected in FY 95 vary somewhat from the data for samples collected in FY 93 and 94, the areas of high, medium, and low tritium concentrations on surface soils are similar for the two years. This indicates that the mechanisms (and sources) supplying tritium to the surface soils are rather constant from year to year, and only the local environment affects the absolute concentrations of tritium on the surface soils.

An additional piece of data that supplements the soil and surface water information we collected at Area G is supplied by vegetation sampling done at several Area G locations. Fresquez et al., 1995, found elevated levels of tritium in vegetation collected at just those two locations of Area G where surface soils were most highly elevated in tritium—north of the TRU pads and west of the tritium shafts. Also, Fresquez found that vegetation collected from around Area G was generally elevated in radionuclide concentrations above analogous vegetation sample radioactive concentrations considered to be background.

By observing the box plots in Appendix B for the tritium distribution in soils collected in FY 93–95, it is apparent that the tritium distributions in perimeter soils are different from and higher than the distribution of tritium in soils from the expansion area. This result was expected. The possible difference in the distributions of tritium (slightly higher in the FY 94 soils) in the soils collected have been explained above.

Unless more is learned about the surface tritium, a sample taken at a particular moment can only provide a snapshot of the tritium surface concentration in soil at that particular time.

The flux effect or dependence on localized moisture content on soils may be minimized by taking all samples during a one or two day sampling period since, in this case, each sampling location would be subjected to similar atmospheric conditions. A narrow time window sampling strategy would at least serve as a control for the seasonal and daily changes in the rate at which tritium is removed from the surface. This surface sampling approach will be adopted in future years.

As sampling for tritium continues on a year-to-year basis, the true or representative distribution of soil tritium throughout Area G should become more apparent. With more surface tritium sample data in hand, the overall distribution of surface tritium at Area G should be established so that a determination can be made as to whether it is possible to define true annual increases or decreases in tritium activity in surface soils and runoff water.

9.2 Uranium

There in no apparent unnatural distribution of uranium in Area G perimeter soils indicating little or no impact from disposal or storage operations on uranium concentrations in surface soils. The mean concentration of uranium in FY 95 soil samples is 2.67 ± 0.57. The uranium concentration in the FY 95 expansion area background soils is 2.80 ± 0.40 μg/g. As in previous years, the analytical results from FY 95 indicate no increased levels of uranium in perimeter soils at Area G. The box plot in Appendix B that compares FY 93, 94, 95 and the background uranium data also supports this conclusion. As previously mentioned, in FY 94 total uranium was analyzed by ICPMS, and this data was biased high compared to total uranium concentrations generated by the KPA method.

9.3 Plutonium Isotopes

As stated in Section 7.3, the locations of elevated plutonium readings are consistent with the history of plutonium disposal at Area G. Figure 2 indicates that the lower-numbered, or older pits (1–24), all the disposal shafts, and the TRU pads are located in the eastern half of Area G. We assume that increased levels of contaminant concentrations in surface soils are directly related to the location, quantity, and date when material was disposed of in disposal units. That is, there is a greater probability of finding a contaminant adjacent to a disposal unit where large amounts of contaminants have been emplaced. Also, the longer a contaminant is held in a specific location, the higher the probability that this contaminant will be disseminated to its immediate surroundings. In fact, we find the highest plutonium activities in soils at the eastern end of Area G, especially adjacent to the TRU pads and inactive disposal pits 2–10.

We also observe a geographic correlation between elevated plutonium levels in perimeter soils and elevated levels of plutonium in the sediment fractions of the water samples. Figure 7 (plutonium levels in perimeter soils) and Figure 8 (plutonium levels in single-stage sample sediments) show that the area adjacent to the TRU pads and inactive disposal pits 2–10 have the highest plutonium levels for both surface soil and single-stage sediment fraction samples.

In Appendix B, box plots are presented that depict the distributions of the total plutonium concentrations in surface soil samples collected in FY 93, FY 94, and FY 95, as well as the comparable data for samples collected from the baseline expansion area. The box plots show the similarities of the FY 93, FY 94, and FY 95 total plutonium distributions and indicate that the distributions from all three years have higher concentrations and a wider distribution than the total plutonium in samples from the expansion area.

9.4 Americium-241

As stated in Section 7.4, the tendency is to find elevated americium-241 levels in perimeter surface soil samples where there are elevated levels of plutonium isotopes. This trend is generally illustrated by comparing the data depicted in Figures 6 and 8. The box plots for the Am-241 distributions found in Appendix B indicate there is little statistical difference between the FY 95, FY 94, and FY 93 Am-241 data. The box plots do indicate that the americium-241 concentrations in soils collected from the active part of Area G in all three years are statistically different (greater) from the americium-241 concentrations in soil collected from the expansion area.

9.5 Cesium-137

The FY 95 distribution of Cs-137 in perimeter soils is similar to that found in FY 93 and FY 94. There are no locales along the Area G perimeter where Cs-137 is found in soils in significantly elevated concentrations. The range and mean of Cs-137 concentrations in perimeter soils are very similar to the expansion area Cs-137 range and mean.

9.6 Metals

The analytical chemistry results for soil metals (see Table 4) from FY 95 sampling (6 samples collected for metals analysis) when compared with the soil metals concentrations from the expansion area found in Table 5 indicate that there is very little or no impact on metal surface soil concentrations due to disposal or storage operations in the active part of Area G. Box plots were constructed for the three metals (barium, chromium, and lead) where there were enough values reported to yield a meaningful distribution. Values for the other metals were generally below detection limits. These box plots indicate similar distributions and metals concentrations for FY 94 and 95, and the expansion area soil samples.

Table 5: FY 1994 and 1995 TA-54 Area G (OU 1148) Expansion Area (Baseline/Background) Soil Data

FY 1994 Data

Sample Location	Collection Date	Ag µg/g	As µg/g	Ba µg/g	Be µg/g	Cd µg/g	Cr µg/g	Hg µg/g	Ni µg/g	Pb µg/g	Sb µg/g	Se µg/g	Tl µg/g	% Water	^{3}H pCi/L	^{241}Am pCi/g	^{137}Cs pCi/g	^{234}U pCi/g	^{235}U pCi/g	^{238}U pCi/g	^{238}Pu pCi/g	^{239}Pu pCi/g	Total Pu pCi/g
G-X-6	7/29/94	<.69	2.9	159	1.2	<.52	8.1	<.02	<8.6	13	<.23	<.69	<.23	14.7	420	0.007	<.01	1.42	0.08	1.42	0.009	0.013	0.022
G-X-8	7/29/94	<.72	<2.2	65.8	<.54	<.43	4	<.02	<4.3	15	<.24	<.72	<.24	16.9	320	0.016	0.99	1.27	0.07	1.43	0.005	0.036	0.041
G-X-8R	7/29/94	<.7	<2.1	95.8	<.6	<.23	5.1	<.02	<4.4	14	<.23	<.7	<.23	17.9	300	0.014	1.01	1.79	0.08	1.88	0.005	0.043	0.048
G-X-9	7/29/94	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	13.4	120	0.008	0.64	1.43	0.1	1.43	0.002	0.023	0.025
G-X-10	7/29/94	<.71	<2.1	80.3	<.63	<.24	6.2	<.02	<5.7	11	<.24	<.71	<.24	15.1	710	0.007	<.16	1.36	0.04	1.54	0.007	0.019	0.026
G-X-12	7/29/94	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	11.2	370	0.014	1.2	1.38	0.06	1.52	0.003	0.051	0.054
G-X-13	7/29/94	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	12.7	280	0.008	<.16	1.23	0.07	1.39	0.002	0.009	0.011
G-X-16	7/29/94	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	15.6	260	0.015	0.62	1.55	0.08	1.58	0.002	0.042	0.044
G-X-19	7/29/94	<.66	<1.9	56.8	<.45	<.44	3.8	<.02	<2.6	9.9	<.22	<.66	<.22	8.7	260	0.008	0.34	1.06	0.05	1.11	0.002	0.012	0.014
G-X-21	7/29/94	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	9.7	250	0.008	0.32	1.18	0.06	1.38	0.001	0.016	0.017
G-X-24	7/29/94	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	12.1	380	0.027	<.23	2.02	0.09	1.91	0.005	0.149	0.154
G-X-26	7/29/94	<.67	2.2	67.1	<.56	<.34	4.5	<.02	<3.7	13	<.22	<.67	<.22	13	630	0.016	1.8	1.65	0.11	1.63	0.005	0.047	0.052
G-X-27	7/29/94	<.67	<2	85.1	<.5	<.22	4.7	<.02	<3.3	10	<.22	<.67	<.22	13.5	280	0.011	0.85	1.39	0.09	1.4	0.004	0.03	0.034
G-X-28	7/29/94	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	10.9	180	0.005	<.17	1.2	0.06	1.24	0.001	0.01	0.011
G-X-30	7/29/94	<.65	2.2	133	<.4	<.22	4.7	<.02	<4.2	11	<.22	<.65	<.22	9.6	350	0.008	0.62	1.57	0.12	1.51	0.002	0.025	0.027
G-X-33	7/29/94	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	11.5	340	0.014	1.32	1.7	0.04	1.78	0.004	0.054	0.058
G-X-37	7/29/94	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	7.6	510	0.007	0.47	1.25	0.07	1.23	0.002	0.023	0.025
G-X-38	7/29/94	<.62	2.2	62.2	<.75	<.52	7.2	<.02	<7.9	16	<.21	<.62	<.21	4.5	580	0.02	0.76	1.36	0.05	1.41	0.009	0.042	0.051
G-X-38R	7/29/94	<.62	4.8	136	<.68	<.53	7.4	<.02	<7.2	15	<.21	<.62	<.21	4.5	490	0.021	0.97	1.39	0.06	1.47	0.007	0.053	0.06
G-X-39	7/29/94	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	11.2	310	0.005	0.14	1.09	0.06	1.27	0.002	0.014	0.016

