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Prepared by
Oak Ridge Associated Universities

Prepared for
Division of Facility and Site Decommissioning

U.S. Department of Energy

VERIFICATION OF REMEDIAL ACTION ON VENTILATION SYSTEMS JONES CHEMICAL LABORATORY UNIVERSITY OF CHICAGO CHICAGO, ILLINOIS

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

FINAL REPORT
JANUARY 1989

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OF
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VERIFICATION OF
REMEDIAL ACTION ON VENTILATION SYSTEMS
JONES CHEMICAL LABORATORY
UNIVERSITY OF CHICAGO
CHICAGO, ILLINOIS

INTRODUCTION

Between 1942 and 1952 facilities at the University of Chicago were used by the Manhattan Engineer District and the Atomic Energy Commission (predecessors of the Department of Energy) for development of separation and verification techniques involving uranium and plutonium. These activities were conducted in Jones Chemical Laboratory, Kent Chemical Laboratory, Ryerson Physical Laboratory, and Eckhart Hall. In 1952, operations were transferred to the new Argonne National Laboratory (ANL) in DuPage County, and the University of Chicago facilities were decontaminated to levels for unrestricted release in effect at that time. A search of records during the 1970's indicated that the documentation of the decontamination efforts was inadequate and ANL performed additional radiological evaluations of the facilities in 1976 and 1977. Limited areas of these facilities were identified as having residual contamination in excess of the current (mid 1970's) guideline levels and ANL performed further remedial actions. The cleanup was completed in 1984 and is described in Argonne reports ANL-OHS/HP-83-107, ANL-OHS/HP-84-105, and ANL-OHS/HP-84-108.[1-3] These reports indicated that the cleanup was effective in reducing all identified areas of residual contamination to guideline levels, except within the exhaust ventilation ductwork in Jones Chemical Laboratory. This facility was renovated after completion of MED/AEC activities and as a result, many sections of ductwork were not readily accessible. Beginning in mid 1987, Bechtel National, Inc. (BNI), the Project Management Contractor for the Department of Energy's (DOE) Formerly Utilized Sites Remedial Action Program (FUSRAP), conducted characterization surveys and performed remedial action where necessary at the Jones Chemical Laboratory, to assure that the residual contamination levels in the ductwork satisfied the present radiological protection criteria.

It is the policy of the DOE to perform independent verifications of the effectiveness of remedial actions conducted within FUSRAP. The Radiological Site Assessment Program of Oak Ridge Associated Universities (ORAU) has been

designated by DOE as the organization responsible for this task at the University of Chicago.

FACILITY DESCRIPTION

The University of Chicago campus is located on a 171 acre site within the city of Chicago (Figure 1). The main campus consists of 127 buildings. The Jones Chemical Laboratory building is located near the center of the campus, facing the central quadrangle, near Ellis Avenue and East 58th Street (Figure 2). The Jones Chemical Laboratory building, currently used as laboratories, classrooms, and offices, consists of six levels: a basement, four above-ground floors, and an attic.

PROCEDURES

During the period of September 22 to October 9, 1987 ORAU performed verification surveys of remediated areas. These surveys were limited to fume hood exhaust ducts, storage cabinet exhaust ducts, the roof, and the drains within the laboratory sections of the building. A plan view of the laboratory roof, indicating duct locations, is shown in (Figure 3). This report describes the procedures and findings of the verification activities.

Objectives

The objectives of the verification were to confirm that the surveys, sampling, and analyses conducted during all phases of remedial action, and supporting documentation provide an accurate and complete description of the radiological condition of the property and, thereby, confirm that remedial actions have been effective in meeting established criteria (Appendix C).

Procedures

1. Radiological survey reports, engineering drawings, work plans, and the post-remedial action report (references 4-6) were reviewed for general thoroughness and accuracy, and to assure that areas exceeding criteria were identified and remediated.

2. The survey encompassed approximately 25% of the remediated area, and focused on the inner surfaces of ductwork and building surfaces located adjacent to contaminated or remediated ductwork. Approximately 10% of non-remediated ductwork was also selected for independent measurements. Verification activities were conducted concurrently with remedial action.

3. Alpha, beta-gamma, and gamma scans were performed on floors, lower walls, inner surfaces of ducts, and adjacent equipment. Portable ZnS alpha scintillation detectors, "pancake" GM beta-gamma detectors and NaI(Tl) gamma scintillation detectors were used with scaler/ratemeters to perform the scans. Areas of elevated radiation levels were identified for additional remediation and measurements.

4. Total and removable alpha and beta-gamma contamination levels were measured at duct inlets and outlets, representative locations within the duct and on adjacent surfaces. Typically 5 to 20 measurements were made at each duct depending upon its length and radiological history.

5. Samples of ductwork, building material, and residues were collected from remediated areas.

6. Samples and direct measurement data were returned to Oak Ridge, Tennessee, for analysis and interpretation. Debris and residue samples were analyzed by solid state gamma spectrometry. Plutonium, uranium, thorium, and radium were the radionuclides of primary interest; however, spectra were reviewed for other identifiable photopeaks. Smears were analyzed for gross alpha and beta. Additional information concerning major instrumentation, sampling equipment, and analytical procedures is provided in Appendices A and B. Results were compared with DOE's remedial action guidelines (Appendix C) established for the University of Chicago.

FINDINGS AND RESULTS

Document Review

Review of the radiological survey data and decontamination reports prepared by Argonne National Laboratory for the Jones Chemical Laboratory indicated that contaminated areas included the fume hoods and storage cabinet exhaust ducts, drains, the roof, and attic. The post-remedial action report, prepared by BNI, accurately described the remediation of these areas and the radiological status following completion of the remedial actions. Data presented in the post-remedial action report demonstrated that the remedial actions were effective in meeting the established guidelines at all identified areas.

Verification Surveys

ORAU surveyed approximately 25% of the remediated area and 10% of the non-remediated area. Surface alpha and beta-gamma scans identified five locations of elevated contact radiation, ducts V11B4 and V24C2, areas on the fourth floor near ducts V23A3 and V30A1, and on the southwest end of the fifth floor. Additional remediation efforts by BNI at these locations effectively reduced contamination levels to within guideline levels. Two hundred and fifty eight and one hundred sixty one measurements for total and removable contamination, respectively, were performed and the results are summarized in Table 1. These measurements reflect the final radiological conditions for the areas surveyed. Total contamination levels ranged from <18 to 190 dpm/100 cm^2 for alpha and <360 to 5100 dpm/100 cm^2 for beta-gamma. Removable contamination levels ranged from <3 to 10 dpm/100 cm^2 and <6 to 20 dpm/100 cm^2 for alpha and beta-gamma contamination levels respectively.

A total of nine miscellaneous samples of debris, residue, and roof tile were collected. Radionuclide concentrations are reported in Table 2. With one exception, minimal concentrations were detected. The exception was a residue sample from the base of a blower near duct V24D3. The U-238 concentration was

450 pCi/g of residue. The blower was removed and the area scabbled. Subsequent surveys verified that these efforts had reduced contamination levels to within guidelines.

COMPARISON OF RESULTS WITH GUIDELINES

The DOE remedial action guidelines applicable to Jones Chemical Laboratory at the University of Chicago are given in Appendix C. Total and removable contamination levels measured by this survey were within these guidelines.

With one exception, radionuclide concentrations in miscellaneous samples were below the guideline concentrations established for the University of Chicago. The exception was a residue sample taken near duct V24D3. The area was remediated and subsequent surveys verified that the levels were below the guidelines.

During the period of September 22, 1987 to October 9, 1987, ORAU performed an independent survey to verify the adequacy of remedial actions and supporting documentation for the decontamination of ventilation systems in Jones Chemical Laboratory at the University of Chicago. The verification activities included document reviews, independent direct measurements, and sample analyses. Based on the results and findings of these activities, it is ORAU's opinion that the remedial actions on the ventilation systems at Jones Chemical Laboratory in Chicago, Illinois have been effective in satisfying the established DOE guidelines

JCL1

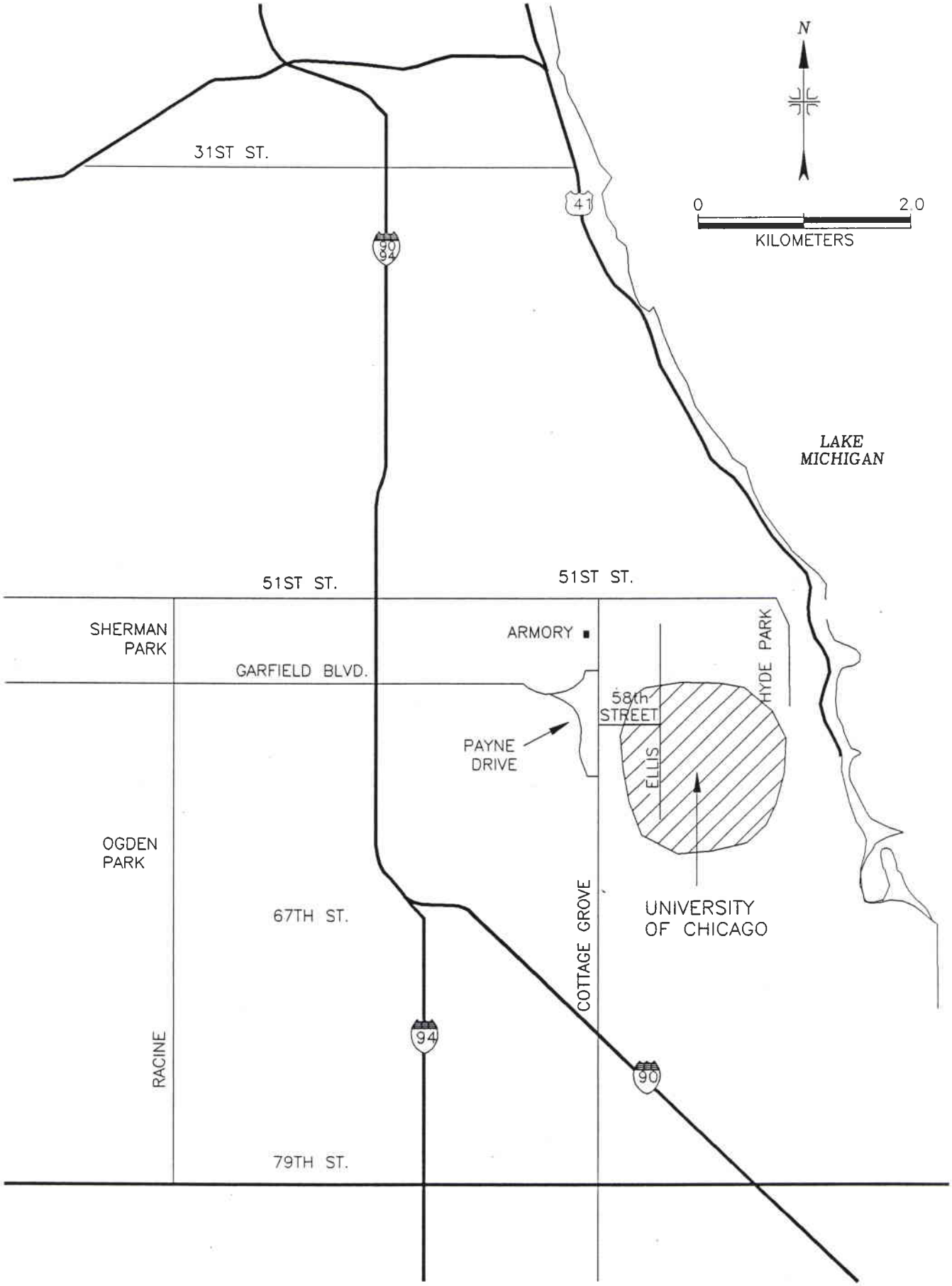


FIGURE 1: Map of South Chicago, Illinois, Indicating the Location of the University of Chicago Campus

