ORISE
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION

May 25, 2007

Ms. Susan Heston
Environmental Engineer
U.S. Department of Energy
Argonne Site Office (ASO)
9800 South Cass Avenue
Argonne, Illinois 60439

DOE CONTRACT NO. DE-AC05-06OR23100
SUBJECT: FINAL REPORT—VERIFICATION SURVEY OF THE BUILDING 315 ZERO POWER REACTOR-6 FACILITY, ARGONNE NATIONAL LABORATORY-EAST, ARGONNE, ILLINOIS

Dear Ms. Heston:

The Oak Ridge Institute for Science and Education (ORISE) performed verification survey activities in selected portions of the Building 315 Zero Power Reactor-6 at the Argonne National Laboratory-East (ANL-E) facility in Argonne, Illinois on September 26 and 27, 2006. These survey activities were requested by the U.S. Department of Energy (DOE) and were performed in accordance with a survey plan that was approved by the DOE. The survey activities included alpha plus beta and gamma surface scans, alpha and beta direct measurements, and removable activity sampling. A preliminary letter report documenting the survey results was submitted on November 8, 2006. The preliminary letter report included ORISE's exposure rate measurements; however, it was later determined that the exposure rate instrument malfunctioned. A draft report was submitted on February 22, 2007; DOE did not have any comments on the draft report and requested that ORISE submit the final report. The enclosed final report documenting the verification survey activities and results does not include exposure rate measurements.

If you have any questions or comments, please direct them to me at 865.576.0065 or Scott Kirk at 865.574.0685.

Sincerely,

Wade C. Adams
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VERIFICATION SURVEY OF THE BUILDING 315 ZERO POWER REACTOR-6 FACILITY ARGONNE NATIONAL LABORATORY-EAST ARGONNE, ILLINOIS

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Argonne Site Office

FINAL REPORT

MAY 2007

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VERIFICATION SURVEY OF THE BUILDING 315 ZERO POWER REACTOR-6 FACILITY ARGONNE NATIONAL LABORATORY-EAST ARGONNE, ILLINOIS

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ABBREVIATIONS AND ACRONYMS

α	alpha
β-γ	beta-gamma
ε_i	instrument efficiency
ε_s	surface efficiency
ε_{total}	total efficiency
μR/h	microroentgens per hour
ANL-E	Argonne National Laboratory - East
ASO	Argonne Site Office
b_i	number of background counts in the interval
BKG	background
cm	centimeter
cm^2	square centimeter
cpm	counts per minute
CR	characterization report
d′	index of sensitivity
DOE	U.S. Department of Energy
DP	decommissioning plan
dpm	disintegrations per minute
dpm/100 cm^2	disintegrations per minute per 100 square centimeters
FSS	final status survey
FSSP	final status survey plan
FSSR	final status survey report
ha	hectare
IEAV	Independent Environmental Assessment and Verification
ISM	integrated safety management
ISO	International Organization for Standardization
ITP	Intercomparison Testing Program
IV	independent verification
IVS	independent verification survey
IVT	Independent Verification Team
JHA	job hazard analysis
keV	kiloelectron volts
m	meter
m^2	square meter
MACE	Melt Attack and Coolability Experiments
MAPEP	Mixed Analyte Performance Evaluation Program
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MCCI	Melt Coolability and Concrete Interaction
MDA	minimum detectable activity
MDC	minimum detectable concentration
MDCR	minimum detectable count rate
MeV	megaelectron volts

ABBREVIATIONS AND ACRONYMS (continued)

min	minute
mg/cm^2	milligrams per square centimeter
mm	millimeter
mrad/h	millirad per hour
mrem/yr	millirem per year
NaI	sodium iodide
NIST	National Institute of Standards and Technology
NORM	naturally occurring radioactive material
NRIP	NIST Radiochemistry Intercomparison Program
ORISE	Oak Ridge Institute for Science and Education
ROC	radionuclides-of-concern
s	second
SU	survey unit
TRU	transuranics
ZPR	Zero Power Reactor
ZPR6DDP	Zero Power Reactor-6 Decontamination and Decommissioning Project

VERIFICATION SURVEY OF THE
BUILDING 315 ZERO POWER REACTOR-6 FACILITY
ARGONNE NATIONAL LABORATORY-EAST
ARGONNE, ILLINOIS

INTRODUCTION AND SITE HISTORY

Argonne National Laboratory-East (ANL-E) is owned by the U.S. Department of Energy (DOE) and is operated under a contract with the University of Chicago. Fundamental and applied research in the physical, biomedical, and environmental sciences are conducted at ANL-E and the laboratory serves as a major center of energy research and development. Building 315, which was completed in 1962, contained two cells, Cells 5 and 4, for holding Zero Power Reactor (ZPR)-6 and ZPR-9, respectively. These reactors were built to increase the knowledge and understanding of fast reactor technology. ZPR-6 was also referred to as the Fast Critical Facility and focused on fast reactor studies for civilian power production. ZPR-9 was used for nuclear rocket and fast reactor studies. In 1967, the reactors were converted for plutonium use. The reactors operated from the mid-1960's until 1982 when they were both shut down. Low levels of radioactivity were expected to be present due to the operating power levels of the ZPR's being restricted to well below 1,000 watts.

To evaluate the presence of radiological contamination, DOE characterized the ZPRs in 2001. Currently, the Melt Attack and Coolability Experiments (MACE) and Melt Coolability and Concrete Interaction (MCCI) Experiments are being conducted in Cell 4 where the ZPR-9 is located (ANL 2002 and 2006).

ANL has performed final status surveys (FSS) on Cell 5 that formerly contained the ZPR-6. For the FSS, ANL is following the guidance presented in Draft NUREG/CR-5849, "Manual for Conducting Radiological Surveys in Support of License Termination," and portions of NUREG-1575, Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)," as appropriate and DOE Order 5400.5, "Radiation Protection of the Public and Environment." (NRC 1992 and 2000 and DOE 1993 and 1995). At the time of the FSS, all contaminated systems and associated components within the scope of the surveyed areas had been removed (ANL 2006).

DOE's Argonne Site Office (ASO) is responsible for oversight of the Building 315, Zero Power Reactor-6 remedial action and FSS activities. It is the policy of the DOE to perform independent (third party) verification of FSS activities (DOE 2006). The purpose of these independent verifications (IV) is to confirm that remedial actions have been effective in meeting established and site-specific guidelines and that the documentation accurately and adequately describes the radiological conditions at the site. The Oak Ridge Institute for Science and Education (ORISE) has been designated by the DOE as the organization responsible for this task at ANL, and has been requested to verify the final radiological status of the cleanup activities associated with the Building 315, ZPR-6 Decontamination and Decommissioning Project (ZPR6DDP) at ANL-E.

SITE DESCRIPTION

ANL-E is located near the city of Lemont, in DuPage County, Illinois approximately 43 kilometers [km (27 miles)] southwest of downtown Chicago (Figure 1). The ANL-E reservation occupies approximately 690 hectares [ha (1,700 acres)] of which laboratory and support facilities occupy about 80 ha (200 acres) and the remaining 610 ha (1,500 acres) is devoted to forest and landscape areas within the site perimeter (Figure 2). The site lies north of the Des Plaines River Valley, south of Interstate Highway 55, west of Illinois Highway 83, and east of Lemont Road. The site consists of approximately 120 buildings; approximately 30 buildings house either administrative offices or major research programs. The facility is surrounded by the 910 ha (2,280 acres) Waterfall Glen Forest Preserve, which is owned by the DuPage County Forest Preserve District. The terrain is gently rolling, partially wooded, former prairie and farmland with small ponds and streams. The land area surrounding ANL-E consists of residential, commercial, and industrial properties (ANL 2002).

Building 315 is located on Old Bluff Road west of Meridian Road, just east of the Advanced Photon Source (Figure 2). The ZPR-6 and ZPR-9 reactor facilities (Figure 3) are located in blast-resistant, highly reinforced concrete cells which measure 12 meters [m (40 feet)] by 9 m (30 feet) and have a height of 9 m. A 1.5 m (5 feet) thick wall separates Cell 5 (ZPR-6) from its control room. The other walls, floor and ceiling have 1.3 m (4 feet) of reinforced concrete as shielding. Access to the cell is through an airlock from the control room and both ends of the airlock are equipped with steel-plated concrete blast doors. Located in the south corner of the cell is an emergency escape chute. A fuel storage and preparation workroom separates Cells 4 and 5 (ANL 2005 and 2006).

OBJECTIVES

The objectives of the verification survey were to provide independent document reviews and measurement and sampling data for use by the DOE in confirming the radiological status of the

Building 315 ZPR-6 facility, and to determine whether or not this facility satisfies the guideline requirements for release for unrestricted use. This information was then used to determine the adequacy of the ANL FSS documentation and the conclusions reached as to the radiological status of each area relative to the guidelines for the ZPR-6 facility.

DOCUMENT REVIEW

ORISE has reviewed the ANL's decommissioning plan (DP) and final status survey plan (FSSP) for the Building 315 ZPR6DDP for adequacy and appropriateness and a letter documenting this review was submitted to the DOE (ANL 2005 and 2006 and ORISE 2006a). ORISE also reviewed the ANL characterization report (CR) for verification survey planning purposes (ANL 2002). The final survey data was reviewed prior to ORISE's mobilization to the site or while at the site during verification survey activities.

ANL's draft final status survey report (FSSR) was to be reviewed after the verification survey activities were completed and after the issuance of ORISE's interim verification letter report (ORISE 2006b). Due to a delay in the issuance of the FSSR, DOE requested that ORISE submit the draft and final reports prior to ANL's submittal of the FSSR. The draft verification report was submitted to the DOE on February 22, 2007 (ORISE 2007).

