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Soil radionuclide concentrations and preliminary stormwater model assessment at Material Disposal Area G, Los Alamos National Laboratory

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By

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ABSTRACT

Material Disposal Area G (MDA-G) is at Technical Area (TA) 54 at Los Alamos National Laboratory (LANL). MDA-G has been the principal facility for the disposal of low-level, solid-mixed, and transuranic (TRU) waste since 1957, it is currently LANL's primary facility for radioactive solid waste burial and storage. As part of the annual environmental surveillance effort at MDA-G, surface soil samples are collected around the facility's perimeter to characterize possible radionuclide movement off the site through surface water runoff. During 1998, 39 soil samples were collected and analyzed for percent moisture, tritium, plutonium-238 & 239 and americium-241. The results from these samples are compared with baseline or background soil samples collected in an undisturbed area west of the active portion MDA-G to assess radionuclide levels. The 1998 results are also compared to the results from analogous samples collected during 1996 and 97, to assess changes over time in radionuclide activity concentrations in surface soils around the perimeter of MDA-G. The results indicate elevated levels of all the radionuclides assessed in MDA-G surface soils vs the baseline soils. The comparison of 1998 soil data to previous years indicates no significant increase or decrease in radionuclide concentrations; an upward or downward trend in concentrations is not detectable at this time. Continued annual soil sampling will be necessary to realize a trend if one exists. The radionuclide levels found in the perimeter surface soils are significantly above background but still considered relatively low (particularly considering the amount of low-level radioactive waste that has been disposed of at MDA-G over the past 40+ years). The data do indicate that some radioactive material is moving off the site via the surface water runoff/sediment pathway, but in low quantities, which would not be considered a significant risk to human health or the environment. This perimeter surface soil data will be used for planning purposes at MDA-G; techniques to prevent sediment transport off-site will be implemented in the areas where the highest radionuclide concentrations are indicated.

Also presented is a stormwater model evaluation for MDA-G. A test model was developed and evaluated using HEC-HMS stormwater simulation software. The test model was developed for a single drainage/subbasin (out of 10) at MDA-G. Precipitation events at MDA-G with known stormwater discharge quantities were used in an attempt to calibrate the model. After calibration, the model was tested on other known precipitation events. The results of this initial evaluation are positive. Out of the 4 storms tested, the model estimated stormwater intensity and volume close to the known stormwater discharge for 2 of them. The model never underestimated runoff; it was overestimated (desired vs underestimation) in all 4 tests. An accurate tool for estimating stormwater intensities and volume for predicted precipitation events would be invaluable for a facility like MDA-G, for erosion prevention planning and sediment transport estimations. This test model shows some promising results but more work (increased knowledge of site hydrologic parameters, model calibration, testing, etc.) would be necessary to develop a complete, useful, and relatively accurate stormwater model for MDA-G.

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Acronyms and Abbreviations

AA	atomic absorption
cpm	counts per minute
COPC	contaminant of potential concern
CST	Chemical Science and Technology Division, LANL
EPA	Environmental Protection Agency
ER	Environmental Restoration Project, LANL
ESH	Environment, Safety, and Health Division, LANL
FIDLER	field instrument for detection of low-energy radiation
FIMAD	Facility for Information Management and Display
FY	fiscal year
HASP	health and safety plan
HAZWOPER	hazardous waste operations
ICPMS	inductively coupled plasma mass spectral (analysis)
keV	kiloelectron volts (10^3 electron volts)
KPA	kinetic phosphorescence analysis
LANL	Los Alamos National Laboratory
MCA	multichannel analyzer
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
NMED	New Mexico Environment Department
OU	operable unit
pCi	Picocurie (10^{-12} curies)
RAS	Radioactivity/alpha spectroscopy
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
ROI	(spectral) region of interest
SOP	standard operating procedure
SW	solid waste
TA	technical area
TRU	transuranic (waste)
TWISP	Transuranic Waste Inspectable Storage Project
WILD	brand-name surveying station
WSS	Waste Site Studies

1.0 INTRODUCTION

Los Alamos National Laboratory (LANL) is a multidisciplinary research facility owned by the Department of Energy (DOE) and managed by the University of California. The Laboratory is located in north-central New Mexico approximately 60 miles northeast of Albuquerque and 20 miles northwest of Santa Fe (see Figure 1). The Laboratory site covers 43 square miles of the Pajarito Plateau, which consists of a series of fingerlike mesas separated by deep canyons containing ephemeral and intermittent streams that run from west to east. Mesa tops range in elevation from approximately 6,200 ft to 7,800 ft. The eastern portion of the plateau stands 300 ft to 900 ft above the Rio Grande [Rothman, 1992].

MDA-G is at Technical Area (TA) 54 at LANL (see Figure 2). MDA-G has been the principal facility for the disposal of low-level, solid mixed, and transuranic (TRU) waste since 1957; it is currently LANL's primary facility for radioactive solid waste burial and storage. MDA-G consists of 63 acres and is located on the east end of Mesita del Buey, one of the fingerlike mesas in the Los Alamos area (see Figure3) [Fresquez, et al., 1995]. Wastes (contaminated equipment, paper, plastics, clothing, building materials, soils, and process wastes) generated at LANL are placed in pits, trenches, or shafts and then covered with fill material (see Figures 4 and 5). Tritium, uranium, plutonium, and a variety of fission and activation products are the main isotopes in waste materials deposited at MDA-G (U.S. DOE, 1979). In the early years of MDA-G's operation, tritiated liquid wastes were disposed of in shafts.

From the standpoint of the surrounding environment, an important question is whether there has been an environmental impact outside of MDA-G due to the disposal and storage operations that

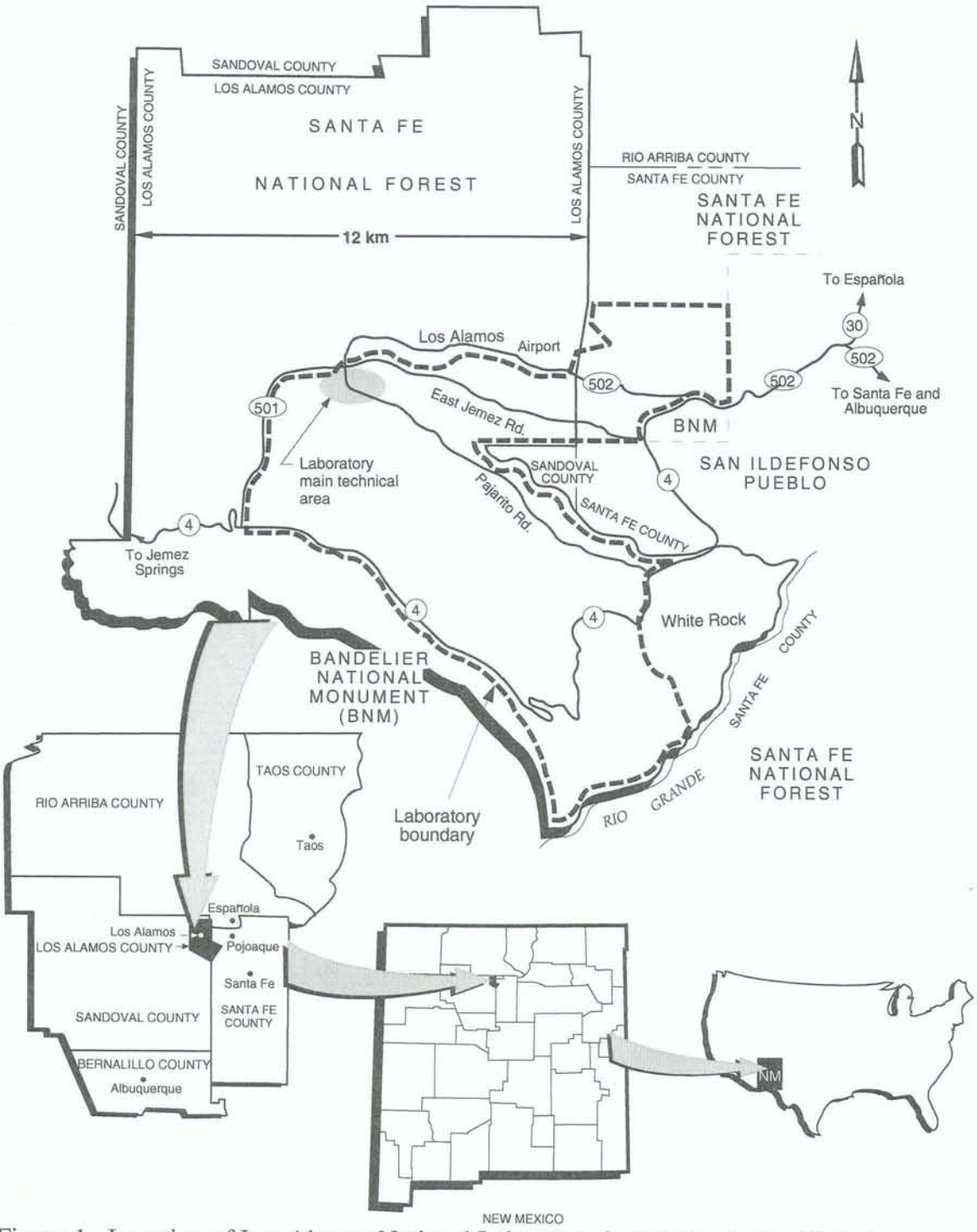


Figure 1. Location of Los Alamos National Laboratory in Relation to the Untied States and New Mexico.

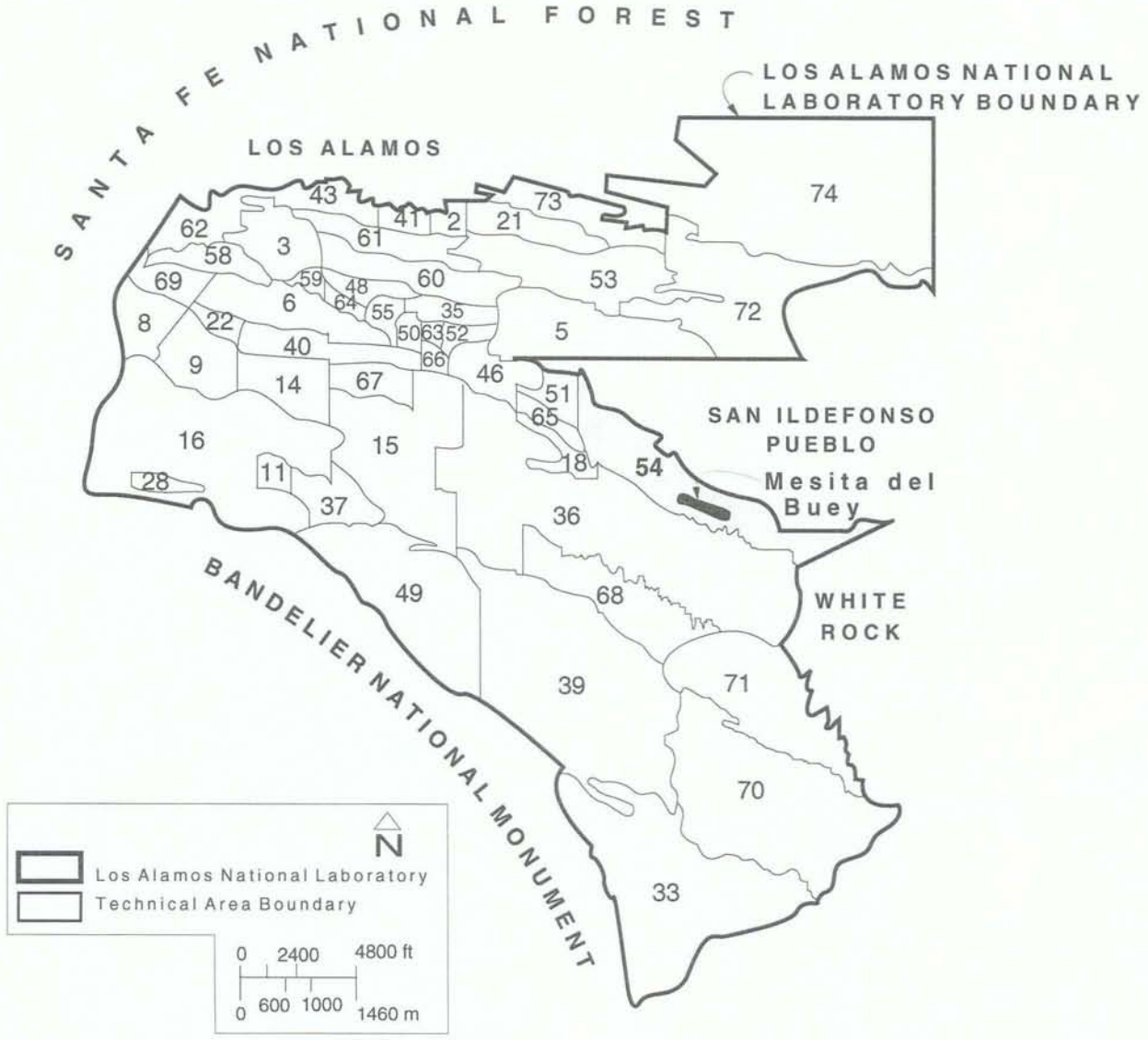


Figure 2. Location of TA-54 and Area G at Los Alamos National Laboratory. The 74 technical areas (TAs) of the Laboratory are shown here, with TA-54 located south of San Ildefonso Indian Reservation property. Area G (shaded in gray) runs along Mesita del Buey and parallels Pajarito Road.

Figure 3. Aerial Photograph of TA-54 / MDA-G and Surrounding Area, NW View (1993).

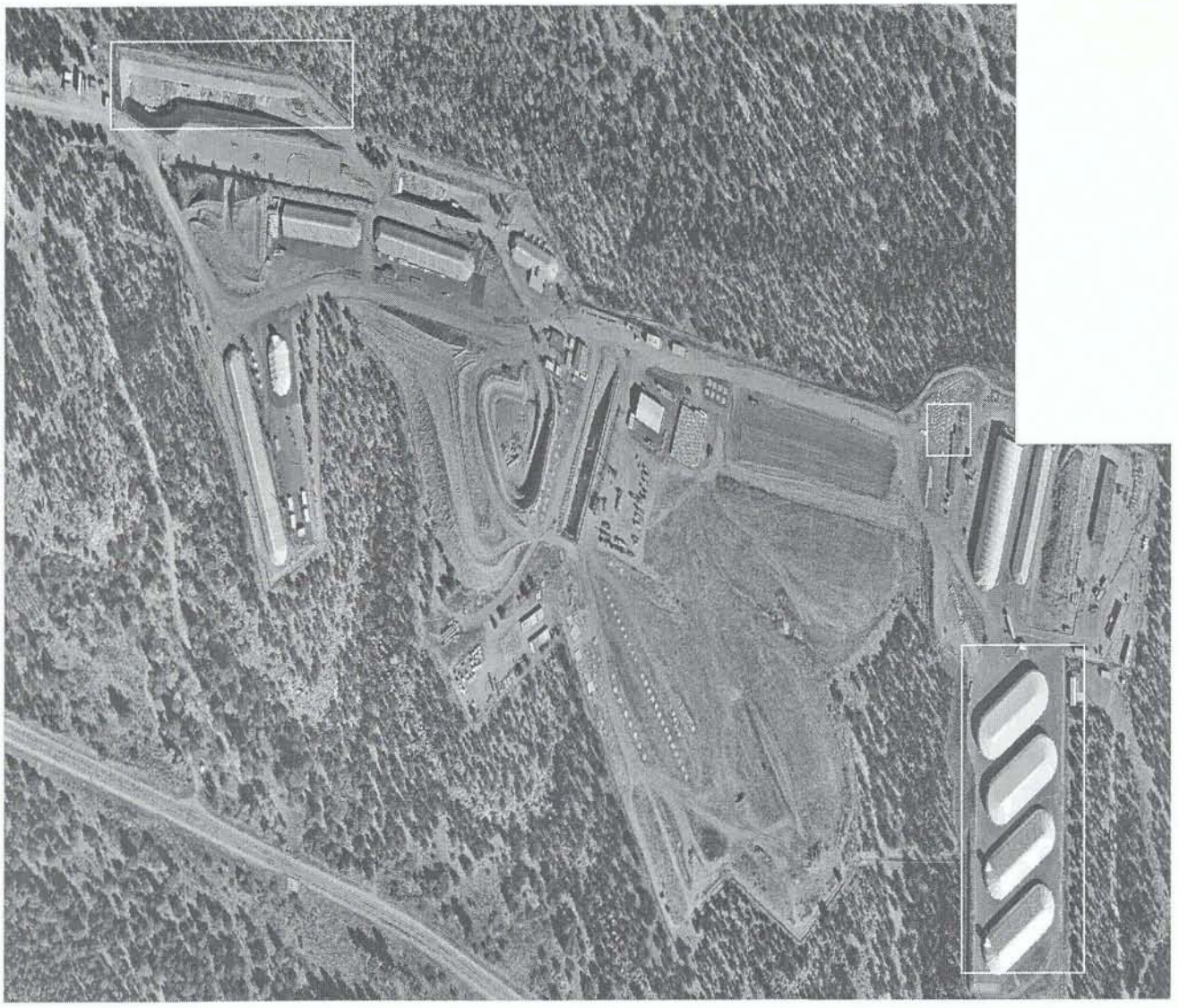
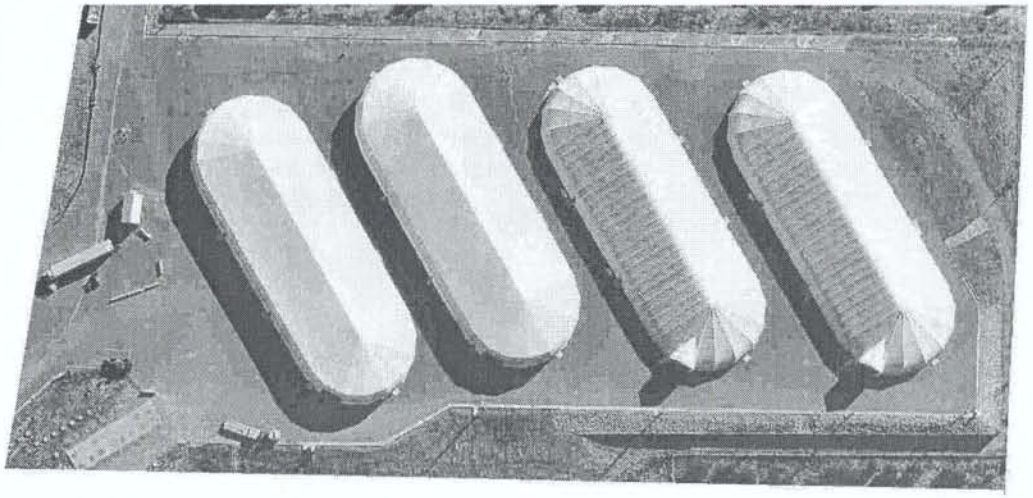
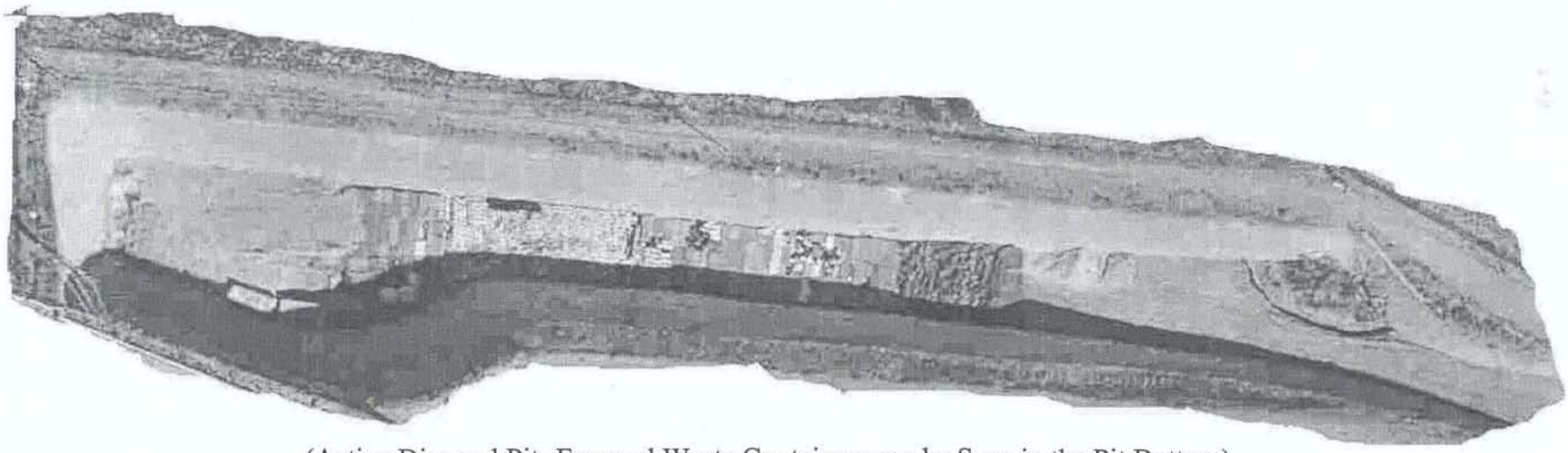


Figure 4. High Resolution Aerial Photograph of MDA-G, White Boxes Indicate Location of Close-ups Seen in Figure 5.