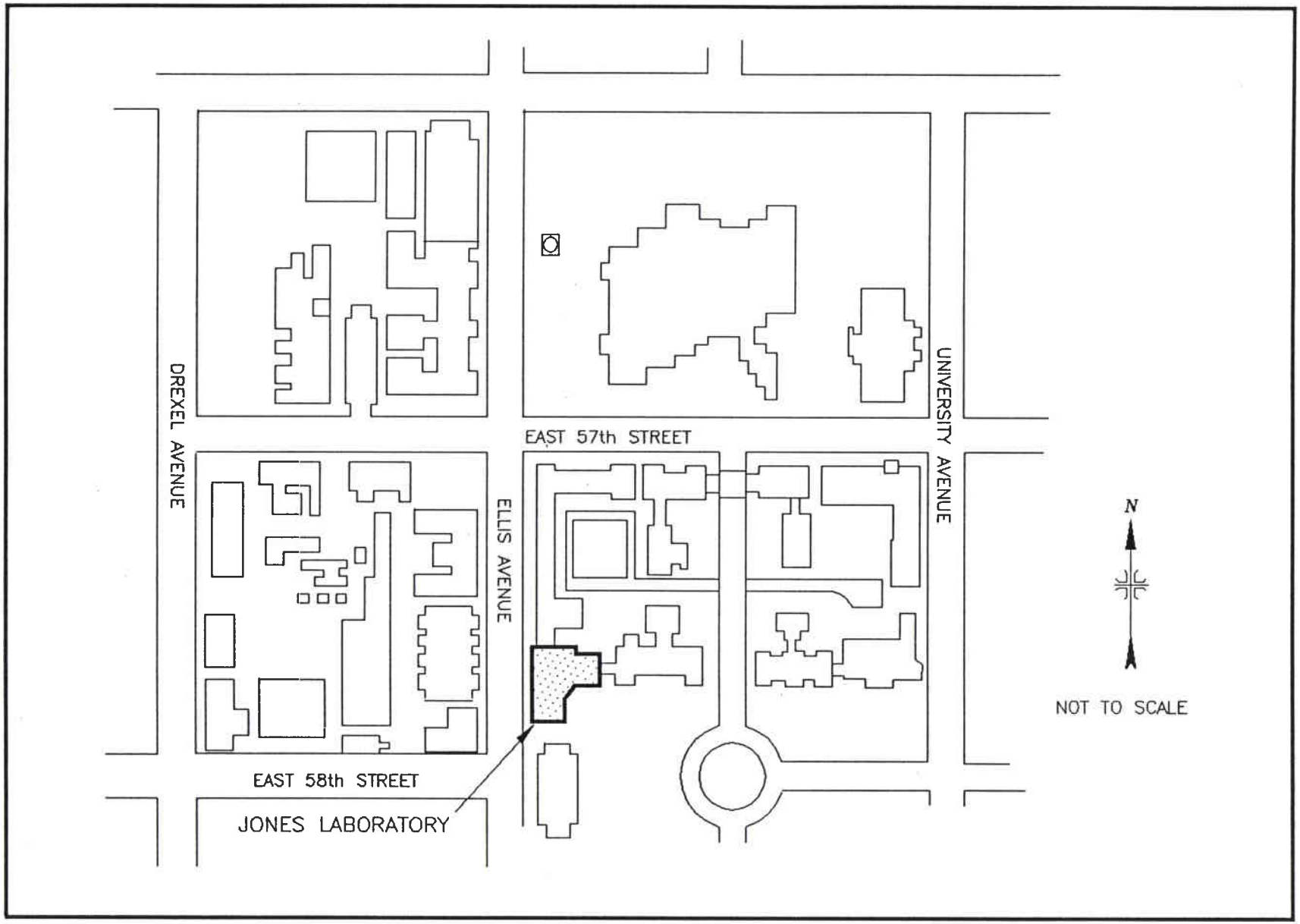


FIGURE 2: Map of the University of Chicago Campus Indicating the Location of Jones Chemical Laboratory

JCL3

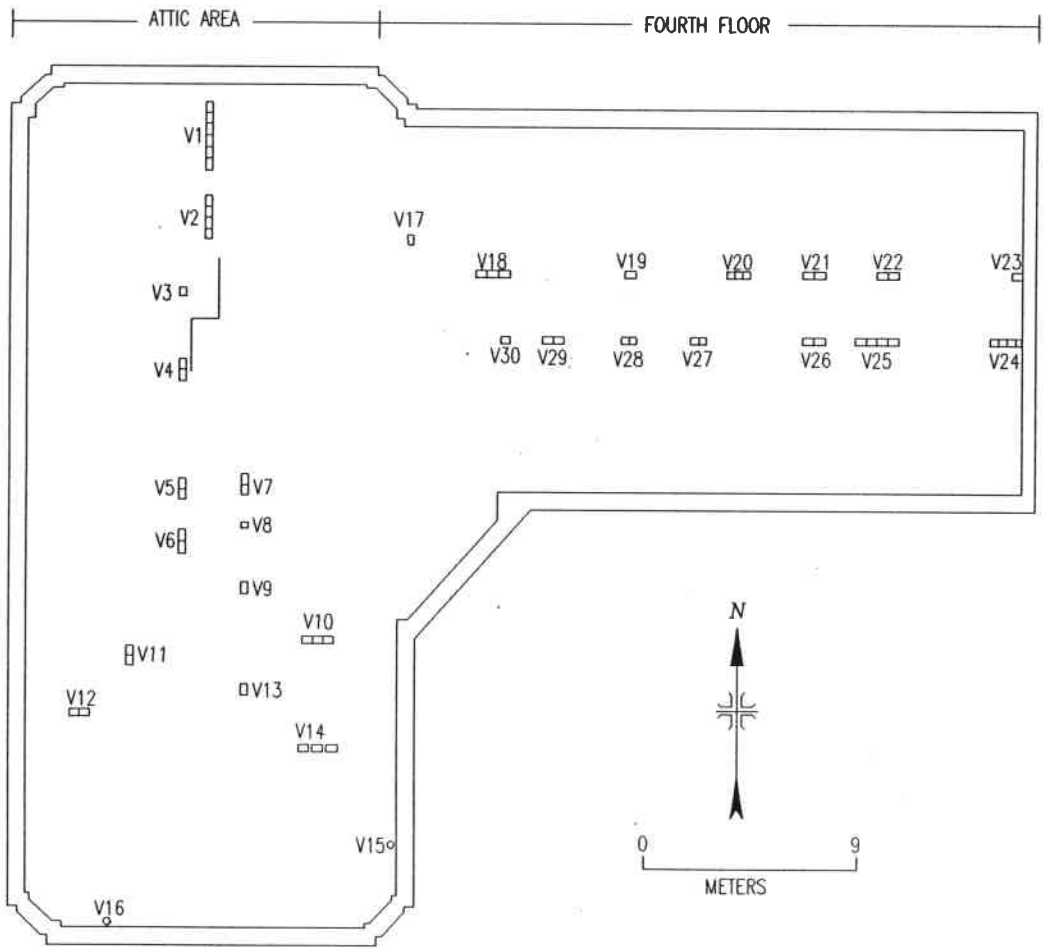


FIGURE 3: Plan View of Jones Chemical Laboratory Indicating Duct Locations

JCL4

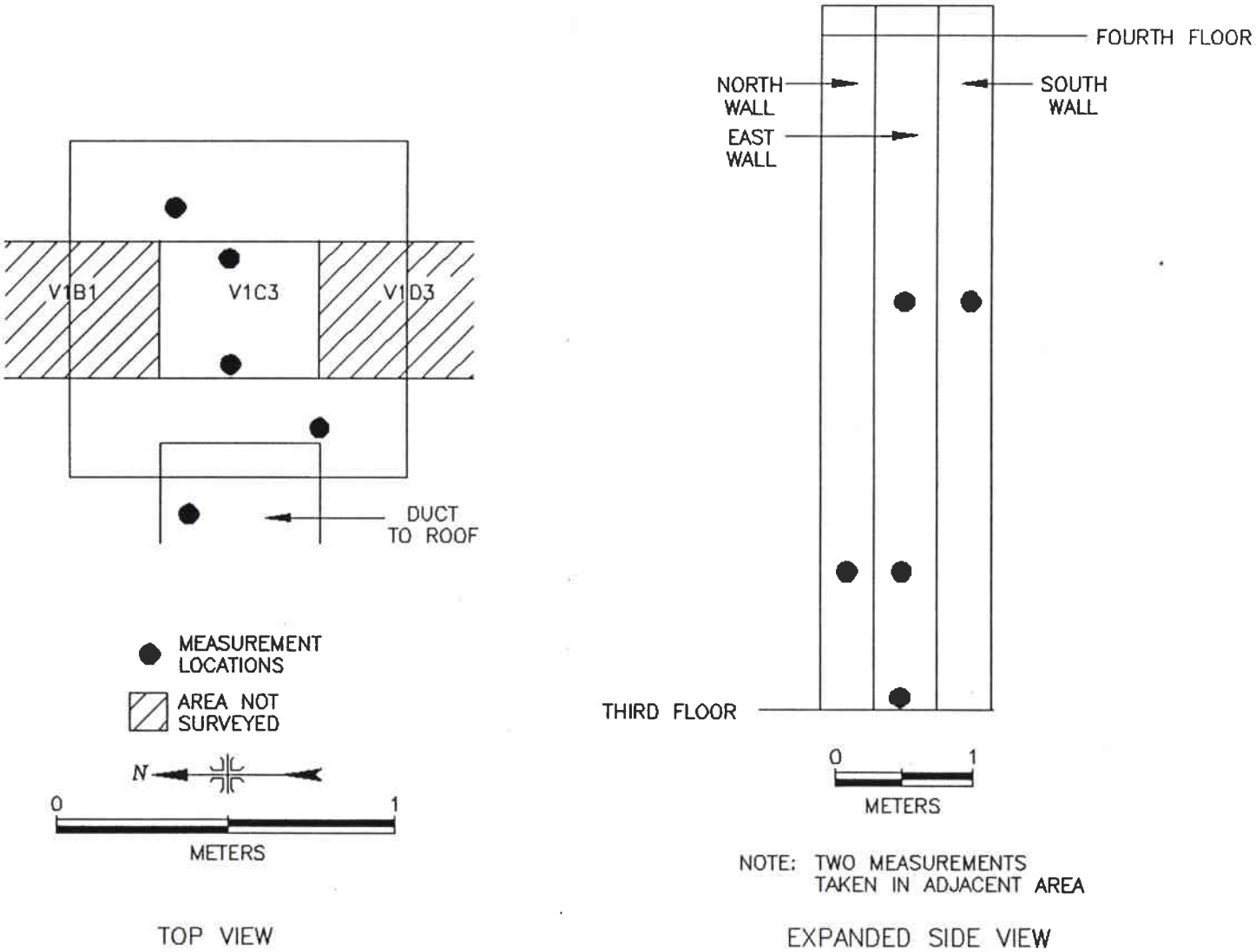


FIGURE 4: Locations for Total and Removable Contamination Measurements in Duct V1C3

JCL5

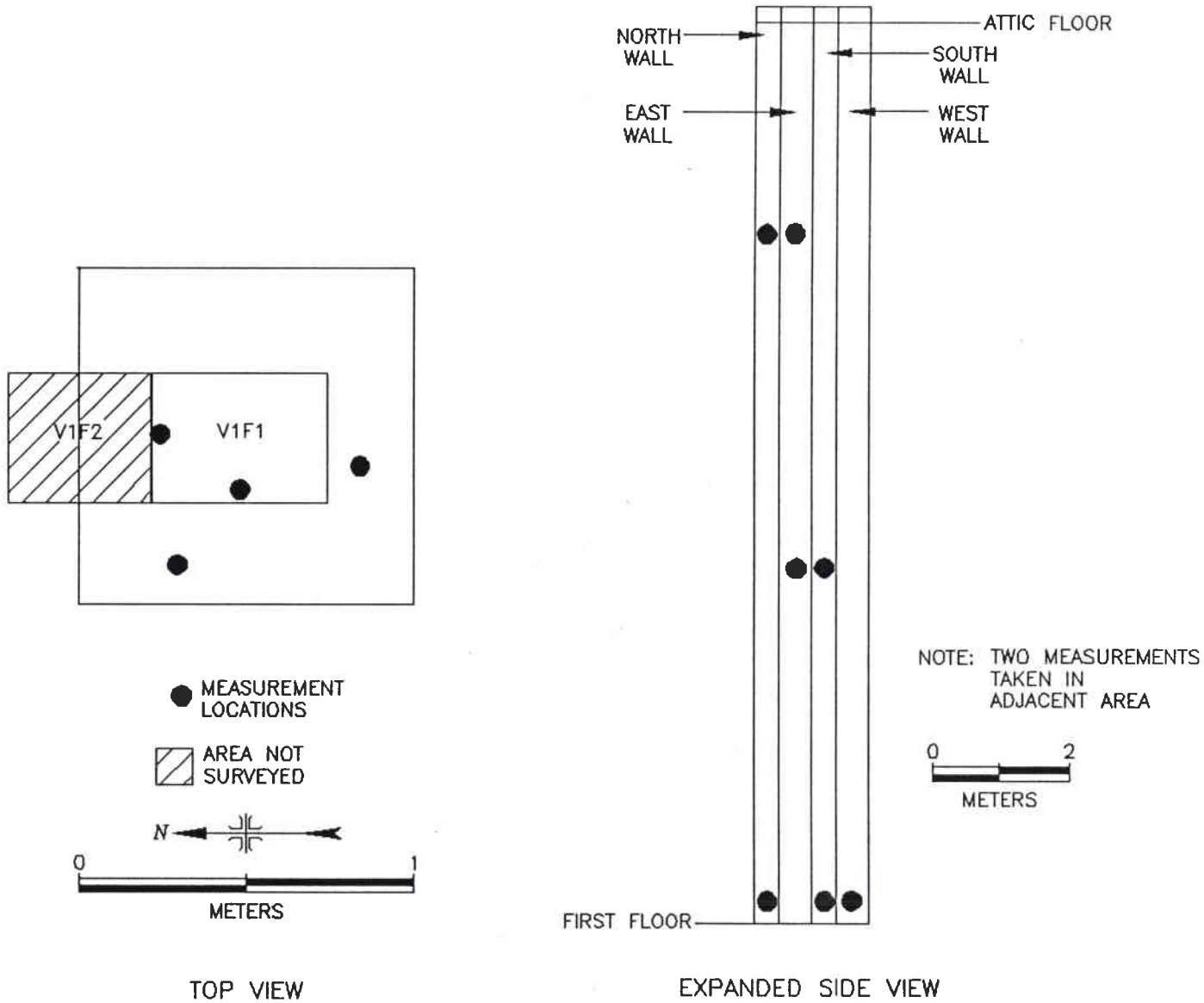


FIGURE 5: Locations for Total and Removable Contamination Measurements in Duct V1F1

