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Prepared by
Oak Ridge Associated
Universities

Prepared for
Office of
Operational
Safety

U.S. Department
of Energy

POST REMEDIAL ACTION SURVEY

PROPERTY OF MODERN LANDFILL, INC.

FORMER LOOW SITE

LEWISTON, NEW YORK

J.D. BERGER

Radiological Site Assessment Program
Manpower Education, Research, and Training Division

FINAL REPORT

January 1982

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J.D. Berger

Project Staff

R.D. Condra C.F. Riemke
P.W. Frame C.F. Weaver
W.O. Helton L.A. Young

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This report is based on work performed under contract number DE-AC05-76OR00033 with the Department of Energy.

TABLE OF CONTENTS

	Page
List of Figures	ii
List of Tables	iv
Introduction	1
Survey Procedures	3
Results	6
Comparison of Survey Results With Guidelines	10
Summary	11
References	37

Appendices:

Appendix A: Instrumentation and Analytical Procedures

Appendix B: Guidelines for Cleanup of Formerly Utilized Sites

Appendix C: Evaluation of Radiation Exposures on Portions of the Modern Landfill, Inc. Property, Lewiston, New York

LIST OF FIGURES

		Page
FIGURE 1.	Plan View of LOOW Site Indicating Location of Modern Landfill Property.	13
FIGURE 2.	Modern Landfill, Inc. Property Showing Prominent Surface Features	14
FIGURE 3.	Grid System Established For Survey Reference: Shaded Regions Indicate Areas of Remedial Action . . .	15
FIGURE 4.	Area of Building Foundations 718 and 707-F, Showing 15 foot Grid System For Remedial Action Survey	16
FIGURE 5.	Area of Vine Street Showing Grid System Established For Post Remedial Action Survey.	17
FIGURE 6.	Locations of Measurements and Samples to Confirm Previous Survey Results in Areas Undisturbed by Remedial Action.	18
FIGURE 7.	Area of Building Foundations, Indicating Locations of Soil Samples	19
FIGURE 8.	Locations of Soil Samples Collected From Areas of Remedial Action Along Vine Street.	20
FIGURE 9.	Exposure Rates (μR/h) at 1 Meter Above the Surface Along Grid Lines C, G, K, 3, 6, and 11: Measurements to Confirm Results of the January 1981 Survey.	21
FIGURE 10.	Surface Beta-Gamma Dose Rates (μrad/h) Along Grid Lines C, G, K, 3, 6, and 11: Measurements to Confirm Results of the January 1981 Survey	22
FIGURE 11.	Locations of Elevated Surface Contact Radiation Levels Identified in the Vicinity of the Building Foundations.	23
FIGURE 12.	Exposure Rates (μR/h) at 1 Meter Above the Surface, Measured in the Area of Remedial Action Near the Building Foundations 718 and 707-F	24
FIGURE 13.	Surface Dose Rates (μrad/h), Measured in the Vicinity of Building Foundations 718 and 707-F	25
FIGURE 14.	Locations of Elevated Surface Contact Radiation Levels Along Vine Street Measured After Remedial Action But Prior to Removal of Additional Soil	26

List of Figures, cont.

Page

FIGURE 15. Exposure Rates (μR/h) at 1 Meter Above the Surface, Measured Along Vine Street. 27

FIGURE 16. Surface Beta-Gamma Dose Rates (μrad/h) Measured Along Vine Street 28

LIST OF TABLES

		Page
TABLE 1.	Concentrations of Radionuclides in Surface Soil From Areas of Modern Landfill Property Undisturbed by Remedial Action.	29
TABLE 2.	Locations Near Foundations 718 and 707-F, Where Surface Contact Exposure Rates Exceeded 20 μR/h.	30
TABLE 3.	Concentrations of Radionuclides in Systematic Surface Soil Samples From the Area of Building Foundations 707-F and 718	31
TABLE 4.	Concentrations of Radionuclides in Biased Soil Samples Collected From the Area of Building Foundations 707-F and 718	33
TABLE 5.	Locations Along Vine Street Indicating Surface Contact Exposure Rates Exceeding 20 μR/h.	34
TABLE 6.	Concentrations of Radionuclides in Systematic Surface Soil Samples Collected From the Remedial Action Area of Vine Street.	35

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INTRODUCTION

Beginning in 1944, the Manhattan Engineer District and its successor, the Atomic Energy Commission (AEC), used portions of the Lake Ontario Ordnance Works (LOOW), Lewiston, New York, for storage of radioactive wastes. These wastes were primarily residues from uranium processing operations, however, they also included: contaminated rubble and scrap from decommissioned facilities, biological and miscellaneous wastes from the University of Rochester, and low-level fission-product waste from contaminated liquid evaporators at the Knolls Atomic Power Laboratory (KAPL). Receipt of radioactive waste was discontinued in 1954, and following cleanup activities by Hooker Chemical Co., 525 hectares of the original 612 hectare LOOW site were declared surplus. This property was eventually sold by the General Services Administration to various private, commercial, and governmental agencies.[1]

Modern Landfill, Inc. is the current owner of a 81 hectare tract from the former LOOW property (Figure 1). A triangular shaped section, 6.5 hectares in area located in the northwest corner of this tract, has undergone radiological assessment followed by remedial action to remove radioactive residues. That section is the subject of this survey report.

Site Description

The site is bounded on all sides by paved roads--Castle Garden Road on the west, "O" Street on the north, and Vine Street on the southeast. The actual property boundaries lie 50 ft east and south respectively of the centerlines of Castle Garden Road and "O" Street. A chain link fence along the west and north boundaries separates Modern Landfill property from the Department of Energy's Niagara Falls

Storage Site. The land is level with alternating open and sparsely wooded areas. Surface features include a railroad track with three spurs, a drainage ditch ("K" ditch), and concrete foundations of four buildings (706, 707-E, 707-F, and 718) which were previously demolished. There are also several piles of brush and debris from land clearance during an earlier radiological survey. Figure 2 is a plot plan of the site.

Radiological History

Records and past aerial photographs indicate that containers of radioactive wastes were handled and/or stored on the Modern Landfill property. These wastes were primarily K-65 residues from the high-grade African ores. Drums of this material were temporarily stored along Vine Street, Castle Garden Road, and "O" Street, awaiting transfer into the concrete tower located on the DOE property north of "O" Street, or shipment to Fernald, Ohio. Limited storage and handling of fission product wastes from KAPL is also believed to have occurred in the vicinity of buildings 707-F and 718, near Castle Garden Road. Radiological surveys, conducted by the Oak Ridge Operations Office of the AEC in June 1972, showed elevated direct radiation levels along Vine Street near its intersection with Castle Garden Road and at the northeast corner of the property.[2] These latter levels are due primarily to the K-65 residues stored in the nearby tower. Surface soil contamination was also noted at several locations and limited removal of soil was performed in those areas. The radiation levels were reduced to less than 50 μR/h above background at three feet above the surface--the guideline used by the AEC for decommissioning excess properties.

In October 1978, an aerial radiological survey of LOOW was conducted by EG&G. This survey did not identify significant gamma radiation levels on the Modern Landfill property.[3] However, a mobile scan of accessible LOOW roads, performed by Oak Ridge National Laboratory in November 1980, confirmed the earlier AEC findings.[4] In January 1981, a comprehensive survey of the Modern Landfill site was

conducted by Oak Ridge National Laboratory.[5] The survey indicated that the central portion of the property contained no radioactive residues, but that surface soil near building foundations 707-F and 718 contained elevated levels of Ra-226 and Cs-137 and that there were elevated concentrations of Ra-226 along portions of Vine Street. The possibility of buried containers of pyrophoric zirconium scrap near building foundations 707-E and 706 was also raised.

Under an agreement between Modern Landfill and the Department of Energy (DOE), remedial action was performed during May and early June 1981 to remove areas of soil exceeding the release criteria. Soil removal was performed in the vicinity of pads 707-F and 718 and approximately 2 to 4 m either side of Vine Street. The soil was transferred to the adjacent Niagara Falls Storage Site (NFSS) of DOE for interim storage. This work was performed by the property owner with radiological support provided by the Eberline Instrument Corp., Albuquerque, New Mexico. Ground penetrating radar surveys were also conducted around pads 707-E and 706 to identify subsurface metalic deposits which might be buried zirconium or other wastes -- none were found. A more detailed description of the remedial action and the results of the supporting survey will be presented by Eberline Instrument Corp., in a separate report.

Following the remedial action the post remedial action survey of the property was performed on June 25-27, 1981, by Oak Ridge Associated Universities.

SURVEY PROCEDURES

Objectives

The objectives of this survey were to verify the adequacy of remedial action, and to evaluate the current radiological status of the property with respect to the guidelines for release for unrestricted use.

Procedures

1. Grid System

A 100 ft* grid system was established on the Modern Landfill property as part of the January 1981 radiological survey (Figure 3). This same base grid system was used for the remedial action and post-remedial action surveys, although a more closely spaced 15 ft grid was established in the vicinity of the building foundations and along Vine Street. To simplify sampling point identification along Vine Street, ORAU also established additional grid points at 50 ft intervals along the road center, beginning at the fence line near Castle Garden Road. These grid points were later referenced to the main property grid for survey report uniformity. Figures 4 and 5 indicate the grid systems used for the post remedial action survey.

2. Confirmation of Previous Survey Findings

It was possible that remedial action activities near the building foundations and along Vine Street may have resulted in the spread of contamination. To determine if this had occurred, measurements of direct radiation levels and sampling of surface soil were performed on portions of the Modern Landfill property which had not been disturbed by the remedial action. Gamma exposure rates at 1 m above the surface and beta-gamma dose rates at 1 cm above the surface were measured at the intersections of grid lines, i.e. at 100 ft intervals, along east/west lines C, G, and K, and north/south lines 3, 6, and 11. Exposure rates were determined with NaI(Tl) scintillation detectors, cross calibrated with a pressurized ion chamber. Beta-gamma dose rates were measured using an end-window Geiger-Mueller detector and a portable scaler/ratemeter. Conversion to dose rate (μrad/h) was performed by cross calibration with a thin walled ionization chamber.

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* *English rather than metric units of measurement are used in this report when referencing the grid system, since this system was originally established in units of feet.*

Surface (0-5 cm) soil samples were collected at 200 ft intervals along the same grid lines used for direct measurements. The radiation levels and soil concentrations were compared to the data obtained for the corresponding locations during the January 1981 survey. The locations of these measurements and samples are shown on Figure 6.

3. Area of Building Foundations

Walkover surface gamma scans were performed in the vicinity of the building foundations 707-F and 718, using NaI(Tl) scintillation detectors. Approximately 1.5 m intervals were used for the scan, and areas exceeding 10,000 cpm (20 μR/h) at contact with the ground were noted. Gamma exposure rates and beta-gamma dose rates (see section 2 above) were measured at 1 m and 1 cm above the surface respectively at the intersections of the 15 ft grid lines, established during the remedial action. Systematic surface soil samples were collected at the centers of the 15 ft x 15 ft grid blocks (Figure 7). Biased samples of surface soil were also collected at locations of elevated contact radiation levels identified during the walkover scan. During the survey, the property owner volunteered to perform additional soil removal in areas of elevated direct readings. The removed soil was transferred to the NFSS where it was added to the pile of debris which originated from the earlier remedial action activities on this property. Following this further clean-up, each location was remeasured and resampled.

4. Vine Street Area

A walkover gamma scan was conducted at 1.5 m intervals, covering the road surface and shoulders, extending 30 ft either side of road center. Locations of contact levels exceeding 10,000 cpm (20 μR/h) were identified, and the property owner immediately removed additional surface soil or road surface to reduce the levels. Soil samples were not obtained from the areas of elevated direct readings until after this further clean-up. Gamma exposure rates and beta-gamma dose rates were measured at 1 m and 1 cm respectively, above the surface at 50 ft

intervals along the road center and 15 ft and 30 ft either side of road center. Along the southeast portion of Vine Street systematic surface soil samples were collected at 50 ft intervals, 15 ft from road center, and at 100 ft intervals, 30 ft from road center. Since no elevated contact locations were noted from the walkover scan of the northeast portion of Vine Street, systematic soil samples were collected at 100 ft intervals, both 15 ft and 30 ft from the road center, along this portion of the road. Sample locations are indicated on Figure 8.

5. Sample Analysis

Soil samples were analyzed by gamma spectrometry for Ra-226, Cs-137, U-235, U-238, Th-232, and K-40. Six samples having elevated Cs-137 concentrations were also analyzed for Sr-90. Additional information concerning analytical procedures is contained in Appendix A.

RESULTS

Confirmation of January 1981 Survey Results

Gamma-Ray Exposure Rates

The exposure rates at 1 m above the surface, measured at 100 ft intervals along the six grid lines (C, G, K, 3, 6, and 11), are listed on the plan view (Figure 9). These exposure rates range between 10 and 21 μR/h, compared to the results of the January 1981 survey when the exposure rates over the entire site ranged from 3.6 to 25.9 μR/h. The lower values obtained during the January survey may be partially attributed to the snow cover present at the time of these measurements. There is a general increase in the exposure rate as one approaches the northeast corner of the property due to the proximity of the K-65 storage tower; this was noted during the January 1981

survey also. The average exposure rate within the property boundaries was 12.8 μR/h.

Beta-Gamma Surface Dose Rates

Surface dose rates measured along the six grid lines are presented on Figure 10. These measurements ranged from 15 to 45 μrads/h. These measurements confirm the conclusions of the January 1981 report, i.e. there is not a significant beta component in the direct radiation field on this property.

Soil Samples

Concentrations of radionuclides in the soil samples collected from the previously surveyed area are listed in Table 1. The concentration of radium-226 ranged from 0.63 to 1.4 pCi/g. These levels are comparable to the average background radium-226 concentration of 1 pCi/g for the LOOW region. The cesium-137 concentrations in these same soils ranged from 0.17 to 1.2 pCi/g, again, comparable to the average background concentration of approximately 0.5 pCi/g for this region. Uranium-235, uranium-238, and thorium-232 concentration ranges were <0.03* to 0.22 pCi/g, <2.3 to 8.2 pCi/g, and 0.52 to 1.3 pCi/g respectively. Determination of potassium-40, performed as a general practice for soil samples, indicated concentrations from 10 to 17 pCi/g.

<u>Area of Building Foundations</u>

Walkover Surface Scan

The walkover surface scan of the area surrounding building foundations 718 and 707-F indicated 11 locations which exceeded 20 μR/h at surface contact. These locations, indicated on Figure 11, ranged from 27 to 265 μR/h and were due to small isolated deposits.

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* *The less than symbol indicates that the concentration measured was less than the minimum statistics detection limit of the procedure.*

After the property owner removed additional soil from these areas, the contact exposure rates ranged from 13 to 24 μR/h. Contact radiation levels before and after the additional soil removal are presented in Table 2.

Gamma Exposure Rates

Exposure rates measured at 1 m above the ground surface ranged from 9 to 18 μR/h with an average of 12.8 μR/h (Figure 12). The levels near foundation 718 are comparable to those noted over the remainder of the property (see above section on rechecks of previously surveyed areas). The levels in the vicinity of foundation 707-F are slightly higher (2-7 μR/h) than those near foundation 718.

Surface Dose Rates

Beta-gamma surface dose rates are presented on Figure 13. They range from 11 to 85 μrads/h with an average level of 27 μrads/h. As was noted for exposure rates at 1 m above the surface, the surface dose rates are higher near foundation 707-F than they are near foundation 718 and the remainder of the property undisturbed by remedial action. The difference is variable but averages approximately two times higher.

Soil Concentrations

Concentrations of radionuclides determined in surface soil samples from around the foundations area are listed in Tables 3 and 4. The systematic samples contained Ra-226 and Cs-137 concentrations ranging from 0.36 to 4.9 pCi/g and 0.05 to 24 pCi/g, respectively. Uranium-235, U-238 and Th-232 concentrations ranged from <0.03 to 0.2 pCi/g, <1.4 to 16 pCi/g, and 0.32 to 1.2 pCi/g respectively. Biased soil samples, collected from the areas of elevated contact levels identified by the walkover scan, contained Ra-226 from 0.68 to 12 pCi/g. These concentrations were reduced to 0.59 to 2.6 pCi/g

after additional soil removal. The Cs-137 concentrations ranged from 16 to 1025 pCi/g before further cleanup and from 2.5 to 69 pCi/g after additional soil was removed. Uranium-235, U-238 and Th-232 concentrations were 0.020 to 25 pCi/g, <6.7 to 49 pCi/g, and 0.44 to 1.5 pCi/g respectively before and 0.15 to 1.5 pCi/g, <2.2 to 30 pCi/g, and 0.33 to 1.5 pCi/g respectively after additional soil removal. It was noted that the ratios of U-235/238 in samples, containing high concentrations of Cs-137, are above those found in natural uranium, i.e. 1:22. This suggests that the KAPL waste may have contained slightly enriched uranium along with the fission products. Strontium-90 concentrations determined for six of the biased samples, highest in Cs-137, ranged from 12.8 to 111 pCi/g. The Cs-137/Sr-90 activity ratio ranged from 0.5 to 29 with an average of 6.5. There is no correlation of these ratios; however the average indicates that the Cs-137 concentrations exceed the Sr-90 concentrations.

Area Along Vine Street

Walkover Surface Scan

The walkover surface scan located numerous areas of surface contact levels exceeding 20 μR/h. These locations, shown on Figure 14, were of both a point and extended source (general contamination) nature. Measurements at these locations before and after additional soil removal are listed in Table 5. These levels ranged from 36 to 128 μR/h and 11 to 33 μR/h before and after additional cleanup, respectively. All of these locations were noted between the intersection of Vine Street with Castle Garden Road and grid point F, 9+00. No significant increases in radiation levels which could be attributed to residues or contamination in surface soil, were detected between F, 9+00 and the northern boundary fence along "O" Street.

Gamma Exposure Rates

Gamma exposure rates 1 m above the surface along Vine Street ranged from 9 to 43 μR/h with an average of 17.3 μR/h (Figure 15).

Southwest of grid point D, 11+00 the levels were between 9 and 20 μR/h; northeast of this point - in the direction of the K-65 storage tower - the levels ranged from 16 to 43 μR/h, with the maximum levels (39 to 43 μR/h) along the north boundary fence line closest to these stored residues.