(ANP = Analysis not performed)

(continued)

Table 5 (continued): FY 1994 and 1995 TA-54 Area G (OU 1148) Expansion Area (Baseline/Background) Soil Data

FY 1994 Data (cont.)

Sample Location	Collection Date	Ag µg/g	As µg/g	Ba µg/g	Be µg/g	Cd µg/g	Cr µg/g	Hg µg/g	Ni µg/g	Pb µg/g	Sb µg/g	Se µg/g	Tl µg/g	% Water	^{3}H pCi/L	^{241}Am pCi/g	^{137}Cs pCi/g	^{234}U pCi/g	^{235}U pCi/g	^{238}U pCi/g	^{238}Pu pCi/g	^{239}Pu pCi/g	Total Pu pCi/g
G-X-43	7/29/94	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	12.1	280	0.005	<.17	1.63	0.1	1.8	0.004	0.012	0.016
G-X-44	7/29/94	<.63	3	261	<.85	<.59	7.5	<.02	<8.3	11	<.21	<.63	<.21	10.2	440	0.002	<.17	1.17	0.04	1.23	0.001	0.008	0.009
G-X-45	7/29/94	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	15	150	0.005	<.11	1.16	0.06	1.1	0.003	0.005	0.008
G-X-48	7/29/94	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	14.8	560	0.005	<.15	1.35	0.08	1.42	0.003	0.01	0.013
G-X-50	7/29/94	<.63	2.7	76.6	<.42	<.59	5.7	<.02	<3.5	19	<.21	<.63	<.21	4.4	450	0.008	<.15	1.75	0.09	1.77	0.004	0.017	0.021
G-X-51	7/29/94	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	10.7	410	0.003	<.16	1.06	0.06	1.23	0.001	0.001	0.002
G-X-53	7/29/94	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	12.5	280	0.011	<.15	1.01	0.04	0.94	0.003	0.028	0.031

FY 1995 Data

Sample Location	Collection Date	Ag µg/g	As µg/g	Ba µg/g	Be µg/g	Cd µg/g	Cr µg/g	Hg µg/g	Ni µg/g	Pb µg/g	Sb µg/g	Se µg/g	Tl µg/g	% Water	^{3}H pCi/L	^{241}Am pCi/g	^{137}Cs pCi/g	Total Uranium µg/g	^{238}Pu pCi/g	^{239}Pu pCi/g	Total Pu pCi/g
G-X-1	6/1/95	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	8.04	-100	ANP	ANP	2.54	0.004	0.011	0.015
G-X-2	6/1/95	<1	2	61	0.61	<.4	4.3	0.03	<2	7.37	<.25	<.3	<.25	11.5	0.0	ANP	ANP	2.59	0.003	0.008	0.011
G-X-3	6/1/95	<1	1	34	0.45	<.4	2.8	<.04	<2	8	<.25	<.3	<.25	7.46	0.0	ANP	ANP	3.44	0.005	0.016	0.021
G-X-4	6/1/95	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	5.66	100	ANP	ANP	2.19	0.001	0.001	0.002
G-X-5	6/1/95	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	5.24	-300	ANP	ANP	2.19	0.037	0.052	0.089
G-X-11	6/1/95	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	12.4	-200	ANP	ANP	2.67	0.084	0.045	0.129
G-X-14	6/1/95	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	14.5	-400	ANP	ANP	2.57	0.064	0.04	0.104
G-X-15	6/1/95	<1	3	95	0.91	<.4	8.4	<.04	<2	9.5	<.25	0.3	<.25	13.7	0.0	ANP	ANP	2.67	0.006	0.012	0.018
G-X-17	6/1/95	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	16.4	-100	ANP	ANP	3.48	0.003	0.052	0.055
G-X-18	6/1/95	<1	3	82	0.71	<.4	8.8	<.04	<2	18.4	<.25	0.5	<.25	23.6	-400	ANP	ANP	2.76	0.002	0.031	0.033
G-X-20	6/1/95	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	15.0	100	ANP	ANP	2.82	0.004	0.022	0.026
G-X-20R	6/1/95	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	17.3	-100	ANP	ANP	2.72	0.068	0.088	0.156

(ANP = Analysis not performed)

(continued)

Table 5 (continued): FY 1994 and 1995 TA-54 Area G (OU1148) Expansion Area (Baseline/Background) Soil Data

FY 1995 Data (cont.)

Sample Location	Collection Date	Ag µg/g	As µg/g	Ba µg/g	Be µg/g	Cd µg/g	Cr µg/g	Hg µg/g	Ni µg/g	Pb µg/g	Sb µg/g	Se µg/g	Tl µg/g	% Water	^{3}H pCi/L	^{241}Am pCi/g	^{137}Cs pCi/g	Total Uranium µg/g	^{238}Pu pCi/g	^{239}Pu pCi/g	Total Pu pCi/g
G-X-22	6/1/95	<1	3	99	0.71	<.4	9.4	0.04	<2	11.7	<.25	<.3	<.25	14.0	-200	ANP	ANP	2.67	0.02	0.005	0.025
G-X-23	6/1/95	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	9.29	-200	ANP	ANP	3.54	0.04	0.03	0.07
G-X-25	6/1/95	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	7.06	-300	ANP	ANP	3.22	0.008	0.015	0.023
G-X-29	6/1/95	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	11.2	-300	ANP	ANP	2.72	0.007	0.047	0.054
G-X-31	6/1/95	<1	2	86	0.65	0.4	6.8	0.05	<2	11.5	<.25	<.3	<.25	7.0	-200	ANP	ANP	2.45	0.004	0.016	0.02
G-X-32	6/1/95	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	13.4	-100	ANP	ANP	2.79	0.002	0.004	0.006
G-X-34	6/1/95	<1	4	89	0.79	<.4	10	<.04	<2	17.4	<.25	<.3	<.25	18.2	-200	ANP	ANP	2.76	0.05	0.04	0.09
G-X-35	6/1/95	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	8.86	0.0	ANP	ANP	3.80	0.009	0.023	0.032
G-X-36	6/1/95	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	16.7	-200	ANP	ANP	3.28	0.002	0.008	0.01
G-X-40	6/1/95	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	17.8	-100	ANP	ANP	3.21	0.047	0.046	0.093
G-X-41	6/1/95	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	22.3	-300	ANP	ANP	2.88	0.003	0.01	0.013
G-X-42	6/1/95	<1	4	85	0.71	<.4	9.3	<.04	<2	12.3	<.25	0.4	<.25	13.3	300	ANP	ANP	2.43	0.003	0.007	0.01
G-X-46	6/1/95	<1	3	100	0.59	<.4	6.8	<.04	<2	12	<.25	<.3	<.25	10.7	-200	ANP	ANP	2.35	0.002	0.005	0.007
G-X-47	6/1/95	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	16.4	-100	ANP	ANP	2.67	0.008	0.011	0.019
G-X-49	6/1/95	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	15.2	0.0	ANP	ANP	2.91	0.062	0.026	0.088
G-X-49R	6/1/95	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	15.4	-300	ANP	ANP	2.57	0.041	0.007	0.048
G-X-54	6/1/95	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	6.16	-200	ANP	ANP	2.41	0.033	0.01	0.043
G-X-55	6/1/95	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	ANP	5.73	-100	ANP	ANP	3.64	0.004	0.027	0.031