JCL6

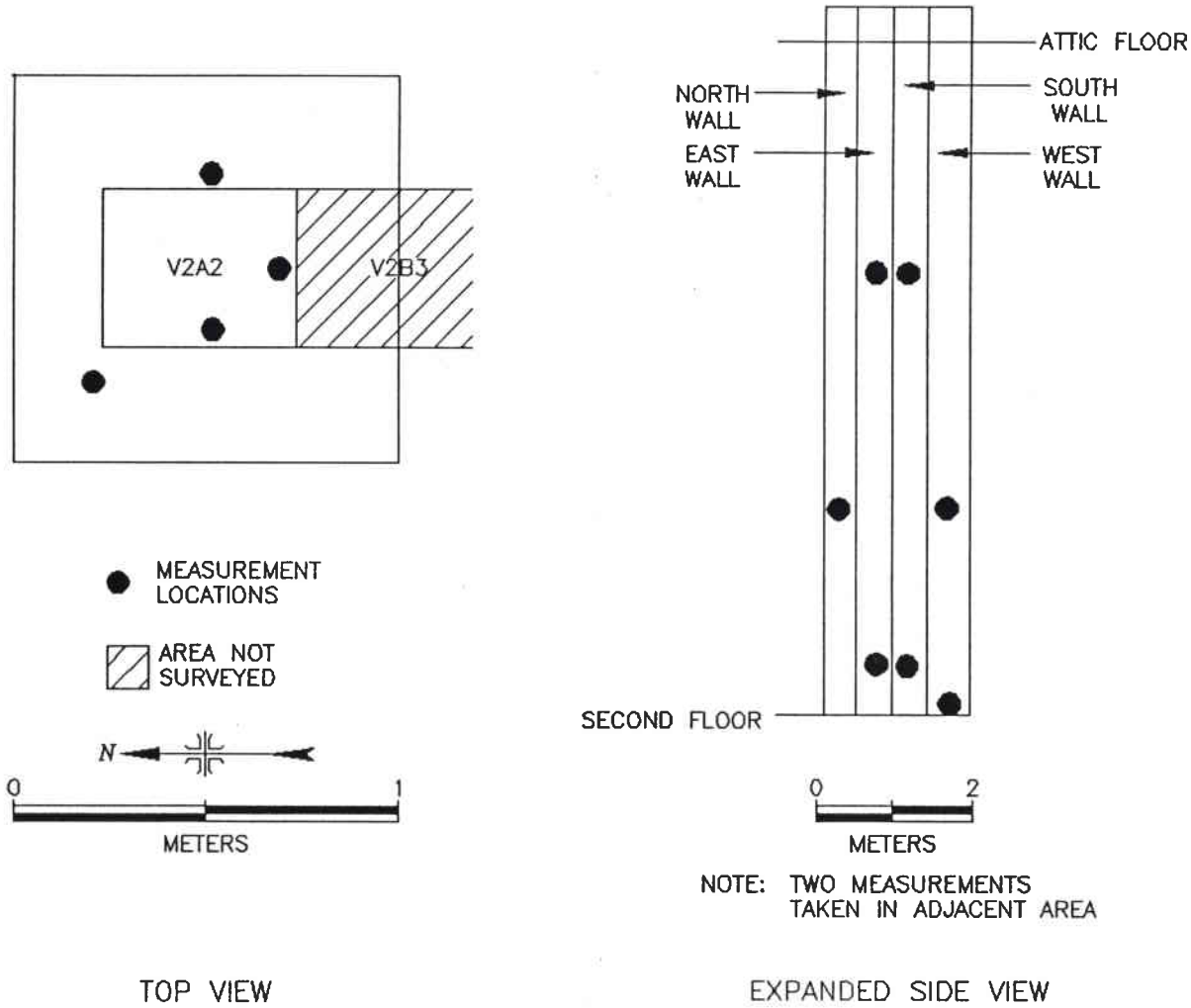


FIGURE 6: Locations for Total and Removable Contamination Measurements in Duct V2A2

JCL7

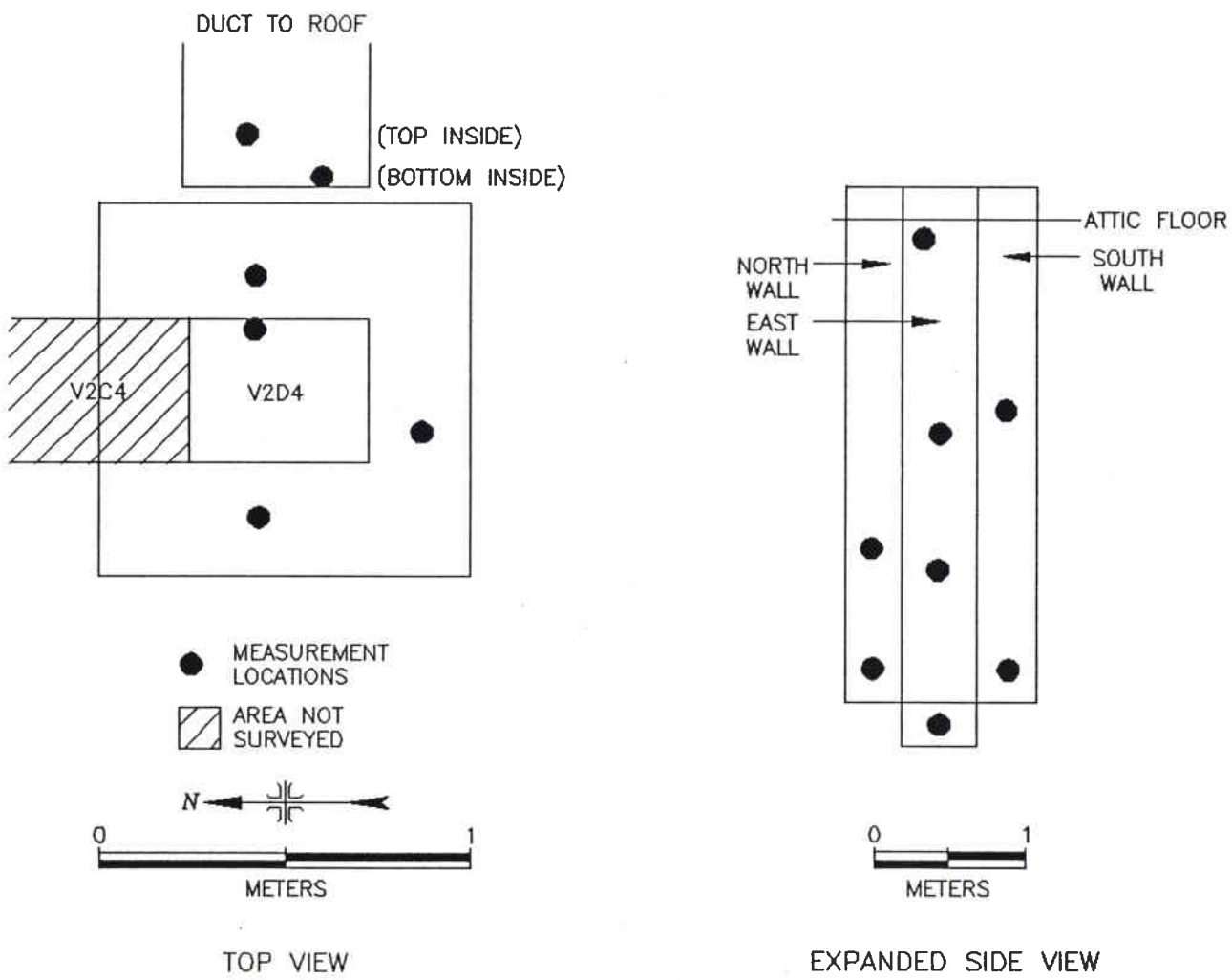


FIGURE 7: Locations for Total and Removable Contamination Measurements in Duct V2D4

JCL8

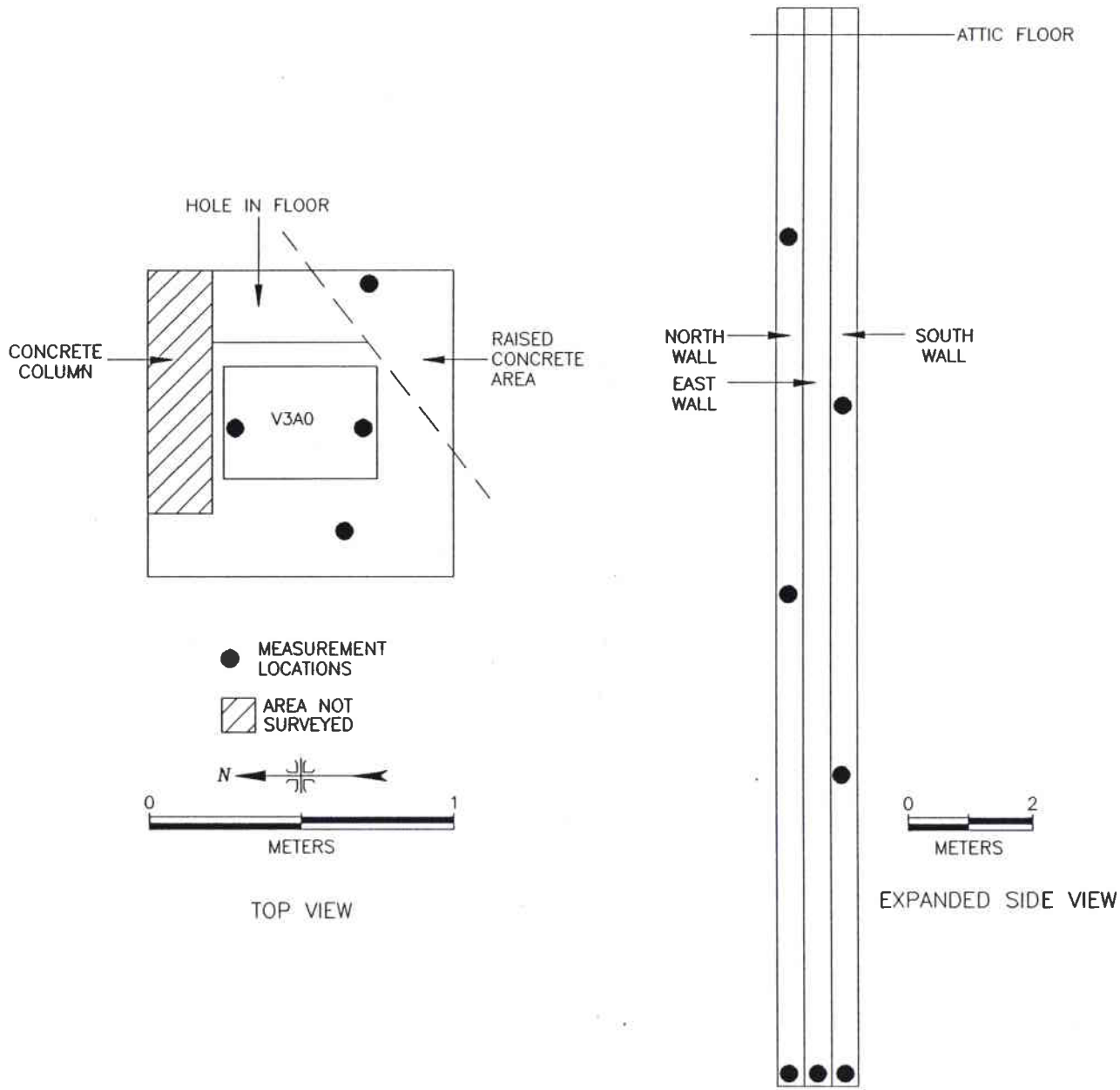


FIGURE 8: Locations for Total and Removable Contamination Measurements in Duct V3A0

