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PRELIMINARY ENGINEERING EVALUATION OF REMEDIAL ACTION ALTERNATIVES

BAYO CANYON SITE, LOS ALAMOS, NEW MEXICO

SEPTEMBER 1982

Bechtel Job 14501
Bechtel National, Inc.
Nuclear Fuel Operations

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BAYO CANYON SITE

LOS ALAMOS, NEW MEXICO

SUMMARY REPORT

SEPTEMBER 1982

Prepared for

UNITED STATES DEPARTMENT OF ENERGY

OAK RIDGE OPERATIONS OFFICE

by

BECHTEL NATIONAL, INC.

OAK RIDGE, TENNESSEE

FOREWORD

The final engineering summary report that follows reflects an approach agreed upon by DOE-ORO and the Project Management Contractor, Bechtel National, Inc. (BNI). The report is based on information prepared by Ford, Bacon and Davis Utah, Inc. and preliminary engineering performed by BNI. It is not intended that every possible remedial action option be developed in detail in this summary report.

Engineering judgement was used to identify the options that are compared in the cost/benefit (risk) summary. This comparison and back-up information contained in the summary report were prepared to support the selection of a remedial action to be implemented at the Bayo Canyon site.

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INTRODUCTION AND SUMMARY

Under the Formerly Utilized Sites Remedial Action Program (FUSRAP), the U.S. Department of Energy (DOE) has proposed to carry out remedial actions at the Bayo Canyon site in Los Alamos County, New Mexico. DOE has determined that strontium-90, in excess of DOE's proposed clean-up criteria, exists in three subsurface areas which were the solid and liquid waste disposal areas at the Bayo Canyon site.

This summary report has been prepared to document the options considered and provide a technical and economical basis for selecting a preferred remedial action to be implemented at the Bayo Canyon site. In addition to information developed by Bechtel, the Project Management Contractor, it presents information provided to Bechtel by Ford, Bacon and Davis Utah Inc. (FB&DU), and the Environmental Analysis[1] of the Bayo Canyon site prepared by Los Alamos National Laboratory (LANL).

Appendices A, B, and C to this report contain a site history, site description, and a discussion of remedial action options. Major portions of these appendices were extracted from work performed by Ford, Bacon and Davis Utah, Inc. Appendix D, Radiological Data, is extracted verbatim from a LANL report[2].

CLEAN-UP CRITERIA AND SITE CONTAMINATION

The clean-up criterion that applies at the Bayo Canyon site is 100 pCi/g of Sr-90. Surface contamination concentrations are generally less than the criteria, but subsurface contamination exceeds the criteria in three areas. Sampling has indicated that the contamination is situated from about 8 to 40 feet (2.4 m to 12.2 m) below the surface in these areas. Health risks and radiological conditions at Bayo Canyon are discussed in detail in the LANL Environmental Analysis[1]. Radiological conditions are also discussed in Appendix D, Radiological Data.

Dose calculations indicate that doses from surface contamination for recreational users of the canyon, permanent residents, and construction workers, and doses for workers involved in excavation of contaminated soil if the excavation and disposal option is selected, are only small percentages of applicable guidelines.

If the minimal action option is selected, the canyon, except for the restricted area, would be available for development of as many as 400 homes. The restricted area could be used for a park, tennis courts, etc., and the Sr-90 activity could decay to levels permitting unrestricted usage in about 160 years.

REMEDIAL ACTION OPTIONS

Three remedial action options are being considered for the Bayo Canyon site. A detailed discussion of how these options were selected is given in Appendix C. The options are:

- No action - leaving the property unchanged and incurring no expenses.

- Minimal action - placing monument markers around a 1.5-acre rectangular-shaped restricted area and placing a restrictive covenant on the deed to prevent excavation of the land for 160 years. Contamination above clean-up criteria would remain undisturbed below the surface. Surveillance would be conducted by local authorities on routine patrol to confirm that no digging has occurred in the restricted area.

- Excavation and disposal - removing the overlying soil, and excavating the subsurface soil that exceeds the clean-up criteria. The contaminated soil would be transported to the LANL waste disposal site.

COST/BENEFIT SUMMARY

Table 1 is a cost/benefit summary for the remedial action options that were considered for the Bayo Canyon site. The costs shown for the options are preliminary Bechtel estimates. The cost for the minimal action option is a small fraction of the cost for excavation and disposal. Environmental impacts are low for the minimal action option, and only about 1.5 acres are unavailable to the county for residential development. The no-action option has no cost but, if intrusion occurs, would result in the exposure of workers or the public to Sr-90 concentrations that are about eleven times the criteria for clean-up.

ENVIRONMENTAL CONSIDERATIONS

An environmental analysis[1] performed for the Bayo Canyon site determined that no environmental impacts are associated with either the no-action or minimal action alternatives. The impact associated with the disposal alternative is small, especially considering previous decommissioning action that took place at the site in 1963.

TABLE 1

COST/BENEFIT SUMMARY

BAYO CANYON SITE

OPTION	DESCRIPTION	COST[1]	DISCUSSION/BENEFITS (RISK)
No action	Property unchanged	None	If no action is taken and the area is developed as now planned, there is a high probability that the contaminated material located from about 8 to 40 feet below the surface will be uncovered or that the present covering soil will be removed. Workers constructing home foundations and utilities would encounter ^{90}Sr concentrations of 1100 pCi/g as compared with the criteria for clean-up of 100 pCi/g for ^{90}Sr.
Minimal Action	Place restrictive covenant on deed. Place six (6) monument markers around restricted area of about 1.5 acres.	$ 8,600	The county will encumber the deed with a restrictive covenant that will run with the land (in legal parlance). There is virtually no environmental impact, the cost is low, and about 1.5 acres are unavailable to the county for residential development. The contaminated soil presents no radiological hazard if kept at depth.[2]
Disposal	Excavate 17,500 yd^3. Dispose of 1,910 yd^3 (bulk) at LANL waste site. Backfill and revegetate conventional excavation.	$1,071,500	Benefits are slight over the minimal action alternative. Significant additional environmental impacts and cost are associated with implementing this option. Disposal eliminates concern about the monuments being inadvertently destroyed and excavation occuring in the restricted area before the contamination decays to clean-up criteria levels in about 160 years.

(1) Preliminary cost estimate performed by Bechtel. For the minimal action cost, it was assumed that surveillance will be conducted by local authorities on routine patrol during and after residential development. Surveillance will consist of confirming that no digging has occurred in the restricted area. Monitoring will be performed annually and for the minimal action option will cost an additional $3000 per year.

(2) From the Environmental Analysis of the Bayo Canyon site (LANL, 1982). The determination made by LANL in the report has been concurred with by the New Mexico State Environmental Improvement Division (EID). Risks associated with the options are discussed in detail in the LANL report. Based on the calculations performed by LANL, the 50-year dose commitment to the bone resulting from excavation into the contaminated material by a construction crew would be 0.03 mrem or 0.2 percent of the radiation protection standard.

REFERENCES

1. "Environmental Analysis of the Bayo Canyon (TA-10) Site; Los Alamos, New Mexico;" Los Alamos National Laboratory; Los Alamos, New Mexico; May 1982.

2. "Radiological Survey of the Bayo Canyon, Los Alamos, New Mexico"; prepared for U.S. Department of Energy under contract W-7405-ENG-36; Los Alamos Scientific Laboratory, Los Alamos, NM; June 1979.

APPENDIX A

SITE HISTORY

SITE HISTORY

The United States Government has instituted a program entitled "Formerly Utilized MED/AEC Sites Remedial Action Program", or FUSRAP. This remedial action program for the Manhattan Engineer District (MED)/Atomic Energy Commission (AEC) sites was initiated in 1974 by the AEC, was continued under the Energy Research and Development Administration (ERDA), and is presently being managed by the Department of Energy (DOE). The objectives of this DOE program include determining the radiological conditions of the former MED/AEC sites, proposing remedial action options that could be undertaken where corrective actions are necessary, analyzing the environmental impacts, and estimating the costs associated with the remedial action.

A portion of Bayo Canyon, located in Los Alamos County in north-central New Mexico, has been designated as a former MED/AEC site because between 1944 and 1961 it was used as a site for experiments employing conventional high explosives in conjunction with research on nuclear weapons development. The experiments were initially performed under the auspices of the MED and later for the AEC. The site was decontaminated and decommissioned in 1963, however, the southeastern portion of the site still contains subsurface contamination.

Facilities for the experiments with high explosives were constructed in 1943 in Bayo Canyon for Project Y, sponsored by the MED. Nuclear weapons blast diagnostics were studied using conventional high explosives containing uranium and other radiation sources. The radiation sources used in the blast diagnostics tests contained from several hundred to several thousand curies of La-140 per test shot, along with a smaller amount of Sr-90. The explosions scattered the radioactive materials around two firing points. The La-140 has decayed away, but the Sr-90 and its daughter Y-90, along with U-238, remain on the site in measurable quantities. In addition, there are contaminated leach pits on the site where radioactive liquid and solid wastes from the radiochemistry laboratory were dispersed.

In the past, the Bayo Canyon site was referred to as Technical Area 10 (TA-10). Figure A-1 shows the portion of the former test area designated as the Bayo Canyon site. The principal structures comprising TA-10 included a radiochemistry laboratory (TA-10-1), two assembly buildings (TA-10-10 and TA-10-12), an inspection building (TA-10-8), a personnel building (TA-10-21), and control buildings at two detonation control complexes (TA-10-13 and TA-10-15) with adjacent firing pads.

Decommissioning of the test site began in 1960 with the demolition of several buildings. In 1963, the remaining buildings were demolished, the sewer systems removed, the contaminated waste

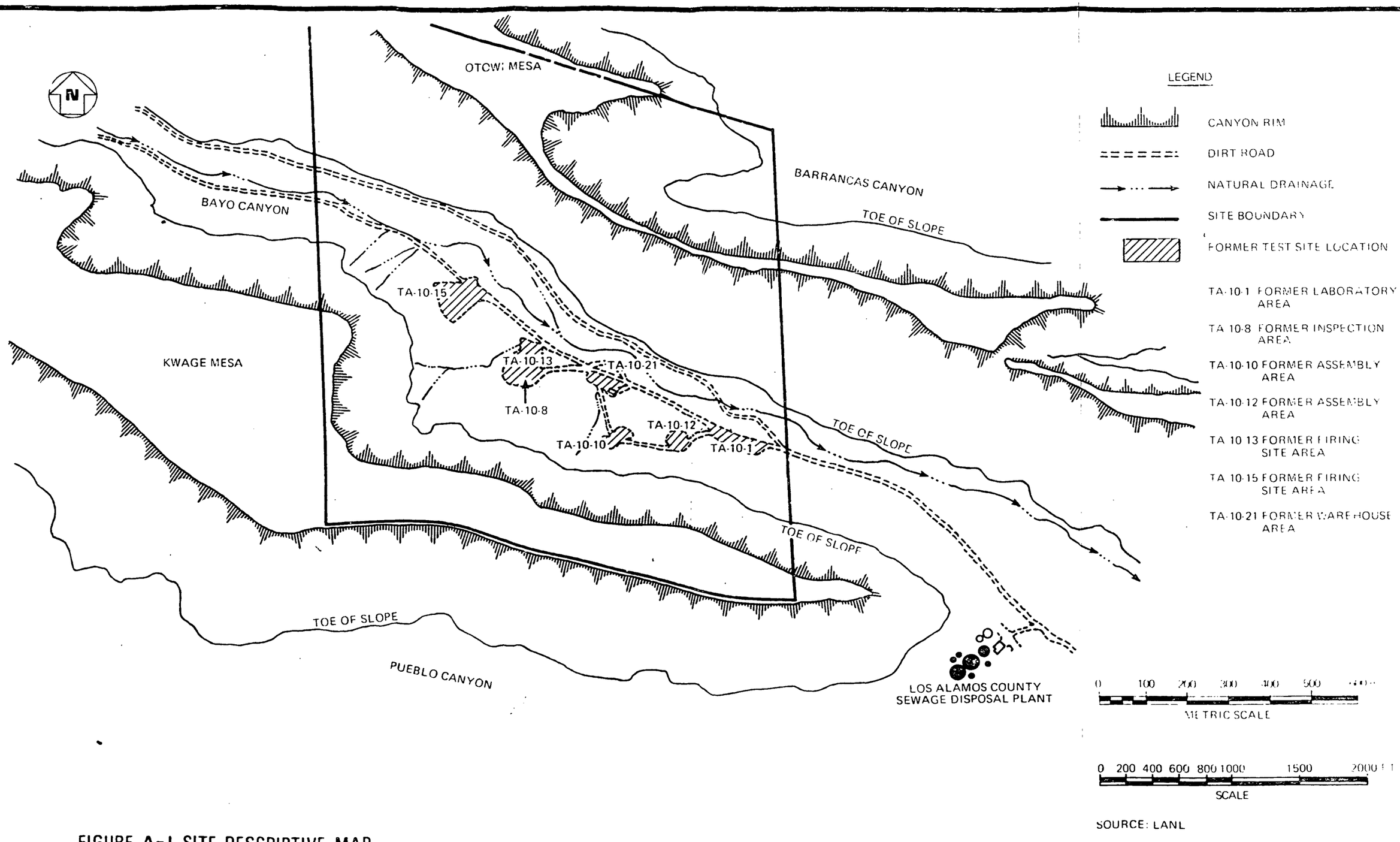

FIGURE A-1. SITE DESCRIPTIVE MAP

pits excavated, and the surface debris removed within a radius of about 2,500 ft (760 m) from the detonation control buildings. Debris was disposed of at the contaminated waste burial site at the Los Alamos National Laboratory (LANL).

After decommissioning, the land was transferred from the U.S. Government to Los Alamos County by quit claim deed on July 1, 1967. It was recognized at the time of decommissioning that some radioactive materials probably remained in the canyon. Consequently, several follow-up radiological surveys were conducted over the years.

A U.S. Geological Survey study in 1956 concluded, and a 1961 survey[1] verified, that because of the basically dry conditions in Bayo Canyon, there was little possibility that contaminants from the surface or from liquid waste disposal pit seepage would move any significant distance in the shallow ground water. In 1961-1962, an aerial gamma-radiation survey was conducted for the AEC near the LANL nuclear facilities and in portions of northern New Mexico. The survey showed that the radiation measurements were not higher than normal for Bayo Canyon. Between 1965 to 1970, sediments from two locations in the channel downstream from the Bayo Canyon site were analyzed and showed no contamination. In 1972, a survey of Kwage Mesa just south of Bayo Canyon showed that radiation levels were not statistically different from the reference location in northern New Mexico (the analysis did not include Sr-90). Beginning in 1973, some resurvey work was undertaken in Bayo Canyon by the Health Division of LANL at the request of the AEC to determine the radiological conditions at the site. The subsurface contamination indicated by this 1973 survey led to the drilling of 11 auger holes in 1974. Samples from these holes showed elevated activity around the sanitary outfall and some migration through the tuff north of the TA-10-41 and TA-10-42 acid waste pits. In 1975, a second aerial survey that included west-to-east flights over Bayo Canyon was performed. The results showed that radiation activity was only slightly higher than normal background levels for most areas in the southwestern United States.

In 1976, ERDA identified the Bayo Canyon site as an MED/AEC site. Consequently, LANL personnel began a resurvey in 1976 for possible residual contamination. The radiological survey was completed in 1977, and the final report[1] on the survey results was issued in June 1979. The results of this survey indicated that the Bayo Canyon site should be considered for remedial action[2].

Bayo Canyon is currently used exclusively for recreation (picnics, trail riding, hiking, firearms practice, wood cutting, and pinon nut gathering). Projected future use includes possible residential development.

APPENDIX A REFERENCES

1. "Radiological Survey of Bayo Canyon, Los Alamos, New Mexico; "Final Report, by Los Alamos Scientific Laboratory, Los Alamos, New Mexico; for U. S. Department of Energy, Assistant Secretary for Environment, Division of Environmental Control Technology, Washington, D. C.; under Contract No. W-7405-ENG-36; June 1979.

2. "A Background Report for the Formerly Utilized MED/AEC Sites, Remedial Action Program;" Draft Report; by Environmental Controls and Analysis Directorate, Eastern Technical Division, The Aerospace Corporation; for the Division of Environmental Control Technology, Assistant Secretary for Environment, U. S. Department of Energy; under Contract No. EX-76C-03-110 (PA-10); Dec 1978.

APPENDIX B

SITE DESCRIPTION

SITE DESCRIPTION

The site is located in Bayo Canyon in north-central New Mexico, in Los Alamos County, adjacent to and east of the town of Los Alamos. Albuquerque is about 62 mi (100 km) to the south-southwest. Figure B-1 shows the site location, and Figure B-2 is a site vicinity map. The site is accessible via the New Mexico State Highway 4, onto a dirt road leading west to Pueblo Canyon, then to Bayo Canyon. Bayo Canyon is one of many canyons cut into the Pajarito Plateau, as shown in Figure B-3. The site encompasses approximately 350 acres and is roughly in the shape of a parallelogram.

As shown in the aerial view of the Bayo Canyon site, Figure B-4, the canyon is bounded on the south by Kwage Mesa and on the north by Otowi Mesa. The mean elevation of the mesa tops is about 7,100 ft (2,160 m)[2]. The elevation of the canyon floor is about 6,600 ft (2,012 m) above sea level, and the canyon slopes to the southeast at a three-percent grade.

The north boundary of the site is considered to be on a generally east-west line along the top of Otowi Mesa. The south boundary is an east-west line along the top of Kwage Mesa. The east boundary is a north-south line approximately 500 ft (152 m) east of the former radiochemistry laboratory (TA-10-1). The west boundary lies approximately 1,000 ft (305 m) to the west of the former TA-10-15 firing site area.

PHYSICAL CONDITIONS

Since the decommissioning of the Bayo Canyon test site in 1963, the only remaining physical structures indicating former test activities are a concrete pad from a former warehouse, an asphalt pad at the former personnel building, an asphalt pad (parking area) at the former radiochemistry building, and deteriorated asphalt paved areas where firing tests were performed. The road through the site is paved but the paving is in a deteriorated condition.