Beta-Gamma Dose Rates

Dose rates at 1 cm above the surface ranged from 11 to 75 μrad/h (Figure 16). The average was 31 μrad/h. The pattern for these measurements was similar to that for the exposure rates, with the higher levels being noted along the northeastern portion of the road.

Soil Concentrations

Table 6 presents the concentrations of radionuclides determined in surface soil samples collected along Vine Street, following cleanup of areas of elevated direct radiation levels (refer to the previous section describing the results of the walkover surface scan). These samples contained Ra-226 and Cs-137 concentrations ranging from 0.23 to 23 pCi/g and 0.02 to 1.2 pCi/g, respectively. Uranium-235, U-238, and Th-232 concentrations ranged from 0.04 to 1.4 pCi/g, <1.9 to 12 pCi/g, and <0.07 to 1.2 pCi/g, respectively.

COMPARISON OF SURVEY RESULTS WITH GUIDELINES

The soil cleanup criteria for sites, formerly utilized by the Manhattan Engineer District and Atomic Energy Commission, are presented in Appendix B. With the exception of several small areas along Vine Street, the radionuclide concentrations in surface soil of the Modern Landfill property are less than 5 pCi/g of Ra-226, 80 pCi/g of Cs-137, and 100 pCi/g of Sr-90 above the area background levels. Of 66 soil samples collected along Vine Street, five exceeded 5 pCi/g of Ra-226 above background; four of these samples were between 5 and 10 pCi/g and based on the concentrations of other samples in the same

areas, the average per 100 m^2 is less than 5 pCi/g. One location, 20 ft south of the road at grid point I+15, 5+90, had a net Ra-226 concentration of 22 pCi/g (23 pCi/g minus 1 pCi/g background). Averaging with three nearby sample locations (numbers 160, 161, and 164) will result in an average concentration over a 100 m^2 area of approximately 7.7 pCi/g above background. This level exceeds the cleanup criteria of 5 pCi/g above background, averaged over 100 m^2 and additional remedial action will be necessary if this location is to satisfy the criteria for unrestricted release of the property.

The cleanup criteria for formerly utilized sites does not provide guidance regarding direct radiation exposure levels. The Nuclear Regulatory Commission's Standards for Protection Against Radiation (10CFR20.105) limits the annual radiation dose to an individual in the general population to 500 millirem.[6] Assuming continual exposure, i.e. 168 h/wk, this is equivalent to an average exposure rate of approximately 60 μR/h. There are no locations on the Modern Landfill property which exceed that value.

An evaluation of the current radiation exposures at this site is presented in Appendix C. This section also compares these levels with the background exposure in the Niagara, New York, area and the scientifically based guidelines established for the protection of radiation workers and the general public.

SUMMARY

A post remedial action survey was conducted on a 6.5 hectare portion of former Lake Ontario Ordnance Works property belonging to Modern Landfill, Inc., Lewiston, New York. The survey included surface radiation scans, measurements of direct radiation levels, and analysis for radionuclide concentrations of surface soil samples. Emphasis was in areas of two building foundations and along Vine Street where remedial action had been recently performed by the property owner. During the survey several isolated regions of

residual surface contamination were identified and additional soil removal was performed in these regions.

The results of the survey indicate that direct radiation levels throughout the property are within the applicable federal guidelines for unrestricted areas. Soil concentrations satisfy the criteria for cleanup of formerly utilized sites with the exception of one small area along Vine Street, where the average radium-226 level of 7.7 pCi/g slightly exceeds the guideline of 5 pCi/g. An evaluation of the potential radiation exposures to persons at the site indicates that these exposures are within the federal guidelines and risks to such persons are negligible.

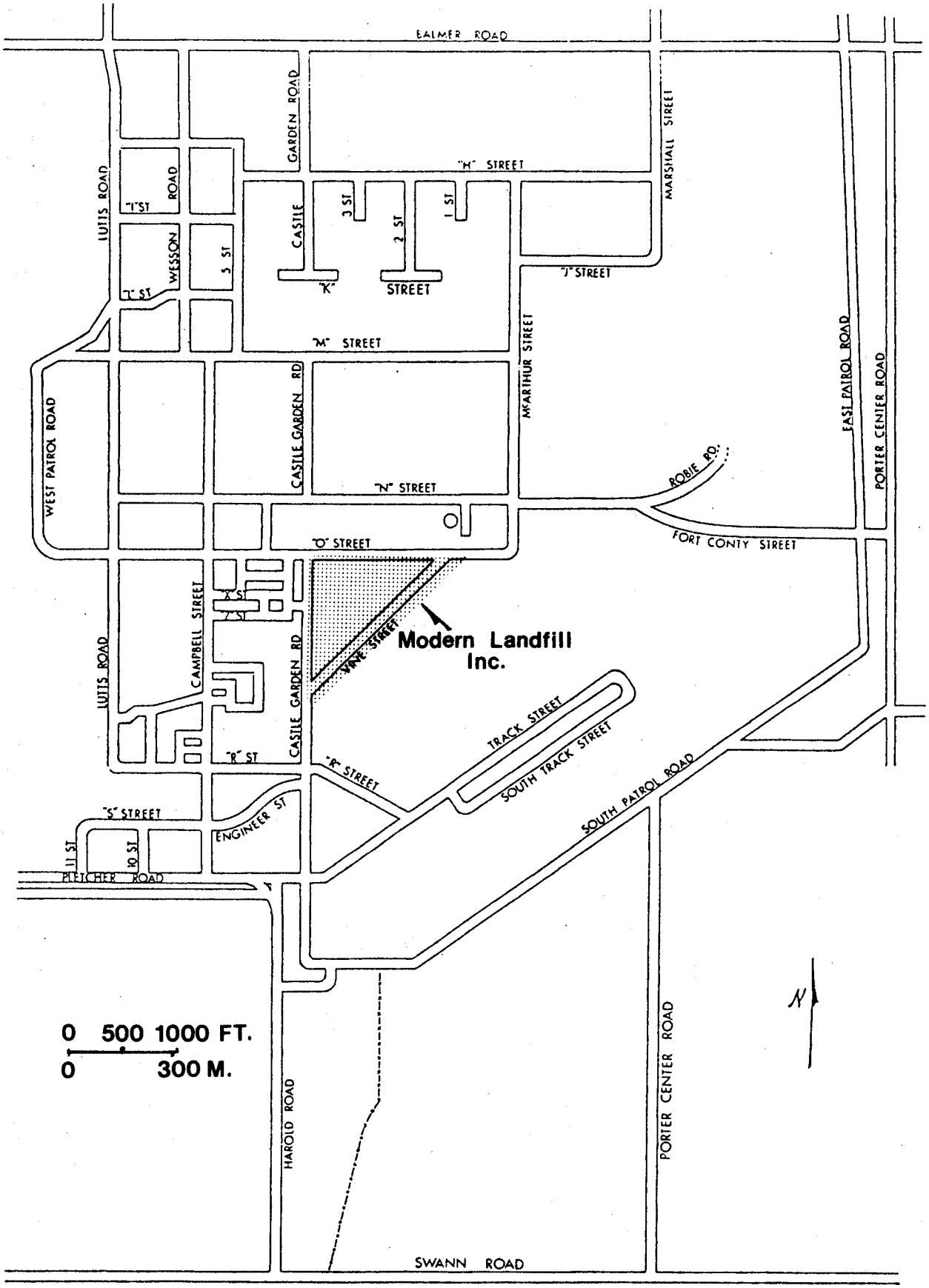

FIGURE 1. Plan View of LOOW Site Indicating Location of Modern Landfill Property.

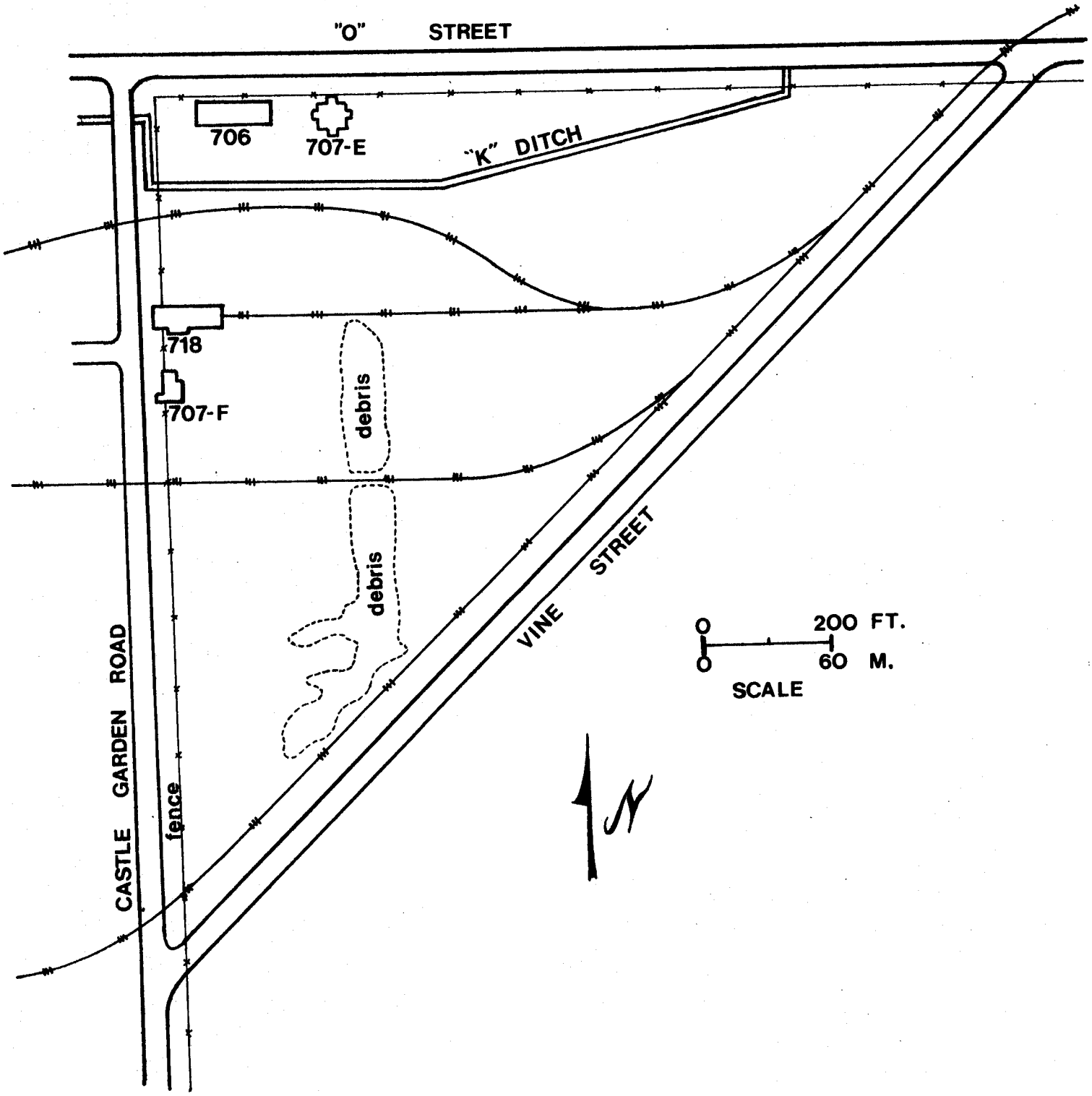

FIGURE 2. Modern Landfill, Inc. Property Showing Prominent Surface Features.

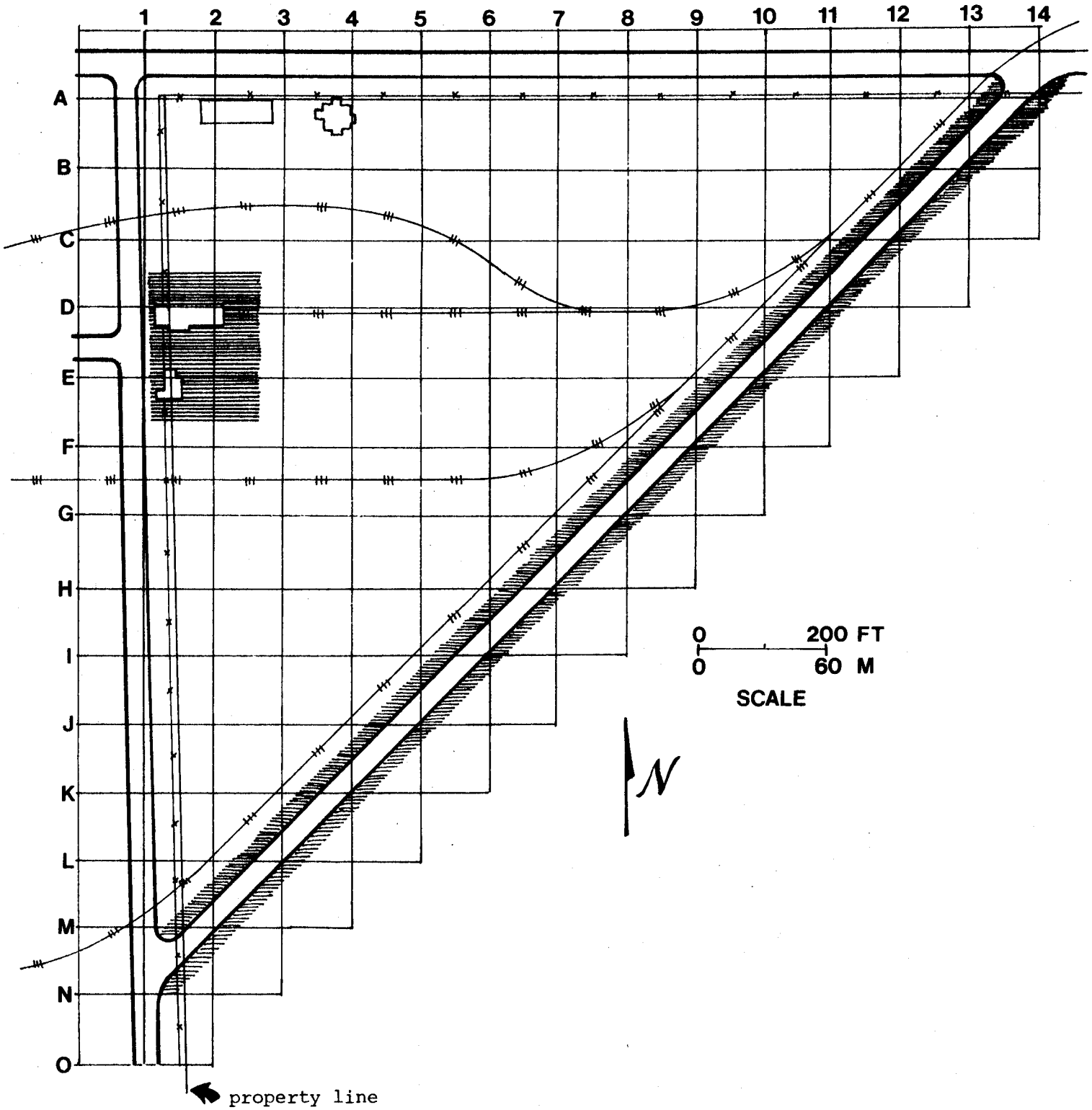

FIGURE 3. Grid System Established for Survey Reference: Shaded Regions Indicate Areas of Remedial Action.

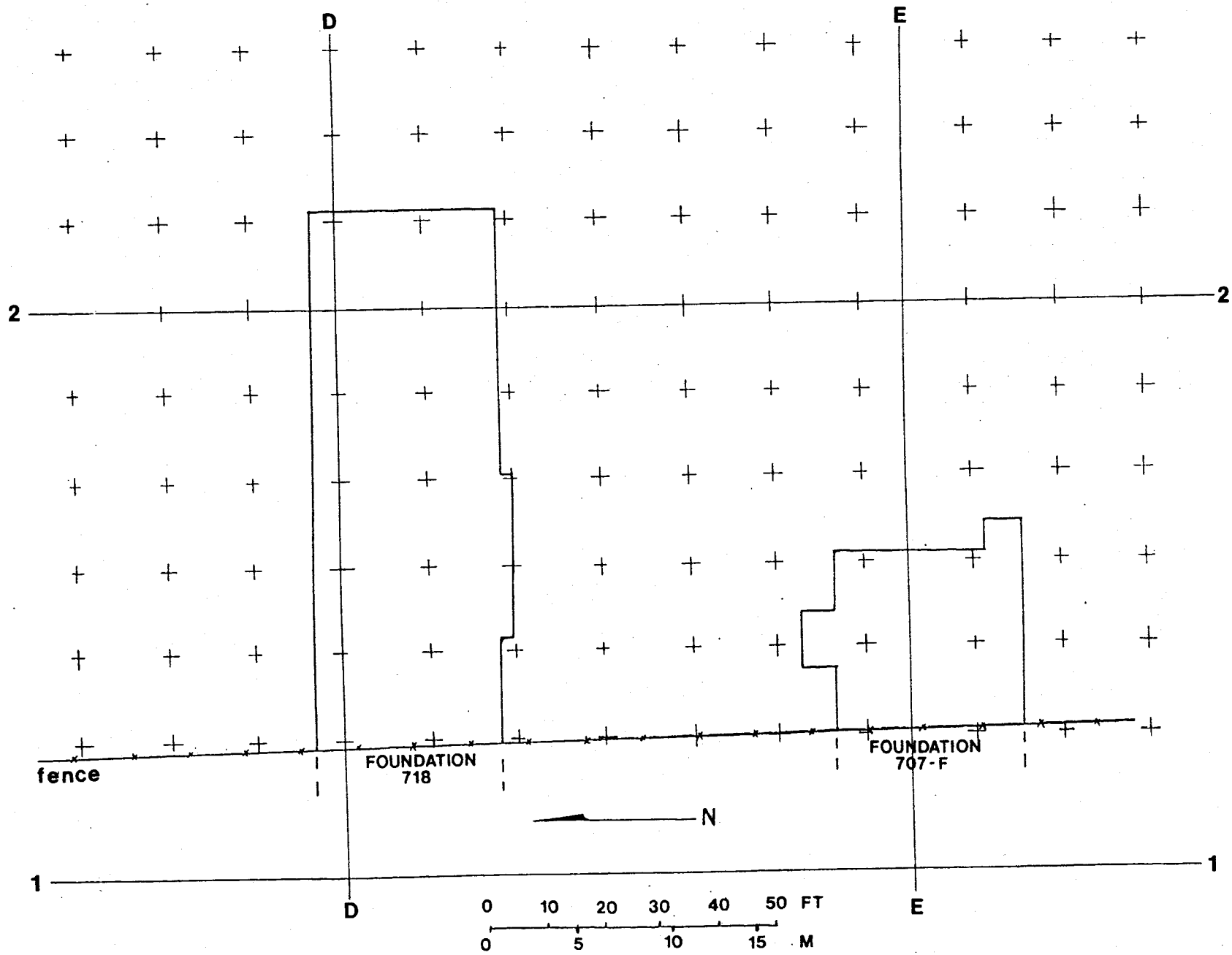

FIGURE 4. Area of Building Foundations 718 and 707-F, Showing 15 foot Grid System for Remedial Action Survey.