JCL9

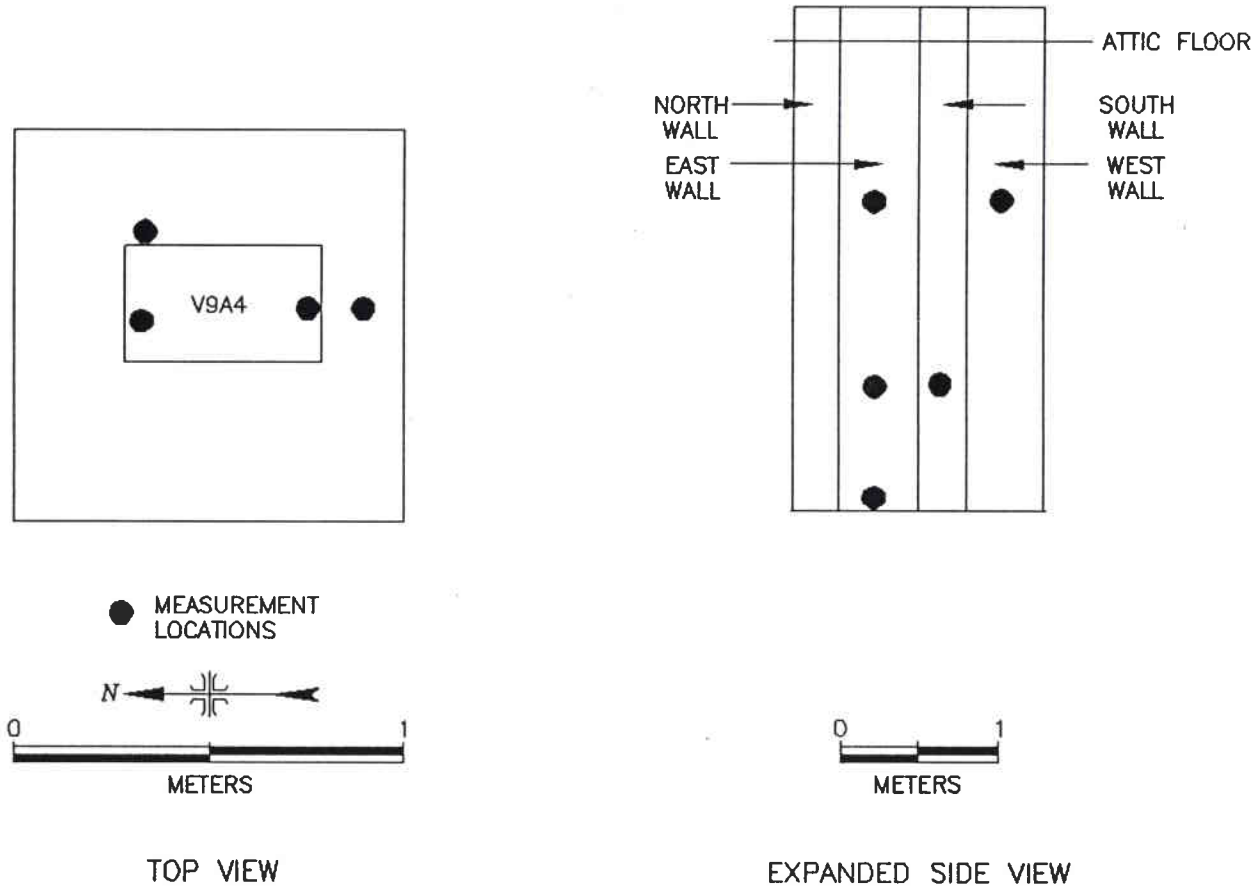


FIGURE 9: Locations for Total and Removable Contamination Measurements in Duct V9A4

JCL10

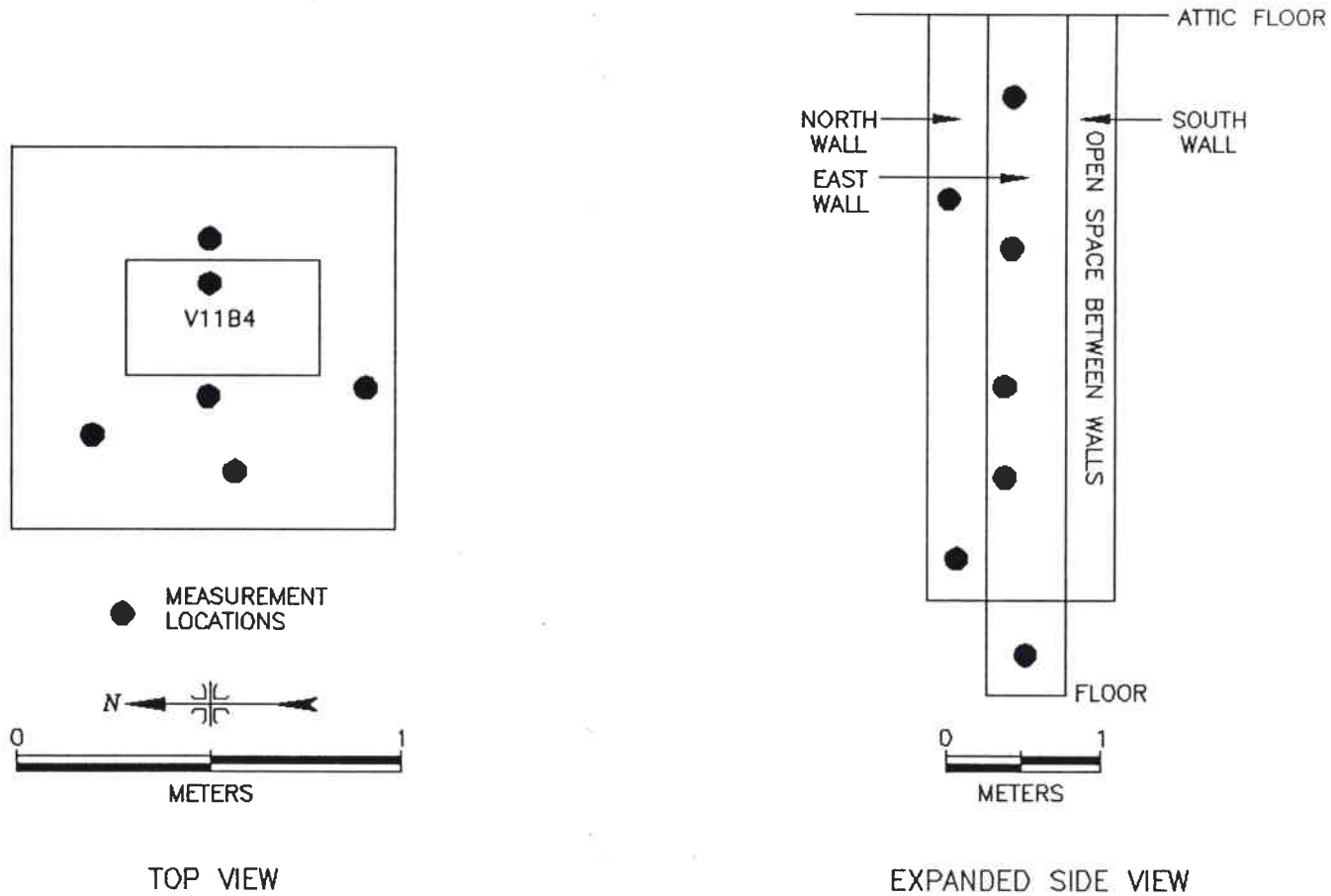


FIGURE 10: Locations for Total and Removable Contamination Measurements in Duct V11B4

JCL11

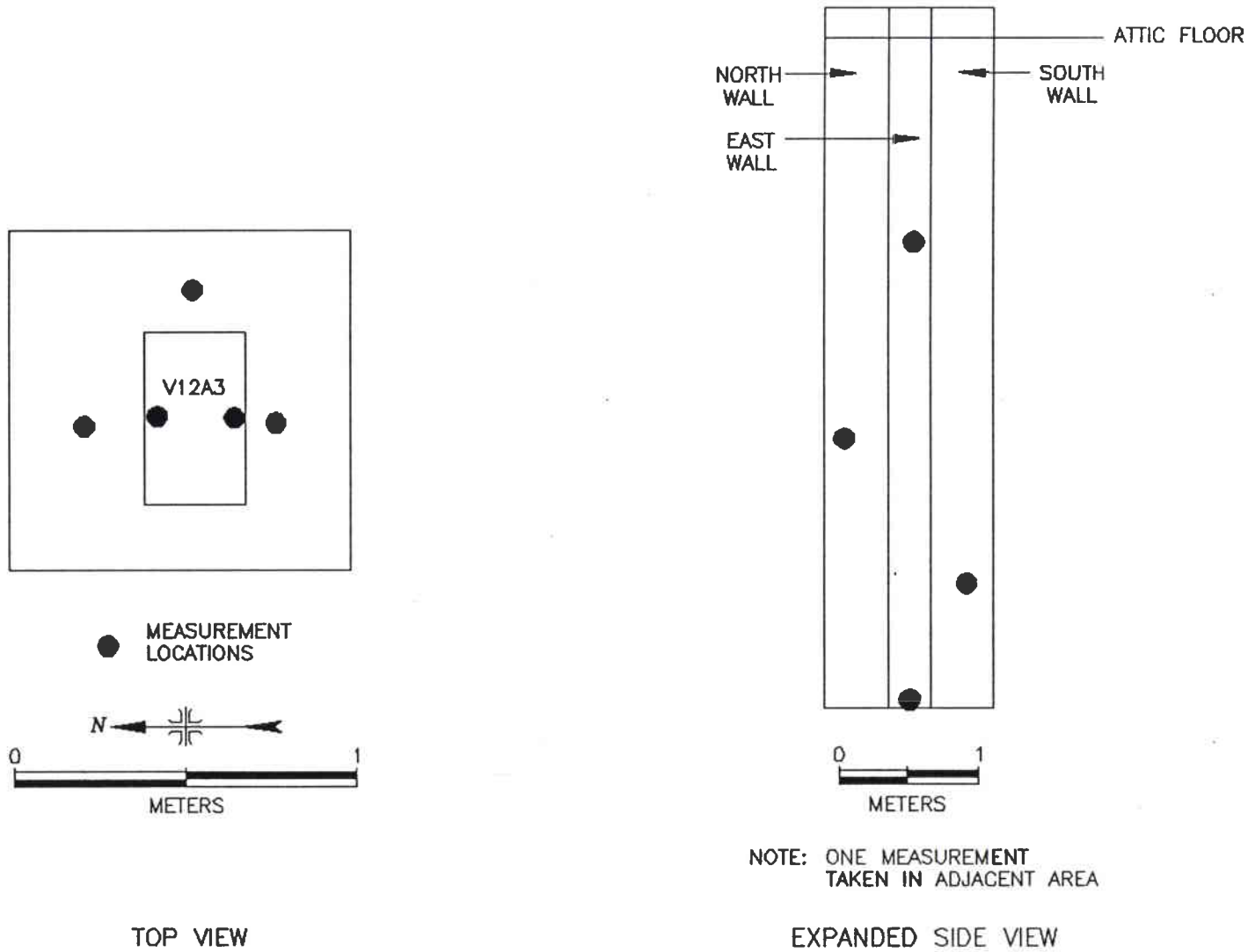


FIGURE 11: Locations for Total and Removable Contamination Measurements in Duct V12A3

JCL12

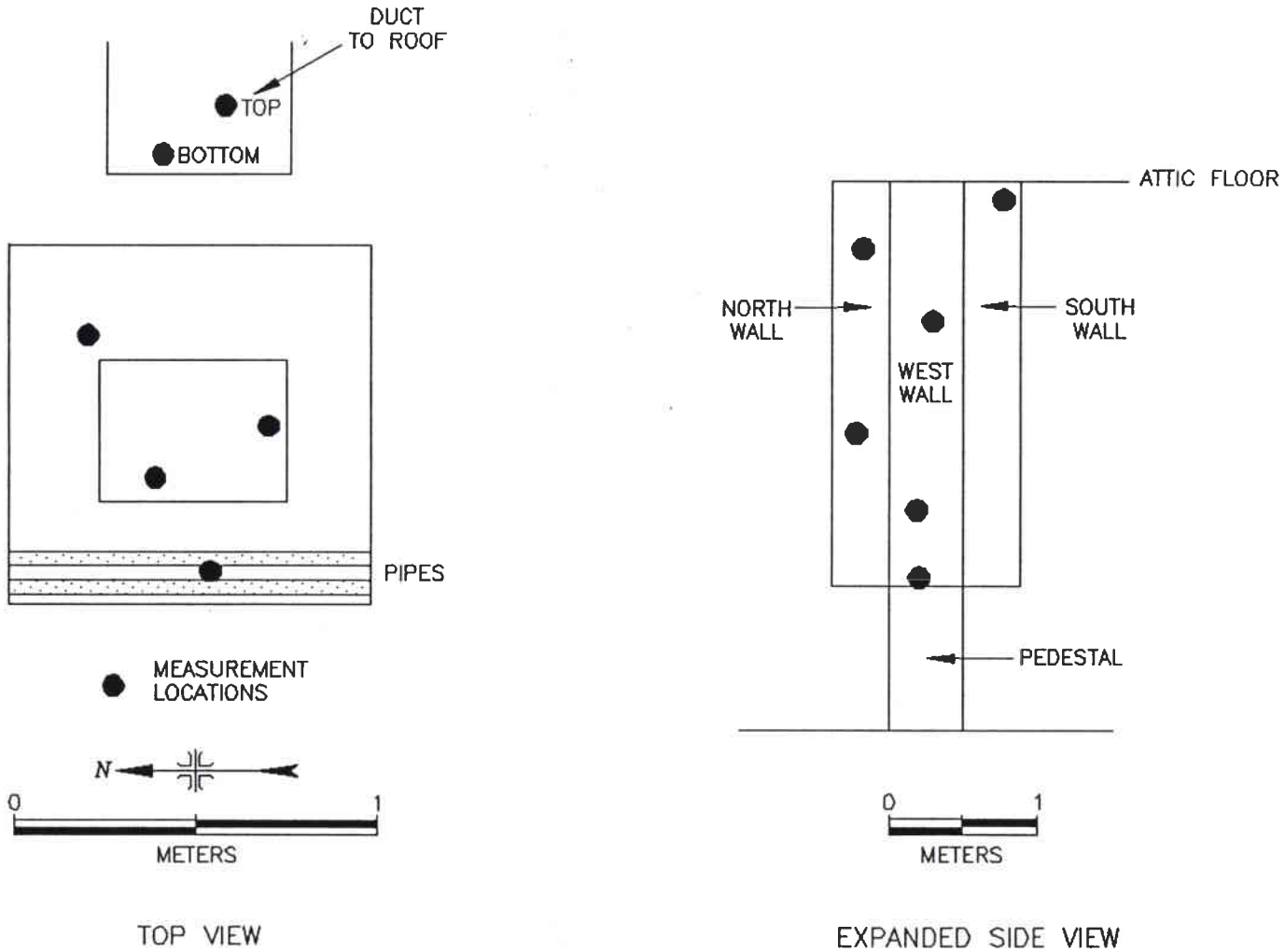


FIGURE 12: Locations for Total and Removable Contamination Measurements in Duct V13A4