Bayo Canyon has a semiarid mountain climate characterized by normally fair weather. The average temperature in July is about 73°F (23°C) and in January about 21°F (-6°C)[1]. Thundershowers in late summer provide most of the total annual precipitation; winter snows provide the remainder. Water flow in the canyon stream is intermittent, with most of the runoff occurring in July and August during heavy thunderstorms. The runoff period is generally short, e.g., several hours. The average annual precipitation increases from about 9 in. (23 cm) along the Rio Grande River to about 18 in. (46 cm) on the mesa plateaus, to about 30 in. (76 cm) along the crest of the mountains in the immediate vicinity of Los Alamos[1].

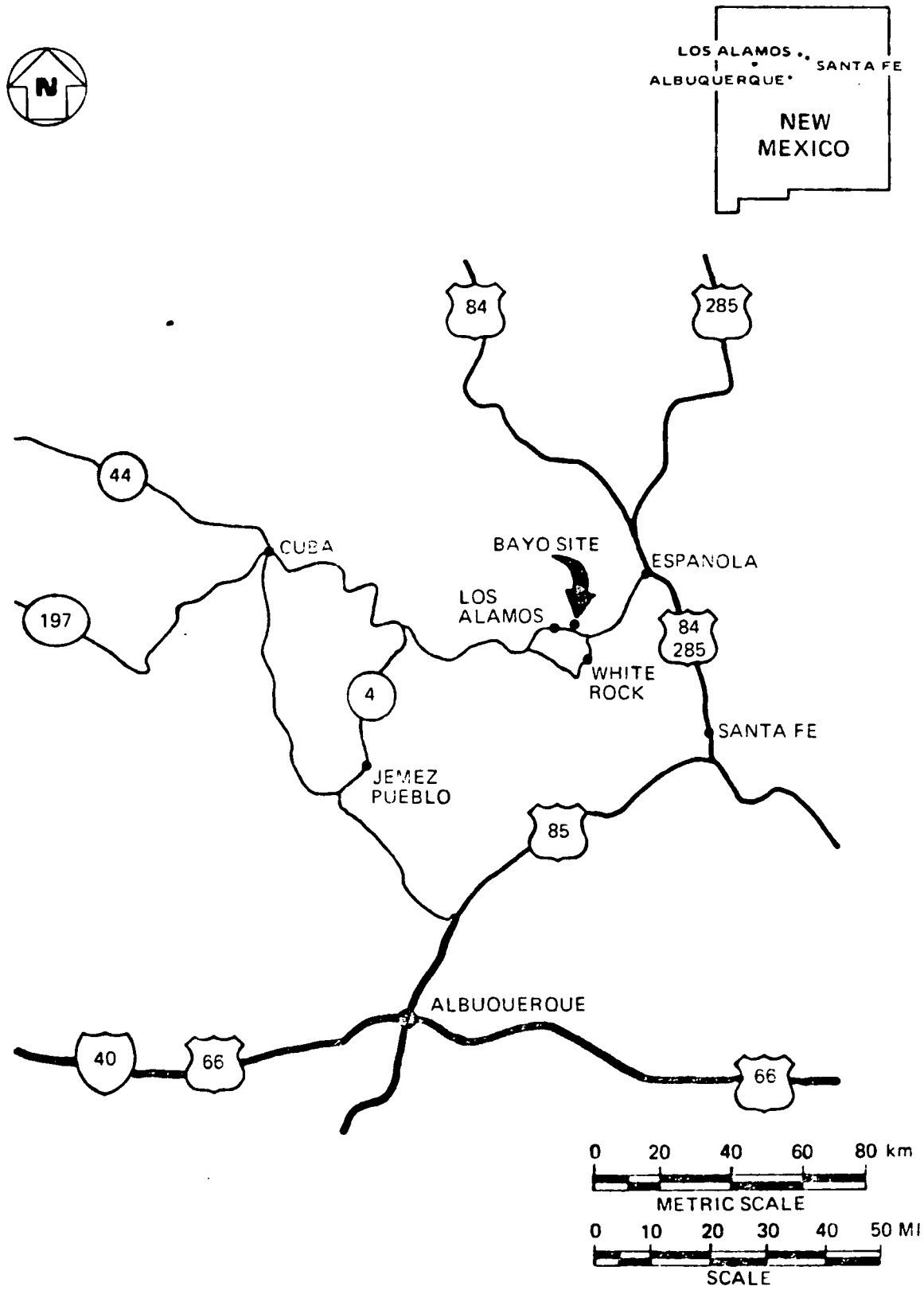

FIGURE B-1. SITE LOCATION MAP

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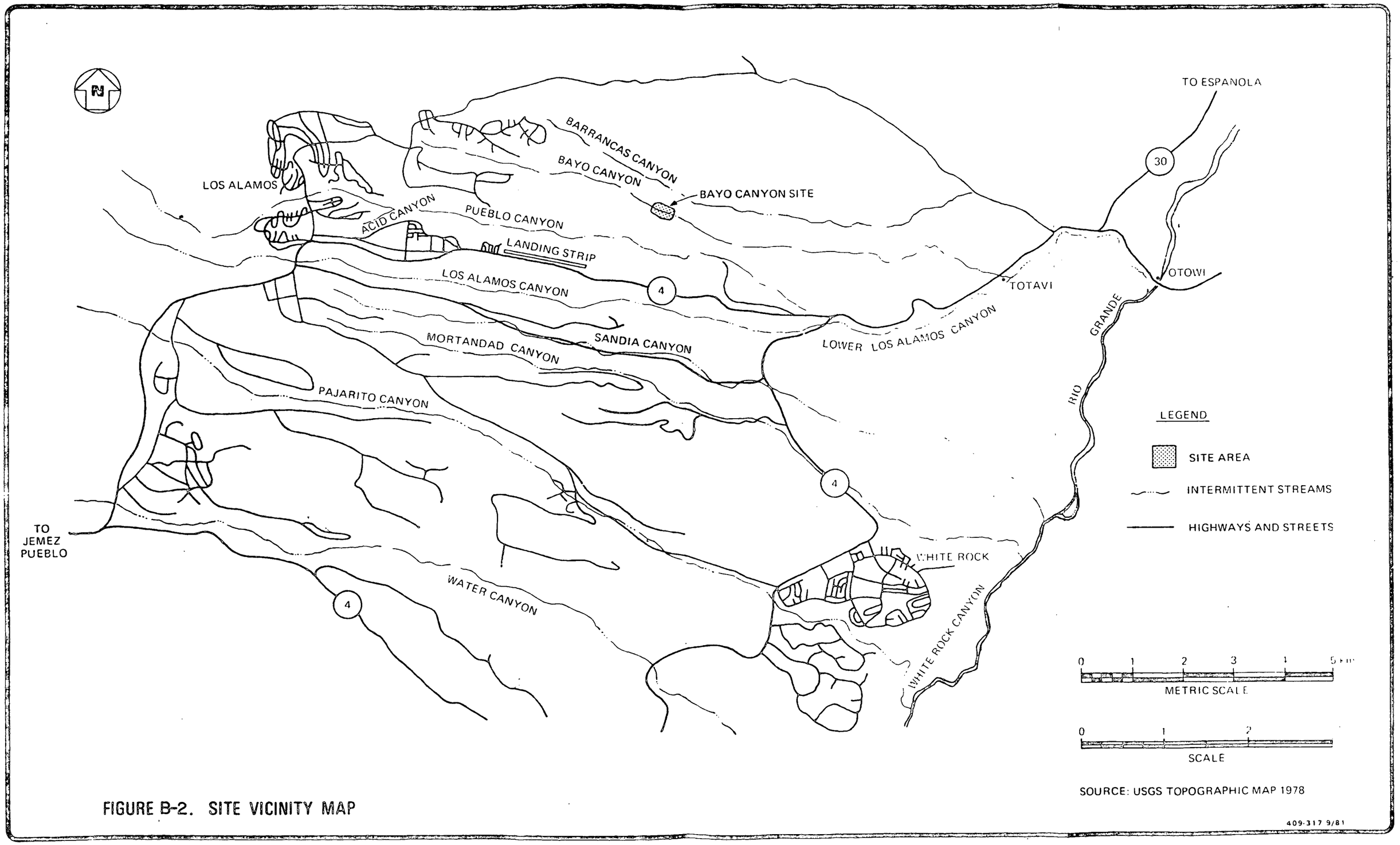
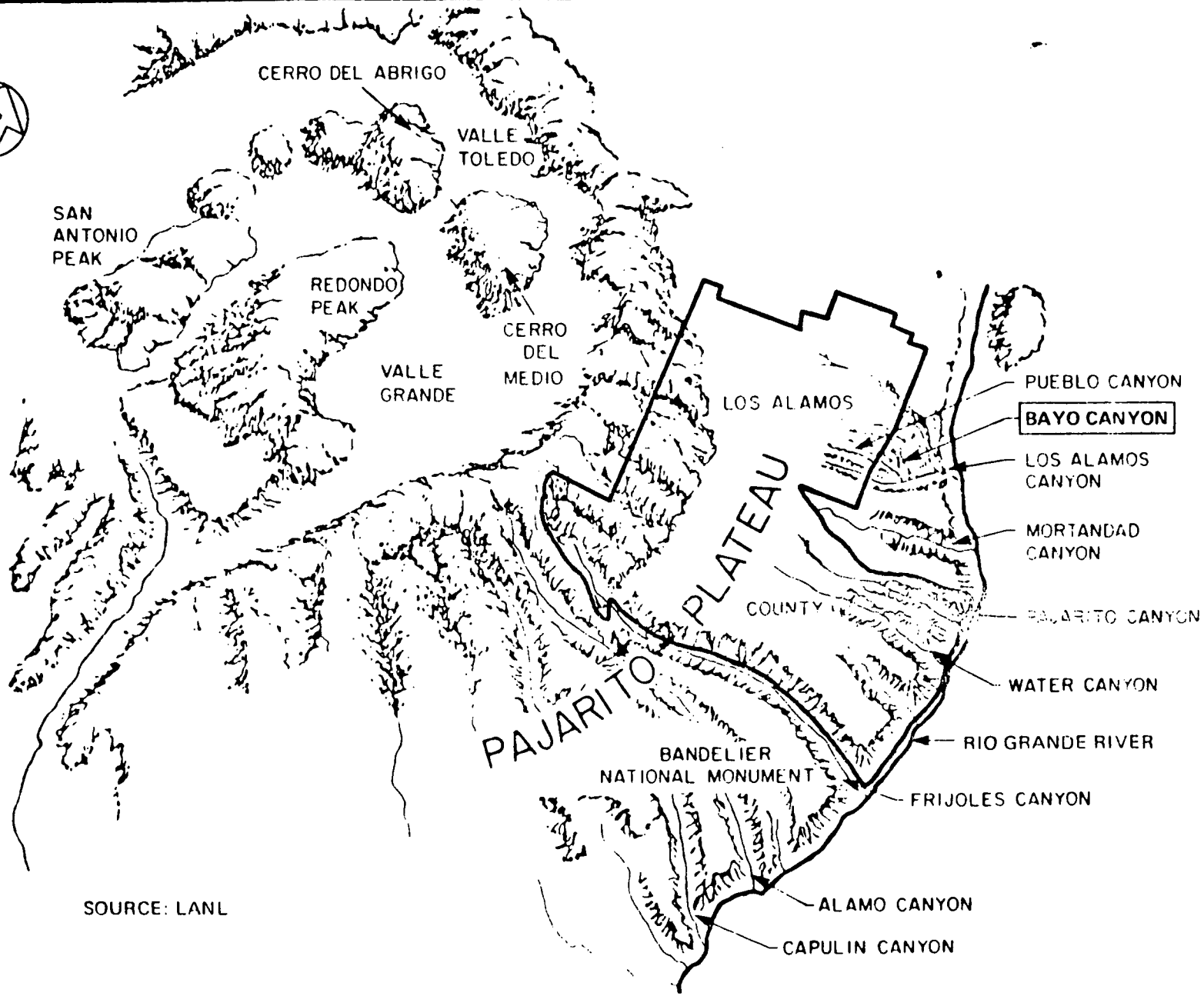


FIGURE B-2. SITE VICINITY MAP



SOURCE: LANL

FIGURE B-3. PHYSIOGRAPHIC SETTING OF BAYO CANYON

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Ford, Bacon & Davis Utah, Inc.

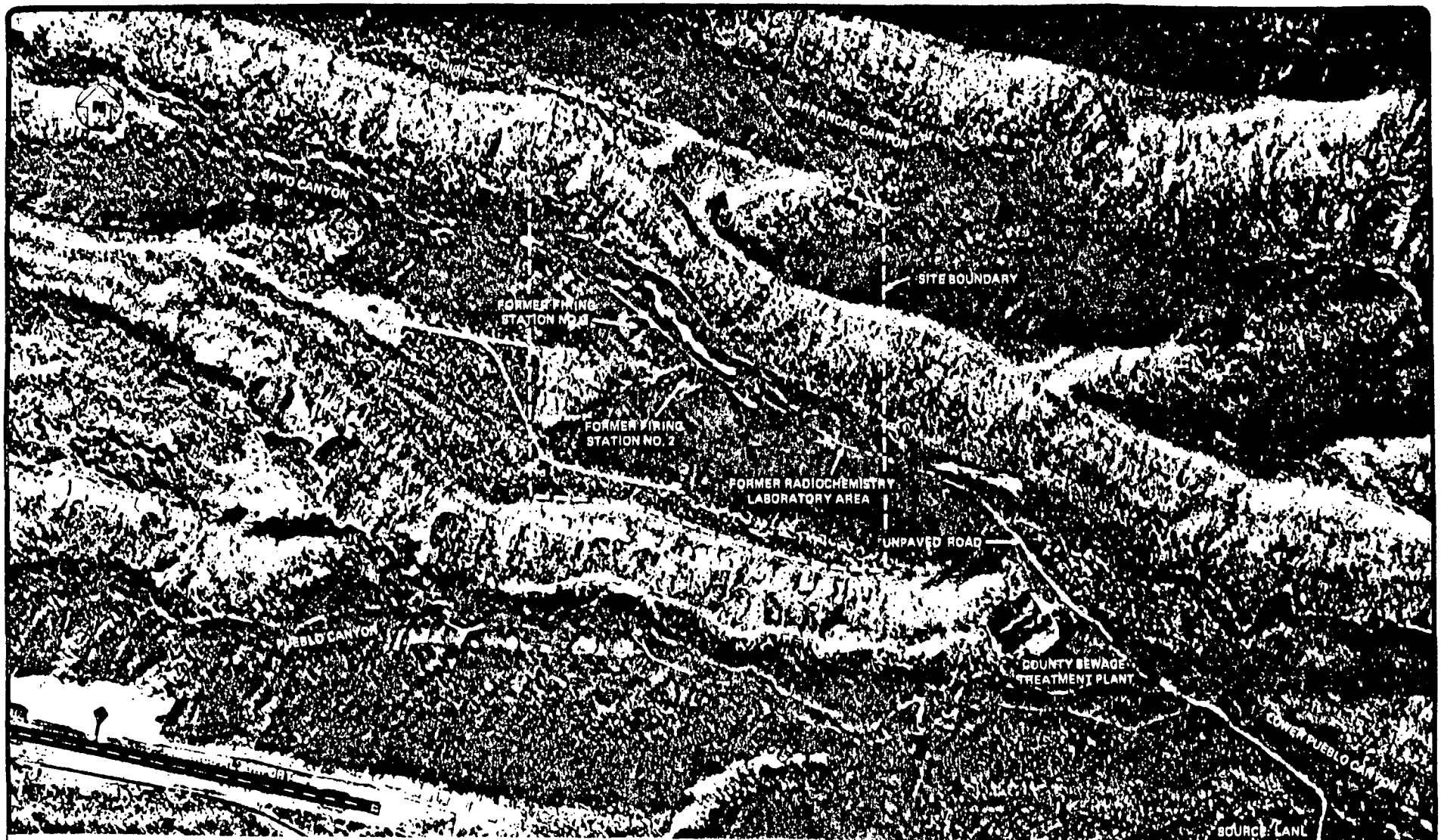


FIGURE B-4. AERIAL PHOTOGRAPH OF BAYO CANYON SITE

Bayo Canyon heads on the Pajarito Plateau and is tributary to the lower reach of Los Alamos Canyon, which in turn drains into the Rio Grande River. Available data suggest that there is no hydrological connection between any Bayo Canyon surface water and the main aquifer, which is about 790 ft (241 m) below the surface.

Clay soils and tuff outcrops on top of Otowi Mesa on the north and Kwage Mesa south of the site support a pinon-juniper brushland. A sandy soil that has developed on the talus slope facing north from Kwage Mesa and on the canyon floor supports pine and fir mixed with pinon and scrub oak, grading into grass and sagebrush on the canyon floor[2].

The site is underlain by the Otowi member of the Bandelier Tuff[3]. This member is a massive aggregate of poorly sorted rhyolitic pumice fragments and some fine pumice glass. It contains only a limited amount of perched ground water. From a point about 1 mi (1.6 km) downstream from the site to the confluence with Los Alamos Canyon, Bayo Canyon is underlain by the conglomerate of the Puye Formation, a member of the Santa Fe Group. This member consists of interbedded silt, sand, and gravel derived from contemporaneous erosion and volcanism[3].

The Bayo Canyon site is located in a seismic Zone 2 area, where moderate damage from earthquakes could occur[4]. The earthquake recorded nearest to the site occurred in Santa Fe County to the southeast on May 18, 1918. The quake was graded at intensity VI-VIII (Modified Mercalli scale). The most recently recorded event occurred on January 22, 1966, at Dulce, about 80 mi (113 km) northwest of the site. The magnitude of this event was measured at 5.5 on the more recently developed Richter scale.

RADIOLOGICAL CONDITIONS

The LANL performed a radiological survey of the Bayo Canyon test site for DOE in 1976-1977[2]. Data on surface and subsurface soils, air concentrations, and gamma surveys were obtained. The information presented in the following paragraphs is a summary of the findings of the radiological surveys performed by LANL and supplemented by FB&DU in 1980. The LANL survey data are included as Appendix D of this report.

