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

Environmental Surveillance for Fiscal Year 1993

Los Alamos
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Acronyms and Abbreviations

cpm	counts per minute
CST	Chemical Science and Technology Division, LANL
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
HAZWOPER	hazardous waste operations
keV	kiloelectron volts (10^3 electron volts)
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
TA	Technical Area
TRU	transuranic (waste)
TWISP	Transuranic Waste Inspection Project
WILD	brand-name surveying station
WSS	Waste Site Studies
XRF	x-ray fluorescence

AREA G PERIMETER SURFACE-SOIL AND SINGLE-STAGE WATER SAMPLING

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by

Ron Conrad, Marquis Childs, Catherine Rivera-Dirks, and Fawn Coriz

ABSTRACT

ESH-19 personnel collected soil and single-stage water samples around the perimeter of Area G at Los Alamos National Laboratory to characterize possible contaminant movement through surface-water runoff. These samples were analyzed for tritium, total uranium, isotopic plutonium, americium-241 (soil only), and cesium-137. The metals, mercury, lead, and barium, were analyzed using x-ray fluorescence.

Elevated levels of tritium (as high as 117,200 pCi/L) were found in soil samples along the eastern half of the north side of Area G. To the east and south of the transuranic waste pads, the soil samples showed slight increases (3000–5000 pCi/L) above baseline tritium levels (100–1000 pCi/L for Area G soils). Only one single-stage water sample had a tritium activity greater than 2000 pCi/L. Although we propose two subsurface-to-surface tritium migration mechanisms, we do not know how well our sample results reflect possible fluctuations in the Area G near-surface tritium distribution.

The uranium soil concentrations had an average value of 2.59 ± 0.70 µg/g. For soil samples, the average plutonium-238 activity was 0.28 ± 0.80 pCi/g and the average for total plutonium-239 and -240 was 0.21 ± 0.51 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. Cesium-137 activities in soils had a wide distribution and ranged from 0.019–2.38 pCi/g. Soil mercury was detected in only 5 out of 83 samples, with the highest value at 6.1 µg/g. Other metal concentrations were found within natural background ranges.

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 and transuranic (TRU) radioactive waste since 1957. Our investigation focused principally on the possibility of contaminated sediment movement through surface-water runoff out of the site perimeter. Soil samples were analyzed for tritium, total uranium, isotopic plutonium, americium-241, and cesium-137. The metals, mercury, lead, and barium, were analyzed using x-ray fluorescence. Filtered-water fractions from single-stage collectors were analyzed for tritium, isotopic plutonium, total uranium, and cesium-137. Filtered-sediment fractions were analyzed for isotopic plutonium only.

Elevated levels of tritium (as high as 117,200 pCi/L) in soil were found for sampling locations along the eastern half of the north side of Area G. To the east and south of the TRU

pads, the soil samples showed slight increases (3000–5000 pCi/L) above baseline tritium levels (100–1000 pCi/L for soils in Area G). Six single-stage water samples had tritium activities over 1000 pCi/L, but in FY 93 only one single-stage water sample had a tritium activity greater than 2000 pCi/L. Two primary mechanisms, vapor-phase transport or capillary action, may allow tritium to move from subsurface soils to surface soils. Tritium's residence time in surface soils is unknown, however, and we do not know how well our sample results reflect tritium's actual distribution at Area G.

The uranium concentrations ranged from 1.1–5.3 μg/g with an average value of 2.59 ± 0.70 μg/g, slightly above background concentrations for soil uranium found throughout the Laboratory. Plutonium-238 activities ranged from 0.001–4.987 pCi/g with an average of 0.28 ± 0.80 pCi/g. The total activities for plutonium-239 and -240 ranged from 0.001–1.944 pCi/g with an average of 0.21 ± 0.51 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 samples. The two areas of elevated americium-241 activity reflected the elevated activities found for plutonium. Cesium-137 activities in soils had a wide distribution and ranged from 0.019–2.38 pCi/g. The interpretation of the cesium-137 distribution may have to await additional results from future studies.

Soil mercury was detected in only 5 out of 83 samples, and of these 5 samples, the highest value was 6.1 μg/g. Barium and lead concentrations around the Area G perimeter were found within the expected natural background concentration ranges as reported by Longmire et al. (1995).

1.0 INTRODUCTION

Area 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 and TRU radioactive waste since 1957 (see Figure 1). From the environmental surveillance standpoint, one question that has to be addressed is whether there has been an impact on the surrounding environment from the disposal operations that have taken place at 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 ground water pathway) for spread of radioactive contamination from Area G surface sediments are airborne dispersion of particulate matter (and tritium in the form of water vapor) and off-site movement of contaminated sediments and/or dissolved chemical compounds by surface-water runoff. This 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).

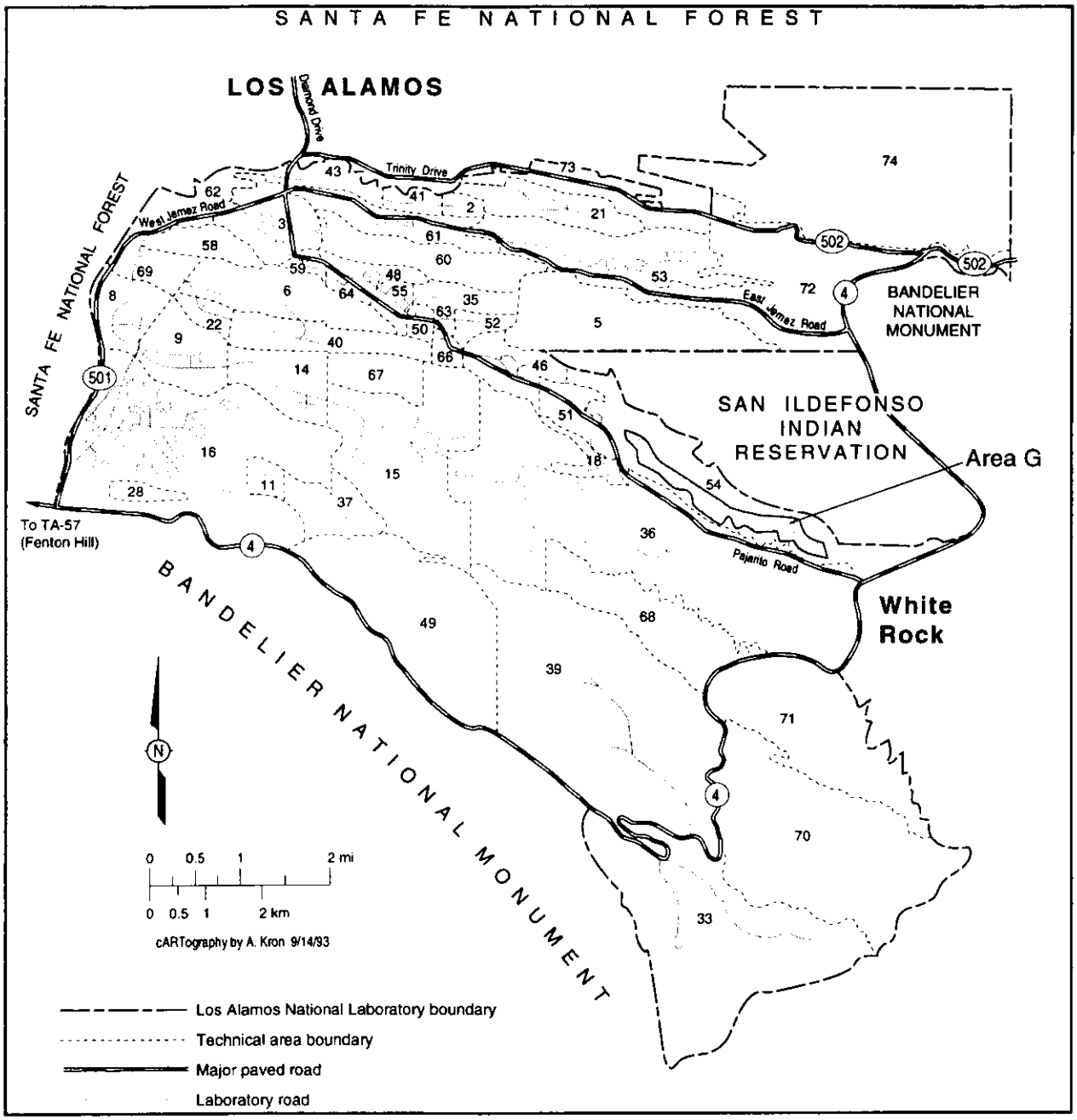

Figure 1: Location of TA-54 and Area G at Los Alamos National Laboratory. The 74 technical areas (TAs) of the Laboratory are shown here, with TA-54 located south of the San Ildefonso Indian Reservation. Area G (in gray) runs along Mesita del Buey and parallels Pajarito Road.

Our investigation focuses principally on the possibility of contaminated sediment movement through surface-water runoff out of the perimeter of Area G. Extensive surface-soil and surface-water-runoff sampling was initiated in FY 93 around the perimeter of Area G. Sampling locations were intentionally selected to best indicate possible contamination moving outside the perimeter of Area G; thus, these sampling locations should be considered as those locations most sensitive to possible contaminant migration. The data collected during FY 93 can be used to

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

2. establish baseline concentrations for possible contaminants of concern for future Area-G surveillance efforts.

Sediment movement out of Area G via the surface-water pathway is important because this is the major mechanism for disseminating nongaseous contaminants from the surface of Area G to outlying areas. Contamination of the ground surface of Area G may have resulted from

1. dispersion of material from active pits by natural phenomena and anthropic activities;
2. movement of contaminated sediments off the TRU pads or other 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 radioactive material from trucks carrying waste into Area G; and
6. transport of contaminated materials to the surface by burrowing animals or vegetation.

Radioactive surface 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 where surface-water-runoff channels are established;
2. quantify the levels of radioactive and several RCRA metal contaminants in surface soils and in surface-water runoff at Area G and compare baseline levels from surface-soil samples taken in adjacent, nonimpacted locations; or
3. provide data that can serve as a baseline for contaminant concentrations to compare with future data from subsequent surveillance projects; and
4. document whether contaminants (either dissolved in water or as sediments) are moving off-site through surface-water runoff.

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

2.1 Areal Extent

The investigation to define off-site migration of radionuclides 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 cut into the hillsides around the perimeter of Area G. The single-stage-sampler locations are designed to collect runoff either on the mesa top (just outside the fence line) or at points before the runoff enters the bottom of the two adjoining canyons, Cañada del Buey and Pajarito Canyon.

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 Environmental Safety and Health Division, Group 18 (ESH-18).

2.2 Data Needs

The data needs for the perimeter surveillance study are

1. surveyed sample locations with specifications of 0.1-ft accuracy in the horizontal plane and 1.0-ft accuracy in the vertical plane with northings and eastings referenced to NAD 1983,
2. surface-soil samples (0–6 in. deep) from preexisting runoff pathways just outside the Area G perimeter fence,
3. 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,
4. analyses of soil samples for those constituents listed below in Section 5.4, and
5. analyses of all surface-water-runoff samples for constituents listed below in Section 5.4.

Several perimeter locations to the west of active operations at Area G also were sampled to provide guidelines for analyte background levels in surface soil and water. These baseline sites are located where no radioactive-waste disposal has occurred, along the perimeter of the area into which Area G is expected to expand. In FY 94 a grid was established in this area, just west of the old Area G gate. Surface-soil and water samples from this area were analyzed for the constituents listed in Section 5.4. In the future, these data will serve as baseline concentrations for constituents of interest at new disposal locations for Area G.

3.0 HEALTH AND SAFETY TRAINING FOR WSS PERSONNEL

All field work was performed by members of the ESH-19 Waste Site Studies (WSS) team. Each member of the team received and was up-to-date for the following training:

General Employee Training (GET)

24- or 40-hour HAZWOPER Courses
Annual 8-hour HAZWOPER Refresher Courses
HAZWOPER Supervisor Course (if applicable)
Rad Worker I or II Courses
CPR and First Aid Courses
All-Terrain Vehicle Safety Instruction
Area G Site-Specific Training

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.

All field work was done according to the WSS site-specific Health and Safety Plan (HASP) for Area G. All members of the team read and signed the HASP and agreed to abide by the plan.

In addition, each team member watched the Area G site-specific training video, was aware of the health and safety rules and guidelines under which Area G employees operate, and performed all 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-ins. 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.

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 using 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, an aluminum stake was emplaced to memorialize the position. A brass tag that was stamped with the unique site identification number was attached to each stake.

The unique sampling locations at the perimeter of Area G were coded as G-##-0#. 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 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 93 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 a tagged aluminum stake with tags G-24-1 and G-24-2. The letters "S" and/or "W" on the brass tag indicated whether these sites are for soil only, water only, or both types of samples as follows:

1. surface-soil samples only ("S" on tag),
2. single-stage water samples only ("W" on tag), and
3. surface-soil and single-stage water samples ("S" and "W" on tag).

On the map depicting the perimeter surveillance locations (Figure 2), soil-sample points are in orange, single-stage water sample points are in blue, and the combination points for surface-soil and single-stage samples are in green. This map was prepared by the Facility for Information Management and Display (FIMAD). These coordinates are referenced to NAD 1983.

4.2 Sampling Techniques

The following standard sampling and instrument procedures, adopted by the WSS team to collect and preserve the 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-01.06	Management of RFI-Generated Waste
LANL-ER-SOP-03.01	Land Surveying Procedures
LANL-ER-SOP-06.03	Sampling for Volatile Organics
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-ER-SOP-14.01	Berthold Low Alpha and Beta Activity Counter. Calibration, Quality Control, Detection Limit, and Use
LANL-ESH-8-008	General Field Work
Spectrace 9000	Instrumental Procedure for XRF Measurement
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, 60-s counts were made at the soil surface to detect any 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 for ESP-1 counts 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. After samples were screened for gross radioactivity (see section 5.1 below), those requiring analytical chemistry services were delivered to the Sample Receiving Facility (Chemical Science and Technology Division, Group 3, or CST-3), located in Room 190, SM-59-1, TA-59. CST-3 personnel took formal custody of the samples at that time. All samples were analyzed on-site at LANL.

5.0 SAMPLE ANALYSIS

5.1 Soil Samples—Gross Alpha and Beta Counting

After the soil samples were collected, they were taken to TA-59 where small aliquots of each sample were prepared for gross radioactivity counting and x-ray fluorescence (XRF) metal measurements. The main purpose of the gross counts was to determine whether the samples could be brought into Building SM-59-1 (that is, whether the samples met the CST-3 building limits for radioactivity, which have been established to minimize background counts in the building).

5.2 Soil Samples—XRF Measurements

Little information is available on metal concentrations in soils at Area G. Thus, we determined that it would be valuable to begin measuring certain metal concentrations in soils with the relatively inexpensive XRF technique. In this study, XRF data were used to screen for elevated metal levels and to determine whether subsequent soil sampling for standard laboratory analysis was required. XRF is a low-cost, nondestructive method that analyzes soils for total metal concentrations. This technique's sensitivity is adequate for the three metals of interest at Area G—lead, barium, and mercury. These three metals have been used throughout the Laboratory for decades, and they undoubtedly have been disposed of in varying quantities at Area G. These potential soil contaminants, in their unoxidized elemental forms or as oxidized compounds associated with soils, are expected to be disseminated into the environment by any of

the routes discussed above in Section 1.0. Therefore, it was important to begin assessing Area G for elevated metal levels in soils.

XRF measurements were made using a Spectrace 9000 XRF instrument according to the manufacturer's SOP. To prepare samples for XRF measurement, small plastic cups were half filled with soil and a small ceramic mortar was used to grind the soil in the cup for one minute. This procedure grinds larger particles to a smaller size, produces more surface area for the XRF probe, and ultimately allows more accurate measurements. These XRF data are included in Table 1.

5.3 Water Samples—pH and Conductivity Measurements

The single-stage water samples were collected in 1-gal. polyethylene bottles according to SOP LANL-ER-SOP-06.10, referenced above in section 4.2. 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. The water was also prepared for submittal to CST-3 for analyses. Although the pH, temperature, and conductivity measurements were made at TA-59 and thus were not truly field measurements, we decided that the delay was not significant because there was a built-in delay between the filling of the bottles during a storm event and collection of the sample bottles. Single-stage sample collection occurs only after those storm events that result in runoff significant enough to actually fill the bottles. Because these summer storm events normally occur in the mid or late afternoon, it was not until the next day that the WSS team could go to Area G to check whether or not the single-stage samplers collected water. If the sample bottles collected water over the weekend, it may have been 72 h from the time the water flowed into the bottle until it was picked up by the WSS team. For these reasons, it did not seem critical to perform the pH and conductivity measurements in the field. The pH and specific conductivity results are found in Table 2.