PROCEDURES

ORISE performed verification surveys of the ANL Building 315 ZPR-6 facility during the period September 26 and 27, 2006. The survey was performed in accordance with the site-specific survey plan submitted to and approved by the DOE and the ORISE Survey Procedures and Quality Assurance Manuals (ORISE 2006c and d, ORISE 2005). Additional information concerning major instrumentation, sampling equipment, and survey and analytical procedures may be found in Appendices A and B.

The following radiological survey procedures were used by ORISE to conduct verification survey activities on various building surfaces that have been evaluated by ANL and are to be released for unrestricted use. ANL divided areas into structural or system surfaces and classified the survey units (SUs) as Affected Areas, Areas Adjacent to Affected Areas, and Unaffected Areas. These classifications were based on the potential and extent of the area of origin's radiological hazards based on historical process knowledge (ANL 2006).

REFERENCE GRID

The reference grid systems established by ANL were used where possible. Otherwise, measurement locations on ungridded surfaces were referenced to prominent building features.

SURFACE SCANS

Gamma surface scans were performed over 100% of accessible floor surfaces within each SU. Alpha plus beta surface scans were performed on approximately 50% of the accessible floor and lower wall of each SU. Upper surface (greater than two meters) alpha plus beta scans were performed on approximately 10% of the accessible surfaces. Accessibility to some surfaces was restricted due to safety concerns for ORISE personnel; these areas included inside the escape chute and near the crane that remained energized. Particular attention was given to remediated and adjacent surfaces, cracks and joints in the floors and walls, and other locations where residual radioactive material may have accumulated. Scans were performed using gas proportional and sodium iodide (NaI) scintillation detectors coupled to ratemeters or ratemeter-scalers with audible indicators. Locations of elevated direct radiation were noted for further investigation.

SURFACE ACTIVITY MEASUREMENTS

Construction material-specific background measurements were collected from unaffected and/or non-impacted areas of the site for correcting gross activity measurements performed on structural and system surface SUs. Direct measurements for total alpha and total beta activity were performed at five judgmentally selected locations within the Anti Room, the Men's Room, and the North and South Air Locks (Figures 4 through 7). Randomly selected direct measurements were performed at 10, 5, and 20 locations within the Dock, Room S-036, and Cell 5, respectively (Figures 8 through 10). Direct measurements were performed using gas proportional detectors coupled to ratemeter-scalers. Smear samples, for determining removable gross alpha and gross beta activity levels, were collected from each direct measurement location.

INSTRUMENT COMPARISON

Four locations having residual elevated beta activity were selected to conduct survey instrumentation comparisons between ORISE and ANL. Additionally, the instrumentation comparisons were also performed with an ANL provided radioactive check source (SrY-90 #DN642; 0.034 μCi or 75,480 dpm).

SAMPLE ANALYSIS AND DATA INTERPRETATION

Samples and data were returned to ORISE's laboratory in Oak Ridge, Tennessee for analysis and interpretation. Sample analyses were performed in accordance with the ORISE Laboratory Procedures Manual (ORISE 2006e). Dry smear samples were analyzed for gross alpha and gross beta activity using a low-background gas proportional counter. Smear results and direct measurements for total surface activity were converted to units of disintegrations per minute per 100 square centimeters (dpm/100 cm^2). Additional information concerning major instrumentation and analytical procedures is provided in Appendices A and B.

FINDINGS AND RESULTS

DOCUMENT REVIEW

ORISE reviewed ANL's DP and FSSP and a comment letter documenting that review was provided to DOE (ANL 2005 and 2006 and ORISE 2006a). The procedures, methods, and data submitted by ANL were considered to be lacking in detail regarding their calibration source and efficiencies. These questions had not been completely addressed by ANL prior to the verification survey activities. However, ORISE determined through conducting survey instrument comparisons, verifications survey activities, and reviews of the raw data, that ANL's raw data does appropriately document the radiological status of the ZPR-6 facility.

SURFACE SCANS

With the exception of the elevated radiation levels in the Men's Room due to the glazed tile and the disconnected smoke detector, and the slightly elevated alpha activity levels in S-036, the ORISE independent verification surveys (IVS) did not detect any elevated radiation levels above the established guidelines within the ZPR-6 facility. The elevated levels of residual contamination detected in the Men's Room were due to naturally occurring radioactive material (NORM) within the glazed floor and lower wall tile and from the smoke detector which contained radium-226. The elevated alpha activity in Room S-036 was attributed to radon buildup in a closed basement room. ANL personnel removed the smoke detector from the Men's Room and two more radium smoke detectors from other locations outside the surveyed areas.

SURFACE ACTIVITY LEVELS

IVS direct measurement results ranged from -72 to 120 dpm/100 cm^2 for alpha and -760 to 660 dpm/100 cm^2 for beta. Removable activity ranged from 0 to 5 dpm/100 cm^2 for alpha and -5 to 8 dpm/100 cm^2 for beta. The ranges of surface activity levels for the areas surveyed by ORISE are as follows:

Survey Units	Range of Surface Activity Measurements (dpm/100 cm^2)			
	Total Alpha	**Total Beta**	**Removable Alpha[a]**	**Removable Beta[a]**
Anti Room	-43 to 7	-520 to 100	0 to 1	-1 to 8
Men's Room	-36 to 14	-760 to 660	0 to 1	-5 to 5
North Air Lock	-51 to 0	-370 to 270	0 to 3	-4 to 4
South Air Lock	-51 to 29	-440 to -270	0 to 5	-2 to 3
Dock	-72 to 7	-470 to 160	0 to 3	-3 to 3
S-036	14 to 120	-24 to 430	0 to 5	-3 to 4
Cell 5	-51 to 7	-330 to 180	0 to 5	-4 to 5

[a]The minimum detectable activities (MDA) of the analytical procedures for removable alpha and beta activity are 9 and 15 dpm/100 cm^2, respectively.

A complete listing of the verification surface activity results is presented in Table 1. Approximately 70% of the surface activity measurements were negative values. This is due, in part, to the low ambient background levels within the surveyed areas as compared to the area where construction material backgrounds were measured.

INSTRUMENT COMPARISON

As part of the IVS activities, survey instrument measurement comparisons were performed for beta activity at four direct measurement locations. These comparison measurements were used to verify calibration and instrument operations. The results of the comparison effort are reported in Table 2. ORISE's beta activity results ranged from 16 to 1,270 dpm/100 cm^2 and ANL's results ranged from 8 to 379 dpm/100 cm^2. ORISE determined that the discrepancies in the direct measurement calculations were due to several differences in measurement technique, determination of calibration efficiency and detector size.

The discrepancies were attributed to differences in instrument calibration (i.e., 2 π vs. 4 π detector geometry) and direct measurement procedures (i.e., beta shielding and background subtraction). ORISE calibrates instrumentation in accordance with ISO-7503 recommendations (ISO 1988); where the total efficiency for each instrument/detector combination consists of the product of the 2π instrument efficiency (ε_i) and surface efficiency (ε_s): $\varepsilon_{total} = \varepsilon_i \times \varepsilon_s$. ORISE selected Tc-99 as the calibration source as it provides a conservative representation of the primary radionuclides-of-concern (ROC); the ε_i was determined to be 0.39. ISO-7503 recommends an ε_s of 0.25 for beta emitters with a maximum energy of less than 0.4 MeV. Therefore, ORISE's calibration efficiency (ε_{total}) was determined to be 0.1. Appendix B provides additional detail of the ORISE calibration procedures.

ORISE used a gas proportional detector with a physical surface area of 126 cm^2 to determine surface activity levels. ORISE also performed unshielded and shielded beta measurements at each direct and background measurement location. This method accounts for the ambient background within the facility to provide a more accurate evaluation of the beta component for determining direct measurement activity at a specific measurement location.

ANL's total efficiency for each instrument/detector combination consists of the product of the 4π Sr-90 efficiency and the Tc-99 correction factor. Therefore, ANL's calibration efficiency was determined to be 0.4 and the Tc-99 correction factor was determined to be 1.58. ANL used a gas proportional detector with a physical surface area of 100 cm^2. ANL determines the gross activity at the measurement location and subtracts a material specific background (these measurements are unshielded).

For the instrument comparison with the ANL check source, the average Sr-90 source counts observed for the ORISE and ANL instrumentation was 26,553 and 25,120 cpm, respectively. Based on the source activity of 75,480 dpm, the 4π instrument efficiencies were calculated to be 0.35 for

ORISE instrumentation and 0.33 for ANL instrumentation. Therefore, the source check result was within the expected 4π efficiency values. However, it should be noted that the Sr-90 efficiency listed for the ANL instrumentation that was used in this comparison was listed as 0.40.

COMPARISON OF RESULTS WITH GUIDELINES

The ROCs are fission and activation products (and associated progeny); depleted, natural and enriched uranium; and transuranics (TRU). The major contaminants identified by ANL are U-238, U-235, U-234, Th-234, and Cs-137. Other radionuclides include Co-60, Sr-90 and TRU (ANL 2002).

The applicable surface activity guidelines from DOE Order 5400.5 (DOE 1993 and 1995) are those for transuranics and beta-gamma emitters which are provided in Appendix C. ANL elected to use the more restrictive alpha and beta-gamma activity guidelines for unrestricted release of the ZPR-6 facility; the most restrictive surface activity release guidelines are as follows:

Total Surface Activity (dpm/100 cm^2)			
Radionuclides	**Average**	**Maximum**	**Removable**
Alpha Emitters	100	300	20
Beta-Gamma Emitters	1000	3000	200

The DOE's exposure rate guideline is 20 μR/h above background (DOE 1993).

With the exception of direct measurement location 35 in Room S-036 (Table 1), all direct surface activity measurements were below the average surface activity release criteria. Further investigations in the immediate 1 m^2 area indicated that this elevated alpha activity location was less than 200 cm^2 and would not exceed the grid block averaging criteria.