Soil Samples

Soil samples were collected by LANL from the firing sites, the canyon floor, and the natural drainage area. Analysis of these samples revealed the presence of small amounts of Sr-90 and U-238 at depths of about 0 to 12 in. (0 to 30 cm). To better define the limits of contamination, additional holes were drilled in 1980 by LANL for FB&DU. The locations of these holes are shown in Figure B-5. Soil samples were collected at 3-ft (1-m) intervals in each hole down to 15 ft (4.6 m) in depth and at 5 ft (1.5 m) intervals thereafter. The results of the analysis are indicated in Table B-1.

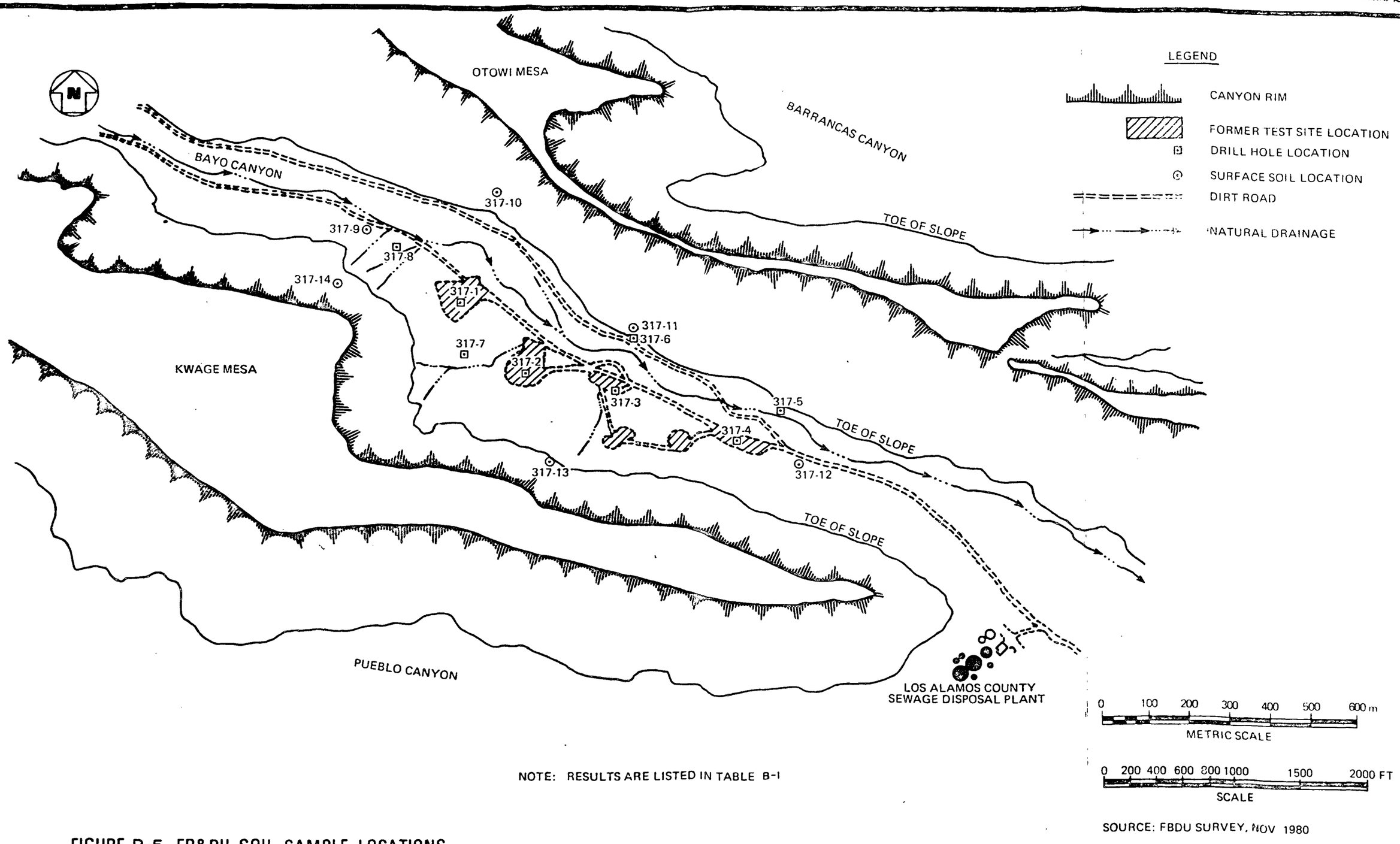


FIGURE B-5. FB&DU SOIL SAMPLE LOCATIONS

TABLE B-1

FB&DU SOIL SAMPLES FROM BAYO CANYON
(page 1 of 2)

Sample No.	Depth[a] (ft)	^{90}Sr (pCi/g)	^{238}U[b] (pCi/g)	^{40}K (pCi/g)
1A	0-3	1.60	1.5	26.3
1B	3-6	0.20	1.5	30.4
1C	6-9	<0.05	1.7	22.7
1D	9-12	0.38	1.6	29.0
1E	12-15	1.00	1.7	20.8
1F	12-20	<0.05	1.4	26.9
1G	20-25	<0.05	1.6	23.1
2A	0-3	<0.05	1.3	30.4
2B	3-6	<0.05	1.3	17.6
2C	6-9	<0.05	1.4	39.1
2D	9-12	<0.05	1.4	28.4
2E	12-15	<0.05	1.4	24.4
2F	15-20	<0.05	1.4	29.5
2G	20-25	<0.05	1.4	27.4
2H	25-30	0.37	1.6	27.7
2I	30-37	<0.05	1.8	33.2
3A	0-3	<0.05	1.1	24.9
3B	3-6	<0.05	1.2	33.5
3C	6-9	<0.05	1.1	26.9
3D	9-12	<0.05	1.2	31.9
3E	12-15	<0.05	1.5	31.3
3F	15-20	<0.05	1.9	28.9
4A	0-3	0.25	1.5	23.8
4B	3-6	0.12	1.5	27.4
4C	6-9	<0.05	1.9	21.6
4D	9-12	<0.05	2.0	61.1
4E	12-15	<0.05	1.4	24.9
4F	15-20	<0.05	1.1	25.6
4G	20-25	<0.05	1.4	27.3
5A	0-3	<0.05	0.63	22.6
5B	3-6	<0.05	1.3	28.5
5C	6-9	<0.05	0.97	30.8
5D	9-12	0.31	1.2	29.9
5E	12-15	<0.05	1.3	24.8
5F	15-20	0.14	1.5	28.9
5G	20-25	<0.05	1.3	25.5
5H	25-30	0.11	1.3	26.6
5I	30-37	<0.05	--	25.4

TABLE B-1

FB&DU SOIL SAMPLES FROM BAYO CANYON
(page 2 of 2)

Sample No.	Depth[a] (ft)	^{90}Sr (pCi/g)	^{238}U[b] (pCi/g)	^{40}K (pCi/g)
6A	0-3	<0.05	0.77	22.0
6B	3-6	<0.05	0.77	25.3
6C	6-9	<0.05	--	25.4
6D	9-12	<0.05	0.83	25.8
6E	12-15	<0.05	0.90	25.6
6F	12-20	<0.05	1.0	26.3
6G	20-25	<0.05	1.2	28.3
6H	25-30	<0.05	1.6	30.4
6I	30-37	4.32	1.7	37.1
7A	0-3	<0.05	1.7	31.7
7B	3-6	<0.05	1.7	31.9
7C	6-9	<0.05	1.8	24.8
7D	9-12	<0.05	1.8	33.5
7E	12-15	<0.05	1.9	27.2
7F	15-18	<0.05	1.5	19.7
8A	0-3	<0.05	1.6	24.1
8B	3-6	<0.05	1.5	25.5
8C	6-9	<0.05	1.5	14.1
8D	9-12	<0.05	1.2	22.7
9	0-1	<0.05	1.5	20.2
10	0-1	0.69	1.0	27.4
11	0-1	0.12	1.6	23.1
12	0-1	0.22	1.4	29.9
13	0-1	<0.05	1.6	23.2
14	0-1	0.20	1.6	25.3

[a] Meters = $\frac{ft}{3.3}$

[b] LANL analysis of FB&DU samples.

Samples were taken by LANL near and at the former waste pits and near the radiochemistry laboratory area to depths of about 65 ft (20 m). The Sr-90 concentrations ranged up to 4,310 pCi/g at 15 to 20 ft (5 to 6 m) below the surface at location 43 E, which is just east of the TA-10-43 liquid waste pit.

The LANL soil samples were tested for gross alpha and gross beta. Representative samples were also tested for specific nuclides including Sr-90. Gross beta concentrations were due not only to Sr-90 but also K-40 (a beta emitter) which was present in concentrations from 20 to 37 pCi/g. In every sample analyzed, where gross beta was greater than 100 pCi/g, Sr-90 was also greater than 100 pCi/g, and where gross beta was less than 100 pCi/g, Sr-90 was also less than 100 pCi/g. Gross beta appears to be a conservative indicator for soil concentrations of Sr-90. From the standpoint of radiation protection, it also conservative to assume that alpha contamination was due to U-238.

The combined effect of alpha and beta contamination also was considered. When two or more radionuclides are present in a soil sample, the maximum permissible concentration (MPC) of each will be reduced from the normal MPC for a single radionuclide. If C_1, C_2, $C_3 \ldots C_n$ represent the concentrations of each nuclide present in a particular soil sample, and if M_1, M_2, $M_3 \ldots M_n$ represent the MPC's of these radionuclides, then the permissible concentration of each radionuclide in the sample is given by the equation:

$$\frac{C_1}{M_1} + \frac{C_2}{M_2} + \cdots \frac{C_n}{M_n} \leq 1.00$$

At all sampling locations on the test site within 8 ft (2.4 m) of the surface, the combined gross alpha and gross beta summation was less than 1.0. At points below 8 ft (2.4 m) in depth, the only places where this index exceeded 1.0 were the waste pits where Sr-90 concentrations exceeded 100 pCi/g.

External Gamma Radiation

External gamma radiation was measured by FB&DU in Bayo Canyon using a Ludlum Model 125 Micro R Meter calibrated with a Cs-137 source. Measurements were made on the canyon floor, talus slopes, the tops of Kwage and Otowi Mesas, and the opposite side of Otowi Mesa into Barrancas Canyon. Measurements ranged from 14 to 34 μR/hr. The higher direct gamma readings generally were not in the immediate vicinity of the firing pads. This was observed independently by LANL and FB&DU personnel.

Delta measurements were conducted by FB&DU to determine the general extent of surface contamination. Delta measurements are made by holding a scintillation probe with a 1 x 1 in. (2.54 x 2.54 cm) NaI (TL) crystal detector near the ground and taking two readings: one wth the crystal unshielded and one with a 0.5-in.-thick (1.27-cm-thick) lead shield between the probe and the

ground. The lead shield attentuates the 168 KeV gamma from Ra-226 and the 48 KeV gamma from U-238 more nearly completely than those from such natural soil constituents as K-40 (1,460 KeV). The difference in the two readings, called the "delta," is thus an indication of the presence of radium or uranium in the soil. It has been experimentally determined by FB&DU personnel using Ludlum Measurements instrumentation that a delta of 400 counts per minute corresponds to a soil concentration of Ra-226 of approximately 5 pCi/g. However it should be noted that Sr-90, the primary contaminant at Bayo Canyon, does not emit a gamma ray. Therefore, this measurement does not define the limits of Sr-90 contamination.

Figure B-6 depicts the results of the gamma measurements made by FB&DU. The upper number at each grid point is the "delta", while the lower number represents the external gamma radiation level at that location, in μR/hr.

Background gamma radiation levels measured by LANL ranged from 19 to 23 μR/hr, and from 14 to 22 μR/hr as measured by FB&DU at four locations: one above (west) and one below (east) of the test site in Bayo Canyon, and two in Los Alamos townsite.

Radon and Radon Daughter Concentrations

Since Sr-90 and U-238 are the only contaminants introduced by the previous testing activities, there should be no radium or radium daughter concentrations above those expected from native uranium in the soil. Radon and radon daughter concentrations were measured at locations indicated in Figure B-7. The concentrations measured were consistent with the expected flux from the background concentrations of natural uranium present in the soils. These findings are consistent with the statement[2] that: "Surface uranium averaged about 4.9 μg/g or about 1.5 times the amount usually present in the volcanic-derived soils of the area."

Water Samples

Neither LANL nor FB&DU personnel collected water samples in Bayo Canyon. Surface water only flows in the canyon after a thunderstorm, and no ground water was found in holes drilled by FB&DU as deep as about 36 ft (11 m) below the surface. Data from LANL indicate that the main aquifer is about 790 ft (241 m) below the canyon surface[2]. Based on the great distance between the lowest depths of contamination and the aquifer, and on knowledge of the area geology, it is improbable that a hydrological connection exists between the surface water and ground water.

Contaminated Areas

Based on soil data from LANL and FB&DU, the only areas having contaminated material in excess of the proposed criteria are within an area which includes the former waste pits TA-10-41, -42, and -48, at depths ranging from 8 ft (2.4 m) to 40 ft (12.2 m) below the surface (see Figures B-8 and B-9). Volumes of contaminated soil have been estimated from the 1977 LANL survey data (contained in Appendix D of this report).

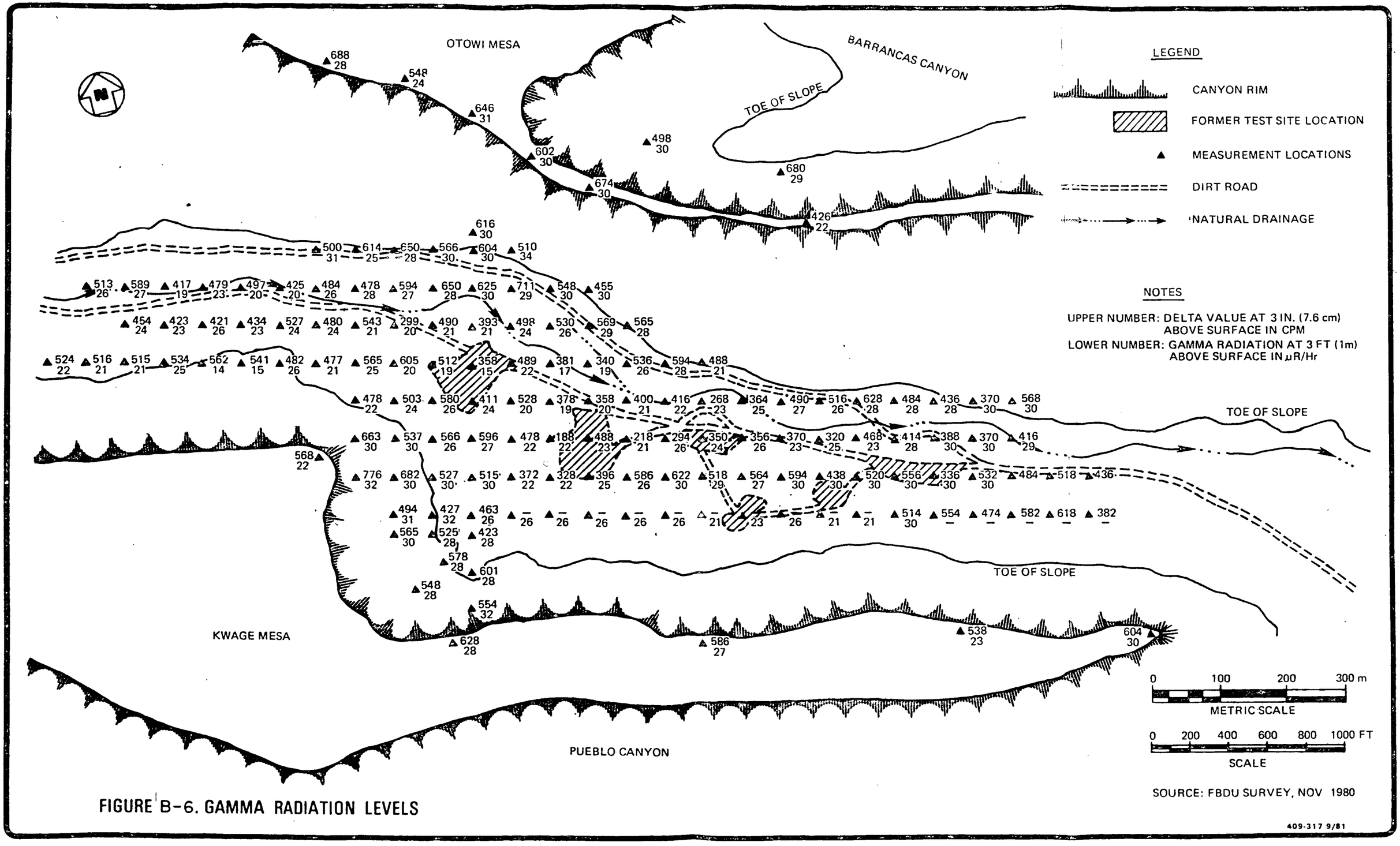
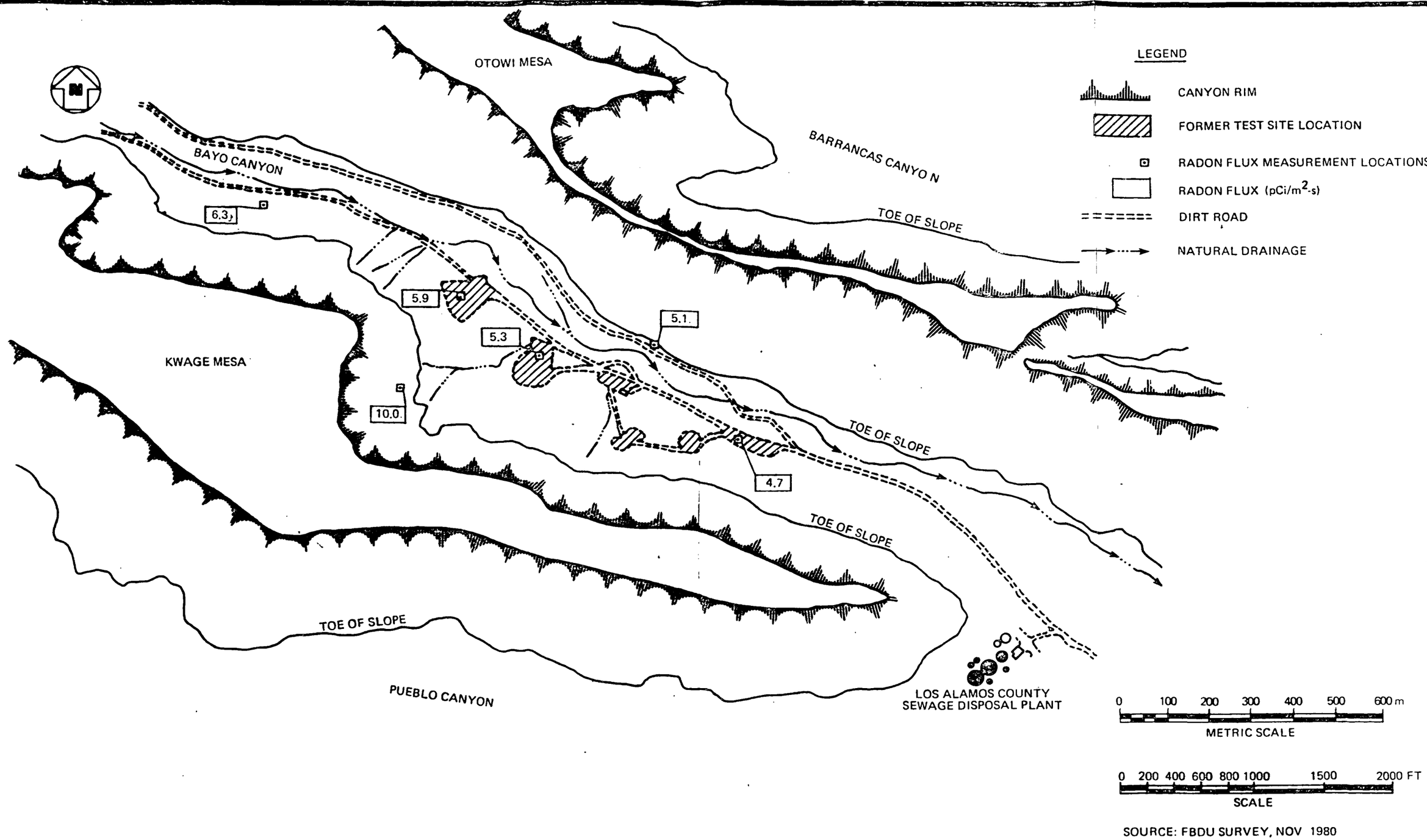