JCL13

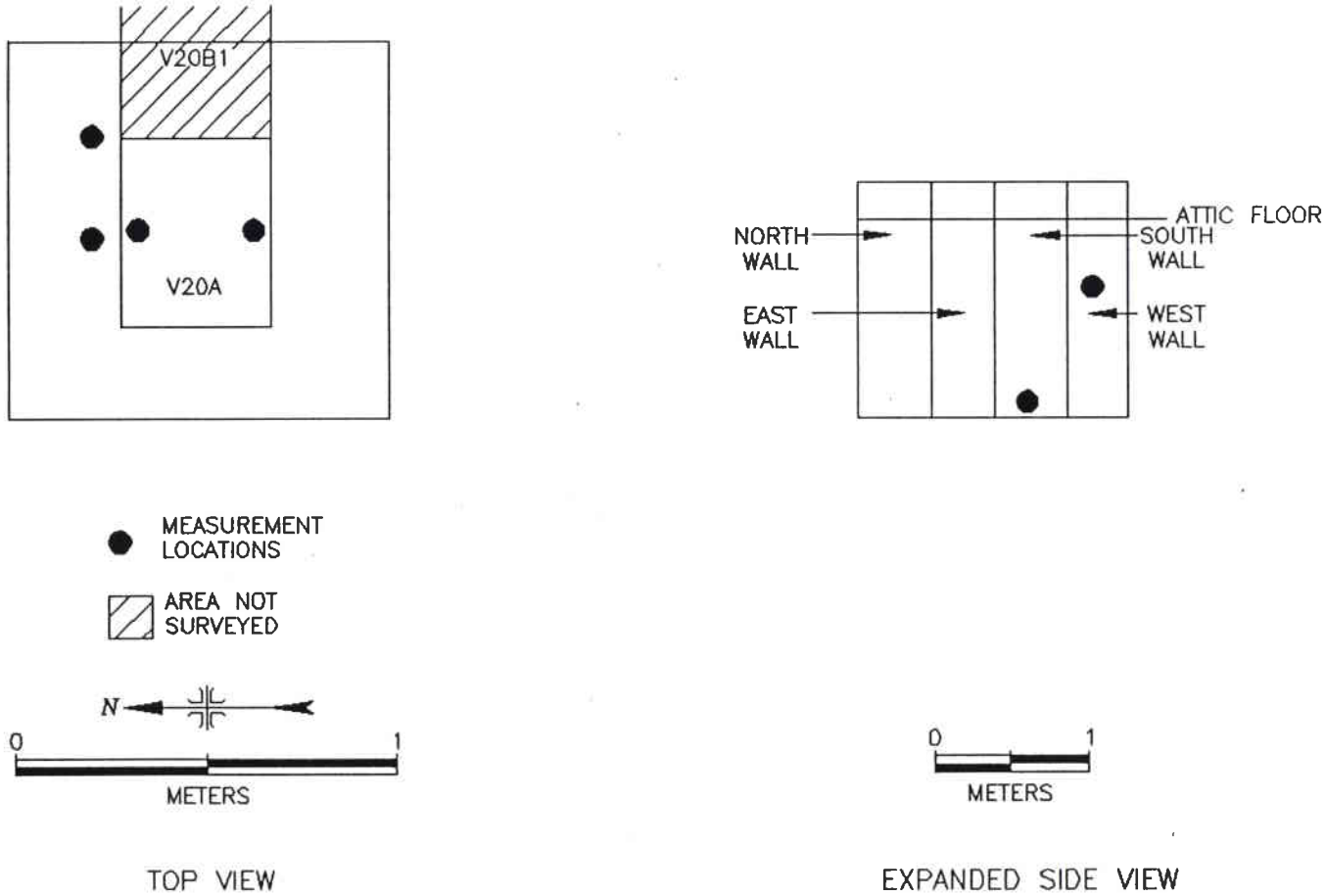


FIGURE 13: Locations for Total and Removable Contamination Measurements in Duct V13A4

JCL14

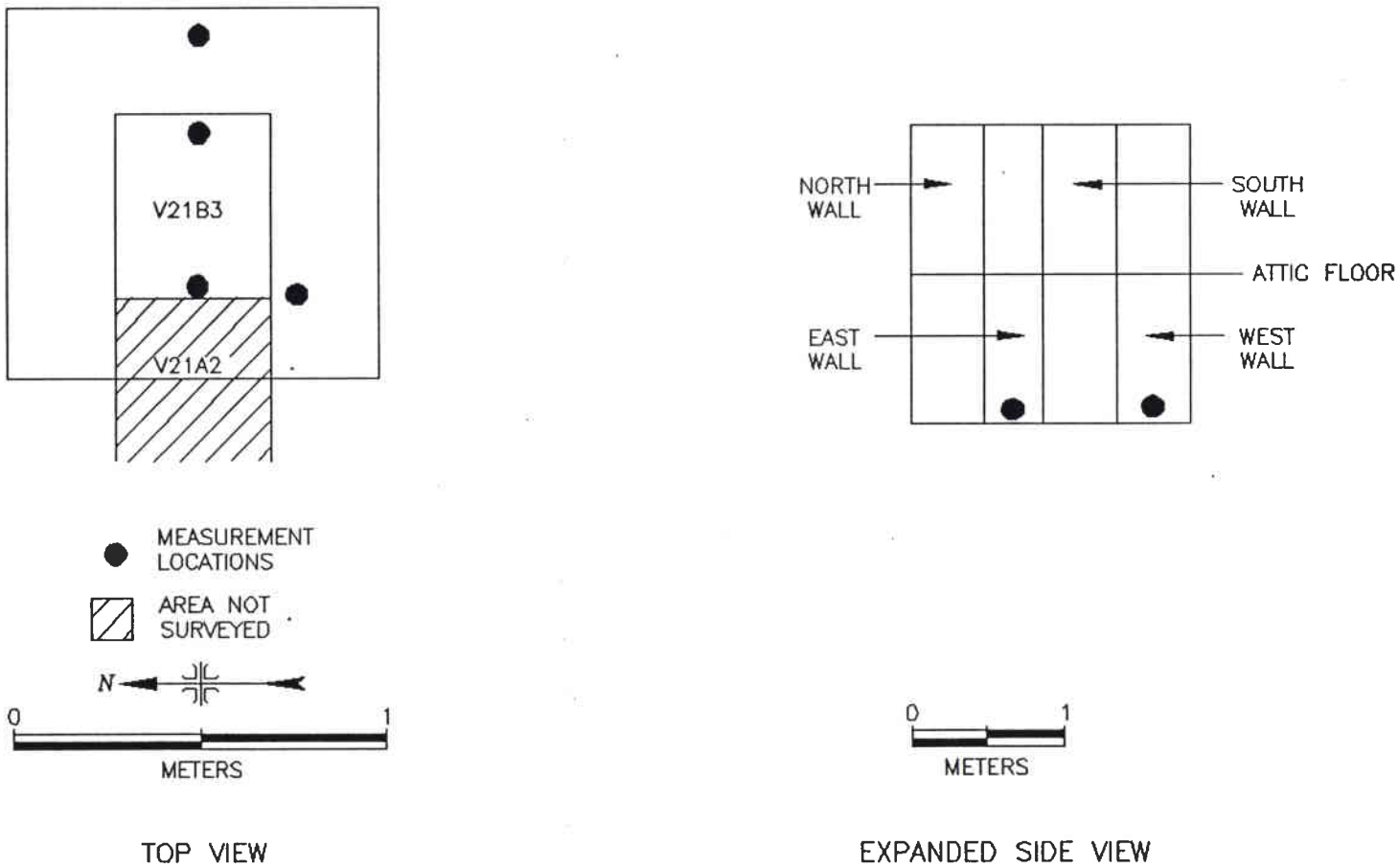


FIGURE 14: Locations for Total and Removable Contamination Measurements in Duct V21B3

JCL15

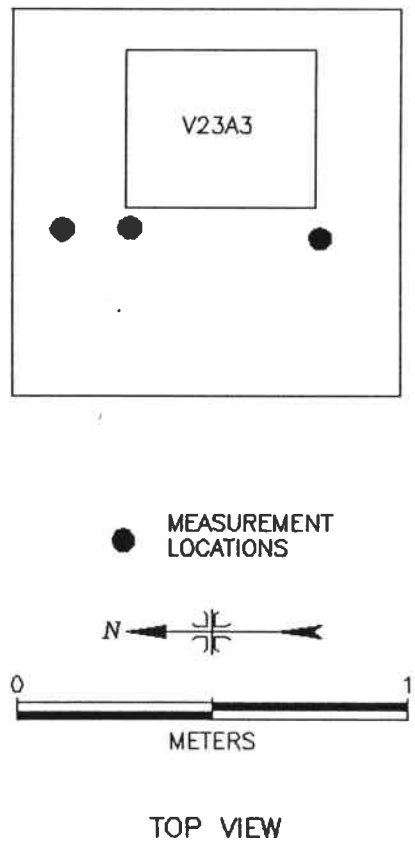


FIGURE 15: Locations for Total and Removable Contamination Measurements in Duct V23A3

JCL16

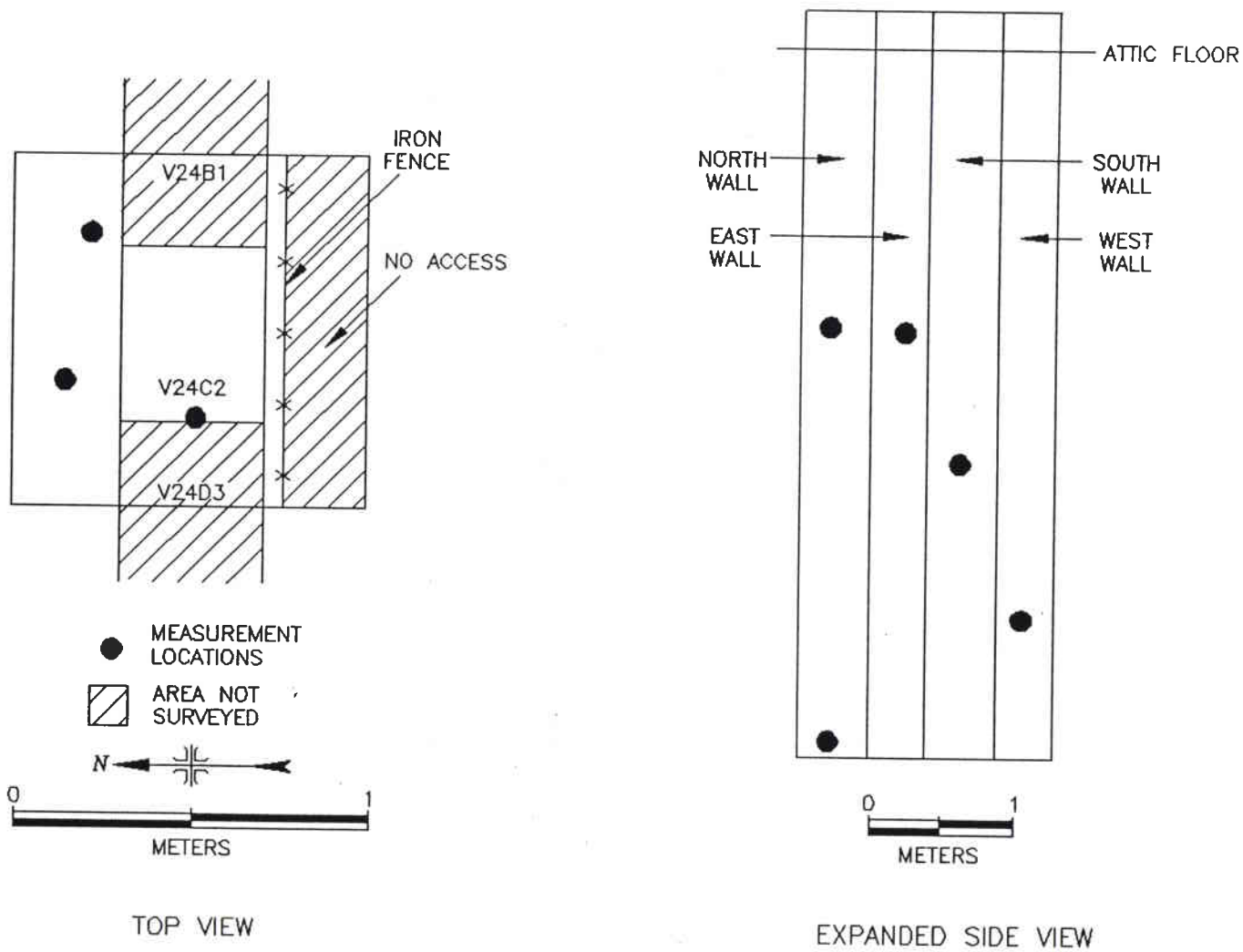


FIGURE 16: Locations for Total and Removable Contamination Measurements in Duct V24C2