During ORISE's performance of exposure rate measurements, the radiation instrumentation for determining exposure rates malfunctioned and ORISE was unable to independently assess exposure rates. Hence, ORISE performed a review on ANL's exposure rate measurements to determine the adequacy of ANL's FSS exposure rate results. Based on this review and ORISE's independent gamma radiation surface scans, which indicated gamma radiation levels within the facility were at background levels, it is ORISE's opinion that ANL's FSS exposure rate results satisfy DOE's exposure rate release criteria.

SUMMARY

During the period of September 27 and 28, 2006, at the request of the U.S. Department of Energy (DOE) Argonne Site Office, the Oak Ridge Institute for Science and Education (ORISE) conducted independent verification radiological survey activities at Argonne National Laboratory's Building 315, Zero Power Reactor-6 facility in Argonne, Illinois. Independent verification survey activities included document and data reviews, alpha plus beta and gamma surface scans, alpha and beta surface activity measurements, and instrumentation comparisons. An interim letter report and a draft report, documenting the verification survey findings, were submitted to the DOE on November 8, 2006 and February 22, 2007, respectively (ORISE 2006b and 2007).

Based upon ORISE's verification survey results, Argonne National Laboratory's (ANL's) surface activity and exposure rate measurements are commensurate with the site-specific release criteria. Therefore, it is ORISE's opinion that the radiological conditions for ANL's Zero Power Reactor-6 facility are commensurate with the cleanup criteria for the final status survey (FSS) as specified in DOE Order 5400.5 (ANL 2006).

Survey instrumentation comparisons were also performed between ORISE and ANL using the SrY-90 radioactive check source provided by ANL and at four direct measurement locations of residual surface beta activity. ORISE identified differences in calibration and direct measurement techniques that accounted for the discrepancies with the instrument comparison data. However, through a review of the ANL preliminary direct measurement data, ORISE was able to determine that ANL's FSS surface activity levels and exposure rates satisfy the DOE guidelines for unrestricted use.