(TRU Waste Storage Domes)

(Concrete Capped Disposal Shafts)



(Active Disposal Pit- Exposed Waste Containers can be Seen in the Pit Bottom)

Figure 5. Close-ups of Waste Management Features at MDA-G (from Figure 4).

have taken place within MDA-G. One aspect of this question is whether contamination associated with surface soil within MDA-G somehow migrates off-site. The two most likely pathways (other than ground water, due to its approximate 900-foot depth and geological conditions) for spread of contaminants from MDA-G surface sediments are airborne dispersion of particulate matter or gases and off-site movement of contaminated sediments by surface water runoff. The principal goal of this investigation is to identify any locations around the perimeter of MDA-G where elevated levels of radionuclides exist and the locations where the probability of off-site migration is highest. Extensive surface soil sampling was initiated in 1993 around the perimeter of MDA-G and continues on an annual basis; additional samples will be collected in Summer, 1999. This report will focus on samples collected during 1998 including a comparison with sampling results from 1996 and 1997; an assessment of these most recent data is desired by MDA-G management personnel. Sampling locations were intentionally selected to best indicate whether contaminants were moving off-site via the soil transport by stormwater pathway; thus, these sampling locations should be considered as locations most sensitive to possible contaminant migration outside of MDA-G. The data collected during 1998 can be used to:

A. compare to baseline "activity concentrations" (concentrations) of radionuclides on soils sampled in an undisturbed area of TA-54 to determine if radionuclide concentrations in perimeter surface soils are above "background" and to what degree;

B. compare to the 1996 and 1997 soil sampling results to look for indications of trends (increasing, decreasing, or unchanging radionuclide concentrations);

C. determine whether there has been movement of contaminants off-site; and

D. assist MDA-G Waste Management personnel attempts to engineer techniques to prevent off-site movement of contaminants by either indicating areas of concern or assessing

effectiveness of engineering fixes already in place to preclude off-site movement of contaminants.

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

A. dispersion of material from active pits by natural phenomena and anthropogenic activities;

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

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

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

E. dispersion of contaminants from trucks carrying waste into MDA-G;

F. transport of contaminants or contaminated materials from inactive pits, shafts, or pads to the surface by burrowing animals, vegetation, or anthropogenic activities; and/or

G. waste disposal of contaminated sediments on the ground surface.

[B. Wechsler (MDA-G Environmental Programs Manager), personal communication, February, 1999]

Radioactive surface soil contamination at low levels has been documented within the confines of MDA-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 [LANL, 1997]. To meet these needs, a soil sampling network was established around the perimeter of MDA-G. 39 soil samples were collected in 1998, 1997, and 1996, at the same locations each year. Figure 6, located in the pocket on the back cover, displays the sampling locations and topographic characteristics of MDA-G.

Also included in this paper is a storm water model assessment for MDA-G. A single drainage was evaluated using rainfall/runoff simulation software to assess the potential for developing a complete surface water model for MDA-G. The model of the single drainage was calibrated and tested using known precipitation/runoff data. The results were positive and indicate potential for the development of a complete model. A model like this would be an invaluable tool for a facility like MDA-G for determining expected stormwater discharge quantities for predicted rainfall events; this would be useful for planing purposes (erosion/sediment transport prevention, etc.) at MDA-G. The complete assessment and results are presented in section 10.0.

2.0 OBJECTIVES OF INVESTIGATION

The objectives of this sampling project and data assessment were to:

A. quantify the levels of radioactive contaminants in surface soils around the perimeter of MDA-G and compare to baseline levels from surface soil samples taken in adjacent, non-impacted locations;

B. make a comparison of soil radionuclide concentrations from 1998 with results from 1996 and 1997 to look for indications of increasing or decreasing radionuclide concentrations;

C. document whether contaminants (associated with sediments) have migrated off-site; and

D. assess the potential for developing a site-wide stormwater model by developing and testing a model of a single drainage at the site.

Enhanced MDA-G perimeter surveillance occurs annually in order to provide an up-to-date picture of existing radioactive contamination in perimeter surface soils. Ultimately, any measurable impacts on unimpacted adjacent areas can be documented by comparing these data with those from future surveillance efforts.

2.1 Areal and Temporal Extent

The investigation to define off-site migration of contaminants via the surface water pathway is limited to the near mesa top perimeter just outside the boundary/security fence of MDA-G and one major drainage within the disposal area itself (see 1998 sampling locations in Figure 6). Surface soil-sampling stations were installed in small arroyos or rivulets incised into the hillsides around the perimeter of MDA- G.

This study is not intended to define potential contamination in the environment downstream from MDA-G. The sediments in the canyon bottoms, surface water, and ground water located downstream from MDA-G are all monitored on an annual basis by the Water Quality and Hydrology Group (ESH-18) of the Environment, Safety, and Health Division (ESH). The Canyons Focus Group within LANL's Environmental Restoration Project is undertaking an intensive investigation of the impacts to the canyons resulting from past Laboratory operations

and waste disposal practices. Based on available funding, this environmental surveillance project will continue annually so the ability to compare contemporary with historical data is available.

2.2 Data Needs

The data needs for this 1998 MDA-G soil investigation are:

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

B. the results from the soil sampling that occurred in 1996 and 1997; and

C. the results from the sampling that occurred in an undisturbed area (the Development Area) of TA-54 during 1994 and 1995, the baseline/background comparison data.

The Development Area (formerly known as the Expansion Area) sites that were sampled in 1994 and 1995 are located where no radioactive waste disposal has occurred and in a location where Waste Management operations are expected to develop in the future. In 1994, a regular 100 x 100-ft grid was established in this area, just west of the old MDA-G gate (the area west of the shaded yellow expanse in Figure 6). The analytical data from 54 samples collected in this area will serve as baseline or pre-operational concentrations for constituents of interest when disposal operations are initiated in this Development Area. This information is also presented in this paper to serve as one benchmark against which perimeter soil radionuclide concentrations will be compared.

3.0 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.

3.1 Land Survey

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

At all of the sampling locations (coordinates referenced to North American datum [NAD] 1983), an aluminum stake was placed to memorialize the position.

The unique sampling locations on the perimeter of MDA-G were coded as G-##-#. The first two numbers after "G" in the sequence refer to one of seventy permanent survey monuments, each of which is identified by a piece of rebar driven into the ground and tagged with an aluminum cap marked with the location number. These 70 monuments were originally installed in 1991 as part of the old A411 material disposal area (MDA) low-energy gamma, field instrument for detection of low-energy radiation (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 perimeter soil sampling sites were numbered in reference to these 70 permanent, surveyed locations. For instance, three soil sampling sites are sited near monument MDA-29.

These locations are identified by aluminum stakes with numbered tags G-29-1, G-29-2, and G-29-3 (see map-Figure 6).

The Development Area soil sampling 100 x 100 ft grid was also memorialized by surveying in the locations. At each location, a 4-ft aluminum stake was pounded into the ground. Numbered brass tags attached to the stake describe the locations with the notation, G-X-##. The gridded locations are numbered consecutively from G-X-1 through G-X-55, excluding point G-X-7 which was sited off the edge of the mesa top.

On the map depicting the perimeter and Development Area surveillance locations (Figure 6), soil-sample points are in blue. The Development MDA-Grid points cover the fenced-in area immediately west of the active (yellow area in Figure 6) portion of MDA-G. Doug Walther of the LANL Facility for Information Management and Display (FIMAD) team prepared this map.

3.2 Field Techniques

The following standard sampling and instrument procedures were adopted to collect the soil samples and to make associated measurements:

Standard Operating Procedure (SOP) Number	**Title**
LANL-ER-SOP-01.02	Sample Containers and Preservation
LANL-ER-SOP-03.01	Land Surveying Procedures
LANL-ER-SOP-06.09	Spade and Scoop Method for Collection of Soil Samples
LANL-ESH-8-008	General Field Work

Before soil samples were collected, 1-minute counts were made at the soil surface to define surface soil beta/gamma activity. These readings were made with an Eberline ESP-1 beta/gamma

meter equipped with a "pancake" probe (similar to a Geiger counter) . The beta/gamma measurements were taken principally to define any potential radioactive hazards at sampling points. A typical soil-background level taken with the ESP-1 counter at MDA-G was 300 counts per minute (cpm).

3.3 Chain-of-Custody Procedure

In addition to the above SOPs, LANL-ESH-8-002, "Chain-of-Custody for Environmental Samples" procedure was followed. 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 or locked in a room or cooler to which only the sampling team had keys. All samples requiring analytical chemistry services were delivered to the Chemical Science and Technology Division's (CST's) Sample Receiving Facility Group (CST-3) located at SM-59-1, TA-59. CST-3 personnel took formal custody of the samples at that time. All samples collected in 1998 were analyzed on-site at LANL.

4.0 SAMPLE ANALYSIS

The analytical chemistry data for samples referred to in this report are found in Tables 1–4.

4.1 Requested Analytical Services

4.1.1 Surface Soil Samples

The data are reported in the units of picocuries per liter (pCi/L) for tritium and picocuries per gram (pCi/g) for all other analytes besides % water. PCi/g is a unit of measurement which indicates X x 10^{-12} curies (an equivalent amount of radioactivity as emitted by one gram of

Table 1: 1998 TA-54 Area G Perimeter Surface Soil Data (Sample locations can be found in Figures 6-9. Please note that negative values sometimes result from counting statistics when average background activities are subtracted from gross analytical results.)

Sample Location	Collection Date	% Water	^{3}H pCi/L	^{241}Am pCi/g	^{238}Pu pCi/g	^{239}Pu pCi/g	Total Pu pCi/g
G-29-01	02/10/98	15	19,100	0.23	0.017	0.013	0.030
G-29-02	02/10/98	29	15,000	0.24	0.004	0.016	0.020
G-29-03	02/10/98	10.3	162,700	0.09	0.010	0.029	0.039
G-30-01	02/10/98	16.4	9,700	0.39	0.015	0.022	0.037
G-31-01	03/13/98	26	33,700	0.04	0.033	0.025	0.058
G-31-02	03/13/98	9	15,000	0.92	0.011	0.012	0.023
G-31-03	02/10/98	11	6,500	0.03	0.002	0.004	0.006
G-32-01	02/10/98	9	5,500	0.45	0.005	0.011	0.016
G-32-02	02/10/98	26.2	2,900	0.09	0.007	0.042	0.049
G-34-05	03/25/98	10	520	1.11	0.012	0.052	0.064
G-34-09	03/25/98	13	1,120	2.01	0.018	0.046	0.064
G-34-10	03/25/98	5	2,070	1.07	0.040	1.338	1.378
G-34-15	03/25/98	9	1,220	1.1	0.222	0.029	0.250
G-38-02	02/25/98	16	8,900	0.94	0.081	2.109	2.190
G-39-01	02/10/98	15.6	4,070	0.49	0.378	0.095	0.472
G-39-02	02/25/98	2	8,100	0.14	0.061	0.145	0.207
G-40-01	02/10/98	11.7	4,640	0.42	0.621	0.152	0.773
G-40-02	02/10/98	2.58	11,500	0.17	2.064	0.179	2.243
G-41-02	02/10/98	18.4	5,330	0.45	2.226	0.260	2.486
G-42-01	02/25/98	23	4,080	-0.3	0.261	0.136	0.397
G-42-06	03/13/98	17	2,370	1.1	0.097	0.150	0.247
G-43-01	03/13/98	20	2,140	1.51	0.507	0.599	1.106
G-44-01	03/13/98	18	4,220	1.1	0.101	0.077	0.178
G-44-07	03/13/98	18	1,320	0.02	0.118	0.207	0.325
G-45-01	03/13/98	10	26,300	0.08	2.519	0.304	2.824
G-45-04	03/13/98	25	2,440	0.4	0.238	0.566	0.804
G-45-05	03/13/98	26	2,880	0.93	0.413	1.615	2.028
G-45-06	03/13/98	19	25,700	-0.09	1.736	0.275	2.011
G-45-07	02/10/98	25.5	2,010	0.27	0.492	0.347	0.839
G-46-01	03/13/98	19	4,430	0.21	1.303	0.272	1.575
G-46-02	02/10/98	32.5	1,430	0.28	1.942	0.690	2.632
G-47-01	03/25/98	12	1,460	0.46	0.234	0.721	0.955
G-48-02	03/25/98	9.5	1,150	1.67	0.077	0.583	0.660
G-49-01	03/25/98	12	800	0.63	0.038	0.357	0.394
G-49-04	03/25/98	12	1,260	-0.14	0.011	0.065	0.076
G-50-01	03/25/98	7	1,780	1.23	0.016	0.069	0.085
G-50-02	03/25/98	8	1,210	0.55	0.028	0.050	0.078
G-52-03	03/25/98	19	1,420	1.7	0.016	0.034	0.050
G-58-01	03/25/98	7	3,780	0.59	0.049	0.007	0.056
Mean		**15.2**	**10506**	**0.58**	**0.411**	**0.300**	**0.711**
Median		**15.0**	**3780**	**0.45**	**0.077**	**0.136**	**0.250**
Std. Dev.		**7.5**	**26212**	**0.56**	**0.706**	**0.462**	**0.876**
Max		**32.5**	**162700**	**2.0**	**2.519**	**2.109**	**2.824**
Min		**2.0**	**520**	**-0.3**	**0.002**	**0.004**	**0.006**

Table 2: 1997 TA-54 Area G Perimeter Surface Soil Data (Sample locations can be found in Figures 6-9. Please note that negative values sometimes result from counting statistics when average background activities are subtracted from gross analytical results.)

Sample Location	Collection Date	% Water	^{3}H pCi/L	^{241}Am pCi/g	^{238}Pu pCi/g	^{239}Pu pCi/g	Total Pu pCi/g
G-29-01	03/19/97	10.7	8,831	0	0.022	0.014	0.036
G-29-02	03/19/97	20.4	19,327	-0.07	0.016	0.029	0.044
G-29-03	03/19/97	13.1	67,446	-0.01	0.003	0.008	0.011
G-30-01	03/19/97	10.4	29,636	0.04	0.036	0.019	0.054
G-31-01	03/19/97	26.5	111,000	0.07	0.015	0.032	0.047
G-31-02	03/19/97	12.5	82,562	0.04	0.006	0.005	0.011
G-31-03	03/19/97	11.5	19,853	-0.05	0.005	0.007	0.013
G-32-01	03/19/97	13.6	31,377	0.03	0.014	0.054	0.069
G-32-02	03/19/97	26.3	13,836	-0.03	0.011	0.063	0.074
G-32-03	03/19/97	13.4	4,918	-0.05	0.005	0.021	0.027
G-34-04	03/19/97	14.7	635	-0.07	0.019	0.031	0.050
G-34-07	03/19/97	6.4	1,097	0.04	0.002	0.016	0.019
G-34-10	03/19/97	7.2	1,443	0.26	0.037	1.205	1.242
G-34-13	03/19/97	9.3	2,015	-0.05	0.141	0.056	0.198
G-38-02	03/20/97	11.6	22,723	-0.01	0.055	0.630	0.685
G-39-01	03/20/97	3.7	1,508	0.21	0.240	0.120	0.360
G-39-02	03/20/97	2.8	2,316	0.01	0.045	0.085	0.130
G-40-01	03/20/97	7.6	784	0.16	0.790	0.450	1.240
G-40-02	03/20/97	7.9	860	0	2.400	0.156	2.556
G-41-02	03/20/97	12.1	579	0.15	0.780	1.710	2.490
G-42-01	03/20/97	16.5	1,288	0.12	1.180	0.620	1.800
G-43-01	03/20/97	23.2	1,327	0.36	1.280	0.380	1.660
G-44-07	03/20/97	16.1	1,941	0.15	0.124	0.214	0.338
G-45-04	03/20/97	23.0	2,509	-0.02	0.540	0.280	0.820
G-45-05	03/20/97	23.5	3,113	0.18	0.230	0.550	0.780
G-45-06	03/20/97	18.8	2,508	0.05	1.740	0.280	2.020
G-45-07	03/20/97	14.7	2,765	0.04	0.570	0.220	0.790
G-46-01	03/20/97	19.2	6,173	0.43	4.890	1.580	6.470
G-46-02	03/20/97	27.3	954	0.21	1.860	0.930	2.790
G-47-01	03/20/97	12.1	2,110	0.25	0.129	0.420	0.549
G-48-02	03/20/97	9.8	1,340	0.12	0.050	0.520	0.570
G-49-01	03/19/97	17.4	1,162	0.01	0.032	0.314	0.346
G-49-04	03/19/97	18.9	909	0.16	0.018	0.100	0.118
G-50-01	03/19/97	17.0	519	0.43	0.057	0.161	0.218
G-50-02	03/20/97	21.5	1,147	0.09	0.043	0.099	0.142
G-52-01	03/19/97	14.5	288	0.06	0.022	0.039	0.061
G-52-02	03/19/97	11.3	789	0.43	0.027	0.068	0.095
G-52-03	03/19/97	18.8	544	0.22	0.034	0.092	0.126
G-55-01	03/19/97	18.1	558	-0.03	0.002	0.013	0.015
G-58-01	03/19/97	9.8	95	-0.03	0.016	0.019	0.036
Mean		**14.8**	**11,370**	**0.10**	**0.437**	**0.290**	**0.727**
Median		**14.1**	**1,725**	**0.05**	**0.040**	**0.100**	**0.170**
Std. Dev.		**6.2**	**23,784**	**0.14**	**0.928**	**0.415**	**1.219**
Max		**27.3**	**111,000**	**0.43**	**4.890**	**1.710**	**6.470**
Min		**2.8**	**95**	**-0.07**	**0.002**	**0.005**	**0.011**

Table 3: 1996 TA-54 Area G Perimeter Surface Soil Data (Sample locations can be found in Figures 6-9. Please note that negative values sometimes result from counting statistics when average background activities are subtracted from gross analytical results.)