5.4 Requested Analytical Services

5.4.1 Surface-Soil Samples

The following analytical services were requested for soil samples taken during FY 93:

1. isotopic plutonium by radioactivity/alpha spectroscopy (RAS),
2. total uranium by kinetic phosphorescence analysis,
3. tritium by distillation of soil moisture and then scintillation counting,
4. cesium-137 by gamma spectroscopy and americium-241 by gamma spectroscopy or RAS, and
5. percent moisture by gravimetric methods.

5.4.2 Single-Stage Water Samples

The following analyses were requested for single-stage water samples:

Unfiltered-water samples

1. total suspended solids.

For the remaining part of the water sample, we requested that the sample first be filtered through a 0.45-μm filter. The following analyses were then requested for many of the samples:

Filtered-water fractions

1. tritium,
2. isotopic plutonium,
3. total uranium,
4. gross alpha, beta, and gamma activity, and
5. cesium-137 by gamma spectroscopy.

Filtered-sediment fractions

1. Isotopic plutonium.

5.4.3 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 soils or sediment-fraction samples were analyzed for plutonium and 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.

Table 1: 1993 TA-54 Area G (OU 1148) perimeter soil data. Samples can be located on the maps of Figures 3 through 12 by referring to the sample location numbers listed in the first column of this table. Please note that negative values sometime result from counting statistics when average background activities are subtracted from gross analytical results.

Sample		XRF data			Soil moisture	Radioisotope data						
		Ba	Hg	Pb		^{3}H	^{241}Am	^{137}Cs	U*	^{238}Pu	^{239}Pu†	Total Pu‡‡
Location	Date	(µg/g)	(µg/g)	(µg/g)	(wt %)	(pCi/L)	(pCi/g)	(pCi/g)	(µg/g)	(pCi/g)	(pCi/g)	(pCi/g)
G-9-1	7/6/93	263.	ND‡	19.	1.4	600	–0.0156	0.332	3.5	0.002	0.02	0.022
G-10-1	7/6/93	189.	ND	16.	1.56	1000	0.102	0.8	3.2	0.012	0.03	0.042
G-10-2	7/21/93	125.	ND	ND	22.26	300	CON††	2.38	3.87	0.022	0.092	0.114
G-11-1	7/6/93	165.	ND	ND	1.38	1200	0.141	0.474	2.3	0.009	0.016	0.025
G-12-1	7/6/93	268.	ND	4.	1.56	1500	–0.015	0.151	2.3	0.018	0.01	0.028
G-12-3	7/6/93	273.	ND	7.	2.16	700	0.005	1.43	3.1	0.012	0.07	0.082
G-13-1	7/6/93	299.	ND	7.	2.58	300	0.001	–0.019	2.2	0.003	0.008	0.011
G-13-9	7/6/93	211.	ND	6.	1.37	1000	–0.016	0.383	3.1	0.002	0.021	0.023
G-14-1	7/6/93	228.	ND	18.	1.52	1500	0.009	0.389	2.3	0.006	0.009	0.015
G-15-1	7/6/93	216.	ND	ND	1.91	1300	–0.012	0.309	3.	0.014	0.02	0.034
G-15-2	7/6/93	206.	ND	11.	1.07	ISM**	–0.024	1.	5.3	0.007	0.047	0.054
G-16-1	7/6/93	208.	ND	10.	1.65	3000	0.022	1.1	3.2	0.012	0.052	0.064
G-17-1	7/6/93	228.	ND	21.	1.14	ISM	0.019	0.105	2.2	0.004	0.013	0.017
G-17-2	7/6/93	193.	ND	ND	2.71	3100	0.0002	1.83	3.8	0.011	0.077	0.088
G-17-3	7/6/93	236.	ND	ND	2.06	800	0.014	0.313	3.3	0.008	0.021	0.029
G-18-1	7/6/93	154.	ND	4.	2.78	1300	0.037	0.404	3.1	0.005	0.015	0.02
G-18-4	7/6/93	80.	ND	ND	0.26	0	0.0279	0.188	2.5	0.011	0.015	0.026
G-19-1	7/6/93	231.	ND	ND	2.39	1400	0.0834	0.0317	2.6	0.002	0.015	0.017
G-20-1	7/6/93	167.	ND	ND	1.29	3500	–0.024	1.25	2.4	0.015	0.044	0.059
G-20-2	7/6/93	237.	ND	7.	2.14	5100	–0.018	0.0374	2.3	0.009	0.014	0.023
G-21-1	7/6/93	180.	6.	2.	0.33	ISM	–0.003	0.09	1.6	0.008	0.006	0.014
G-21-2	7/6/93	209.	ND	ND	1.46	1900	0.004	0.285	2.8	0.012	0.009	0.021
G-22-1	7/6/93	231.	ND	ND	1.68	3700	0.005	0.02	3.1	0.005	0.001	0.006
G-23-1	7/8/93	230.	ND	22.	1.48	ISM	0.016	0.214	2.3	0.007	0.007	0.014
G-23-2	7/8/93	194.	ND	3.	0.72	ISM	–0.0091	0.371	2.2	0.032	0.027	0.059
G-24-1	7/8/93	187.	ND	11.	0.49	ISM	0.0949	0.567	2.1	0.038	0.03	0.068

(continued)

* Total Uranium
† Plutonium-239 and -240
‡ ND—Not Detectable
** ISM—Insufficient Soil Moisture
†† CON—Sample Consumed, No Data
‡‡ Total plutonium-238, -239, and -240

Table 1 (continued): 1993 TA-54 Area G (OU 1148) perimeter soil data. Samples can be located on the maps of Figures 3 through 12 by referring to the sample location numbers listed in the first column of this table. Please note that negative values sometime result from counting statistics when average background activities are subtracted from gross analytical results.

Sample		XRF data			Soil moisture	Radioisotope data						
		Ba	Hg	Pb		^{3}H	^{241}Am	^{137}Cs	U*	^{238}Pu	^{239}Pu†	Total Pu‡‡
Location	Date	(µg/g)	(µg/g)	(µg/g)	(wt %)	(pCi/L)	(pCi/g)	(pCi/g)	(µg/g)	(pCi/g)	(pCi/g)	(pCi/g)
G-24-2	7/8/93	213.	ND	27.	4.33	100	0.0552	1.11	2.	0.007	0.045	0.052
G-25-1	7/8/93	222.	ND	6.	1.8	ISM	0.116	1.75	4.5	0.007	0.058	0.065
G-26-1	7/8/93	223.	5.	26.	2.83	ISM	0.151	1.7	4.3	0.009	0.08	0.089
G-27-1	7/8/93	204.	ND	8.	1.78	ISM	0.0757	0.898	3.5	0.005	0.033	0.038
G-28-1	7/8/93	234.	ND	5.	1.	100	0.107	0.232	2.5	0.003	0.006	0.009
G-28-2	7/8/93	153.	4.	6.	0.68	100	0.23	0.74	2.1	0.011	0.027	0.038
G-28-3	7/8/93	131.	6.	14.	0.77	100	0.0915	0.376	2.5	0.063	0.054	0.117
G-29-1	7/8/93	225.	ND	1.	0.79	1000	0.132	0.395	1.9	0.059	0.025	0.084
G-29-2	7/8/93	170.	ND	3.	1.17	2200	0.123	0.741	2.4	0.007	0.025	0.032
G-29-3	7/8/93	165.	6.	ND	0.7	11700	0.191	0.443	2.9	0.013	0.012	0.025
G-30-1	7/8/93	139.	ND	ND	0.63	2000	0.218	0.39	3.2	0.041	0.043	0.084
G-31-1	7/8/93	149.	ND	4.	2.5	11400	0.109	0.982	3.6	0.023	0.065	0.088
G-31-2	7/8/93	180.	ND	23.	0.34	1000	0.094	0.376	2.4	0.004	0.01	0.014
G-31-3	7/8/93	170.	ND	ND	0.37	500	0.124	0.231	2.	0.004	0.009	0.013
G-32-1	7/8/93	164.	ND	11.	1.12	2000	0.0604	0.787	2.2	0.007	0.028	0.035
G-32-2	7/8/93	164.	ND	3.	1.31	800	0.196	0.495	2.8	0.007	0.024	0.031
G-32-3	7/8/93	188.	ND	4.	1.3	500	0.0957	0.438	2.8	0.012	0.027	0.039
G-33-1	7/8/93	220.	ND	14.	1.49	300	0.0567	1.17	3.4	0.009	0.107	0.116
G-34-1	7/8/93	94.	ND	7.	0.35	ISM	0.0643	0.159	2.	0.007	0.018	0.025
G-34-2	7/8/93	154.	ND	ND	0.91	100	0.207	0.405	2.8	0.002	0.201	0.203
G-34-3	7/8/93	168.	ND	2.	1.01	100	0.0185	0.144	3.1	0.001	0.018	0.019
G-34-4	7/8/93	199.	ND	10.	0.89	100	-0.0241	0.2	2.7	0.023	0.036	0.059
G-35-1	7/12/93	171.	ND	ND	5.14	3000	<.67	0.21	2.1	0.013	0.1	0.113
G-35-2	7/12/93	306.	ND	ND	2.81	5700	<.61	0.97	2.2	0.004	0.042	0.046
G-36-1	7/12/93	187.	ND	14.	8.65	1400	1.08	0.69	2.2	0.03	0.216	0.246
G-36-2	7/12/93	183.	ND	ND	3.58	2800	0.64	0.1	1.9	0.002	0.014	0.016

(continued)

* Total Uranium
† Plutonium-239 and -240
‡ ND—Not Detectable
** ISM—Insufficient Soil Moisture
†† CON—Sample Consumed, No Data
‡‡ Total plutonium-238, -239, and -240

Table 1 (continued): 1993 TA-54 Area G (OU 1148) perimeter soil data. Samples can be located on the maps of Figures 3 through 12 by referring to the sample location numbers listed in the first column of this table. Please note that negative values sometime result from counting statistics when average background activities are subtracted from gross analytical results.

Sample		XRF data			Soil moisture	Radioisotope data						
		Ba	Hg	Pb		^{3}H	^{241}Am	^{137}Cs	U*	^{238}Pu	^{239}Pu†	Total Pu‡‡
Location	Date	(µg/g)	(µg/g)	(µg/g)	(wt %)	(pCi/L)	(pCi/g)	(pCi/g)	(µg/g)	(pCi/g)	(pCi/g)	(pCi/g)
G-38-1	7/12/93	245.	ND	ND	3.33	2600	<0.43	0.07	1.9	0.041	1.944	1.985
G-38-2	7/12/93	165.	ND	ND	2.74	127600	<0.53	<0.05	1.7	0.065	0.691	0.756
G-39-1	7/12/93	163.	ND	10.	10.66	800	<0.56	<0.06	1.9	0.844	0.35	1.194
G-39-2	7/12/93	189.	ND	ND	3.78	3600	<0.44	<0.05	1.1	0.052	0.131	0.183
G-40-1	7/12/93	126.	ND	ND	3.4	3100	<0.21	0.3	2.3	3.298	0.32	3.618
G-40-2	7/12/93	136.	ND	ND	3.98	2600	<0.17	0.22	2.	2.045	0.189	2.234
G-41-2	7/12/93	134.	ND	ND	4.06	2300	<0.26	0.45	2.8	1.485	0.062	1.547
G-42-1	7/12/93	77.	ND	3.	3.3	5400	<0.25	0.23	2.2	2.11	0.727	2.837
G-43-1	7/12/93	124.	ND	ND	4.71	11700	<0.44	<0.06	2.5	0.516	0.44	0.956
G-43-2	7/12/93	204.	ND	ND	5.18	6300	<0.3	0.36	2.1	0.286	0.164	0.45
G-44-1	7/12/93	131.	ND	ND	3.74	110800	<0.51	<0.09	2.7	1.134	0.433	1.567
G-45-1	7/12/93	136.	ND	ND	3.24	117200	<0.43	<0.08	2.4	4.987	0.368	5.355
G-46-1	7/12/93	148.	ND	ND	8.68	18800	0.33	1.37	2.4	2.152	0.609	2.761
G-46-2	7/12/93	193.	ND	ND	2.55	21100	<0.25	0.24	2.5	2.314	0.073	2.387
G-47-1	7/12/93	251.	ND	21.	2.77	7100	0.54	0.45	2.4	0.126	3.4	3.526
G-48-1	7/13/93	273.	ND	ND	3.23	5450	0.162	0.74	2.11	0.099	0.237	0.336
G-48-2	7/13/93	239.	ND	23.	2.34	5900	0.52	0.42	2.05	0.149	0.923	1.072
G-48-3	7/13/93	217.	ND	ND	2.17	16100	0.469	0.09	1.87	0.185	1.613	1.798
G-49-1	7/13/93	180.	ND	ND	12.77	1100	0.677	0.31	2.58	0.106	2.	2.106
G-50-1	7/13/93	254.	ND	10.	2.79	20700	1.02	0.06	2.24	0.083	0.315	0.398
G-50-2	7/13/93	313.	ND	ND	2.55	7600	0.4	<0.03	2.45	0.09	0.178	0.268
G-51-1	7/13/93	281.	ND	ND	3.84	39050	0.257	0.15	2.98	0.035	0.034	0.069
G-52-1	7/13/93	227.	ND	8.	0.096	2050	0.008	0.07	1.71	0.007	0.012	0.019
G-52-2	7/13/93	235.	ND	8.	10.3	2300	0.183	0.5	2.8	0.016	0.024	0.04
G-52-3	7/13/93	297.	ND	ND	2.59	3000	0.01	0.39	2.38	0.04	0.051	0.091
G-53-1	7/13/93	243.	ND	ND	3.47	950	204.	0.41	2.91	0.012	0.03	0.042

(continued)

* Total Uranium
† Plutonium-239 and -240
‡ ND—Not Detectable
** ISM—Insufficient Soil Moisture
†† CON—Sample Consumed, No Data
‡‡ Total plutonium-238, -239, and -240

Table 1 (continued): 1993 TA-54 Area G (OU 1148) perimeter soil data. Samples can be located on the maps of Figures 3 through 12 by referring to the sample location numbers listed in the first column of this table. Please note that negative values sometime result from counting statistics when average background activities are subtracted from gross analytical results.

Sample		XRF data			Soil moisture	Radioisotope data						
		Ba	Hg	Pb		^{3}H	^{241}Am	^{137}Cs	U*	^{238}Pu	$^{239}Pu^{\dagger}$	Total Pu‡‡
Location	Date	(µg/g)	(µg/g)	(µg/g)	(wt %)	(pCi/L)	(pCi/g)	(pCi/g)	(µg/g)	(pCi/g)	(pCi/g)	(pCi/g)
G-54-1	7/13/93	204.	ND	ND	2.46	1850	0.151	0.29	1.6	0.015	0.031	0.046
G-54-2	7/13/93	226.	ND	ND	1.35	1200	–0.103	0.18	1.77	0.011	0.03	0.041
G-55-1	7/13/93	288.	ND	ND	2.81	1000	0.167	0.14	2.47	0.009	0.014	0.023
G-57-1	7/13/93	277.	ND	ND	4.06	500	0.183	1.09	4.23	0.009	0.069	0.078
G-58-1	7/13/93	184.	ND	10.	1.26	4250	0.112	<0.03	2.65	0.038	0.019	0.057

* Total Uranium
† Plutonium-239 and -240
‡ ND—Not Detectable
** ISM—Insufficient Soil Moisture
†† CON—Sample Consumed, No Data
‡‡ Total plutonium-238, -239, and -240

Table 2: 1993 TA-54 Area G (OU 1148) water fraction data from single-stage samplers. Samples can be located on the maps of Figures 3 through 12 by referring to the sample location numbers listed in the first column of this table. Please note that negative values sometime result from counting statistics when average background activities are subtracted from gross analytical results.

