Plum Brook Reactor Facility

Final Status Survey Report

Attachment 5

Revision 1

Hot Retention Area
(Building 1155)

FINAL STATUS SURVEY REPORT ROUTING AND APPROVAL SHEET

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Section 2.4 was edited to clarify the configuration of the HRA for the FSS and to describe the disposition of materials following building demolition in May 2010.

In response to an NRC comment, a note was added to Table 2 and an explanatory paragraph added to Section 4.4 to explain the use of the DCGL, instead of the $DCGL_{EMC}$, as the scan investigation-action level in Class 1 survey units.

Table 9 and Table 9 notes are revised in response to NRC comment as follows:

> Survey units are identified for which the DCGL is adjusted to account for the 2.5 mrem dose contribution from "insignificant radionuclides" (there is no adjustment of DCGLs for embedded piping in the HRA).

Table 9 was also modified by the addition of a column to show that a check was performed to verify that the total dose was less than 25 mrem/y considering the dose contributions from residual contamination and insignificant radionuclides.

The introductory paragraph of Section 5.2 was edited to clarify the evaluations presented in Table 9.

Typographical and punctuation errors in the text were corrected. The acronym "LGBR" was corrected to "LBGR" on pages vii, 13 (Table 5 and in text).

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Rev 1

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LIST OF ACRONYMS & SYMBOLS

α	alpha; denotes alpha radiation, also type I error probability in hypothesis testing
AEC	Atomic Energy Commission
ALARA	As Low As Reasonable Achievable
AF	Area Factor
β	beta; denotes beta radiation, also type II error probability in hypothesis testing
b_i	background counts in observation interval
B_R	Background count rate
BPL	Byproduct License
CRB	Cold Retention Basin
CFR	Code of Federal Regulations
cm	centimeters
cm^2	square centimeters
cpm	counts per minute
Δ	delta, $DCGL_W$ – LBGR
d'	Scan surveyor sensitivity index
DCGL	Derived Concentration Guideline Level
$DCGL_{EMC}$	DCGL for small areas of elevated activity, used with the Elevated Measurement Comparison test (EMC)
$DCGL_W$	DCGL for average concentrations over a survey unit, used with statistical tests. (the "W" suffix denotes "Wilcoxon)"
dpm	disintegrations per minute
E_i	Detector, or instrument efficiency
E_s	Surface efficiency
E_t	Total efficiency
EMC	Elevated Measurement Comparison
EPA	US Environmental Protection Agency
FSS	Final Status Survey
FSSP	Final Status Survey Plan
FSSR	Final Status Survey Report
γ	gamma
g	gram
gpm	gallons per minute
HTD	hard to detect
HL	Hot Laboratory, Building 1112
HPT	Hot Pipe Tunnel
HRA	Hot Retention Area, Building 1155
HEPA	High Efficiency Particulate Air – generic term for high-efficiency air filter
i	observation counting interval during scan surveys
in.	inch
LMI	Ludlum Measurements, Inc.
LBGR	Lower Bound of the Gray Region
m^2	square meters
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual

LIST OF ACRONYMS & SYMBOLS, Continued

MDC	Minimum Detectable Concentration
MDC_{scan}	Minimum Detectable Concentration for scanning surveys
MDC_{static}	Minimum Detectable Concentration for static surface activity measurements
MDCR	Minimum Detectable Count Rate
mrem	millirem
MW	Megawatt
MWH	Montgomery Watson Harza, Inc.
NASA	National Aeronautics and Space Administration
N	Number of FSS measurements or samples established in a survey design
NA	Not Applicable
NRC	US Nuclear Regulatory Commission
OW	Outside Walls
PBRF	Plum Brook Reactor Facility
PNL	Pacific Northwest Laboratory
Φ	Standard normal distribution function
p	surveyor efficiency for scan surveys
pCi/g	picocuries per gram
%	percent
PPH	Primary Pump House, Building 1134
QC	Quality Control
RESRAD	RESidual RADioactive – a pathway analysis computer code developed by Argonne National Laboratory for assessment of radiation doses. It is used to derive cleanup guideline values for soils contaminated with radioactive materials
RESRAD-BUILD	A companion code to RESRAD for evaluating indoor building contamination and developing site-specific DCGLs
s	seconds
σ	generic symbol for standard deviation of a population
SAIC	Science Applications International Corporation
SNL	Sandia National Laboratory
SR	Survey Request
t_s	background count time
t_b	sample count time
TBD	Technical Basis Document
μ	Mean activity concentration
UCM	Unusual Condition Measurement
UL	Upper limit of the confidence interval about the mean
VSP	Visual Sample Plan
WEMS	Water Effluent Monitoring System
WHB	Waste Handling Building, Building 1133
$Z_{1-\alpha}$	Proportion of standard normal distribution values less than $1-\alpha$
$Z_{1-\beta}$	Proportion of standard normal distribution values less than $1-\beta$
∞	Mathematical symbol for infinity

1.0 Introduction

This report presents the results of the final status radiological survey of the Plum Brook Reactor Facility (PBRF) Hot Retention Area (HRA, Building 1155). It is Attachment 5 of the PBRF Final Status Survey Report (FSSR) [1]. This attachment describes the HRA, its operational history and final condition for the final status survey (FSS). It describes the methods used in the FSS and presents the results of the survey measurements.