Sample Location	Collection Date	% Water	^{3}H pCi/L	^{241}Am pCi/g	^{238}Pu pCi/g	^{239}Pu pCi/g	Total Pu pCi/g
G-29-1	07/25/96	4.6	70,153	0.08	0.022	0.019	0.041
G-29-2	07/25/96	5.6	316,445	0.14	0.022	0.029	0.052
G-29-3	07/25/96	4.6	716,004	0.19	0.002	0.013	0.015
G-30-1	07/25/96	1.7	47,405	0.61	0.011	0.009	0.020
G-31-1	07/25/96	4.4	47,405	0.20	0.014	0.048	0.062
G-31-2	07/25/96	1.5	118,665	0.00	0.012	0.015	0.028
G-31-3	07/25/96	4.0	27,468	1.07	0.006	0.009	0.015
G-32-1	07/25/96	8.1	14,095	0.02	0.007	0.054	0.061
G-32-2	07/25/96	3.9	8,638	0.13	0.007	0.054	0.060
G-32-3	07/25/96	2.3	7,965	0.16	0.007	0.027	0.034
G-34-4	07/25/96	3.8	1,594	1.10	0.025	0.053	0.078
G-34-5	08/08/96	5.0	1,493	0.13	0.022	0.061	0.083
G-34-7	08/08/96	2.6	1,466	0.16	0.001	0.017	0.018
G-34-9	08/08/96	4.6	1,328	1.08	0.004	0.011	0.015
G-34-10	08/08/96	3.3	1,652	1.08	0.079	1.620	1.699
G-34-13	08/08/96	2.2	1,385	0.90	0.112	0.015	0.127
G-38-2	07/25/96	2.3	19,918	0.32	0.051	0.452	0.503
G-39-1	07/25/96	2.3	2,725	13.10	0.590	0.168	0.758
G-39-2	07/25/96	0.1	1,585	0.11	0.031	0.052	0.083
G-40-1	08/07/96	3.6	1,880	0.55	2.650	0.763	3.413
G-40-2	08/05/96	4.4	1,480	0.15	0.511	0.074	0.585
G-41-2	08/07/96	2.7	1,911	0.76	1.810	0.180	1.990
G-42-1	07/25/96	1.6	2,493	0.27	0.654	0.661	1.316
G-42-6	08/05/96	6.2	4,550	0.14	0.113	0.130	0.243
G-44-7	08/05/96	6.9	13,900	0.21	0.208	0.178	0.385
G-45-4	08/05/96	4.0	18,500	0.37	0.571	0.320	0.892
G-45-5	08/05/96	5.2	18,500	0.50	0.243	0.428	0.672
G-45-6	07/26/96	2.8	34,259	0.09	0.059	0.042	0.101
G-45-7	07/26/96	2.9	38,305	0.02	0.246	0.119	0.366
G-46-1	08/05/96	6.1	22,960	1.09	2.866	0.314	3.180
G-46-2	07/26/96	3.1	9,864	0.88	2.462	0.450	2.912
G-47-1	07/26/96	4.1	7,196	0.09	0.134	0.443	0.577
G-49-1	08/05/96	2.3	1,340	0.19	0.005	0.043	0.048
G-49-4	07/26/96	4.3	1,561	0.03	0.018	0.079	0.096
G-50-1	07/26/96	2.8	5,232	0.09	0.027	0.067	0.094
G-50-2	07/26/96	5.8	3,602	0.54	0.068	0.072	0.140
G-52-1	07/26/96	2.6	1,805	0.14	0.021	0.036	0.057
G-52-2	07/26/96	5.4	835	0.01	0.028	0.053	0.081
G-52-3	07/26/96	4.0	16,961	0.09	0.042	0.042	0.084
G-58-1	07/26/96	3.5	566	0.09	0.032	0.016	0.048
Mean		**3.8**	**40,377**	**0.67**	**0.345**	**0.181**	**0.526**
Median		**3.8**	**6,214**	**0.18**	**0.031**	**0.054**	**0.089**
Std. Dev.		**1.6**	**121,651**	**2.05**	**0.741**	**0.299**	**0.891**
Max		**8.1**	**716,004**	**13.10**	**2.866**	**1.620**	**3.413**
Min		**0.1**	**566**	**0.00**	**0.001**	**0.009**	**0.015**

Table 4: FY 1994 and 1995 TA-54 Area G (OU 1148) Development Area (Baseline/Background) Soil Data

Sample Location	Collection Date	% Water	^{3}H pCi/L	^{241}Am pCi/g	^{238}Pu pCi/g	^{239}Pu pCi/g	Total Pu pCi/g
G-X-6	7/29/94	14.7	420	0.007	0.009	0.013	0.022
G-X-8	7/29/94	16.9	320	0.016	0.005	0.036	0.041
G-X-8R	7/29/94	17.9	300	0.014	0.005	0.043	0.048
G-X-9	7/29/94	13.4	120	0.008	0.002	0.023	0.025
G-X-10	7/29/94	15.1	710	0.007	0.007	0.019	0.026
G-X-12	7/29/94	11.2	370	0.014	0.003	0.051	0.054
G-X-13	7/29/94	12.7	280	0.008	0.002	0.009	0.011
G-X-16	7/29/94	15.6	260	0.015	0.002	0.042	0.044
G-X-19	7/29/94	8.7	260	0.008	0.002	0.012	0.014
G-X-21	7/29/94	9.7	250	0.008	0.001	0.016	0.017
G-X-24	7/29/94	12.1	380	0.027	0.005	0.149	0.154
G-X-26	7/29/94	13	630	0.016	0.005	0.047	0.052
G-X-27	7/29/94	13.5	280	0.011	0.004	0.03	0.034
G-X-28	7/29/94	10.9	180	0.005	0.001	0.01	0.011
G-X-30	7/29/94	9.6	350	0.008	0.002	0.025	0.027
G-X-33	7/29/94	11.5	340	0.014	0.004	0.054	0.058
G-X-37	7/29/94	7.6	510	0.007	0.002	0.023	0.025
G-X-38	7/29/94	4.5	580	0.02	0.009	0.042	0.051
G-X-38R	7/29/94	4.5	490	0.021	0.007	0.053	0.06
G-X-39	7/29/94	11.2	310	0.005	0.002	0.014	0.016
G-X-43	7/29/94	12.1	280	0.005	0.004	0.012	0.016
G-X-44	7/29/94	10.2	440	0.002	0.001	0.008	0.009
G-X-45	7/29/94	15	150	0.005	0.003	0.005	0.008
G-X-48	7/29/94	14.8	560	0.005	0.003	0.01	0.013
G-X-50	7/29/94	4.4	450	0.008	0.004	0.017	0.021
G-X-51	7/29/94	10.7	410	0.003	0.001	0.001	0.002
G-X-53	7/29/94	12.5	280	0.011	0.003	0.028	0.031
G-X-1	6/1/95	8.04	-100	ANP	0.004	0.011	0.015
G-X-2	6/1/95	11.5	0.0	ANP	0.003	0.008	0.011
G-X-3	6/1/95	7.46	0.0	ANP	0.005	0.016	0.021

(continued)

Table 4: 1994 and 1995 TA-54 Area G (OU 1148) Development Area (Baseline/Background) Soil Data (continued)

Sample Location	Collection Date	% Water	^{3}H pCi/L	^{241}Am pCi/g	^{238}Pu pCi/g	^{239}Pu pCi/g	Total Pu pCi/g
G-X-4	6/1/95	5.66	100	ANP	0.001	0.001	0.002
G-X-5	6/1/95	5.24	-300	ANP	0.037	0.052	0.089
G-X-11	6/1/95	12.4	-200	ANP	0.084	0.045	0.129
G-X-14	6/1/95	14.5	-400	ANP	0.064	0.04	0.104
G-X-15	6/1/95	13.7	0.0	ANP	0.006	0.012	0.018
G-X-17	6/1/95	16.4	-100	ANP	0.003	0.052	0.055
G-X-18	6/1/95	23.6	-400	ANP	0.002	0.031	0.033
G-X-20	6/1/95	15.0	100	ANP	0.004	0.022	0.026
G-X-20R	6/1/95	17.3	-100	ANP	0.068	0.088	0.156
G-X-22	6/1/95	14.0	-200	ANP	0.02	0.005	0.025
G-X-23	6/1/95	9.29	-200	ANP	0.04	0.03	0.07
G-X-25	6/1/95	7.06	-300	ANP	0.008	0.015	0.023
G-X-29	6/1/95	11.2	-300	ANP	0.007	0.047	0.054
G-X-31	6/1/95	7.0	-200	ANP	0.004	0.016	0.02
G-X-32	6/1/95	13.4	-100	ANP	0.002	0.004	0.006
G-X-34	6/1/95	18.2	-200	ANP	0.05	0.04	0.09
G-X-35	6/1/95	8.86	0.0	ANP	0.009	0.023	0.032
G-X-36	6/1/95	16.7	-200	ANP	0.002	0.008	0.01
G-X-40	6/1/95	17.8	-100	ANP	0.047	0.046	0.093
G-X-41	6/1/95	22.3	-300	ANP	0.003	0.01	0.013
G-X-42	6/1/95	13.3	300	ANP	0.003	0.007	0.01
G-X-46	6/1/95	10.7	-200	ANP	0.002	0.005	0.007
G-X-47	6/1/95	16.4	-100	ANP	0.008	0.011	0.019
G-X-49	6/1/95	15.2	0.0	ANP	0.062	0.026	0.088
G-X-49R	6/1/95	15.4	-300	ANP	0.041	0.007	0.048
G-X-54	6/1/95	6.16	-200	ANP	0.033	0.01	0.043
G-X-55	6/1/95	5.73	-100	ANP	0.004	0.027	0.031
Mean		**12.2**	**101.9**	**0.010**	**0.013**	**0.026**	**0.039**
Median		**12.4**	**100.0**	**0.008**	**0.004**	**0.019**	**0.026**
Std. Dev.		**4.3**	**294.5**	**0.006**	**0.020**	**0.024**	**0.036**
Max		**23.6**	**710.0**	**0.027**	**0.084**	**0.149**	**0.156**
Min		**4.4**	**-400.0**	**0.002**	**0.001**	**0.001**	**0.002**

ANP = analysis not performed

radium) of the radionuclide is present per gram of soil sample. PCi/L is the same measurement except instead of per gram of soil it is X x 10^{-12} curies per liter of water. This unit is used for tritium because water in the sample is extracted and the water is analyzed for tritium.

The following analytical services were requested for soil samples taken during 1998:

1. isotopic plutonium by radioactivity/alpha spectroscopy (RAS);

2. tritium by distillation of soil moisture and scintillation counting;

3. americium-241 by gamma spectroscopy; and

4. percent water by gravimetric methods.

4.1.2 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 the dried soil samples were analyzed for plutonium, they were first extracted by a hot nitric acid/hydrofluoric acid leaching procedure that effectively dissolves the entire sample [Carter, 1993]. Standard CST analytical chemistry procedures were then followed for separating, plating, and counting radionuclides.

For tritium analyses on soils, the soil moisture is distilled from the soil. This soil moisture is analyzed for tritium by scintillation counting [R. Robinson (Analytical Laboratory Manager), personal communication, January, 1998].

5.0 DEVELOPMENT AREA BASELINE STUDY

An approximately 10-acre site directly west of active MDA-G has been identified as the location for the development of Waste Management disposal operations in the future. Baseline surface soil and water chemistry data have been collected to define the ambient conditions before any operations are initiated in this area. This baseline data will not only be used in the future to define any impacts from the active operations that will be taking place in this area, but will serve in this study as baseline or local background for comparison to perimeter soil samples collected in 1998. A summary of the Development Area analytical chemistry data is found in Table 4. These data are used in box plots presented in Figures 13-15.

6.0 SOIL SAMPLING RESULTS

Figures 7 through 9 illustrate the distribution of radionuclides in surface soils collected on the perimeter of MDA-G. A discussion of individual constituents is found below. LANL's Screening Action Level (SAL) for each isotope is also presented for comparison purposes. The SAL is an initial screening number used by LANL's Environmental Restoration Program. For rad, it is based on a 10 milirem annual dose (very low) for a resident on the site containing the particular soil concentration. This is a conservative number used for initial screening of a site.

6.1 Tritium

The analytical radiochemistry results for the 1998 soil samples are presented in Table 1. Figure 7 is a map that displays the sampling locations, which are color coded to indicate tritium concentrations at each location and the general distribution of tritium in the perimeter surface soils. Figure 10 depicts the perimeter and Development Area tritium distributions for the soil samples collected during 1996, 1997, and 1998. The tritium results are displayed for each sampling location for the three aforementioned years; the mean tritium baseline is also displayed. Figure 13 contains box plots depicting the distribution of tritium concentration on surface soils collected around the MDA-G perimeter in 1996 through 1998 and compares tritium distributions with data from soil samples collected in the Development Area in 1994 and 1995 (period used to collect samples and establish baseline). This figure displays min, max, 25-50 percentile, and median tritium concentrations. From Table 4, baseline tritium concentrations ranged from 0 to 710 pCi/L, with a mean value of 101.9 ± 294.5. The SAL for tritium in soil is 2.3 million pCi/L.

From the perimeter soil sampling (those samples taken from locations in minor drainages into which sediments are expected to be carried and water to flow during a storm event) it is shown that there is elevated tritium activity in soils collected around the entire active portion of MDA-G. The tritium concentrations in soils collected in 1998 are, by and large, lower than analogous samples collected in 1996 and are more similar to samples collected in 1997. Tritium on soil samples collected adjacent to the tritium disposal shafts are most elevated over baseline from

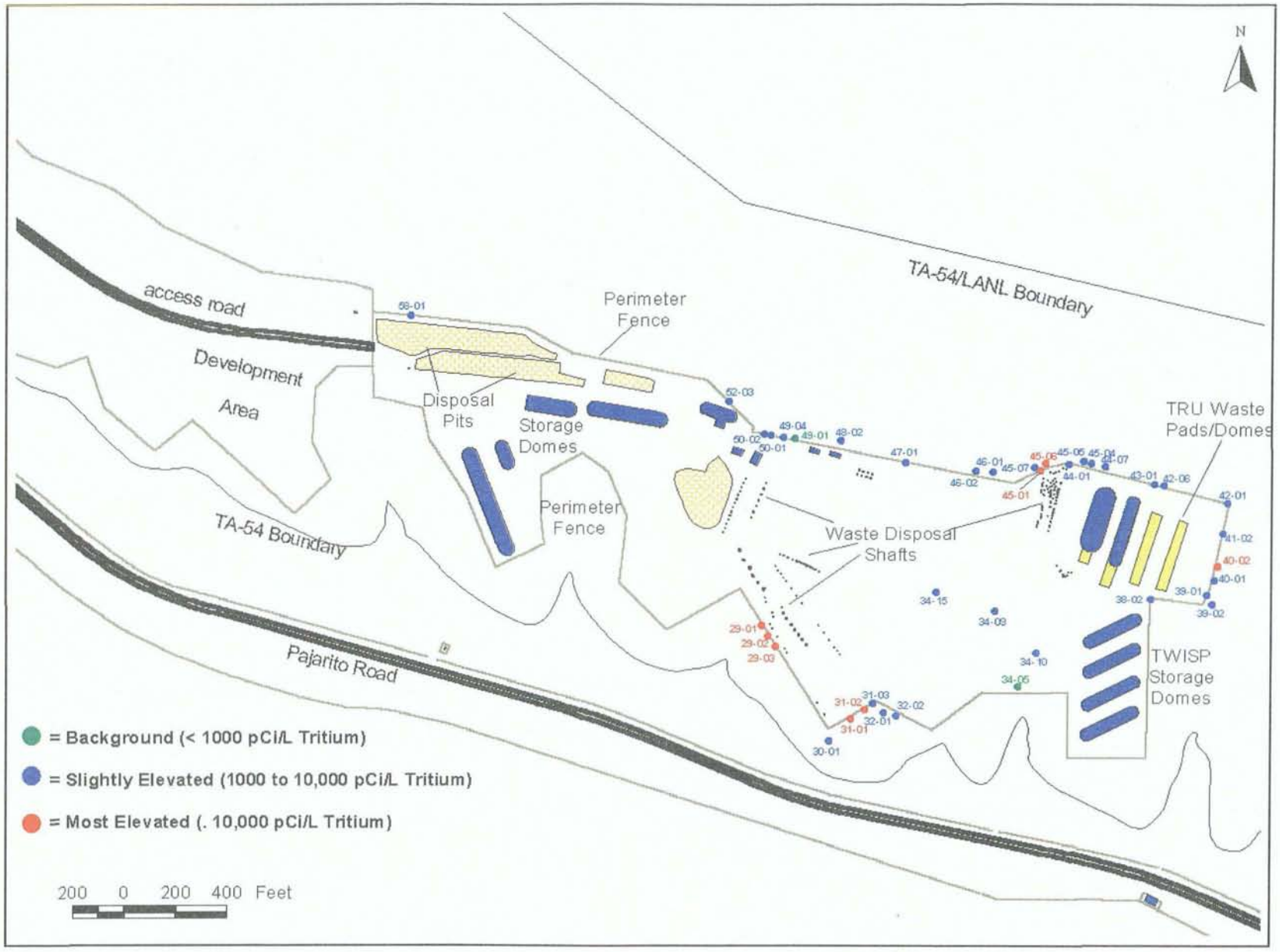


Figure 7. Tritium soil-sample locations and analytical results (1998) at Area G. The number is the sample location identification number, and the color represents its tritium concentration range (in picocuries per liter). There are three categories in the tritium concentration range: background (green), slightly elevated (blue), and most elevated (red). All the significant Area G landmarks and features are identified on the figure.