Sample		Radioisotope data							Water data	
		^{3}H	^{241}Am	^{137}Cs	^{238}Pu	$^{239}Pu^{*}$	Total Pu	Total U	pH	Conductivity
Location	Date	(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	(µg/L)		(µmhos)
G-9-1	8/5/93	-300.	LIA†	LIA	0.044	0.005	0.049	1.918	7.1	40
G-10-2	8/5/93	-100.	LIA	LIA	0.009	0.018	0.027	1.862	7.3	70
G-11-1	8/5/93	0.	LIA	LIA	0.006	0.006	0.012	1.69	7.1	40
G-11-1	8/30/93	-200.	0.042	NS‡	0.002	-0.002	0.002	0.213	6.2	30
G-12-1	8/5/93	-100.	0.018	LIA	0.009	0.007	0.016	0.139	7.2	30
G-12-1	8/23/93	200.	0.023	0.235	0.004	0.004	0.008	0.295	7.7	20
G-12-2	8/5/93	-100.	LIA	LIA	-0.001	0.023	0.023	0.859	7.1	50
G-13-1	7/16/93	200.	0.016	<0.64	0.011	0.023	0.034	5.4	7.1	100
G-13-1	7/23/93	0.	0.024	-0.067	0.016	0.032	0.048	0.79	8.	100
G-13-2	7/16/93	300.	0.063	<0.92	0.022	0.033	0.055	2.33	7.2	110
G-13-2	8/5/93	-200.	LIA	LIA	0.019	0.014	0.033	3.031	7.3	80
G-13-2	7/23/93	200.	0.015	0.541	0.	0.052	0.052	0.496	7.8	90
G-13-3	8/5/93	-300.	LIA	LIA	0.001	0.003	0.004	2.968	7.5	40
G-13-3	8/30/93	0.	0.074	LIA	0.016	-0.002	0.016	1.132	6.3	18
G-13-4	7/16/93	500.	0.058	<0.46	0.053	0.024	0.077	3.69	7.2	250
G-13-4	7/16/93	500.	0.058	39.5	0.053	0.024	0.077	3.69	7.2	250
G-13-4	7/30/93	100.	0.047	0.608	0.017	0.045	0.062	1.874	7.3	290
G-13-5	8/23/93	200.	0.056	0.406	0.046	0.013	0.059	0.878	7.0	130
G-13-5	7/30/93	100.	0.04	0.54	0.025	0.03	0.055	2.01	7.5	290
G-13-6	8/5/93	-100.	LIA	LIA	0.009	0.007	0.016	2.619	7.1	30
G-13-9	8/5/93	100.	LIA	LIA	0.007	0.019	0.026	5.04	7.1	140
G-13-9	8/23/93	-200.	0.049	0.318	0.012	0.002	0.014	0.028	7.1	80
G-14-1	7/16/93	300.	0.099	0.81	0.044	0.037	0.081	3.04	7.2	340
G-14-1	7/23/93	200.	0.046	-0.158	0.005	0.04	0.045	0.628	8.1	100
G-15-1	8/23/93	100.	0.076	0.478	0.006	0.015	0.021	0.735	7.3	100
G-15-1	8/5/93	-100.	LIA	LIA	0.032	0.004	0.036	2.542	7.3	30
G-16-1	8/5/93	-400.	LIA	LIA	0.007	0.029	0.036	1.761	7.1	30

(continued)

* Plutonium-239 and -240

† LIA—Lost in Analysis

‡ NS—None Submitted

Table 2 (continued): 1993 TA-54 Area G (OU 1148) water fraction data from single-stage samplers. Samples can be located on the maps of Figures 3 through 12 by referring to the sample location numbers listed in the first column of this table. Please note that negative values sometime result from counting statistics when average background activities are subtracted from gross analytical results.

Sample		Radioisotope data							Water data	
		^{3}H	^{241}Am	^{137}Cs	^{238}Pu	$^{239}Pu^{*}$	Total Pu	Total U	pH	Conductivity
Location	Date	(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	(µg/L)		(µmhos)
G-16-1	8/30/93	0	0.062	NS	–0.009	0.004	0.004	0.066	6.3	18
G-17-1	7/16/93	400	0.049	1.45	0.005	0.011	0.016	4.8	7.8	50
G-17-1	7/23/93	200	0.038	–0.17	–0.015	0.031	0.031	0.213	8.3	50
G-17-2	7/16/93	500	0.026	0.94	0.012	0.018	0.03	2.89	7.7	40
G-17-2	7/23/93	300	0.033	–0.299	0.008	0.008	0.016	0.15	8.	50
G-17-3	8/23/93	–100	0.003	0.03	0.005	–0.006	0.005	0.044	7.6	20
G-17-3	8/5/93	400	0.	LIA	0.002	0.01	0.012	1.72	7.3	50
G-18-1	8/23/93	200	0.031	0.226	0.006	–0.002	0.006	0.079	7.7	20
G-18-1	8/5/93	–200	0.06	LIA	0.016	0.014	0.03	1.8	7.5	60
G-18-3	7/16/93	300	0.079	<.89	0.025	0.015	0.04	4.42	7.4	50
G-18-3	7/23/93	100	0.012	–0.47	0.	0.009	0.009	0.09	7.5	60
G-19-1	7/30/93	200	0.06	1.48	0.0059	0.0099	0.0158	1.531	7.7	50
G-19-1	9/14/93	200	0.04	0.552	0.001	0.013	0.014	0.808	8.6	80
G-19-2	8/5/93	–400	0.029	LIA	0.014	0.006	0.02	0.0262	7.3	30
G-19-2	8/30/93	200	0.023	NS	–0.002	0.017	0.017	0.058	6.2	20
G-21-1	7/16/93	300	0.157	<1.22	0.147	0.049	0.196	16.34	7.	440
G-21-1	7/30/93	100	0.054	1.23	0.008	0.029	0.037	4.54	7.8	190
G-21-2	7/16/93	100	0.157	2.01	0.112	0.126	0.238	6.45	7.1	460
G-21-2	7/30/93	200	0.05	0.448	0.023	0.02	0.043	2.88	7.7	220
G-22-1	8/5/93	–300	LIA	LIA	–0.007	0.016	0.016	1.943	7.	70
G-22-1	8/30/93	0	0.027	NS	0.005	0.007	0.012	0.023	6.3	29
G-24-1	8/30/93	1000	0.026	NS	0.011	0.021	0.032	0.13	6.8	31
G-28-1	8/30/93	200	0.055	NS	0.017	0.003	0.02	0.168	6.6	20
G-28-2	8/5/93	–200	0.016	LIA	0.004	–0.003	0.004	0	7.4	50
G-28-2	8/30/93	100	0.04	NS	0.018	0.002	0.02	0.121	6.4	28
G-28-3	8/5/93	0	0.059	LIA	0.024	0.015	0.039	1.374	7.5	40
G-28-3	8/30/93	–100	0.02	NS	0.014	0.019	0.033	0.137	6.5	30

(continued)

* Plutonium-239 and -240
† LIA—Lost in Analysis
‡ NS—None Submitted

Table 2 (continued): 1993 TA-54 Area G (OU 1148) water fraction data from single-stage samplers. Samples can be located on the maps of Figures 3 through 12 by referring to the sample location numbers listed in the first column of this table. Please note that negative values sometime result from counting statistics when average background activities are subtracted from gross analytical results.

Sample		Radioisotope data							Water data	
		^{3}H	^{241}Am	^{137}Cs	^{238}Pu	$^{239}Pu^{*}$	Total Pu	Total U	pH	Conductivity
Location	Date	(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	(µg/L)		(µmhos)
G-29-3	8/23/93	2300	0.038	0.269	–0.009	0.022	0.022	0.008	7.4	50
G-30-1	8/5/93	200	0.06	LIA	0.018	0.013	0.031	0.822	7.6	70
G-31-2	8/5/93	100	0.022	LIA	0.005	0.021	0.026	2.423	7.6	50
G-31-3	8/23/93	1400	0.048	0.016	0.007	0.014	0.021	0.338	7.5	110
G-32-1	8/5/93	–200	0.029	LIA	–0.013	0.003	0.003	1.682	7.5	50
G-32-1	8/30/93	700	0.038	NS	–0.008	0.013	0.013	0.105	6.3	95
G-34-2	8/30/93	300	0.018	NS	–0.011	0.022	0.022	0.225	6.4	85
G-34-2	9/14/93	300	0.052	0.0608	0.005	0.003	0.008	0.4	8.6	30
G-34-3	8/30/93	100	0.054	NS	0.005	0.013	0.018	0.333	6.3	30
G-34-4	8/5/93	–200	0.081	LIA	–0.003	0.026	0.026	2.673	7.7	40
G-34-4	8/30/93	100	0.015	NS	–0.003	0.021	0.021	0.166	6.4	31
G-36-1	8/5/93	–300	0.04	LIA	0.003	–0.007	0.003	2.312	7.6	60
G-39-3	7/16/93	600	1.02	<1.22	0.218	0.155	0.373	6.73	7.6	130
G-39-3	8/23/94	300	0.099	0.613	0.013	0.057	0.07	0.567	7.6	130
G-39-4	7/23/93	600	0.094	0.146	0.032	0.041	0.073	2.16	7.8	140
G-39-4	7/30/94	400	0.352	0.	0.053	0.128	0.181	5.52	8.5	160
G-41-1	8/5/93	–300	0.091	LIA	0.552	0.035	0.587	5.151	7.6	70
G-41-1	8/30/93	–100	0.183	NS	0.604	0.036	0.64	2.83	7.7	65
G-41-3	7/30/93	300	0.03	1.357	0.002	0.021	0.023	1.228	8.6	40
G-41-3	8/30/93	400	0.02	NS	0.009	0.022	0.031	0.944	6.6	111
G-41-4	7/16/93	400	0.079	0.99	0.097	0.038	0.135	5.76	7.3	140
G-41-4	7/30/93	200	0.049	0.827	0.015	0.054	0.069	0.9	8.5	40
G-41-5	8/5/93	–100	0.062	LIA	0.097	0.008	0.105	2.493	7.6	50
G-42-2	8/30/93	200	0.048	NS	0.017	0.022	0.039	0.598	6.5	21
G-42-3	8/30/93	400	0.03	NS	–0.005	0.028	0.028	0.293	6.4	43
G-42-4	8/5/93	100	0.076	LIA	0.002	0.015	0.017	1.949	7.5	30
G-43-3	8/5/93	200	0.028	LIA	0.041	–0.004	0.041	0.848	6.5	28

(continued)

* Plutonium-239 and -240
† LIA—Lost in Analysis
‡ NS—None Submitted

Table 2 (continued): 1993 TA-54 Area G (OU 1148) water fraction data from single-stage samplers. Samples can be located on the maps of Figures 3 through 12 by referring to the sample location numbers listed in the first column of this table. Please note that negative values sometime result from counting statistics when average background activities are subtracted from gross analytical results.

Sample		Radioisotope data							Water data	
		^{3}H	^{241}Am	^{137}Cs	^{238}Pu	$^{239}Pu^{*}$	Total Pu	Total U	pH	Conductivity
Location	Date	(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	(µg/L)		(µmhos)
G-44-2	8/5/93	–200	0.02	LIA	0.013	0.012	0.025	1.923	7.2	50
G-44-3	8/5/93	400	0.05	LIA	0.017	0.013	0.03	0.303	7.2	40
G-44-3	8/30/93	200	0.035	LIA	LIA	LIA	LIA	0.005	7.5	50
G-45-2	7/16/93	300	0.025	<1.67	0.023	0.034	0.057	4.26	7.8	30
G-45-2	7/23/93	100	0.01	0.072	0.014	0.056	0.07	1.55	8.	30
G-47-2	8/5/93	–100	LIA	LIA	0.027	–0.002	0.027	2.071	7.3	20
G-49-1	7/23/93	0	0.144	0.141	0.066	0.199	0.265	1.45	7.5	140
G-49-1	7/23/93	400	0.216	1.41	0.01	0.119	0.129	2.06	7.1	900
G-49-2	7/16/93	500	1.08	1.26	0.153	0.593	0.746	0.	6.9	900
G-49-2	7/23/93	0	0.029	–0.429	0.009	0.065	0.074	0.684	7.6	600
G-50-1	7/16/93	1000	0.446	<0.91	0.01	0.045	0.055	7.97	7.3	310
G-50-1	8/30/93	100	0.065	NS	0.	–0.005	0.00	0.782	7.3	310
G-50-3	7/16/93	1100	0.133	0.637	0.019	0.006	0.025	5.44	7.3	410
G-50-3	7/23/93	800	0.011	0.81	0.02	0.03	0.05	1.48	8.	150
G-51-2	7/23/93	0	0.018	0.288	0.033	0.019	0.052	0.1	7.8	80
G-51-2	7/30/93	300	0.03	0.944	0.012	0.006	0.018	0.64	8.1	80
G-51-3	8/30/93	200	0.024	NS	–0.002	0.023	0.023	0.125	6.5	45
G-51-3	7/23/93	500	0.028	0.525	0.011	0.05	0.061	0.4	7.6	80
G-51-4	8/5/93	0	LIA	LIA	0.004	0.015	0.019	2.37	7.5	110
G-51-4	7/23/93	1900	0.029	–0.172	0.	0.01	0.01	0.14	7.5	60
G-55-2	8/5/93	–300	LIA	LIA	0.001	0.044	0.045	0.001	7.3	20
G-56-1	8/5/93	–400	LIA	LIA	0.003	0.001	0.004	0.322	7.3	20
G-56-1	8/30/93	200	0.044	NS	0.001	0.011	0.012	0.133	6.5	15
G-56-2	8/5/93	100	LIA	NS	0.003	–0.003	0.003	1.618	NS	NS
G-56-2	8/30/93	100	0.035	NS	–0.004	0.01	0.010	0.056	6.6	21
G-56-3	8/5/93	–100	LIA	LIA	–0.003	0.018	0.018	0.949	7.7	20
G-56-3	8/30/93	100	0.025	NS	–0.011	0.026	0.026	0.097	6.8	18

(continued)

* Plutonium-239 and -240

† LIA—Lost in Analysis

‡ NS—None Submitted

Table 2 (continued): 1993 TA-54 Area G (OU 1148) water fraction data from single-stage samplers. Samples can be located on the maps of Figures 3 through 12 by referring to the sample location numbers listed in the first column of this table. Please note that negative values sometime result from counting statistics when average background activities are subtracted from gross analytical results.

Sample		Radioisotope data							Water data	
		^{3}H	^{241}Am	^{137}Cs	^{238}Pu	$^{239}Pu^{*}$	Total Pu	Total U	pH	Conductivity
Location	Date	(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	(pCi/L)	(µg/L)		(µmhos)
G-57-2	8/5/93	0	LIA	LIA	0.005	0.004	0.009	0.804	7.4	20
G-58-3	8/5/93	–200	LIA	LIA	0.01	0.02	0.03	2.723	7.3	30
G-58-3	8/30/93	200	0.049	NS	–0.006	0.001	0.001	0.102	6.9	50

* Plutonium-239 and -240
† LIA—Lost in Analysis
‡ NS—None Submitted

Table 3: 1993 TA-54 Area G (OU 1148) sediment fraction data from single-stage samplers. Listed here are the plutonium results for sediment filtered from the single-stage water samples.

Sample		Plutonium Data (pCi/g)		
Location	Date	^{238}Pu	^{239}Pu*	Total Pu†
G-9-1	8/5/93	0.017	0.005	0.022
G-10-2	8/5/93	0.013	0.116	0.129
G-11-1	8/5/93	0.053	0.384	0.437
G-11-1	8/3093	0.042	0.228	0.27
G-12-1	8/5/93	0.031	0.04	0.071
G-12-1	8/23/93	0.081	0.077	0.158
G-12-2	8/5/93	0.017	0.005	0.022
G-13-1	7/16/93	0.021	0.022	0.043
G-13-2	8/5/93	0.081	0.097	0.178
G-13-2	7/16/93	0.015	0.014	0.029
G-13-3	8/5/93	0.012	0.046	0.058
G-13-3	8/30/93	0.194	0.056	0.25
G-13-4	7/16/93	0.042	0.034	0.076
G-13-4	7/30/93	0.106	0.086	0.192
G-13-5	8/23/93	0.045	0.083	0.128
G-13-5	7/30/93	0.167	0.101	0.268
G-13-6	8/5/93	0.032	0.071	0.103
G-13-9	8/23/93	0.023	0.091	0.114
G-13-9	8/5/93	0.041	0.052	0.093
G-14-1	7/16/93	0.027	0.031	0.058
G-15-1	8/23/93	0.105	0.197	0.302
G-15-1	8/5/93	0.231	0.004	0.235
G-16-1	8/5/93	0.129	0.029	0.158
G-16-1	8/30/93	0.126	0.211	0.337
G-17-1	7/16/93	0.034	0.014	0.048
G-17-2	7/16/93	0.012	0.02	0.032
G-17-3	8/23/93	0.09	0.103	0.193
G-17-3	8/5/93	0.032	0.106	0.138
(continued)				

* Plutonium-239 and -240
† Total plutonium-238, -239, and -240

Table 3 (continued): 1993 TA-54 Area G (OU 1148) sediment fraction data from single-stage samplers. Listed here are the plutonium results for sediment filtered from the single-stage water samples.