JCL17

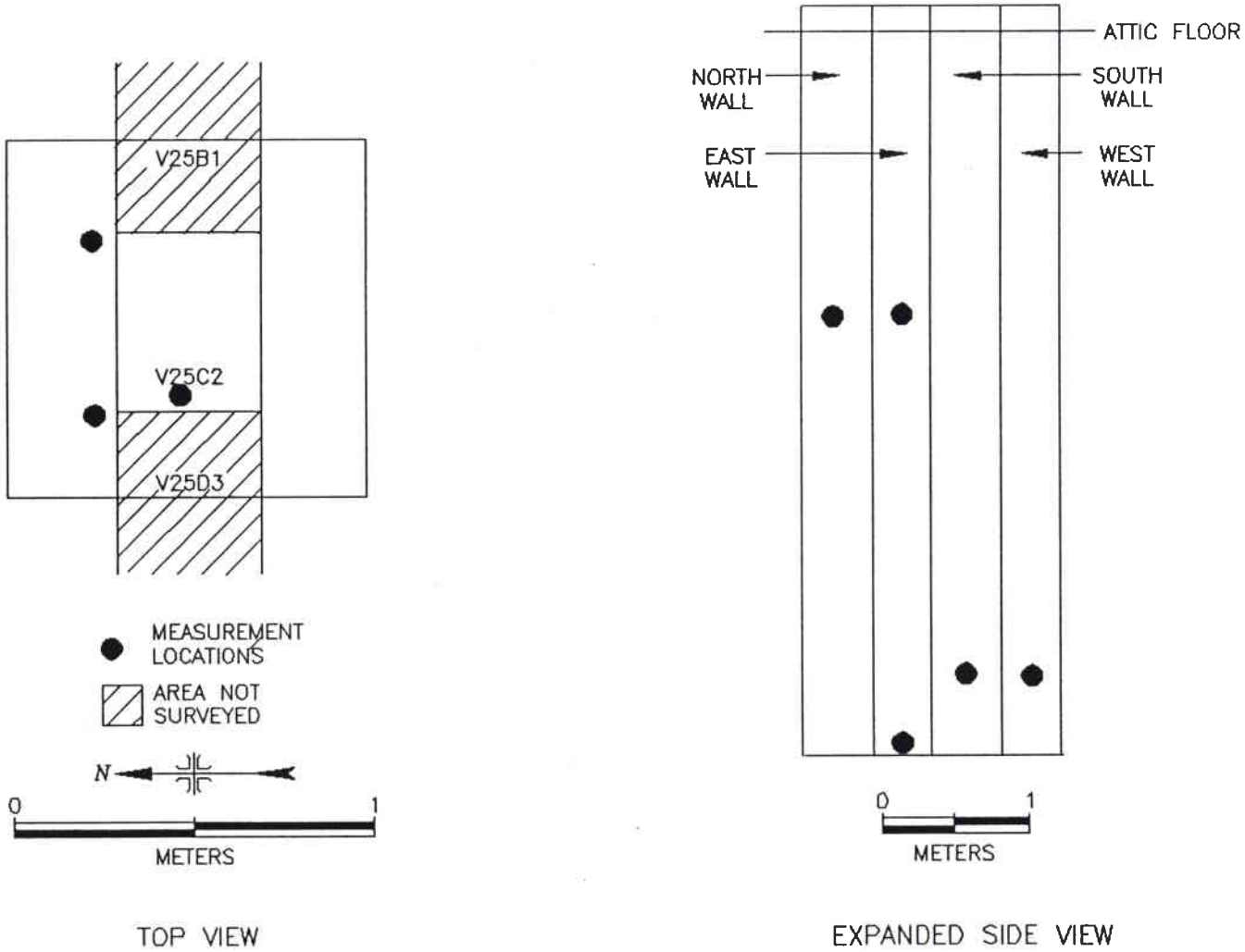
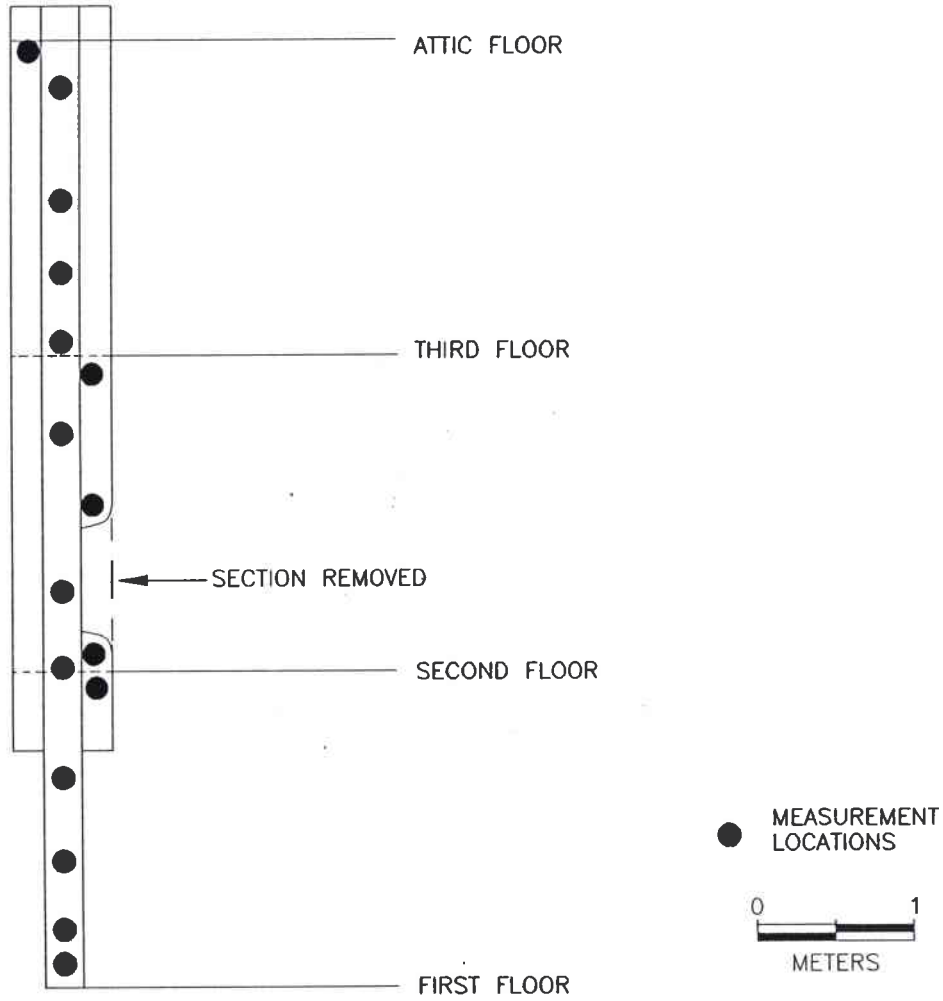


FIGURE 17: Locations for Total and Removable Contamination Measurements in Duct 25C2

JCL18



EXPANDED SIDE VIEW

FIGURE 18: Locations for Total and Removable Contamination Measurements in Duct V30A1

JCL19

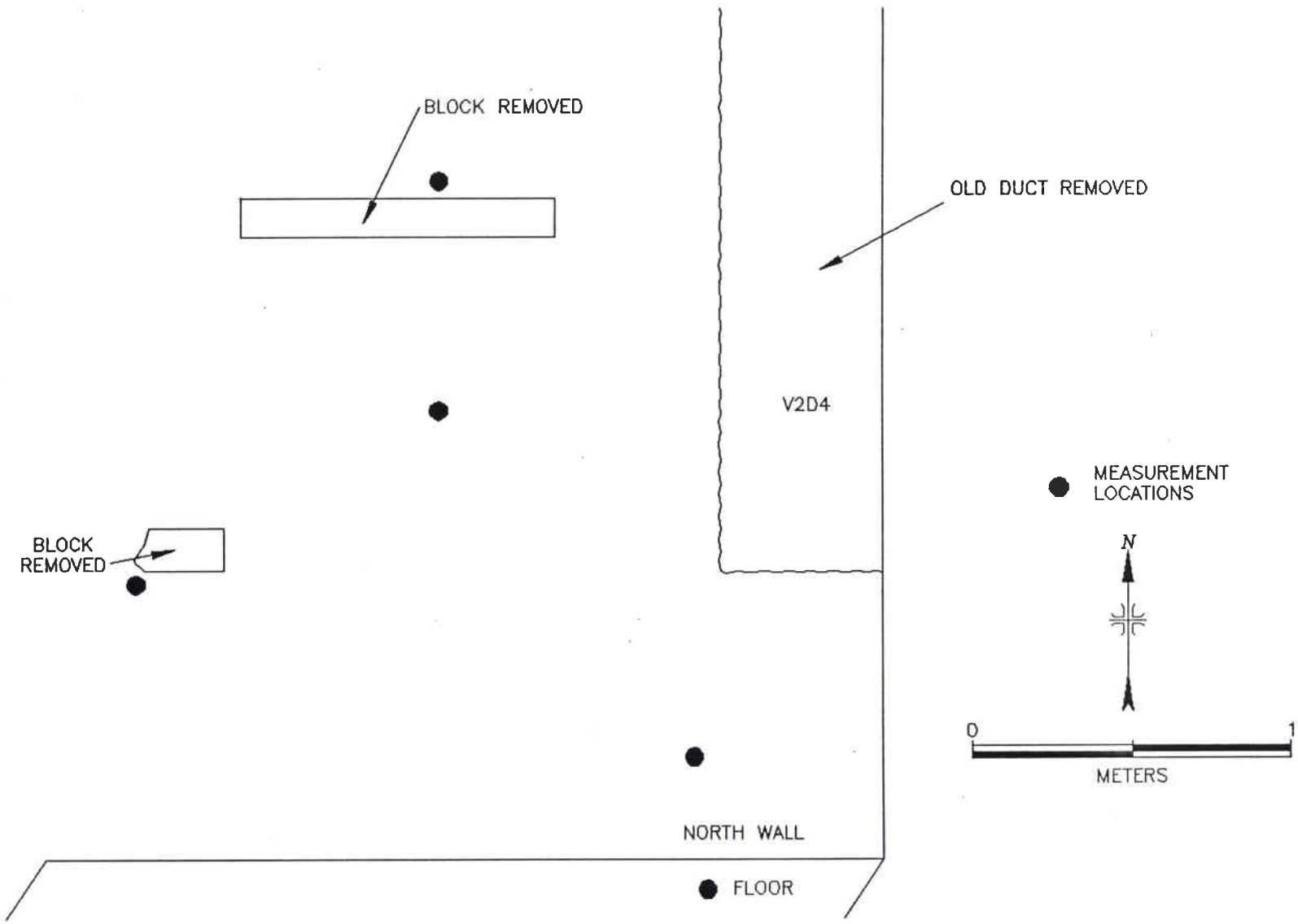


FIGURE 19: Locations for Total and Removable Contamination Measurements on the Fourth Floor Near Duct V2D4

JCL20

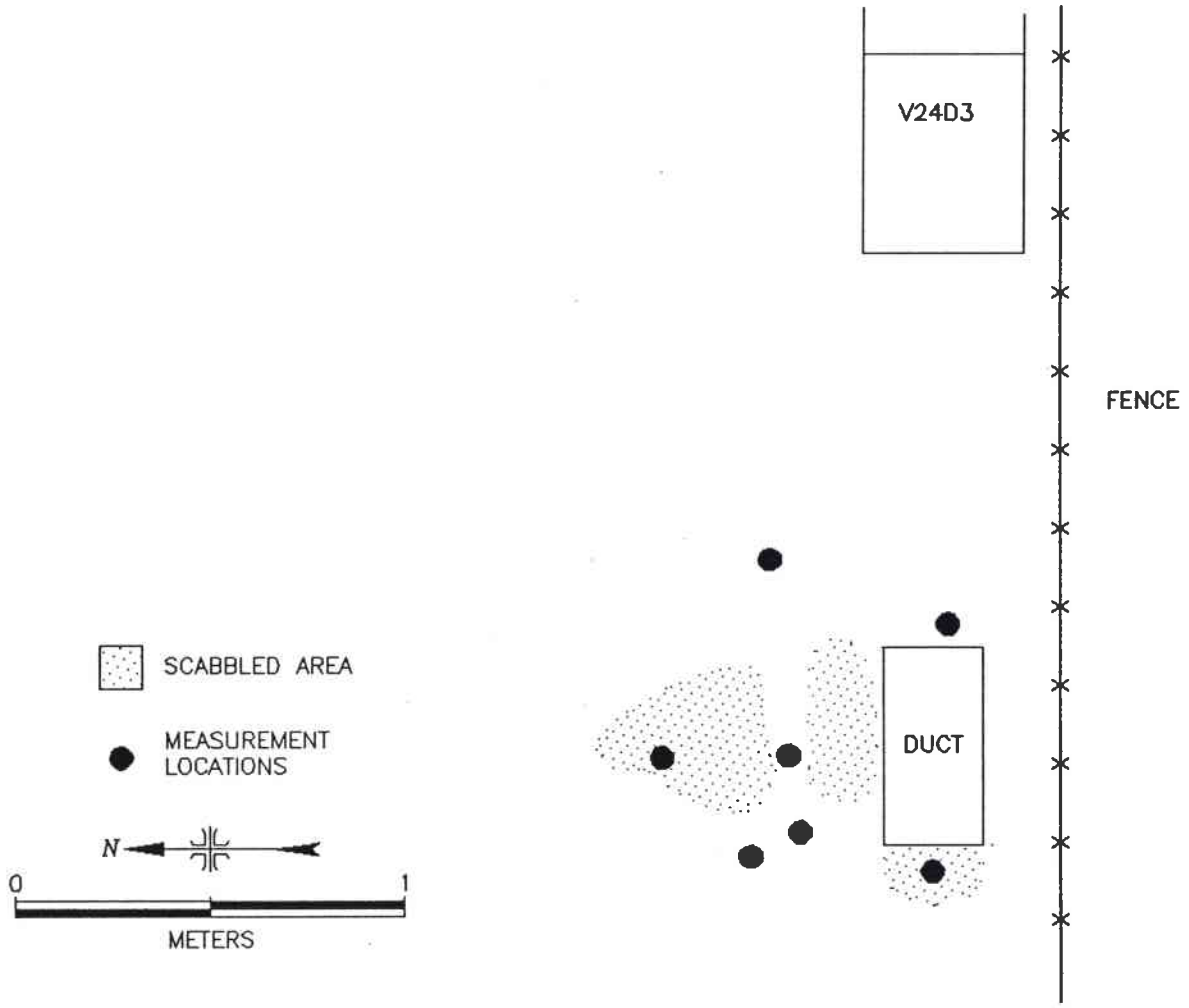


FIGURE 20: Locations for Total and Removable Contamination Measurements on the Fourth Floor Near Duct V24D3