(ANP = Analysis not performed)

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APPENDIX A:

FIDLER PROBE MEASUREMENTS AT AREA G PERIMETER SITES

Environmental Surveillance for Fiscal Year 1995

I. PURPOSE

A FIDLER (field instrument for the detection of low-energy radiation) probe was utilized during FY 95 to measure low-energy gamma and x-radiation on surface soils at 70 locations around the perimeter of Area G. These 70 locations were sited in 1991 at minor drainages emanating from Area G and represent what are considered locations biased to receive surface water runoff (and associated sediments) from Area G during precipitation events. By calibrating the probe so it is measuring low level gamma activity emanating from surface soils, one can determine whether there is elevated gamma activity on soils at specific sites located in small drainages around the perimeter of Area G. Upon measurement of low-energy gamma radiation on an annual basis at the MDA survey points, it may be possible to discern whether there are changes from year to year of the surface soils low-energy gamma activity and receive an early warning of the movement of radioactive contaminants out of Area G.

The FIDLER measurements continue a practice of environmental surveillance done at radioactive material disposal areas (MDAs) located at LANL. Until 1991, a PHOSWICH instrument (with a detector composed of solid-state detectors arrayed as a "sandwich") was used to take these surface soil low-energy gamma measurements at Area G, and at that time 16 unsurveyed locations were the sites of the annual measurements. In 1991, 70 locations were surveyed in and permanent markers were established for standardizing the measurement points. In 1992, a FIDLER probe was obtained, and this probe was used to make the Area G low-energy gamma survey at the 70 locations. This procedure was continued in FY 93, FY 94, and FY 95.

II. METHODOLOGY

A FIDLER probe (a thin layer sodium iodide crystal-photomultiplier tube assembly) in association with a multichannel analyzer (MCA) can focus in on a region of interest (ROI) of the low-energy gamma and x-ray spectrum that represents radionuclides of interest.

At Area G the radionuclides of interest are Am-241 (as an indicator for the presence of plutonium) and Cs-137. Am-241 is always found with plutonium, and because it has a strong peak (60 keV) in the low-energy gamma spectrum, it can be measured in the field with a FIDLER probe to serve indirectly as an indicator of the presence of Pu on surface soils. The ROI around the 60 keV peak is termed ROI 2. A second peak at 17 keV is surrounded by another region of interest, ROI 1, which is also indicative of the presence of Am/Pu. Cs-137 has a peak in the low-energy gamma spectrum at 32 keV. The ROI about the 32 keV peak is termed ROI 3.

The calibration of the instrument and measurements taken with the FIDLER are done in accordance with LANL-ER-SOP-10.04, FIDLER Instrument System.

During field measurements, the probe is situated in a fixed geometry in a tripod with the entry window of the probe 12.0 inches from the ground surface. At each of the 70 MDA survey locations (and 10 background soil points located immediately across the road from Area J), a 100 second count is made for ROIs 1 and 2, and ROI 3. Three numbers are received at each survey point. These numbers are in units of $\mu Ci/m^2$ (microcurie per square meter) for ROIs 1 and 2, and counts per 100 sec for ROI 3. In the spreadsheet (Table A-1), the values of the regions of interest that reflect Am/Pu (ROIs 1 and 2) are listed for each survey point. The 100 sec count for ROI 3 (the Cs-137 ROI) is also listed.

III. RESULTS AND DISCUSSION

The ten background soil location counts in FY 95 yielded an average of 0 $\mu Ci/m^2$ and 0.70 $\mu Ci/m^2$ for ROIs 1 and 2, respectively, and 480 counts per 100 sec for ROI 3. By comparing these averages with the equivalent counts measured at each of the 70 MDA survey points, it is easy to see from Table A-1 that, except for MDA location Number 1, the low-energy gamma activity for the 70 survey points around Area G is decidedly higher than the activity measured by the FIDLER for the three ROIs for the 10 background locations.

A scatter plot of the counts for ROI 2 for each MDA survey point taken in FY 93, 94, and 95 is found in Figure A-1. The count results at 2 of these locations (MDA-17 and MDA-43) are definitively higher than the measurements at adjacent locations. It is not mere coincidence that these two MDA survey points are adjacent to radioactive waste storage domes. One dome (the one nearest MDA-17) is the mixed waste storage dome where thousands of drums of mixed waste are stored. The second dome is over TRU pad 3. The higher than expected gamma counts at these two MDA survey locations have been attributed to "shine" that originates from the domes. Shine can be thought of as gamma radiation emanating from a nonpoint source location (such as a dome or pile of hot material). Shine manifests itself over a larger distance than the 1 foot distance between the FIDLER probe and the ground surface. That is, if shine is present at a particular MDA survey location, the FIDLER probe will add the shine gamma component to the gamma component emanating from the soil. By placing a shield (e.g., a person's body) between the suspected source of the shine or by pointing the probe opening away from the suspected source of the shine, one can determine (if one obtains lower 100 sec counts) that, in fact, the elevated low-energy gamma counts are due to shine. Also, a soil sample taken at this location would not exhibit any extraordinary gamma activity because the soil itself is not the source of the gamma radiation. By following up on all three of these tests for shine, we determined that the high readings at MDA 17 and 43 were due to shine and not high gamma activity on soils.

Table A-1: FY 95 FIDLER Counts of Low-Energy Gamma Activity Around the Perimeter of Area G

MDA Survey Point	Spectroscopic Region of Interest		
	ROI 1 ($\mu Ci/m^2$)	ROI 2 ($\mu Ci/m^2$)	ROI 3 Counts/100 s
G-1	0	0.503	713
G-2	0	0.610	886
G-3	0	0.734	985
G-4	0	0.628	895
G-5	0	0.734	1030
G-6	0	0.684	966
G-7	0	0.692	967
G-8	0	0.702	1010
G-9	0	0.755	1020
G-10	0	0.776	1130
G-11	0	0.734	1030
G-12	0	0.758	1040
G-13	0	0.797	989
G-14	0	0.795	1100
G-15	0	0.839	1107
G-16	0	0.850	1200
G-17	0	1.280	1710
G-18	0	0.906	1310
G-19	0	0.902	1210
G-20	0	0.906	1340
G-21	0	0.860	1280
G-22	0	0.998	1730
G-23	0	0.986	1430
G-24	0	0.869	1270
G-25	0	0.881	1240
G-26	0	0.813	1150
G-27	0	0.776	1120
G-28	0	0.943	1310
G-29	0	0.965	1220

(continued)

Table A-1 (continued): FY 95 FIDLER Counts of Low-Energy Gamma Activity Around the Perimeter of Area G