FIGURES

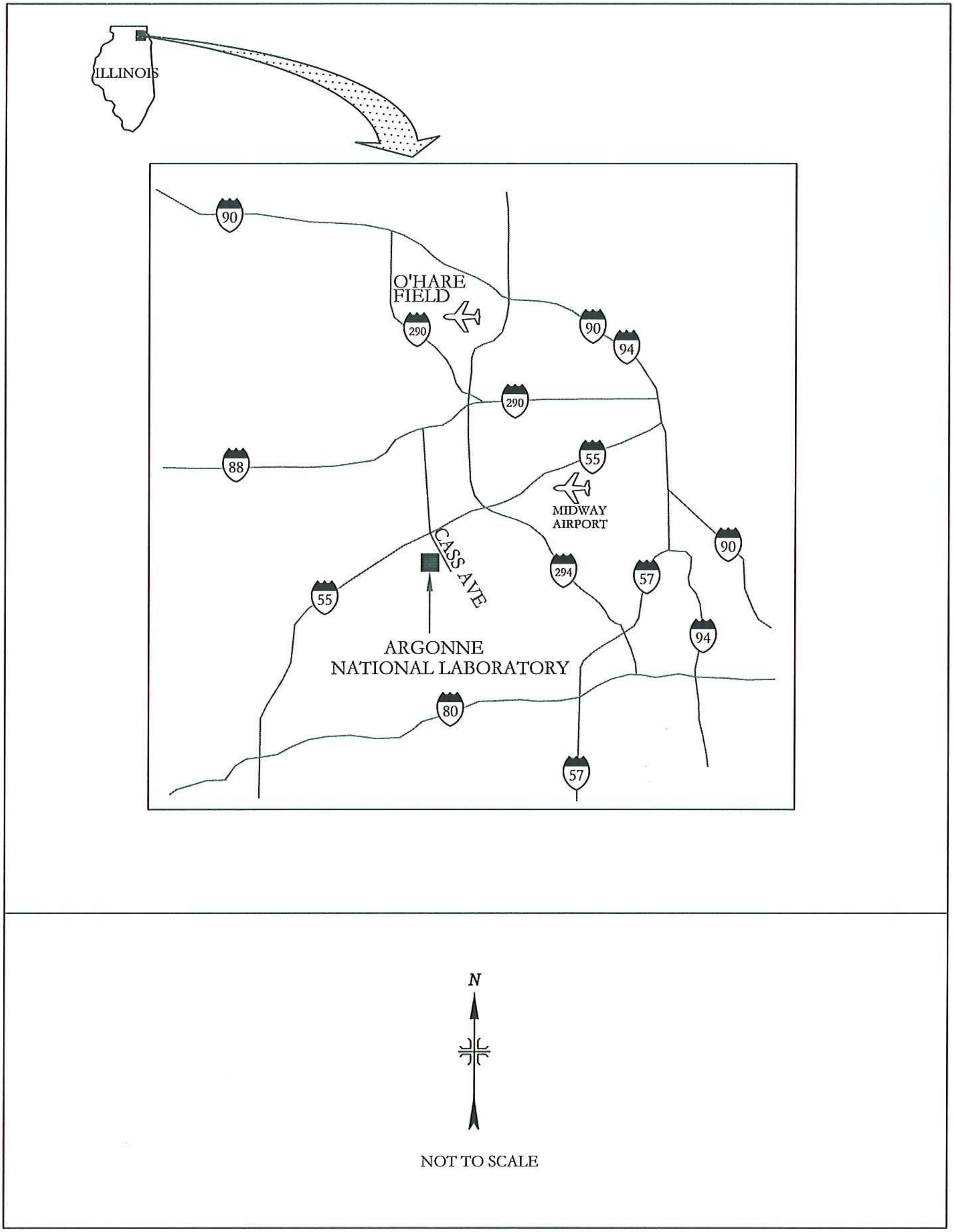

FIGURE 1: Location of Argonne National Laboratory - East

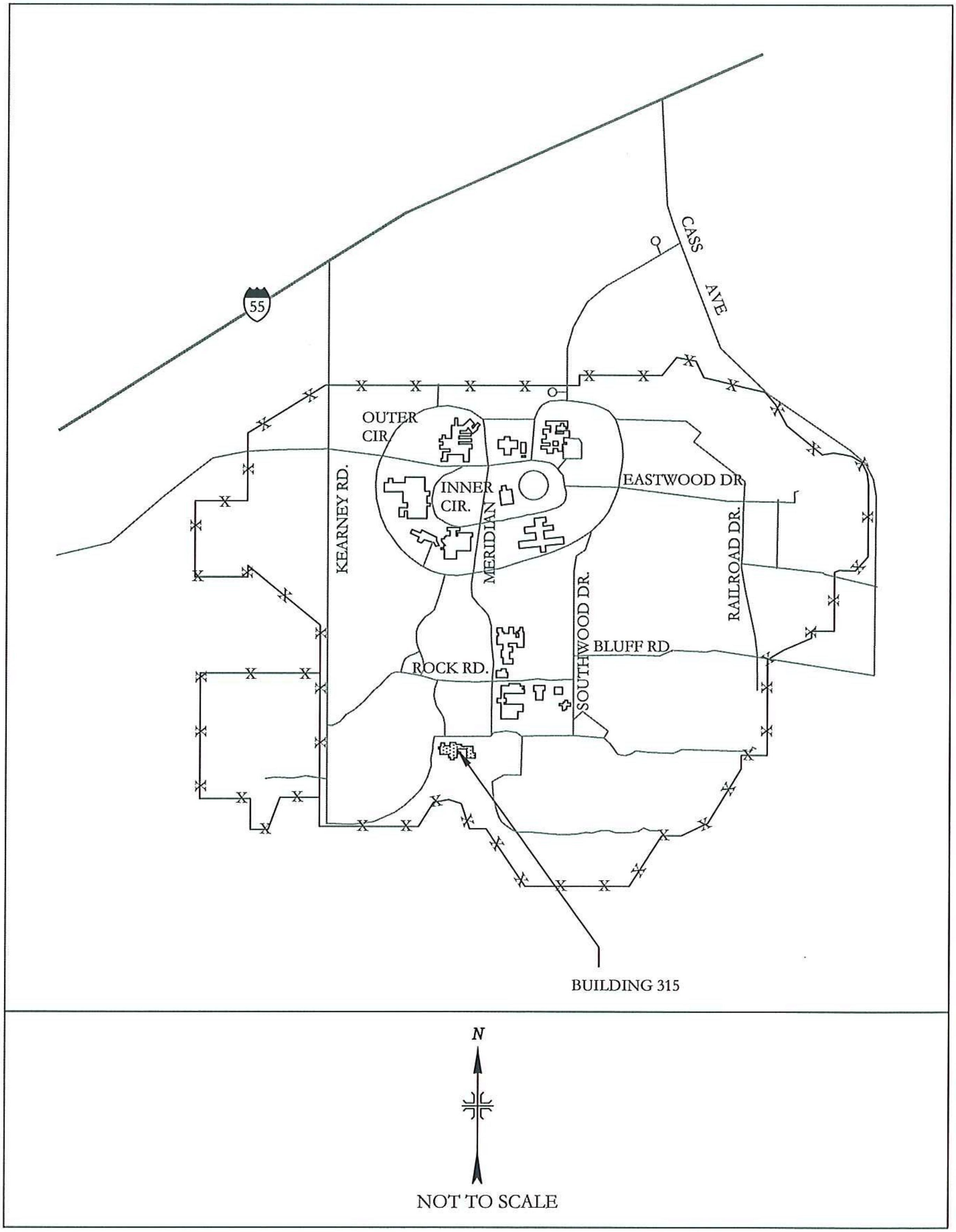

FIGURE 2: Location of Building 315

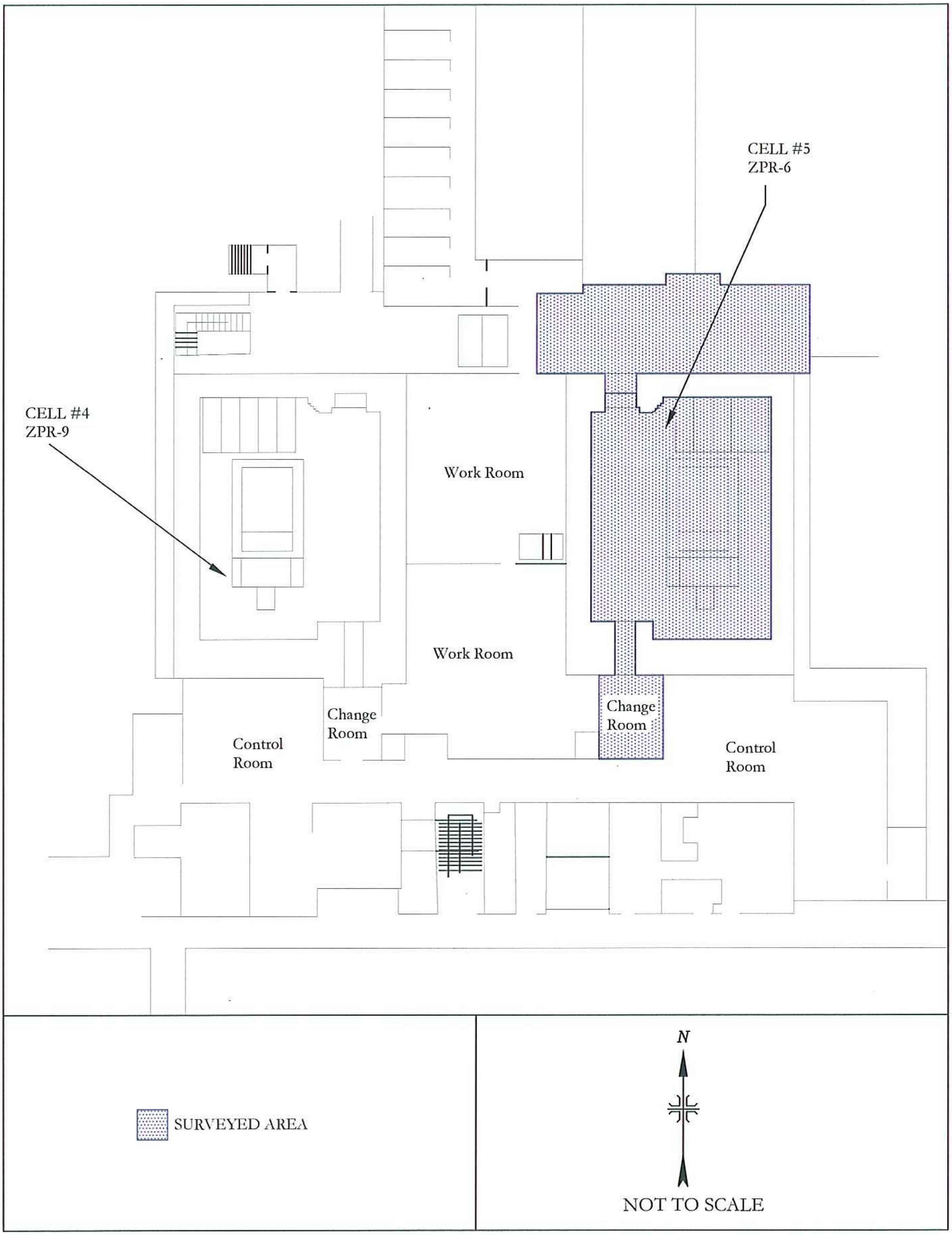

FIGURE 3: Plot Plan for Building 315 Main Floor, Indicating Location of Cell 5 (ZPR-6)