Sample		Plutonium Data (pCi/g)		
Location	Date	^{238}Pu	$^{239}Pu^{\dagger}$	Total Pu†
G-18-1	8/23/93	0.144	0.086	0.23
G-18-1	8/5/93	0.19	0.226	0.416
G-18-3	7/16/93	0.026	0.014	0.04
G-19-1	7/30/93	0.137	0.06	0.197
G-19-1	9/14/93	0.094	0.107	0.201
G-19-2	8/5/93	0.103	0.208	0.311
G-19-2	8/30/93	0.331	0.429	0.76
G-21-1	7/16/93	0.077	0.035	0.112
G-21-1	7/30/93	0.114	0.039	0.153
G-21-2	7/16/93	0.048	0.055	0.103
G-21-2	7/30/93	0.214	0.09	0.304
G-22-1	8/5/93	0.042	0.049	0.091
G-22-1	8/30/93	0.103	0.098	0.201
G-24-1	8/30/93	0.032	0.259	0.291
G-28-1	8/30/93	0.038	0.111	0.149
G-28-2	8/5/93	0.128	0.003	0.131
G-28-2	8/30/93	0.216	0.111	0.327
G-28-3	8/5/93	0.306	0.015	0.321
G-28-3	8/30/93	0.244	0.119	0.363
G-29-2	8/23/93	0.072	0.137	0.209
G-30-1	8/5/93	0.079	0.013	0.092
G-31-2	8/5/93	0.094	0.021	0.115
G-31-3	8/23/93	0.077	0.083	0.16
G-32-1	8/5/93	0.066	0.003	0.069
G-32-1	8/30/93	0.028	0.063	0.091
G-34-2	8/30/93	0.037	0.155	0.192
G-34-2	9/14/93	0.129	0.147	0.276
G-34-3	8/30/93	0.329	0.632	0.961

(continued)

* Plutonium-239 and -240

† Total plutonium-238, -239, and -240

Table 3 (continued): 1993 TA-54 Area G (OU 1148) sediment fraction data from single-stage samplers. Listed here are the plutonium results for sediment filtered from the single-stage water samples.

Sample		Plutonium Data (pCi/g)		
Location	Date	^{238}Pu	$^{239}Pu^{\dagger}$	Total Pu†
G-34-4	8/5/93	0.015	0.026	0.041
G-34-4	8/30/93	0.367	0.227	0.594
G-36-1	8/5/93	0.005	0.027	0.032
G-39-3	7/16/93	0.321	0.098	0.419
G-39-3	8/23/93	0.054	0.102	0.156
G-39-4	7/30/93	0.582	1.017	1.599
G-41-1	8/5/93	1.188	0.082	1.27
G-41-1	8/30/93	26.61	1.258	27.868
G-41-3	7/30/93	0.132	0.074	0.206
G-41-3	8/30/93	0.003	0.019	0.022
G-41-4	7/16/93	0.104	0.032	0.136
G-41-4	7/30/93	0.451	0.085	0.536
G-41-5	8/5/93	0.182	0.038	0.22
G-42-2	8/30/93	0.271	0.135	0.406
G-42-4	8/5/93	0.623	0.46	1.083
G-43-3	8/3093	0.681	0.272	0.953
G-43-3	8/5/93	1.11	0.193	1.303
G-44-2	8/5/93	0.65	0.1	0.75
G-44-3	8/5/93	0.786	0.182	0.968
G-44-3	8/30/93	1.518	0.256	1.774
G-45-2	7/16/93	0.344	0.018	0.362
G-47-2	8/5/93	0.375	0.087	0.462
G-49-1	7/23/93	0.136	0.665	0.801
G-49-2	7/16/93	0.136	0.768	0.904
G-50-1	7/16/93	0.093	0.157	0.25
G-50-1	8/30/93	0.086	0.207	0.293
G-50-3	7/16/93	0.055	0.054	0.109
G-51-2	7/30/93	0.181	0.161	0.342

(continued)

* Plutonium-239 and -240

† Total plutonium-238, -239, and -240

Table 3 (continued): 1993 TA-54 Area G (OU 1148) sediment fraction data from single-stage samplers. Listed here are the plutonium results for sediment filtered from the single-stage water samples.

Sample		Plutonium Data (pCi/g)		
Location	Date	^{238}Pu	^{239}Pu*	Total Pu†
G-51-3	8/30/93	0.1	0.098	0.198
G-51-4	8/5/93	0.123	0.205	0.328
G-55-2	8/5/93	0.241	0.044	0.285
G-56-1	8/5/93	0.062	0.001	0.063
G-56-1	8/30/93	0.667	0.732	1.399
G-56-2	8/5/93	0.024	0.003	0.027
G-56-2	8/30/93	0.039	0.036	0.075
G-56-3	8/5/93	0.018	0.018	0.036
G-56-3	8/30/93	0.046	0.031	0.077
G-57-2	8/5/93	0.1	0.004	0.104
G-58-3	8/5/93	0.041	0.02	0.061
G-58-3	8/30/93	0.164	0.101	0.265

* Plutonium-239 and -240
† Total plutonium-238, -239, and -240

6.0 PERIMETER SOIL-SAMPLE RESULTS FOR CONSTITUENTS OF INTEREST

6.1 Tritium

The analytical radiochemistry results from CST are presented in Tables 1–2. Figures 3 and 4 depict the perimeter tritium distributions for the soil and single-stage water samples. The tritium values for the water samples depicted in Figure 4 may be an average of measurements made for tritium if several samples were collected after individual storm events at a particular sampling station. For the perimeter soil samples (those samples taken from locations in minor drainages into which we expected sediments to be carried and water to flow during a storm event), there is definitely some elevated tritium activity. From Figure 3, elevated levels of tritium (as high as 117,200 pCi/L) in soil are apparent for sampling locations between monuments G-42 and G-51. These locations are along the eastern half of the north side of Area G. To the east and south of the TRU pads (between monuments G-35 and G-41), the soil samples show slight increases (3000–5000 pCi/L) above baseline tritium levels (100–1000 pCi/L for soils in Area G). One isolated soil sample, G-38-02, on the perimeter at the south edge of the TRU pads, had a relatively high tritium activity (127,600 pCi/L). Adjacent soil samples, however, had soil tritium activities of only several thousand pCi/L. The other area of elevated soil tritium activities is adjacent to the tritium disposal shafts and encompasses sample series 29–31. Soil samples from this area had tritium activities as high as 11,700 pCi/L.

Storm-water runoff (single-stage) samples were also collected in the majority of those locations where perimeter soil samples were taken. We collected 110 water samples by the single-stage-sampler method (at many stations several collections were made on different dates). The analytical chemistry data for these samples are presented in Tables 2 and 3. Only the water fractions of the single-stage samples were analyzed for tritium. The tritium activity of the vast majority (77%) of the samples ranged from reported values of 0–400 pCi/L. Although our detection limit for tritium with 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 generated. We consider the activity range of 0–400 pCi/L to be at the baseline for surface-water runoff at Area G. Six single-stage water samples had tritium activities over 1000 pCi/L, but in FY 93 only one single-stage water sample had a tritium activity greater than 2000 pCi/L. This sample was from location G-29-2, and the tritium activity was 2300 pCi/L. Another sample collected nearby at G-31-3 had a tritium activity of 1400 pCi/L. Both G-29-2 and G-31-3 are adjacent to disposal shafts where significant curies of tritium were disposed.

An important consideration regarding the tritium results for single-stage samplers is that they reflect the surface-soil environment only at the time of the storm event. Recent ambient conditions at a particular location will determine the availability of tritium at the time a sample is taken. When

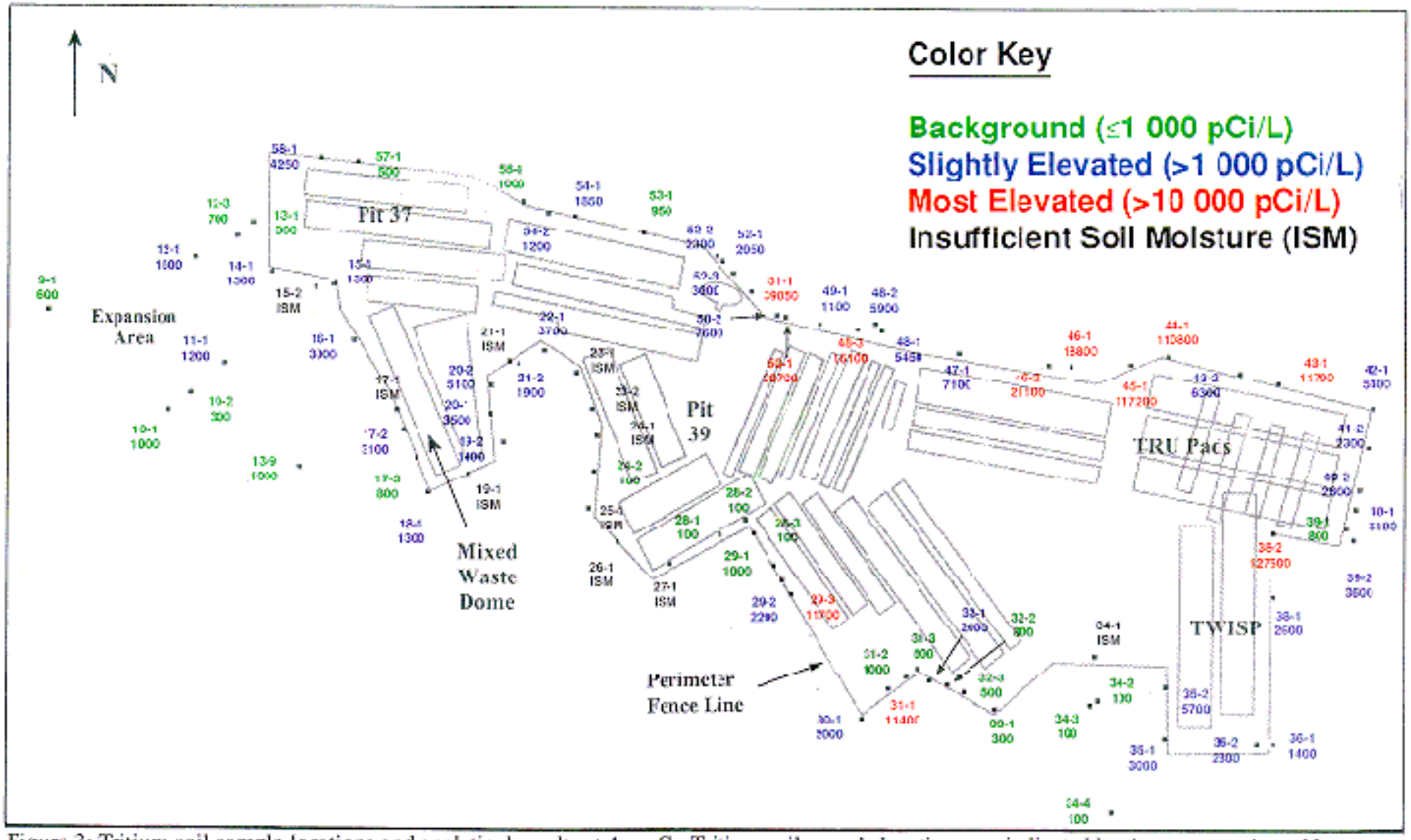

Figure 3: Tritium soil-sample locations and analytical results at Area G. Tritium soil-sample locations are indicated by the square points. Next to each point is a pair of color coded numbers: the hyphenated sample identification number and the tritium concentration in picocuries per liter. Several Area G landmarks are outlined and labeled for orientation: the perimeter fence line, active pits 37 and 39, the expansion area to the west, and the transuranic waste pads (TRU Pads) and the Transuranic Waste Inspection Project (TWISP) to the east.

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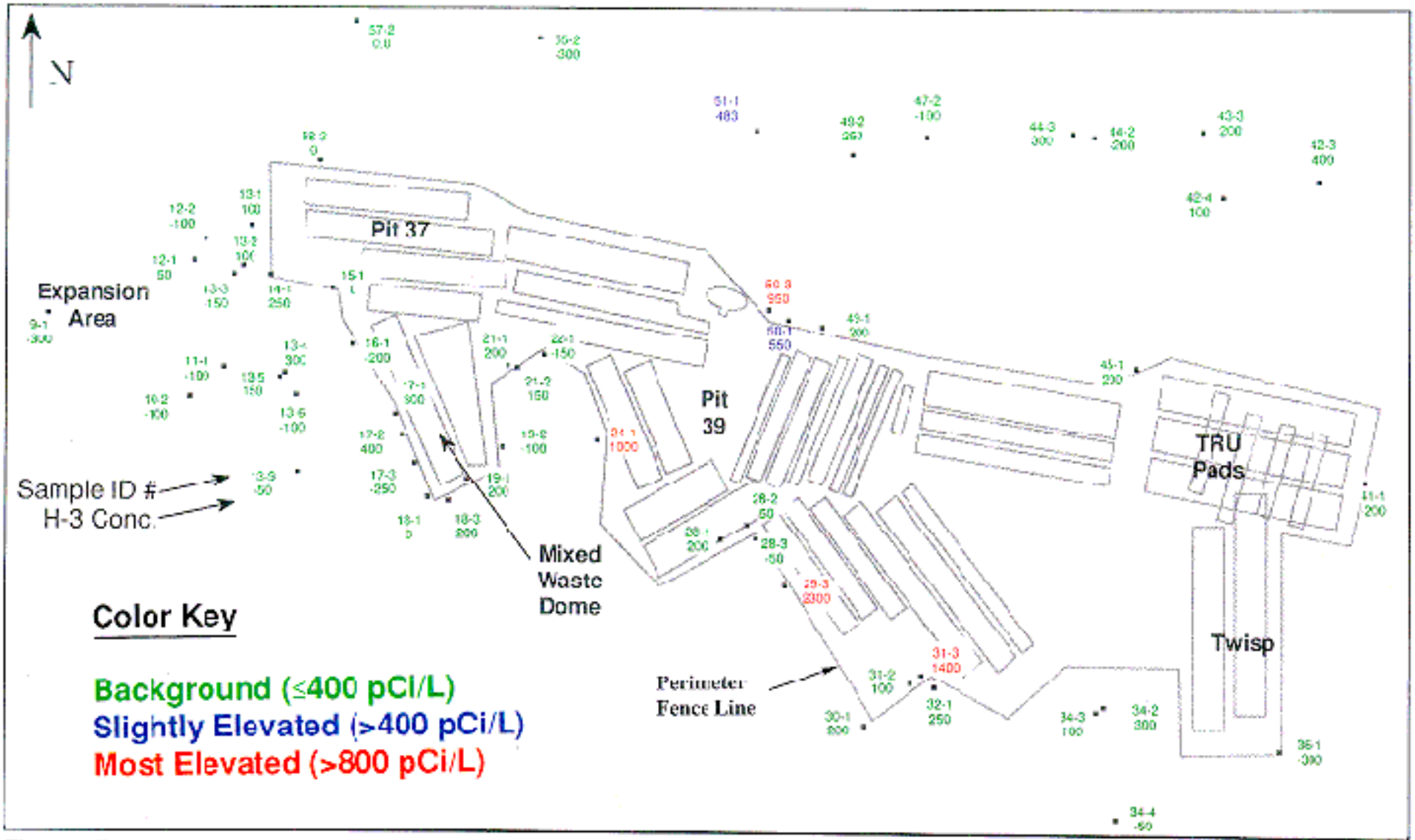

Figure 4: Tritium analytical results for the filtered-water fraction from single-stage samples at Area G. Single-stage water-sample locations are indicated by the square points. Next to each point is a pair of color-coded numbers: the hyphenated sample identification number and the tritium concentration in picocuries per liter of filtered water. Several Area G landmarks are outlined and labeled for orientation: the perimeter fence line, active pits 37 and 39, the expansion area to the west, and the transuranic waste pads (TRU Pads) and the Transuranic Waste Inspection Project (TWISP) to the east.