MDA Survey Point	Spectroscopic Region of Interest		
	ROI 1 ($\mu Ci/m^2$)	ROI 2 ($\mu Ci/m^2$)	ROI 3 Counts/100 s
G-30	0	0.857	1130
G-31	0	0.628	885
G-32	0	0.902	1130
G-33	0	0.795	1160
G-34	0	0.797	966
G-35	0	0.813	1170
G-36	0	0.734	1050
G-37	0	0.795	1310
G-38	0	0.943	1530
G-39	0	0.832	1500
G-40	0	1.000	1580
G-41	0	0.944	1610
G-42	0	1.050	1900
G-43	0	2.390	8210
G-44	0	1.590	2990
G-45	0	1.380	2400
G-46	0	0.998	1520
G-47	0	0.776	1130
G-48	0	0.797	1110
G-49	0	0.776	1100
G-50	0	0.734	1000
G-51	0	0.860	1170
G-52	0	0.839	1240
G-53	0	1.020	1860
G-54	0	1.130	2080
G-55	0	1.000	1083
G-56	0	0.881	1350
G-57	0	0.839	1120

(continued)

Table A-1 (continued): FY 95 FIDLER Counts of Low-Energy Gamma Activity Around the Perimeter of Area G

MDA Survey Point	Spectroscopic Region of Interest		
	ROI 1 ($\mu Ci/m^2$)	ROI 2 ($\mu Ci/m^2$)	ROI 3 Counts/100 s
G-58	0	0.797	1110
G-59	0	0.755	1040
G-60	0	0.776	1110
G-61	0	0.734	995
G-62	0	0.739	1100
G-63	0	0.734	1050
G-64	0	0.776	1040
G-65	0	0.702	1070
G-66	0	0.755	1020
G-67	0	0.702	1030
G-68	0	0.692	881
G-69	0	0.680	1000
G-70	0	0.671	948
BKG-1	0	0.797	1040
BKG-2	0	0.671	975
BKG-3	0	0.671	934
BKG-4	0	0.650	866
BKG-5	0	0.608	865
BKG-6	0	0.650	912
BKG-7	0	0.776	1040
BKG-8	0	0.755	1000
BKG-9	0	0.734	1020
BKG-10	0	0.692	965

Finally, the scatter plot (Figure A-1) indicates that, except for location MDA-1, all of the MDA survey point counts are elevated over background. From points 2–13 (moving from Area L to the old Area G gate), the counts are slightly elevated. From MDA survey points 14 through 44 (encompasses all the MDA survey points from the old gate through the TRU pads), there is a slow trend in gamma activity upward. From MDA survey points 45 through 55, the gamma activity trends first downward through MDA survey point 51, then upward through MDA survey point 55. Finally, from MDA survey points 56–70, the gamma activity trend is slowly downwards as the survey points proceed westward and out of Area G. It is difficult at this time to determine whether the trends in low-energy gamma radiation for the Area G MDA survey points are due to incremental increases or decreases in soil gamma activity or whether these trends are due to manifestations of area wide shine that affects the individual soil gamma activities.

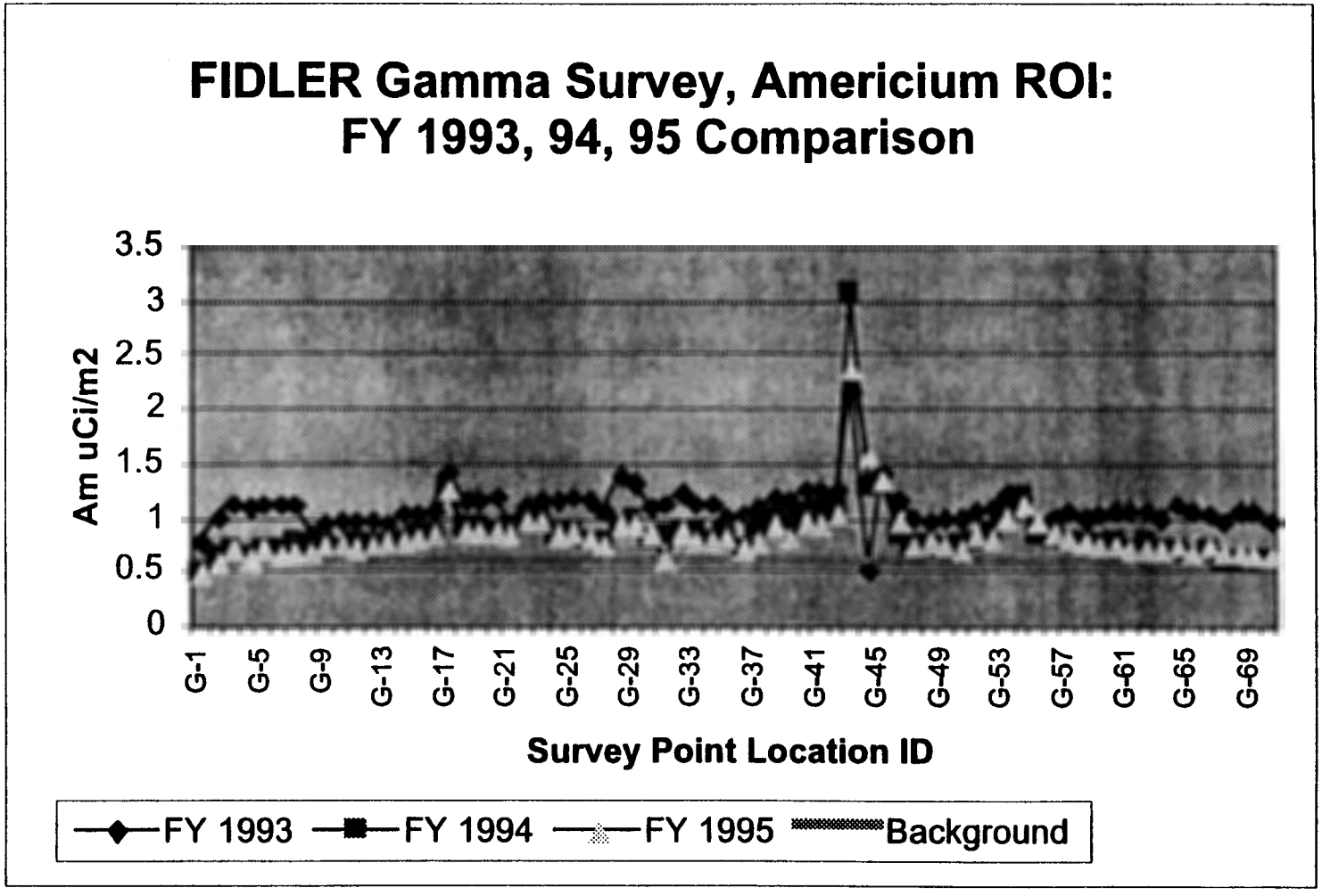
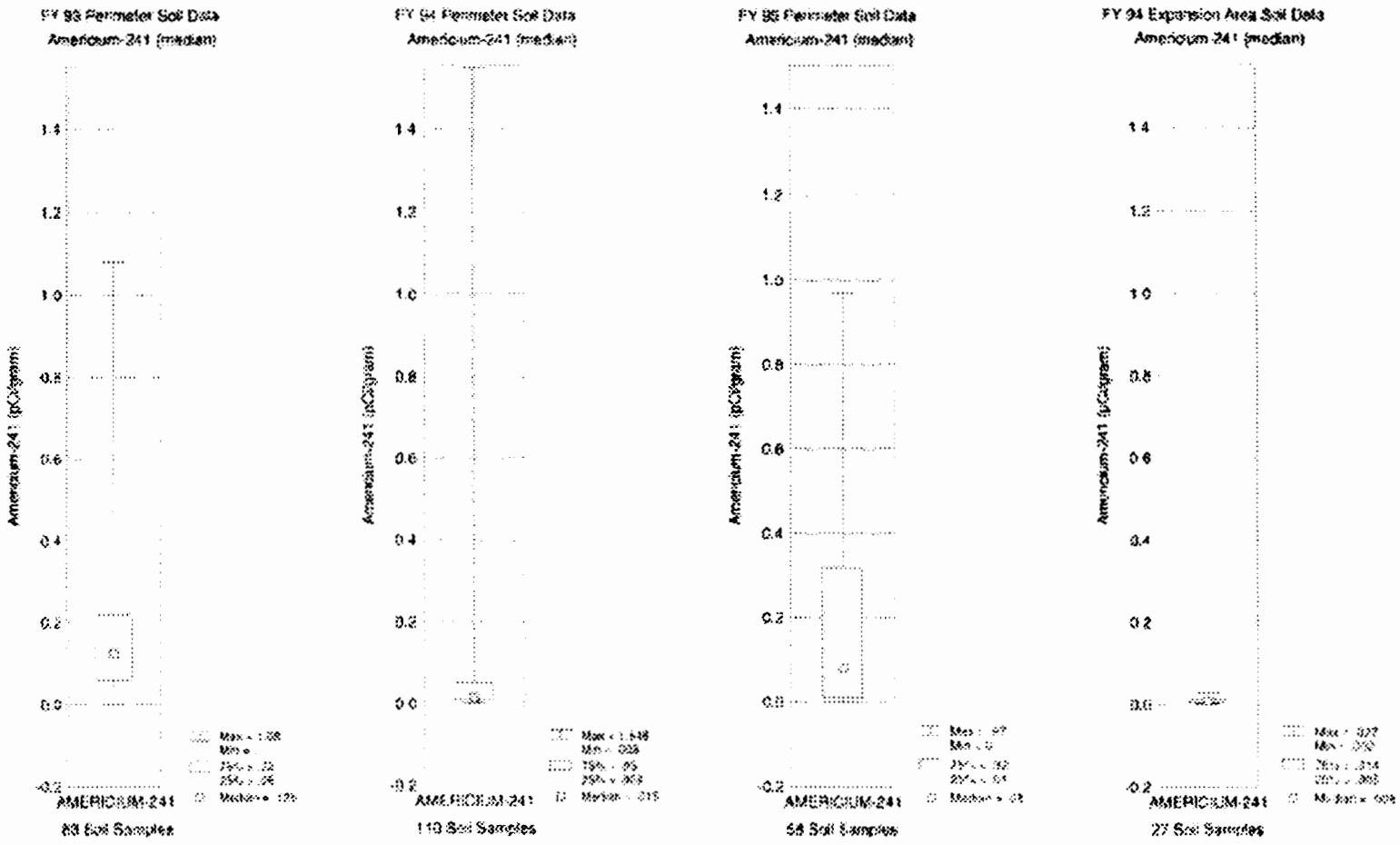