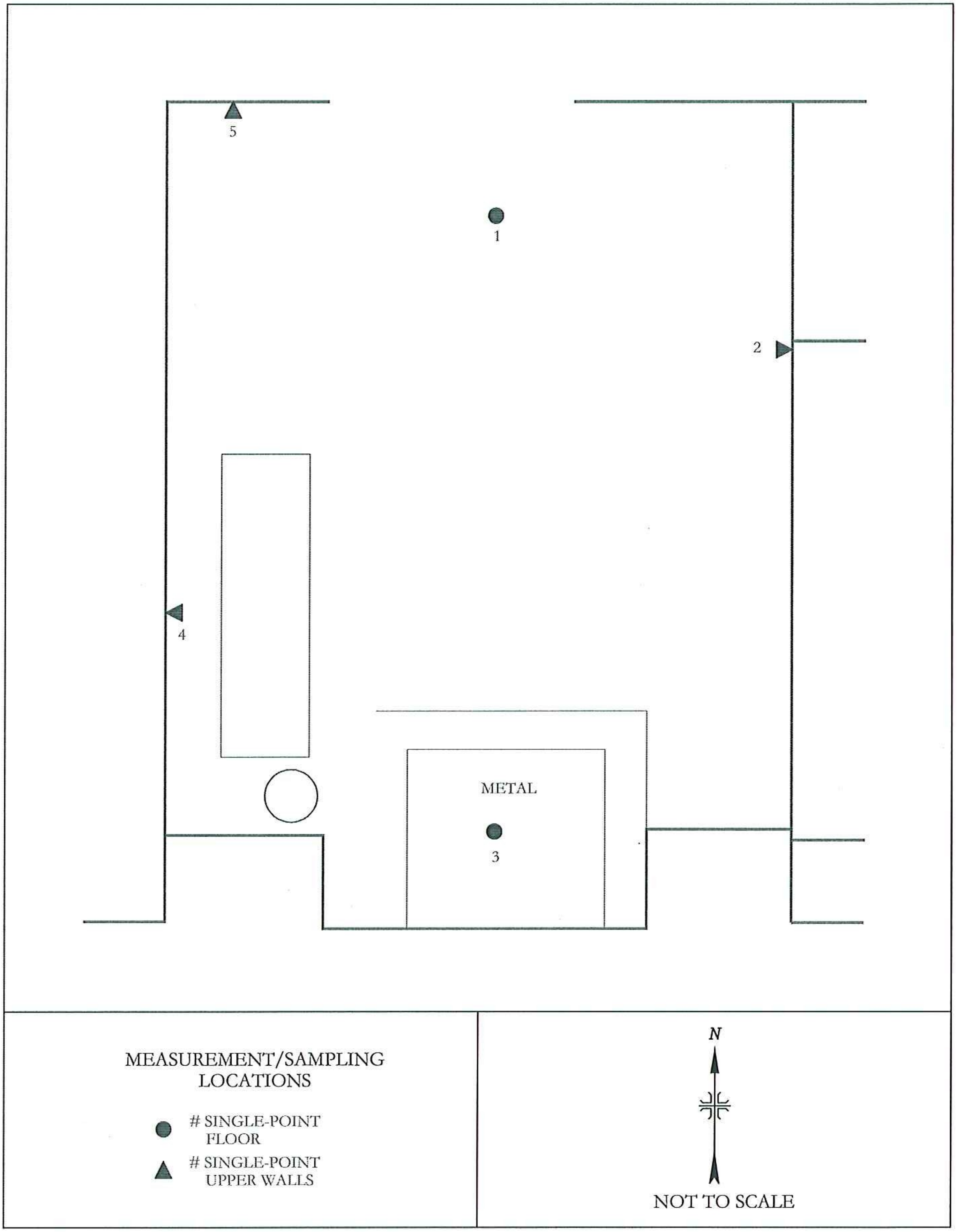

FIGURE 4: Air Lock Anti-Room - Measurement and Sampling Locations

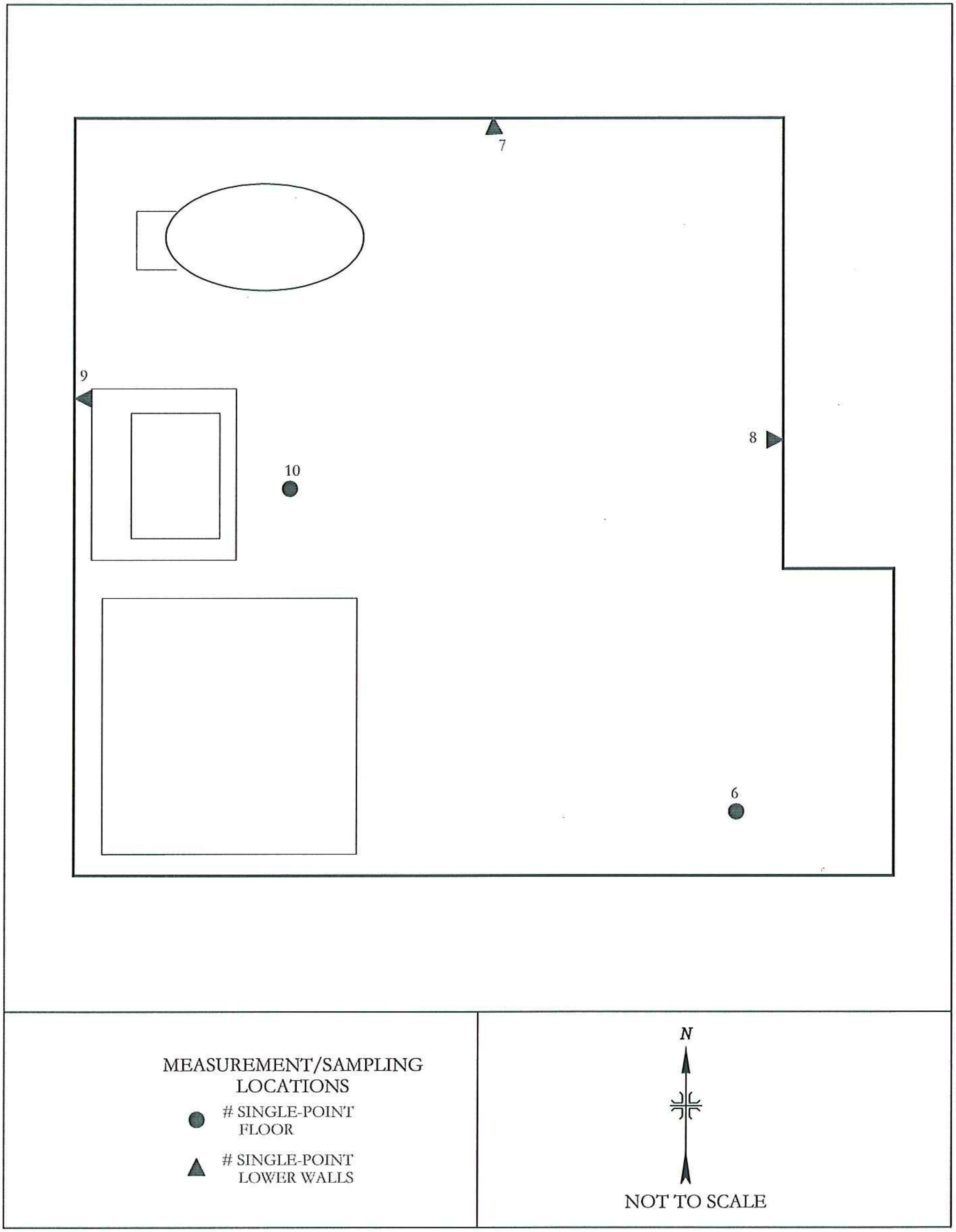

FIGURE 5: Men's Room - Measurement and Sampling Locations

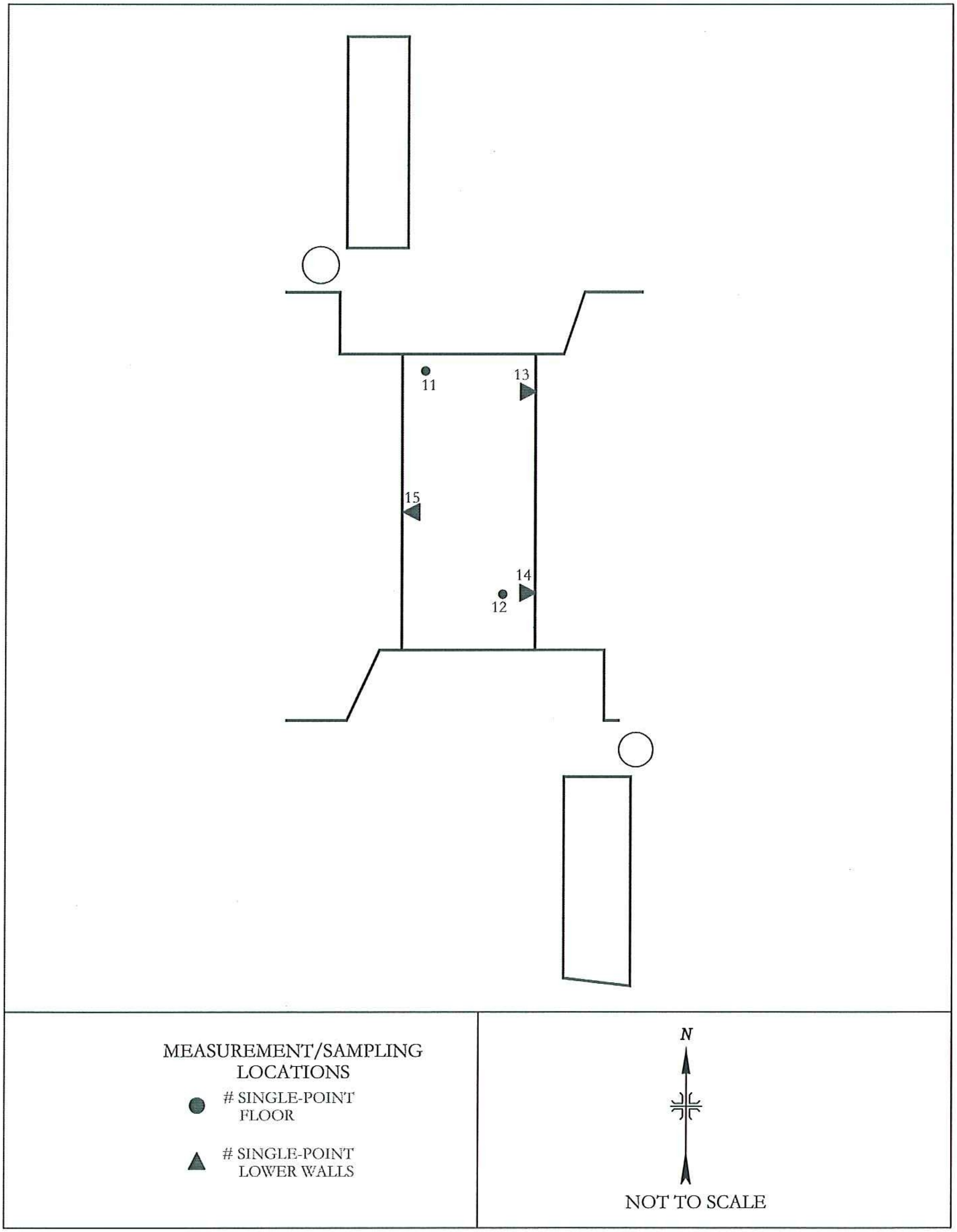

FIGURE 6: North Air Lock - Measurement and Sampling Locations

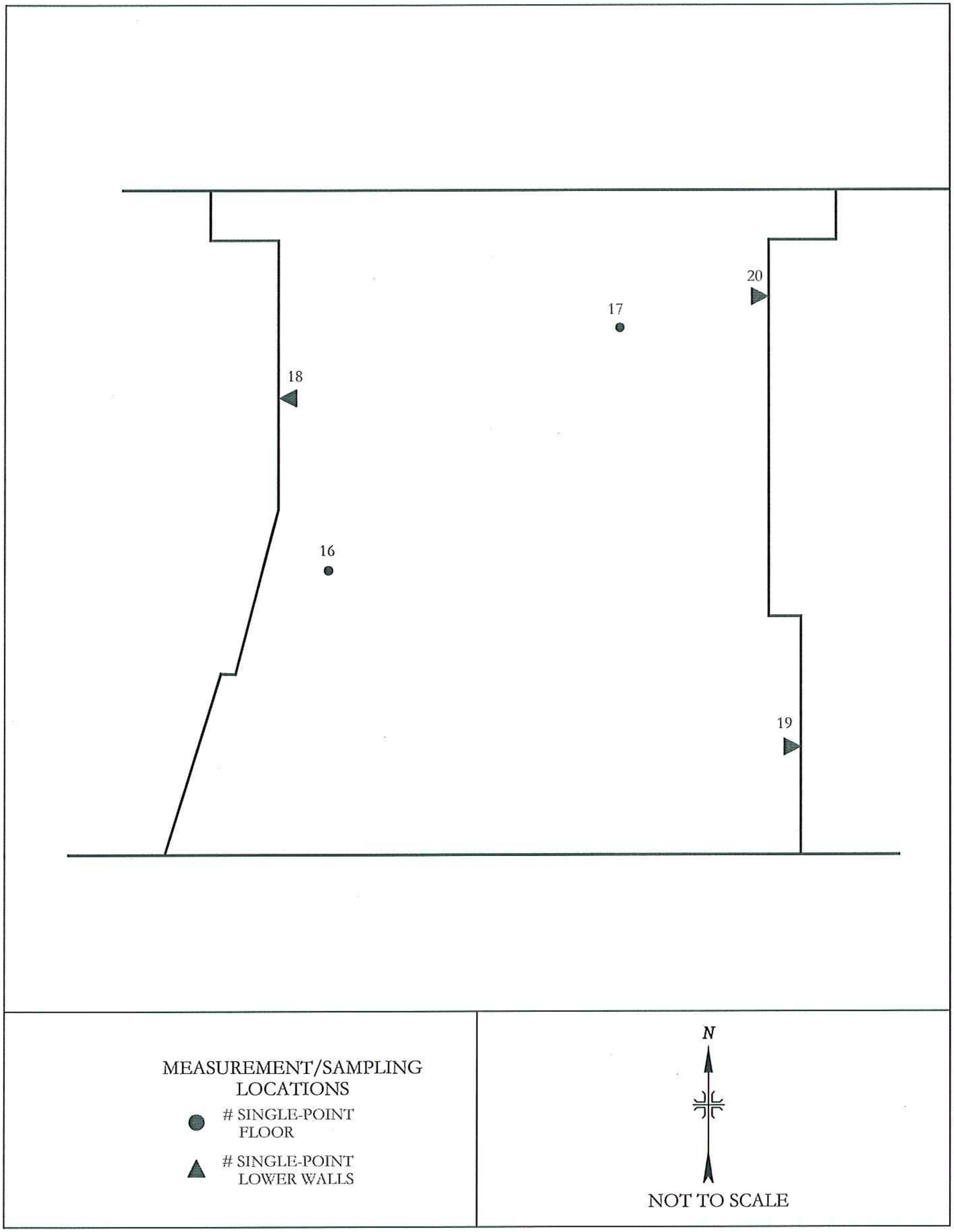

FIGURE 7: South Air Lock - Mesurement and Sampling Locations

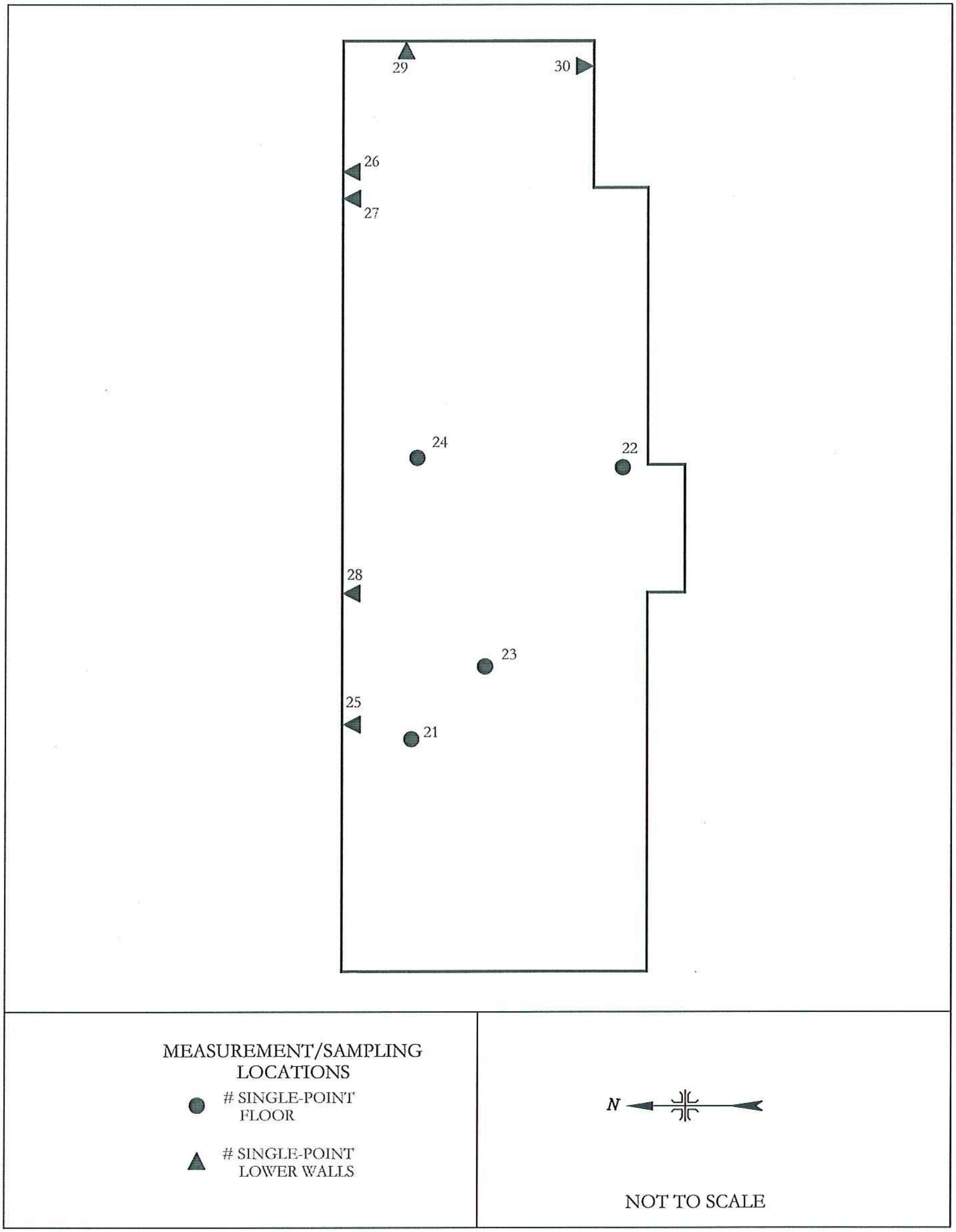

FIGURE 8: West Dock - Measurement and Sampling Locations

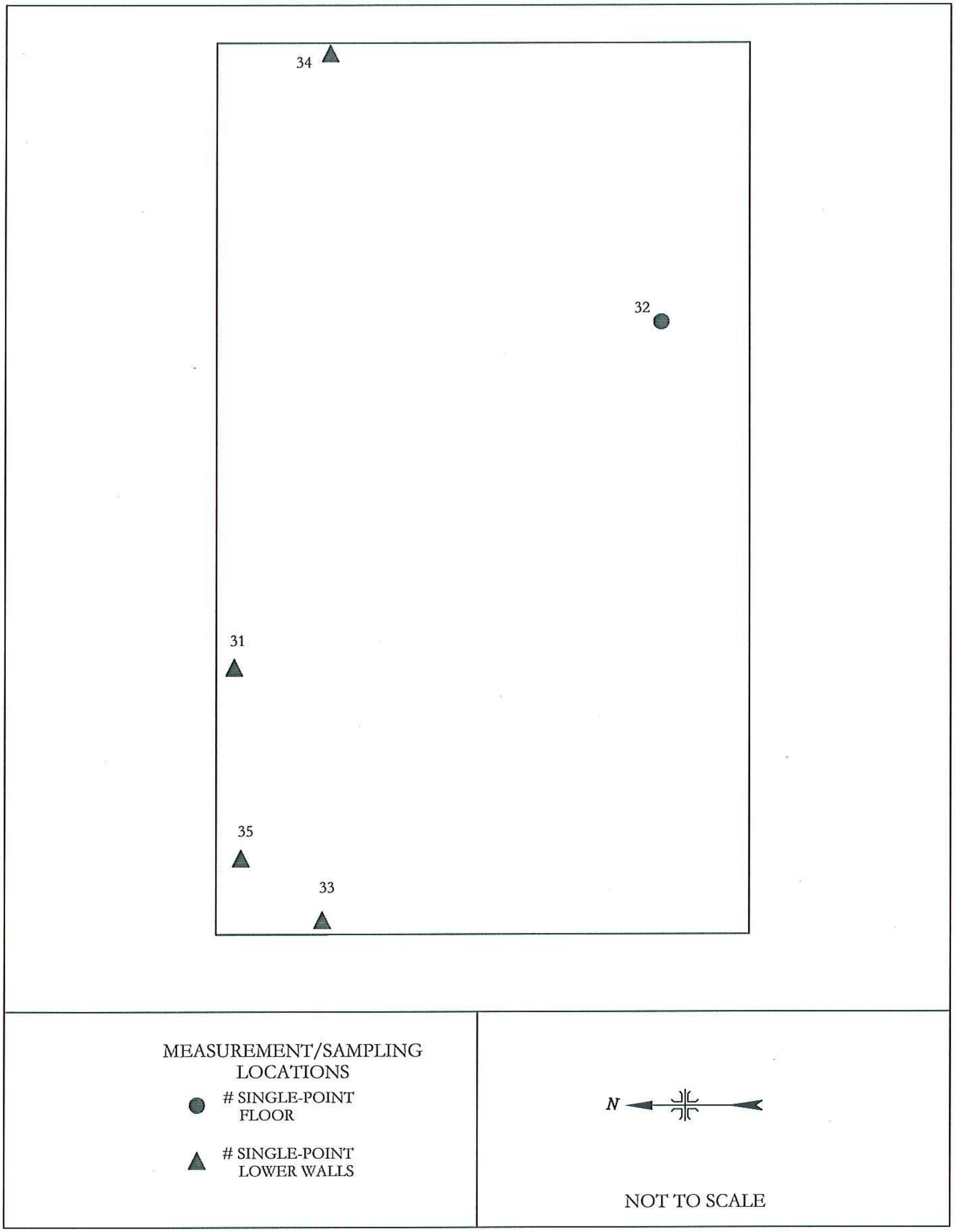

FIGURE 9: Room S-036 - Measurement and Sampling Locations

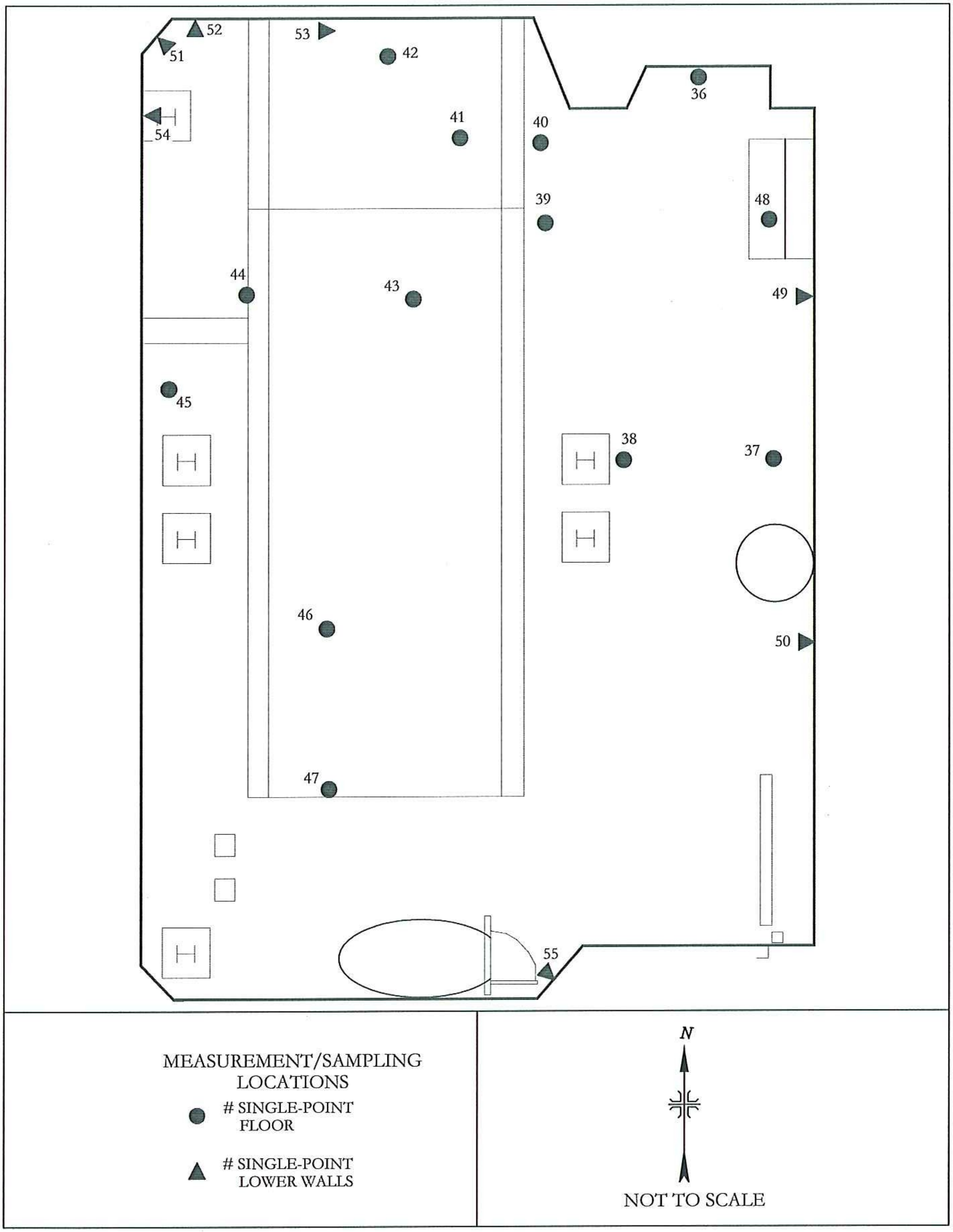

FIGURE 10: Cell-5, Zero Power Reactor -6 - Measurement and Sampling Locations

TABLES

TABLE 1

SURFACE ACTIVITY LEVELS
BUILDING 315 ZERO POWER REACTOR-6
ARGONNE NATIONAL LABORATORY
ARGONNE, ILLINOIS

Location/ Grid Block[a]	Surface-Wall Direction[b]	Total Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)	
		Alpha	Beta	Alpha	Beta
Anti Room					
1 (B-1)	F	7	-360	1	4
2 (B-2)	LW-E	-43	100	0	-1
3 (B-4)	F	-7	-290	1	8
4 (B-3)	LW-W	-7	-410	0	4
5 (A-1)	LW-N	-22	-520	0	-1
Men's Room					
6 (A-3)	F	14	130	0	-2
7 (B-2)	LW-N	-7	-760	0	-5
8 (B-2)	LW-E	0	470	0	-3
8 (Post-Source)	LW-E	--[c]	160	--	--
9 (B-1)	LW-W	-36	660	0	5
10 (B-1)	F	-14	-32	1	4
North Air Lock					
11 (A-1)	F	-51	270	0	2
12 (B-3)	F	0	0	0	-1
13 (B-3)	LW-E	-14	-260	1	-4
14 (A-4)	LW-E	-29	-370	3	4
15 (B-4)	LW-W	-29	40	0	-1

TABLE 1 (Continued)

**SURFACE ACTIVITY LEVELS
BUILDING 315 ZERO POWER REACTOR-6
ARGONNE NATIONAL LABORATORY
ARGONNE, ILLINOIS**

Location/ Grid Block[a]	Surface-Wall Direction[b]	Total Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)	
		Alpha	Beta	Alpha	Beta
South Air Lock					
16 (A-2)	F	-14	-290	0	-1
17 (B-1)	F	29	-320	5	-1
18 (B-3)	LW-W	-51	-370	0	3
19 (B-5)	LW-E	-22	-270	0	-2
20 (B-3)	LW-E	0	-440	0	-2
Dock					
21 (D-4)	F	-22	-56	0	-1
22 (A-9)	F	-14	-470	3	-3
23 (C-5)	F	-14	-170	0	-2
24 (D-9)	F	-72	130	0	-3
25 (C-4)	LW-N	-51	-56	1	-2
26 (B-12)	LW-N	0	-270	1	2
27 (C-12)	LW-N	0	160	0	3
28 (B-6)	LW-N	-29	-200	0	3
29 (B-1)	LW-E	-14	-110	0	-1
30 (A-1)	LW-S	7	-120	1	-3

TABLE 1 (Continued)

SURFACE ACTIVITY LEVELS
BUILDING 315 ZERO POWER REACTOR-6
ARGONNE NATIONAL LABORATORY
ARGONNE, ILLINOIS

Location/ Grid Block[a]	Surface-Wall Direction[b]	Total Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)	
		Alpha	Beta	Alpha	Beta