FIGURE B-6. GAMMA RADIATION LEVELS



SOURCE: FBDU SURVEY, NOV 1980

FIGURE B-7. RADON FLUX CANISTER LOCATIONS

409-317 9/81

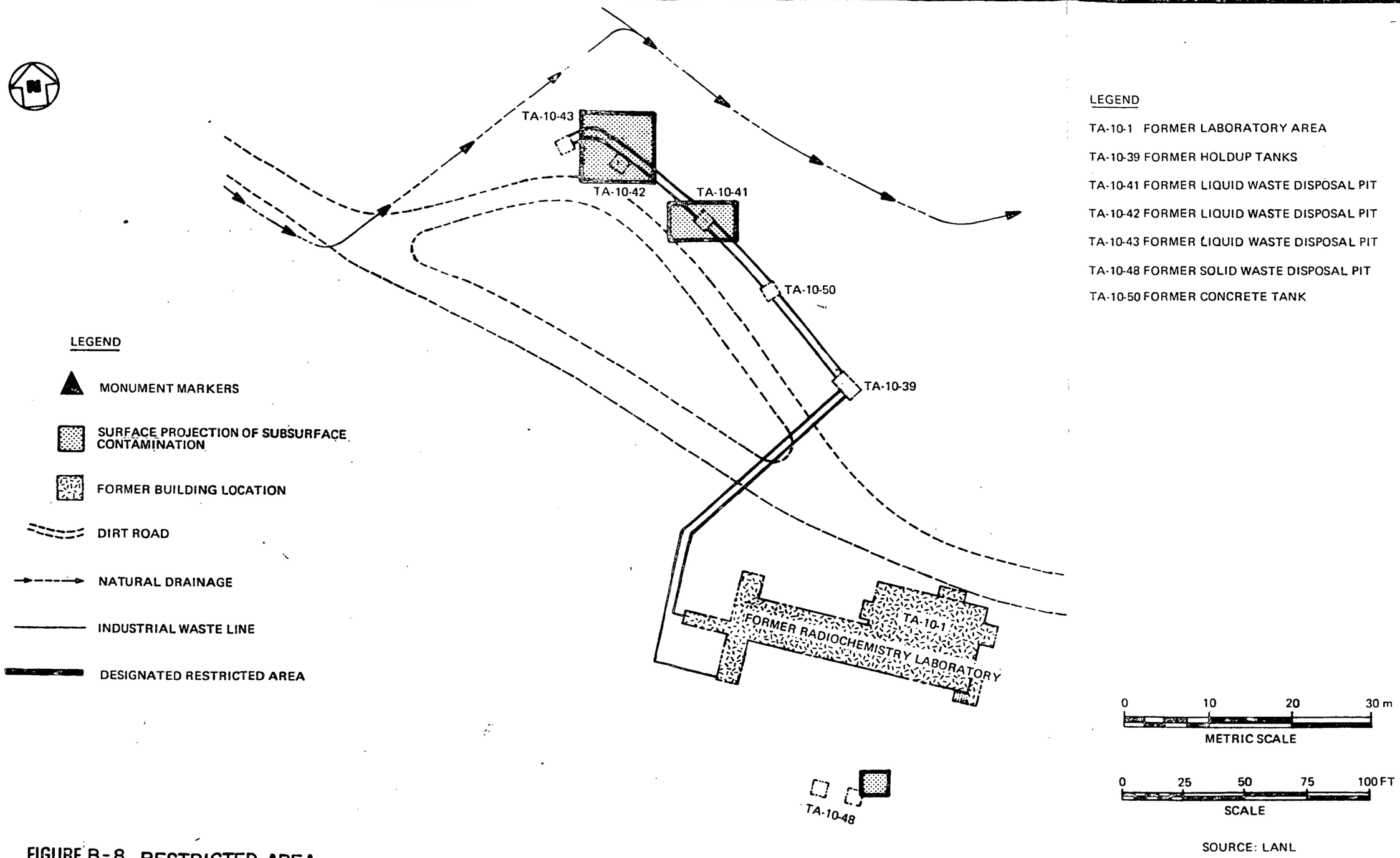
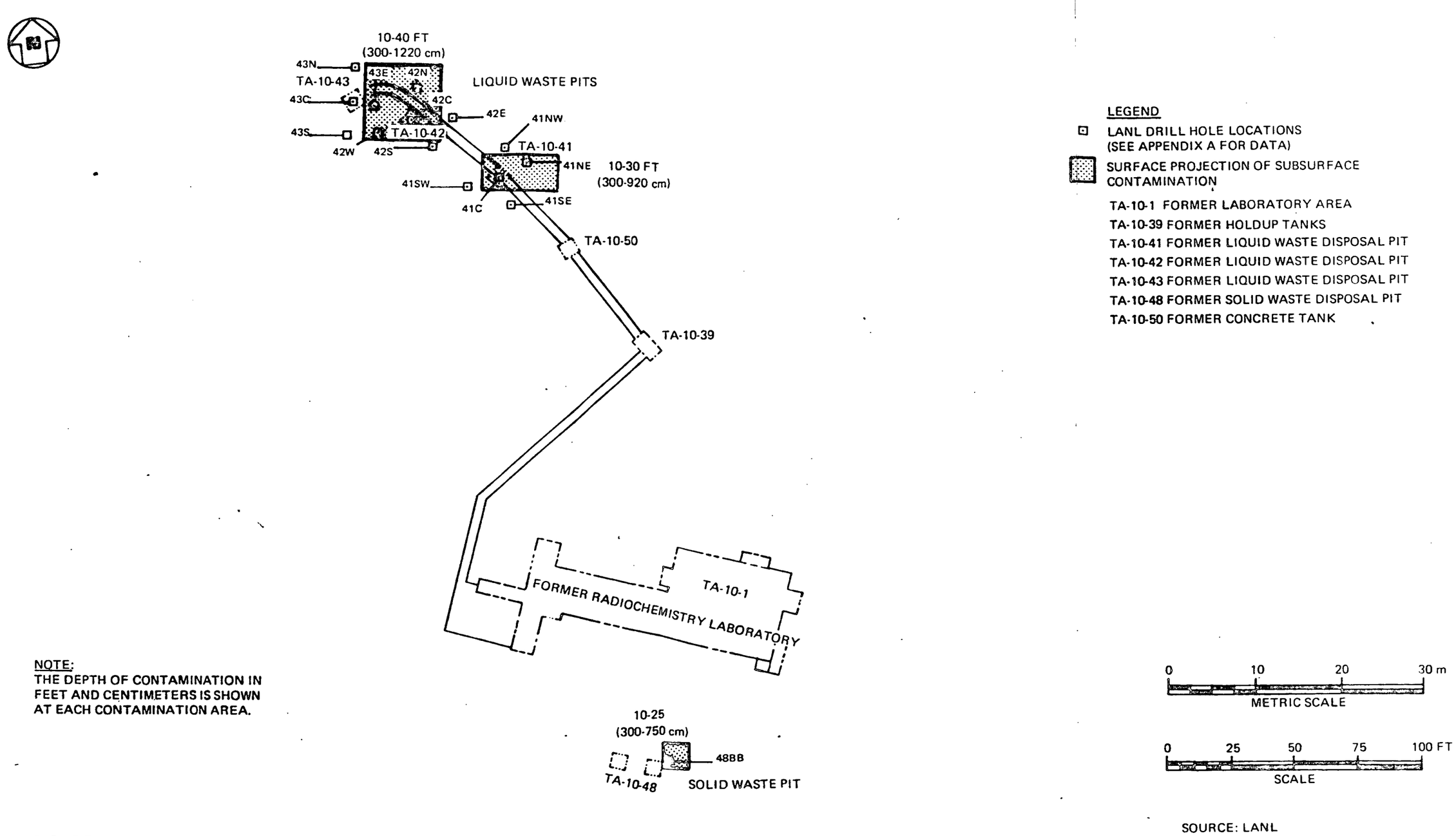


FIGURE B-8. RESTRICTED AREA



NOTE:
THE DEPTH OF CONTAMINATION IN FEET AND CENTIMETERS IS SHOWN AT EACH CONTAMINATION AREA.

FIGURE B-9. SURFACE PROJECTION OF SUBSURFACE CONTAMINATION

Contamination was found at a depth of 10 to 30 ft (3.0 to 9.1 m) in two sample holes at former waste pit TA-10-41. Samples from five adjacent test holes did not show any contamination above guideline criteria. This would indicate the contamination is limited to a fairly small area.

Samples from four test holes near former waste pit TA-10-42 showed contamination at depths of 8 to 40 ft (2.4 to 12.2 m). Contamination was not found in the samples from three other nearby test holes. The contaminated area appears to be larger than at the other two waste pits but seems to be confined to an area of less than 1,000 ft^2 (93 m^2).

APPENDIX B REFERENCES

1. "Radiological Survey of the Site of a Former Radioactive Liquid Waste Treatment Plant (TA-45) and the Effluent Receiving Areas of Acid, Pueblo, and Los Alamos Canyons;" Draft Report; Los Alamos Scientific Laboratory; Los Alamos, New Mexico; Contract No. W-7405-ENG-36; June 1980.

2. "Radiological Survey of Bayo Canyon, Los Alamos, New Mexico;" Final Report; Los Alamos Scientific Laboratory, Los Alamos, New Mexico; for the U.S. Department of Energy, Assistant Secretary for Environment, Division of Environment Control Technology, Washington, D.C.; under Contract No. W-7405-ENG-36; June 1979.

3. R. L. Griggs; "Geology and Ground-Water Resources of the Los Alamos Area, New Mexico;" U.S. Geological Survey Water-Supply Paper 1753; Washington, D.C.; 1964.

4. "Earthquake Information Bulletin;" Vol 7; No. 3; U.S. Department of Interior, U.S. Geological Survey; May-June 1975.

APPENDIX C

BASIC REMEDIAL ACTION ALTERNATIVES AND PROPOSED OPTIONS

BASIC REMEDIAL ACTION ALTERNATIVES AND PROPOSED OPTIONS

The proposed options for remedial action for the contaminated areas at the Bayo Canyon site have been formulated based on the site-specific conditions described in Appendix B and on the basic remedial action alternatives considered in this chapter that should be considered for any remedial action site. A presentation of the basic alternatives and proposed options follows.

BASIC REMEDIAL ACTION ALTERNATIVES

There are five basic alternatives for categorizing the remedial actions for contaminated properties. From these five basic alternatives, three options for remedial action have been formulated for the contaminated areas at the Bayo Canyon site. The five basic alternatives are defined in the paragraphs that follow.

Basic Alternative I - No Action

In this alternative, no action is taken at all; consequently, the contaminated property remains unchanged. This basic alternative is one of the possible courses of action that requires consideration based on the Council of Environmental Quality guidelines[1]. This alternative is the basis against which population health effects analyses can be compared, and also the basis for comparison of current environmental impacts with the impacts that would result from implementation of other alternatives.

Basic Alternative II - Minimal Action

Minimal action implies that no remedial actions are taken to clean up the contamination. Minimal action involves only those measures that effectively limit public exposure to radioactive sources, such as restricting access to a contaminated property.

In general, this alternative requires that the property be purchased by a government agency and held in perpetuity, secured by fencing and posted with appropriate warning signs, maintained, and radiologically monitored periodically for water, soil, and air contamination.

Basic Alternative III - Stabilization/Entombment

Stabilization refers to the covering of a contaminated area with a required amount of compacted clean soil. Entombment involves the total encapsulation of contaminated materials with a permanent casing such as concrete.

Access to a site could be restricted, as could uses for the site. Periodic radiological monitoring of the environment normally is required, as is periodic maintenance.

Basic Alternative IV - Partial Decontamination

Partial decontamination involves remedial action to remove or contain easily accessible active or potentially active sources to prevent further contamination. For open lands, for example, surface contamination could be removed to prevent spreading. Highly radioactive soil could be removed, leaving soil with lower levels of contamination to be removed later. Contaminated ditches and streams could be cleaned up to stop the spread of contamination, leaving adjacent soil to be removed at a later time.

Access to the contaminated area of the site would be restricted. A program of surveillance and maintenance normally would be required to ensure containment of contamination.

Basic Alternative V - Decontamination and Restoration

Decontamination and restoration remedial actions are formulated so that all above-criteria contamination is removed from a property in order to make it available for unrestricted use. Contaminated soils are excavated to the extent needed to meet the appropriate decontamination criteria. All contaminated debris from buildings and contaminated soils are transported safely to an appropriate disposal site. Restoration of the property follows after completion of decontamination efforts. Certification by ASEP of decontamination then allows unrestricted use of the property.

REMEDIAL ACTION OPTIONS

In consideration of the basic alternatives presented above, three remedial action options have been formulated for the areas of Bayo Canyon containing subsurface contamination. Future use of the contaminated areas is dependent on the action specified for each option.

Basic Alternative I (No Action) is the basis for a proposed option for the Bayo Canyon site.

Basic Alternative II (Minimal Action) can be used as a foundation for an option for the Bayo Canyon site. The contaminants would be effectively stabilized in place by overlayment of below-guideline soils. Site surveillance would be performed to help prevent or detect any intrusion into the subsurface materials.

Basic Alternative III (Stabilization/Entombment) is not used as a basis for formulation of an option for the Bayo Canyon site for several reasons. Foremost is that the surface contamination is of very low level and does not represent a hazard to persons using the area for recreational purposes[2]. The soil covering the subsurface contamination prevents health impacts. If the land use were changed (e.g., building houses, growing crops, digging into the subsurface contamination), health effects could eventually occur. Entombment is impractical and would be more costly than complete

decontamination and restoration. For these reasons this basic alternative is not a sound basis for formulating an option for the Bayo Canyon site.

Basic Alternative IV (Partial Decontamination) appears to be impractical for the Bayo Canyon site since no surface contamination exists and the subsurface contamination begins 8 ft (2.4 m) below the ground surface. Partial decontamination was accomplished by LANL when the site was decommissioned in 1963. Consequently, there is no readily available (surface) above-guideline contamination to be removed.

Basic Alternative V (Decontamination and Restoration) is a viable approach for formulating an option for the Bayo Canyon site. An option based on this basic alternative would allow unrestricted use of the site property.

Option A - No Action

In this option, no action would be taken at the Bayo Canyon site, which means the property would remain unchanged and no costs would be incurred. The public would be informed that no action would be taken. Implementation of Option A must be considered so that the impacts of the current conditions can be compared with impacts that would result from implementation of other options. The impacts are addressed in the LANL environmental report[2].

Option B - Minimal Action

For Option B, the area in which the above-guideline contamination is located is referred to as the "restricted area." This area includes approximately 1.5 acres containing the former radiochemistry laboratory area and the former solid and liquid waste disposal areas. Implementation of Option B would not result in reducing the subsurface contamination. The LANL survey identified one surface sample location with above-criteria contamination. The LANL reported that this evidently was an isolated spot that was eliminated when they took the soil sample. The LANL has not been able to relocate the contaminated spot. This indicates that above-criteria surface contamination is not present at the Bayo Canyon site.

The designated restricted area in which the subsurface contamination exceeds the guideline criteria would require county control to prevent the construction of housing, gardens, etc., until that time when radioactivity on the site has decayed to below-guideline levels. This restrictive covenant would last for approximately 160 years. This length of time would deplete the Sr-90 to less than 100 pCi/g. Governmental ownership and control would be required due to the intent of Los Alamos County to make Bayo Canyon available for a residential subdivision. Monument markers would be emplaced around the restricted area to note the presence of subsurface radioactivity. A crew of four would require from 5 to 10 days to complete the remedial actions. Finally,

radiological surveys would be required before, during, and after remedial action to ensure that decontamination efforts accomplish the planned goals.