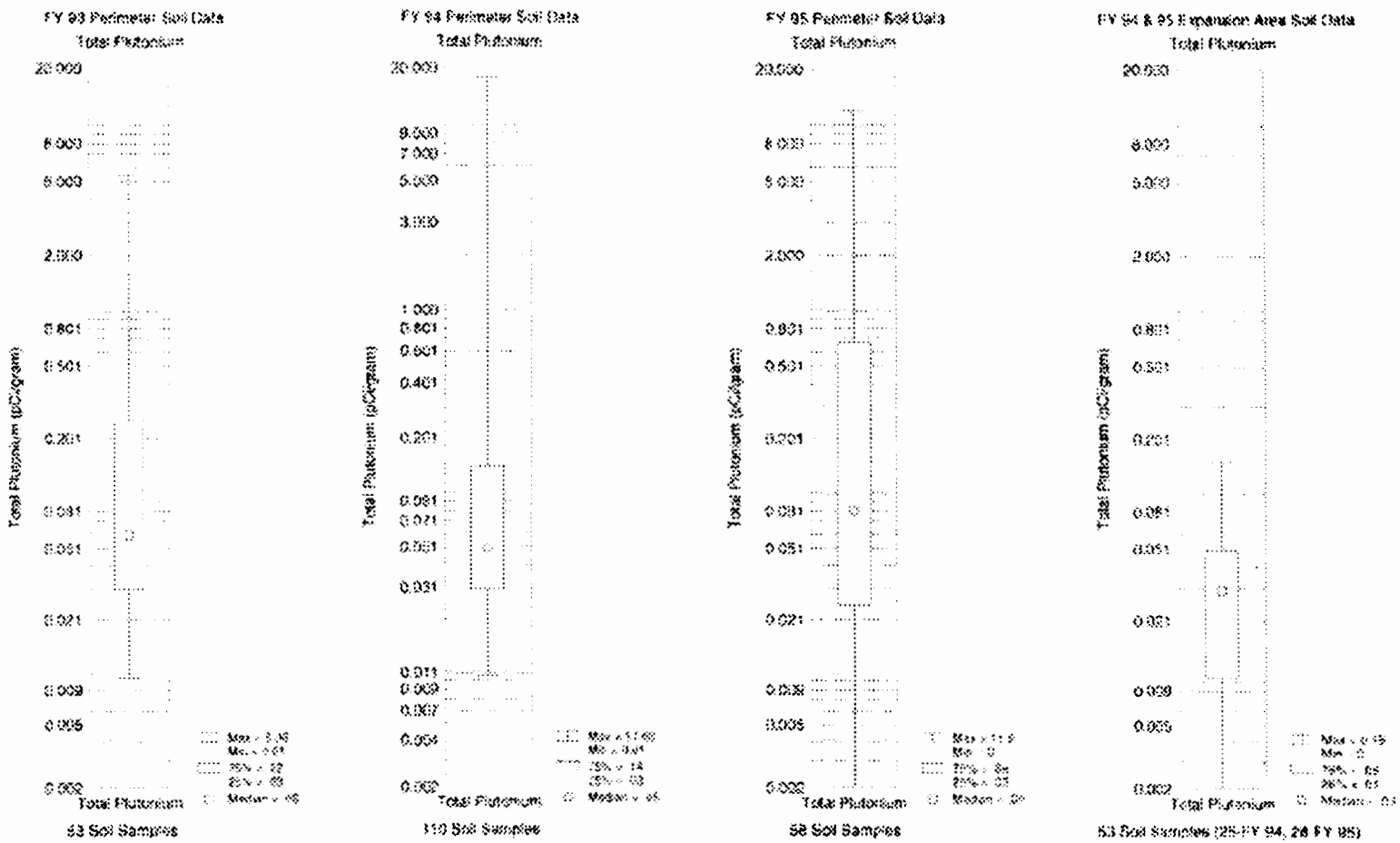
Figure A-1: Scatter plot of FY 93, FY 94, and FY 95 FIDLER of low-energy gamma activity around the perimeter of Area G. Americium-241 (ROI 2) results are displayed in $\mu Ci/m^2$. The high values for locations G-17 and G-43 were shown to be due to shine artifacts.

APPENDIX B:

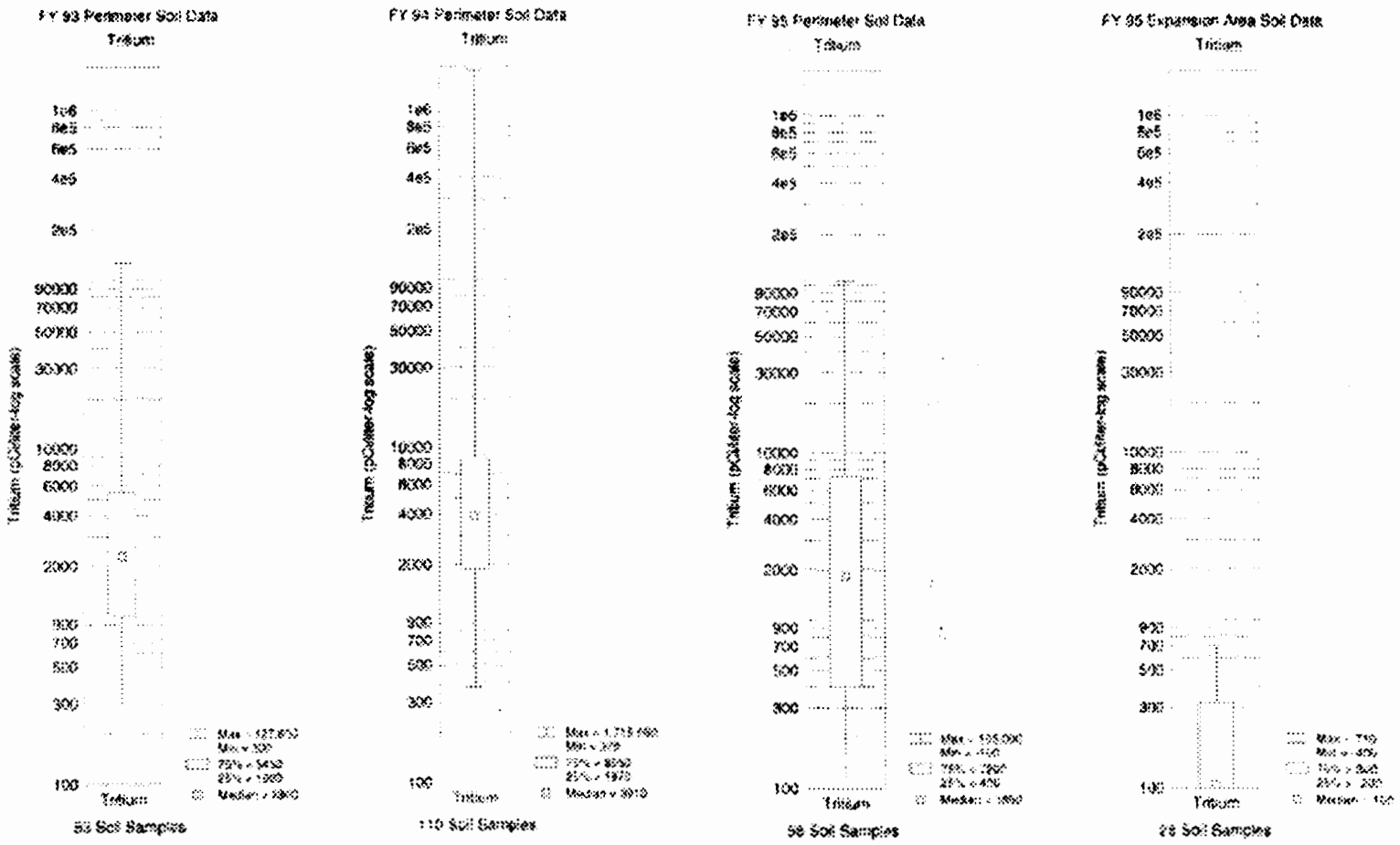
BOX PLOTS



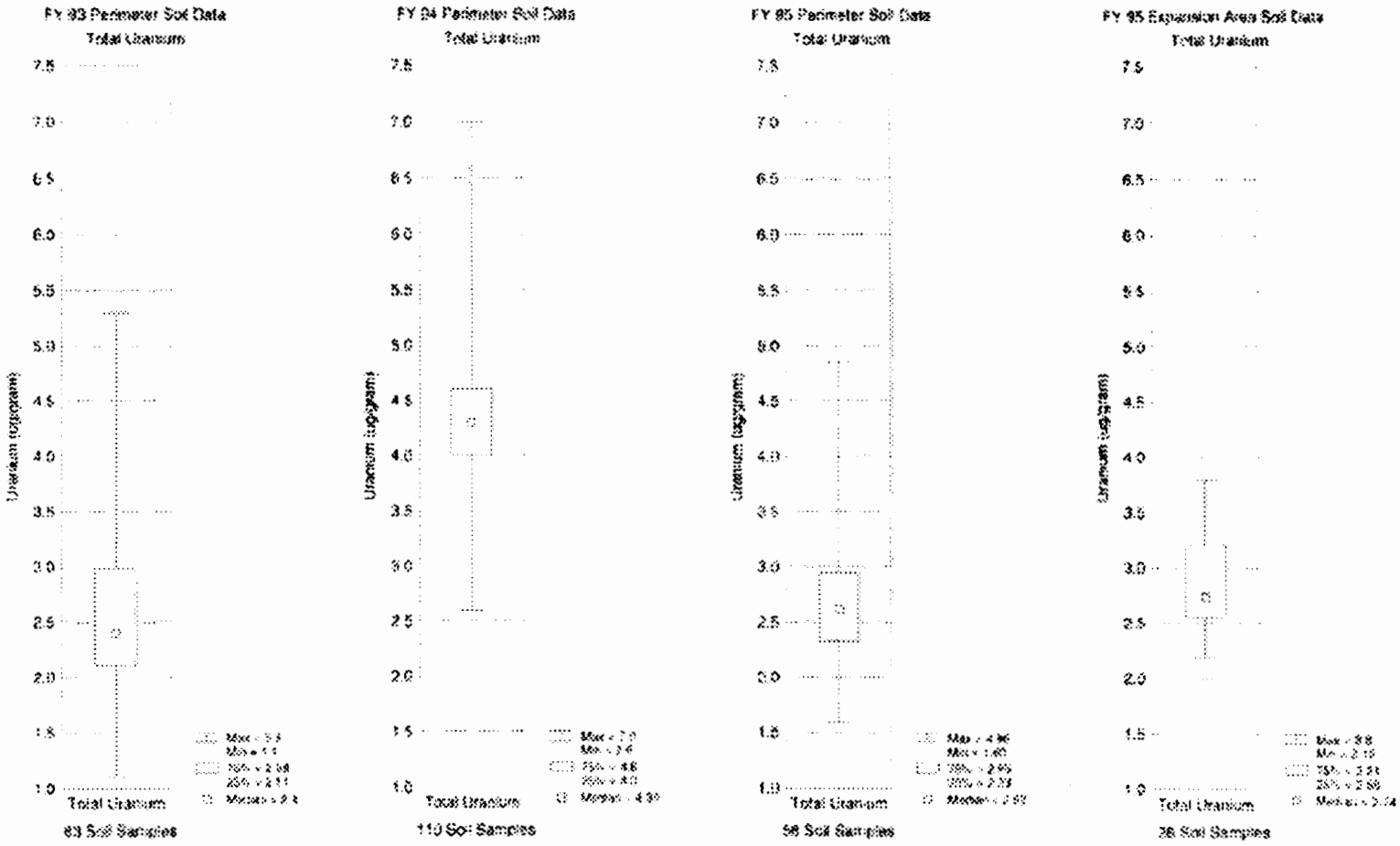
Area G Americium-241 Surface Soil Box Plot Comparisons



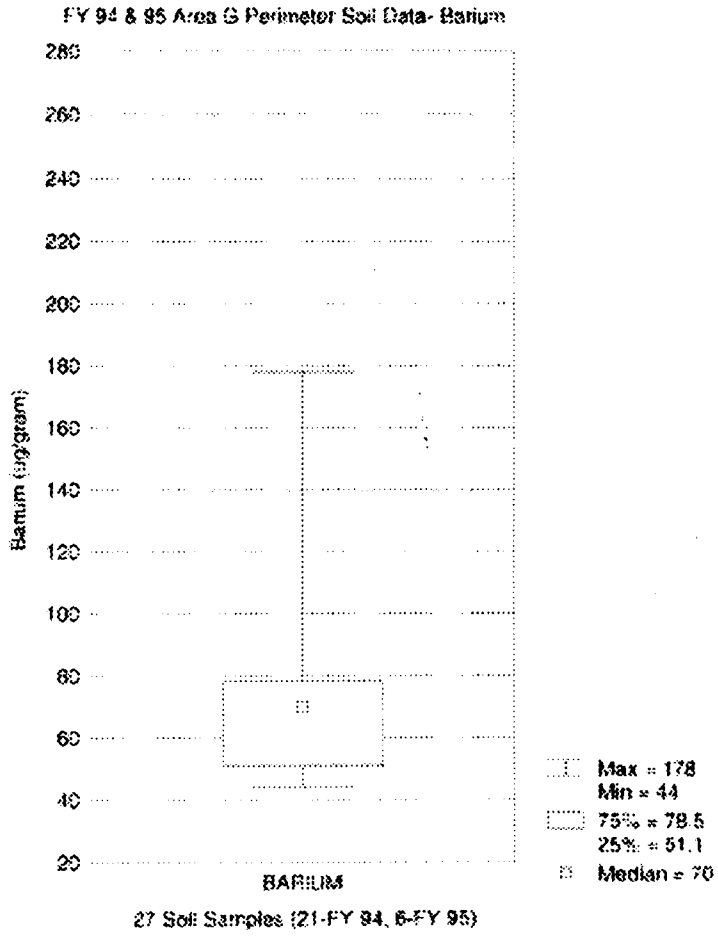
Area G Total Plutonium Surface Soil Box Plot Comparisons