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precipitation falls, surface moisture interactions are limited to the top few centimeters of surface soils. At that time, any tritium in those surface-soil regions could be mobilized by either the

1. solubilization of ionic forms of tritium or tritiated compounds,
2. erosion of tritium-bound sediments, or
3. upward movement of tritium from the subsurface and entrainment by running water.

With respect to the soil samples, we assumed that tritium was incorporated into the tightly bound water that is associated with sediment particles. When the laboratory prepared a soil sample for tritium analysis, water was distilled out of a weighed sample of soil. The tritium in the distilled water was deemed to represent the tritium content of the soil and was reported as activity per liter of soil moisture.

6.2 Uranium

All perimeter soil samples were also analyzed for total uranium. Total uranium analysis data (Table 1) are reported as the mass of all of the uranium isotopes present in a soil sample. The value reported is thus the total mass (in micrograms) of uranium per gram of soil. For the 83 perimeter soil samples analyzed, the uranium concentrations ranged from 1.1–5.3 μg/g. The average value for total uranium in perimeter soils was 2.59 μg/g, with a standard deviation of ± 0.70 μg/g. The geographic distribution for these soil uranium readings is depicted in Figure 5. Total uranium concentrations were also analyzed for the filtered-water fractions of the single-stage samples. These data are tabulated in Table 2 and their locations are depicted in Figure 6. The uranium values presented in Figure 6 may be an average of several uranium measurements made on water samples collected during multiple precipitation events. The uranium in water varied from less than 1 μg/L to 16.3 μg/L.

6.3 Plutonium Isotopes

During the FY 93 perimeter surface-soil sampling campaign, 83 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 also are presented in Table 1. The plutonium-238 activities range from 0.001 pCi/g to 4.987 pCi/g. The average plutonium-238 activity for this data set is 0.28 pCi/g, with a standard deviation of ± 0.80 pCi/g. The mean value is far above the median value because several samples have elevated plutonium levels. The median plutonium-238 value for the same sample set is 0.012 pCi/g. For plutonium-239, activities range from 0.001–1.944 pCi/g. The mean plutonium-239 activity is 0.21 pCi/g, with a standard deviation of ± 0.51 pCi/g. The plutonium-239 data is also skewed upward, with the median plutonium-239 value for the same sample set at 0.034 pCi/g. For convenience, the total plutonium isotope activity for each sample is also presented in Table 1. In the figures included in this paper, total plutonium isotope activity is plotted by location. Table 1 and Figure 7 show 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 activity) to the east (where there was a great deal of waste-disposal activity). The highest total plutonium activities are associated with the TRU pads and the lower-numbered inactive pits (location series 38–45), with elevated readings also found to the west of the TRU pads along the northern edge of Area G up through location series 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 93 were separated into a water fraction and a sediment fraction. Isotopic plutonium analyses were run on both fractions. These data are included in Tables 2 (filtered water data) and 3 (sediment data) and depicted in Figures 8 and 9. Please note that calculations for total plutonium values in the tables treat as zero any negative isotopic values. For example, the total plutonium reported for the water fraction of sample G-12-2 is 0.023 pCi/L. Also, the plutonium numbers presented in the figures may be an average of several total plutonium values measured for separate samples collected during multiple precipitation events.

6.4 Americium-241

Perimeter surface soils also were analyzed for americium-241, which is always found with plutonium in soils because it is a direct radioactive decay product of plutonium-241. Corroboration of plutonium results is possible by using the attendant americium-241 analytical results. Table 1 includes the soil americium-241 results, while Figure 10 depicts the geographic distribution of the americium-241 readings. The americium-241 results presented in Figure 10 may be the average of several measurements from separate samples collected after multiple precipitation events. The americium-241 results for perimeter soils varied from 0.001 pCi/g to as much as 1.2 pCi/g. A series of samples that were slightly elevated in americium-241 was found in the vicinity of Pit 23, Pits A–H, and adjacent to the tritium disposal shafts in the area of sample series 28–32 (all of these pits and shafts are inactive and covered). A second area with elevated americium-241 soil levels was found adjacent to the TRU pads in the area of series 48–51. These two areas of elevated americium-241 reflect the elevated activities of plutonium in soils reported above in section 6.3 (compare Figures 7 and 10). The collocation of plutonium and americium activity is expected as stated above.

6.5 Cesium-137

Cesium-137 is another isotope of interest at Area G. All perimeter soils and many of the filtered-water fractions for single-stage samples were analyzed by gamma spectroscopy for cesium-137, and these data are found in Tables 1 and 2. Figure 11 illustrates a fairly even distribution of cesium-137 in perimeter surface soils at Area G. Cesium-137 activities in soils range from 0.019 to 3.28 pCi/g. The highest value came from a soil sample collected at the far

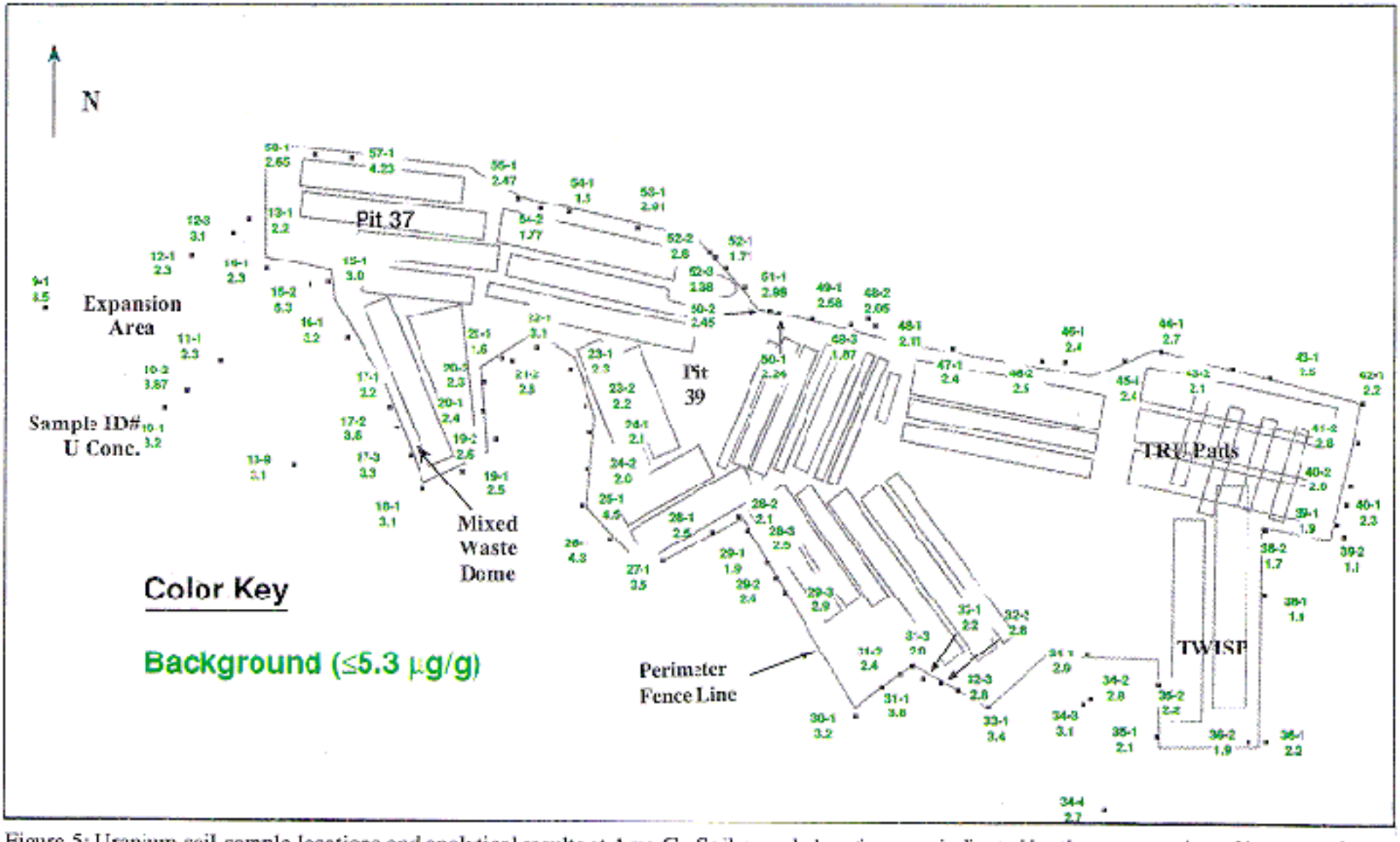

Figure 5: Uranium soil-sample locations and analytical results at Area G. Soil-sample locations are indicated by the square points. Next to each point is a pair of color-coded numbers: the hyphenated sample identification number and the uranium concentration in micrograms per gram of soil. Several Area G landmarks are outlined and labeled for orientation: the perimeter fence line, active pits 37 and 39, the expansion area to the west, and the transuranic waste pads (TRU Pads) and the Transuranic Waste Inspection Project (TWISP) to the east.

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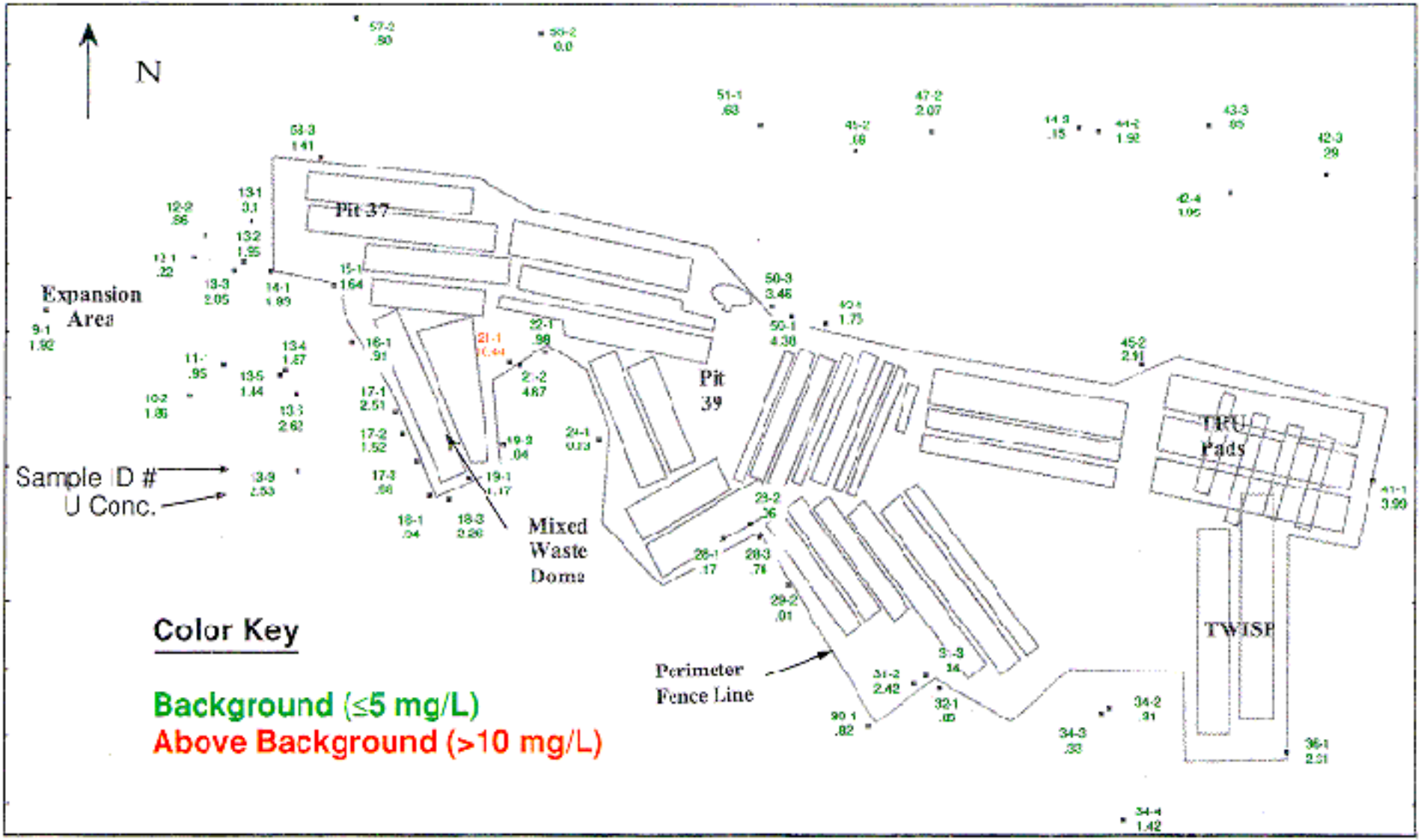

Figure 6: Uranium analytical results for the filtered-water fraction from single-stage samples at Area G. Single-stage-sample locations are indicated by the square points. Next to each point is a pair of color-coded numbers: the hyphenated sample identification number and total isotopic uranium concentration in milligrams per liter of filtered water. Several Area G landmarks are outlined and labeled for orientation: the perimeter fence line, active pits 37 and 39, the expansion area to the west, and the transuranic waste pads (TRU Pads) and the Transuranic Waste Inspection Project (TWISP) to the east.

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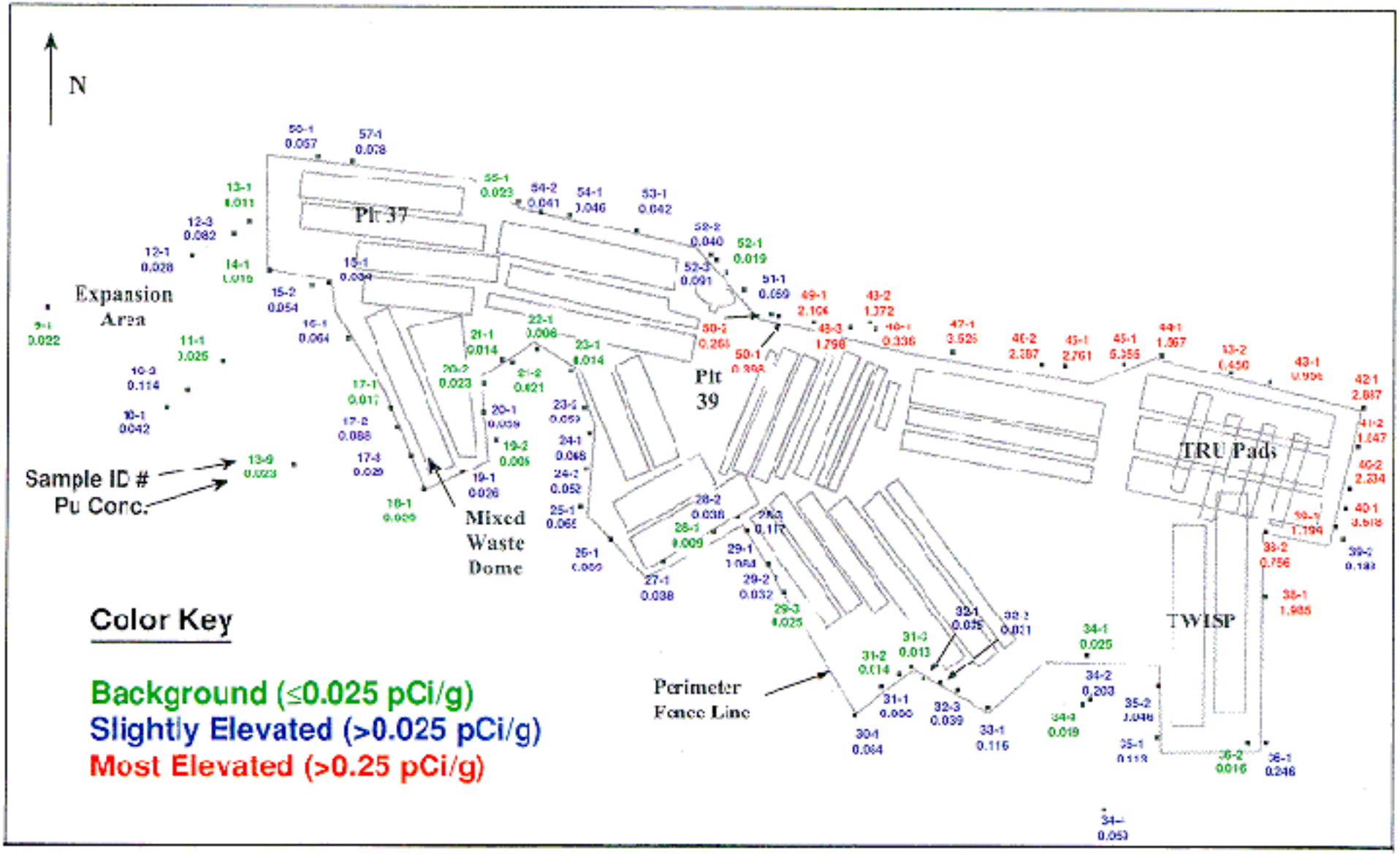