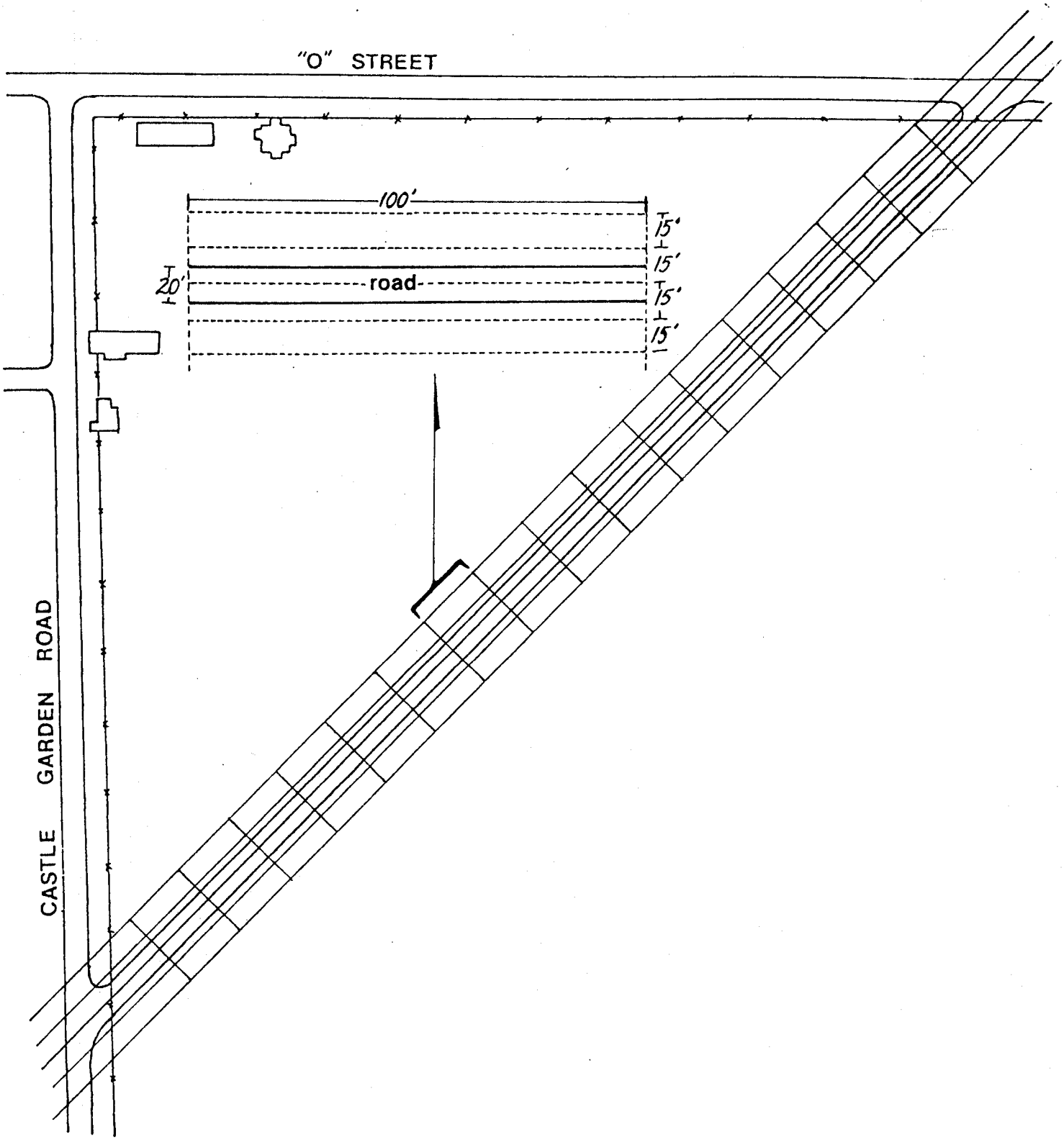

FIGURE 5. Area of Vine Street Showing Grid System Established For Post Remedial Action Survey.

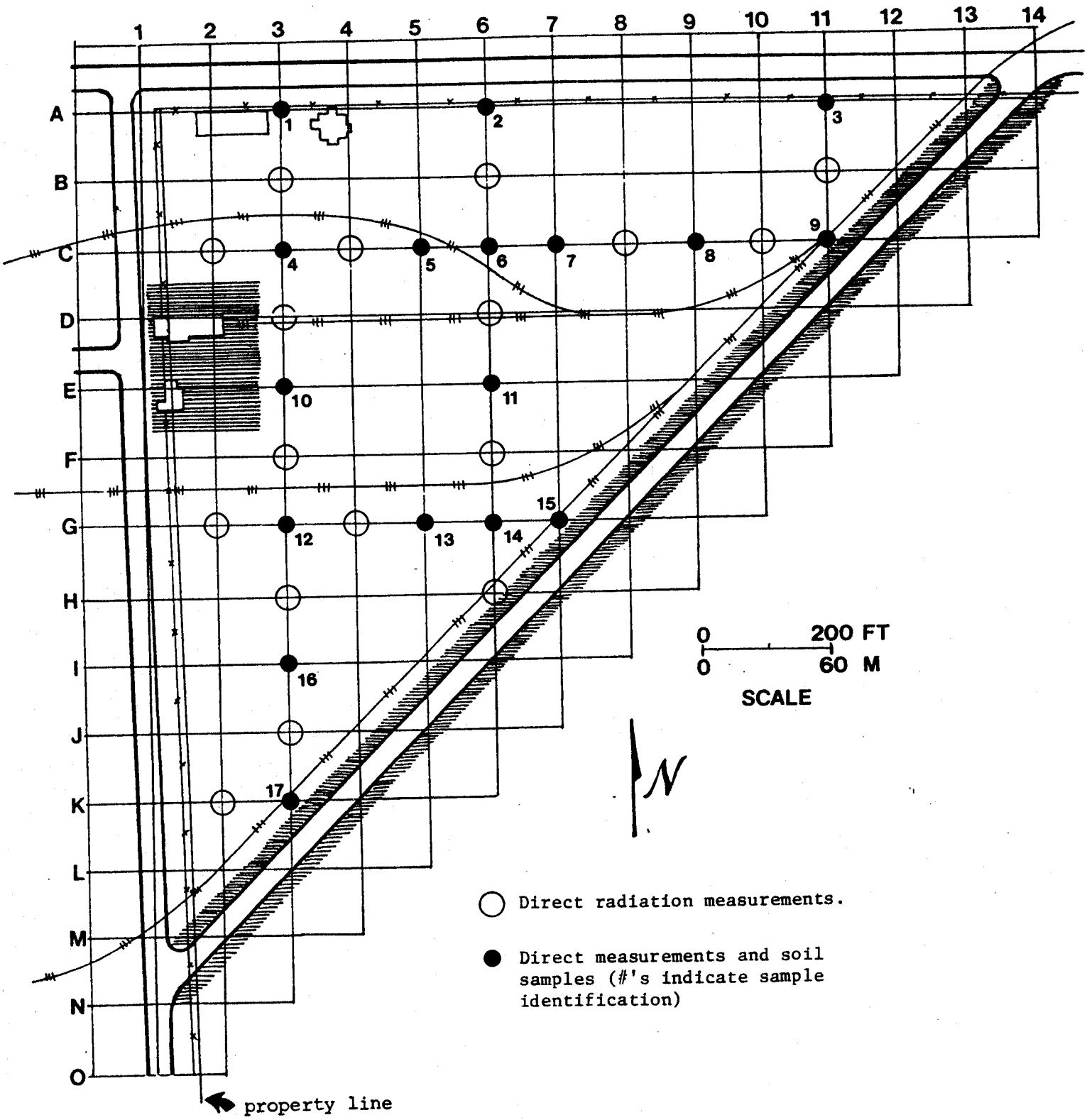

FIGURE 6. Locations of Measurements and Samples to Confirm Previous Survey Results in Areas Undisturbed by Remedial Action.

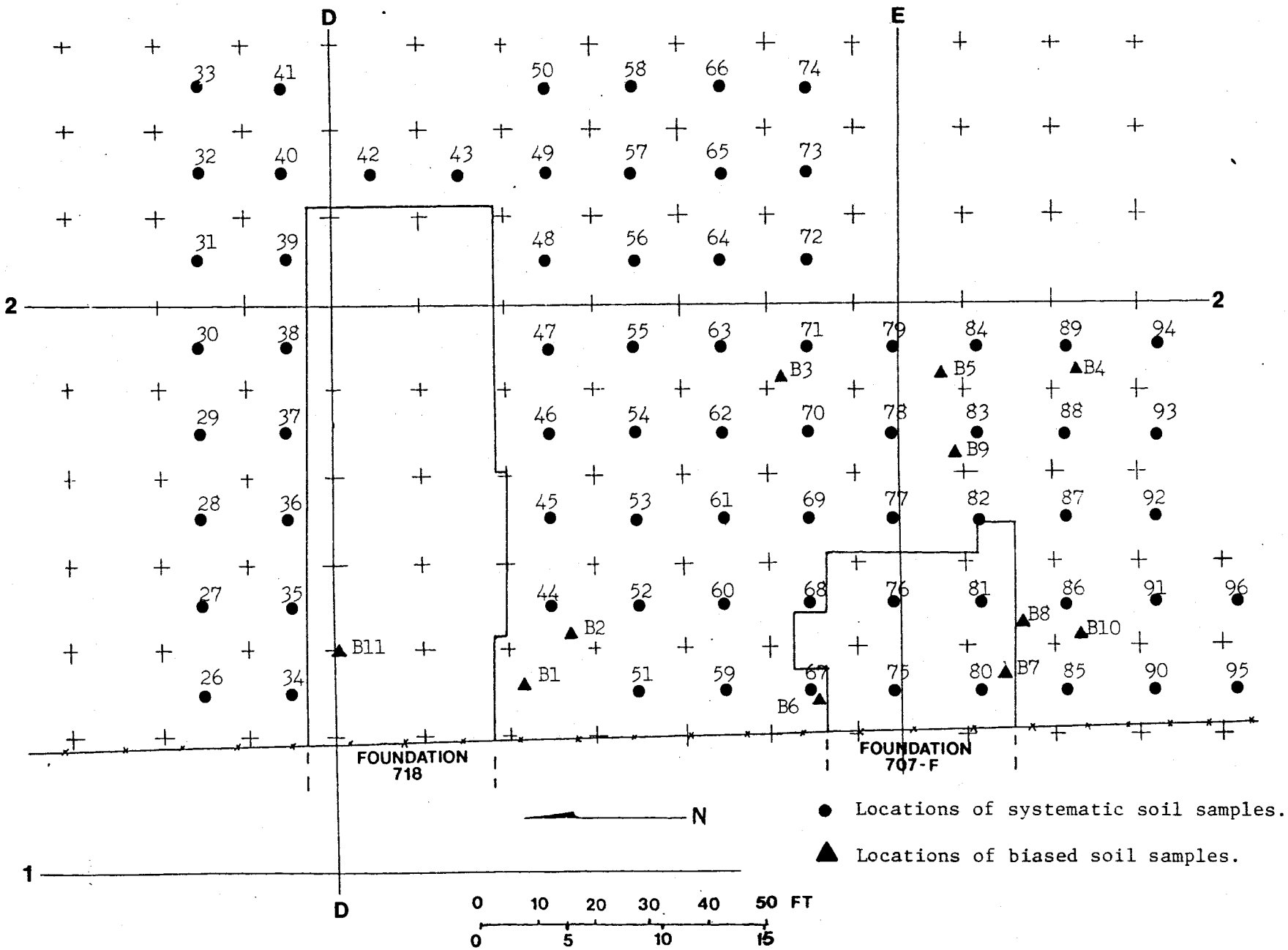

FIGURE 7. Area of Building Foundations, Indicating Locations of Soil Samples

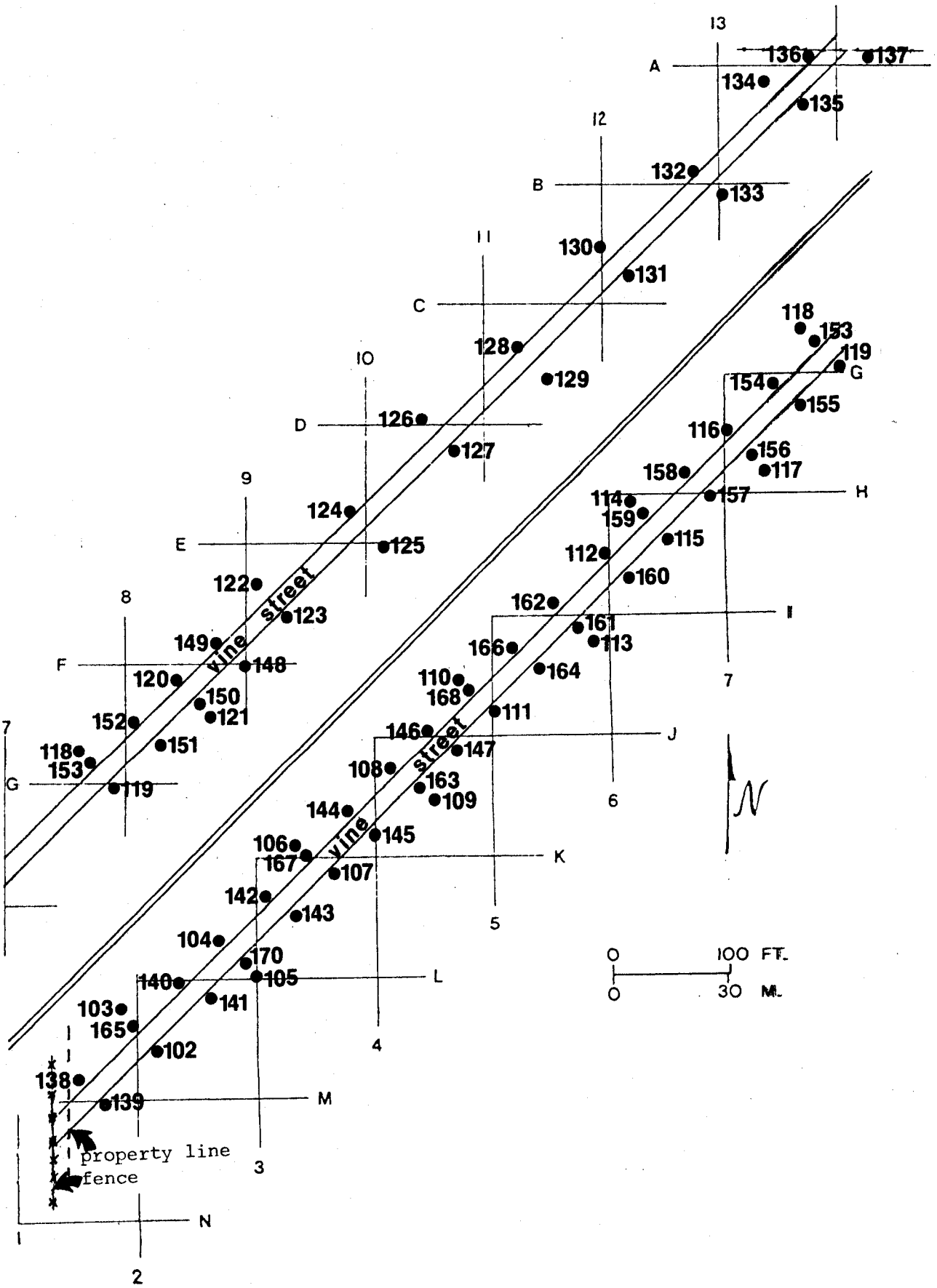

FIGURE 8. Locations of Soil Samples Collected From Areas of Remedial Action Along Vine Street

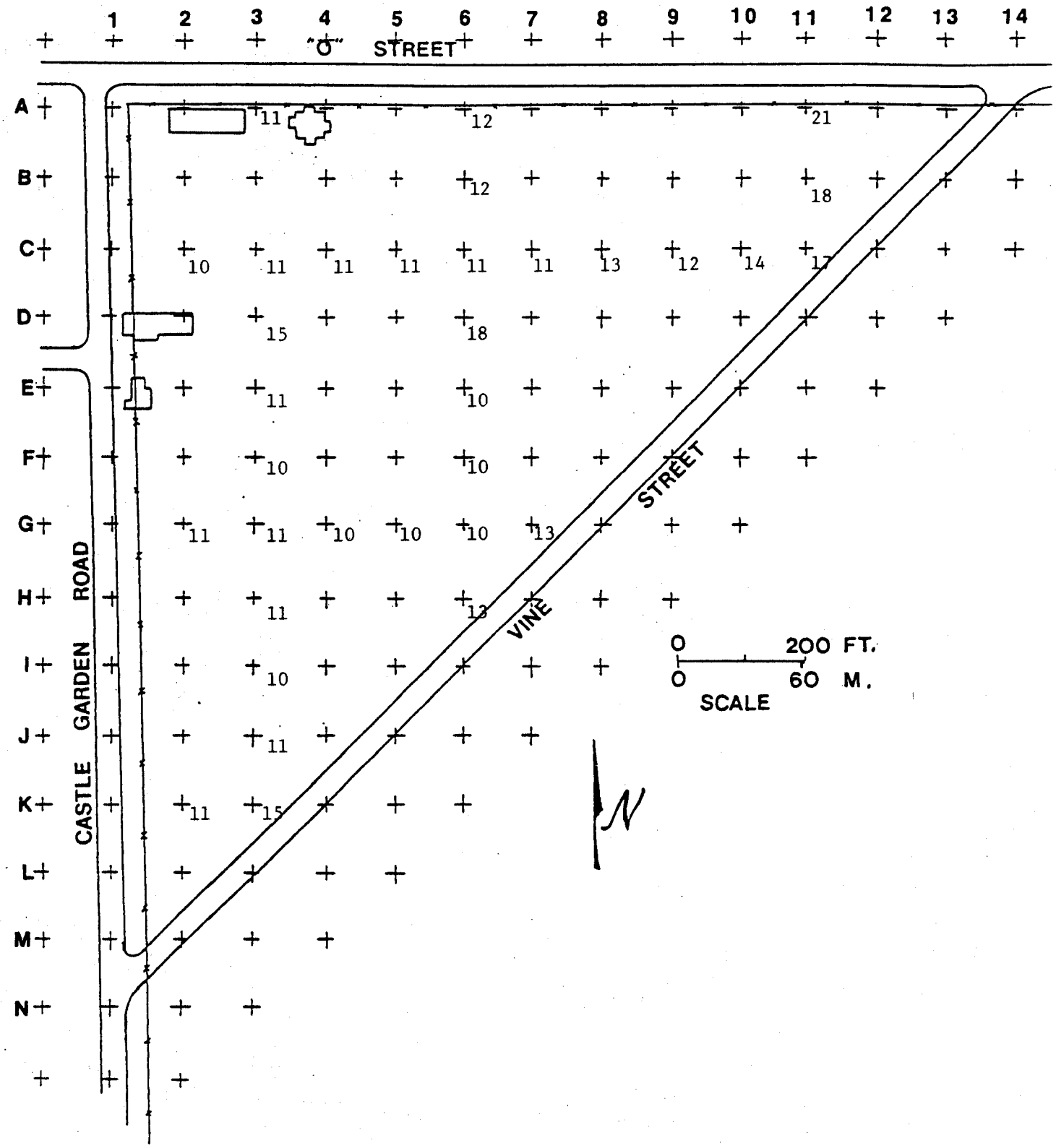

FIGURE 9. Exposure Rates (μR/h) at 1 Meter Above the Surface Along Grid Lines C, G, K, 3, 6, and 11: Measurements to Confirm Results of the January 1981 Survey.