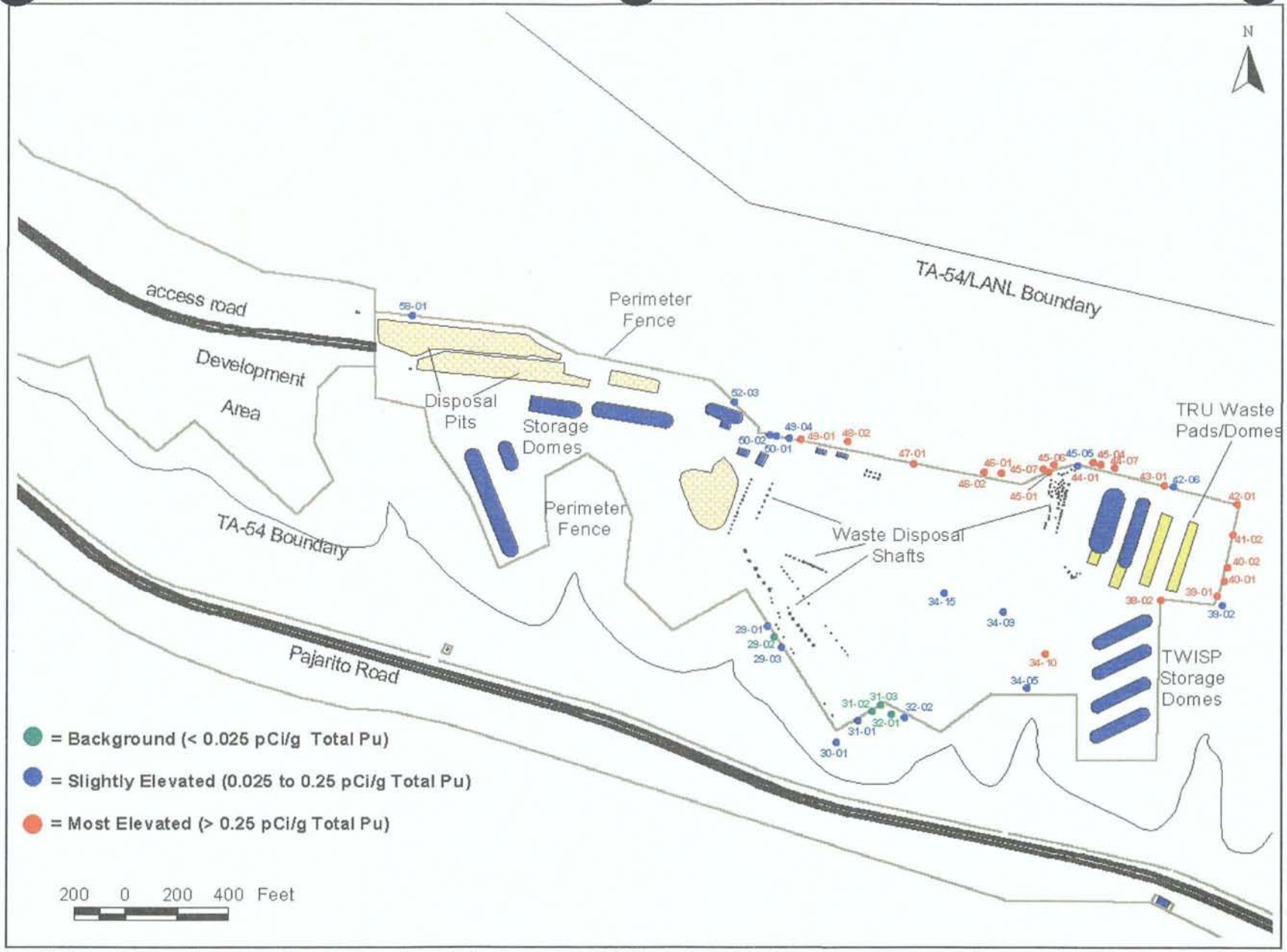


Figure 8. Total plutonium soil-sample locations and analytical results (1998) at Area G. The color represents the americium concentration range (in pCi/g). There are three categories in the plutonium concentration range: background (green), slightly elevated (blue), and most elevated (red). All the significant Area G landmarks and features are identified on the figure.

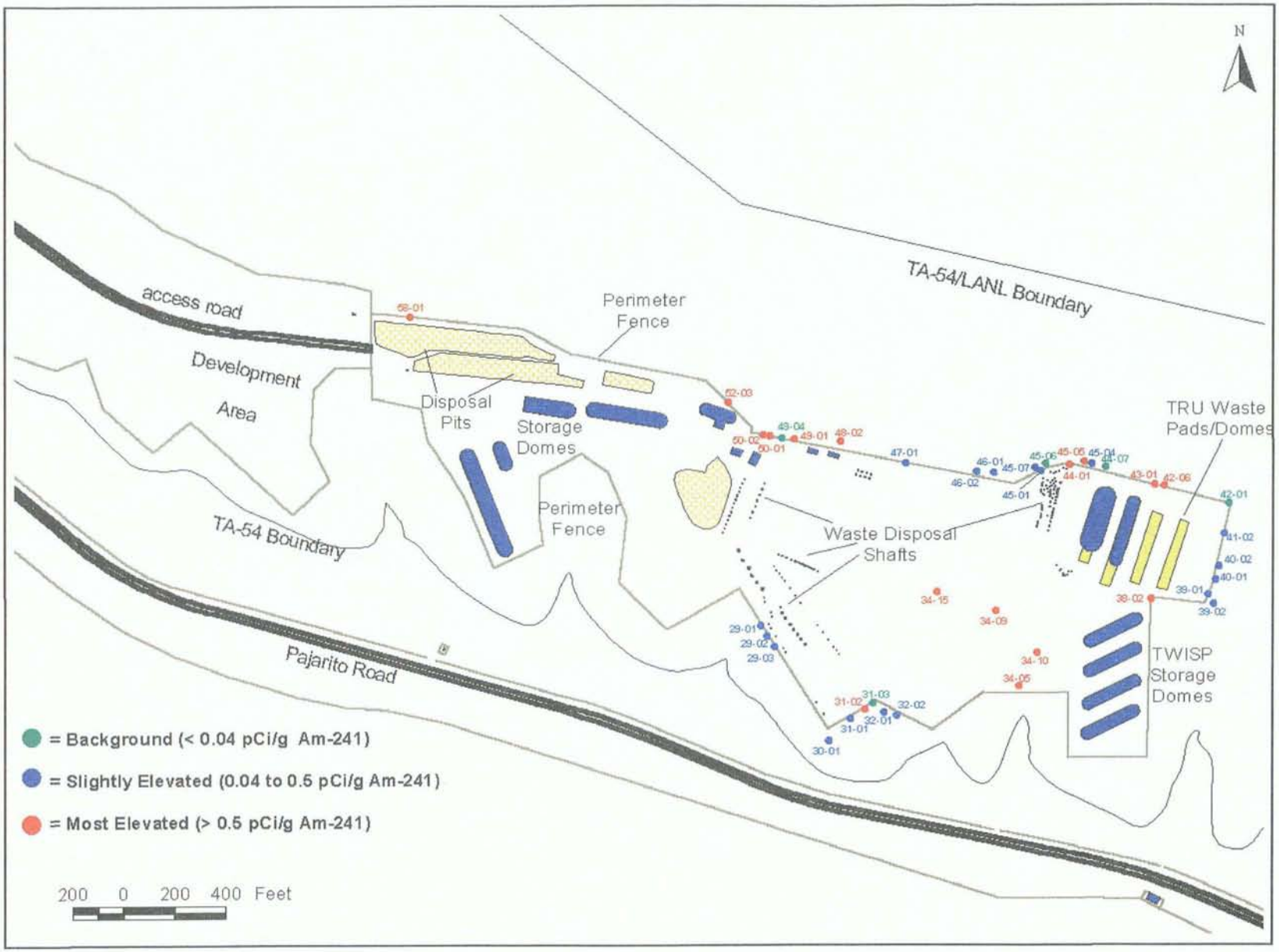


Figure 9. Am-241 soil-sample locations and analytical results (1998) at Area G. The color represents the americium concentration range (in pCi/g). There are three categories in the americium concentration range: background (green), slightly elevated (blue), and most elevated (red). All the significant Area G landmarks and features are identified on the figure.

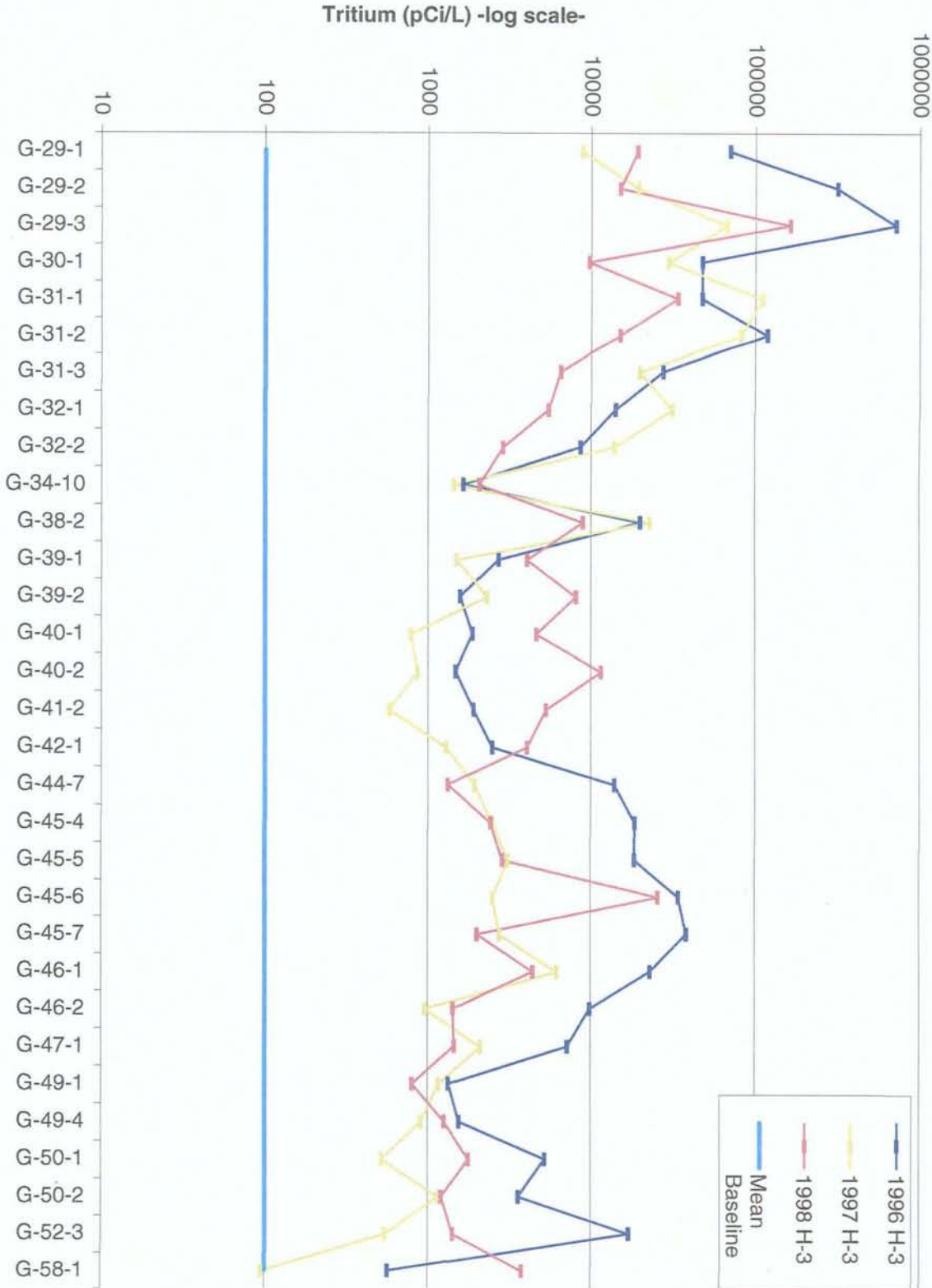


Figure 10. Comparison of Tritium Soil Data from Sampling Years 1996, 1997, and 1998.

sampling locations G-29 to G-32. These locations are along the southern edge and adjacent to one set of tritium disposal shafts (see Figure 7). In the area adjacent to the TRU pads NE corner, locations G-40 to G-45, the soil samples also show moderately elevated tritium activity. One isolated soil sample, G-38-02, on the perimeter at the south edge of the TRU pads, had a relatively high tritium concentration (8,900 pCi/L). This particular soil sample also had elevated tritium concentrations in soil samples collected in 1996 and 1997.

The locale for the most elevated perimeter soil tritium concentrations in 1998 is adjacent to the tritium disposal shafts located on the Pajarito Canyon side of MDA-G and encompasses sample series G-29 to 32. Soil samples collected from this area in 1998 had tritium activities as high as 162,700 pCi/L. Figure 10 is a scatter plot depicting the soil tritium concentrations at analogous locations for the years 1996, 1997, and 1998. This figure indicates that the localized regions of elevated tritium concentrations on the perimeter of MDA-G were the same during these years, but soil tritium concentrations varied significantly from year to year. The significance of year-to-year measured soil tritium concentrations will be discussed.

Tritium results for surface soils reflect the surface soil environment only at the time of the soil sampling. The ambient conditions at a particular location are one factor that will determine the concentration and availability of tritium at the time a sample is taken. When precipitation falls, soil-surface water interactions are generally limited to the top few inches of soils [Sparks, 1999]. At that time, tritium concentrations in the surface soil stratum could be altered by the precipitation, resulting in:

1. stormwater transport of tritiated water from a particular location;

2. erosion of tritium-bound sediments; or

3. dilution resulting from tritium-deficient water being added to "soil moisture" containing the soil tritium.

It is known that on soil, tritium is incorporated into the associated water molecules that is termed soil moisture [NRC, 1993]. When the laboratory prepares a soil sample for tritium analysis, soil moisture is distilled out of a weighed sample. The tritium measured in the distilled-off water is deemed to represent the tritium content of the soil and is reported as activity per liter of soil moisture. If it had recently rained or snowed before the sampling event or if the soil came from a location that was naturally damp (e.g., an area shaded from the sun) or where anthropogenic activities (such as a water truck spraying the ground surface) had impacted the soil, this water added to the natural soil moisture would cause a dilution of the tritium concentration in that soil. From year-to-year, the geographical regions of baseline, slightly elevated, and most elevated (see Figure 7) tritium concentrations on soils are the same. However, the absolute concentrations of tritium measured on soil over these time periods are shown to be generally different. In particular, Table 1 indicates that soil samples collected in March of 1997 and 1998, when the soil was still relatively moist from the winter snow accumulation and spring rains, contained soil moisture generally greater than the soil moisture found in samples collected in the summer of 1996. Along with the higher soil moistures, it is evident that the tritium concentrations in 1997 and 1998 soils are generally significantly lower that soil tritium concentrations for samples collected in the summer period of 1996. The other factor affecting soil tritium concentrations in the 1996, 1997, and 1998 soil samples is that the tritium flux is greater during the hot summer months than it is during the remainder of the year [NRC, 1993].

By minimizing the period of time taken for the collection of all the samples for a particular year, one can hopefully eliminate most of the local environmental impacts discussed above (for samples collected in a single year).

6.2 Plutonium Isotopes

During the 1998 perimeter surface soil sampling, 39 soil samples were collected and 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 for 1998, 1997, and 1996 are presented in Tables 1, 2, and 3 respectively. The 1998 plutonium-238 concentrations range from 0 pCi/g to 2.5 pCi/g and the average plutonium-238 activity was 0.411 ± 0.706 pCi/g. The Pu-238 concentrations in 1997 ranged from 0.002 to 4.89 pCi/g and averaged 0.437 ± 0.928 pCi/g. The Pu-238 concentrations in 1996 ranged from 0.001 to 2.866 pCi/g and averaged 0.345 ± 0.741 pCi/g. The baseline data (Table 4) ranged from 0.001 to 0.084 pCi/g Pu-238 and averaged 0.013± 0.02 pCi/g. The SAL for Pu-238 in soil is 27 pCi/g. The 1998 plutonium-239 concentrations range from 0 pCi/g to 2.1 pCi/g and the average plutonium-239 activity was 0.3 ± 0.462 pCi/g. The Pu-239 concentrations in 1997 ranged from 0.005 to 1.71 pCi/g and averaged 0.29 ± 0.415 pCi/g. The Pu-239 concentrations in 1996 ranged from 0.009 to 1.620 pCi/g and averaged 0.181 ± 0.299 pCi/g. The baseline data (Table 4) ranged from 0.001 to 0.149 pCi/g Pu-239 and averaged 0.026 ± 0.024 pCi/g. The SAL for Pu-239 in soil is 29 pCi/g. For all three years, the mean values are far above the median values because several samples have elevated plutonium concentrations and the frequency distribution plot is positively skewed for both Pu-238 and Pu-239. For convenience, the sum of the plutonium isotope activity "total" for each sample is also presented in Tables 1 to

4 (box plots of the total plutonium distribution on perimeter and expansion area surface soils collected in 1996, 1997 and 1998 are presented in Figure 14). In Figure 8, total plutonium isotope relative activity in perimeter soils collected in 1998 is plotted by location. Figure 8 shows that perimeter surface soils increase in plutonium concentration as one moves from the west of MDA-G (with little or no history of waste disposal or storage activity) to the east (where waste disposal or storage has occurred for the longest periods of time). The highest total plutonium activities are associated with the TRU pads and the vicinity of the inactive disposal pits (location series G-38 to 45), with elevated readings also found to the west of the TRU pads along the northern edge of MDA-G up through location series G-49. There are other elevated plutonium readings from sites scattered around the perimeter, but these sites are found predominantly in the eastern half of MDA-G. Figure 11 is a plot of the total plutonium concentrations for 1996, 1997, and 1998 soil samples, for each sampling location the mean baseline activity is also displayed.