Option C - Decontamination and Restoration with Disposal

For this option, the contaminated areas would be decontaminated to meet the clean-up criteria. Excavation would be performed with conventional earthmoving equipment. Uncontaminated soil would be stockpiled at the excavation site to be reused later as backfill. Contaminated soil would be transported by truck to the LANL waste disposal site. Although there is a relatively small volume of contaminated soil, it would be necessary to excavate a large volume of uncontaminated soil to remove the underlying contaminated soil.

Soil stockpiled during excavation would then be returned to the resulting pits and compacted into place. Additional fill material would be required to replace the contaminated soil that was removed. This material would be obtained from a location close to the site, as was done when the site was decommissioned in 1963. The area disturbed by excavation and stockpiling operations would then be revegetated. Little topsoil exists near the site and revegetation would be accomplished directly on the backfill material. This approach was used successfully when the site was decommissioned.

After restoration, the site could be released for unrestricted use. Periodic surveillance or monitoring would not be necessary. A crew of approximately 10 would require about 55 to 65 working days to complete the remedial action.

APPENDIX C REFERENCES

1. "Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act"; Council on Environmental Quality, Executive Office of the President; 43FR55987-56007, 40CFR, Parts 1500-1508; Nov 29, 1978.

2. "Environmental Analysis of the Bayo Canyon Site, Los Alamos, New Mexico; Los Alamos National Laboratory; Los Alamos, New Mexico; (May 1982)

APPENDIX D

RADIOLOGICAL DATA

APPENDIX D

SURVEY DATA

The data in this appendix consist of the 1977 survey results organized into 32 tables of which the first 30 deal with radioactivity in soil. Tables XXXI and XXXII deal with radioactivity in grasses. Corresponding data for rodents were omitted as unreliable because of insufficient biomass.

Gross alpha and gross beta results for soils (soils and bedrock) were obtained by scintillation counting described in Appendix B, Instrumentation. Available radiochemical analyses of some samples are presented with scintillator counter results to allow comparisons. Tables of results are arranged according to depth in the soil, and depth in turn is related to the sampling method as described in Section III, Methods. Tables D-I and D-II include ring samples and the 0-5 cm depth of profile samples. Tables D-III through D-V span the profile intervals from 5 cm to 30 cm. Tables D-VI through D-X relate to the 0-30 cm depth of soil. Samples from the latter were taken by core sampling. Table D-XI and D-XII are from the samples scooped from trenches dug by backhoe. The latter samples were used to evaluate the interval from 60 to 120 cm. Tables D-XIII through D-XXX were taken in 150 cm increments to as deep as 2000 cm by auger drill to evaluate depth intervals below 120 cm. Tables D-XXXIII and D-XXXIV contain data on penetrating radiation measurements. An index of tables precedes the actual data tables.

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TABLE D-I

GROSS-ALPHA AND -BETA ACTIVITY IN 0-5 CM LAYER (pCi/g)

Location	Gross β	Gross α	Location	Gross β	Gross α	Location	Gross β	Gross α
CTR	1	25	C5-15	2	35	C7-24	3	8
CTR-5	0	32	C6-1	3	13	C7-25	3	19
CTR-5b	0	32	C6-2	2	32	C7-26	2	17
C1-1	3	44	C6-3	2	25	C7-27	2	10
C1-2	2	48	C6-4	4	14	C7-28	3	10
C1-3	4	27	C6-5	3	12	C7-29	2	14
C2-1	3	80	C6-6	0	23	C7-30	3	35
C2-2	3	27	C6-7	2	13	C8-1	6	8
C2-3	2	50	C6-8	2	0	C8-2	5	10
C2-4	4	36	C6-9	2	27	C8-3	6	11
C2-5	4	44	C6-10	1	19	C8-4	6	19
C2-6	3	29	C6-11	5	5	C8-5	5	25
C3-1	3	12	C6-12	2	19	C8-6	6	8
C3-2	2	36	C6-13	2	30	C8-7	4	27
C3-3	4	23	C6-14	2	14	C8-8	5	35
C3-4	2	41	C6-15	2	30	C8-9	3	37
C3-5	6	44	C6-16	2	36	C8-10	3	7
C3-6	2	31	C6-17	3	11	C8-11	5	10
C3-7	4	30	C6-18	3	22	C8-12	7	30
C3-8	2	16	C6-19	1	24	C8-13	5	21
C4-1	4	47	C6-20	2	30	C8-14	6	1
C4-2	1	5	C7-1	2	20	C8-15	5	25
C4-3	6	30	C7-2	2	45	C8-16	5	10
C4-4	3	20	C7-3	1	29	C8-17	6	10
C4-5	3	20	C7-4	3	22	C8-18	4	9
C4-6	8	25	C7-5	3	8	C8-19	4	29
C4-7	3	12	C7-6	3	16	C8-20	4	4
C4-8	3	23	C7-7	1	17	C8-21	3	25
C4-9	3	18	C7-8	2	2	C8-22	2	20
C4-10	3	30	C7-9	2	16	C8-23	3	5
C5-1	1	26	C7-10	2	7	C8-24	3	0
C5-2	6	14	C7-11	1	29	C8-25	3	16
C5-3	3	36	C7-12	4	2	C8-26	1	0
C5-4	4	20	C7-13	4	13	C8-27	4	16
C5-5	3	74	C7-14	3	10	C8-28	1	7
C5-6	4	27	C7-15	3	13	C8-29	2	0
C5-7	3	23	C7-16	2	25	C8-30	3	32
C5-8	4	16	C7-17	3	11	C9-1	4	12
C5-9	4	41	C7-18	3	13	C9-2	3	18
C5-10	3	29	C7-19	2	27	C9-3	5	26
C5-11	4	29	C7-20	2	25	C9-4	4	15
C5-12	3	29	C7-21	1	18	C9-5	4	18
C5-13	3	26	C7-22	4	22	C9-6	5	22
C5-14	4	45	C7-23	3	23	C9-7	1	60

TABLE D-I (cont)

Location	Gross β	Gross α
C9-8	4	57
C9-9	7	32
C9-10	4	53
C9-11	5	38
C9-12	5	36
C9-13	4	24
C9-14	7	18
C9-15	3	44
C9-16	4	23
C9-17	4	34
C9-18	3	33
C9-19	3	54
C9-20	2	38
C9-21	1	14
C9-22	5	24
C9-23	5	10
C9-24	3	18
C9-25	3	10
C9-26	4	5
C9-27	4	16
C9-28	4	32
C9-29	5	10
C9-30	5	2
C9-31	5	22
C9-32	4	2
C9-33	4	17
C9-34	3	27
C9-35	3	14
C9-36	5	16
C9-37	8	10
C9-38	6	13
C9-39	4	20
C9-40	5	12
C9-41	5	7
C9-42	7	15
C9-43	4	10
C9-44	3	9
C9-45	5	15
WA-1	5	44
WA-2	2	14
WA-3	1	12
WA-4	1	16
WA-5	5	14
WB-1	3	23
WB-2	1	10
WB-3	3	8
WB-4	2	11
WB-5	2	24
WC-1	4	8
WC-2	3	17
WC-3	7	11

Location	Gross β	Gross α
WC-4	1	7
WC-5	3	6
WD-5	2	8
WD-6	7	6
EA-1	1	4
EA-2	1	24
EA-3	1	20
EA-4	5	24
EA-5	3	10
EA-6	2	30
EB-1	3	14
EB-2	2	23
EB-3	36	2
EB-4	3	8
EB-5	2	6
EB-6	2	18
EC-1	6	22
EC-2	2	7
EC-3	2	17
EC-4	1	8
EC-5	0	22
EC-6	4	17
ED-1	1	6
ED-2	6	14
ED-3	1	22
ED-4	3	10
ED-5	1	11
ED-6	2	18
C2-1P	4	38
C3-5P	7	32
C6-17P	6	22
C7-18P	5	5
C8-2P	5	10
C8-14P	5	1
C9-3P	5	26
C9-45P	3	23
WB-5P	5	39
WC-3P	5	2
EB-2P	6	24
EC-1P	6	22
SC-2BP	4	17
SC-4CP	2	14
SC-6CP	1	0
SC-7CP	3	4
TA10-1#1	2	18
TA10-1#2	2	14
TA10-3	4	19
TA10-4	3	19
TA10-5	3	4
TA10-7	2	7
TA10-21	3	26

TABLE D-II

GROSS-ALPHA AND -BETA ACTIVITY VS SELECTED RADIOCHEMICAL ANALYSES IN THE 0-5 CM LAYER

(pCi/g except as noted)

Location	Gross β	^{90}Sr	^{137}Cs	Gross α	U-T[a]	^{238}Pu	^{239}Pu
CTR	1	0.75	0.12	25	4.2	0.0	0.014
CTR-5	0	0.78	0.21	32	4.1	0.0	0.014
CTR-5b	0	0.46	0.0	32	4.4	0.0	0.027
C1-3	4	3.45	---	27	9.5	---	---
C2-1	3	(3.40)[b]	---	80	(0.54)[b]	---	0.058
C2-4	4	4.13	---	36	7.8	---	---
C5-2	6	3.27	0.15	14	4.3	0.0	0.0
C5-5	3	0.60	---	74	4.0	---	---
C5-11	4	1.95	---	29	8.9	---	---
C6-11	5	0.41	---	5	4.6	---	---
C7-9	2	0.61	---	16	4.7	---	---
C7-21	1	0.23	---	18	7.0	---	---
C8-1	6	0.89	1.49	8	3.6	0.027	0.03
C8-16	5	0.79	---	10	4.5	0.14	8.76
C8-17	6	2.5	2.13	10	3.7	0.0	0.079
C9-8	4	0.45	0.579	58	3.5	0.0	0.032
C9-10	4	0.49	0.688	53	3.3	0.0	0.066
C9-14	7	0.69	---	18	4.5	---	---
C9-19	3	1.00	1.85	54	3.2	0.0	0.166
C9-33	4	3.7	---	17	5.9	---	---
WA-1	5	0.87	---	44	3.6	---	---
WA-5	5	0.48	---	14	3.4	---	---
WD-6	7	0.97	---	6	5.6	---	---
EA-4	5	0.30	0.33	24	3.7	0.0	0.022
EB-3	36	132.0	1.14	2	2.4	0.009	0.076
EC-6	4	0.221	0.16	17	2.6	0.0	0.0
ED-2	6	0.29	0.20	14	4.6	0.0	0.03
C2-1P	4	3.4	---	38	0.54	---	---
C3-5P	7	3.8	---	32	12.0	---	---
C6-17P	6	0.218	---	22	2.9	---	---
C7-18P	5	0.62	---	5	4.1	---	---
C8-2P	5	0.55	0.20	10	2.5	0.0	0.0
C8-14P	5	0.207	---	2	3.0	---	---
C9-3P	5	0.63	0.73	26	3.9	0.0	0.013
C9-45P	3	0.34	0.30	23	6.8	0.0	0.20
WB-5P	11	0.191	---	39	3.9	---	---
WC-3P	5	0.73	---	2	4.8	---	---
EB-2P	6	0.09	0.50	24	3.4	0.0	0.020
EC-1P	6	0.98	1.51	22	2.9	0.0	0.052
SC-2BP	4	8.20	---	17	7.6	---	---
SC-4CP	2	0.0	---	14	4.7	---	---
SC-6CP	1	0.078	0.0	0	2.1	0.003	0.0
SC-7CP	3	0.36	0.49	4	2.5	0.0	0.013
TA10-1#1	2	5.40	0.25	18	3.2	0.004	0.098
TA10-1#2	2	2.81	0.38	14	2.3	0.015	0.030
TA10-3	4	1.54	0.47	19	1.7	0.0	0.029
TA10-4	3	1.92	0.18	19	1.3	0.0	0.019
TA10-5	3	1.87	0.38	4	1.5	0.006	0.02
TA10-7	2	0.69	0.18	7	2.1	0.005	0.008
TA10-21	3	0.47	0.31	26	2.4	0.001	0.0113

[a]Total uranium in $\mu g/g$.

[b]See C2-1P

TABLE D-III

GROSS-ALPHA AND -BETA ACTIVITY VS SELECTED RADIOCHEMICAL ANALYSES IN THE 5-10 CM LAYER
(pCi/g except as noted)

Location	Gross β	^{90}Sr	^{137}Cs	Gross α	U-T[a]	^{238}Pu	^{239}Pu
C2-1P	4	0.31	---	22	3.0	---	---
C3-5P	6	1.73	---	21	5.9	---	---
C6-17P	6	0.08	---	2	2.7	---	---
C7-18P	4	0.43	---	25	4.1	---	---
C8-2P	4	0.40	0.0	34	2.2	0.0	0.0
C8-14P	4	0.55	---	18	3.1	---	---
C9-3P	5	0.82	0.48	36	3.6	0.0	0.018
C9-45P	4	0.30	0.19	26	1.6	0.0047	0.018
WB-5P	4	0.289	---	22	3.1	---	---
WC-3P	6	0.173	---	2	4.4	---	---
EB-2P	5	1.03	0.0	23	3.4	0.0	0.0
EC-1P	4	0.10	0.0	15	2.1	0.0	0.0
SC-2BP	6	2.77	---	41	2.3	---	---
SC-4CP	3	0.28	---	18	3.1	---	---
SC-6CP	3	0.26	0.0	8	1.9	0.0017	0.004
SC-7CP	3	0.20	0.0	5	2.1	0.0	0.0076
TA10-1#1	4	3.99	0.11	30	2.6	0.014	0.007
TA10-1#2	4	3.85	0.071	17	1.4	0.0	0.054
TA10-3	2	2.64	0.17	14	2.5	0.034	0.076
TA10-4	3	1.41	0.12	4	1.4	0.0	0.0
TA10-5	3	2.93	0.24	23	1.4	0.004	0.030
TA10-7	3	0.48	0.09	29	2.0	0.0	0.0101
TA10-21	3	0.15	0.042	37	2.0	0.0	0.007

[a]Total uranium in $\mu g/g$.

TABLE D-IV

GROSS-ALPHA AND -BETA ACTIVITY VS SELECTED RADIOCHEMICAL ANALYSES IN THE 10-20 CM LAYER

(pCi/g except as noted)

Location	Gross β	^{90}Sr	^{137}Cs	Gross α	U-T[a]	^{238}Pu	^{239}Pu
C2-1P	4	0.211	---	37	3.4	---	---
C3-5P	3	0.025	---	23	3.1	---	---
C6-17P	5	0.07	---	8	2.8	---	---
C7-18P	4	0.07	---	26	3.2	---	---
C8-2P	5	0.177	0.0	30	2.2	0.0	0.015
C8-14P	7	0.34	---	16	3.1	---	---
C9-3P	4	0.52	0.0	2	3.7	0.0	0.013
C9-45P	3	0.38	0.14	5	2.9	0.0077	0.013
WB-5P	6	0.193	---	10	3.4	---	---
WC-3P	5	0.172	---	10	4.8	---	---
EB-2P	5	0.212	0.0	9	3.1	0.0	0.013
EC-1P	4	0.110	0.0	14	2.4	0.0	0.021
SC-2BP	4	2.62	---	37	3.0	---	---
SC-4CP	2	0.61	---	26	3.1	---	---
SC-6CP	1	0.23	0.08	2	1.2	0.0	0.011
SC-7CP	3	0.32	0.47	7	1.6	0.0039	0.0087
TA10-1#1	4	3.30	0.0	23	2.2	0.0	0.011
TA10-1#2	3	3.56	0.071	23	1.9	0.0076	0.019
TA10-3	3	5.17	0.22	18	2.3	0.0	0.122
TA10-4	1	0.70	0.0	8	1.9	0.0	0.0
TA10-5	3	2.91	0.02	20	1.4	0.005	0.036
TA10-7	3	0.23	0.035	23	2.9	0.014	0.011
TA10-21	4	0.18	0.0	22	2.0	0.0	0.0

[a]Total uranium in $\mu g/g$.

TABLE D-V

GROSS-ALPHA AND -BETA ACTIVITY VS SELECTED RADIOCHEMICAL ANALYSES IN THE 20-30 CM LAYER
(pCi/g except as noted)

Location	Gross β	^{90}Sr	^{137}Cs	Gross β	U-T[b]	^{238}Pu	^{239}Pu
C2-1P	5	0.05	---	1	2.9	---	---
C3-5P	4	0.189	---	24	2.9	---	---
C6-17P	3	0.243	---	6	2.8	---	---
C7-18P	4	0.0	---	8	3.9	---	---
C8-2P	5	0.222	0.0	22	2.6	0.0	0.011
C8-14P	4	0.19	---	5	3.5	---	---
C9-3P	2	0.215	0.0	2	3.3	0.0	0.0
C9-45P	3	0.17	0.10	13	3.1	0.0088	0.019
WB-5P	4	0.141	---	15	3.1	---	---
WC-3P	6	0.06	---	2	4.4	---	---
EB-2P	4	0.254	0.0	20	3.2	0.0	0.016
EC-1P	4	0.114	0.0	12	2.4	0.0	0.0
SC-2BP	5	3.81	---	38	2.8	---	---
SC-4CP	4	1.00	---	11	3.2	---	---
SC-6CP	1	0.29	0.12	6	1.5	0.0	0.003
SC-7CP	3	0.27	0.50	5	1.8	0.0	0.020
TA10-1#1	2	2.23	0.034	10	1.6	0.0	0.012
TA10-1#2	4	4.16	0.057	25	1.1	0.010	0.019
TA10-3	2	0.57	0.07	32	1.9	0.004	0.031
TA10-4	3	0.54	0.051	10	2.5	0.0	0.002
TA10-5	4	1.04	0.0	10	3.3	0.0	0.005
TA10-7	3	0.16	0.042	17	2.5	0.0022	0.0045
TA10-21	2	0.27	0.058	13	3.6	0.0	0.005

[a]Total uranium in $\mu g/g$.