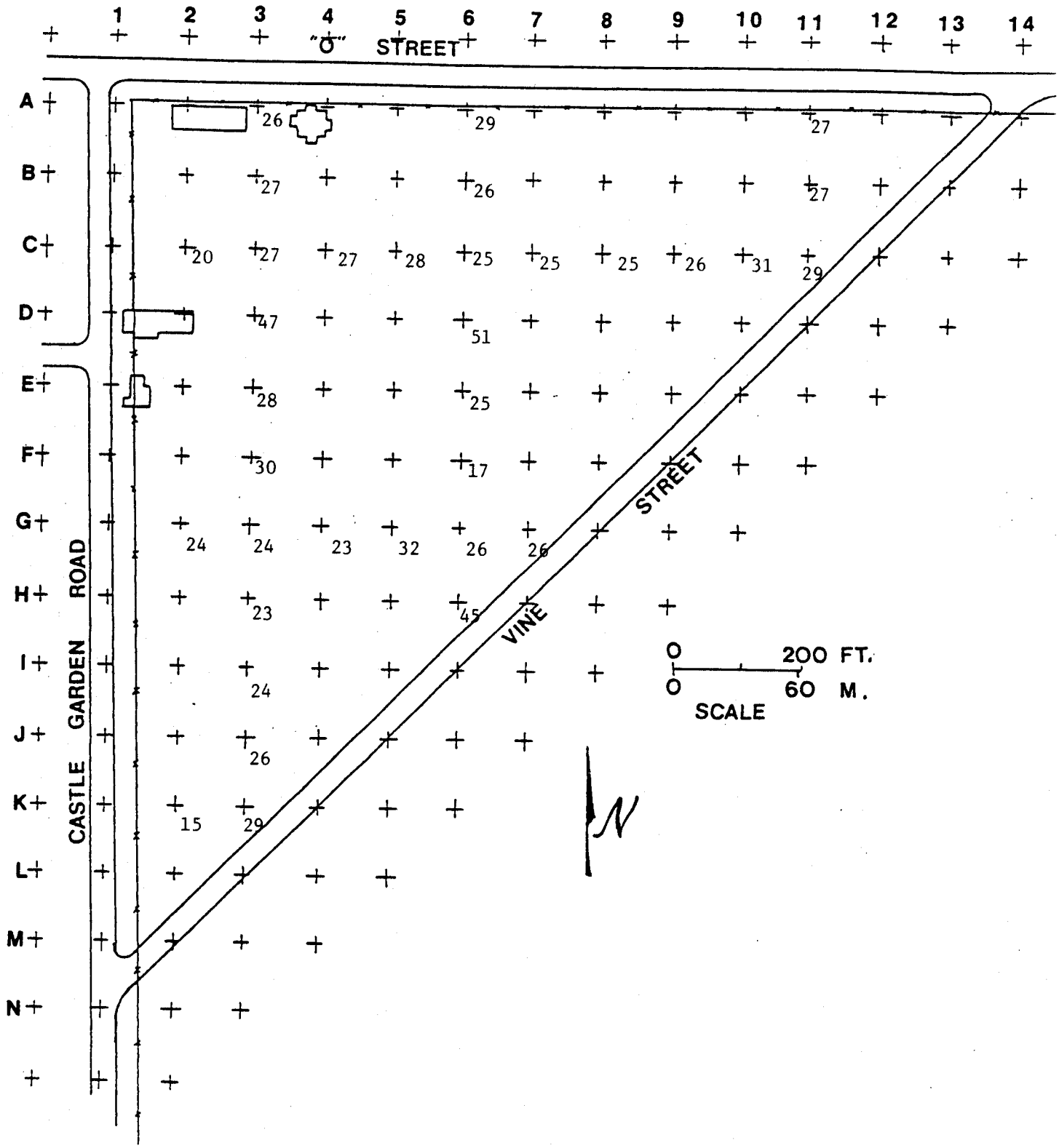

FIGURE 10. Surface Beta-Gamma Dose Rates (μrad/h) Along Grid Lines C, G, K, 3, 6, and 11: Measurements to Confirm Results of the January 1971 Survey.

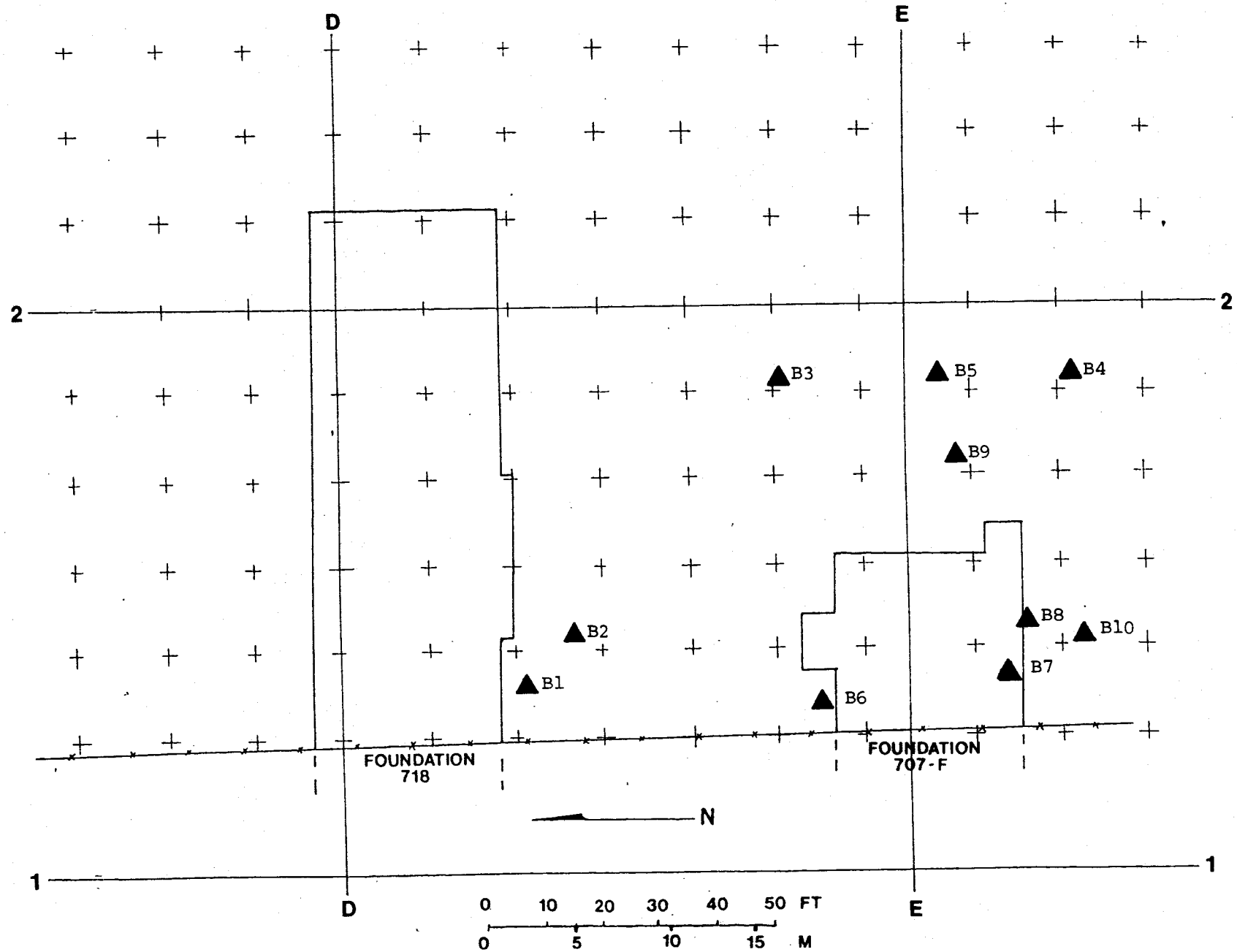

FIGURE 11. Locations of Elevated Surface Contact Radiation Levels Identified in the Vicinity of the Building Foundations. (These elevated areas were identified following the remedial action but prior to additional soil removal performed during the survey.)

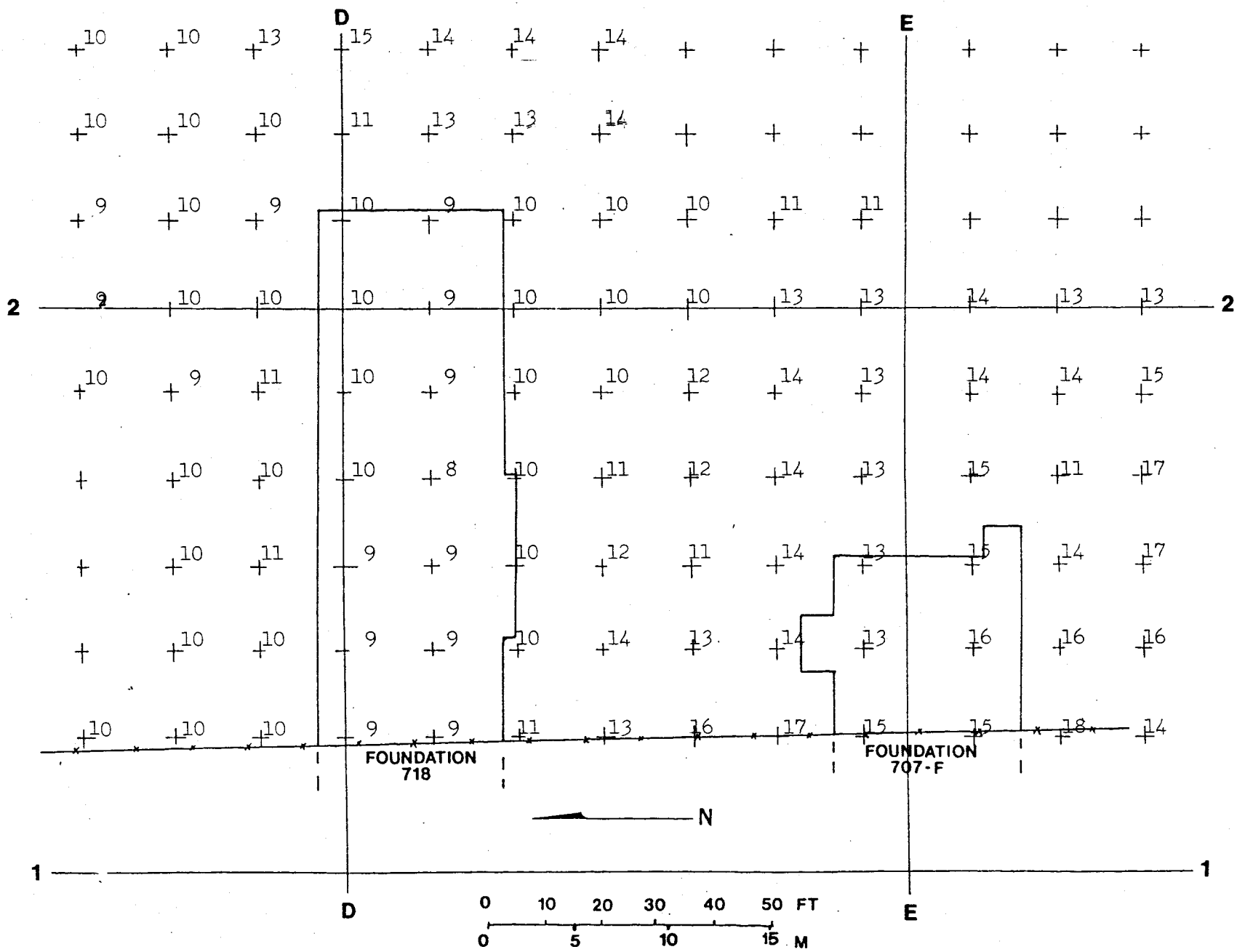

FIGURE 12. Exposure Rates (μR/h) at 1 Meter Above the Surface, Measured in the Area of Remedial Action Near the Building Foundations 718 and 707-F.

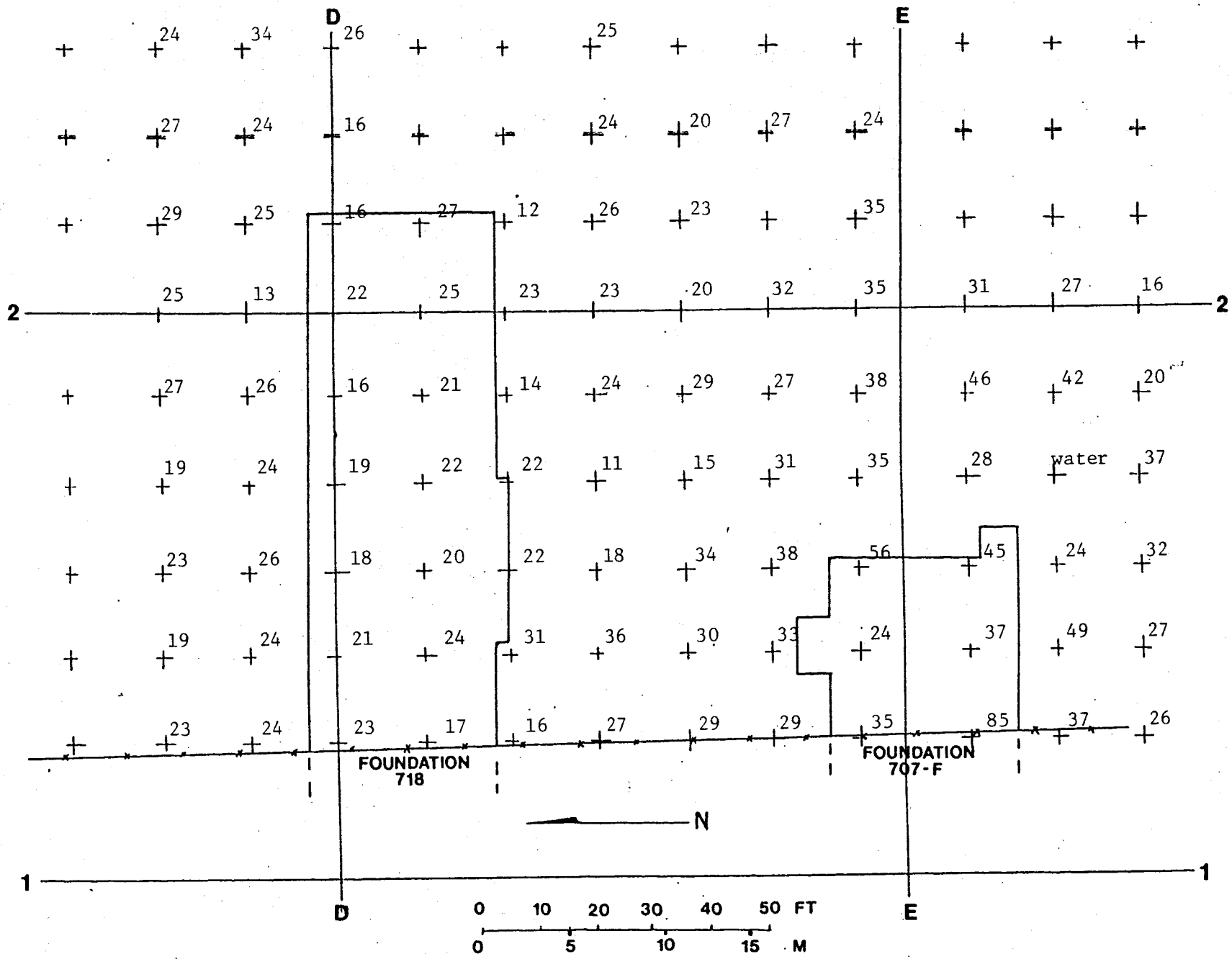

FIGURE 13. Surface Dose Rates (μrad/h), Measured in the Vicinity of Building Foundations 718 and 707-F.