6.3 Americium

Am-241 is usually detected when plutonium is found in soils because it is a direct radioactive decay product of plutonium [Walker, et. al., 1989]. Corroboration of plutonium distribution in soils is possible by using the attendant Am-241 analytical results. Am-241 was analyzed by the gamma spectroscopy method for all soil samples collected at MDA-G in 1998. Table 1 includes the soil Am-241 results, whereas Figure 9 depicts the geographic distribution of the 1998 Am-241 readings (box plots depicting the Am-241 distribution in surface soils collected at perimeter and expansion area locations in 1996, 1997 and 1998 can be found in Figure 15). The 1998 Am-241 values for perimeter soils varied from not detectable to 2.01 pCi/g. The mean Am-241 concentration in soils was 0.58 ± .56 pCi/g in 1998. The elevated reading of 13.10 pCi/g in 1996 occurred at location G-39-1. This number is considered to be an outlier since at this location in

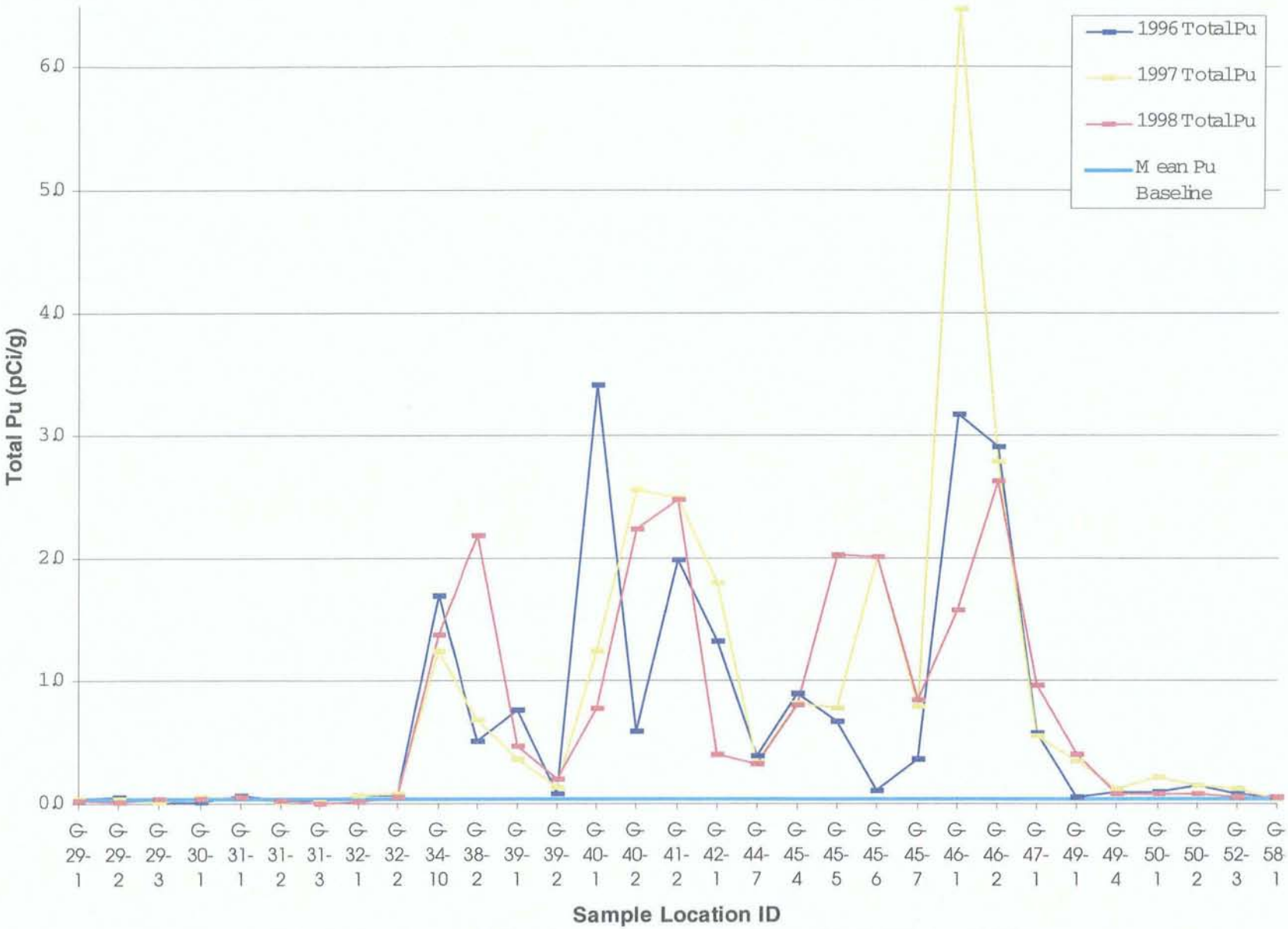


Figure 11. Comparison of Total Plutonium Soil Data from Soil Sampling Years 1996, 1997, and 1998.

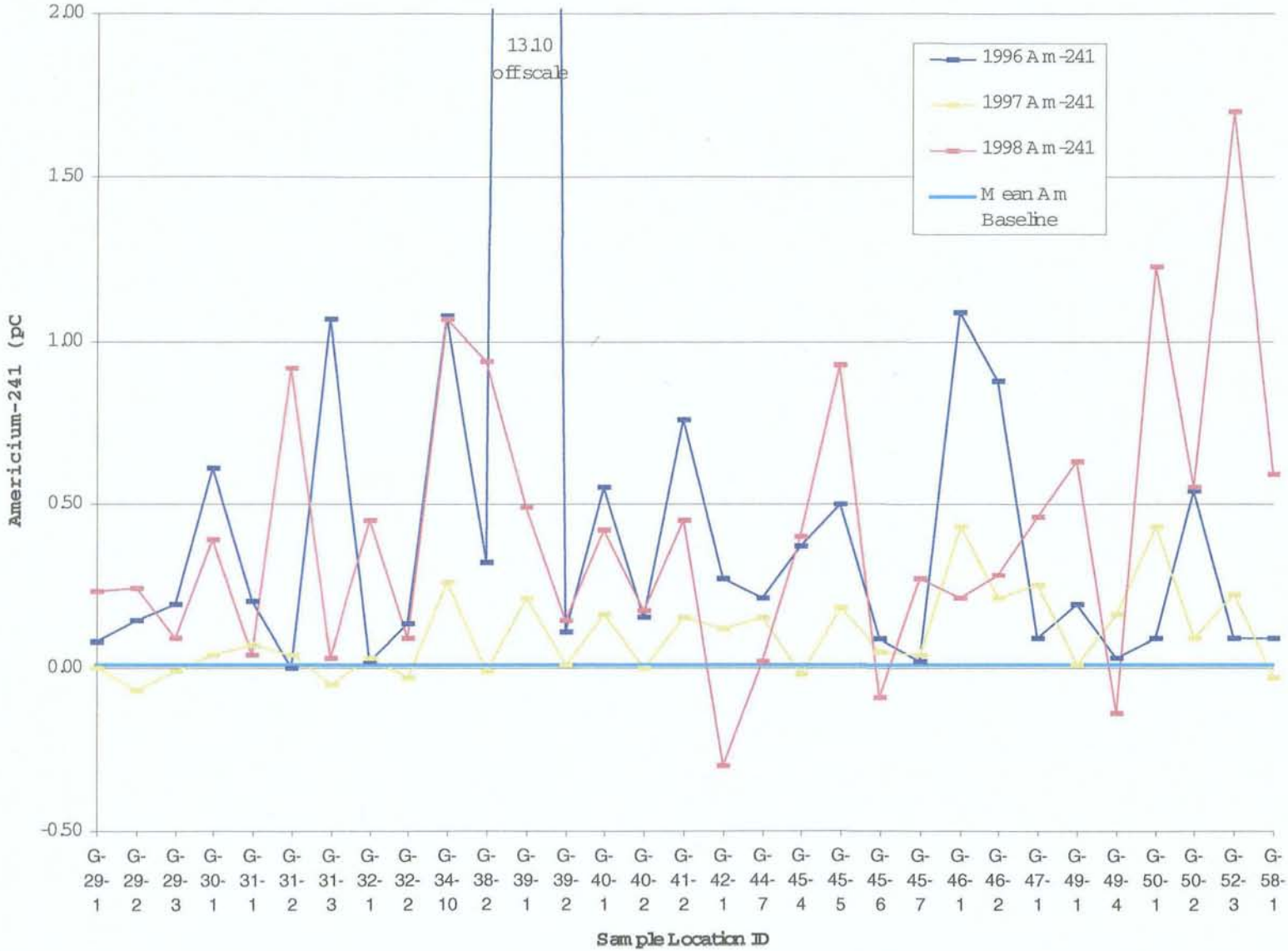


Figure 12. Comparison of Americium Soil Data from Soil Sampling Years 1996, 1997, and 1998.

1997, the Am-241 activity in soil was 0.21 pCi/g and in 1998 the value was 0.49 pCi/g. The SAL for Am-241 in soil is 22 pCi/g. The mean 1996 Am-241 concentration is subsequently biased high because of the elevated outlier activity. An area with elevated Am-241 soil levels was found adjacent to the TRU pads in the area of series G-42 to 52. This location of elevated Am-241 reflects the elevated activities of plutonium in soils reported in this section (compare Figures 8 and 9). Figure 11 is a plot of the Am-241 concentrations for 1996, 1997, and 1998 soil samples, for each sampling location; the mean baseline activity is also displayed.

7.0 STATISTICAL CONSIDERATIONS

Independent perimeter surface soil data sets are available for 1996 through 1998 as well as the 1994 and 1995 MDA-G Development Area baseline data. It is appropriate to compare this information. The comparisons made in this report are:

1. whether the 1998 MDA-G perimeter soil data are statistically different from the Development Area baseline data; and

2. whether the perimeter radionuclide soil data collected in 1998 are statistically different from the analogous sample data collected in 1996 and 97.

It is expected that the soil data for the perimeter soil samples can be shown to be statistically different from the Development Area where disposal operations have not occurred. On the other hand, a more difficult question may be determining whether, for example, the plutonium activity in perimeter soils at MDA-G is increasing, decreasing, or staying the same from year to year. Because concentration changes from year to year are expected to be small, one can use statistical techniques to assist in determining whether there truly are significant concentration changes of constituents on soil from one year to the next.

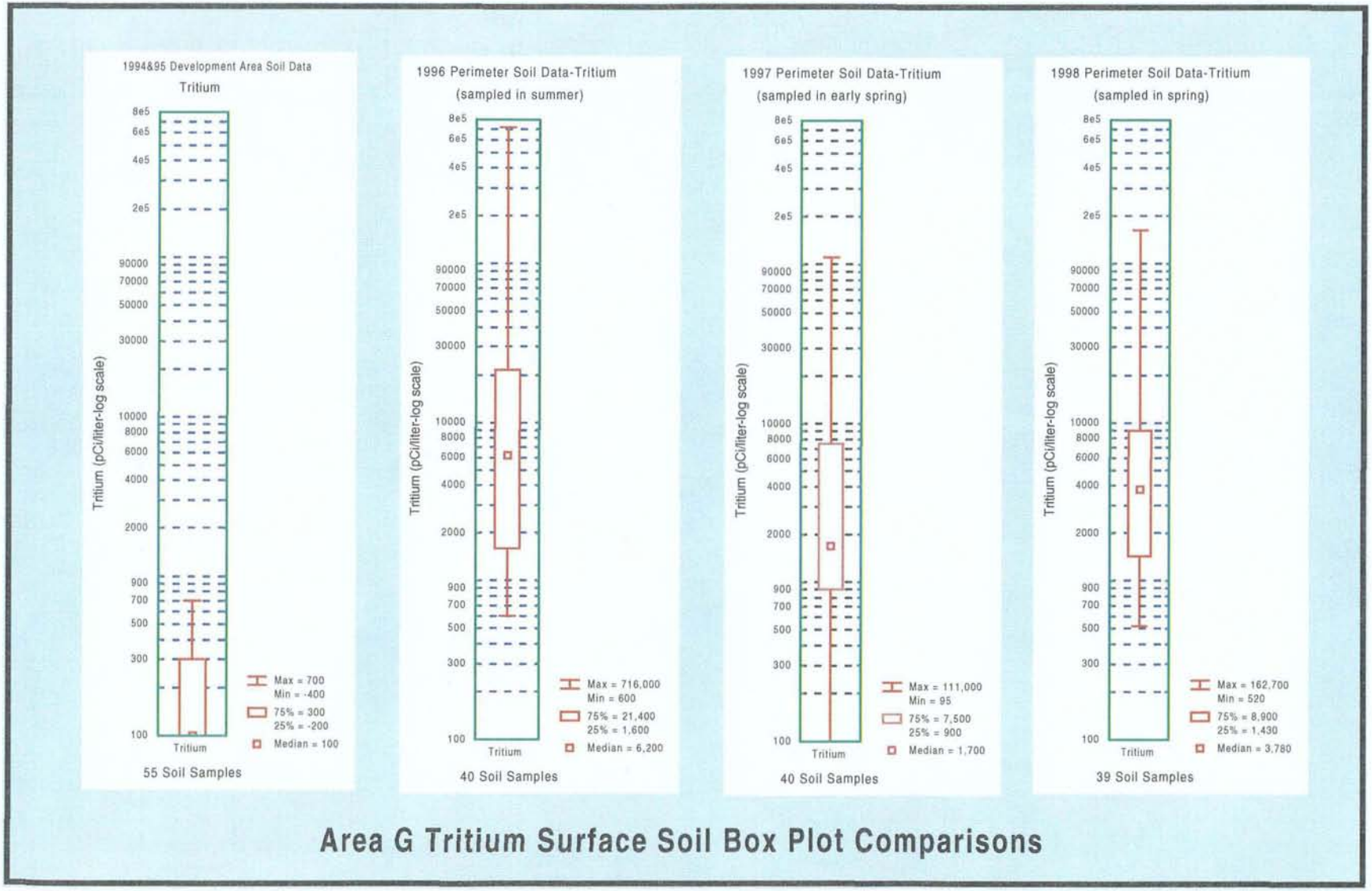


Figure 13. Tritium Box Plot Comparison of Soil Data from 1996, 97, and 98 vs Baseline Development Area Data. Each Plot Shows Min, Max, 25-50 Percentile, and Median. All Plots are of the Same Scale.

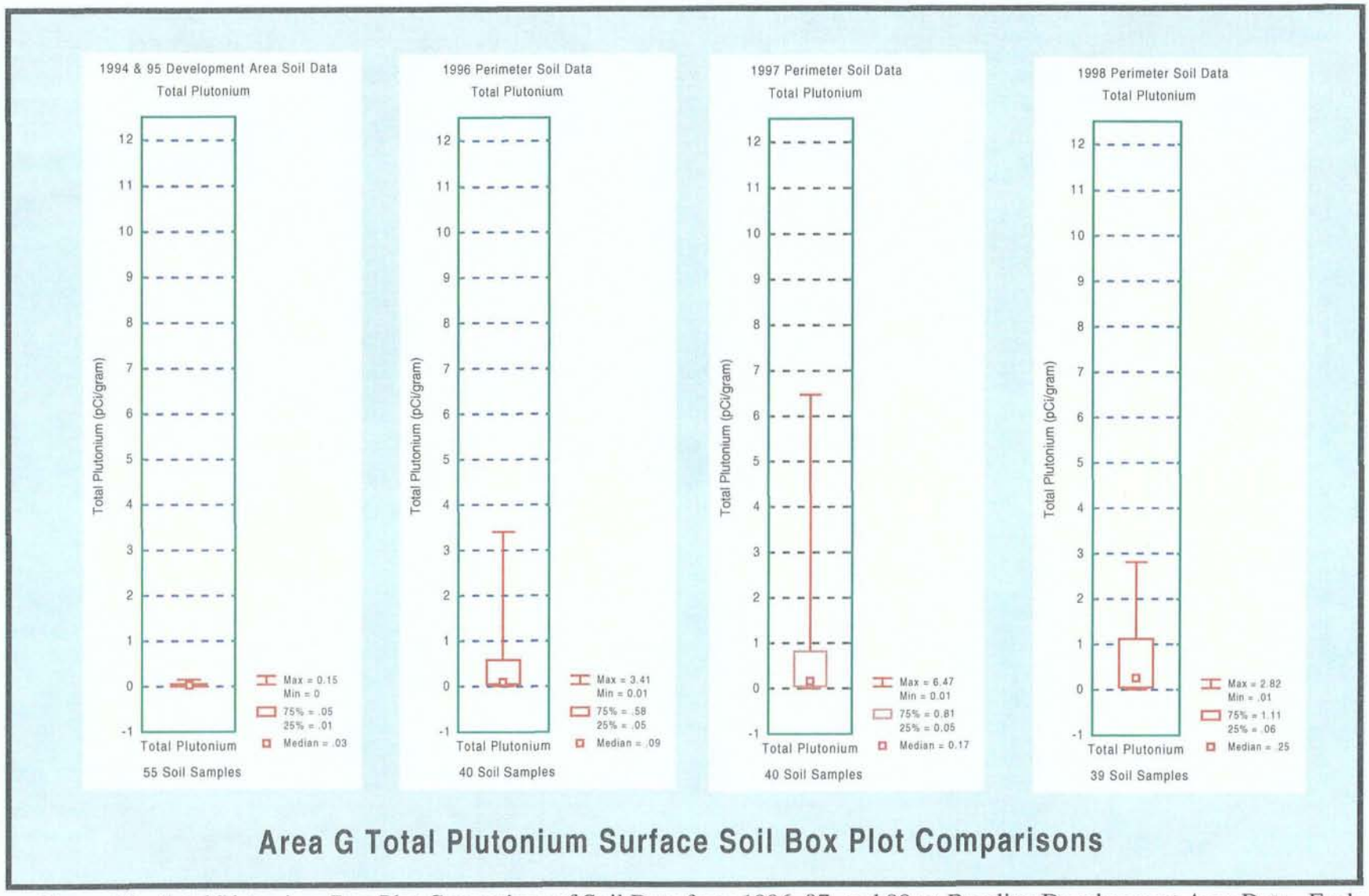


Figure 14. Total Plutonium Box Plot Comparison of Soil Data from 1996, 97, and 98 vs Baseline Development Area Data. Each Plot Shows Min, Max, 25-50 Percentile, and Median. All Plots are of the Same Scale.