JCL21

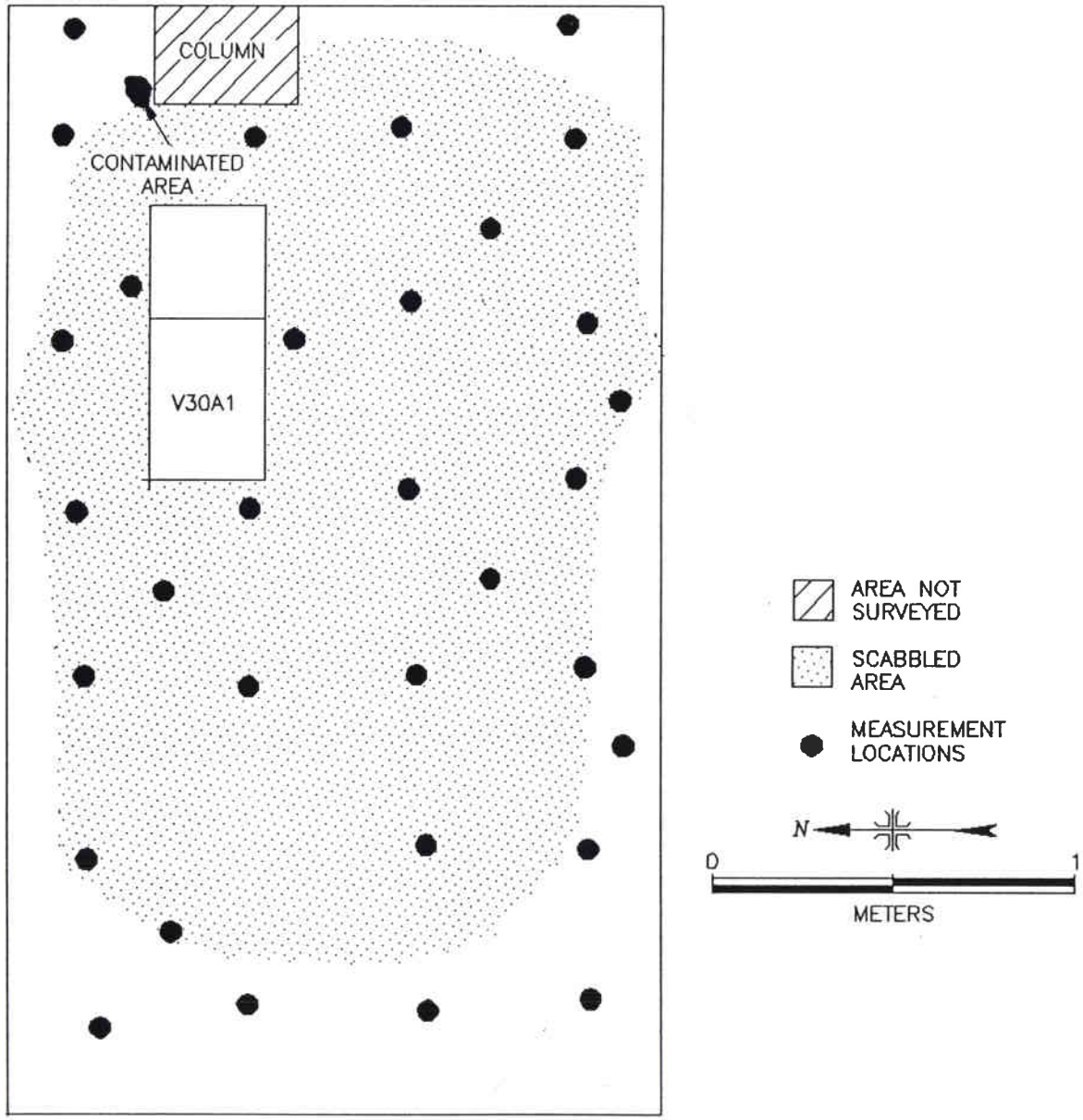


FIGURE 21: Locations for Total and Removable Contamination Measurements on the Fourth Floor Near Duct V30A1

JCL22

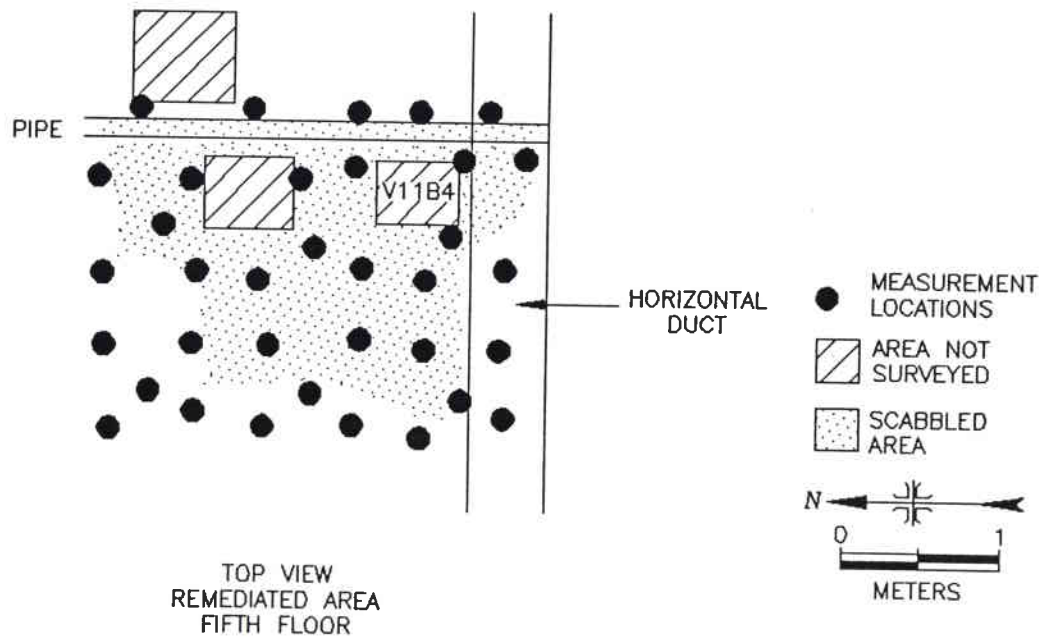


FIGURE 22: Locations for Total and Removable Contamination Measurements on the Fifth Floor Near Duct V11B4

JCL23

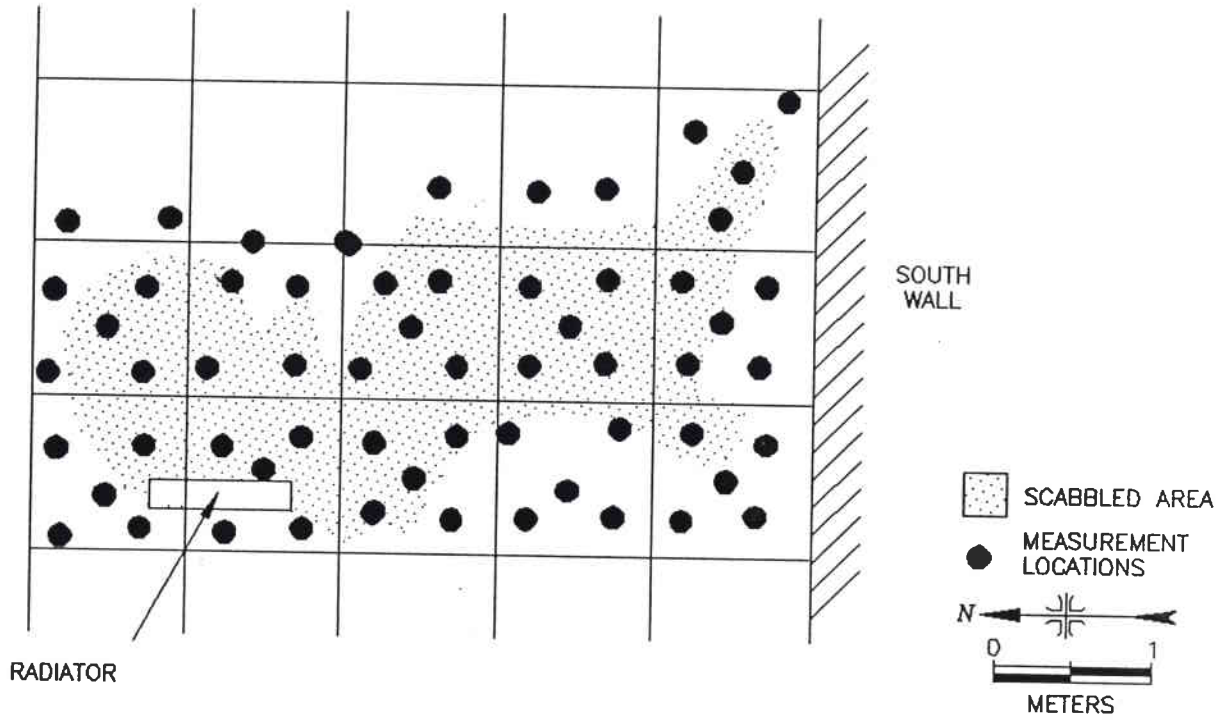


FIGURE 23: Locations for Total and Removable Contamination Measurements on the Southwest End of the Fifth Floor

TABLE 1

SUMMARY OF SURFACE CONTAMINATION MEASUREMENTS
JONES CHEMICAL LABORATORY
UNIVERSITY OF CHICAGO
CHICAGO, ILLINOIS

Duct or Location	Number of Measurements	Total Contamination		Removable Contamination	
		Alpha (dpm/100 cm^2) Range of Measurements	Beta-gamma (dpm/100 cm^2) Range of Measurements	Alpha (dpm/100 cm^2) Range of Measurements	Beta-gamma (dpm/100 cm^2) Range of Measurements
V1C3	12	<18- 54	<360-2600	<3-5	<6-7
V1F1	13	<18- 62	<360-2600	<3-5	<6-9
V2A2	14	≤18	<360-2200	<3	≤6
V2D4	14	<18- 71	<360-2100	≤3	<6-8
V3A0	11	<18- 36	<360-2300	<3-5	<6-7
V9A4	9	<18- 45	520-1900	<3-9	<6-7
V11B4	14	<18-170	<360-2400	<3-10	<6-19
V12A3	9	<18- 71	<360-2300	≤3	<6-7
V13A4	14	<18- 98	<360-2100	<3-7	<6-9
V20A3	6	<18- 45	670-2100	≤3	≤6
V21B3	6	<18- 36	1300-2600	<3-7	≤6
V23A3	3	45- 71	1000-5100	≤3	<6
V24C2	8	<18- 27	1300-2300	<3-5	<6
V25C2	9	<18- 62	640-2400	≤3	<6
V30A1	15	<18- 45	<360-1800	<3-9	<6-20
Fourth Floor Near V2D4	5	45- 98	610-2000	<3-7	<6-8
Fourth Floor Near V24D3	7	<18-130	<360-3500	≤3	<6
Fourth Floor Near V30A1	33	<18- 80	<360- 880	<3-9	<6-9
Fifth Floor Near V11B4	35	<18- 98	<360- 940	<3-7	<6-8
Fifth Floor SW end	21	<18-190	<360-4200	≤3	≤6

[a]Refer to Figures 4-23.