Figure 7: Total isotopic plutonium soil-sample locations and analytical results at Area G. Soil-sample locations are indicated by the square points. Next to each point is a pair of color-coded numbers: the hyphenated sample identification number and the total isotopic plutonium concentration in picocuries per gram of soil. Several Area G landmarks are outlined and labeled for orientation: the perimeter fence line, active pits 37 and 39, the expansion area to the west, and the transuranic waste pads (TRU Pads) and the Transuranic Waste Inspection Project (TWISP) to the east

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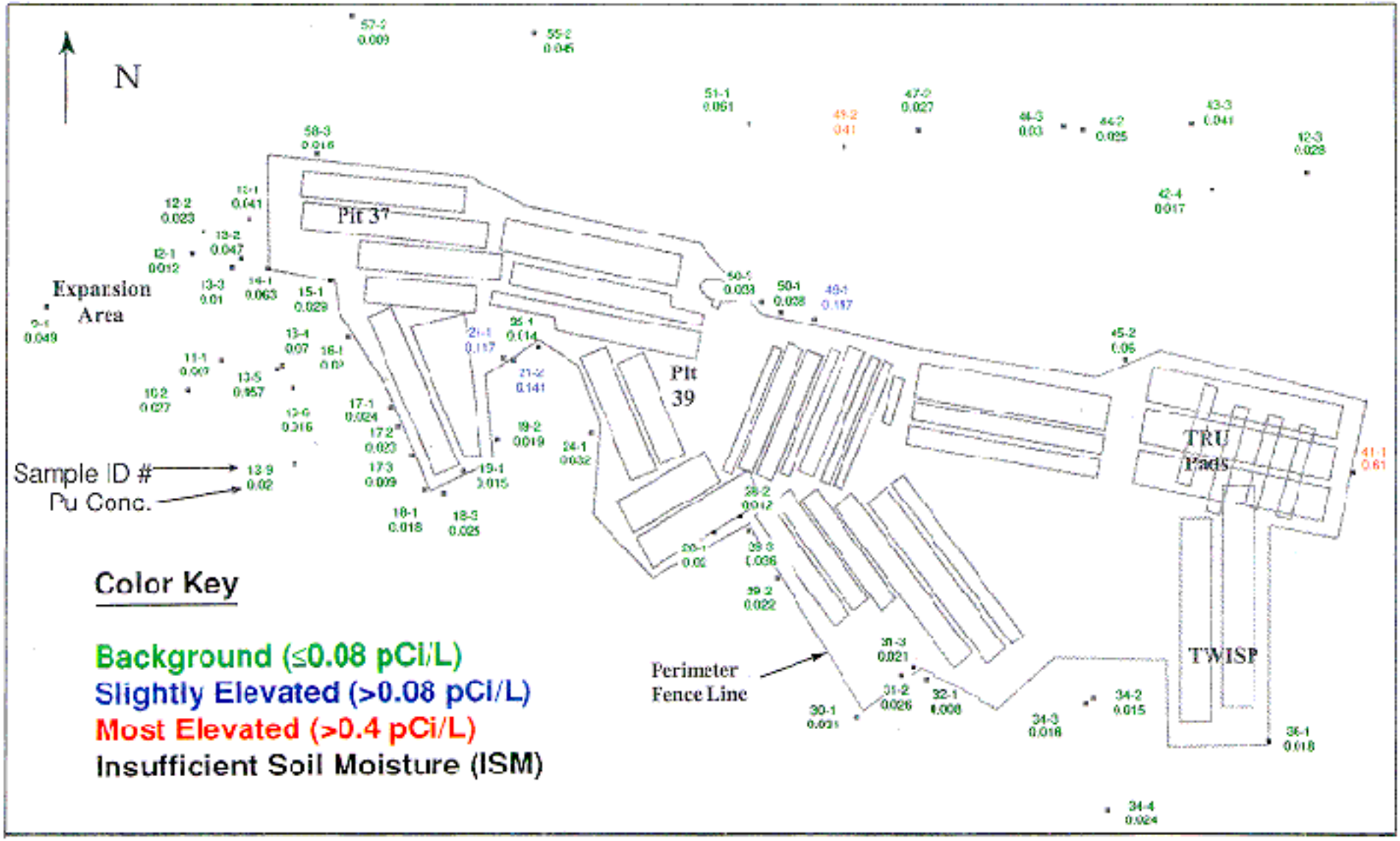

Figure 8: Total isotopic plutonium analytical results for the filtered-water fraction from single-stage samples at Area G. Single-stage water-sample locations are indicated by the square points. Next to each point is a pair of color-coded numbers: the hyphenated sample identification number and total isotopic plutonium concentration in picocuries per liter of filtered water. Several Area G landmarks are outlined and labeled for orientation: the perimeter fence line, active pits 37 and 39, the expansion area to the west, and the transuranic waste pads (TRU Pads) and the Transuranic Waste Inspection Project (TWISP) to the east.

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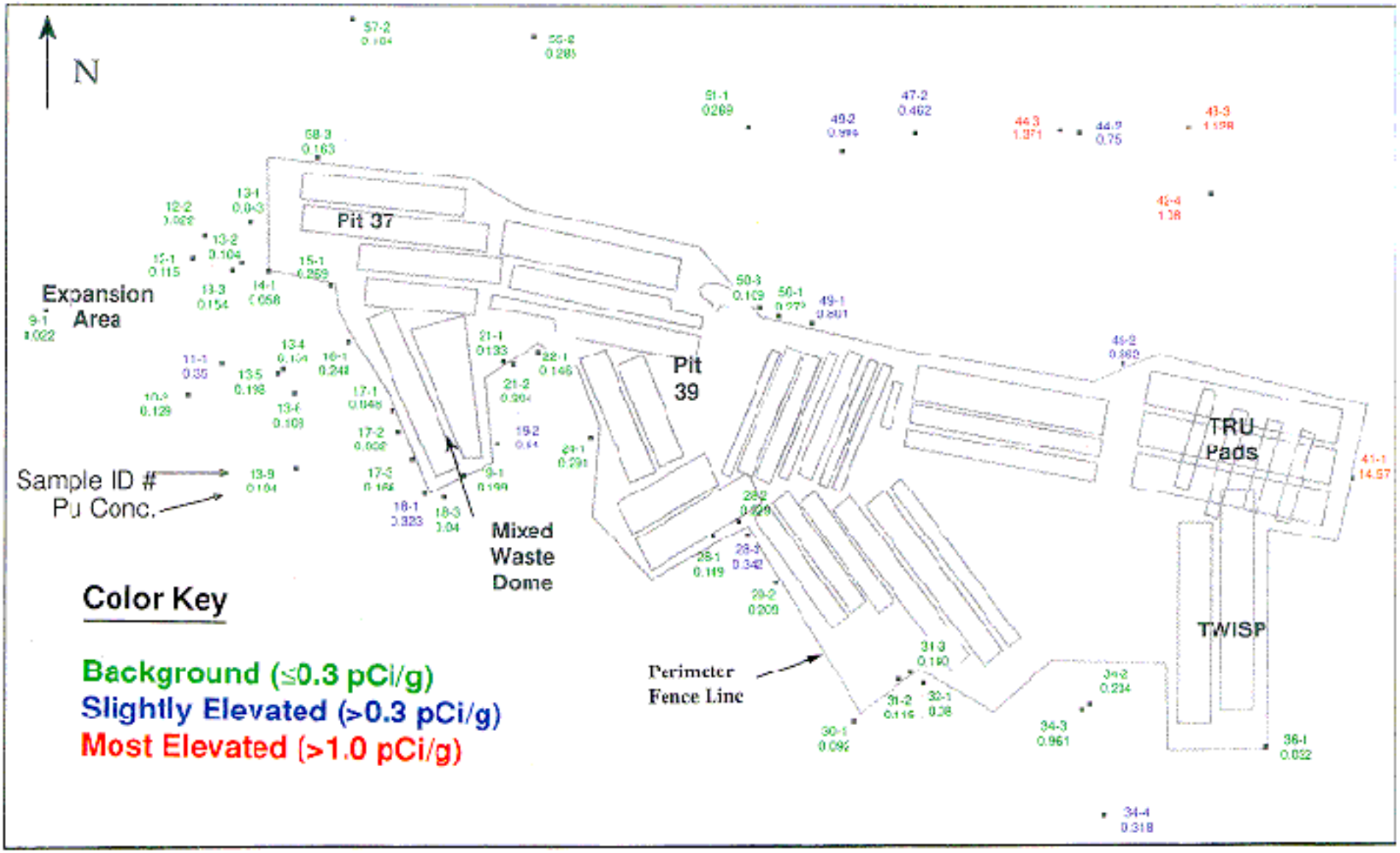

Figure 9: Total isotopic plutonium analytical results for sediments from single-stage samples at Area G. Single-stage-sample locations are indicated by the square points. Next to each point is a pair of color-coded numbers: the hyphenated sample identification number and total isotopic plutonium concentration in picocuries per gram of filtered sediment. Several Area G landmarks are outlined and labeled for orientation: the perimeter fence line, active pits 37 and 39, the expansion area to the west, and the transuranic waste pads (TRU Pads) and the Transuranic Waste Inspection Project (TWISP) to the east.

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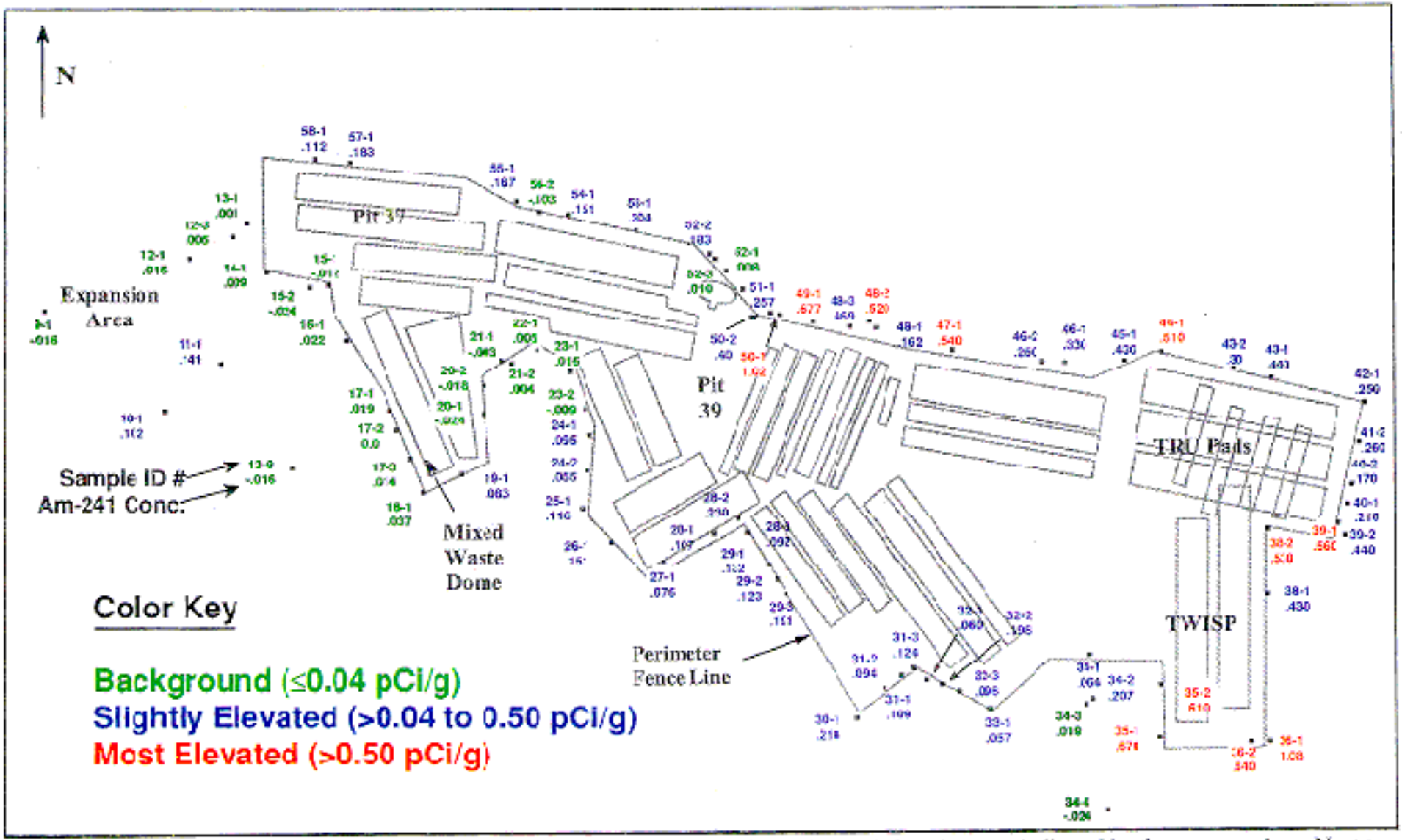

Figure 10: Americium-241 soil-sample locations and analytical results at Area G. Soil-sample locations are indicated by the square points. Next to each point is a pair of color-coded numbers: the hyphenated sample identification number and the americium-241 concentration in picocuries per gram of soil. Several Area G landmarks are outlined and labeled for orientation: the perimeter fence line, active pits 37 and 39, the expansion area to the west, and the transuranic waste pads (TRU Pads) and the Transuranic Waste Inspection Project (TWISP) to the east.

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western end of the site, adjecent to an area where no disposal of radioactive waste has occurred to date. Although there are no cesium-137 values as elevated as 2.38 pCi/g for soil samples collected at the eastern half of Area G (series 24–48), the soil activities for samples collected from this area appear in general to have a somewhat higher cesium-137 activity than soil samples collected from the western end of Area G (a mean of 0.53 pCi/g for the eastern side versus 0.47 pCi/g for the western side).

The cesium-137 geographic distribution for the filtered-water measurements from single-stage samples is depicted in Figure 12. The numbers presented in the figure may be an average of measurements of separate samples collected during multiple precipitation events. To calculate the averages from any one sampling point when more than one sample was collected, any value reported as a "less than" was ignored. These data show a wide distribution of cesium-137 activities around the Area G perimeter. Any interpretation of this distribution may have to await additional results from future studies.

6.6 Metals

Because few data are available on RCRA-regulated metal concentrations in Area G surface soils, we initiated a preliminary analysis of surface soils for three specific metals using XRF. The XRF technique is a nondestructive method that irradiates soil particles with x-rays from one of several sources. Measurements of the subsequent fluorescent radiation can identify particular metals and determine their quantity when internal calibrations are performed using pure metals. We chose three pilot metals for this study: barium, lead, and mercury. All three of these metals have been used by the Laboratory throughout its history for one reason or another. Table 1 includes the results for the XRF determination of soil metals. The concentrations of barium in perimeter soils varied from 77 μg/g to 331 μg/g. The concentrations of lead in perimeter soils varied from nondetects (less than 0.92 μg/g) to 26.7 μg/g. Soil mercury was detected in only 5 out of 83 samples, and of these 5 samples, the highest value was 6.1 μg/g. There is a very high uncertainty for these low values for soil mercury when the XRF technique is used. Barium and lead concentrations around the Area G perimeter are within the expected natural background concentration ranges as reported by Longmire et al. (1995). Longmire did not report soil-background levels for mercury.