S-036 Escape					
31 (A-2)	LW-N	72	-24	1	-2
32 (A-4)	F	14	430	1	-1
33 (A-3)	LW-W	43	100	0	-3
34 (A-1)	LW-E	29	150	0	2
35 (B-1)	LW-N	120[d]	370	5	4
Cell 5					
36 (I-1)	F	-36	87	0	1
37 (I-6)	F	-36	-40	0	-1
38 (G-6)	F	7	-280	1	-3
39 (F-3)	F	-7	130	0	-1
40 (F-2)	F	-29	-190	1	-1
41 (E-2)	F	-51	0	0	5
42 (D-1)	F	-36	180	0	2
43 (D-4)	F	-7	32	0	-2
44 (B-4)	F	-22	-130	1	4
45 (A-5)	F	-22	-71	5	-2
46 (C-8)	F	-36	-290	0	-4
47 (C-10)	F	-7	-330	1	1

TABLE 1 (Continued)

SURFACE ACTIVITY LEVELS
BUILDING 315 ZERO POWER REACTOR-6
ARGONNE NATIONAL LABORATORY
ARGONNE, ILLINOIS

Location/ Grid Block[a]	Surface-Wall Direction[b]	Total Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)	
		Alpha	Beta	Alpha	Beta
Cell 5 (continued)					
48 (I-3)	F	-36	40	1	-1
49 (B-4)	LW-E	-22	-220	0	-3
50 (A-8)	LW-E	7	-250	3	5
51 (B-1)	LW-N	-29	-100	0	3
52 (A-1)	LW-N	-22	-160	0	-1
53 (B-3)	LW-N	-7	-95	0	4
54 (B-11)	LW-W	-22	-190	0	-4
55 (A-6)	LW-S	-29	-170	1	1

[a]Refer to Figures 4 through 10.
[b]F = floor, LW = lower wall, UW = upper wall, C = ceiling, N = north, E = east, S = south, and W = west.
[c]Measurement not performed.
[d]Measurement exceeded the average criteria; investigations in the immediate 1 m^2 area indicated this elevated activity location was less than 200 cm^2 and would not exceed the grid block averaging criteria.

TABLE 2

INSTRUMENT COMPARISON
SURFACE ACTIVITY LEVELS
AND CHECK SOURCE
BUILDING 315 ZERO POWER REACTOR-6
ARGONNE NATIONAL LABORATORY
ARGONNE, ILLINOIS

Comparison Measurement Location	Total Beta Activity (dpm/100 cm^2)	
	ORISE	**ANL**[a]
1	1,087	379
2	1,270	225
3	16	32
4	905	8
ANL Check Source SrY-90 #DN 642; 75,480 dpm[b]		
Source counts	26,553 cpm	25,120 cpm
4π instrument efficiency	0.3518	0.3328

[a]Direct measurement result provided by ANL personnel.
[b]SrY-90 #DN 642, Expected source activity was 75,480 dpm on September 27, 2006.

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APPENDIX A
MAJOR INSTRUMENTATION

APPENDIX A

MAJOR INSTRUMENTATION

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

SCANNING INSTRUMENT/DETECTOR COMBINATIONS

Alpha-Beta

Ludlum Floor Monitor Model 239-1
combined with
Ludlum Ratemeter-Scaler Model 2221
coupled to
Ludlum Gas Proportional Detector Model 43-37, Physical Area: 550 cm^2
(Ludlum Measurements, Inc., Sweetwater, TX)

Ludlum Ratemeter-Scaler Model 2221
coupled to
Ludlum Gas Proportional Detector Model 43-68, Physical Area: 126 cm^2