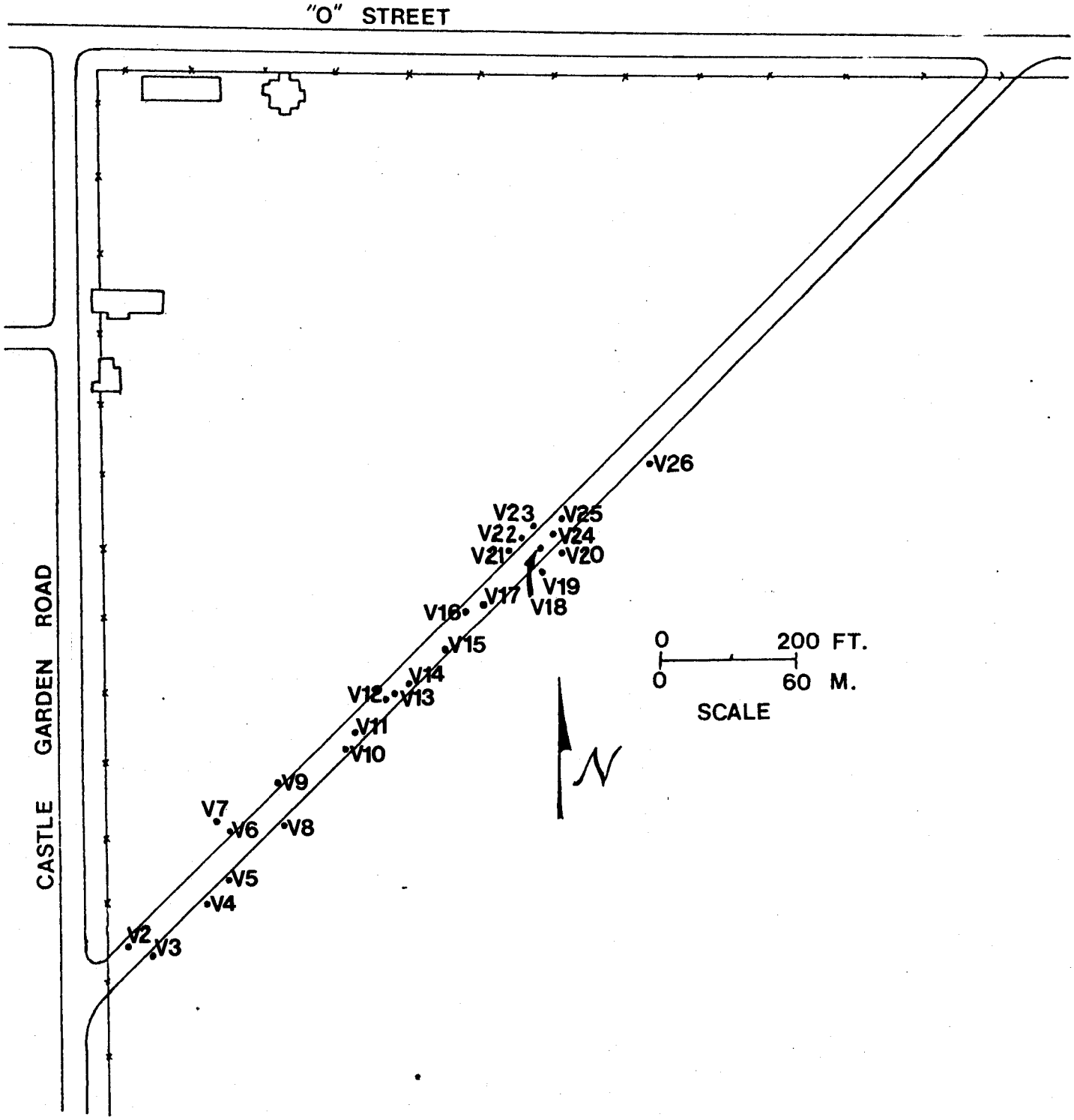

FIGURE 14. Locations of Elevated Surface Contact Radiation Levels Along Vine Street Measured After Remedial Action But Prior to Removal of Additional Soil.

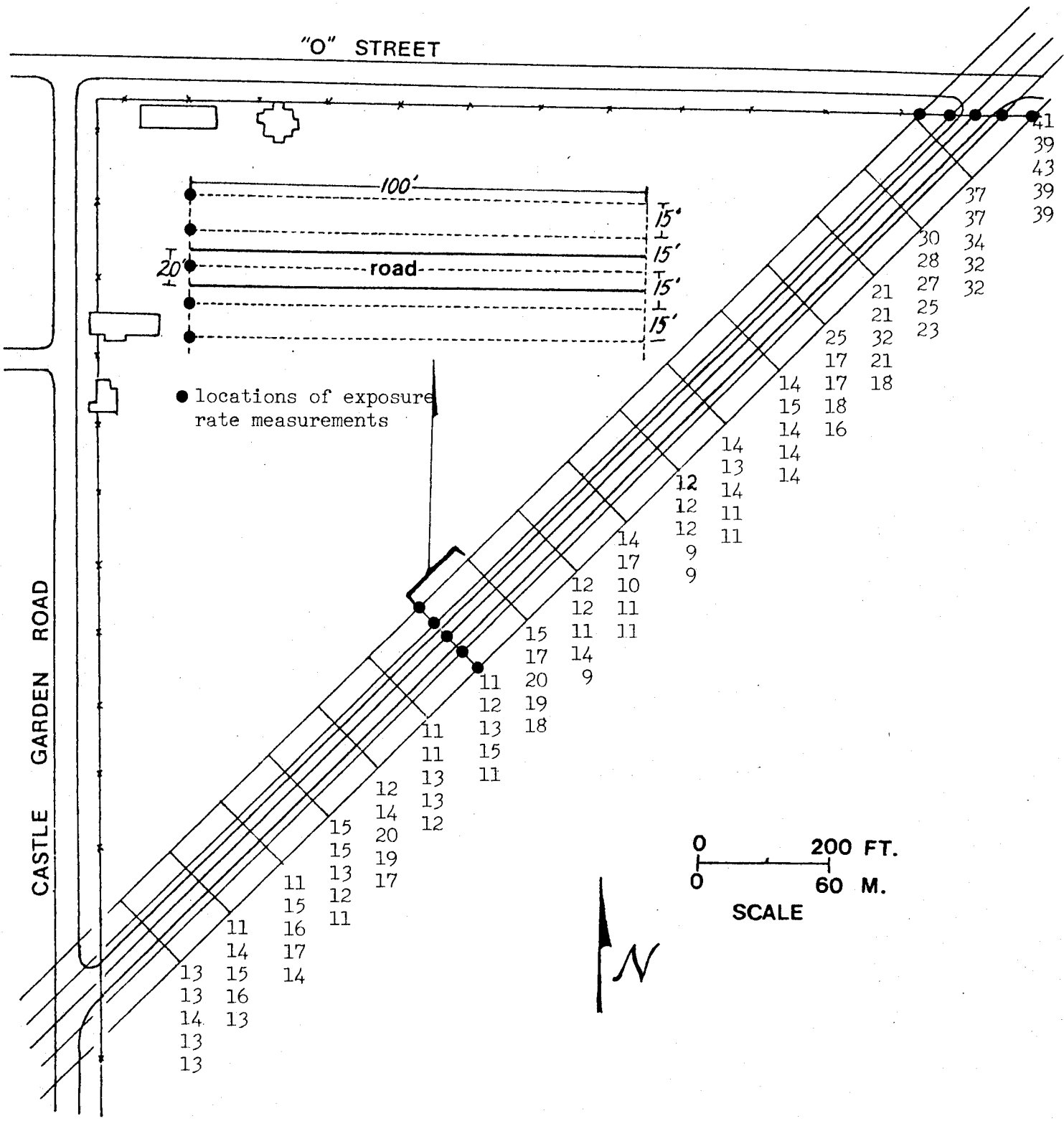

FIGURE 15. Exposure Rates (μR/h) at 1 Meter Above the Surface, Measured Along Vine Street.

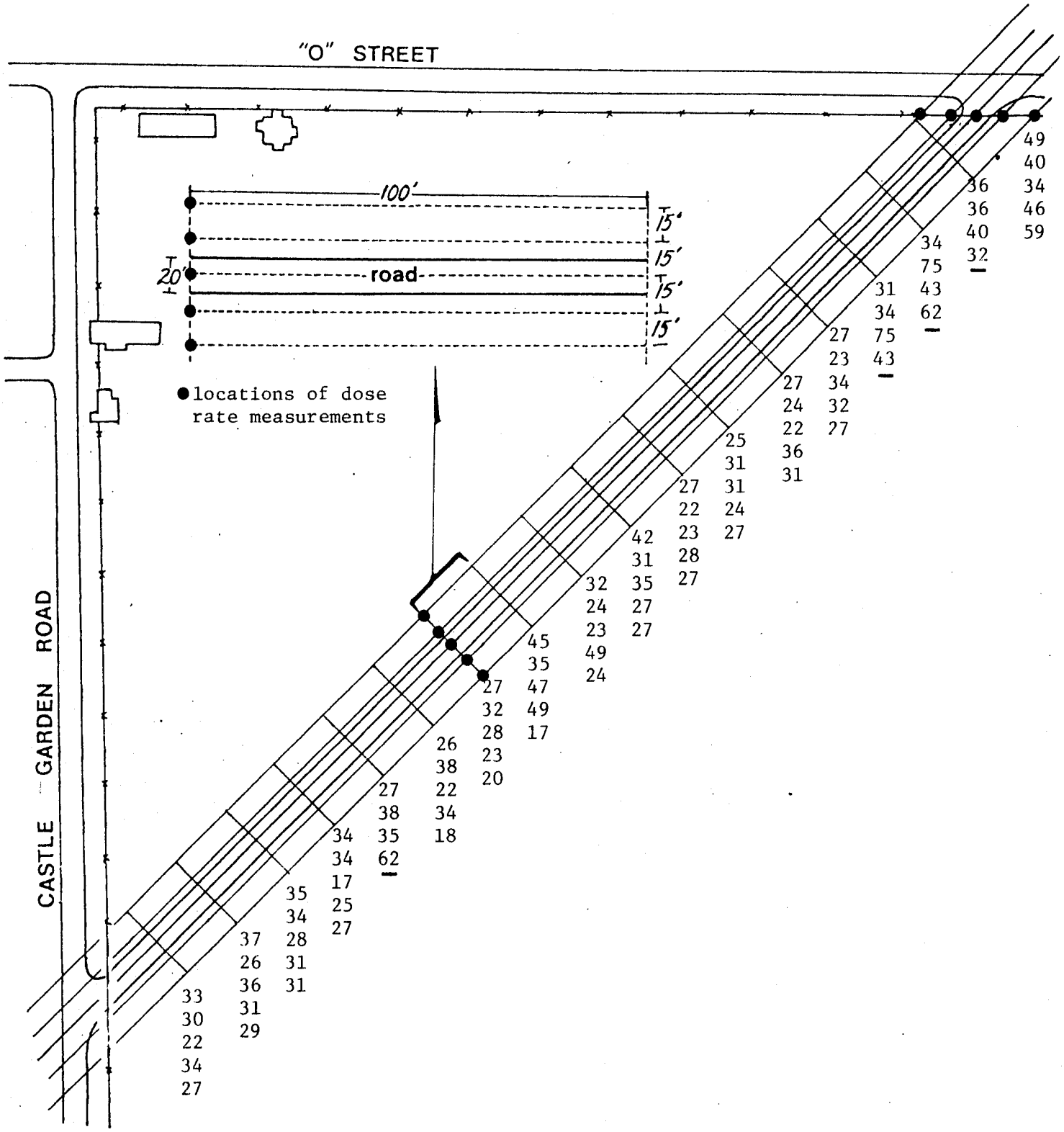

FIGURE 16. Surface Beta-Gamma Dose Rates (μrad/h) Measured Along Vine Street.

TABLE 1

CONCENTRATIONS OF RADIONUCLIDES IN SURFACE SOIL FROM AREAS OF MODERN LANDFILL PROPERTY UNDISTURBED BY REMEDIAL ACTION

Sample Number[a]	Concentration (pCi/g)					
	Ra-226	Cs-137	U-235	U-238	Th-232	K-40
1	0.93 ± 0.14[b]	0.38 ± 0.06	0.08 ± 0.06	<2.4	0.90 ± 0.24	14 ± 2
2	1.2 ± 0.2	0.57 ± 0.09	0.12 ± 0.07	5.8 ± 5.2	0.67 ± 0.24	15 ± 2
3	0.73 ± 0.13	0.18 ± 0.06	0.07 ± 0.06	<3.3	1.0 ± 0.2	15 ± 2
4	0.63 ± 0.15	0.17 ± 0.06	0.07 ± 0.06	<3.8	0.75 ± 0.25	17 ± 2
5	0.87 ± 0.14	0.32 ± 0.07	<0.03	<2.9	0.72 ± 0.22	17 ± 2
6	1.1 ± 0.2	0.71 ± 0.11	0.07 ± 0.07	<4.6	1.1 ± 0.3	16 ± 2
7	1.1 ± 0.2	0.66 ± 0.09	0.08 ± 0.07	8.2 ± 6.2	0.61 ± 0.26	15 ± 2
8	0.85 ± 0.12	0.53 ± 0.08	0.05 ± 0.05	3.5 ± 2.9	0.67 ± 0.18	10 ± 1
9	0.64 ± 0.16	0.75 ± 0.12	0.09 ± 0.08	<6.2	0.81 ± 0.38	14 ± 2
10	1.4 ± 0.2	0.87 ± 0.11	0.12 ± 0.07	<3.5	0.83 ± 0.25	15 ± 2
11	0.87 ± 0.17	0.92 ± 0.11	0.10 ± 0.08	<3.9	0.52 ± 0.27	10 ± 2
12	1.0 ± 0.2	0.97 ± 0.10	0.08 ± 0.07	<2.7	0.98 ± 0.23	15 ± 2
13	0.88 ± 0.16	0.89 ± 0.11	0.17 ± 0.08	4.0 ± 6.0	0.91 ± 0.28	14 ± 2
14	0.85 ± 0.15	0.52 ± 0.10	0.13 ± 0.07	2.6 ± 3.7	1.1 ± 0.3	13 ± 2
15	1.4 ± 0.2	0.69 ± 0.09	0.12 ± 0.08	<2.3	0.68 ± 0.25	14 ± 2
16	1.3 ± 0.2	1.2 ± 0.1	0.15 ± 0.08	7.2 ± 6.4	1.3 ± 0.3	17 ± 2
17	0.96 ± 0.15	0.48 ± 0.09	0.22 ± 0.08	8.6 ± 6.2	1.1 ± 0.3	12 ± 2

[a] Refer to Figure 6 for sample locations.
[b] Errors indicated are 2σ based on counting statistics only.

TABLE 2

LOCATIONS NEAR FOUNDATIONS 718 and 707-F, WHERE SURFACE CONTACT EXPOSURE RATES EXCEEDED 20 μR/h

Location[a]	Grid Point	Radiation levels measured following remedial action only (μR/h)	Radiation levels after additional soil removal (μR/h)
B1	D+91, 1+90	36	20
B2	D+43, 1+40	267	14
B3	D+32, 1+34	40	18
B4	D+85, 1+30	44	24
B5	E+20, 1+33	51	18
B6	E+21, 1+44	36	18
B7	E+33, 1+41	27	24
B8	E+28, 1+85	27	22
B9	E+10, 1+75	27	16
B10	E+7, 1+89	29	20

[a] Refer to Figure 11.