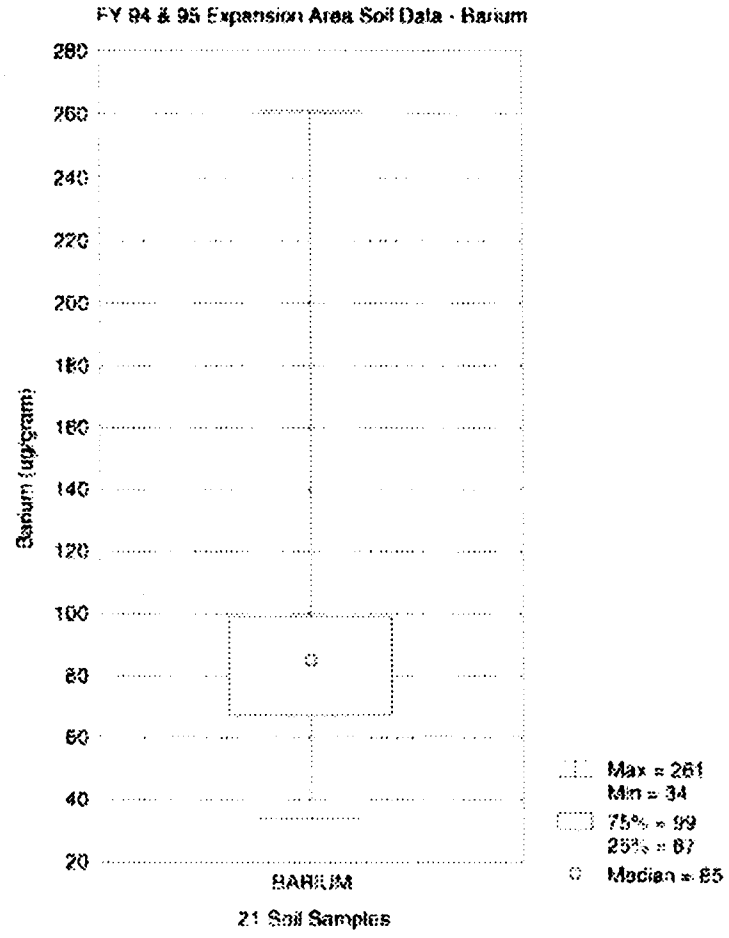


Area G Tritium Surface Soil Box Plot Comparisons

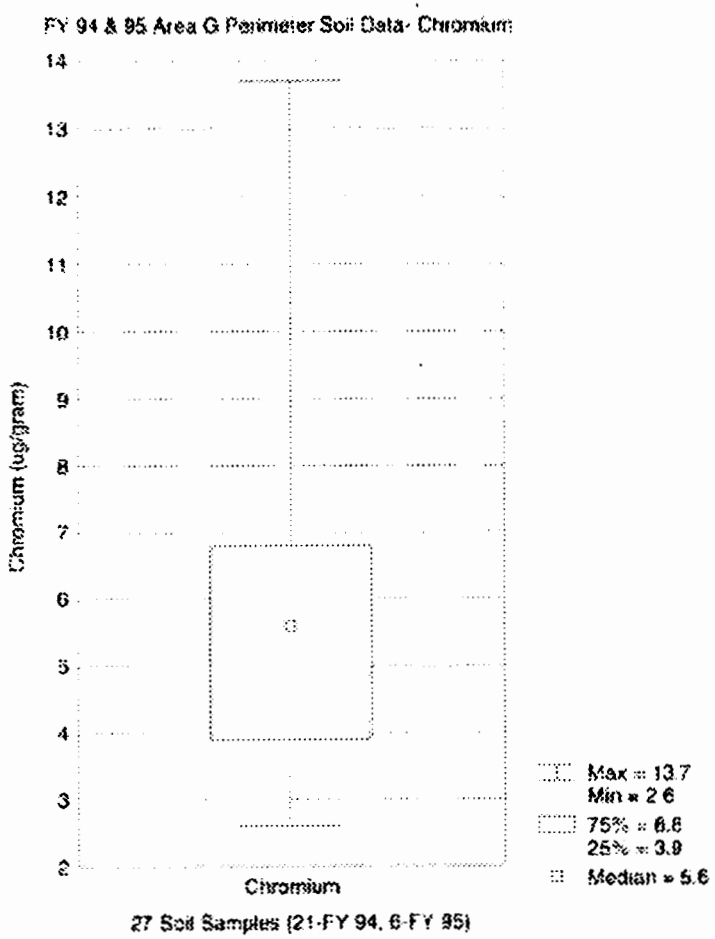


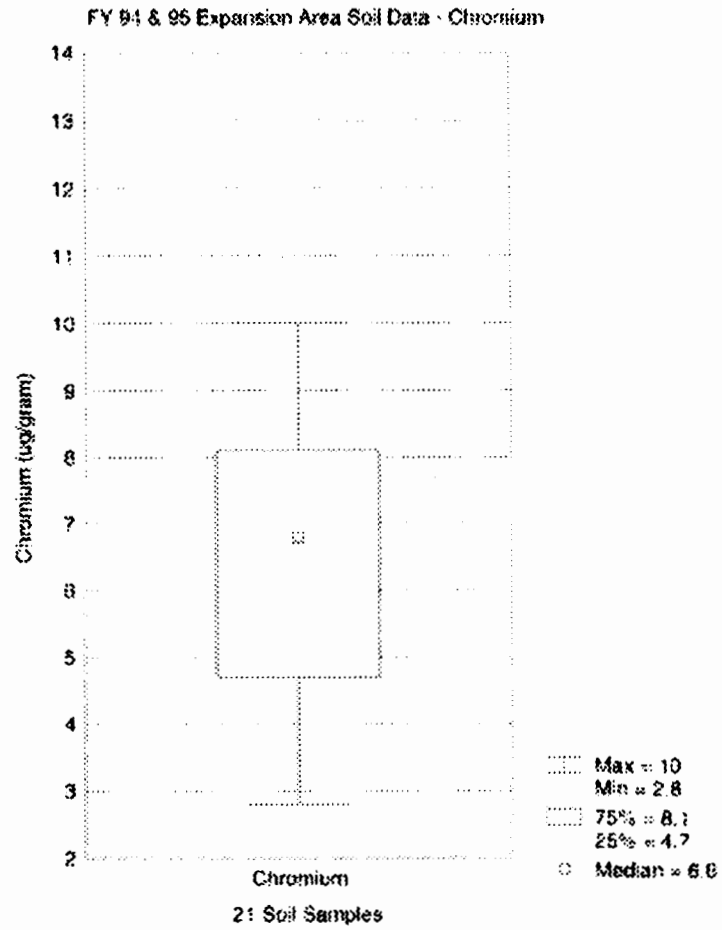
Area G Total Uranium Surface Soil Box Plot Comparisons