(Ludlum Measurements, Inc., Sweetwater, TX)

Gamma

Ludlum Model 12
(Ludlum Measurements, Inc., Sweetwater, TX)
coupled to
Victoreen NaI Scintillation Detector Model 489-55, Crystal: 3.2 cm x 3.8 cm
(Victoreen, Cleveland, OH)

DIRECT MEASUREMENT INSTRUMENT/DETECTOR COMBINATIONS

Alpha

Ludlum Ratemeter-Scaler Model 2221
coupled to
Ludlum Gas Proportional Detector Model 43-68, Physical Area: 126 cm^2
(Ludlum Measurements, Inc., Sweetwater, TX)

DIRECT MEASUREMENT INSTRUMENT/DETECTOR COMBINATIONS (CONTINUED)

Beta

Ludlum Ratemeter-Scaler Model 2221
coupled to
Ludlum Gas Proportional Detector Model 43-68, Physical Area: 126 cm^2
(Ludlum Measurements, Inc., Sweetwater, TX)

LABORATORY ANALYTICAL INSTRUMENTATION

Low Background Gas Proportional Counter
Model LB-5100-W
(Canberra/Tennelec, Oak Ridge, TN)

APPENDIX B

SURVEY AND ANALYTICAL PROCEDURES

APPENDIX B
SURVEY AND ANALYTICAL PROCEDURES

PROJECT HEALTH AND SAFETY

The proposed survey and sampling procedures were evaluated to ensure that any hazards inherent to the procedures themselves were addressed in the current job hazard analysis (JHA). All survey and laboratory activities were conducted in accordance with ORISE health and safety and radiation protection procedures.

A walkdown of the survey areas was performed in order to evaluate and identify potential health and safety issues. ANL provided general site-specific safety awareness—confined space in the escape chute and that the crane was still energized. Survey work was performed per the ORISE generic health and safety plan, a site-specific integrated safety management (ISM) pre-job hazard checklist, and the safety procedures discussed during the training.

QUALITY ASSURANCE

Analytical and field survey activities were conducted in accordance with procedures from the following documents of the Independent Environmental Assessment and Verification (IEAV) Program:

- Survey Procedures Manual (August 7, 2006)
- Laboratory Procedures Manual (April 8, 2006)
- Quality Assurance Manual (July 28, 2005)

The procedures contained in these manuals were developed to meet the requirements of Department of Energy (DOE) Order 414.1C and the U.S. Nuclear Regulatory Commission *Quality Assurance Manual for the Office of Nuclear Material Safety and Safeguards* and contain measures to assess processes during their performance.