TABLE D-VI
GROSS-ALPHA AND -BETA ACTIVITY IN 0-30 CM LAYER
(pCi/g)

Location	Gross β	Gross α	Location	Gross β	Gross α	Location	Gross β	Gross α
CTR	2	35	C6-5	1	22	C8-2	6	25
C1-1	2	52	C6-6	5	26	C8-3	6	20
C1-2	3	51	C6-7*			C8-4	3	15
C1-3	2	32	C6-8	1	19	C8-5	5	10
C2-1	1	29	C6-9	2	44	C8-6	6	26
C2-2	2	62	C6-10	3	22	C8-7	5	8
C2-3	2	29	C6-11	3	17	C8-8	4	46
C2-4	2	39	C6-12	3	23	C8-9	4	42
C2-5	3	23	C6-13	2	32	C8-10	5	26
C2-6	1	39	C6-14	3	37	C8-11	5	17
C3-1	1	20	C6-15	2	19	C8-12*		
C3-2	3	25	C6-16	2	22	C8-13	5	4
C3-3	2	24	C6-17	1	29	C8-14	4	15
C3-4	1	47	C6-18	1	23	C8-15	5	11
C3-5	3	25	C6-19	2	29	C8-16	4	20
C3-6	4	16	C6-20	2	26	C8-17	4	35
C3-7	4	30	C7-1	2	41	C8-18	6	25
C3-8	4	32	C7-2	5	14	C8-19	5	19
C4-1	3	51	C7-3	5	27	C8-20	5	11
C4-2	2	12	C7-4	4	27	C8-21	4	20
C4-3	3	38	C7-5	1	17	C8-22	3	5
C4-4	4	25	C7-6*			C8-23	3	5
C4-5	3	26	C7-7	2	29	C8-24	3	2
C4-6	2	45	C7-8	2	19	C8-25	3	14
C4-7	2	47	C7-9*			C8-26	3	1
C4-8	2	30	C7-10	2	22	C8-27	4	11
C4-9	2	35	C7-11	1	18	C8-28	2	4
C4-10	4	48	C7-12	3	13	C8-29	2	22
C5-1	2	30	C7-13	2	13	C8-30	2	32
C5-2	2	27	C7-14	5	0	C9-1	7	15
C5-3	4	26	C7-15	2	17	C9-2	2	15
C5-4	1	29	C7-16	6	9	C9-3	4	21
C5-5	4	38	C7-17	3	30	C9-4	4	24
C5-6	3	23	C7-18	2	41	C9-5	4	45
C5-7	3	26	C7-19	3	12	C9-6	3	12
C5-8	3	12	C7-20	4	23	C9-7*		
C5-9	4	19	C7-21	4	23	C9-8	4	53
C5-10	7	42	C7-22	2	22	C9-9	3	45
C5-11	4	32	C7-23	2	7	C9-10	3	73
C5-12	3	12	C7-24	3	11	C9-11	5	50
C5-13	3	23	C7-25	2	10	C9-12*		
C5-14	3	24	C7-26	4	20	C9-13	4	16
C5-15	0	35	C7-27	2	14	C9-14	3	23
C6-1	2	36	C7-28	1	0	C9-15	4	21
C6-2	6	10	C7-29	2	30	C9-16	3	54
C6-3	3	24	C7-30	2	23	C9-17	3	36
C6-4	1	16	C8-1	2	36	C9-18*		

*Not sampled; bedrock < 30 cm.

TABLE D-VI (cont)

Location	Gross β	Gross α	Location	Gross β	Gross α	Location	Gross β	Gross α
C9-19*			EB-6	6	22	SC-6C1	2	11
C9-20*			EC-1	1	6	SC-6C2	3	50
C9-21	4	22	EC-2	1	0	SC-6C3	1	4
C9-22	4	14	EC-3	1	13	SC-7C1	2	17
C9-23	9	8	EC-4	5	1	SC-7C2	2	2
C9-24	6	21	EC-5	3	10	SC-7C3	1	12
C9-25	4	24	EC-6	2	16	SC-8C1	2	48
C9-26	5	4	ED-1	2	20	SC-8C2	2	50
C9-27	4	10	ED-2	2	0	SC-8C3	3	37
C9-28	5	10	ED-3	2	17	SC-1D1	2	27
C9-29	5	9	ED-4	2	10	SC-1D2	3	25
C9-30*			ED-5	2	12	SC-1D3	2	36
C9-31*			ED-6	5	26	SC-2D1	2	25
C9-32	4	10	C2-1P	4	24	SC-2D2	4	30
C9-33*			C3-5P	5	37	SC-2D3	2	47
C9-34	3	19	C6-17P	5	10	SC-3D1	2	33
C9-35	2	30	C7-18P	5	16	SC-3D2	2	23
C9-36	4	15	C8-2P	5	24	SC-3D3	2	27
C9-37	5	24	C8-14P	5	10	SC-4D1	3	18
C9-38	6	10	C9-3P	4	17	SC-4D2	2	27
C9-39	5	36	C9-45P	3	17	SC-4D3	1	16
C9-40*			WB-5P	5	22	SC-2BP	5	33
C9-41	6	28	WC-3P	6	4	SC-4CP	3	17
C9-42	5	23	EB-2P	5	19	SC-6CP	2	4
C9-43	6	6	EC-1P	5	16	SC-7CP	3	5
C9-44	4	7	SC-1A1	4	17	10-1N	4	33
C9-45	5	12	SC-1A2	4	17	10-1E	4	29
WA-1	2	38	SC-1A3	6	23	10-2E	3	22
WA-2	1	23	SC-2A1	7	41	10-3E	2	35
WA-3	1	18	SC-2A2	3	30	10-4E	2	24
WA-4	1	12	SC-2A3	2	42	10-5E	3	37
WA-5	3	25	SC-1B1	5	35	10-6E	2	12
WB-1	3	13	SC-1B2	4	19	10-7E	4	16
WB-2	1	12	SC-1B3	6	18	10-8E	0	30
WB-3	5	10	SC-2B1	4	37	10-1W	2	30
WB-4	1	19	SC-2B2	4	37	10-2W	1	33
WB-5	2	22	SC-2B3	3	39	10-3W	2	18
WC-1	5	13	SC-3B1	12	14	10-4W	3	25
WC-2	2	12	SC-3B2	5	25	10-5W	4	27
WC-3	2	14	SC-3B3	7	35	10-6W	3	12
WC-4	3	0	SC-1C1	2	12	10-7W	2	33
WC-5	1	10	SC-1C2	1	19	1001	1	17
WD-5	2	20	SC-1C3	2	17	1002	4	1
WD-6	2	6	SC-2C1	2	42	1003	3	19
EA-1	2	47	SC-2C2	2	8	1004	3	33
EA-2	2	7	SC-2C3	3	18	1005	3	25
EA-3	1	29	SC-3C1	2	19	1006	2	19
EA-4	3	22	SC-3C2	3	31	1008	5	27
EA-5	4	24	SC-3C3	1	33	TA10-1=1P	3	20
EA-6	2	41	SC-4C1	1	22	TA10-1=2P	3	20
EB-1	4	24	SC-4C2	2	14	TA10-3P	3	21
EB-2	2	32	SC-4C3	1	17	TA10-4P	3	10
EB-3	4	10	SC-5C1	1	35	TA10-5P	3	14
EB-4	3	22	SC-5C2	2	36	TA10-7P	3	19
EB-5	1	23	SC-5C3	2	31	TA10-21P	3	24

*Not sampled; bedrock <30 cm.

TABLE D-VII

GROSS-ALPHA AND -BETA ACTIVITY VS SELECTED RADIOCHEMICAL ANALYSES IN THE 0-30 CM LAYER

(pCi/g except as noted)

Location	Gross β	^{90}Sr	^{137}Cs	Gross α	U-T[a]	^{239}Pu	^{240}Pu
CTR	2	0.34	0.0	35	3.6	0.0	0.027
C3-3	2	0.41	---	24	7.0	---	---
C3-7	4	4.05	---	30	12.0	---	---
C4-2	2	0.36	---	12	6.9	---	---
C5-9	4	0.61	---	18	4.6	---	---
C6-2	6	1.23	0.0	10	4.9	0.0	0.0
C6-6	5	0.49	---	26	3.8	---	---
C6-15	2	0.23	---	19	4.9	---	---
C7-2	5	0.54	0.19	14	4.4	0.0	0.0
C7-16	6	0.79	---	9	5.5	---	
C8-9	4	0.27	---	42	3.4	---	---
C8-21	4	0.23	---	20	7.8	---	---
C9-1	7	0.43	0.0	15	3.3	0.0	0.12
C9-24	6	0.45	---	21	4.5	---	---
WB-3	5	0.237	---	10	2.9	---	---
WC-1	5	0.223	---	13	3.8	---	---
EB-6	6	0.267	0.26	22	3.3	0.0	0.026
EC-4	5	0.60	0.0	1	1.6	0.0	0.08
ED-6	5	0.144	0.26	26	4.1	0.0	0.026
C2-1P	4	0.70	---	24	2.69	---	---
C3-5P	5	0.99	---	37	4.98	---	---
C6-17P	5	0.15	---	10	2.80	---	---
C7-18P	5	0.20	---	16	3.70	---	---
C8-2P	5	0.29	0.05	24	2.38	0.0	0.01
C8-14P	5	0.30	---	10	3.18	---	---
C9-3P	4	0.49	0.30	17	3.63	0.0	0.01
C9-45P	3	0.29	0.18	17	3.40	0.01	0.02
WB-5P	5	0.19	---	22	3.3	---	---
WC-3P	6	0.23	---	4	4.60	---	---
EB-2P	5	0.34	0.13	19	3.2	0.0	0.01
EC-1P	5	0.26	0.38	16	2.4	0.0	0.0
SC-3B1	12	4.27	---	14	7.2	---	---
SC-3B2	5	8.77	---	25	5.9	---	---
SC-3B3	7	23.2	---	35	19.0	---	---
SC-8C1	2	0.17	0.19	48	1.5	0.0	0.007
SC-8C2	2	0.59	0.50	50	2.5	0.004	0.022
SC-8C3	3	0.28	0.14	37	1.6	0.0	0.024
SC-2BP	5	3.97	---	33	3.97	---	---
SC-4CP	3	0.58	---	17	3.53	---	---
SC-6CP	2	0.23	0.05	4	1.68	0.0	0.0
SC-7CP	3	0.29	0.37	5	2.00	0.0	0.01
10-1N	4	0.95	---	33	4.2	---	---
10-1E	4	3.5	---	29	6.6	---	---
10-2E	3	1.86	---	22	3.6	---	---
10-3E	2	2.18	---	35	3.8	---	---

TABLE D-VII (cont)

Location	Gross β	^{90}Sr	^{137}Cs	Gross α	U-T[a]	^{238}Pu	^{239}Pu
10-4E	2	1.64	---	24	3.4	---	---
10-5E	3	4.23	---	37	3.0	---	---
10-6E	2	3.95	---	12	3.1	---	---
10-7E	4	3.64	---	16	5.4	---	---
10-8E	0	2.18	---	30	11.1	---	---
10-1W	2	1.55	---	30	3.4	---	---
10-2W	1	2.59	---	33	50.0	---	---
10-3W	2	2.86	---	18	10.0	---	---
10-4W	3	1.55	---	25	3.3	---	---
10-5W	4	4.09	---	27	3.4	---	---
10-6W	3	3.00	---	12	3.1	---	---
10-7W	2	0.62	---	33	3.5	---	---
1001	1	2.36	---	17	1.7	---	---
1002	4	1.14	---	1	8.4	---	---
1003	3	0.41	---	19	7.4	---	---
1004	3	2.91	---	33	6.5	---	---
1005	3	3.86	---	25	3.3	---	---
1006	2	2.00	---	19	5.7	---	---
1008	5	6.91	---	27	3.3	---	---
TA10-1#1P	3	3.73	0.10	20	2.40	0.0	0.03
TA10-1#2P	3	3.60	0.14	20	1.68	0.01	0.03
TA10-3P	3	2.48	0.23	21	2.10	0.01	0.06
TA10-4P	3	1.17	0.09	10	1.78	0.0	0.01
TA10-5P	3	2.19	0.16	14	1.90	0.0	0.02
TA10-7P	3	0.39	0.09	19	2.38	0.01	0.01
TA10-21P	3	0.27	0.10	24	2.50	0.0	0.01

[a]Total uranium in $\mu g/g$.

TABLE D-VIII

GROSS-ALPHA AND -BETA ACTIVITY VS PENETRATING DOSE FROM THE 0-30 CM LAYER

(pCi/g vs μR/h)

Location	Gross β	Gross α	Pen. Dose*	Location	Gross β	Gross α	Pen. Dose*
CTR	2	35	20.00	C8-4	3	15	22.00
C1-1	2	52	20.00	C8-13	5	4	21.70
C2-1	1	29	20.80	C8-14	4	15	26.12
C2-4	2	39	21.00	C8-15	5	11	22.77
C3-1	1	20	21.18	C8-16	4	20	21.70
C4-5	3	26	20.00	C8-17	4	35	20.85
C4-8	2	30	20.00	C8-18	6	25	21.00
C5-1	2	30	21.00	C8-19	5	19	22.23
C5-5	4	38	20.00	C8-20	5	11	22.61
C5-10	7	42	18.00	C8-22	3	5	22.75
C6-1	2	36	18.00	C8-23	3	5	24.83
C6-2	6	10	21.00	C8-24	3	2	24.70
C6-3	3	24	21.00	C8-25	3	14	22.75
C6-4	1	16	21.00	C8-26	3	1	23.03
C6-7	---	---	23.00	C8-27	4	11	23.73
C6-10	3	22	23.00	C8-28	2	4	21.66
C6-13	2	32	20.00	C9-1	7	15	21.18
C6-16	2	22	20.00	C9-2	2	15	18.96
C6-19	2	29	18.00	C9-3	4	21	23.73
C7-1	2	41	20.50	C9-4	4	24	22.00
C7-3	5	27	19.43	C9-7	---	---	19.52
C7-4	4	27	21.00	C9-8	4	53	18.70
C7-5	1	17	22.00	C9-9	3	45	19.55
C7-7	2	29	22.00	C9-10	3	73	19.08
C7-10	2	22	23.00	C9-11	5	50	18.97
C7-15	2	17	22.00	C9-12	---	---	18.48
C7-16	6	9	24.26	C9-16	3	54	20.19
C7-17	3	30	21.34	C9-17	3	36	18.20
C7-18	2	41	20.50	C9-18	---	---	19.36
C7-19	3	12	20.54	C9-19	---	---	19.21
C7-20	4	23	20.04	C9-20	---	---	19.08
C7-21	4	23	20.92	C9-22	4	14	23.72
C7-22	2	22	21.84	C9-23	9	8	21.00
C7-23	2	7	22.30	C9-24	6	21	21.22
C7-24	3	11	24.14	C9-25	4	24	21.03
C7-25	2	10	22.60	C9-26	5	4	17.66
C7-26	4	20	23.12	C9-27	4	10	21.60
C7-27	2	14	20.29	C9-28	5	10	23.38
C7-28	1	0	18.83	C9-29	5	9	24.35
C8-1	2	36	20.00	C9-30	---	---	24.35
C8-2	6	25	19.18	C9-33	---	---	22.00
C8-3	6	20	19.67	C9-40	---	---	20.00

*Total penetrating photon dose from all sources in μR/h.

TABLE D-IX

NATURALLY OCCURRING URANIUM AND THORIUM IN SURFACE SOIL
(μg/g)

Location	U-T[a]	^{232}Th
C8-17	3.70	16.8
C9-8	3.50	20.1
C9-10	3.30	16.6
C9-19	3.20	15.7
EB-3	2.40	11.9
SC-8C1	1.60	12.3
SC-8C2	2.50	11.5
SC-8C3	1.50	9.2

[a]Total uranium

TABLE D-X

IN SITU MEASUREMENT[a] OF NATURALLY OCCURRING RADIONUCLIDES VS PENETRATING DOSE ESTIMATES[b]

Location	^{40}K (pCi/g)	U-T (μg/g)	^{232}Th (μg/g)	μR/hr
No. Mesa (GLO Landmark)	35.5	6.09	19.5	23.89
No. Mesa (Stables)	29.5	3.98	15.1	20.44
WB-3	32.7	5.09	16.4	21.54
Bayo Floor (Pit under Bayo Point)	33.9	5.33	16.9	22.16
C9-27	37.3	8.09	22.7	26.14
EB-3	35.0	3.91	13.8	20.55
Otowi Mesa (Survey Landmark)	32.8	0.51	16.1	18.95

[a]GeLi γ spectral analyses.

[b]Estimate includes 0.45 μR/h for fallout and ~7 μR for cosmic influence.

TABLE D-XI

GROSS-ALPHA AND -BETA ACTIVITY IN 60-120 CM LAYER

(pCi/g)

Location	Gross β	Gross α	Location	Gross β	Gross α	Location	Gross β	Gross α
BDH-1	4	47	BDH-26	4	49	BDH-46	3	49
BDH-2	2	26	BDH-27	8	42	BDH-47	2	39
BDH-3	1	24	BDH-28	7	36	BDH-48	2	62
BDH-4	4	20	BDH-29	2	37	BDH-49&50	4	26
BDH-5	2	18	BDH-30	13	41	BDH-51	3	35
BDH-6	4	44	BDH-31	3	29	BDH-52	4	56
BDH-7	4	27	BDH-32	3	39	BDH-53	2	20
BDH-8&9	3	47	BDH-33	2	41	BDH-54	9	44
BDH-10	5	23	BDH-34	4	22	BDH-55	2	23
BDH-11	2	49	BDH-33&34	2	32	BDH-56	2	36
BDH-12	2	48	BDH-35	3	36	BDH-57	3	51
BDH-13	2	47	BDH-36	4	25	BDH-58	2	8
BDH-14	2	39	BDH-35&36	4	38	BDH-59	12	6
BDH-15	1	25	BDH-38	2	27	BDH-60	48	0
BDH-16	2	43	BDH-39	2	29	BDH-61	4	27
BDH-17	2	33	BDH-40	3	49	BDH-62	2	23
BDH-18	2	37	BDH-39&40	3	12	BDH-63	2	18
BDH-19	4	26	BDH-41	3	36	BDH-64	3	32
BDH-20&21	5	42	BDH-42	3	22	BDH-65	4	44
BDH-22	2	27	BDH-41&42	2	24	BDH-66	2	14
BDH-23	1	30	BDH-43	3	30	BDH-67	3	17
BDH-24	2	12	BDH-44	1	37	BDH-69	3	4
3DH-24&25	3	20	BDH-45	3	26			

TABLE D-XII

GROSS-ALPHA AND -BETA ACTIVITY VS SELECTED RADIOCHEMICAL ANALYSES IN THE 60-120 CM LAYER

(pCi/g except as noted)

Location	Gross β	^{90}Sr	^{137}Cs	Gross α	U-T[a]	^{238}Pu	^{239}Pu
BDH-1	4	5.08	---	47	---	---	---
BDH-8&9	3	0.11	---	47	---	---	---
BDH-20&21	5	5.81	---	42	---	---	---
BDH-24&25	3	9.46	---	20	---	---	---
BDH-30	13	26.2	---	41	---	---	---
BDH-49&50	4	0.37	---	26	---	---	---
BDH-60	48	67.2	0.0	0	1.00	0.0	0.0
BDH-69	3	0.06	---	4	---	---	---

[a]Total uranium in μg/g.