TABLE 3

CONCENTRATIONS OF RADIONUCLIDES IN
SYSTEMATIC SURFACE SOIL SAMPLES
FROM THE AREA OF
BUILDING FOUNDATIONS 707-F AND 718

Sample Number[a]	Grid Point	Concentration (pCi/g)					
		Ra-226	Cs-137	U-235	U-238	Th-232	K-40
26	C+77, 1+32	1.4 ± 0.2[b]	0.77 ± 0.08	0.06 ± 0.06	<2.5	0.57 ± 0.20	11 ± 1
27	C+77, 1+47	1.2 ± 0.2	0.84 ± 0.11	0.12 ± 0.07	4.9 ± 4.6	0.72 ± 0.26	13 ± 2
28	C+77, 1+62	1.1 ± 0.2	1.0 ± 0.1	0.07 0.06	3.6 ± 3.3	0.73 ± 0.25	13 ± 2
29	C+77, 1+77	0.82 ± 0.12	0.51 ± 0.08	0.10 ± 0.06	3.2 ± 3.7	0.69 ± 0.18	11 ± 1
30	C+77, 1+92	0.89 ± 0.14	0.89 ± 0.10	0.11 ± 0.07	<3.7	0.81 ± 0.25	13 ± 2
31	C+77, 2+08	0.86 ± 0.14	0.73 ± 0.08	0.10 ± 0.07	8.8 ± 4.3	0.49 ± 0.22	13 ± 1
32	C+77, 2+23	0.91 ± 0.15	0.70 ± 0.09	0.11 ± 0.07	<3.4	0.65 ± 0.23	13 ± 2
33	C+77, 2+38	0.94 ± 0.14	0.61 ± 0.09	0.04 ± 0.07	6.6 ± 5.9	0.79 ± 0.25	13 ± 2
34	C+92, 1+32	1.3 ± 0.2	2.3 ± 0.2	0.16 ± 0.09	4.3 ± 4.8	0.52 ± 0.25	11 ± 2
35	C+92, 1+47	1.3 ± 0.2	2.4 ± 0.2	0.16 ± 0.09	4.3 ± 4.8	0.43 ± 0.22	11 ± 2
36	C+92, 1+62	1.8 ± 0.3	2.1 ± 0.2	0.15 ± 0.10	5.7 ± 8.1	0.65 ± 0.25	11 ± 2
37	C+92, 1+77	1.6 ± 0.2	1.9 ± 0.1	0.20 ± 0.09	<3.2	0.60 ± 0.23	12 ± 2
38	C+92, 1+92	1.1 ± 0.1	0.05 ± 0.04	0.13 ± 0.05	6.1 ± 3.5	0.46 ± 0.19	9.1 ± 1.2
39	C+92, 2+08	3.1 ± 0.3	2.2 ± 0.2	0.27 ± 0.18	7.3 ± 7.4	0.45 ± 0.29	8.9 ± 1.8
40	C+92, 2+23	3.0 ± 0.3	2.0 ± 0.2	0.42 ± 0.11	<3.7	0.73 ± 0.27	7.3 ± 1.4
41	C+92, 2+38	1.1 ± 0.2	0.78 ± 0.10	0.11 ± 0.07	5.4 ± 5.0	0.92 ± 0.26	13 ± 2
42	D+08, 2+23	2.2 ± 0.3	2.7 ± 0.2	0.40 ± 0.16	5.8 ± 5.9	0.59 ± 0.25	6.7 ± 1.4
43	D+23, 2+23	1.6 ± 0.2	3.9 ± 0.2	0.06 ± 0.06	<2.5	0.95 ± 0.21	7.5 ± 1.0
44	D+38, 1+47	2.2 ± 6.2	2.0 ± 0.2	0.10 ± 0.16	<3.5	0.87 ± 0.25	11 ± 2
45	D+38, 1+62	0.60 ± 0.09	0.62 ± 0.07	0.07 ± 0.04	3.4 ± 3.5	0.32 ± 0.11	8.9 ± 1.0
46	D+38, 1+77	0.77 ± 0.14	0.78 ± 0.10	0.10 ± 0.07	<3.8	0.58 ± 0.22	12 ± 2
47	D+38, 1+92	0.75 ± 0.14	0.69 ± 0.09	0.11 ± 0.07	<3.8	0.67 ± 0.25	12 ± 2
48	D+38, 2+08	0.98 ± 0.12	0.56 ± 0.07	<0.03	<3.1	0.53 ± 0.19	9.7 ± 1.2
49	D+38, 2+23	1.4 ± 0.2	0.93 ± 0.10	0.13 ± 0.07	6.4 ± 6.4	0.54 ± 0.22	12 ± 1
50	D+38, 2+38	1.1 ± 0.2	0.96 ± 0.10	0.14 ± 0.07	6.6 ± 5.2	0.46 ± 0.22	11 ± 1
51	D+53, 1+32	3.6 ± 0.3	4.3 ± 0.2	0.18 ± 0.12	7.8 ± 7.7	1.2 ± 0.3	7.1 ± 1.3
52	D+53, 1+47	2.8 ± 0.2	2.0 ± 0.1	0.11 ± 0.09	<4.9	0.96 ± 0.26	11 ± 1
53	D+53, 1+62	0.99 ± 0.14	0.82 ± 0.09	0.09 ± 0.06	4.4 ± 4.4	0.37 ± 0.20	11 ± 1
54	D+53, 1+77	1.2 ± 0.2	0.76 ± 0.10	0.11 ± 0.07	<3.8	0.73 ± 0.26	9.3 ± 1.4
55	D+53, 1+92	1.2 ± 0.2	0.79 ± 0.10	0.08 ± 0.07	4.3 ± 5.2	0.84 ± 0.25	12 ± 2
56	D+53, 2+08	1.3 ± 0.2	0.90 ± 0.10	0.12 ± 0.08	<4.3	0.76 ± 0.23	12 ± 2
57	D+53, 2+23	1.3 ± 0.2	1.0 ± 0.1	0.11 ± 0.07	<3.5	0.64 ± 0.26	14 ± 2
58	D+53, 2+38	1.0 ± 0.1	0.49 ± 0.07	0.08 ± 0.05	2.6 ± 3.5	0.74 ± 0.19	12 ± 1
59	D+68, 1+32	4.8 ± 0.3	7.5 ± 0.3	0.56 ± 0.12	16 ± 8	1.1 ± 0.3	6.9 ± 1.4
60	D+68, 1+47	4.9 ± 0.3	7.9 ± 0.3	0.47 ± 0.12	8.9 ± 7.6	1.0 ± 0.3	9.3 ± 1.4
61	D+68, 1+62	1.4 ± 0.2	5.0 ± 0.2	1.2 ± 0.2	<3.8	0.82 ± 0.21	12 ± 2
62	D+68, 1+77	2.1 ± 0.2	1.2 ± 0.1	0.08 ± 0.08	6.7 ± 5.3	0.48 ± 0.23	8.5 ± 1.1
63	D+68, 1+92	1.5 ± 0.2	1.3 ± 0.1	0.15 ± 0.07	4.1 ± 6.1	0.57 ± 0.24	11 ± 1
64	D+68, 2+08	1.5 ± 0.2	0.76 ± 0.09	0.13 ± 0.07	<2.9	0.39 ± 0.20	9.1 ± 1.3

Table 3, continued

Sample Number	Grid Point	Concentration (pCi/g) Ra-226	Cs-137	U-235	U-238	Th-232	K-40
65	D+68, 2+23	0.86 ± 0.11	0.10 ± 0.05	0.09 ± 0.05	2.7 ± 3.8	0.74 ± 0.18	11 ± 1
66	D+68, 2+38	1.4 ± 0.14	0.29 ± 0.05	0.05 ± 0.05	4.2 ± 3.7	0.57 ± 0.17	9.9 ± 1.2
67	D+83, 1+32	1.1 ± 0.1	3.2 ± 0.2	0.26 ± 0.07	7.3 ± 4.7	0.94 ± 0.22	14 ± 2
68	D+83, 1+47	0.36 ± 0.08	0.90 ± 0.08	0.11 ± 0.04	4.0 ± 3.2	0.44 ± 0.15	7.0 ± 1.0
69	D+83, 1+62	1.2 ± 0.2	6.5 ± 0.2	0.25 ± 0.10	5.2 ± 5.5	0.62 ± 0.22	12 ± 1
70	D+83, 1+77	3.9 ± 0.2	2.4 ± 0.1	0.27 ± 0.09	<3.6	0.78 ± 0.25	9.4 ± 1.3
71	D+83, 1+92	2.5 ± 0.2	2.7 ± 0.2	0.20 ± 0.10	<3.3	0.66 ± 0.26	11 ± 2
72	D+83, 2+08	1.0 ± 0.2	1.1 ± 0.1	0.12 ± 0.08	8.6 ± 4.9	0.82 ± 0.26	9.8 ± 1.4
73	D+83, 2+23	3.9 ± 0.2	2.3 ± 0.1	0.27 ± 0.09	<3.6	0.78 ± 0.25	9.4 ± 1.3
74	D+83, 2+38	1.9 ± 0.2	0.91 ± 0.09	0.15 ± 0.07	<2.6	0.60 ± 0.23	11 ± 1
75	D+98, 1+32	0.42 ± 0.10	7.0 ± 0.2	0.10 ± 0.07	3.1 ± 3.1	0.49 ± 0.15	8.8 ± 1.1
76	D+98, 1+47	0.54 ± 0.10	1.6 ± 0.1	<0.02	3.4 ± 2.7	0.57 ± 0.14	7.6 ± 1.0
77	D+98, 1+62	0.81 ± 0.13	15 ± 3	0.18 ± 0.10	8.2 ± 5.0	0.57 ± 0.18	11 ± 1
78	D+98, 1+77	0.83 ± 0.12	0.71 ± 0.08	0.10 ± 0.06	2.3 ± 3.5	0.68 ± 0.19	10 ± 1
79	D+98, 1+92	1.2 ± 0.2	1.7 ± 0.1	0.16 ± 0.07	7.9 ± 5.4	0.78 ± 0.24	11 ± 1
80	E+15, 1+32	0.42 ± 0.09	3.1 ± 0.2	0.06 ± 0.05	<1.4	0.43 ± 0.16	7.8 ± 1.0
81	E+15, 1+47	0.43 ± 0.08	1.9 ± 0.1	0.04 ± 0.04	<1.9	0.39 ± 0.12	7.2 ± 1.0
82	E+15, 1+62	0.50 ± 0.15	14 ± 1	0.23 ± 0.09	8.9 ± 4.2	0.60 ± 0.17	12 ± 1
83	E+15, 1+77	0.81 ± 0.12	0.77 ± 0.09	0.17 ± 0.06	6.0 ± 4.2	0.51 ± 0.18	7.7 ± 1.2
84	E+15, 1+92	1.1 ± 0.1	0.92 ± 0.10	0.17 ± 0.08	4.1 ± 4.5	0.53 ± 0.20	9.1 ± 1.3
85	E+30, 1+32	1.0 ± 0.1	4.8 ± 0.2	0.18 ± 0.08	<1.9	0.48 ± 0.18	10 ± 1
86	E+30, 1+47	0.72 ± 0.12	3.8 ± 0.2	0.14 ± 0.06	3.5 ± 3.8	0.78 ± 0.18	12 ± 1
87	E+30, 1+62	0.58 ± 0.09	0.86 ± 08	0.05 ± 0.06	<1.9	0.57 ± 0.17	10 ± 1
88	E+30, 1+77	1.2 ± 0.1	0.86 ± 09	0.17 ± 0.07	1.9 ± 2.9	0.68 ± 0.20	12 ± 1
89	E+30, 1+92	1.9 ± 0.2	1.2 ± 0.1	0.13 ± 0.08	7.1 ± 6.2	0.74 ± 0.25	12 ± 2
90	E+45, 1+32	1.4 ± 0.2	2.6 ± 0.2	0.27 ± 0.08	<2.9	0.60 ± 0.24	12 ± 2
91	E+45, 1+47	1.3 ± 0.2	24 ± 1	0.95 ± 0.17	16 ± 7	0.66 ± 0.20	13 ± 1
92	E+45, 1+62	4.4 ± 0.2	0.15 ± 0.05	0.18 ± 0.08	6.7 ± 5.5	0.73 ± 0.23	2.5 ± 0.8
93	E+45, 1+77	1.8 ± 0.2	1.1 ± 0.1	0.19 ± 0.10	<4.9	0.76 ± 0.28	8.2 ± 1.3
94	E+45, 1+92	1.2 ± 0.2	0.88 ± 0.10	0.15 ± 0.07	3.5 ± 5.1	0.68 ± 0.24	9.9 ± 1.4
95	E+60, 1+32	0.94 ± 0.14	0.96 ± 0.10	0.10 ± 0.07	<3.9	0.86 ± 0.25	11 ± 2
96	E+60, 1+47	0.96 ± 0.15	1.1 ± 0.1	0.14 ± 0.08	6.6 ± 6.9	0.73 ± 0.24	9.2 ± 1.4

[a] Refer to Figure 7.
[b] Errors are 2σ based on counting statistics only.

TABLE 4

CONCENTRATIONS OF RADIONUCLIDES IN BIASED SOIL SAMPLES
COLLECTED FROM THE AREA OF BUILDING FOUNDATIONS 707-F AND 718

Sample Number[a]	Concentration (pCi/g)						
	Ra-226	Cs-137	U-235	U-238	Th-232	K-40	Sr-90
B1	1.9 ± 0.5[b]	220 ± 1	3.1 ± 0.6	24 ± 11	0.45 ± 0.29	4.9 ± 1.1	
B1*	2.6 ± 0.3	69 ± 0.8	0.67 ± 0.27	4.4 ± 6.4	0.46 ± 0.27	5.2 ± 1.0	12.8 ± 1.0
B2	12 ± 1	1025 ± 3	25 ± 1	22 ± 16	0.86 ± 0.60	5.8 ± 1.0	35.2 ± 1.4
B2*	1.4 ± 0.2	31 ± 0.5	0.32 ± .15	<4.9	0.33 ± 0.20	4.9 ± 0.9	
B3	2.8 ± 0.4	89 ± 0.9	0.78 ± 0.23	<6.7	0.60 ± 0.26	9.0 ± 1.5	51.0 ± 1.6
B3*	2.3 ± 0.3	40 ± 0.6	0.47 ± 0.19	11 ± 8	0.86 ± 0.27	11 ± 2	29.6 ± 1.2
B4	1.1 ± 0.2	20 ± 0.4	0.48 ± 0.15	8.0 ± 6.5	0.83 ± 0.32	9.3 ± 1.3	
B4*	1.3 ± 0.3	57 ± 0.8	1.2 ± 0.3	30 ± 10	1.5 ± 0.3	14 ± 2	111 ± 3
B5	1.2 ± 0.3	65 ± 0.7	0.70 ± 0.25	8.1 ± 7.8	1.5 ± 0.3	11 ± 1	65.4 ± 2.4
B5*	1.4 ± 0.2	25 ± 0.5	0.39 ± 0.17	8.8 ± 6.3	0.63 ± 0.26	13 ± 2	
B6	1.7 ± 0.3	72 ± 0.8	1.7 ± 0.2	49 ± 10	0.87 ± 0.23	11 ± 1	
B6*	2.0 ± 0.3	65 ± 0.7	1.5 ± 0.2	29 ± 7	0.67 ± 0.21	11 ± 1	
B7	0.78 ± 0.14	16 ± 0.3	0.50 ± 0.12	15 ± 5	0.71 ± 0.22	14 ± 1	
B7*	0.87 ± 0.17	20 ± 0.4	0.39 ± 0.12	10 ± 6	0.68 ± 0.19	13 ± 1	
B8	0.68 ± 0.22	64 ± 0.6	0.20 ± 0.16	7.4 ± 4.0	0.44 ± 0.14	8.8 ± 1.1	
B8*	0.59 ± 0.11	2.5 ± 0.1	0.19 ± 0.06	5.2 ± 4.5	0.71 ± 0.18	10 ± 1	
B9*	1.0 ± 0.2	14 ± 0.3	0.22 ± 0.09	<3.0	0.67 ± 0.20	13 ± 1	
B10	1.1 ± 0.2	30 ± 0.5	0.64 ± 0.12	15 ± 6	0.62 ± 0.18	9.9 ± 1.2	
B10*	0.4 ± 0.1	11 ± 0.3	0.15 ± 0.08	<2.2	0.41 ± 0.13	6.3 ± 0.9	
B11[c]	0.74 ± 0.09	4.1 ± 0.1	0.18 ± 0.05	<1.6	0.31 ± 0.11	5.7 ± 0.7	

[a] Samples without * were collected after remedial action but prior to additional soil removal. Samples with * were collected after the property owner removed additional soil in these areas.
[b] Errors indicated are 2 σ based on counting statistics only.
[c] Sample of sediment from pit below building foundation 718.

TABLE 5

LOCATIONS ALONG VINE STREET
INDICATING SURFACE CONTACT
EXPOSURE RATES EXCEEDING 20 μR/h

Location[a]	Grid Point	Radiation levels measured following remedial action only (μR/h)	Radiation levels after additional soil removal (μR/h)
V2	L+85, 1+70	44	13
V3	L+85, 1+95	51	16
V4	L, 2+70	76	18
V5	K+70, 3+00	71	27
V6	K+50, 3+00	140	16
V7	K+45, 2+90	89	11
V8	K+10, 3+60	36	22
V9	J+70, 3+80	178	27
V10	I+85, 4+90	67	16
V11	I+70, 4+95	44	22
V12	I+20, 5+45	56	22
V13	I+20, 5+50	56	22
V14	I+15, 5+60	71	22
V15	H+70, 6+05	44	22
V16	H+8, 6+50	93	27
V17	H+5, 6+55	111	18
V18	G+35, 7+45	40	22
V19	G+50, 7+50	51	16
V20	G+30, 7+65	71	18
V21	G+45, 7+10	38	20
V22	G+35, 7+20	44	33
V23	G+20, 7+25	56	29
V24	G+10, 7+60	44	20
V25	F+95, 7+65	78	18
V26	F+15, 8+95	51	11

[a] Refer to Figure 14.

TABLE 6

CONCENTRATIONS OF RADIONUCLIDES IN SYSTEMATIC SURFACE SOIL SAMPLES COLLECTED FROM THE REMEDIAL ACTION AREA OF VINE STREET

Sample Number [a]	Grid Point	Concentration (pCi/g)					
		Ra-226	Cs-137	U-235	U-238	Th-232	K-40
102	L+60, 2+20	8.0 ± 0.3[b]	0.50 ± 0.08	0.63 ± 0.11	8.3 ± 7.6	0.95 ± 0.25	8.5 ± 1.2
103	L+25, 1+90	1.4 ± 0.2	1.2 ± 0.1	0.06 ± 0.10	6.1 ± 6.6	0.76 ± 0.32	15 ± 2
104	K+65, 2+70	1.2 ± 0.1	0.22 ± 0.06	0.12 ± 0.06	<3.8	0.63 ± 0.19	11 ± 1
105	L+00, 3+00	1.6 ± 0.2	0.52 ± 0.08	0.19 ± 0.07	6.5 ± 5.8	0.80 ± 0.26	12 ± 2
106	J+85, 3+30	2.6 ± 0.2	0.23 ± 0.07	0.12 ± 0.08	<3.6	1.2 ± 0.3	17 ± 2
107	K+20, 3+60	3.4 ± 0.2	0.50 ± 0.09	0.22 ± 0.08	<2.4	0.58 ± 0.23	12 ± 2
108	J+30, 4+15	2.4 ± 0.2	0.46 ± 0.08	0.27 ± 0.09	10 ± 8	1.1 ± 0.3	18 ± 2
109	J+60, 4+45	1.4 ± 0.2	0.41 ± 0.07	0.26 ± 0.12	2.6 ± 4.1	0.98 ± 1.23	14 ± 2
110	I+45, 4+70	3.3 ± 0.3	0.45 ± 0.08	0.31 ± 0.10	<4.0	0.92 ± 0.24	14 ± 2
111	I+80, 5+05	0.69 ± 0.10	0.04 ± 0.04	0.06 ± 0.05	5.8 ± 4.8	0.56 ± 0.20	13 ± 1
112	H+85, 5+55	1.1 ± 0.1	0.46 ± 0.08	0.15 ± 0.06	<2.7	0.61 ± 0.21	10 ± 1
113	I+15, 5+90	23 ± 0.1	0.60 ± 0.11	1.4 ± 0.2	<6.7	0.62 ± 0.38	14 ± 2
114	H+ 5, 6+15	1.1 ± 0.1	0.52 ± 0.09	0.15 ± 0.07	3.0 ± 4.5	0.70 ± 0.22	12 ± 2
115	H+40, 6+50	3.5 ± 0.2	0.21 ± 0.06	0.30 ± 0.09	2.7 ± 4.1	0.56 ± 0.19	12 ± 1
116	G+50, 7+00	1.9 ± 0.2	0.14 ± 0.05	0.19 ± 0.07	<2.7	0.95 ± 0.24	12 ± 1
117	G+80, 7+30	1.2 ± 0.1	0.60 ± 0.08	0.08 ± 0.06	<2.1	0.78 ± 0.20	11 ± 1
118	F+70, 7+60	1.8 ± 0.2	0.44 ± 0.08	0.11 ± 0.08	<4.6	1.2 ± 0.3	13 ± 2
119	G , 7+90	5.7 ± 0.3	0.33 ± 0.07	0.20 ± 0.11	5.3 ± 7.9	<0.22	9.4 ± 1.3
120	F+ 5, 8+40	0.88 ± 0.13	0.09 ± 0.06	0.05 ± 0.07	<4.2	0.37 ± 0.22	8.9 ± 1.3
121	F+40, 8+75	1.1 ± 0.2	0.71 ± 0.10	0.08 ± 0.07	3.6 ± 4.7	1.1 ± 0.3	11 ± 2
122	E+25, 9+05	0.88 ± 0.15	0.70 ± 0.10	0.10 ± 0.08	2.9 ± 4.0	0.67 ± 0.25	12 ± 2
123	E+55, 9+35	0.97 ± 0.14	0.59 ± 0.09	0.07 ± 0.06	<3.0	0.80 ± 0.23	11 ± 2
124	D+70, 9+85	0.73 ± 0.13	0.31 ± 0.06	0.12 ± 0.05	<3.0	0.95 ± 0.22	11 ± 2
125	E+ 5, 10+15	0.85 ± 0.13	0.67 ± 0.09	0.18 ± 0.07	4.0 ± 4.7	0.77 ± 0.24	13 ± 2
126	C+90, 10+50	0.59 ± 0.13	0.54 ± 0.09	0.08 ± 0.06	3.5 ± 5.0	0.62 ± 0.26	12 ± 2
127	D+20, 10+80	0.77 ± 0.12	0.47 ± 0.07	0.10 ± 0.06	<2.0	0.61 ± 0.20	11 ± 1
128	C+25, 11+30	0.83 ± 0.12	0.54 ± 0.08	0.08 ± 0.06	<2.8	0.44 ± 0.21	11 ± 2
129	C+60, 11+60	0.81 ± 0.13	0.48 ± 0.08	0.05 ± 0.06	4.2 ± 4.6	0.59 ± 0.23	10 ± 2
130	B+45, 11+90	0.77 ± 0.15	0.81 ± 0.10	0.10 ± 0.08	<4.5	0.63 ± 0.28	12 ± 2
131	B+80, 12+25	0.76 ± 0.12	0.50 ± 0.07	0.07 ± 0.05	3.8 ± 4.3	0.86 ± 0.21	11 ± 1
132	A+85, 12+70	0.64 ± 0.12	0.35 ± 0.07	0.08 ± 0.06	<2.8	0.52 ± 0.18	11 ± 2
133	B+20, 13+00	1.4 ± 0.2	0.50 ± 0.08	0.10 ± 0.06	<3.1	0.72 ± 0.22	11 ± 1
134	A+10, 13+30	0.94 ± 0.15	0.26 ± 0.07	0.06 ± 0.06	4.2 ± 5.1	0.78 ± 0.25	14 ± 2
135	A+40, 13+65	0.81 ± 0.12	0.42 ± 0.07	0.09 ± 0.05	<2.4	0.58 ± 0.19	11 ± 1
136	A-10, 13+65	0.73 ± 0.11	0.10 ± 0.04	0.08 ± 0.05	3.8 ± 3.8	0.86 ± 0.20	13 ± 2
137	A-10, 14+30	1.1 ± 0.2	0.48 ± 0.07	0.09 ± 0.07	8.0 ± 4.2	0.70 ± 0.23	11 ± 1
138	L+70, 1+65	3.5 ± 0.3	0.37 ± 0.09	0.11 ± 0.10	3.4 ± 7.4	0.50 ± 0.30	13 ± 2
139	M , 1+85	1.5 ± 0.1	0.04 ± 0.04	0.15 ± 0.06	3.9 ± 4.3	0.79 ± 0.18	15 ± 1