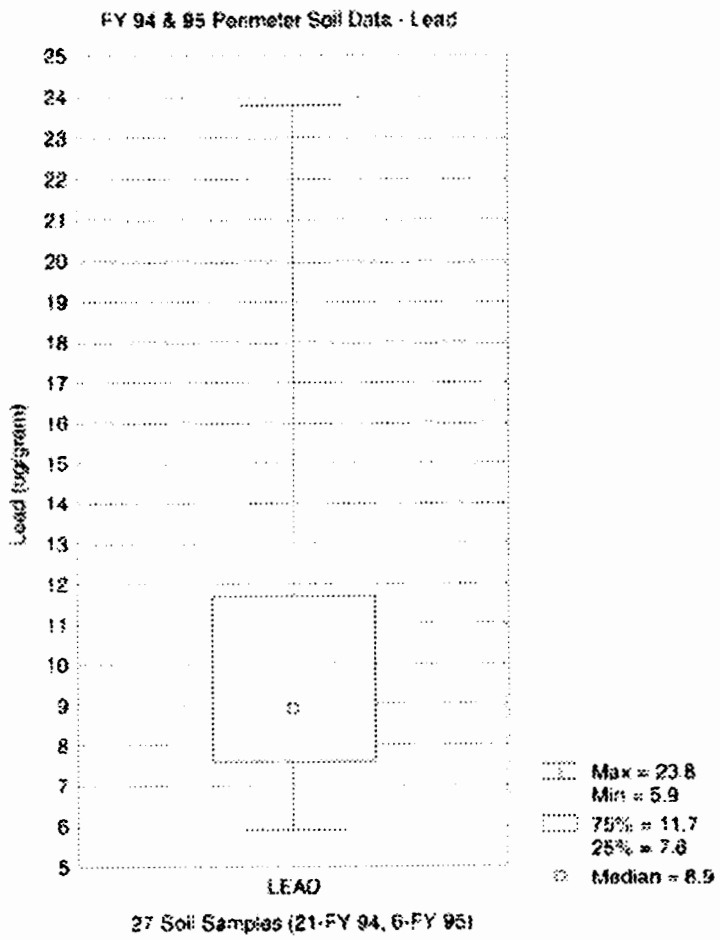


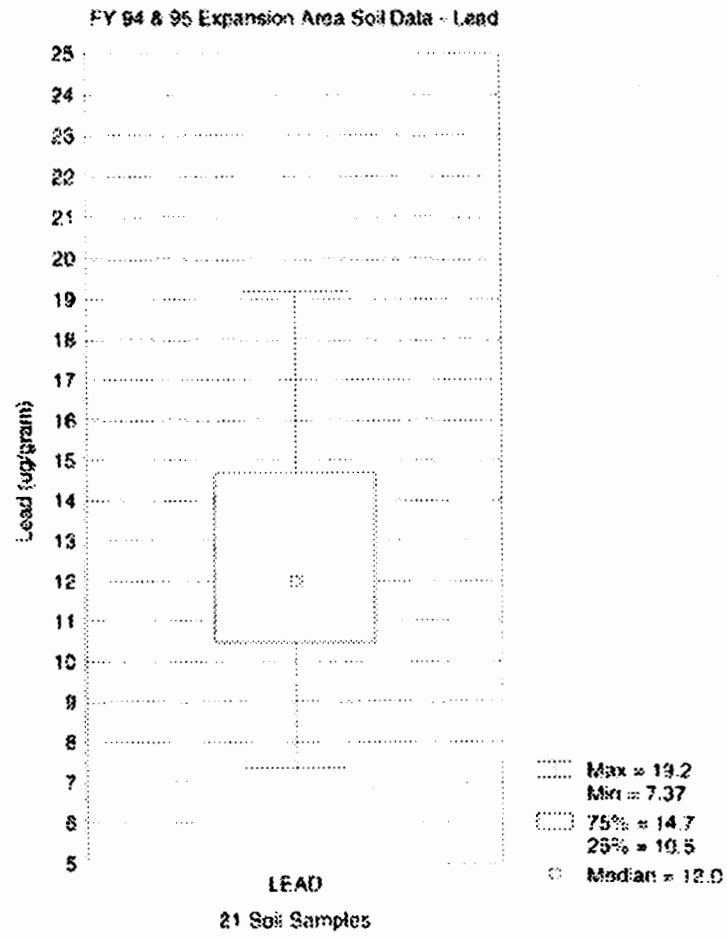
Area G Barium Surface Soil Box Plot Comparisons



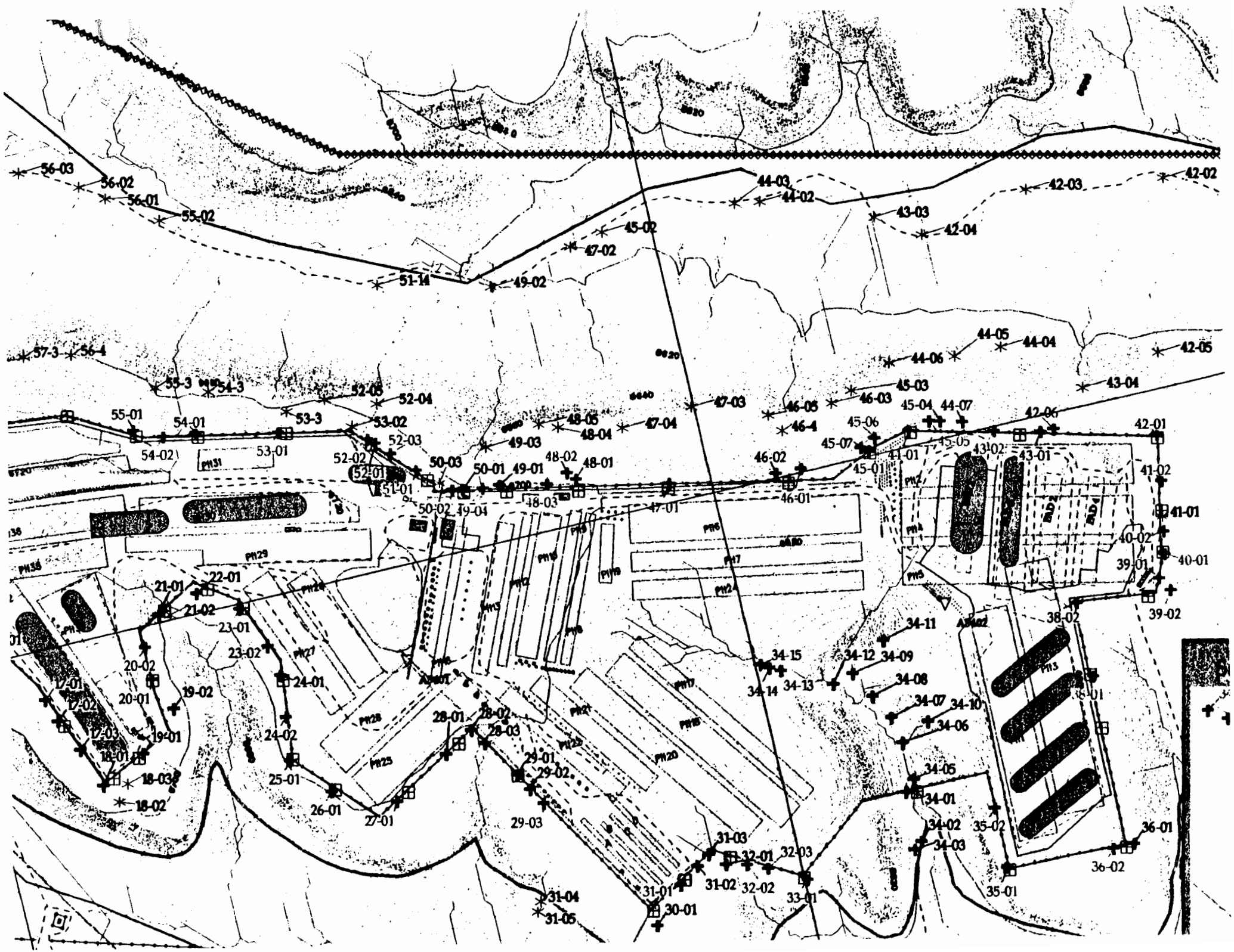


Area G Chromium Surface Soil Box Plot Comparisons





Area G Lead Surface Soil Box Plot Comparisons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