TABLE 2

RADIONUCLIDE CONCENTRATIONS IN MISCELLANEOUS SAMPLES
JONES CHEMICAL LABORATORY
UNIVERSITY OF CHICAGO
CHICAGO, ILLINOIS

Sample Description	Radionuclide Concentration (pCi/g)							
	Ra-226	Th-228	Th-232	U-234	U-235	U-238	Pu-238	Pu-239/240
V30A1-Debris	13.3 ± 0.7[a]	1.0 ± 0.2	2.7 ± 0.7	0.8 ± 0.1	0.1 ± 0.1	0.7 ± 0.1	<0.1	0.1 ± 0.2
V30A1-Debris	3.9 ± 0.4	1.0 ± 0.1	3.2 ± 0.6	3.8 ± 0.2	0.2 ± 0.1	3.9 ± 0.2	<0.1	0.1 ± 0.1
Roof Tile	2.1 ± 0.8	0.8 ± 0.4	1.8 ± 1.3	0.2 ± 0.1	<0.1	0.2 ± 0.1	<0.1	0.1 ± 0.1
Roof Tile	2.9 ± 0.8	1.7 ± 0.4	3.9 ± 1.2	1.8 ± 0.2	0.1 ± 0.1	1.5 ± 0.2	0.1 ± 0.1	0.1 ± 0.1
V2D4 - Residue	2.2 ± 1.7	<1.9	<1.1	-[b]	<1.2	8.9 ± 4.3	-	-
V1F1 - Debris	2.1 ± 1.0	0.7 ± 0.8	<1.2	-	0.8 ± 2.1	3.0 ± 7.0	-	-
Brick from Wall	1.6 ± 0.3	0.5 ± 0.2	1.5 ± 0.5	-	<0.3	1.3 ± 1.0	-	-
V1B3-Debris	3.7 ± 0.4	1.0 ± 0.2	3.2 ± 0.8	-	0.5 ± 0.6	5.7 ± 0.9	-	-
Residue from blower near V24D3	2.3 ± 2.8	0.4 ± 1.2	3.1 ± 2.5	-	14.3 ± 6.1	450 ± 28[c]	-	-

[a]Uncertainties represent the 95% confidence levels, based only on counting statistics; additional laboratory uncertainties of 6 to 10% have not been propagated in these data.
[b]Dash indicates analysis not performed.
[c]Blower was removed and subsequent surveys verified that contamination levels had been reduced to within guidelines.

REFERENCES

1) Argonne National Laboratory, Formerly Utilized MED/AEC Sites Remedial Action Program Radiological Survey of the George Herbert Jones Chemical Laboratory, The University of Chicago, Chicago, Illinois, Argonne, Illinois, May, 1982.

2) Argonne National Laboratory, Formerly Utilized MED/AEC Sites Remedial Action Program Report of the Decontamination of Jones Chemical Laboratory, Ryerson Physical Laboratory, and Eckhart Hall The University of Chicago, Chicago, Illinois, Argonne, Illinois, August, 1984.

3) Argonne National Laboratory, Formerly Utilized MED/AEC Sites Remedial Action Program Project Management Plan for the Decontamination of Jones Laboratory, Ryerson Physical Laboratory and Eckhart Hall, The University of Chicago, Chicago, Illinois, Argonne, Illinois, January 1984.

4) Bechtel National, Inc., Remedial Action Work Plan At University of Chicago, Chicago, Illinois, Revision 1, Oak Ridge, TN, July 1987.

5) Bechtel National, Inc., Letter Characterization Report for the George Herbert Jones Chemical Laboratory at the University of Chicago Site, Chicago, Illinois, Oak Ridge, TN.

6) Bechtel National, Inc., Post-Remedial Action Report for the George Herbert Jones Chemical Laboratory at the University of Chicago Site, Draft, Oak Ridge, TN, September 1988.

APPENDIX A

MAJOR SAMPLING AND ANALYTICAL EQUIPMENT

APPENDIX A

MAJOR SAMPLING AND ANALYTICAL EQUIPMENT

The display or description of a specific product is not to be construed as an endorsement of that product or its manufacturer by the authors or their employer.

A. Direct Radiation Measurements

Eberline "RASCAL"
Portable Ratemeter-Scaler
Model PRS-1
(Eberline, Santa Fe, NM)

Eberline PRM-6
Portable Ratemeter
(Eberline, Santa Fe, NM)

Eberline Alpha Scintillation Detector
Model AC-3-7
(Eberline, Santa Fe, NM)

Eberline Beta-Gamma "Pancake" Detector
Model HP-260
(Eberline, Santa Fe, NM)

Victoreen NaI Scintillation Detector
Model 489-55
(Victoreen, Cleveland, Ohio)

B. Laboratory Analyses

Low Background Alpha-Beta Counter
Model LB-5110
(Tennelec, Oak Ridge, TN)

High Purity Germanium Detector
Model GMX-23195-S, 23% Efficiency
(EG&G ORTEC, Oak Ridge, TN)

used in conjunction with:
Lead Shield Model G-16
(Gamma Products, Palos Hills, IL)

Multichannel Analyzer
ND66/680 System
(Nuclear Data, Schaumburg, IL)

Alpha Spectrometry System
Tennelec Electronics
(Tennelec, Oak Ridge, TN)

Surface Barrier Detectors
(EG&G ORTEC, Oak Ridge, TN)

Multichannel Analyzer
Model ND-66
(Nuclear Data, Schaumburg, IL)

APPENDIX B

MEASUREMENT AND ANALYTICAL PROCEDURES

APPENDIX B

MEASUREMENT AND ANALYTICAL PROCEDURES

Surface Scans

Surface scans in the facility were performed by passing the probes slowly over the surface. The distance between the probes and the surface was maintained at a minimum - nominally about 1 cm. Identification of elevated levels was based on increases in the audible signal from the recording or indicating instrument. Combinations of detectors and instrument used for the scans were:

Beta-Gamma	- Pancake GM probe with PRM-6 ratemeter.
Beta-Gamma	- Pancake GM probe with PRS-1 scaler/ratemeter.
Gamma	- NaI scintillation detector (3.2 cm x 3.8 cm crystal) with PRM-6 ratemeter.
Alpha	- ZnS probe with PRS-1 scaler/ratemeter.

Alpha and Beta-gamma Surface Contamination Measurements

Measurements of total alpha radiation level were performed using Eberline Model PRS-1 portable scaler/ratemeters with Model AC-3-7 alpha scintillation probes. Measurements of total beta-gamma radiation levels were performed using Eberline Model PRS-1 portable scaler/ratemeters with Model HP-260 thin-window "pancake" GM probes. Count rates (cpm) were converted to disintegration rates (dpm/100 cm^2) by dividing the net rate by the 4 π efficiency and correcting for the active area of the detector. Effective window areas were 59 cm^2 for the ZnS detectors and 15 cm^2 for the GM detectors. The background count rate for ZnS alpha probes averaged approximately 2 cpm; the average background count rate was approximately 40 cpm for the GM detectors.

Removable Contamination Measurements

Smear measurements were performed on numbered filter paper disks, 47 mm in diameter. Smears were placed in labeled envelopes with the location and other pertinent information recorded. A ZnS alpha scintillation counting system was

used to evaluate individual smears at the site; smears were recounted on a low background proportional counter at the Oak Ridge laboratory.

Sample Analysis

Residue samples were dried, mixed, and a portion sealed in 0.5-liter Marinelli beaker. The quantity placed in the beaker was chosen to reproduce the calibrated counting geometry and ranged from 600 to 800 g of soil. Net soil weights were determined and the samples counted using intrinsic germanium detectors coupled to a Nuclear Data Model ND-680 pulse height analyzer system. Background and Compton stripping, peak search, peak identification, and concentration calculations were performed using the computer capabilities inherent in the analyzer system. Energy peaks used for determination of radionuclides of concern were:

U-235 - 0.144 MeV
U-238 - 0.094 MeV from Th-234 (secular equilibrium assumed)
Ra-226 - 0.609 MeV from Bi-214 (secular equilibrium assumed)
Th-232 - 0.911 MeV from Ac-228 (secular equilibrium assumed)

The spectra were also reviewed for the presence of other radionuclides.

Analysis of Miscellaneous Samples

Samples of miscellaneous material (debris, residues, tile, and roof) were crushed, as necessary, and placed in various size containers chosen to reproduce a calibrated counting geometry. Analysis was performed using the same procedure as described above for soil samples.

Alpha Spectrometry for Isotopic Uranium

Aliquots of soil were dissolved by pyrosulfate fusion and precipitated with barium sulfate. The barium sulfate precipitates were redissolved and uranium separated by liquid - liquid extraction. Uranium was then precipitated with a

cerium fluoride carrier and counted using surface barrier detectors (ORTEC), alpha spectrometers (Tennelec), and an ND-66 Multichannel Analyzer (Nuclear Data).

Uncertainties and Detection Limits

The uncertainties associated with the analytical data presented in the tables of this report, represent the 95% confidence levels for that data. These uncertainties were calculated based on both the gross sample count levels and the associated background count levels. When the net sample count was less than the 95% statistical deviation of the background count, the sample concentration was reported as less than the detectable limits of the procedures. Because of variations in background levels and Compton contributions from other radionuclides in samples, the detection limits differ from sample to sample. Additional uncertainties of $\pm$ 6 to 10%, associated with sampling and laboratory procedures, have not been propagated into the data presented in this report.

Calibration and Quality Assurance

Laboratory and field survey procedures are documented in manuals developed specifically for the Oak Ridge Associated Universities' Radiological Site Assessment Program.

With the exception of the measurements conducted with portable gamma scintillation survey meters, instruments were calibrated with NBS-traceable standards. The calibration procedures for the portable gamma instruments are performed by comparison with an NBS calibrated pressurized ionization chamber.

Quality control procedures on all instruments included daily background and check-source measurements to confirm equipment operation within acceptable statistical fluctuations. The ORAU laboratory participates in the EPA and EML Quality Assurance Programs.

APPENDIX C

SUMMARY OF RADIATION GUIDELINES APPLICABLE TO THE UNIVERSITY OF CHICAGO

SUMMARY OF RADIATION GUIDELINES
APPLICABLE TO THE UNIVERSITY OF CHICAGO

BASIC DOSE LIMITS

The basic limit for the annual radiation dose received by an individual member of the general public is 100 mrem/yr.

SOIL (LAND) GUIDELINES (MAXIMUM LIMITS FOR UNRESTRICTED USE)

Radionuclide	Soil Concentration (pCi/g above background)[a,b,c]
Radium-226 Radium-228 Thorium-232 Thorium-232	5 pCi/g, averaged over the first 15 cm of soil below the surface; 15 pCi/g when averaged over any 15-cm-thick soil layer below the surface.
Other radionuclides*	Soil guidelines will be calculated on a site-specific basis using the DOE manual developed for this use.*

No official uranium criteria were derived; however, for comparison purposes the 150 pCi/g limit derived for the National Guard Armory, was used. Refer to *Argonne National Laboratory. Derivation of a Uranium Residual Radioactivity Guideline for the National Guard Armory in Chicago, Illinois, Chicago, IL, May 1987.

STRUCTURE GUIDELINES (MAXIMUM LIMITS FOR UNRESTRICTED USE)

Airborne Radon Decay Products

Generic guidelines for concentrations of airborne radon decay products shall apply to existing occupied or habitable structures on private property that are intended for unrestricted use; structures that will be demolished or buried are excluded. The applicable generic guidelines (40 CFR 192) is: In any occupied or habitable building, the objective of remedial action shall be, and reasonable effort shall be made to achieve an annual average (or equivalent) radon decay product concentration (including background) not to exceed 0.02 WL.[d] In any case, the radon decay product concentration (including background) shall not exceed 0.03 WL. Remedial actions are not required in order to comply with this guideline when there is reasonable assurance that residual radioactive materials are not the cause.

External Gamma Radiation

The average level of gamma radiation inside a building or habitable structure on a site to be released for unrestricted use shall not exceed the background level by more than 20 μR/h.

Indoor/Outdoor Structure Surface Contamination

Radionuclide[f]	Allowable Residual Surface Contaminations (dpm/100 cm^2) Average[g,h]	Maximum[h,i]	Removable[h,j]
Transurancis, Ra-226, Ra-228, Th-230, Th-228Pa-231, Ac-227, I-125, I-129	100	300	20
Th-Natural, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1,000	3,000	200
U-Natural, U-235, U-238, and associated decay products	5,000 α	15,000 α	1,000 α
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above	5,000 β - γ	15,000 β - γ	1,000 β - γ

[a]These guidelines take into account ingrowth of radium-226 from thorium-230 and of radium-228 from thorium-232, and assume secular equilibrium. If either thorum-230 and radium-226 or thorium-232 and radium-228 are both present, not in secular equilibrium, the guidelines apply to the higher concentrations. If other mixtures of radionuclides occur, the concentrations of individual radionuclides shall be reduced so that the dose of the mixtures will not exceed the basic dose limit.

[b]These guidelines represent unrestricted-use residual concentrations above background averaged across any 15-cm-thick layer at any depth and over any contiguous 100-m^2 surface area.

[c]Localized concentrations in excess of these limits are allowable provided that the average concentration over a 100-m^2 area does not exceed these limits.

[d]A working level (WL) is any combination of short-lived radon decay products in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy.

[e]As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

[f]Where surface contamination by both alpha-and beta-gamma-emitting radionuclides exists, the limits established for alpha-and-beta-gamma-emitting radionuclides should apply independently.

[g]Measurements of average contamination should not be averaged over more than 1 m^2. Of objects of less surface area. The average shall be derived for each such object.

[h]The average and maximum radiation levels associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h and 1.0 mrad/h, respectively, at 1 cm.

[i]The maximum contamination level applies to an area of not more than 100 cm^2.

[j]The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and measuring the amount of radioactive material on the wipe with an appropriate instrument of know efficiency. When removable contamination on objects of surface area less than 100 cm^2 is determined, the activity per unit area should be based on the actual area and the neither surface should be wiped. The numbers in this column are maximum amounts.