Table 6, continued

Sample Number	Grid Point	Concentration (pCi/g)					
		Ra-226	Ca-137	U-235	U-238	Th-232	K-40
140	L , 2+35	3.8 ± 0.3	0.73 ± 0.11	0.26 ± 0.11	5.6 ± 8.9	0.59 ± 0.29	10 ± 1
141	L+25, 2+55	2.0 ± 0.2	0.12 ± 0.06	0.14 ± 0.08	<4.9	0.84 ± 0.28	16 ± 2
142	K+30, 3+10	3.6 ± 0.2	0.75 ± 0.10	0.13 ± 0.10	12 ± 8	0.78 ± 0.27	14 ± 2
143	K+55, 3+30	0.23 ± 0.06	0.05 ± 0.02	0.04 ± 0.03	<1.9	0.07 ± 0.09	1.9 ± 0.6
144	J+60, 3+80	7.3 ± 0.3	0.53 ± 0.10	0.27 ± 0.13	3.1 ± 8.8	0.60 ± 0.32	13 ± 2
145	J+85, 4+00	1.2 ± 0.1	0.06 ± 0.03	0.08 ± 0.05	<2.7	0.66 ± 0.18	13 ± 1
146	I+95, 4+50	1.8 ± 0.2	0.51 ± 0.08	0.14 ± 0.07	4.6 ± 5.5	0.77 ± 0.22	13 ± 2
147	J+20, 4+70	2.9 ± 0.2	0.63 ± 0.08	0.12 ± 0.09	5.9 ± 6.5	1.0 ± 0.3	11 ± 2
148	F , 9+00	2.3 ± 0.2	0.74 ± 0.09	0.25 ± 0.08	<3.3	0.80 ± 0.23	11 ± 1
149	E+75, 8+80	0.94 ± 0.12	0.42 ± 0.07	0.12 ± 0.05	<3.4	1.0 ± 0.2	12 ± 1
150	F+30, 8+65	1.9 ± 0.2	0.85 ± 0.09	0.25 ± 0.07	<3.2	0.56 ± 0.21	9.1 ± 1.2
151	F+70, 8+25	1.3 ± 0.2	0.52 ± 0.07	0.17 ± 0.06	5.5 ± 5.2	0.66 ± 0.18	11 ± 1
152	F+45, 8+05	1.1 ± 0.1	0.28 ± 0.06	0.11 ± 0.05	4.0 ± 3.7	0.60 ± 0.17	9.0 ± 1.1
153	F+75, 7+70	2.0 ± 0.2	0.47 ± 0.06	0.18 ± 0.06	5.3 ± 4.2	0.68 ± 0.17	10 ± 1
154	G+10, 7+35	3.3 ± 0.2	0.03 ± 0.04	0.27 ± 0.08	4.8 ± 4.8	0.73 ± 0.21	11 ± 1
155	G+35, 7+55	6.9 ± 0.3	0.41 ± 0.08	0.71 ± 0.12	<3.2	1.0 ± 0.3	11 ± 1
156	G+70, 7+20	1.5 ± 0.1	0.07 ± 0.04	0.13 ± 0.06	5.7 ± 4.3	0.72 ± 0.18	12 ± 1
157	H+ 5, 6+80	1.2 ± 0.1	0.02 ± 0.03	0.15 ± 0.05	4.0 ± 4.2	0.84 ± 0.20	12 ± 1
158	G+80, 6+65	2.1 ± 0.2	0.66 ± 0.07	0.18 ± 0.07	<3.8	0.73 ± 0.21	13 ± 1
159	H+15, 6+25	1.4 ± 0.2	0.57 ± 0.08	0.12 ± 0.06	3.1 ± 3.6	0.81 ± 0.21	12 ± 1
160	H+80, 6+15	1.8 ± 0.1	0.33 ± 0.06	0.14 ± 0.06	<3.1	0.51 ± 0.17	12 ± 1
161	I+10, 5+75	8.1 ± 0.3	0.33 ± 0.08	0.66 ± 0.12	<3.7	0.77 ± 0.25	14 ± 2
162	H+50, 5+95	0.53 ± 0.09	0.08 ± 0.04	0.07 ± 0.04	6.0 ± 4.1	0.59 ± 0.18	11 ± 1
163	J+50, 4+35	1.2 ± 0.1	0.40 ± 0.07	0.23 ± 0.07	3.9 ± 4.9	0.82 ± 0.22	15 ± 2
164	I+50, 5+35	2.0 ± 0.2	0.26 ± 0.06	0.63 ± 0.06	<3.1	0.62 ± 0.22	18 ± 2
165	L+35, 1+95	0.85 ± 0.11	0.51 ± 0.06	0.07 ± 0.05	<2.9	0.64 ± 0.17	13 ± 1
166	I+20, 5+20	1.4 ± 0.1	0.43 ± 0.06	0.21 ± 0.06	<3.1	0.53 ± 0.18	8.7 ± 1.1
167	J+95, 3+40	4.7 ± 0.2	0.38 ± 0.06	0.32 ± 0.09	5.2 ± 5.0	0.53 ± 0.20	13 ± 1
168	I+55, 4+85	1.7 ± 0.1	0.36 ± 0.05	0.09 ± 0.06	3.7 ± 4.2	0.60 ± 0.17	13 ± 1
170	K+90, 2+90	3.7 ± 0.2	0.35 ± 0.07	0.30 ± 0.08	5.1 ± 4.5	0.78 ± 0.23	12 ± 1

[a] Errors indicated are 2σ based on counting statistics only.

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APPENDIX A

INSTRUMENTATION AND ANALYTICAL PROCEDURES

APPENDIX A

Instrumentation and Analytical Procedures

Gamma Scintillation Measurements

Walkover surface scans and measurements of gamma exposure rates were performed using a Victoreen Thyac III Model 490 portable ratemeter with a Victoreen Model 489-5 gamma scintillation probe containing a 3.2 cm x 3.8 cm NaI(Tl) scintillation crystal. Count rates (cpm) were converted to exposure levels (μR/h) using a factor of 440 cpm = 1 μR/h. This factor was determined by comparing the response of the scintillation detector to gamma photons from radium-226 with that of a Reuter Stokes model RSS-111 pressurized ionization chamber.

Beta-Gamma Dose Rate Measurements

Measurements were performed using Eberline "Rascal," Model PRS-1, portable ratemeters with Model HP-260 thin-window, pancake G-M, beta probes. Dose rates (mrad/hr) were determined by comparison of the response of a Victoreen Model 440 ionization chamber survey meter to that of the G-M probes for a composite of soil samples from the site, which were high in radium-226 content. The conversion factor determined was 2.4 cpm = 1 μrad/h.

Soil Sample Analysis

Gamma Spectrometry

Soil samples were dried at 120°C, finely ground, mixed, and a portion placed in a one-liter Marinelli beaker. The quantity placed in each beaker was chosen to reproduce the calibrated counting geometry and ranged from 400 to 600 grams of soil. The beakers were capped but not sealed. Net soil weights were determined and the samples counted using a 23% Ge(Li) detector (Princeton Gamma Tech)

coupled to a Nuclear Data model ND66 pulse height analyzer. The following energy peaks were used for determination of the radionuclides of concern:

Ra-226 - 0.609 MeV from Bi-214 (see discussion below)
Cs-137 - 0.662 MeV
U-235 - 0.185 MeV
U-238 - 1.001 MeV from Pa-234 (secular equilibrium assumed)
Th-232 - 0.907 MeV from Ac-228 (secular equilibrium assumed)
K-40 - 1.46 MeV

The background plus Compton continuum was stripped from each of the photopeaks of interest, prior to applying appropriate calibration and correction factors.

To evaluate the effect of possible radon losses on the equilibrium of Bi-214 with Ra-226, several soil samples were sealed in counting beakers. The relative photopeak intensities of various Ra-226 decay products were noted and compared to the relative intensities of capped, but unsealed, samples over a time period necessary for the Bi-214 peak intensity to stablize. From this comparison it was determined that radon losses resulted in a 20% decrease in the Bi-214 concentration and that this condition reached an equilibrium state in the unsealed sample within approximately three days after sample preparation (drying, grinding, and placing into the beakers). Sufficient time to reach this equilibrium state was therefore allowed between sample preparation and analysis, and a correction for the 20% decrease due to radon loss was applied to all Ra-226 calculations based on the Bi-214 photopeak intensity.

For U-235 analysis, contributions in the 0.185 MeV photopeak area from the 0.186 MeV Ra-226 gamma ray were subtracted. The ratio of the 0.186 MeV to 0.609 MeV peak intensities in a soil sample containing Ra-226, but no U-235, was determined and this ratio was multiplied by the intensity of the 0.609 MeV photopeak in each of the samples to determine the magnitude of this contribution.

Strontium-90

1. Weigh a 5 g aliquot of dried soil.
2. Pipet 1 ml strontium carrier (20 mg/ml) and 1 ml barium carrier (10 mg/ml) into the soil.
3. Add 1 ml of 2M calcium nitrate solution.
4. Add 12.5 g of sodium hydroxide pellets.
5. Fuse over a burner for 30 minutes and then slowly stir in 2.5 g of anhydrous sodium carbonate and heat the clear red melt for 30 minutes. Sometimes it is necessary to add extra sodium hydroxide to special samples. (Note: A crucible cover is used during the fusing procedure to prevent loss of sample, should it spatter.)
6. Remove the crucible from the flame to a cold water bath to crack the mixture. Let stand in cold water approximately 20 minutes
7. Crack the mixture, put the mixture in a one-liter beaker and add 250 ml of boiling distilled water to crucible to remove any remaining melt. Transfer solution from crucible to the one-liter beaker. Place the beaker on a hot plate and set on the medium setting. Boil to disintegrate the fused mixture. Add boiling distilled water to keep the volume between 200-250 mls of solution.
8. Cool in a water bath and then transfer the mixture to a 250-ml centrifuge bottle with distilled water.
9. Centrifuge for 5 minutes and discard the supernate. Wash the precipitate twice with 200-ml portions of hot distilled water.
10. Heat the precipitate on a hot plate until the precipitate begins to bump or bubble. Add 20 ml of 6N hydrochloric acid to dissolve the precipitate. Add 100 ml of hot distilled water to the dissolved sample and filter through an E&D No. 513 or equivalent 32-cm filter into a 500-ml Erlenmeyer flask. Wash with 2 100-ml portions of hot distilled water. Discard the residue.
11. Add dissolved sample and filtrate to 500 ml, 6-percent EDTA solution. In a two-liter glass beaker, adjust the solution to pH 4.2 or until the solution is clear with 15N ammonium hydroxide, then back to 3.8 with concentrated hydrochloric acid.

NOTE: pH 3.8 is very important. If pH is less than 3.8, EDTA may precipitate.

12. Stir the solution vigorously for at least 30 minutes to precipitate the magnesium salt of EDTA. Allow the precipitate to settle overnight.
13. Filter and adjust the filtrate to pH 5.8 with approximately 3 ml 15N ammonium hydroxide. Add 20 ml buffer solution (pH 4.6) and adjust pH to 4.6 with 6N hydrochloric acid or dilute ammonium hydroxide then dilute to 1 liter. (Note: Use E&D No. 513, 32 cm folded paper or equivalent to filter the magnesium salt.)
14. Let the solution flow through the resin column at 20 ml per minute. Stop the flow when just enough solution remains to cover the resin.
15. Combine 200 ml 6 percent EDTA and 400 ml water; adjust to pH 5.1 with 6N ammonium hydroxide, place in reservoir, and let flow at 20 ml per minute.
16. Record time at end of elution as beginning of yttrium-90 ingrowth.
17. Wash the column with 200 ml water at a flowrate of 20 ml per minute. Discard all the effluents.
18. Place 460 ml 1.5N hydrochloric acid in reservoir, and elute at a flowrate of 10 ml per minute.
19. Discard first 60 ml of effluent. Collect the next 400 ml, which contains the strontium fraction.
20. Regenerate resin with 600 ml 4M sodium chloride at a flowrate of 10 ml per minute and collect the effluent. This contains the barium fraction.
21. Wash the column with 200 ml distilled water.
22. To the strontium fraction, add 210 ml concentrated ammonium hydroxide and stir with a magnetic stirrer.
23. Slowly add 10 ml 3N sodium carbonate solution and stir for 30 minutes.
24. Collect the strontium on tared membrane filter. Wash 3 times, once with 10-ml portions of each: deionized water, 95 percent alcohol, and diethyl ether.

25. Weigh, and count radiostrontium in a Tennelec model LB5100 low-background beta counter, after a suitable delay to allow for radon decay.

26. If the first count is not obtained within thirteen hours (i.e., counter jams, power failure, etc.), the sample must be reanalyzed. If the total amount of the sample is very limited or a time factor is involved, repeat the reprecipitation procedure as follows.

    a. Add filter paper and precipitate to a 40 ml centrifuge tube.
    b. Add 5 ml concentrated nitric acid to redissolve sample. Digest for 10 minutes.
    c. Remove filter paper from centrifuge tube. Rinse filter with concentrated nitric acid from dropping bottle.
    d. Add 20 ml of fuming nitric acid.
    e. Cool in ice bath for 30 minutes.
    f. Centrifuge and pour off liquid (fuming nitric acid). Record time (separation time).
    g. Add approximately 5 ml of water to redissolve the sample.
    h. Add 5 ml concentrated ammonium hydroxide. While stirring add 4 ml 3N of sodium carbonate. Stir for 10 minutes.
    i. Filter on a tared filter. Wash three times, once with a 10 ml portion of each: deionized water and ethyl alcohol.
    j. Weigh as strontium carbonate and count for Sr-89 and Sr-90.

27. Calculation of Results

Strontium-89,90 results are obtained using the following equations.

Strontium-90 Calculations:

$$\text{pCi Sr-90/unit} = \frac{[A][B] - [C][D]}{[1+(E)(F)](A) - [1+(E)(G)](C)} \times \frac{1}{(2.22)(H)(I)(J)}$$

A = Decay of Sr-89 from the time of collection to the time of the first count is figured to the nearest one-half day.

B = Net counts per minute of total strontium on second count is figured to the nearest tenth.

C = Decay of Sr-89 from the time of collection to the time of the second count is figured to the nearest one-half day.

D = Net counts per minute of total strontium on first count is figured to the nearest tenth.

E = Ratio of the Y-90/Sr-90 counting efficiencies (including self-absorption corrections).

F = Y-90 ingrowth from the time of separation to the time of second count is figured to the nearest hour.

G = Ingrowth of Y-90 from time of separation to time of first count is figured to the nearest one-half hour.

H = Counting efficiency of Sr-90 (including self-absorption correction).

I = Chemical yield of strontium.

J = Sample volume in liters of sample weight in grams.

A, C, F, G were once found by tables but are now found by the TI59 program since all functions of $e - \lambda t$ where λ is the decay constant of the nuclide and t is elapsed time.

E, H, are efficiencies corrected for self-absorption that have been determined by calibration.

Strontium-89 Calculations:

$$\text{pCi Sr-89/unit} = \frac{A - \{1+(B)(C)\}D}{E} \times \frac{1}{(F)(G)(H)2.22}$$

A = net cpm total strontium on first count.