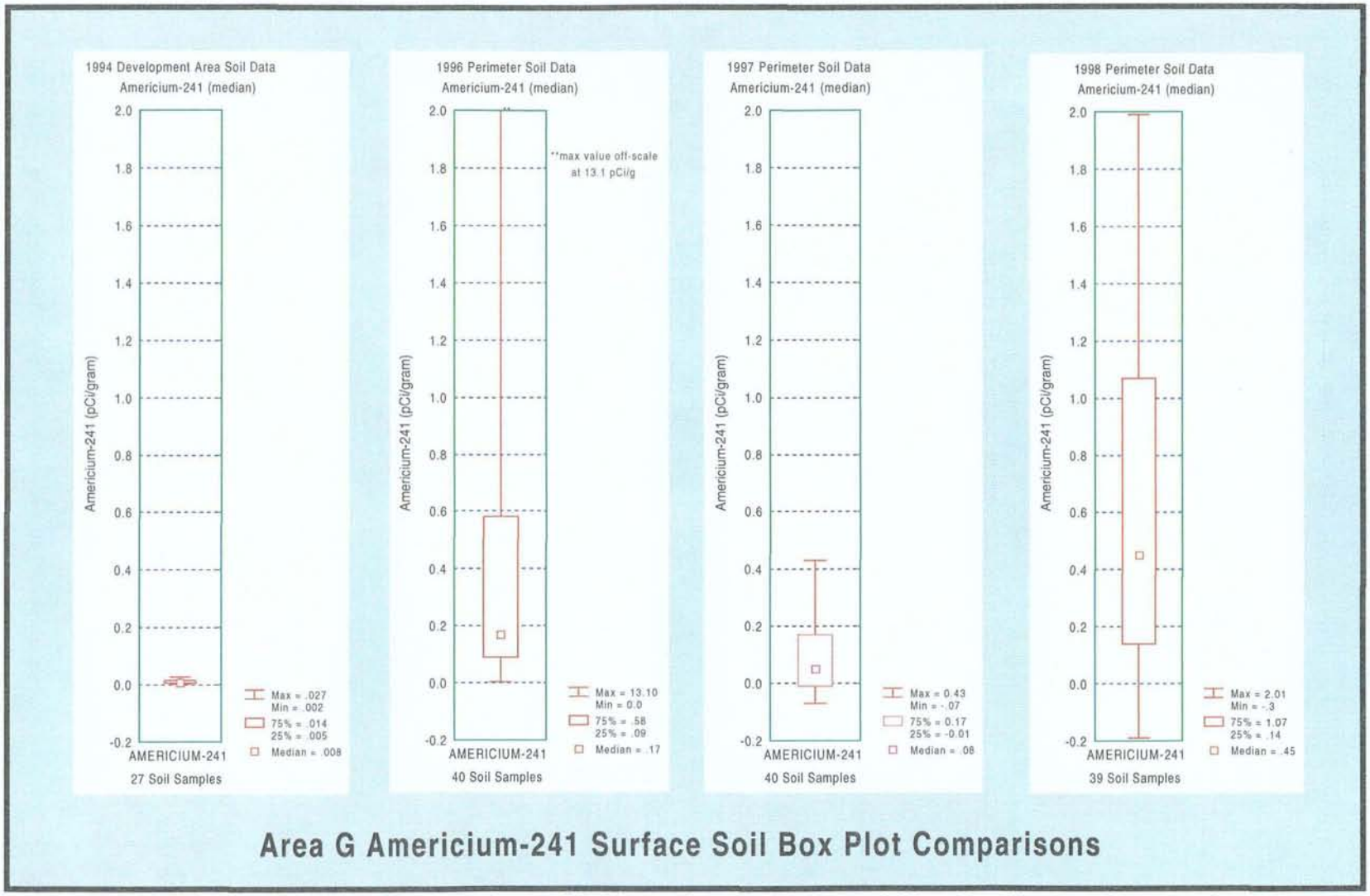


Figure 15. Americium-241 Box Plot Comparison of Soil Data from 1996, 97, and 98 vs Baseline Development Area Data. Each Plot Shows Min, Max, 25-50 Percentile, and Median. All Plots are of the Same Scale.

In Figures 13-15, the analytical data are summarized in box plots (pictorial descriptions of concentration distributions) to assist in making the two types of comparisons discussed above. The first comparison is to look at the constituents measured on perimeter soils and compare these concentrations with constituent concentrations measured on soil samples collected in the proposed MDA-G Development Area (defined as background). Surface soil samples were collected in this Development Area during 1994 and 1995.

The second type of statistical assessment is done by comparing the constituent concentrations for 1998 with constituent concentrations for 1996 and 1997 from analogous locations (for example, by comparing tritium concentrations in soils collected in 1998 to tritium concentrations in soils collected in 1996 and 1997 at and in the vacinity of the same sample locations).

Box plots are used to depict concentration distributions and to assist in comparing the different data sets. Box plots give information on the median, interquantile range, and skewness; all of which help describe the distribution spread and normalcy. By placing the box plots on the same scale and in the same figure, there is an immediate impression of the differences and/or similarities of the distributions being compared. Several considerations must be taken into account, however, in comparing year-to-year data in the box plots. The second caution concerns soil tritium activities only. The time of year when soil samples are collected can grossly affect the measured soil tritium activities for that year's set of samples. The highest soil tritium activities have been found in samples taken in the driest part of the summer when the soil moisture percentage is minimized and evaporation rates (and tritium flux) are maximized. The soil samples taken in 1998 and 1997 were taken in the early spring, not long after snowmelt had occurred. These samples were moister than samples taken in 1996 during the dry part of the summer.

8.0 RESULTS DISCUSSION

In the following paragraphs, the results of the 1998 perimeter soil sampling at MDA-G are assessed and data comparisons are discussed.

8.1 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 found, including LANL, it is know that tritium can migrate some distance from its place of disposal [NRC, 1993]. Tritium in the surface soils at Los Alamos has a wide distribution resulting from both fallout and Laboratory activities. Disposal of hundreds of thousands of curies of tritium in a series of pits, shafts, or pads occurred at MDA-G since this facility opened in 1957 [Fresquez, et. al., 1998]. 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 [Walker, et. al., 1989].

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

Except for inadvertent discharges of tritium to the ground surface, the major sources of surface tritium at MDA-G are tritium contaminated materials that have been disposed of (buried or emplaced) in one or another of the many shafts, pits, and pads (see Figure 5) at the site. The probability of finding tritium on surface soils at elevated levels is expected to be greatest in the

proximity of these sources. Because ground disposal or storage of waste entails subsequent covering by natural tuffaceous material, one important question is, by what pathway does subsurface tritium migrate to the surface, so that it resides in soils and ultimately could be carried off-site? There are possibly two primary mechanisms for tritium transport to the surface: vapor-phase migration and capillary action. Secondary mechanisms would be evapotranspiration, transport to the surface via vegetative growth or burrowing animals, and anthropogenic activities such as excavation of tritium-contaminated soils, tuff, or waste [Sparks, 1999].

Tritiated water (or other tritiated compounds with elevated vapor pressures) can migrate in the vapor phase from the subsurface to the surface. Upon reaching the surface layer of soils, the question is, does tritium simply vent into the atmosphere or is there a mechanism for it to attenuate with surface soils? Because tritium *is* found on surface soils, there must exist a viable mechanism for attenuation. The only obvious mechanisms for tritiated water vapor migrating upward (or laterally) to attenuate to surface soil sediments are condensation on the surface particles when encountering cooler temperatures (e.g., at night) and/or the tendency of very dry or salt-containing surface soils to temporarily absorb this water vapor [NRC, 1993].

A second pathway by which tritium could arrive at the surface would be capillary action. Capillary action is the phenomenon by which water 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) [Sparks, 1999]. Unlike water transported via the vapor phase, water transported by capillary action can also carry dissolved compounds. Thus, non-vapor phase tritium that exists as a dissolved chemical species can also migrate upwards to surface soils by capillary action.

By either of these two mechanisms (vapor-phase transport or capillary action) tritium could move from subsurface soils to surface soils. Tritium's residence time in surface soils is unknown because it is not known 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. It is known, from tritium flux studies (where water vapor escaping from the ground surface is captured on silica gel and the tritium in the water measured) and ambient air monitoring, that tritium is escaping in the vapor phase from the ground surface (Eklund, 1995). It is also known that more tritium escapes the surface during the hotter months. In addition to evaporation, the mechanisms by which tritium can be removed from surface soils are:

1. exchange and runoff with surface water;

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

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

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

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

[B. Wechsler (MDA-G Environmental Programs Manager), personal communication, February1999]

These tritium dispersal mechanisms are important because the actual date and time a sample is taken (and concomitant measured tritium concentration) may be impacted by localized environmental effects. For example, during long dry periods one would expect the movement of tritium on subsurface soils to be from the subsurface to the surface, and ultimately away from the surface by one of the mechanisms mentioned above. If soil sampling occurred after a long dry

period, the question is, would the tritium in the soil be higher or lower than the average value that would be found for that sampling point if samples were taken every day of the year? ESH-17 (LANL's Air Monitoring Group) ambient air data indicates that tritium escapes the surface more readily during the hot months of the year [LANL, 1997]. Or, if soil samples were taken the day after a precipitation event, would a lower than representative soil tritium concentration be expected because some of the tritiated surface soil were carried off by surface water runoff or because the tritium in the soil moisture was diluted by the rain water? These are difficult questions that may only be answered after many years of quality surface soil sampling and data assessment.

For the past three years of systematic soil sampling at MDA-G, a pattern is seen in the distribution of tritium in perimeter soils. By observing the map of MDA-G tritium concentrations on soil (Figure 7), it is evident from the 1998 data that there are specific regions of MDA-G where tritium concentrations are particularly elevated. These regions are predominantly in the areas adjacent to the TRU pads (between MDA stations G-42 and 50) and the tritium storage shafts (between MDA stations G-29 and 31). These tritium data, in fact, mirror the soil tritium data collected at the same locations during 1996 and 97. By examining the line plot in Figure 10, one can see that although the absolute tritium concentrations on soil collected in 1997 and 1998 are significantly lower than the data for samples collected in 1996, the areas of high-, medium-, and low-tritium concentrations on surface soils are similar for the three years. This indicates that the mechanisms (and sources) supplying tritium to the surface soils are rather constant from year to year, and only the local environment and weather affect the absolute concentrations of tritium on the surface soils. A comparison of the water content (% water) in the soil samples verifies that the samples collected in 1996 contained the least water (see Tables 1 to 3).

Additional data that supplement the soil information that was collected at MDA-G are supplied by vegetation sampling done at several MDA-G locations. Fresquez et al. (1995), found elevated levels of tritium in vegetation collected at just those two locations of MDA-G where surface soils were most highly elevated in tritium—north of the TRU pads and west of the tritium shafts. In general, Fresquez, et. al. found that vegetation collected from around MDA-G was generally elevated in radionuclide concentrations above analogous vegetation radioactive concentrations considered to be background.

By observing the box plots in Figure 13 for the tritium distribution in soils collected in 1996–98, it is apparent that the tritium distributions in perimeter soils are different from and higher than the distribution of tritium in soils from the Development Area. This result was expected. Soil tritium concentrations in 1997 and 1998 are much lower than those in 1996. This is anticipated since the 1997 samples were collected in March when the ground was still damp and tritium flux is relatively low, while the 1996 samples were collected during the heat of the summer when soils are dry and tritium flux is relatively high. Unless more is learned about the surface soil tritium history, a sample taken at a particular moment can only provide a snapshot of the tritium surface concentration in soil at that particular time due to the observed variations being caused by changing environmental conditions and probably other factors.

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

continues on a year-to-year basis, the relative distribution of soil tritium throughout MDA-G will become more apparent.

8.2 Plutonium Isotopes

As stated in Section 6.2, the locations of elevated soil plutonium readings are consistent with the history of plutonium disposal at MDA-G. As seen in Figure 6, the lower-numbered, or older pits (1–24), all the disposal shafts, and the TRU pads are located in the eastern half of MDA-G. It is assumed that increased levels of contaminant concentrations in these surface soils are directly related to the location, quantity, and date when material was disposed of in disposal units. That is, there is a greater probability of finding a contaminant adjacent to a disposal unit where large amounts of contaminants have been disposed. Also, the longer a contaminant is held in a specific location, the higher the probability that this contaminant will be disseminated to its immediate surroundings. In fact, the highest plutonium activities in soils are found at the eastern end of MDA-G, especially adjacent to the TRU pads and inactive disposal pits 2–10, where waste has been in place for the longest period of time.

The box plots presented in Figure 14 depict the distributions of the total plutonium concentrations in surface soil samples collected in 1996 through 1998, as well as the comparable data for samples collected from the baseline Development Area. The box plots show the similarities of the 1996 through 98 total plutonium distributions and indicate that the distributions from all three years have higher concentrations and a wider distribution than the total plutonium in samples from the Development Area.

8.3 Americium

As stated in Section 6.3, the tendency is to find elevated Am-241 levels in soil samples where there are elevated levels of plutonium isotopes. This trend is generally illustrated by comparing the data depicted in Figures 8 and 9. The box plots for the Am-241 distributions found in Figure 15 indicate that there is little statistical difference between the 1996 through 98 Am-241 data. The data from 1996 include a value from location G-39-1 that can be considered an outlier and of questionable validity. Location G-39-1 was also sampled in 1997 and 98 with respective Am-241 values of 0.21 and 0.49 pCi/g. The box plots do indicate that the Am-241 concentrations in soils collected from the active part of MDA-G in all three years are statistically different (greater) than the Am-241 concentrations in soil collected from the Development Area.

9.0 PERIMETER SAMPLING RECOMMENDATIONS

The perimeter soil data collected at MDA-G offer the last three years has proven to be very beneficial. The degree of elevated radionuclide concentrations was realized and specific locations within MDA-G with the highest concentrations were identified. This information can be used to minimize off-site migrations by putting in place engineering features to prevent stormwater runoff and sediment transport at areas where concentrations are high. The data can also be used to evaluate features already in place to reduce runoff and sediment transport. Continued collection of perimeter soil samples on an annual basis may also prove to be very beneficial. Historic data can be compared to contemporary data as more and more annual data is collected. These data may eventually lead to an indication of data trends in MDA-G. Questions can be answered such as:

A. Are perimeter soil concentrations decreasing, increasing or remaining stable?

B. What has been the effect of management practices to prevent off-site migration of radionuclides?

C. By what mechanism are contaminants reaching perimeter surface soils?

Continuing this environmental surveillance project and the collection of annual data could lead to the answer to some of these questions and possibly more. But even more important, the direct protection of human health and the environment is provided by this surveillance effort. The soil sampling would detect any significant increase in offsite migration so a rapid mitigation effort could be implemented and impacts to human health and the environment would be minimized.

10.0 STORMWATER MODEL

10.1 Introduction

In a preliminary attempt to develop a rainfall-runoff model for MDA-G, a single drainage basin was evaluated. All major drainages at Area G contain stormwater discharge gauges, so discharge data are available to test and calibrate a model. The software used for this initial evaluation was HEC-HMS (Hydrologic Modeling System) developed by the Hydrologic Engineering Center of the US Army Corps Engineers. HEC-HMS is distributed at no cost by the HEC and can be downloaded from their web-site (http://www.wrc-hec.usace.army.mil). The program was designed for simulating precipitation-runoff processes (HEC, 1999). The following sections describe the method used to conduct the evaluation and the final results are presented.

10.2 Basin Description

MDA-G contains 10 individual drainage areas or subbasins, identified as drainage areas A through J (see Figure 16 -last page). The areas of these subbasins range from 0.89 to 17.54

acres (LANL, 1998). Located in the larger of these drainages are stormwater discharge stations. There are a total of six stations that measure discharge volume and intensity from the drainages, identified as stations G-SWWS-1 through G-SWWS-6 (see Figure 16). The majority of the subbasins drain to Pajarito Canyon on the south and the rest to Canada Del Buey on the north.

10.3 Storm Data/Subbasin Selection

MDA-G rainfall and discharge data were obtained from LANL's Hydrology Group for years 1995 and 1996 for each of the six discharge stations; these years were chosen based on the availability of the data. The rain gauge is located at station G-SWWS-1. The data were evaluated to find which subbasin would work best for testing a stormwater model. A useful subbasin for this project would need to have measurable runoff at the discharge station for an average rainfall event; i.e., it would be impossible to test and calibrate the model without measured discharges following rainfall events. Based on the 1995 and 1996 data, drainage area B (see figure 16) was selected for this evaluation. Drainage B is 13 acres in size, and contains a variety of ground cover types and developed lands. It is located towards the west end of MDA-G and drains to the south to discharge station G-SWMS-2 (see Figure 17). The runoff data showed discharge occurring at station G-2 for most of the rainfall events assessed.

For 1995 and 1996, precipitation occurred on 31 days that caused associated runoff at station G-2. Rain amounts ranged from 0.12 to 1.11 inches per day. Precipitation durations ranged from 17 to 676 minutes, some days include multiple small precipitation events. Total flow at G-2 ranged from 91 to 42,946 gallons (12.17 to 5,741.05 ft^3) per day. The complete data set for the 31 precipitation days is presented in Table 5.

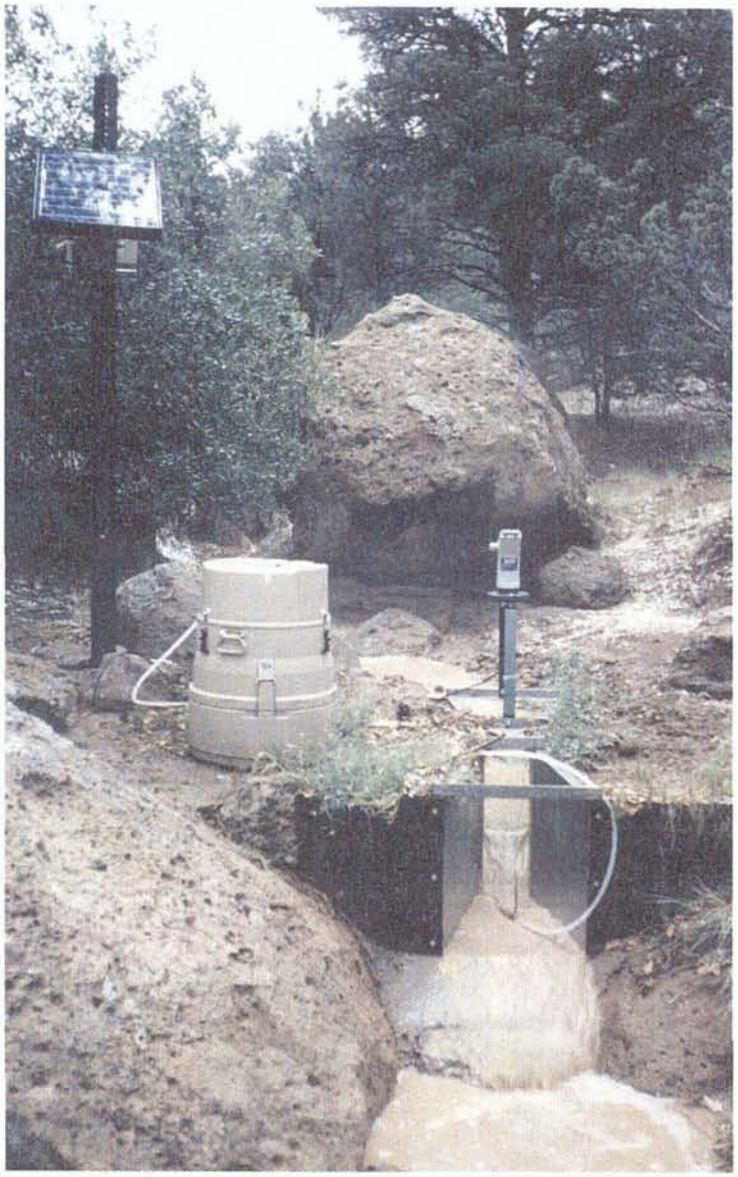


Figure 17. Stormwater Station G-2, Located at Drainage B, During a Storm Event.