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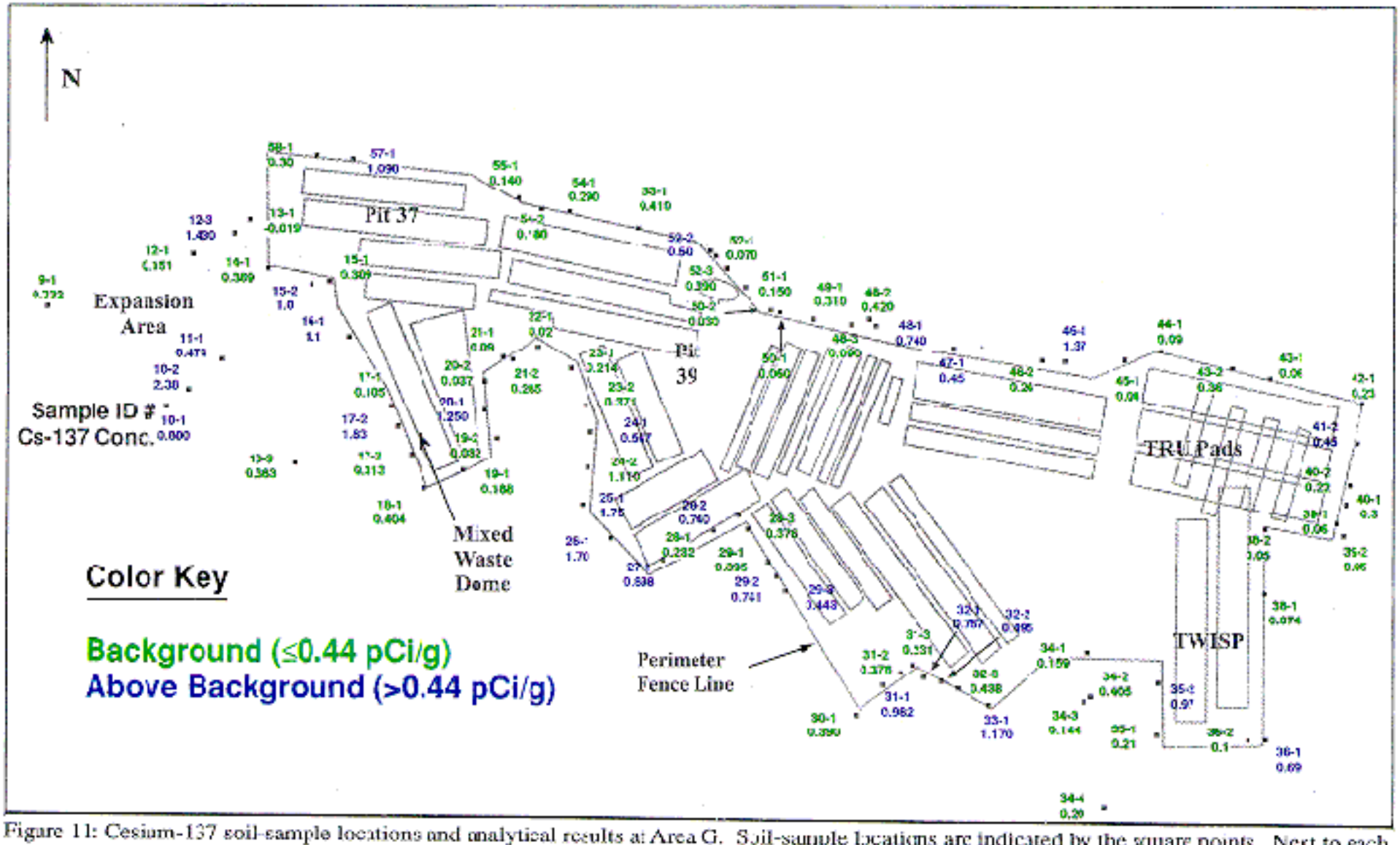

Figure 11: Cesium-137 soil-sample locations and analytical results at Area G. Soil-sample locations are indicated by the square points. Next to each point is a pair of color-coded numbers: the hyphenated sample identification number and the cesium-137 concentration in picocuries per gram of soil. Several Area G landmarks are outlined and labeled for orientation: the perimeter fence line, active pits 37 and 39, the expansion area to the west, and the transuranic waste pads (TRU Pads) and the Transuranic Waste Inspection Project (TWISP) to the east.

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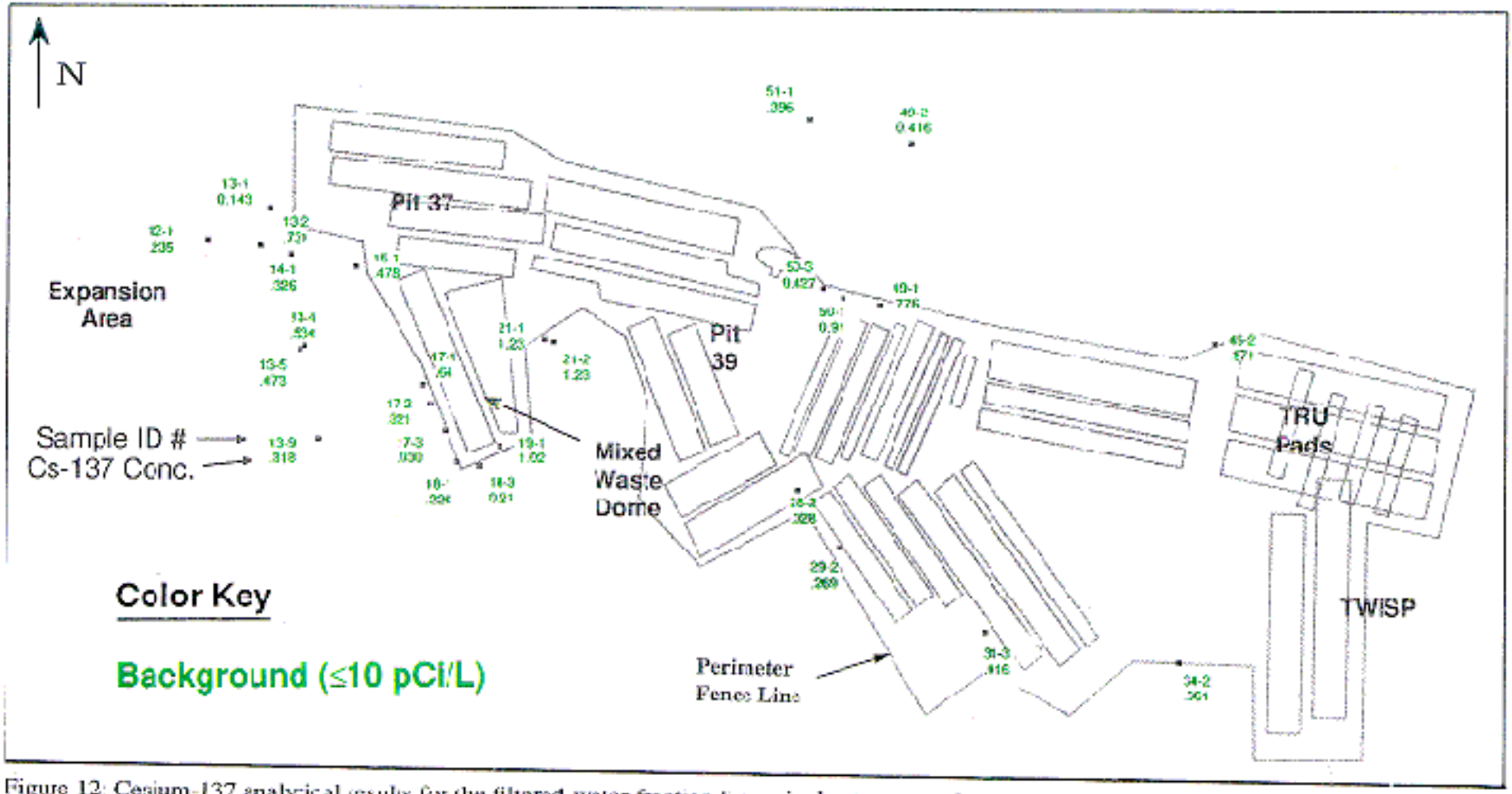

Figure 12: Cesium-137 analytical results for the filtered-water fraction from single-stage samples at Area G. Single-stage water-sample locations are indicated by the square points. Next to each point is a pair of color-coded numbers: the hyphenated sample identification number and the cesium-137 concentration in picocuries per liter of filtered water. Several Area G landmarks are outlined and labeled for orientation: the perimeter fence line, active pits 37 and 39, the expansion area to the west, and the transuranic waste pads (TRU Pads) and the Transuranic Waste Inspection Project (TWISP) to the east.

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7.0 DISCUSSION

7.1 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, weknow that tritium can migrate some distance from its place of origin. Tritium in the soils at Los Alamos has a wide distribution 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.

This investigation began a systematic sampling of perimeter soils at Area G for tritium concentration, which will continue on an annual basis. These analytical results and their interpretation will be an ongoing product of this investigation. An important question that needs to be answered is that of the relationship between the tritium found in surface-soil and water-runoff samples and the actual distribution of tritium at the site. Our goal is to better define the actual tritium distribution in surface soils 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 tritium at Area G are material that has been disposed (buried or emplaced) in one or another of the many shafts, pits, and pads at the site. We expect the probability of finding tritium at elevated levels to be greatest in closest proximity to these sources. Tritium is found in almost all surface soils and in surface-water runoff in the active part of Area G with activities greater than background concentrations. The question is, by what pathway does subsurface tritium migrate to the surface, from which it could possibly be carried offsite? We have identified two primary mechanisms for tritium transport: vapor-phase migration of tritiated water and capillary action. Secondary mechanisms would be evapotranspiration, transport to the surface via vegetation or burrowing animals, and anthropic activities such as excavation of tritium-contaminated soils.

Tritiated water (or other tritiated compounds with high vapor pressures) can migrate in the vapor phase from the subsurface to the surface. Upon reaching the surface, does tritium simply vent into the atmosphere or is there a mechanism for it to concentrate in surface soils? There is no apparent reason for tritiated water vapor to have a preference for either attenuating or concentrating on surface-soil sediments except for the tendency of very dry surface soils to absorb water vapor that may migrate from below.

A second mechanism through which tritium could arrive at the surface (and have some residence time) would be by 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 in the vapor phase, water transported by capillary action can also carry dissolved compounds. Thus, 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. In addition to evaporation, the mechanisms by which tritium can be removed from the surface are

1. exchange with and runoff with surface water,
2. percolation back into the subsurface after a storm event,
3. air reentrainment of surface soils (containing tritium) during periods of high winds or human intervention, and
4. evapotranspiration by vegetation.

These tritium dispersal mechanisms are important because the date and time a sample is taken may have an impact on the measured tritium concentrations in soils and waters. For example, during long dry periods one would expect the movement of tritium on near-surface soils to be from the subsurface to the surface, and ultimately away from the surface by evaporation. The first significant surface-runoff event of the season might yield water samples that have higher or lower than average tritium activities. Similarly, if soil sampling occurred after a long dry period, 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? If soil samples were taken the day after a storm, would a lower than representative tritium concentration be expected because some of the tritiated surface sediments were carried off in surface water or the tritium in the soil diluted by the rain water? Or would a lower tritium concentration be expected because the tritium in the soil exchanged with hydrogen in the precipitation water and was removed?

Is it worthwhile even taking surface-soil and surface-water-runoff samples for tritium? The authors believe it is. If one looks at the maps of Area G tritium activities (Figures 3 and 4), it is evident from the FY 93 data that there are regions of Area G where tritium concentrations are particularly elevated. These regions are predominantly in the perimeter area adjacent to Cañada del Buey between MDA stations 42 and 51. The TRU pad surface and subsurface-soil data also indicate an inventory of tritium in this area, while the other localized areas of elevated tritium are adjacent to the tritium storage shafts (between MDA stations 28 and 31). There are several other isolated locations at Area G where surface soils have elevated levels of tritium.

Unless more is learned about the surface tritium flux (and there are ongoing studies at Area G), a sample taken at any given time can only provide a snapshot of the tritium surface concentration at that particular time. The flux effect may be minimized by taking all samples at the

same time because each surface-soil location would be subjected to the same atmospheric conditions. A simultaneous 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.

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

7.2 Uranium

The measured range of total uranium in perimeter Area G soils is slightly above background concentrations for soil uranium found throughout the Laboratory. Longmire et al. (1995) collected 72 soil samples from background soils at LANL, processed these soils using a nitric acid leaching procedure (Method 3050), and analyzed the extracted metals (including uranium) according to approved SW 846 methods. The mean for total background uranium was 0.94 µg/g with the range for total soil uranium between 0.20–2.40 µg/g. When compared to Longmire's Laboratory-wide background data, perimeter soils at Area G apparently have slightly higher total uranium values. It is possible that the extraction procedure Longmire used (Method 3050) was not sufficiently quantitative because it does not involve as complete a digestion as the method we used to extract soil samples for this study. Longmire also had 75 background soil samples analyzed by neutron activation, a technique which would have yielded analytical results more analogous to the total-soil-digestion method we used. Longmire's mean uranium value using this technique was 3.41 µg/g, a number more in line with the uranium values we report for soils at Area G. In FY 94, soil samples were taken just to the west of active operations at Area G. This area is where Waste Management intends to expand their disposal facilities. These surface-soil samples are being analyzed for total uranium (and other radioisotope and hazardous constituents). The mean value for total uranium from these samples may be more indicative of background levels for Area G than the Longmire background data for LANL. The data on uranium levels in the new expansion area at Area G will be presented at a later date in the FY 94 report on Area G perimeter sampling.

The single-stage water samples were also analyzed for total uranium. Only the filtered-water fractions (after the sediments were filtered out) were analyzed for uranium. The results varied from a high of 16.34 µg/L at G-21-1 to many values less than 1 µg/L. The geographic distribution of the readings for uranium in the water fraction of the single-stage samples is shown in Figure 6.

7.3 Plutonium Isotopes

As stated above in section 6.3, the locations of elevated plutonium readings are consistent with the history of plutonium disposal at Area G. Figure 2 indicates that the lower-numbered pits (Pits 1–24), all the disposal shafts, and the TRU pads are located in the eastern half of Area G. We must consider the location of the disposal units, their age, and the estimated amount of disposed radioactivity to explain why elevated levels of plutonium are being detected. We assume that increased levels of activity in surface soils are directly related to the location, quantity, and age of the disposed material. In other words, there is a greater probability of finding a contaminant adjacent to its place of disposal, greater quantities of disposed contaminants should correlate with higher environmental contaminant levels, and the longer a contaminant is in a specific location, the greater the probability will be that this contaminant will be disseminated. In fact, we find the highest plutonium activities in soils at the eastern end of Area G, in particular adjacent to the TRU pads and disposal pits 2–10.

We also determined that there is a correlation between elevated plutonium levels in the water fraction and elevated plutonium levels in the sediment fraction for the single-stage water samples. Figures 8 and 9 show such a correlation for stations G-39-3, 41-1, 49-1, 41-4, and 49-2. According to our definitions of elevated plutonium values, plutonium levels are elevated in both the water fraction and the sediment fraction for single-stage water samples in these five cases. We also observe a second geographic correlation between elevated plutonium levels in perimeter soils and elevated levels in the sediment fractions of the water samples. Figure 7 (plutonium levels in perimeter soils) and Figure 9 (plutonium levels in single-stage sediments), show that the area adjacent to the TRU pads and disposal pits 2–10 have the highest plutonium levels for both surface-soil and single-stage sediment samples.

Finally, as is known from historical data (Purtymun, 1990) and by examining plutonium isotope activities in the water and sediment fractions for each single-stage sample collected in this study, plutonium is concentrated in the sediment fraction of surface-water runoff. Plutonium and its compounds are relatively water insoluble, thus we expect that plutonium isotope concentrations in the water fraction of single-stage samples will be small. On the other hand, plutonium isotopes can be associated with soil either by ion-exchange adsorption on soil particle surfaces or as insoluble plutonium particles in their own right. If adsorbed on soil particles, plutonium would preferentially bind the smaller-sized particle fractions because of the greater surface area per unit mass of soil. Insoluble plutonium particles would also be expected to have a small diameter. Also, the smaller-sized soil particles would be more easily transported out of Area G than larger particles during a surface-water-runoff event.

7.4 Americium-241

As stated above in Section 6.4, the trend 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 7 and 10.