TABLE D-XIII

GROSS-ALPHA AND -BETA ACTIVITY IN THE 0-150 CM LAYER
(pCi/g)

Location	Gross β	Gross α	Location	Gross β	Gross α
48A-1	2	29	41SW-1	3	32
48B-1	2	17	41C-1	6	20
48AA-1	2	46	42N-1	6	8
48BB-1	2	33	42S-1	4	22
48C-1	0	36	42E-1	8	8
50AL-1	8	30	42W-1	5	22
50BL-1	1	14	42C-1	6	8
50CL-1	4	10	43N-1	3	8
50DL-1	2	32	43S-1	4	46
50EL-1	3	27	43E-1	7	22
50FL-1	2	23	43W-1	5	15
50GL-1	10	33	43C-1	5	24
2168A-1	1	22	44N-1	3	6
2168B-1	2	17	44S-1	4	8
41NW-1	4	20	44E-1	4	29
41SE-1	4	15	44W-1	3	20
41NE-1	3	11	44C-1	2	20

TABLE D-XIV

GROSS-ALPHA AND -BETA ACTIVITY VS ^{90}Sr ACTIVITY IN THE 0-150 CM LAYER
(pCi/g)

Location	Gross β	^{90}Sr	Gross α
41SE-1	4	2.46	15
42S-1	4	0.21	22
43N-1	3	1.13	8
43S-1	4	0.31	46

TABLE D-XV

GROSS-ALPHA AND -BETA ACTIVITY IN 150-300 CM LAYER (pCi/g)

Location	Gross β	Gross α	Location	Gross β	Gross α
48A-2	3	42	41SW-2	3	39
48B-2	2	51	41C-2	35	32
48AA-2	4	17	42N-2	3	17
48BB-2	5	39	42S-2	5	22
48C-2	4	20	42E-2	4	22
50AL-2	4	5	42W-2	8	29
50BL-2	1	16	42C-2	17	6
50CL-2	3	14	43N-2	3	5
50DL-2	3	12	43S-2	4	25
50EL-2	3	33	43E-2	5	10
50FL-2	2	22	43W-2	2	17
50GL-2	2	10	43C-2	5	51
2168A-2	2	24	44N-2	2	11
2168B-2	2	24	44S-2	4	20
41NW-2	4	13	44E-2	3	20
41SE-2	3	0	44W-2	2	24
41NE-2	3	0	44C-2	2	22

TABLE D-XVI

GROSS-ALPHA AND -BETA ACTIVITY VS ^{90}Sr ACTIVITY IN THE 150-300 CM LAYER (pCi/g)

Location	Gross β	^{90}Sr	Gross α
41NW-2	4	0.23	13
41SE-2	3	1.04	0
41NE-2	3	1.90	0
42N-2	3	2.90	17
43N-2	3	0.04	5
43S-2	4	0.15	25
44E-2	3	0.10	20

TABLE D-XVII

GROSS-ALPHA AND -BETA ACTIVITY IN 300-460 CM LAYER (pCi/g)

Location	Gross β	Gross α	Location	Gross β	Gross α
48A-3	3	23	41SW-3	4	6
48B-3	15	12	41C-3	501	32
48AA-3	7	41	42N-3	3	11
48BB-3	91	22	42S-3	4	13
48C-3	3	38	42E-3	3	22
50AL-3	2	10	42W-3	169	25
50BL-3	2	13	42C-3	4	27
50CL-3	1	12	43N-3	2	22
50DL-3	2	16	43S-3	3	24
50EL-3	1	17	43E-3	905	24
50FL-3	3	13	43W-3	4	15
50GL-3	2	36	43C-3	69	18
2168A-3	2	24	44N-3	4	29
2168B-3	1	26	44S-3	2	17
41NW-3	4	13	44E-3	3	1
41SE-3	3	1	44W-3	4	18
41NE-3	4	3	44C-3	3	43

TABLE D-XVIII

GROSS-ALPHA AND -BETA ACTIVITY VS ^{90}Sr AND URANIUM IN 300-460 CM LAYER (pCi/g except as noted)

Location	Gross β	^{90}Sr	Gross α	U-T[a]
48B-3	15	---	12	2.80
48BB-3	91	---	22	5.60
41C-3	501	1140.00	32	---
43E-3	905	1290.0	24	---

[a]Total uranium in μg/g.

TABLE D-XIX

GROSS-ALPHA AND -BETA ACTIVITY IN 460-600 CM LAYER
(pCi/g)

Location	Gross β	Gross α	Location	Gross β	Gross α
48A-4	5	24	41SW-4	3	11
48B-4	5	25	41C-4	539	20
48AA-4	4	17	42N-4	48	30
48BB-4	291	24	42S-4	4	22
48C-4	2	27	42E-4	3	22
50AL-4	---	--	42W-4	206	24
50BL-4	3	29	42C-4	185	17
50CL-4	3	54	43N-4	3	13
50DL-4	2	35	43S-4	3	29
50EL-4	0	29	43E-4	2214	27
50FL-4	3	18	43W-4	4	27
50GL-4	2	18	43C-4	33	30
2168A-4	0	22	44N-4	4	8
2168B-4	2	25	44S-4	5	15
41NW-4	4	6	44E-4	3	13
41SE-4	10	32	44W-4	4	25
41NE-4	4	11	44C-4	3	49

TABLE XX

GROSS-ALPHA AND -BETA ACTIVITY VS SELECTED RADIOCHEMICAL ANALYSES IN 460-600 CM LAYER
(pCi/g except as noted)

Location	Gross β	^{90}Sr	^{137}Cs	Gross α	U-T[a]	^{238}Pu	^{239}Pu
48BB-4	291	810.0	0.025	24	1.9	0.0	0.9
41NW-4	4	0.30	---	6	---	---	---
41NE-4	4	2.60	---	11	---	---	---
41SW-4	3	0.10	---	11	---	---	---
41C-4	539	1060.0	---	20	---	---	---
43N-4	3	0.20	---	13	---	---	---
43S-4	3	0.00	---	29	---	---	---
43E-4	2214	4310.0	---	27	---	---	---
43W-4	4	0.00	---	27	---	---	---

[a]Total uranium in μg/g.

TABLE D-XXI

GROSS-ALPHA AND -BETA ACTIVITY IN 600-760 CM LAYER (pCi/g)

Location	Gross β	Gross α	Location	Gross β	Gross α
48A-5	2	32	41SW-5	4	18
48B-5	3	25	41C-5	355	18
48AA-5	3	6	42N-5	109	25
48BB-5	46	17	42S-5	3	32
48C-5	3	22	42E-5	4	10
50AL-5	---	---	42W-5	839	29
50BL-5	2	61	42C-5	47	22
50CL-5	1	31	43N-5	3	13
50DL-5	1	44	43S-5	4	24
50EL-5	2	25	43E-5	389	8
50FL-5	2	41	43W-5	3	36
50GL-5	1	45	43C-5	12	22
2168A-5	3	26	44N-5	3	8
2168B-5	4	29	44S-5	4	15
41NW-5	4	24	44E-5	2	20
41SE-5	5	20	44W-5	1	20
41NE-5	105	46	44C-5	3	41

TABLE D-XXII

GROSS-ALPHA AND -BETA ACTIVITY VS SELECTED RADIOCHEMICAL ANALYSES IN 600-760 CM LAYER pCi/g.except as noted)

Location	Gross β	^{90}Sr	^{137}Cs	Gross α	U-T[a]	^{238}Pu	^{239}Pu
48BB-5	46	169.00	0.0	17	4.1	0.0	0.011
2168A-5	3	1.59	---	26	---	---	---
2168B-5	4	0.15	---	29	---	---	---
41NE-5	105	90.00	---	46	---	---	---
41SW-5	4	0.50	---	18	---	---	---
42N-5	109	176.0	---	25	---	---	---
43N-5	3	0.09	---	13	---	---	---
43S-5	4	0.09	---	24	---	---	---
43W-5	3	0.22	---	36	---	---	---

[a]Total uranium in μg/g.

TABLE D-XXIII

GROSS-ALPHA AND -BETA ACTIVITY IN 760-920 CM LAYER
(pCi/g)

Location	Gross β	Gross α	Location	Gross β	Gross α
48A-6	3	31	41C-6	208	55
48B-6	3	25	42N-6	49	30
48AA-6	2	36	42S-6	4	32
48BB-6	23	25	42E-6	5	29
48C-6	2	29	42W-6	227	18
50AL-6	2	42	42C-6	52	32
50BL-6	2	74	43N-6	4	15
50CL-6	3	51	43S-6	4	32
50DL-6	2	58	43E-6	224	43
50EL-6	3	49	43W-6	4	39
50FL-6	4	14	43C-6	20	20
50GL-6	4	60	44N-6	4	18
41NW-6	4	51	44S-6	5	25
41SE-6	4	32	44E-6	4	13
41NE-6	22	41	44W-6	2	20
41SW-6	3	17	44C-6	3	36

TABLE D-XXIV

GROSS-ALPHA AND -BETA ACTIVITY VS ^{90}Sr AND URANIUM IN THE 760-920 CM LAYER
(pCi/g except as noted)

Location	Gross β	^{90}Sr	Gross α	U-T[a]
48BB-6	23	---	25	5.00
41NW-6	4	0.32	51	---
41SW-6	3	0.61	17	---
43N-6	4	0.20	15	---
43S-6	4	0.0	32	---
43W-6	4	0.10	39	---

[a]Total uranium in μg/g.

TABLE D-XXV

GROSS-ALPHA AND -BETA ACTIVITY IN 920-1070 CM LAYER
(pCi/g)

Location	Gross β	Gross α	Location	Gross β	Gross α
48A-7	5	22	41C-7	140	24
48B-7	5	18	42N-7	4	43
48AA-7	5	14	42S-7	4	36
48BB-7	20	13	42E-7	5	15
48C-7	3	10	42W-7	108	36
50AL-7	4	58	42C-7	39	8
50BL-7	5	38	43N-7	4	20
50CL-7	4	61	43S-7	3	18
50DL-7	4	77	43E-7	318	18
50EL-7	6	57	43W-7	6	15
50FL-7	4	38	43C-7	30	15
50GL-7	4	41	44N-7	3	8
41NW-7	5	55	44S-7	3	29
41SE-7	5	56	44E-7	4	29
41NE-7	14	39	44W-7	3	39
41SW-7	4	55	44C-7	3	48

TABLE D-XXVI

GROSS-ALPHA AND -BETA ACTIVITY VS ^{90}Sr IN 920-1070 CM LAYER
(pCi/g)

Location	Gross β	^{90}Sr	Gross α
48A-7	5	0.50	22
48B-7	5	0.77	18
48AA-7	5	0.71	14
48BB-7	20	37.2	13
48C-7	3	0.16	10
50AL-7	4	0.31	58
50BL-7	5	0.07	38
50CL-7	4	0.12	61
50DL-7	4	0.16	77
50EL-7	6	0.18	57
50FL-7	4	0.22	38
50GL-7	4	0.12	41
41SW-7	4	0.0	55
41C-7	140	335.0	24
43N-7	4	0.0	20

TABLE D-XXVII

GROSS-ALPHA AND -BETA ACTIVITY IN 1070-1220 CM LAYER (pCi/g)

Location	Gross β	Gross α	Location	Gross β	Gross α
48A-8	3	16	42N-8	8	110
48B-8	3	12	42S-8	6	44
48AA-8	4	6	42E-8	7	17
48BB-8	5	10	42W-8	138	22
50AL-8	4	52	42C-8	20	27
50BL-8	4	54	43N-8	5	55
50CL-8	3	83	43S-8	5	36
50DL-8	3	62	43E-8	148	25
50EL-8	4	33	43W-8	6	25
50FL-8	3	107	43C-8	11	13
50GL-8	4	38	44N-8	5	24
41NW-8	6	55	44S-8	5	37
41SE-8	6	56	44E-8	3	49
41NE-8	19	34	44W-8	4	56
41SW-8	4	74	44C-8	6	46
41C-8	85	63			

TABLE D-XXVIII

GROSS-ALPHA AND -BETA ACTIVITY IN 1220-1370 CM LAYER (pCi/g)

Location	Gross β	Gross α	Location	Gross β	Gross α
48A-9	3	22	50CL-9	4	25
48B-9	3	22	50DL-9	4	39
48AA-9	2	4	50EL-9	5	49
48BB-9	8	14	50FL-9	3	64
50AL-9	4	43	50GL-9	5	54
50BL-9	3	42			

TABLE D-XXIX

GROSS-ALPHA AND -BETA ACTIVITY IN 1370-1530 CM LAYER
(pCi/g)

Location	Gross β	Gross α
48A-10	4	16
48B-10	3	14
48AA-10	3	10
48BB-10	8	4
50AL-10	2	42
50BL-10	2	51
50CL-10	4	56
50DL-10	4	39
50EL-10	5	35
50FL-10	6	77
50GL-70	4	43

TABLE D-XXX

GROSS-ALPHA AND -BETA ACTIVITY IN 1530-2000 CM LAYER
(pCi/g)

Location	Gross β	Gross α
50AL-11	4	37
50AL-12	4	37
50AL-13	1	36

TABLE D-XXXI

BACKGROUND RADIOACTIVITY IN GRASSES
(pCi/g except as noted)

Location	^{90}Sr	^{137}Cs	U-T[a]	^{238}Pu	^{239}Pu
2NE	0.205	0.181	0.07	0.00075	0.00227
4NW	0.205	0.210	0.10	0.0	0.00280
4SW	0.236	0.221	0.09	0.0	0.00489
8SE	0.208	0.150	0.06	0.00107	0.00208
G.G.	0.263	0.307	0.06	0.00039	0.00071
7NW	2.31	0.192	0.06	0.00042	0.0035
8NE	0.179	0.217	0.08	0.00137	0.0036
7SE	0.505	0.285	0.07	0.0	0.00453
8SW	0.789	0.256	0.06	0.0065	0.0041

Total uranium in $\mu g/g$.

TABLE D-XXXII

RADIOACTIVITY IN BAYO SITE GRASSES
(pCi/g except as noted)

Location	^{90}Sr	^{137}Cs	U-T[a]	^{238}Pu	^{239}Pu
EG	0.491	0.061	0.05	0.00069	0.00128
EA-2	0.791	0.109	0.05	0.0	0.00209
EC-2&3	0.852	0.046	0.14	0.0	0.00222
EC-4&5	0.505	0.178	0.05	0.0	0.00241
WB-2	0.408	0.105	0.06	0.00028	0.00207
WB-3	0.572	0.032	0.04	0.0	0.00127
C2-5	0.594	0.062	0.05	0.0	0.00195
C6-10	0.185	0.081	0.07	0.0	0.00152
C6-20	0.0365	0.037	0.06	0.0	0.00131
C7-28	0.246	0.067	0.03	0.00015	0.00557
C7-30	0.446	0.071	0.06	0.00020	0.00178
C8-1	0.375	0.111	0.0001	0.00039	0.00239
C8-20	0.326	0.045	0.06	0.00016	0.00124
C9-2	0.341	0.168	0.10	0.0	0.00287
C9-25	0.198	0.109	0.07	0.00078	0.00261

[a]Total uranium in $\mu g/g$.

TABLE D-XXXIII

EXTERNAL PENETRATING RADIATION IN THE TOWNSITE

TLD Station	Results $\mu R/h$[a]
1. Barranca School	17.3
2. Cumbres School	17.6
3. Golf Course	18.5
4. Arkansas Avenue	18.8
5. Diamond Drive	18.8
6. 48th Street	19.0
7. Fuller Lodge	21.2
8. Acorn Street	17.9
10. Los Alamos Airport	19.7
28. Pajarito Acres	15.9
29. White Rock Sewer Treatment Plant	17.4
	$\bar{x} \pm \sigma = 18.4 \pm 1.4$

[a]4th Quarter 1976 measurements by high-pressure ion chamber.