Quality control procedures include:

- Daily instrument background and check-source measurements to confirm that equipment operation is within acceptable statistical fluctuations.
- Participation in MAPEP, NRIP, and ITP Laboratory Quality Assurance Programs.

- Training and certification of all individuals performing procedures.
- Periodic internal and external audits.

CALIBRATION

Calibration of all field and laboratory instrumentation was based on standards/sources, traceable to the National Institute of Standards and Technology (NIST), when such standards/sources were available. In cases where they were not available, standards of an industry-recognized organization were used.

Detectors used for assessing surface activity were calibrated in accordance with ISO-7503[1] recommendations. The total efficiency (ε_{total}) was determined for each instrument/detector combination and consisted of the product of the 2π instrument efficiency (ε_i) and surface efficiency (ε_s): $\varepsilon_{total} = \varepsilon_i \times \varepsilon_s$.

ORISE selected Tc-99 as the beta calibration source (maximum beta energy of 292 keV) as it provides a conservative representation of the primary beta emitters (Co-60 and Cs-137) and Th-230 as the alpha calibration source. ISO-7503 recommends an ε_s of 0.25 for all alpha emitters and for beta emitters with a maximum energy of less than 0.4 MeV (400 keV) and an ε_s of 0.5 for maximum beta energies greater than 0.4 MeV. Since the maximum beta energy for the chosen ANL ZPR-6 facility calibration source was less than 0.4 MeV, an ε_s of 0.25 was used to calculate ε_{total}.

Surface Scans

Hand-held detectors were placed on contact with the calibration sources. A postulated hot-spot size of 100 cm^2 was assumed *a priori* for determining scanning instrument efficiencies. The beta scanning ε_i value was 0.30 for Tc-99 for the hand-held gas proportional detectors; the calculated scanning ε_{total} value was 0.08 for Tc-99. For the calibration source, emission rates were not corrected for geometry when sources larger than the detectors were used.

The scanning ε_{total} was determined for the floor monitor in the same fashion as above for the hand-held gas proportional detectors except typical efficiencies for the floor monitor were used rather

[1]International Standard. ISO 7503-1, Evaluation of Surface Contamination - Part 1: Beta-emitters (maximum beta energy greater than 0.15 MeV) and alpha-emitters. August 1, 1988.

than specific calibrations for this survey. For the floor monitor, the scanning ε_i for Tc-99 was 0.24; the scanning ε_{total} was 0.06.

Surface Activity Measurements

The calibration ε_i values for the hand-held gas proportional detectors used for the verification survey were 0.38 and 0.43 for Tc-99 and Th-230, respectively. Calibration source emission rates were corrected to the active area of the detector when the calibration source area exceeded the detector area. The static ε_{total} values used were 0.10 and 0.11 for Tc-99 and Th-230, respectively.

SURVEY PROCEDURES

Surface Scans

Surface scans were performed by passing the detectors slowly over the surface; the distance between the detector and the surface was maintained at a minimum - nominally about 1 cm. A large surface area, gas proportional floor monitor with a 0.8 mg/cm^2 window and a NaI scintillation detector were used to scan the floors of the surveyed areas. Wall surfaces were scanned using small area (126 cm^2) hand-held detectors with a 0.8 mg/cm^2 window. Identification of elevated levels was based on increases in the audible signal from the recording and/or indicating instrument.

Scan minimum detectable concentrations (MDCs) were estimated using the calculational approach described in NUREG-1507[2]. The scan MDC is a function of many variables, including the background level. Site beta background levels ranged from 850 to 920 cpm for the large area gas proportional detectors (floor monitors) and 200 to 740 cpm for the hand-held gas proportional detectors. The hand-held gas proportional background for beta activity was re-determined on site and was 218 cpm. Additional parameters selected for the calculation of scan MDC included a three-second observation interval, a specified level of performance at the first scanning stage of 95% true positive rate and 25% false positive rate, which yields a d′ value of 2.32 (NUREG-1507, Table 6.1), and a surveyor efficiency of 0.5. To illustrate an example for the hand-held gas proportional detectors with 0.8 mg/cm^2 windows, the minimum detectable count rate (MDCR) and scan MDC can be calculated as follows:

[2]NUREG-1507. Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions. US Nuclear Regulatory Commission. Washington, DC; June 1998.

b_i = (218 cpm) (3 s) (1 min/60 s) = 10.9 counts

MDCR = (2.32) (10.9 counts)$^{1/2}$ [(60 s/min) / (3 s)] = 153 cpm

$MDCR_{surveyor}$ = 153 / (0.5)$^{1/2}$ = 216 cpm

The scan MDC is calculated using the total scanning efficiency (ε_{total}) of 0.08:

$$\text{Scan MDC} = \frac{MDCR_{surveyor}}{\varepsilon_{total}} \text{ dpm/100 cm}^2$$

The scan MDC for the hand-held gas proportional detector was calculated to be 2,700 dpm/100 cm^2. For the given floor monitor background ranges, the scan MDC ranged from 7,100 to 7,400 dpm/100 cm^2.

Specific scan MDCs for the NaI scintillation detector for the radionuclide mixture in concrete were not determined as the instrument was used solely as a qualitative means to identify elevated gamma activity. MDCs for radionuclides in the concrete would approximate those contained in NUREG-1507.

Surface Activity Measurements

Surface activity measurements were performed on poured concrete, cinderblocks, tile, wall board, and corrugated metal. Because different building materials may have different background levels, average background count rates were determined for each material encountered in the surveyed areas at a location of similar construction and having no known radiological history. The alpha activity background was considered to be 1 cpm for all surfaces. Alpha surface activity was calculated by determining the net count rate (subtracting background from the gross alpha measurement) and then correcting for total efficiency and detector area size. To account for the ambient gamma background, unshielded and shielded measurements were performed at each background and direct measurement location. A 3/8-inch Plexiglas shield was used to determine the gamma count rate associated with the unshielded count rates. This thickness was demonstrated to block the beta particles from Sr-90, including the beta particles from the progeny Y-90. Since Y-90 emits beta particles higher in energy than Cs-137, the Plexiglas shield completely shielded measurements of the Cs-137 beta emissions. The beta activity ambient background count rates (unshielded minus shielded average values in paired measurements) and were as follows:

Construction Material Beta Activity Backgrounds	
Material	**Average Background[a] (cpm)**
Poured Concrete	114
Painted Concrete	69
Concrete Block	140
Metal	46
Glazed Block Tile	327
Floor Tile	398

[a]Average background determined by subtracting unshielded background from shielded background.

Beta surface activity was calculated by determining the net count rate (subtracting the shielded measurement from the unshielded measurement and then subtracting the average construction material beta activity background) and then correcting for total efficiency and detector area size.

The static beta MDCs—calculated using the site re-determined activity ambient check-out count rate—for the gas proportional detector used for direct measurements was 570 dpm/100 cm^2. For alpha activity, the static MDC was 55 dpm/100 cm^2. The physical surface area assessed by the gas proportional detector used was 126 cm^2.

Removable Activity Measurements

Removable gross alpha and gross beta activity levels were determined using numbered filter paper disks, 47 mm in diameter. Moderate pressure was applied to the smear and approximately 100 cm^2 of the surface was wiped. Smears were placed in labeled envelopes with the location and other pertinent information recorded.

RADIOLOGICAL ANALYSIS

Gross Alpha/Beta

Smears were counted for two minutes on a low-background gas proportional system for gross alpha and beta activity. The MDCs of the procedure were 9 dpm/100 cm^2 and 15 dpm/100 cm^2 for gross alpha and gross beta, respectively.

DETECTION LIMITS

Detection limits, referred to as minimum detectable concentration (MDC), were based on 3 plus 4.65 times the standard deviation of the background count [3 + (4.65 $\sqrt{BKG}$)]. Because of variations in background levels, measurement efficiencies, and contributions from other radionuclides in samples, the detection limits differ from sample to sample and instrument to instrument.

APPENDIX C

RESIDUAL RADIOACTIVE MATERIAL GUIDELINES SUMMARIZED FROM DOE ORDER 5400.5 (DOE 1993)

APPENDIX C

RESIDUAL RADIOACTIVE MATERIAL GUIDELINES SUMMARIZED FROM DOE ORDER 5400.5 (DOE 1993)

BASIC DOSE LIMITS

The basic dose limit for the annual radiation dose (excluding radon) received by an individual member of the general public is 100 mrem/yr. In implementing this limit, DOE applies as low as reasonably achievable principles to set site-specific guidelines.

EXTERNAL GAMMA RADIATION

The average level of gamma radiation inside a building or habitable structure on a site that has no radiological restriction on its use shall not exceed the background level by more than 20 μR/h and will comply with the basic dose limits when an appropriate-use scenario is considered.

SURFACE CONTAMINATION GUIDELINES

	Allowable Total Residual Surface Contamination ($dpm/100\ cm^2$)[a]		
Radionuclides[b]	Average[c,d]	Maximum[d,e]	Removable[d,f]
Transuranics, Ra-226, Ra-228, Th-230 Th-228, Pa-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	5,000α	15,000α	1,000α
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above[g]	5,000β-γ	15,000β-γ	1,000β-γ

[a] 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 measured by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

[b] 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.

[c] Measurements of average contamination should not be averaged over an area of more than 1 m^2. For objects of less surface area, the average should be derived for each such object.

[d] The average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h and 1.0 mrad/h, respectively, at a depth of 1 cm.

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

[f] The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping an area of that size 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 known 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 entire surface should be wiped. The numbers in this column are maximum amounts.

[g] This category of radionuclides includes mixed fission products, including the Sr-90 which has been separated from the other fission products or mixtures where the Sr-90 has been enriched.