7.5 Cesium-137

As discussed above in Section 6.5, the highest cesium-137 level found in perimeter soils at Area G is located at a site adjacent to an area where no disposal of radioactive waste has occurred and only slightly elevated levels of cesium-137 in surface perimeter soils have been found. In general, however, there is a slightly higher average level of activity (0.5 pCi/g) at the eastern end of Area G than at the western end (0.47 pCi/g).

7.6 Metals

Our initial results for metals concentrations in perimeter soils at Area G are based on the XRF analytical technique. These results indicate that the three metals tested—barium, mercury, and lead—are within background concentrations for Laboratory soils. The XRF technique, however, is not an accepted EPA method for quantitative metal analysis. For this reason, during the FY 94 field season, some perimeter soils will be collected and submitted to CST-3 for Method 3050 leaching followed by inductively coupled argon plasma and atomic absorption analytical procedures for measuring metals in soil samples. These same samples will also be analyzed by XRF for barium, mercury, and lead so that the accuracy of the XRF technique for these three metals can be determined.

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APPENDIX:
FIDLER PROBE MEASUREMENTS AT AREA G PERIMETER SITES
Environmental Surveillance for Fiscal Year 1993

1.0 PURPOSE

A FIDLER (field instrument for the detection of low-energy radiation) probe was used during FY93 to measure low-energy gamma and x-radiation on surface soils at 70 survey locations around the perimeter of Area G. These 70 locations were surveyed and established in 1991 at minor drainages emanating from Area G in locations that were considered most likely to receive surface-water runoff (and associated sediments) from the site during precipitation events. By configuring the FIDLER probe so that it measured surface-soil gamma activity, we could identify any elevated gamma activity at these specific sites. Such annual measurements of low-energy gamma radiation allow us to determine whether there have been any changes in surface-soil gamma readings. These changes can serve as an early warning of the movement of radioactive contaminants out of Area G.

These FIDLER measurements continue the environmental surveillance of radioactive material disposal areas (MDAs) located at LANL. Until 1991, a PHOSWICH instrument was used for surface-soil, low-energy gamma measurements at Area G. At that time 16 unsurveyed locations were measured annually. In 1991, 70 locations were surveyed and permanent markers were established to standardize the surveillance points. In 1992, a FIDLER probe was purchased and used for Area G low-energy gamma surveys at the 70 MDA survey points. This procedure was continued in FY93.

2.0 METHODOLOGY

A FIDLER probe (a thin-layered sodium iodide crystal/photomultiplier tube assembly) with a multichannel analyzer can focus on regions of interest (ROI) in the low-energy gamma and x-ray spectra, regions that are responsive to radionuclides of interest.

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

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

During field measurements, the probe was mounted using a tripod with the probe's entry window fixed at 12.0 inches from and parallel to the ground surface. A 200-s count was made at each of the 70 MDA survey locations (and at 10 background soil points located immediately across the road from Area J). Three measurements are generated at each survey point: the number of counts per 200-s period for each ROI, 1–3. In Appendix Table 1, the sum of the 200-s counts for the two ROIs that reflect americium/plutonium gamma emissions (ROIs 1 and 2), is listed for each MDA survey point. The 200-s count for ROI 3 (the cesium-137 ROI) is also listed. For example, for location G-1 the sum of the 200-s count for ROI 1 and 2 is listed as 8758 and the 200-s count for ROI 3 is listed as 1712.

3.0 RESULTS AND DISCUSSION

The ten soil-background counts (measured at points located immediately across the road from Area J) yielded an average of 8668 counts per 200 s as the count sum for ROIs 1 and 2, and 1667 counts per 200 s for ROI 3. We compare these background averages to the counts measured using the same procedures at each of the 70 MDA survey points around Area G. From this comparison (Table 1), we can see that, except for location G-1 (or MDA-1), the low-energy gamma activity for the other MDA survey points is decidedly higher than background.

A scatter plot of the count sum for ROIs 1 and 2 at each MDA survey point is shown in Appendix Figure 1. The count results at 2 of these locations (G-17 and G-43) are definitely 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 (nearest G-17) serves as storage for thousands of drums of mixed waste. The second dome is over TRU Pad 2. We attribute the higher-than-expected count rate to "shine" that originates from the domes. Shine can be thought of as gamma radiation emanating from a broad source (such as a dome or pile of hot material). Shine manifests itself over larger distances than the 1-ft distance we used for FIDLER counts of ground-surface activity. We were able to determine if there were any counting artifacts introduced by shine by using the following three tests: (1) placing a shield between the suspected shine source and the FIDLER probe, (2) pointing the probe opening away from the suspected source, both of which tests result in lower 200-s counts; and (3) taking a soil sample, which would not exhibit extraordinary gamma activity because the soil itself is not the source of the measured gamma radiation. From these three tests, we determined that the high readings at MDA survey points G-17 and G-43 were due to shine and not high gamma activity in soils.

Finally, the scatter plot (Appendix Figure 1) indicates that all of the MDA survey counts, except for location G-1, are elevated over background. The counts are slightly elevated from points G-2 through G-13 (moving from Area L to the old Area G gate). From MDA survey points G-14 through G-44, which encompass all the MDA survey points from the old gate through the TRU pads, there is a slow upward trend in gamma activity. For MDA survey points

G-45 through G-54, the gamma activity trends first downward through MDA survey point G-51, then upward through MDA survey point G-54. Finally, from MDA survey points G-55 through G-70, the gamma activity trends slowly downwards as the surveillance proceeds westward and out of Area G. At this time we cannot determine whether the observed 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 individual soil gamma activities.

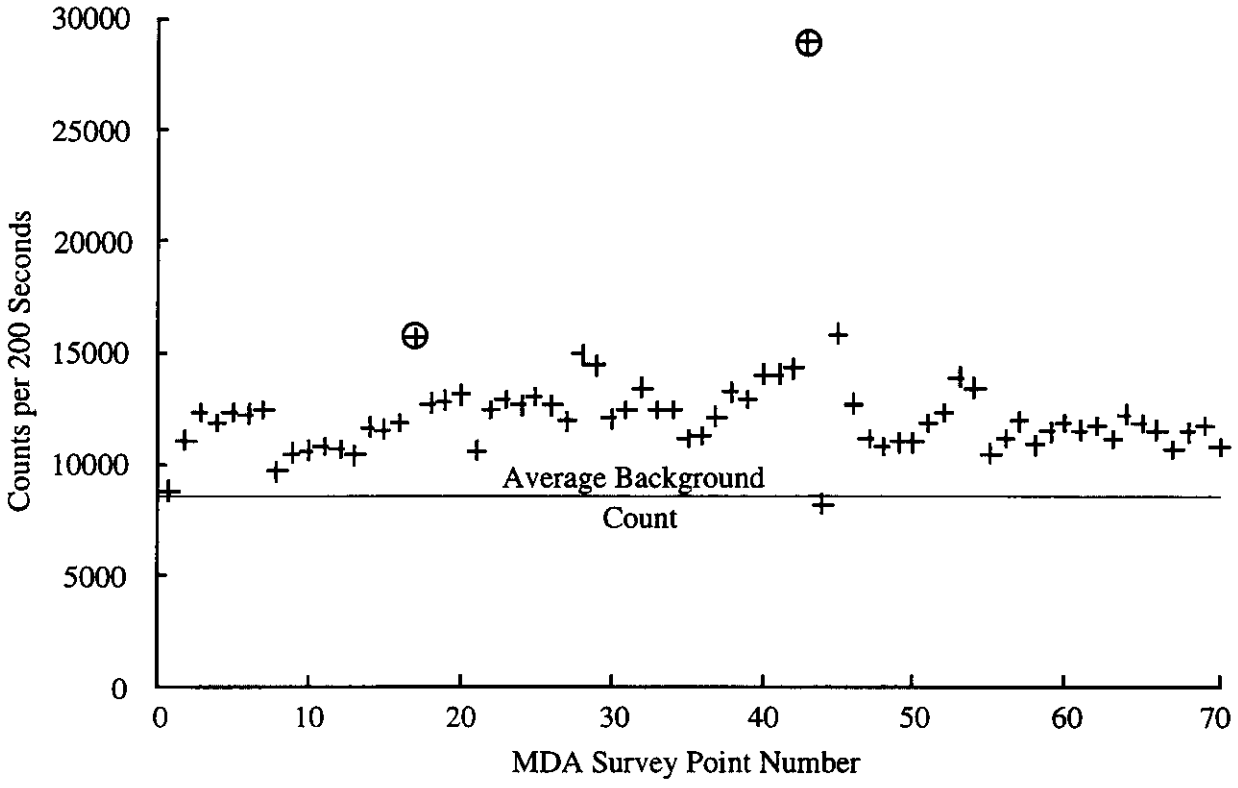
Appendix Table 1: FIDLER surveillance counts of low-energy gamma activity around the periphery of Area G.

MDA Survey Point	Spectroscopic Regions of Interest (Counts/200 s)			
	ROI 1	ROI 2	Σ ROIs (1+2)	ROI 3
G-1	1354	7404	8758	1712
G-2	1759	9371	11130	2026
G-3	1789	10614	12403	2333
G-4	1730	10205	11935	2318
G-5	1885	10491	12376	2418
G-6	1872	10444	12316	2375
G-7	1889	10634	12523	2429
G-8	1689	8002	9691	1942
G-9	1706	8803	10509	1989
G-10	1654	8911	10565	2029
G-11	1743	9060	10803	2152
G-12	1749	8968	10717	2002
G-13	1655	8713	10368	1919
G-14	1958	9717	11675	2254
G-15	1870	9752	11622	2315
G-16	1895	10030	11925	2285
G-17	2462	13236	15698	3044
G-18	1998	10777	12775	2506
G-19	2026	10885	12911	2507
G-20	2084	11056	13140	2588
G-21	1981	8628	10609	2169
G-22	1974	10538	12512	2699
G-23	2070	10874	12944	2764
G-24	1979	10700	12679	2424
G-25	2021	11054	13075	2547
G-26	1995	10687	12682	2330
G-27	1939	10031	11970	2313
G-28	2204	12755	14959	2728
G-29	2175	12323	14498	2672
G-30	1914	10160	12074	2346
G-31	1919	10610	12529	2308
G-32	2112	11322	13434	2499
G-33	1910	10590	12500	2435
G-34	1941	10576	12517	2334
G-35	1812	9426	11238	2205
G-36	1787	9525	11312	2138
G-37	1980	10167	12147	2358
G-38	2244	11026	13270	2943
G-39	2259	10706	12965	3135
G-40	2453	11634	14087	3335

(continued)

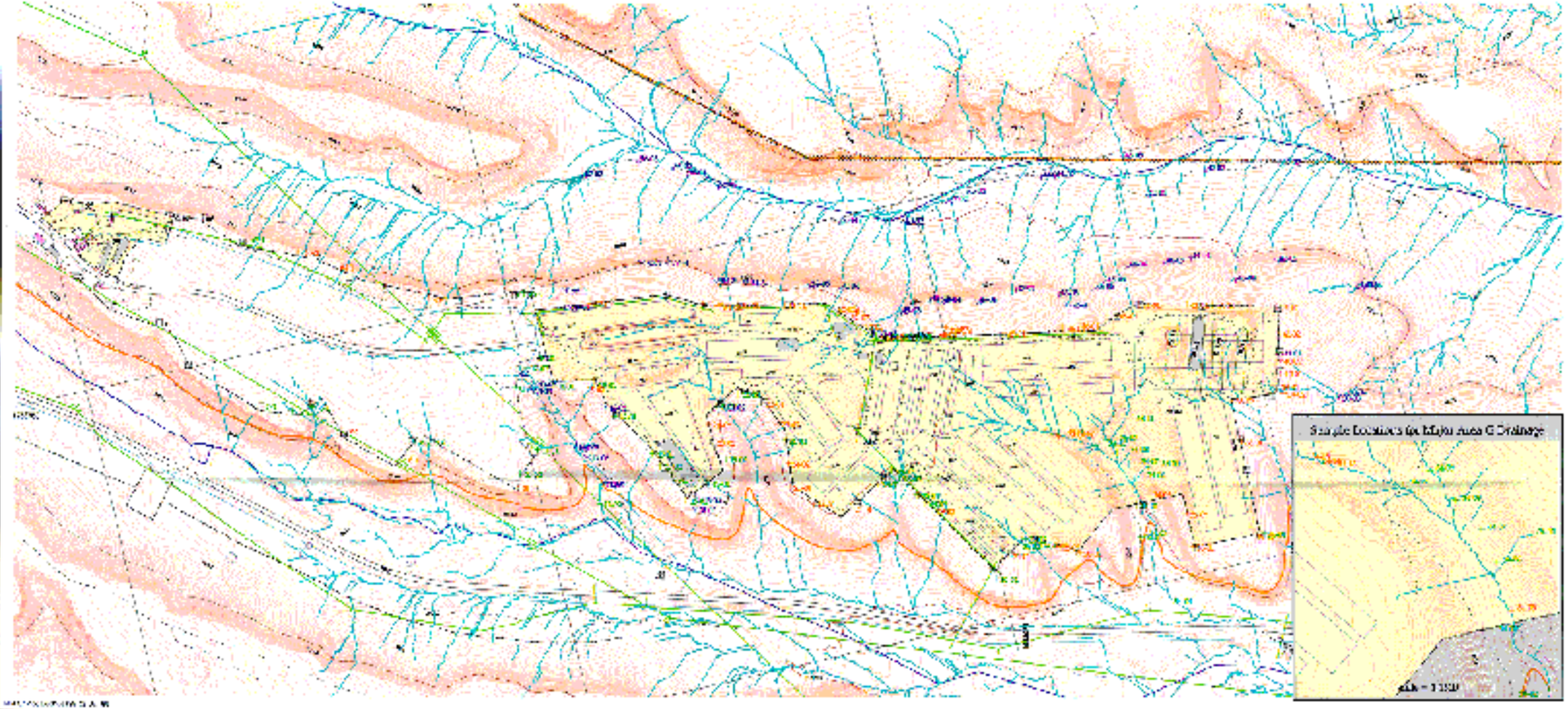
Appendix Table 1 (continued): FIDLER surveillance counts of low-energy gamma activity around the periphery of Area G.

MDA Survey Point	Spectroscopic Regions of Interest (Counts/200 s)			
	ROI 1	ROI 2	Σ ROIs (1+2)	ROI 3
G-41	2560	11548	14108	3235
G-42	2702	11700	14402	3717
G-43	8889	20136	29025	12424
G-44	3410	4826	8236	13832
G-45	2787	13112	15899	3831
G-46	2007	10792	12799	2627
G-47	1767	9471	11238	2251
G-48	1669	9165	10834	2040
G-49	1763	9248	11011	2118
G-50	1763	9233	10996	2029
G-51	1889	10043	11932	2324
G-52	2138	10233	12371	2568
G-53	2745	11245	13990	3686
G-54	2482	11046	13528	3251
G-55	1769	8708	10477	2103
G-56	1848	9324	11172	2124
G-57	1928	10055	11983	2183
G-58	1660	9215	10875	2011
G-59	1929	9521	11450	2156
G-60	1957	9958	11915	2285
G-61	1780	9780	11560	2177
G-62	1848	9947	11795	2160
G-63	1758	9403	11161	2058
G-64	1931	10364	12295	2370
G-65	1860	9998	11858	2214
G-66	1840	9721	11561	2240
G-67	1710	8967	10677	2105
G-68	1739	9776	11515	2123
G-69	1799	10030	11829	2183
G-70	1729	9090	10819	2070
BKG-1	1303	6770	8073	1631
BKG-2	1392	7033	8425	1589
BKG-3	1412	7339	8751	1719
BKG-4	1513	7283	8796	1682
BKG-5	1437	7413	8850	1640
BKG-6	1384	7355	8739	1711
BKG-7	1380	7371	8751	1684
BKG-8	1448	7227	8675	1647
BKG-9	1475	7248	8723	1692
BKG-10	1441	7451	8892	1670



Appendix Figure 1: Scatter plot of FIDLER surveillance counts of low-energy gamma activity around the periphery of Area G. Counts per 200 seconds for the sum of ROIs 1 and 2, spectral regions that indicate americium and plutonium activity, are plotted verses the MDA survey point number. The high values for the circled points at locations G-17 and G-43 were shown to be due to shine artifacts.

OU1148: An G Perimeter Soil and Single Stage Surface Water Sampling Stations



Water Sample location SW-4 contains samples G4-01, G4-02, G4-03, and G4-04

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EMAD