10.4 Model Setup/Inputs

The HEC-HMS model was setup using the initial/constant loss rate for calculating losses and the Kinematic Wave Transform method was used for runoff transformation and channel routing. The initial constant/loss method works as follows: all rainfall is lost until an initial loss, or abstraction, is satisfied for the subbasin; after that, rainfall

Table 5. Precipitation Days in 1995 and 1996 that Produced Runoff at MDA-G Stormwater Station G-2, Sorted by Rainfall Amount.

Storm #	Rain (in)	Rain (gal)	Gauge (gal)	Fraction of Rain at Gauge	Dur. (min)	Date
1	0.12	42361	776	0.02	29	8/12/1995
2	0.12	42361	796	0.02	51	6/28/1996
3	0.13	45891	328	0.01	26	9/24/1995
4	0.16	56481	473	0.01	20	5/18/1995
5	0.16	56481	863	0.02	40	5/24/1995
6	0.18	63541	2177	0.03	97	9/13/1996
7	0.18	63541	749	0.01	31	9/18/1996
8	0.2	70601	2579	0.04	74	7/10/1996
9	0.22	77661	91	0.00	17	7/17/1995
10	0.26	91781	3209	0.03	166	6/30/1995
11	0.27	95311	945	0.01	160	8/24/1995
12	0.27	95311	2582	0.03	158	9/28/1995
13	0.29	102371	5571	0.05	33	6/17/1996
14	0.32	112961	1259	0.01	28	8/5/1995
15	0.34	120021	2599	0.02	279	6/29/1995
16	0.34	120021	2423	0.02	110	6/14/1996
17	0.39	137672	4868	0.04	170	9/14/1996
18	0.4	141202	5339	0.04	132	6/13/1996
19	0.4	141202	7732	0.05	132	6/27/1996
20***	0.45	158852	7647	0.05	142	6/29/1996
21	0.47	165912	5209	0.03	119	6/26/1995
22*	0.49	172972	2232	0.01	112	8/22/1996
23	0.52	183562	5571	0.03	120	6/26/1996
24*	0.55	194152	17402	0.09	69	7/8/1996
25	0.59	208272	19987	0.10	676	7/18/1995
26*	0.62	218863	17323	0.08	203	7/9/1996
27*	0.67	236513	28531	0.12	79	8/29/1995
28**	0.74	261223	19461	0.07	544	8/13/1995
29**	1.04	367124	42946	0.12	456	9/8/1995
30	1.04	367124	37510	0.10	154	9/7/1995
31	1.11	391835	19264	0.05	160	5/29/1995
mean	0.42	148489	8659	0.04	148	
median	0.34	120021	3209	0.03	119	
min	0.12	42361	91	0.00	17	
max	1.11	391835	42946	0.12	676	

*calibration storm, **test storm

***two test storm events came from this single precipitation day which consisted of multiple individual storm events

infiltrates and is lost at a constant rate. No rainfall is lost over the percentage of subbasin area designated as impervious. The kinematic wave transformation method works as follows: distributed outflow from a subbasin may be obtained by utilizing a combination of three conceptual elements: overland flow planes, collector channels, and a main channel. The kinematic wave routing technique is used to route rainfall excess over the overland flow planes. Either the kinematic wave or Muskingum-Cunge

technique can be used to route lateral inflows through a collector channel, and upstream and lateral inflows through the main channel (HEC-HMS Manual, 1999). In subbasin B at MDA-G there is only the main channel; no collector channels are present. For this assessment, kinematic wave method was used for channel routing as well. The inputs for HEC-HMS when using the initial/constant loss method and the kinematic wave transform and routing method are:

1. **initial loss** (in.) [the initial amount of rainfall lost]
2. **constant loss rate** (in./hr.) [the infiltration rate following initial loss]
3. **% impervious area** [fraction of the total subbasin area that is impervious, asphalt, buildings, etc.]
4. **plane** (the subbasin not including the drainage channel)
    a. length (ft.) [overland flow length]
    b. slope (ft./ft.) [representative slope of the plane- rise/run]
    c. Manning's n (no units) [this is a dimensionless resistance factor which accounts for resistance to water flow for various surfaces or ground covers; example values: soil:0.025, asphalt:0.016.
5. **channel** (these inputs are used to describe the drainage channel)
    a. length (ft.) length of channel

b. slope (ft./ft.) slope of channel- rise/run

c. Manning's n (no units) [see above description, the value would be different for a plane vs a channel]

d. shape [would a cross-section of the channel be a circle or trapezoid?]

e. width (ft.) [channel width]

f. side slope of channel [? feet Horizontal:per 1 foot Vertical for trapezoid]

These inputs are essentially used to describe the physical properties and geometry of the subbasin in a way that can be used in the mathematical model. These inputs only describe the subbasin, the other necessary inputs describe known or predicted rainfall events and discharge if known.

The initial HEC-HMS input values for MDA-G subbasin B were acquired through field measurements, maps, and estimations. The initial input values were as follows:

initial loss: 0.4 in. [estimated based on storm events that produced no runoff]

constant loss rate: 1 in./hr. [estimated rate for this region of New Mexico]

impervious area 20% [calculated from Figure 16]

plane length 550 ft [measured on Figure 16]

plane slope 0.1 ft./ft. [measured from facility generated 2 ft. contour map]

plane Manning's n: 0.035 [estimated from Manning's n table] (LMNO, 1999)

channel length: 563 ft. [measured from facility generated 2 ft. contour map]

channel slope: 0.13 ft./ft. [measured from facility generated 2 ft. contour map]

channel Manning's n: 0.3 [from Manning's n table]

channel shape: trapezoid

channel width: 125 ft. [measured from facility generated 2 ft. contour map]

side slope of channel: 1.9 h ft. to 1 v foot [measured from facility generated 2 ft. contour map]

10.5 Model Calibration/Optimization

Once inputs were selected, 4 rainfall events were chosen from the 31 in Table 5 to calibrate and/or optimize the input values (storms marked with an * in Table 5 were selected for the calibration). The 4 calibration storms that were chosen consisted of relatively medium to high levels of rainfall and associated discharge. Both the rainfall data (5-min. increments) and the runoff/discharge data (1-min. increments) were entered into the HEC-HMS model. The model takes the data and runs a routine based on the observed hydrograph from the inputted discharge data and the HEC-HMS calculated hydrograph to determine the optimized value for variable inputs. The variable inputs for this model are initial loss, constant loss, and plane Manning's n. The optimization routine analyzes the 3 variable inputs and calculates a new set of values that give the best fit between the calculated and observed hydrograph. This was done for each of the 4 calibration storms, so 4 sets of values for the 3 variable inputs were generated. The 4 sets of values were then averaged for each variable to obtain a single input value for each.

The model inputs for the 3 variable inputs were then changed to the averaged values from the optimization routine. The values changed to: initial loss 0.8 in., constant loss rate 1.3 in., and plane Manning's n 0.032 . Four additional rainfall events were chosen from Table 5 (storms marked with **) to test the model with the new inputs. The data from the test storms were entered into the model including observed discharge so a comparison between the hydrograph

calculated by the model (using the inputs from the optimization procedure) and the known hydrograph could be made. More detailed information on the test storms and results are presented in the next section.

10.6 Test Storm Results

Test Storm 1

This rainfall event occurred on 9/8/95 and consisted of a total of 0.73 (the total precipitation for the day was 1.04 inches) inches of precipitation in 30 minutes. Table 6 is a summary of the rainfall/runoff event including observed and calculated peak discharge, total discharge, time of peak, and total precipitation. Figure 18 is a graphic representation of the observed vs calculated hydrograph and precipitation. The simulation covered times 12:31 to 14:01, which includes both the precipitation and runoff event.

For Test Storm 1, peak discharge was calculated by HEC-HMS to be 5.9 cfs vs an observed peak discharge of 4.5 cfs; peak discharge was overestimated by 31%. The calculated total discharge was 0.12 in. (42,361 gallons) vs an observed total discharge of 0.09 in (31,770 gal); total discharge was overestimated by 33%. The time of calculated peak discharge was 12:58 vs an observed time of 12:55, only a 3 minute difference.

Table 6. Summary of Test Storm Event 1.

Project:	Area G Main Project	Run Name:	Run A	Subbasin:	Subbasin-1
Start of Simulation:	08Sep95 1231	Basin Model:	Project Basin		
End of Simulation:	08Sep95 1401	Precip. Model:	Precip 1		
Execution Time:	20Mar99 1320	Control Specs:	TEST A		

Volume Units: (•) Inches ( ) Acre-Feet

Computed Results

Peak Discharge:	5.9163 (cfs)	Date/Time of Peak Discharge:	08 Sep 95 1258
Total Precipitation:	0.73 (in)	Total Direct Runoff:	0.13 (in)
Total Loss:	0.60 (in)	Total Baseflow:	0.00 (in)
Total Excess:	0.13 (in)	Total Discharge:	0.12 (in)

Observed Hydrograph at Gage: GAGE 1

Peak Discharge:	4.5020 (cfs)	Date/Time of Peak Discharge:	08 Sep 95 1255
Average Residual:	0.68627 (cfs)		
Total Residual:	0.04 (in)	Total Obs. Discharge:	0.09 (in)

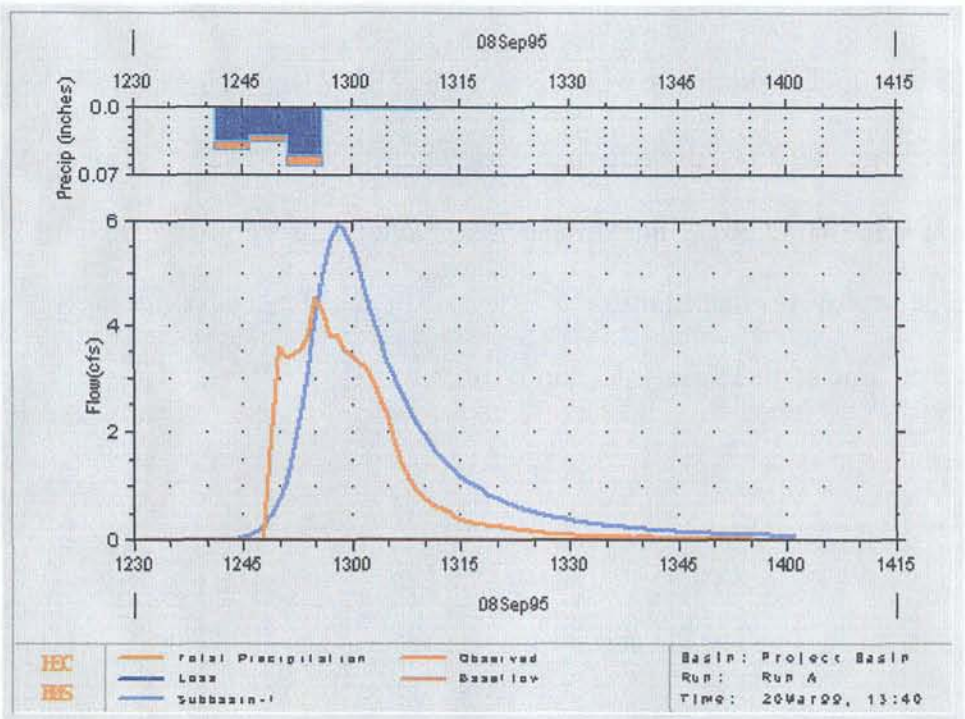


Figure 18. Observed vs Calculated Hydrograph and Precipitation for Test Storm 1.

Test Storm 2

This rainfall event occurred on 8/13/95 and consisted of a total of 0.53 inches of precipitation in 70 minutes. Table 7 is a summary of the rainfall/runoff event including observed and calculated peak discharge, total discharge, time of peak, and total precipitation. Figure 19 is a graphic representation of the observed vs calculated hydrograph and precipitation. The simulation run covered times 14:21 to 16:02, which includes both the precipitation and runoff event.

For Test Storm 2, peak discharge was calculated by HEC-HMS to be 1.5 cfs vs an observed peak discharge of 1.1 cfs; peak discharge was overestimated by 36%. The calculated total discharge was 0.09 in. (31,770 gal) vs an observed total discharge of 0.05 in (17,650 gal); total discharge was overestimated by 80%. The time of calculated peak discharge was 15:04 vs an observed time of 15:27, a 23-minute difference.

Table 7. Summary of Test Storm Event 2

Project:	Area G Main Project	Run Name:	Run B	Subbasin:	Subbasin-1
Start of Simulation:	13Aug95 1421	Basin Model:	Project Basin		
End of Simulation:	13Aug95 1602	Precip. Model:	Precip 1		
Execution Time:	20Mar99 1406	Control Specs:	Test B		
Volume Units:	(•) Inches ( ) Acre-Feet				
Computed Results					
Peak Discharge:	1.4831 (cfs)	Date/Time of Peak Discharge:	13 Aug 95 1504		
Total Precipitation:	0.53 (in)	Total Direct Runoff:	0.09 (in)		
Total Loss:	0.43 (in)	Total Baseflow:	0.00 (in)		
Total Excess:	0.10 (in)	Total Discharge:	0.09 (in)		
Observed Hydrograph at Gage : GAGE 1					
Peak Discharge:	1.1020 (cfs)	Date/Time of Peak Discharge:	13 Aug 95 1527		
Average Residual:	0.32684 (cfs)				
Total Residual:	0.04 (in)	Total Obs. Discharge:	0.05 (in)		

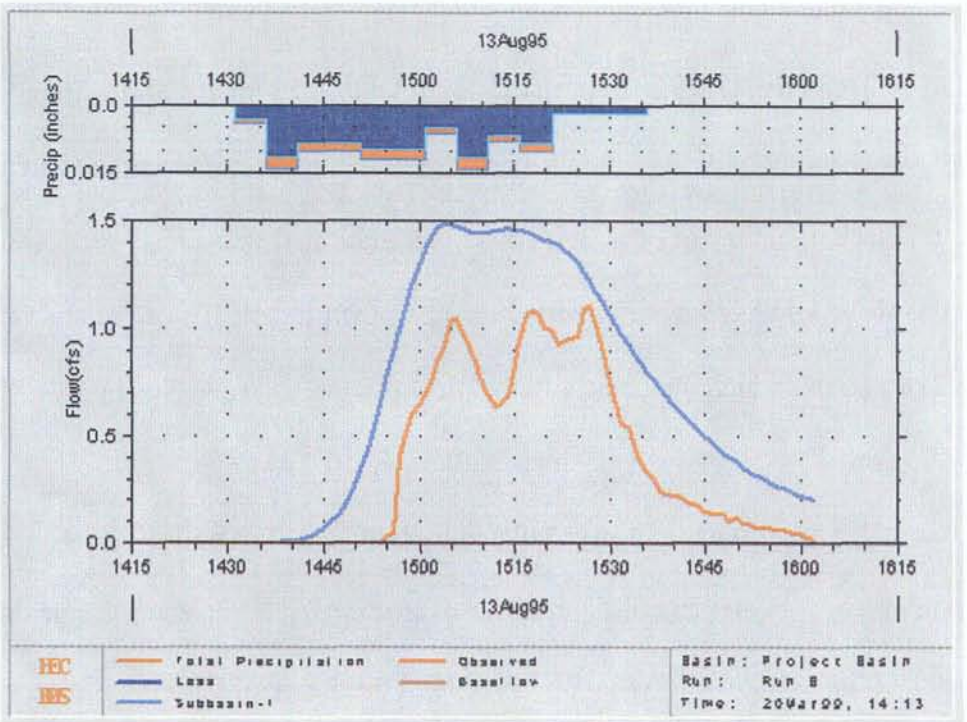


Figure 19. Observed vs Estimated Hydrograph and Precipitation for Test Storm 2.

Test Storm 3

This rainfall event occurred on 6/29/96 and consisted of a total of 0.16 inches of precipitation (a relatively light storm) in 65 minutes. Table 8 is a summary of the rainfall/runoff event including observed and calculated peak discharge, total discharge, time of peak, and total precipitation. Figure 20 is a graphic representation of the observed vs calculated hydrograph and precipitation. The simulation run covered times 02:20 to 04:13, which includes both the precipitation and runoff event.

For Test Storm 3, peak discharge was calculated by HEC-HMS to be 0.4 cfs vs an observed peak discharge of 0.2 cfs; peak discharge was overestimated by 100%. The calculated total discharge was 0.02 in. (7,060 gal) vs an observed total discharge of 0.01 in (3,530 gal); total discharge was overestimated by 100%. The time of calculated peak discharge was 03:05 vs an observed time of 02:53, a 12-minute difference.

Table 8. Summary of Test Storm Event 3.

Project : Area G Main Project Run Name : Run C Subbasin : Subbasin-1

Start of Simulation : 29Jun96 0220 Basin Model : Project Basin
End of Simulation : 29Jun96 0413 Precip. Model : Precip 1
Execution Time : 20Mar99 1458 Control Specs : Test C

Volume Units : (•) Inches ( ) Acre-Feet

Computed Results

Peak Discharge :	0.40266 (cfs)	Date/Time of Peak Discharge :	29 Jun 96 0305
Total Precipitation :	0.16 (in)	Total Direct Runoff :	0.02 (in)
Total Loss :	0.13 (in)	Total Baseflow :	0.00 (in)
Total Excess :	0.03 (in)	Total Discharge :	0.02 (in)

Observed Hydrograph at Gage : GAGE 1

Peak Discharge :	0.17600 (cfs)	Date/Time of Peak Discharge :	29 Jun 96 0253
Average Residual :	0.14801 (cfs)		
Total Residual :	0.02 (in)	Total Obs. Discharge :	0.00 (in)

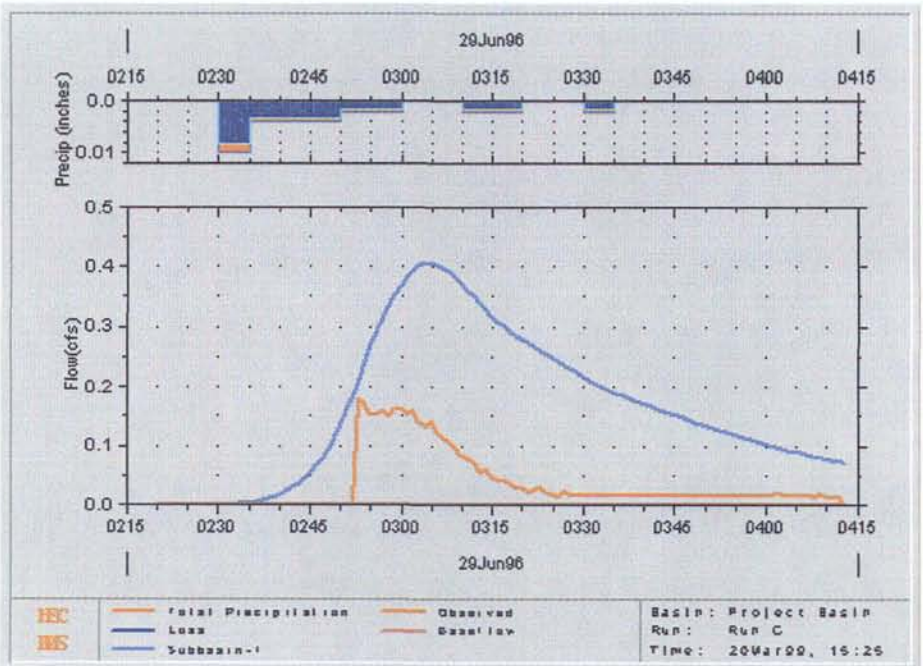


Figure 20. Observed vs Estimated Hydrograph and Precipitation for Test Storm 3.