B = Y-90 ingrowth from time of separation to the time of first count.

C = Ratio of Y-90/Sr-90 counting efficiencies (including self-absorption corrections).

D = Net cpm of Sr-90

E = Decay of Sr-89 from time of collection to the time of first count.

F = Chemical yield of strontium.

G = Counting efficiency of Sr-90 including self-absorption corrections.

H = Sample volume in liters or sample weight in grams.

C and G are efficiencies corrected for self-absorption that have been determined by calibration.

Calibration and Quality Assurance

With the exception of the exposure and dose-rate conversion factors for portable gamma and beta-gamma survey meters; instruments were calibrated with NBS-traceable standards. The calibration procedures for these portable instruments are described above.

Quality control procedures on all instruments included daily background and check-source measurements to confirm lack of malfunctions and nonstatistical deviations in equipment. The ORAU laboratory participates in the EPA Quality Assurance Program.

APPENDIX B

GUIDELINES FOR CLEANUP OF FORMERLY UTILIZED SITES

APPENDIX B

Guidelines for Cleanup of Formerly Utilized Sites

The soil cleanup criteria for the Modern Landfill property and other FUSRAP sites are based primarily upon Ra-226 activity in the soil. The criterion for Ra-226 in soil is:

> The average soil concentration of Ra-226 attributable to residual radioactive materials from MED/AEC activities shall not exceed 5 pCi/g after cleanup where:
>
> (a) The concentration is averaged through a 15 cm layer at any suspect depth (with removal of overlying contaminated material and bore-hole logging data verifying absence of buried contamination -- sampling shall apply only to the exposed 15 cm layer);
>
> (b) the concentration is specified per gram of soil on dry weight (not in situ weight) basis; and
>
> (c) the concentration is averaged over any contiguous 100 square meters as determined from a composite of four samples, each taken at the approximate center of each 25 square meters of said 100 square meters.

In addition to Ra-226, limits of 80 pCi/g of Cs-137 and 100 pCi/g of Sr-90 have also been applied to sites where fission product wastes are present.

APPENDIX C

EVALUATION OF RADIATION EXPOSURES ON PORTIONS OF THE MODERN LANDFILL, INC. PROPERTY LEWISTON, NEW YORK

APPENDIX C

Evaluation of Radiation Exposures on Portions of the Modern Landfill, Inc. Property Lewiston, New York

INTRODUCTION

The U. S. Department of Energy has completed a radiological survey and determined that portions of the Modern Landfill, Inc. property, Lewiston, New York, are presently contaminated with low-level radioactive residues resulting from previous uses of this property. This property is part of the Former Lake Ontario Ordnance Works (LOOW) site where radioactive wastes from Manhattan Engineer District and Atomic Energy Commission operations were handled and stored. These wastes were primarily residues from uranium processing operations; however they also included contaminated rubble and scrap from decommissioned facilities, biological and miscellaneous wastes from the University of Rochester, and low-level fission product waste from contaminated-liquid evaporators at the Knolls Atomic Power Laboratory (KAPL) in Schenectady, New York. Receipt of additional wastes was discontinued at the LOOW site in 1954. Although some storage of radioactive materials on a portion of the site continues under the control of the Department of Energy, work involving handling of radioactive waste has not been performed at LOOW for approximately 25 years.

In 1954 a preliminary cleanup of the LOOW site was performed by Hooker Chemical Company. Approximately 1298 acres of the original 1511 acre site were then declared excess and eventually sold by the General Services Administration to various private, commercial, and governmental agencies. Modern Landfill, Inc. is the current owner of a 199 acre tract from the former LOOW property and proposes to

operate a sanitary landfill on that site. A triangular shaped section of that tract, 16 acres in area, was thoroughly surveyed in January 1981, and found to contain radioactive contamination. Remedial action to remove radioactive residues which were identified by this survey was performed by the property owner in June 1981. Following this cleanup activity, a final survey was conducted by Oak Ridge Associated Universities, Oak Ridge, Tennessee. The findings of that survey indicate that small quantities of cesium-137, strontium-90, and radionuclides from the naturally occurring uranium, actinium, and thorium decay series are still present in the surface soil at this site.

Cesium-137 and strontium-90 are man-made radionuclides created through the fission process such as in a nuclear reactor. Both have half-lives* of approximately 30 years. Cesium-137 emits beta and gamma radiation; strontium-90 emits only beta radiation. The naturally occurring decay series, known as the uranium, actinium, and thorium series, are believed to have been created when the earth was formed, and they are still present today because of their very long half-lives. These series are presented in Tables C-1, C-2, and C-3.

As a radionuclide decays it changes into another substance. In the case of uranium-238, for example, the decay produces thorium-234. Thorium-234 is called the "daughter" of uranium-238; uranium-238 is the "parent" of thorium-234. In turn, thorium-234 is the "parent" of protactinium-234. Radioactive decay started by uranium-238, uranium-235, or thorium-232 continues as shown in the tables until a stable nuclide is formed.

The radionuclides in these decay series are present in small quantities throughout the environment. Concentrations of them normally occur in soil, air, water, food, etc., and are referred to as background concentrations. Radiation exposures resulting from

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* *The half-life is the time required for half of the atoms of a radioactive substance to disintegrate ("decay" or transform).*

this environmental radioactivity are referred to as background exposures. These background exposures are not caused by any human activity, and to a large extent, can be controlled only through man's moving to areas with lower background exposures. Each and every human receives some background exposure daily.

The use of radioactive materials for scientific, industrial, or medical purposes may cause radiation exposures above the background level to be received by workers in the industry, and to a lesser extent, by members of the general public. Scientifically based guidelines have been developed to place an upper limit on these additional exposures. Limits established for exposures to the general public are much lower than the limits established for workers in the nuclear industry.

RADIATION LEVELS ON THE MODERN LANDFILL PROPERTY

The survey identified elevated levels of direct radiation and contamination of the soil above the normal background levels. The major radionuclides noted in these soils are radium-226, cesium-137, and strontium-90. Increased levels of radioactivity resulting from contaminated residues on this property can result in increased radiation exposures to persons. The exposure comes from two primary sources or pathways: direct radiation emitted by the radionuclides in the residue or soil and inhalation of radon gas and its daughter products.* Additional exposures may also be received through ingestion of contaminated food or water or through inhalation of radionuclides suspended in the air. In Table C-4 the exposure levels associated with the Modern Landfill property are summarized and compared with the guidelines and background radiation levels.

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* *Radon-222 is a gas that results from the decay of radium-226, a member of the naturally occurring uranium series (see Table C-1).*

External Radiation Exposure Levels

As Tables C-1, C-2 and C-3 indicate, several members of the naturally occurring decay series emit gamma radiation as does cesium-137. (Gamma rays are pentrating radiation like X-rays). Contaminated areas can, therefore, be sources of external gamma radiation exposure.

The National Council on Radiation Protection and Measurements has recommended a maximum annual whole-body exposure of 500,000 microroentgens* per year to an individual exposed in the general population. This is equivalent to a continuous level of approximately 57 microroentgens per hour. The maximum radiation level on the Modern Landfill property is 49 microroentgens per hour, therefore, the maximum annual external exposure possible at this site would be approximately 375,000 microroentgens. It should be noted that this level occurs only in a very small portion of the property and is due mainly to materials stored on the adjacent DOE facility, also, this exposure is based on continual occupancy of that area. It is improbable that individuals would spend more than a 25% of their time on the site in general, and only a portion of that time would be spent in the region of highest exposure levels. The average exposure level on the property is 15 microroentgens per hour and is a better estimate of the average exposure an individual might receive. For comparison, the average background level in the Lewiston area is about 6 microroentgens per hour and continuous exposure at this level would produce an annual exposure of about 52,400 microroentgens. Also, a typical chest X-ray (according to data from the Department of Health and Human Services) might yield an exposure of about 27,000 microroentgens.

The soil is slightly contaminated with radium, cesium, and strontium which emit beta and gamma radiations. Nuclear Regulatory Commission (NRC) guidelines for decommissioning former nuclear

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* *The Roentgen is the unit of exposure to X- or gamma radiation. A microroentgen is one-millionth of a Roentgen.*

facilities require that the average beta-gamma dose rate measured at a distance of one centimenter above surface does not exceed 0.2 millirad* per hour. The maximum beta-gamma dose rate measured at this site was 0.085 millirad per hour and the average was 0.030 millirad per hour, well within that guideline. The primary concern of this NRC guideline is exposure of skin surfaces. The thickness of ordinary shoe soles is adequate to protect the skin of feet from beta radiation. Other areas of body skin are adequately protected from these exposures if they remain away from these surfaces. In most cases, exposures are negligible at a distance of one foot away from the surface. Potential exposures to beta-gamma radiation from surface residues are therefore negligible at this facility.

Exposure From Inhalation of Radon in Air

The deposits of radium-bearing residues in soil may be indirect sources of radiation exposure on site. As shown in Table C-1 radium-226 changes to radon-222 as a result of radioactive decay. Radon-222 is an inert gas which can emanate from the ground and with its daughter products result in lung exposures. Radon concentrations are continuously monitored near the Modern Landfill site by Mound Laboratories and averaged approximately 0.29 picocuries** per liter of air between October 1980 and April 1981. The guideline for continuous exposure of the general public is 3 picocuries per liter. For comparison the average level monitored in the town of Lewiston during the same time period was 0.20 picocuries per liter.

Other Exposure Considerations

Loose radioactive contamination can result in exposure through ingestion (eating or drinking) of contaminated foodstuffs or inhalation of radionuclides that become airborne through resuspension. The low-levels of contamination in the soil of this

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* *The rad is the unit of beta-gamma dose. A millirad is one-thousandth of a rad.*

** *The curie is the unit indicating the quantity of a radioactive substance. A picocurie is one-millionth-millionth of a curie.*

property and its projected use as a landfill, which will result in covering the existing contaminated soil, preclude significant exposures through these pathways.

ESTIMATES OF HEALTH EFFECTS

The primary health effect associated with radiation exposure is an increased risk of cancer. In general, the risk is assumed to increase as the total dose of radiation increases. Total dose is dependent not only on exposure rate and concentration levels on the property, but also on the nature and duration of the exposure. In addition, a given individual's increased risk is dependent upon many factors including the individual's age at onset of exposure, variability in latency period (time between exposure and physical evidence of disease), the individual's personal habits and state of health, previous or concurrent exposure to other hazardous agents, and the individual's family medical history. Because of these variables, large uncertainties would exist in any estimates of the number of increased cancers in a relatively small working population such as that at the Modern Landfill, Inc. site. Estimates of the increased risks have been calculated and are given in Table C-5. Assumptions made in performing these calculations are:

1. The levels reported in Table C-4 are representative of the conditions and will not change during the year or from year to year.

2. Average exposure levels in Table C-4 are representative of the averages to which an individual working on the property might be exposed.

3. An individual would spend a working lifetime, i.e. 40 hours per week, 50 weeks per year, for 45 years (age 20 to 65) on the site.

4. Background exposure rates to individuals while not on the property will be 6 microroentgens per hour from external gamma radiation.

The risk estimates are based on the 1980 National Academy of Sciences report, "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation," and the 1977 report by the United States Scientific Committee on Effects of Atomic Radiation. The lifetime risk estimate used to calculate the values in Table C-5 is 100 cancer deaths per million persons exposed per rem of radiation exposure. It is believed by many radiation biologists that with low dose rates such as those encountered at the Modern Landfill property, the actual risks of cancer are much less than 100 per million persons per rem, zero not being excluded.

Because radon concentrations on this property are essentially background, no dose or risk from this pathway was evaluated or calculated. Exposures and risk from the secondary pathways of ingestion of food grown on contaminated soils and inhalation of air containing radionuclides resuspended from the soil are considered negligible, based on the low-levels and the intended use of this property. Exposures and risk are therefore limited to one pathway-direct exposure to gamma radiation.

The estimated increased risk due to cancer from exposure to the average radiation level on the Modern Landfill property for a working lifetime is 0.09 per 1000 deaths. This can be compared with the average lifetime risks of cancer in Niagara County of 218 per 1000 deaths based on 1977 crude death rate statistics for this same year. The average lifetime risks of cancer in the State of New York and the United States are 216 per 1000 deaths and 203 per 1000 deaths respectively. An individual working under the assumed conditions will therefore be subject to an increased risk of dying from cancer of 0.009 percent or an increase in total risk from 21.8 to 21.809 percent when compared to the average risk in Niagara County. This may also be expressed as a percent increase in overall risk of getting a fatal cancer of 0.04 percent.

SUMMARY

In summary, portions of the Modern Landfill property at the former LOOW site are contaminated with low-level residues containing cesium-137, strontium-90, and naturally occurring radionuclides. The level of radium-226 contamination in the surface soil in one area exceeds the present criterion for release of property for unrestricted use. Although this contamination is capable of producing slight radiation exposures to persons on this property, these exposures are well within the scientifically-based guidelines, and risks to such persons are negligible.

TABLE C-1

URANIUM DECAY SERIES

Parent	Half-life	Decay Products	Daughter
Uranium-238	4,500,000,000 yrs.	alpha	Thorium-234
Thorium-234	24 days	beta, gamma	Protactinium-234
Protactinium-234	1.2 minutes	beta, gamma	Uranium-234
Uranium-234	250,000 years	alpha	Thorium-230
Thorium-230	80,000 years	alpha	Radium-226
Radium-226	1600 years	alpha	Radon-222
Radon-222	3.8 days	alpha	Polonium-218
Polonium-218	3 minutes	alpha	Lead-214
Lead-214	27 minutes	beta, gamma	Bismuth-214
Bismuth-214	20 minutes	beta, gamma	Polonium-214
Polonium-214	2/10,000 second	alpha	Lead-210
Lead-210	22 years	beta	Bismuth-210
Bismuth-210	5 days	beta	Polonium-210
Polonium-210	140 days	alpha	Lead-206
Lead-206	stable	none	none

TABLE C-2

ACTINIUM DECAY SERIES

Parent	Half-life	Decay Products	Daughter
Uranium-235	710,000,000 years	alpha	Thorium-231
Thorium-231	25.5 hours	beta	Protactinium-231
Protactinium-231	32,000 years	alpha	Actinium-227
Actinium-227	21.6 years	beta, gamma	Thorium-227
Thorium-227	18.2 days	alpha	Radium-223
Radium-223	11.4 days	alpha	Radon-219
Radon-219	4.0 seconds	alpha	Polonium-215
Polonium-215	.0018 seconds	alpha	Lead-211
Lead-211	36.1 minutes	beta, gamma	Bismuth-211
Bismuth-211	2.15 minutes	alpha	Thallium-207
Thallium-207	4.79 minutes	beta	Lead-207

TABLE C-3

THORIUM DECAY SERIES

Parent	Half-Life	Decay Products	Daughter
Thorium-232	14 billon years	alpha	Radium-228
Radium-228	5.8 years	beta	Actinium-228
Actinium-228	6.13 hours	beta	Thorium-228
Thorium-228	1.91 years	alpha	Radium-224
Radium-224	3.64 days	alpha	Radon-220
Radon-220	55 seconds	alpha	Polonium-216
Polonium-216	.15 seconds	alpha	Lead-212
Lead-212	10.6 hour	beta	Bismuth-212
Bismuth-212	60.6 minutes	alpha (1/3)* beta (2/3)*	Thallium-208 Polonium-212
Thallium-208	3.1 minutes	beta	Lead-208
Polonium-212	.0000003 seconds	alpha	Lead-208

*Two decay modes are possible for Bi-212.

TABLE C-4

SUMMARY OF EXPOSURE LEVELS ON MODERN LANDFILL INC. PROPERTY
LEWISTON, NEW YORK

Exposure Source	Levels on Site		Background Levels	Guidelines for General Public	Guidelines for Radiation Workers
	Average	Maximum			
Gamma Radiation from cesium-137 and uranium, thorium, and actinium decay series	15 μR/h [a]	49 μR/h	6 μR/h	0.5 rem [b] per year for individual; equivalent to 250 μR/h above natural background for 40 h/wk and 50 wk/yr or 60 μR/h continuous exposure.	5 rems per year
Radon in air	0.29 pCi/liter [c] (10/80-3/81)	-	0.20 pCi/liter (Lewiston, 10/80-3/81)	3 pCi/liter	30 pCi/liter
Radionuclides in Soil					
Radium-226	1.8 pCi/g	23 pCi/g	Approx. 1.0 pCi/g	EPA Interim Mill Tailings Criteria is 5 pCi/g above background averaged over 100 m^2.	none
Cesium-137	3.6 pCi/g	69 pCi/g	Approx. 0.5 pCi/g	80 pCi/g above background (Criteria developed by Los Alamos Sci. Lab. for cleanup at sites contaminated by fission product residues.)	none
Strontium-90	0.55 pCi/g [d]	111 pCi/g	< 0.5 pCi/g	100 pCi/g (Criteria developed by Los Alamos Sci. Lab. for cleanup at sites contaminated by fission product residues.)	none

[a] The Roentgen (R) is a unit which was defined for radiation protection purposes for people exposed to penetrating gamma radiation. A microroentgen (μR) is one millionth of a Roentgen.

[b] The rem is the unit of ionizing radiation that produces the same biological damage in man as an absorbed dose of 1 roentgen of high voltage x-ray. A roentgen of gamma exposure to a man is equivalent to one rem.

[c] The picocurie (pCi) is a unit which is defined for expressing the amount of radioactivity present in a substance. 1 pCi = 10^{-12} Ci.

[d] Based on the average cesium concentration and an average Sr/Cs ratio of 1/6.5.

TABLE C-5

SUMMARY OF WORKING LIFETIME RADIATION EXPOSURES AND ESTIMATES OF ASSOCIATED CANCER RISK FOR MODERN LANDFILL PROPERTY, LEWISTON, NY

Source of Exposure	Working Lifetime Dose Equivalent Corrected for Background	Increased Risk Due to All Cancers
External gamma radiation	0.9 rems	0.09 per 1000 [a]
Radon	0	0
Inhalation of dust and ingestion of foods grown on site	0	0
TOTAL		0.09 per 1000 [b]

[a] Using risk coefficient of 100 cancer deaths/10^6 person rem. This is approximately a mean value from BEIR-III (1980) and UNSCEAR (1977).

[b] The average lifetime risk of death due to cancer in the United States is 167 per 1000 (16.7 percent).