TABLE D-XXXIV

EXTERNAL PENETRATING RADIATION*
AT THE FORMER BAYO SITE

Canyon Floor

Location	μR/hr	Location	μR/hr	Location	μR/hr	Location	μR/hr	Location	μR/hr
C2-1	20.8	C7-21	20.9	C7-30	19.0	C9-1	21.2	EB-3	18.1
C3-1	21.2	C7-22	21.8	C8-2	19.2	C9-2	19.0	EB-4	20.5
C7-2	19.1	C7-23	22.3	C8-3	19.7	C9-25	21.0	EB-5	19.4
C7-3	19.4	C7-24	24.1	C8-16	21.7	C9-26	17.7	EB-6	20.2
C7-13	20.0	C7-25	22.6	C8-17	20.9	C9-27	21.6	EC-2	18.7
C7-16	24.3	C7-26	23.1	C8-18	21.0	C9-28	23.4	EC-3	18.4
C7-17	21.3	C7-27	20.3	C8-19	22.2	C9-44	20.2	EC-4	19.0
C7-18	20.5	C7-28	18.8	C8-20	22.6	C9-45	19.7	EC-5	19.2
C7-19	20.5	C7-29	19.3	C8-30	20.7	EB-2	21.0	EC-6	19.9
C7-20	20.1								

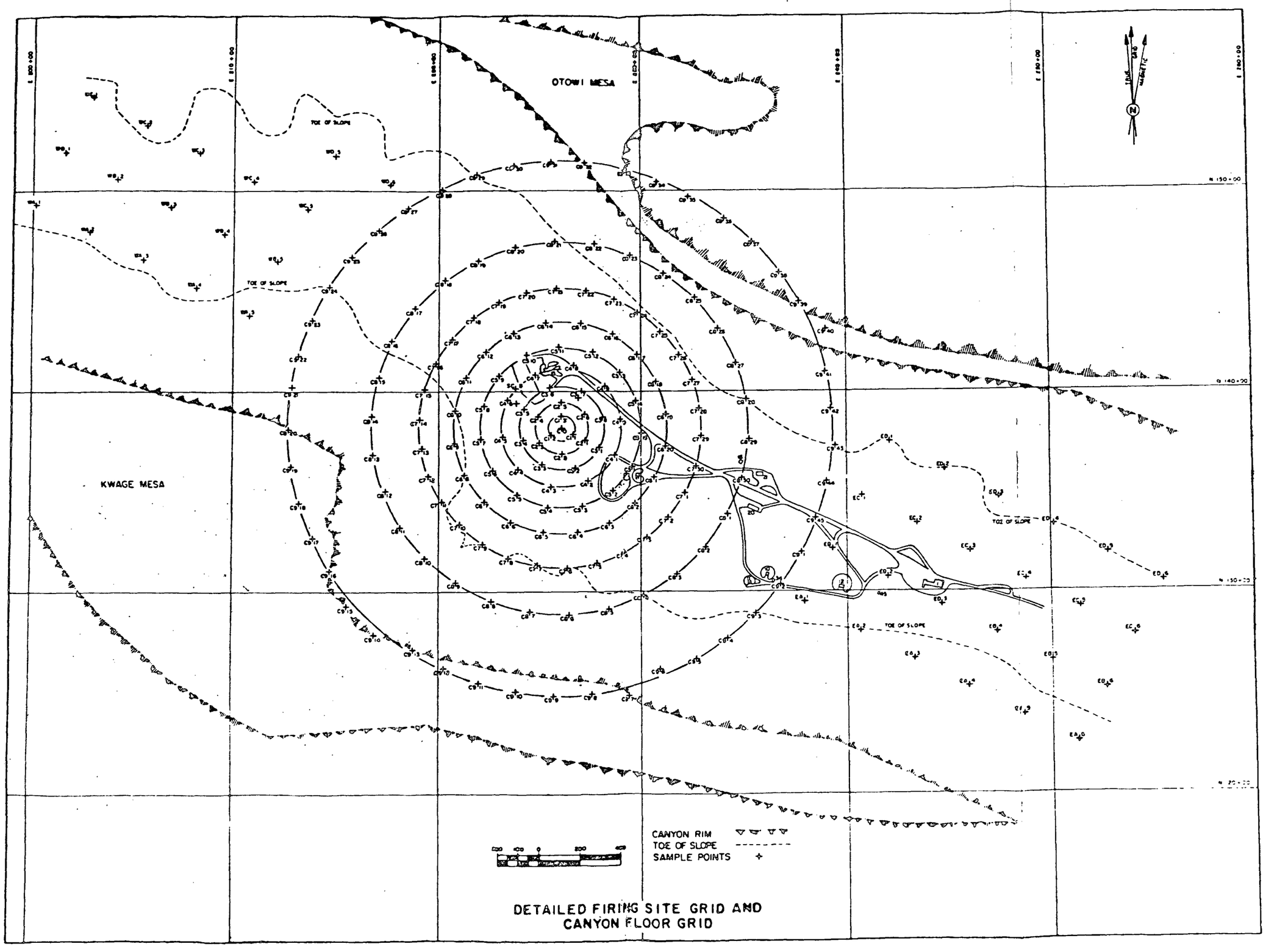
Talus Slopes

Location	μR/hr	Location	μR/hr
C7-15	22.0	C9-3	23.7
C8-13	21.7	C9-22	23.7
C8-14	26.1	C9-23	21.0
C8-15	22.8	C9-24	21.2
C8-22	22.7	C9-29	19.3
C8-23	24.8	C9-30	24.4
C8-24	24.7	C9-31	23.5
C8-25	22.7	C9-37	24.6
C8-26	23.0	C9-41	24.2
C8-27	23.7	C9-42	23.3
C8-28	21.7	C9-43	23.8

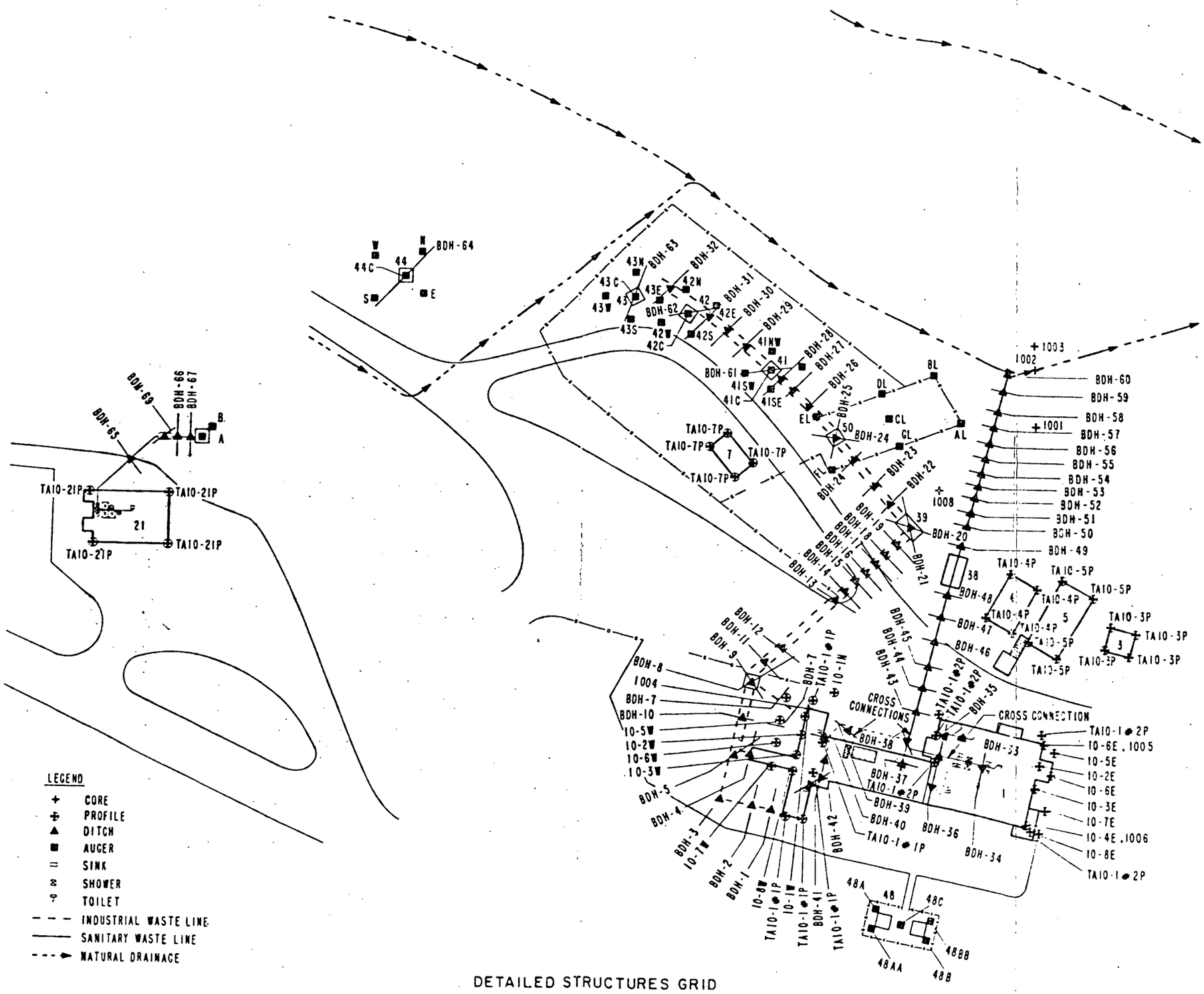
Mesa Tops

Location	μR/hr	Location	μR/hr
C9-7	19.2	C9-16	20.2
C9-8	19.0	C9-17	18.2
C9-9	17.8	C9-18	19.4
C9-10	19.2	C9-19	19.2
C9-11	19.1	C9-20	18.0
C9-12	18.5	C9-40	20.3
C9-13	20.2		

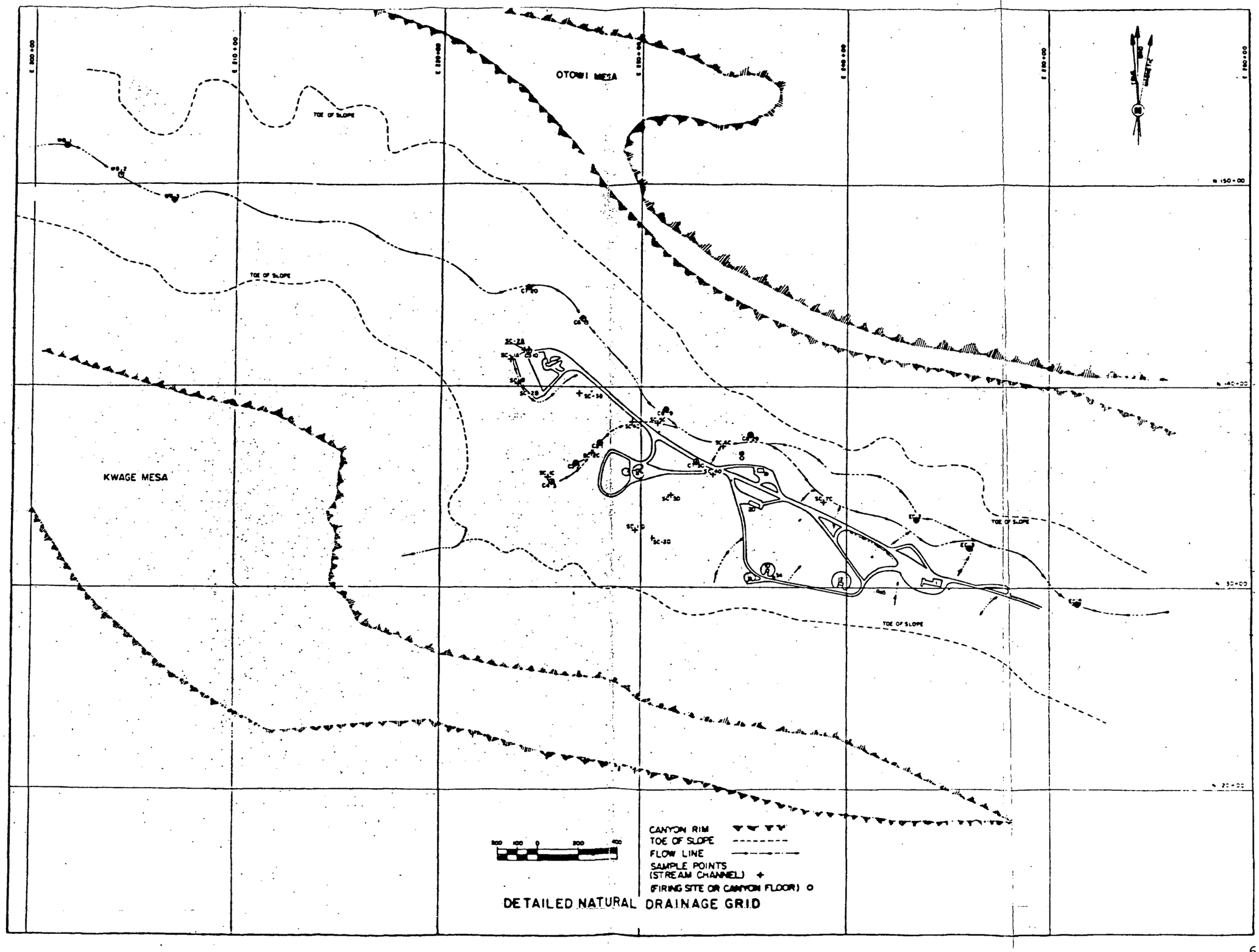
*Measurements by High Pressure Ion Chamber.



DETAILED FIRING SITE GRID AND
CANYON FLOOR GRID



DETAILED STRUCTURES GRID



DETAILED NATURAL DRAINAGE GRID

BAYO CANYON GLOSSARY

BAYO CANYON GLOSSARY

ABBREVIATIONS/TERMS	DEFINITIONS
AEC	Atomic Energy Commission
alpha particle (α)	A positively charged particle emitted from certain radioactive material. It consists of two protons and two neutrons, hence is identical with the nucleus of the helium atom. It is the least penetrating of the common radiation (α, β, γ), hence is not dangerous unless alpha-emitting substances have entered the body.
aquifer	A water-bearing formation below the surface of the earth; the source of wells.
background radiation	Naturally occurring low-level radiation to which all life is exposed. Background radiation levels vary from place to place on the earth.
beta particle (β)	A particle emitted from some atoms undergoing radioactive decay. A negatively charged beta particle is identical to an electron. A positively charged beta particle is called a positron. Beta radiation can cause skin burns and beta emitters are harmful if they enter the body.
Ci	Curie (the unit of radioactivity of any nuclide, defined as precisely equal to 3.7×10^{10} disintegrations/second)
daughter product	The nuclide remaining after a radioactive atom (parent) has undergone radioactive decay. A daughter atom also may be radioactive, producing further daughter products.

EGR	External gamma radiation (gamma radiation emitted from a source(s) external to the body, as opposed to internal gamma radiation emitted from ingested or inhaled sources)
EPA	Environmental Protection Agency
ERDA	Energy Research and Development Administration
erg	The basic unit of work or energy in the centimeter-gram-second system (one erg is equal to 7.4×10^8 ft-lb.)
exposure	Magnitude of radiation to which a person is subjected. It is defined and measured by electrical charge produced per unit mass of air.
exhalation	Emission of radon from earth (usually thought of as coming from a uranium tailings pile, but actually from any location).
FB&DU	Ford, Bacon & Davis Utah Inc.
gamma background	Natural gamma ray activity everywhere present, originating from two sources: (1) cosmic radiation, bombarding the earth's atmosphere continually, and (2) terrestrial radiation. Whole body absorbed dose equivalent in the U.S. due to natural gamma background ranges from about 60 to about 125 mrem/yr
gamma ray (γ)	High energy electromagnetic radiation emitted from the nucleus of a radioactive atom, with specific energies for the atoms of different elements and having high penetrating power
ground water	Subsurface water in the zone of full saturation which supplies wells and springs
health effect	Adverse physiological response to pollutants from tailings (in this report, one health effect is defined as one case of lung cancer produced from inhalation of radioactive materials).

Interim Primary Drinking Water Regulations	Title No. 40 of the Code of Chapter 1, Part 141, dated July 9, 1976.
μR/hr	Microroentgen per hour.
mR/hr	Milliroentgen per hour.
MPC	Maximum permissible concentration (the highest concentration in air or water of a particular radionuclide permissible for occupational or general exposure without taking steps to reduce exposure).
noble gas	One of the gases, such as helium, neon, radon, etc., with completely filled electron shells which is therefore chemically inert.
NRC	Nuclear Regulatory Commission.
nuclide	A general term applicable to all atomic forms of the elements; nuclides comprise all the isotopic forms of all the elements. Nuclides are distinguished by their atomic number, atomic mass, and energy state.
ORNL	Oak Ridge National Laboratory.
pCi/l	Picocurie per liter.
R	Roentgen (a unit of exposure to ionizing radiation. It is that amount of gamma or X-rays required to produce ions carrying one electrostatic unit of electrical charge, either positive or negative, in 1 cubic centimeter of dry air under standard conditions; numerically equal to 2.58 x 10-4 coulombs/kg).
rad	The basic unit of absorbed dose of ionizing radiation. A dose of 1 rad means the absorption of 100 ergs of radiation energy per gram of absorbing material.

radioactivity	The spontaneous decay or disintegration of an unstable atomic nucleus, usually accompanied by the emission of ionizing radiation.
radioactive decay chain	A succession of nuclides, each of which transforms by radioactive disintegration into the next, until a stable nuclide results. The first member is called the parent, the intermediate members are called daughters, and the final stable member is called the end product.
radium	A radioactive element chemically similar to barium, formed as a daughter product of uranium (U-238). The most common isotope of radium, Ra-226, has a half-life of 1,600 years. Radium is present in all uranium-bearing ores. Trace quantities of both uranium and radium are found in all areas, contributing to the gamma background.
radon	A radioactive, chemically inert gas, having a half-life of 3.8 days (Rn-226); formed as a daughter product of radium (Ra-226).
radon background	Low levels of radon gas found in an area, due to the presence of uranium or radium in the soil.
radon concentration	The amount of radon per unit volume.
radon daughter	One of several short-lived radioactive daughter products of radon (several of the daughters emit alpha particles).
RDC	Radon daughter concentration (the concentration in air of short-lived radon daughters, expressed usually in pCi/l; also measured in terms of working level (WL)).
radon flux	The quantity of radon emitted in a unit time per unit area (typical units are in pCi/m^2-s).

recharge	The processes by which water is absorbed and added to the zone of saturation of an aquifer, either directly into the formation or indirectly by way of another formation.
rem	(Acronym for roentgen equivalent man). The unit of dose for any ionizing radiation which produces the same biological effect as a unit of absorbed dose of ordinary X-rays, numerically equal to the absorbed dose in rads multiplied by the appropriate quality factor for the type of radiation. The rem is the basic recorded unit of accumulated dose to personnel.
scintillometer	A radiation detection instrument used for monitoring small changes in background and for low-level radiation, normally utilizing a NaI crystal as a scintillator.
WL	Working level. A unit of radon daughter exposure, equal to any combination of short-lived radon daughters in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy. This level is equivalent to the energy produced in the decay of the daughter products RaA, RaB, RaC, and RaC' that are present under equilibrium conditions in a liter of air containing 100 pCi of Rn-226. It does not include decay of RaD (22 year half-life) and subsequent daughter products.
WLM	Working level month. One WLM is equal to the exposure received from 170 WL hours.