Test Storm 4

This rainfall event also occurred on 6/29/96 and consisted of a total of 0.27 inches of precipitation in 80 minutes. Table 9 is a summary of the rainfall/runoff event including observed and calculated peak discharge, total discharge, time of peak, and total precipitation. Figure 21 is a graphic representation of the observed vs calculated hydrograph and precipitation. The simulation run covered times 18:20 to 21:00, which includes both the precipitation and runoff events.

For Test Storm 4, peak discharge was calculated by HEC-HMS to be 0.8 cfs vs an observed peak discharge of 0.5 cfs; peak discharge was overestimated by 60%. The calculated total discharge was 0.05 in. (17,650 gal) vs an observed total discharge of 0.01 in (3,530 gal); total discharge was overestimated by 500%. The time of calculated peak discharge was 19:10 vs an observed time of 19:15, a 5-minute difference.

Table 9. Summary of Test Storm Event 4.

Project:	Area G Main Project	Run Name:	Run D
Subbasin:	Subbasin-1		
Start of Simulation:	29Jun96 1820	Basin Model:	Project Basin
End of Simulation:	29Jun96 2100	Precip. Model:	Precip 1
Execution Time:	20Mar99 1614	Control Specs:	TEST D
Volume Units:	(•) Inches ( ) Acre-Feet		

Computed Results

Peak Discharge:	0.78068 (cfs)	Date/Time of Peak Discharge:	29 Jun 96 1910
Total Precipitation:	0.27 (in)	Total Direct Runoff:	0.05 (in)
Total Loss:	0.22 (in)	Total Baseflow:	0.00 (in)
Total Excess:	0.05 (in)	Total Discharge:	0.05 (in)

Observed Hydrograph at Gage: GAGE 1

Peak Discharge:	0.48800 (cfs)	Date/Time of Peak Discharge:	29 Jun 96 1915
Average Residual:	0.22457 (cfs)		
Total Residual:	0.05 (in)	Total Obs. Discharge:	0.01 (in)

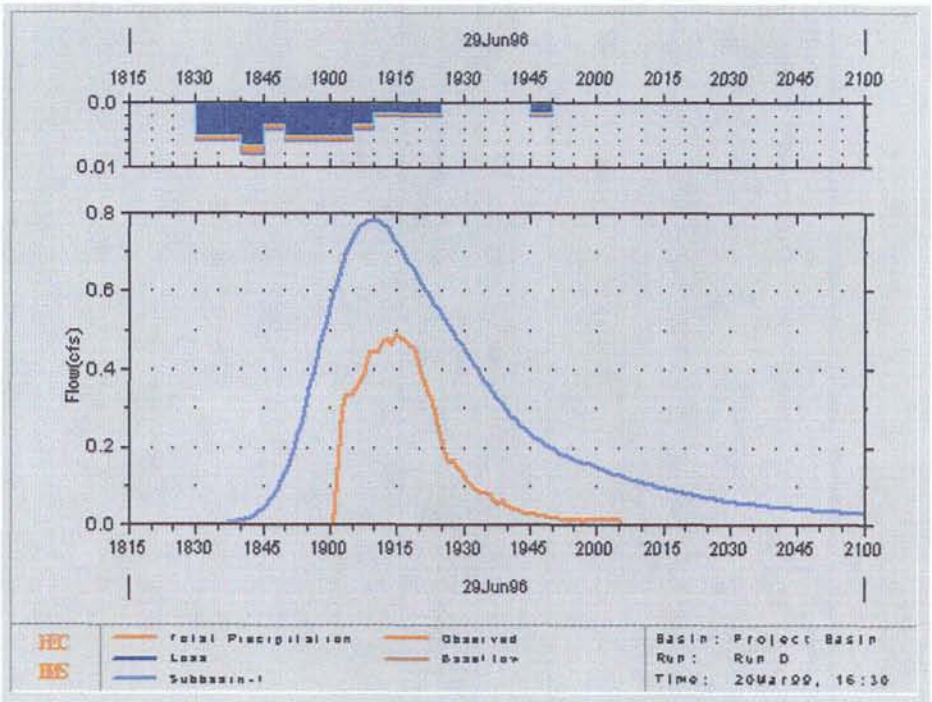


Figure 21. Observed vs Estimated Hydrograph and Precipitation for Test Storm 4.

A summary of the data from the 4 test storms is presented in Table 10. The table includes precipitation amounts, event times, and estimated vs observed peak discharge, total discharge, time of peak, and % errors.

10.7 Stormwater Model Conclusion and Recommendations

Stormwater modeling is an important tool for predicting runoff for various storm events. At a facility like MDA-G predicting runoff is necessary for planning purposes and facility design. For example, it would be very valuable for the facility to have estimated runoff intensities for a 5-year, 10-year, 20-year, etc. predicted storms so the volumes and intensities of runoff could be planned for to reduce erosion and sediment transport.

Table 10. Summary of Results from Test Storm Events.

Test Storm #	Rain (in)	Calculated Peak Flow (cfs)	Observed Peak Flow (cfs)	% Error	Calculated Total Flow (gal)	Observed Total Flow (gal)	% Error	Calculated Peak Time	Observed Peak Time	Time Difference (min)	Date
1	0.73	5.9	4.5	+31	42,361	31,770	+33	12:58	12:55	+3	9/8/95
2	0.53	1.5	1.1	+36	31,770	17,650	+80	15:04	15:27	-23	8/13/95
3	0.16	0.4	0.2	+100	7,060	3,530	+100	03:05	02:53	+12	6/29/96
4	0.27	0.8	0.5	+60	17,650	3,530	+500	19:10	19:15	-5	6/29/96
MIN	0.16	0.40	0.20	31.00	7,060	3,530	33.00	NA	NA	3	NA
MAX	0.73	5.90	4.50	100.00	42,361	31,770	500.00	NA	NA	23	NA
MEDIAN	0.40	1.15	0.80	48.00	24,710	10,590	90.00	NA	NA	-1	NA
MEAN	0.42	2.15	1.58	56.75	24,710	14,120	178.25	NA	NA	-3	NA

This preliminary look at the use of HEC-HMS as a tool to make these predictions showed some promising results. In this assessment, HEC-HMS overestimated runoff intensities and quantities for all storm events tested. This would probably be more desirable than underestimation as it is better to be conservative in the eyes of most facility managers, but a more accurate model is necessary. The model did a better job at predicting the larger storms than it did the smaller storms; the larger storms are of course of most interest. There are probably a variety of reasons why this occurred including an inadequate data set, but guessing at this point would not be productive. The actual set up and use of a complete and useable HEC-HMS model for MDA-G would require a great deal more work and testing of the system. The first step would be to develop a hydrologic schematic for HEC-HMS that included all the drainages and encompassed all the hydrological elements of the facility. More known storm data would need to be evaluated and field measurements collected such as soil porosity. Also, the different techniques available for determining initial loss, etc. would have to be evaluated. The initial/constant loss method used in this preliminary evaluation is probably to simple for this hydrologic system. A more sophisticated method would be necessary to develop a useable and more accurate stormwater model. This initial evaluation is a good start but a long way from a useable product. It was also an excellent learning opportunity that proved to be very interesting.

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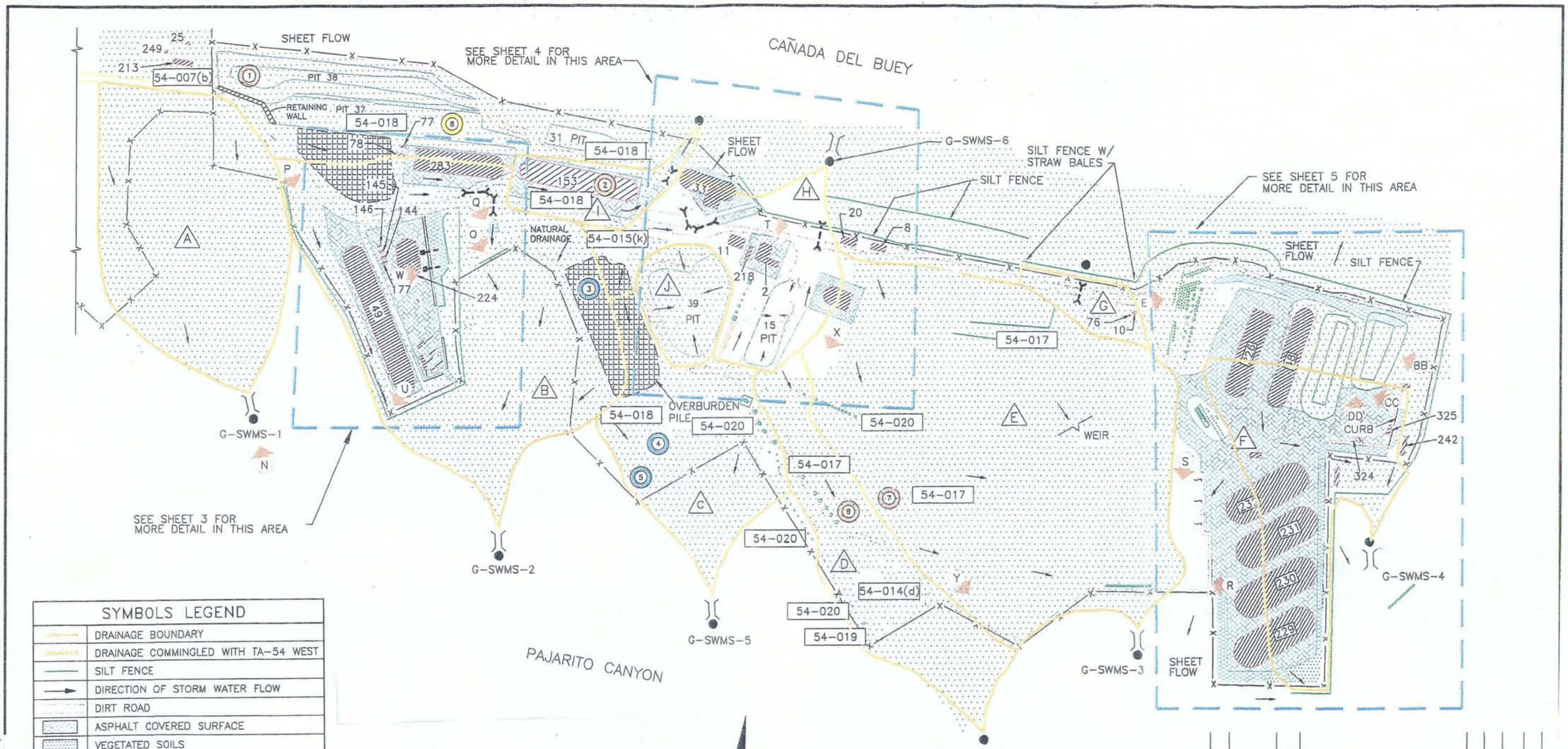

SYMBOLS LEGEND	
	DRAINAGE BOUNDARY
	DRAINAGE COMMINGLED WITH TA-54 WEST
	SILT FENCE
	DIRECTION OF STORM WATER FLOW
	DIRT ROAD
	ASPHALT COVERED SURFACE
	VEGETATED SOILS
	OVER-BURDEN PILE
	RIP-RAP
	EXISTING BUILDING
	SECONDARY CONTAINMENT
	CULVERT
	STORM WATER CATCH BASIN
	STORM WATER DISCHARGE POINT
	CLOSED SHAFTS
	OPEN SHAFTS
-x-x-x-	FENCE
	FIRE HYDRANT
	WATER LINE (BELOW GRADE)
	LOCATION OF PHOTOGRAPH
	STORM WATER SAMPLING STATION

AREA G DRAINAGE AREAS	
A	8.00 ACRES
B	13.00 ACRES
C	4.97 ACRES
D	4.83 ACRES
E	17.54 ACRES
F	6.04 ACRES
G	0.89 ACRES
H	4.53 ACRES
I	1.58 ACRES
J	1.53 ACRES

	SWMUs
54-007(b)	Septic System tank and seepage pit
54-014(d)	Inactive disposal trenches (A-D) used for TRU wastes.
54-015(k)	TRU waste culverts below grade storage in pit 29 (WFP).
54-017	Inactive radioactive and mixed waste disposal pits. (in part)
54-018	Active and inactive radioactive and mixed waste disposal pits. (in part)
54-019	Inactive disposal shafts used for misc. pre-RCRA disposal. (in part)

NO.	DATE	CLASS REV.	REVISIONS	DWN	DES	CHKD	SUB	APP
9	11/30/98	U		JCF	JH	TWL		

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TA-54 SWPP PLAN
AREA G
FACILITY SITE MAP

DRAWN MEW | DESIGN SJV | CHECKED SJV | DATE 9/18/95

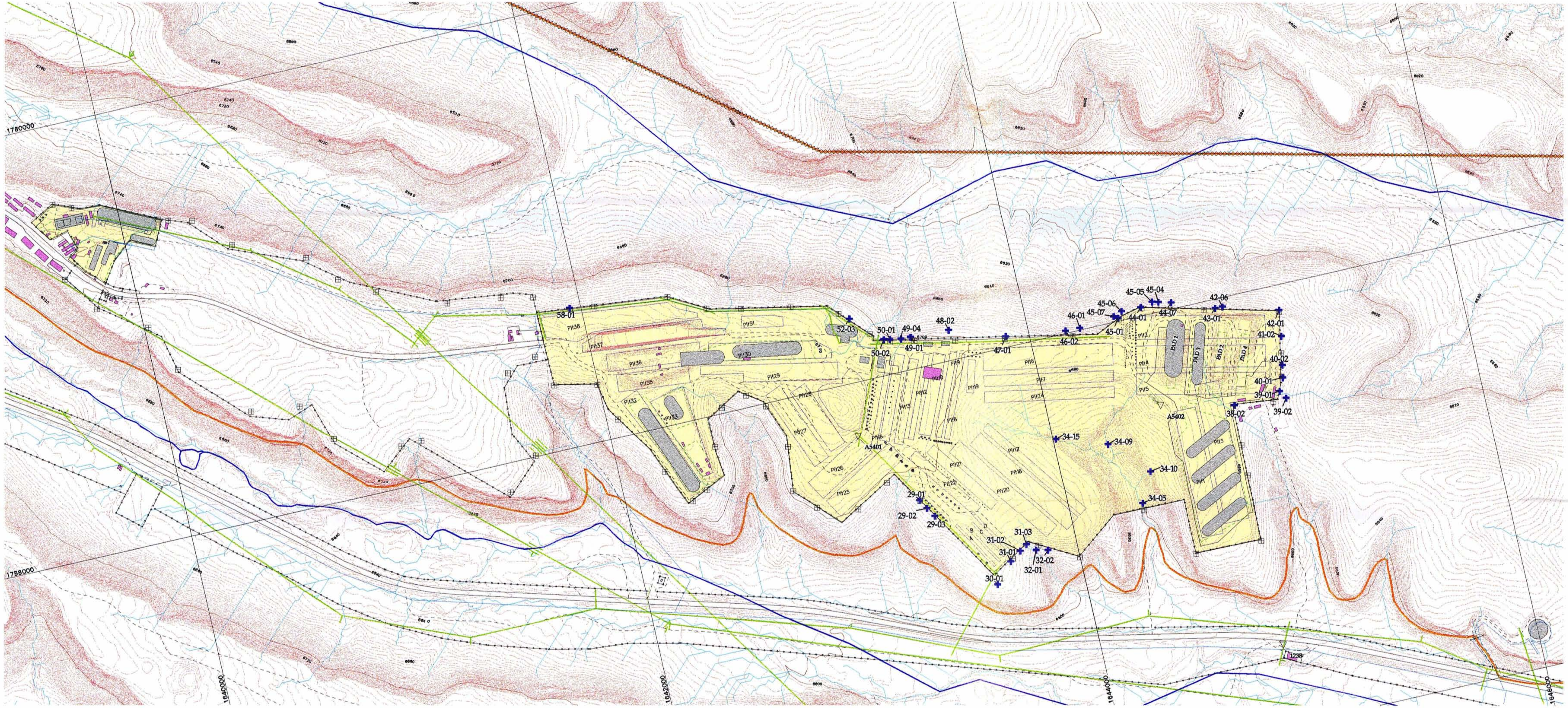
BLDG. TA-54
SUBMITTED | APPROVED FOR RELEASE

Los Alamos National Laboratory, Los Alamos, New Mexico 87545
SHEET C2 | 2 OF 8
CLASSIFICATION U | REVIEWER | DATE 9/18/95
PROJECT ID | DRAWING NO. | REV. 9

I:\JOB\30012743\SWPP\IND\TA54\DWGS\TA-54-G2. 04/14/98 @ 13:50 CMG

FIGURE 16 MDA-G DRAINAGES/SUB-BASINS DEFINED, INCLUDING GROUND COVERAGES.

OU1148: Area G Perimeter Surface Soil Sampling Stations



FIMAD Plot ID: G107553 31 Mar 99

Legend	
Boundary, LANL	Ground Control Points
Boundary, TA	MDA Survey Points
Drainage	G Survey: Soil Sample
Drainage Derived from DEM	
Industrial Fence	
Pads	
Power Line >13.2 kV	
Power Line <13.2 kV	
Road, Dirt	
Road, Paved	
Waste Pits	
Water Line	
Material Disposal Area	
Shaft	
Permanent Structure	
Temporary Structure	

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LOS ALAMOS NATIONAL LABORATORY, Los Alamos, New Mexico

Produced by: Doug Walther
Date: March 31, 1999 FIMAD Plot ID: G107553

N

State Plane Coordinate System, New Mexico Central Zone.
1983 North American Datum

Grid provides NM State Plane coordinates in feet.
Grid interval, in feet: 2000
Contour Interval = 2 Feet

0 91 182 273 364
METERS
0 300 600 900 1200
FEET

Basemap Sources: Boundary, structure, and utility data are from Los Alamos National Laboratory Engineering Division and Los Alamos County Utility and Engineering Departments. Contour data is from Los Alamos National Laboratory Environmental Restoration Program aerial survey, September 1991.