As stated in the PBRF Final Status Survey Plan (FSSP) [NASA 2007], the goal of the decommissioning project is to release the facility for unrestricted use in compliance with the requirements of US NRC 10CFR20 Subpart E. The principal requirement is that the dose to future site occupants will be less than 25 mrem/y. Subpart E also requires that residual contamination be reduced to levels as low as reasonably achievable (ALARA). A Derived Concentration Guideline Level (DCGL) for residual surface contamination has been established for the HRA. Considering the radionuclide mixture established for the HRA, the gross beta DCGL is 34,213 dpm/100-cm^2.[2]

The survey measurement results and supporting information presented herein demonstrate that residual contamination levels in each survey unit of the HRA are well below the DCGL. Additionally, it is shown that residual contamination has been reduced to levels that are consistent with the ALARA requirement. Therefore, the HRA meets the criteria for unrestricted release.

Section 2.0 of the report provides a description of the HRA. This includes the building layout, its relation to other PBRF buildings and facilities, design and materials of construction, building contents and use, systems and services, building modifications, final configuration for the FSS and scope of the FSS for this building.

A brief history of operations is presented in Section 3.0. A chronology of significant milestones is followed by history of operations with radioactive materials. Post shutdown and decommissioning activities are summarized.

Section 4.0 presents the FSS design for the HRA. This section includes applicable FSS Plan requirements, breakdown into survey units and assignment of MARSSIM classification to each, the survey design approach, and instrumentation used for the FSS and measurement sensitivities.

Survey results are presented in Section 5.0. This section includes a summary of the FSS measurements performed in the HRA survey units, comparison to the DCGL, tests performed and an evaluation of residual contamination levels relative to the ALARA criterion.

Supporting information is contained in Appendices. Appendix A contains photos and schematics to supplement the text. Survey design maps, tables of coordinates and total surface beta measurement results for each survey unit are provided in Appendix B.

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[1] The PBRF Final Status Survey Report comprises the report main body and several attachments. The attachments present survey results for individual buildings and open land areas. The entire final report will provide the basis for requesting termination of NRC Licenses TR-3 and R-93 in accordance with 10CFR50.82 (b) (6).

[2] The default radionuclide mixture and DCGL of 27,166 dpm/100-cm^2 are applied to HRA exterior surfaces. See Section 4.1.

2.0 HRA Description

The HRA is a reinforced concrete vault-structure located south of the Fan House adjacent to the west side of the Waste Handling Building (WHB). It is 45 ft. wide (east-west) and 90 ft. long (north-south) with the vault floor 25 ft. below grade. The vault roof, or top surface is at grade level, corresponding to the Reactor Building 0 ft. elevation.[3] The HRA is shown on the PBRF site map in Figure 1. Views of the HRA exterior are shown in Exhibits 1 and 2 of Appendix A.

The HRA was designed to provide holding capacity for large volumes of radioactively contaminated water generated in PBRF reactor operations. It functioned as a tank farm for storage, holdup and decay of water from the hot drain system. The hot drain system collected radioactive water from hot sumps in the Reactor Building and the other PBRF buildings. The twelve HRA tanks had a combined capacity of 512,000 gallons. Eight large (60,000 gallon) steel tanks were housed in the vault and four stainless steel, 8000 gallon tanks were buried underground north of the main HRA vault. These 8 ft. diameter, 20 ft. long tanks were placed horizontally on concrete pedestals with the tank top surfaces buried about 15 ft. below grade. See Figure 2 for an expanded view showing the layout of the underground storage tanks and pipe chase.

A utility pipe chase was located above the vault and extended north of the vault then dropped below grade to connect with the Fan House basement. It contained inlet piping from the hot drain system and outlet piping for water from the HRA. Water held in the HRA was either processed through the Waste Cleanup System for recycling into the quadrants and canals, stored in the Cold Retention Basins (CRB-1154), released after decay (and dilution if required) through the Waste Effluent Monitoring Station (WEMS-1192), or evaporated using the Waste Evaporator System.

The HRA was not manned continuously. Roving operators normally attended to valve and pump operations necessary to transfer water to specified locations, including performing back shift maintenance on equipment. Routine valve operations were performed on the pipe chase roof; the vault was not routinely accessed by personnel. Access to the vault was required on occasion for inspections and equipment maintenance. The main tanks were also entered for periodic removal of sludge buildup and debris.

2.1 Building Construction

The HRA vault was constructed of reinforced poured concrete with 16 in. thick walls and ceiling and 6 in. thick floor. The eight main hot retention tanks, constructed of carbon steel, were 22 ft. in diameter and 23 ft. high. They were placed in the vertical position on welded steel plate catchments on the vault floor. A 12-inch high divider constructed of steel plate enclosed the section around each tank such that individual tank leakage could be monitored via a leakage sump. Access to the vault was provided through hatchways located in the vault roof outside the pipe chase capped by removable concrete shield plugs - one on the east side and one on the west side. Access to the main HRA tank internals was gained from the pipe chase floor through 30 in. man-way openings into each tank.

[3] The main HRA vault was covered with a four ft. thick earthen berm to provide shielding from gamma radiation emanating from contaminated water in the tanks.

The HRA pipe chase consisted of two sections. A lower section, below grade, ran east-west adjacent to the south side of the FH basement wall and then ran south about 50 feet to the north end of the HRA vault. The upper section ran north and south over the length of the HRA vault. The HRA pipe chase walls, floor, and ceiling were reinforced concrete roughly one foot thick, except for the upper section where the floors were about 2 foot thick. The top of the lower section floor was at – 6.5 ft. elevation; the top of the ceiling-roof was just below grade and covered with gravel. The upper section floor was at plus one-foot elevation and the roof at 8.5 ft. elevation. All reactor facility connecting piping, except for several lines to and from the WHB, ran through the FH south wall and through the pipe chase to the HRA tank openings.

Figure 1, PBRF NW Area Showing Reactor Building, HRA and Other Support Buildings

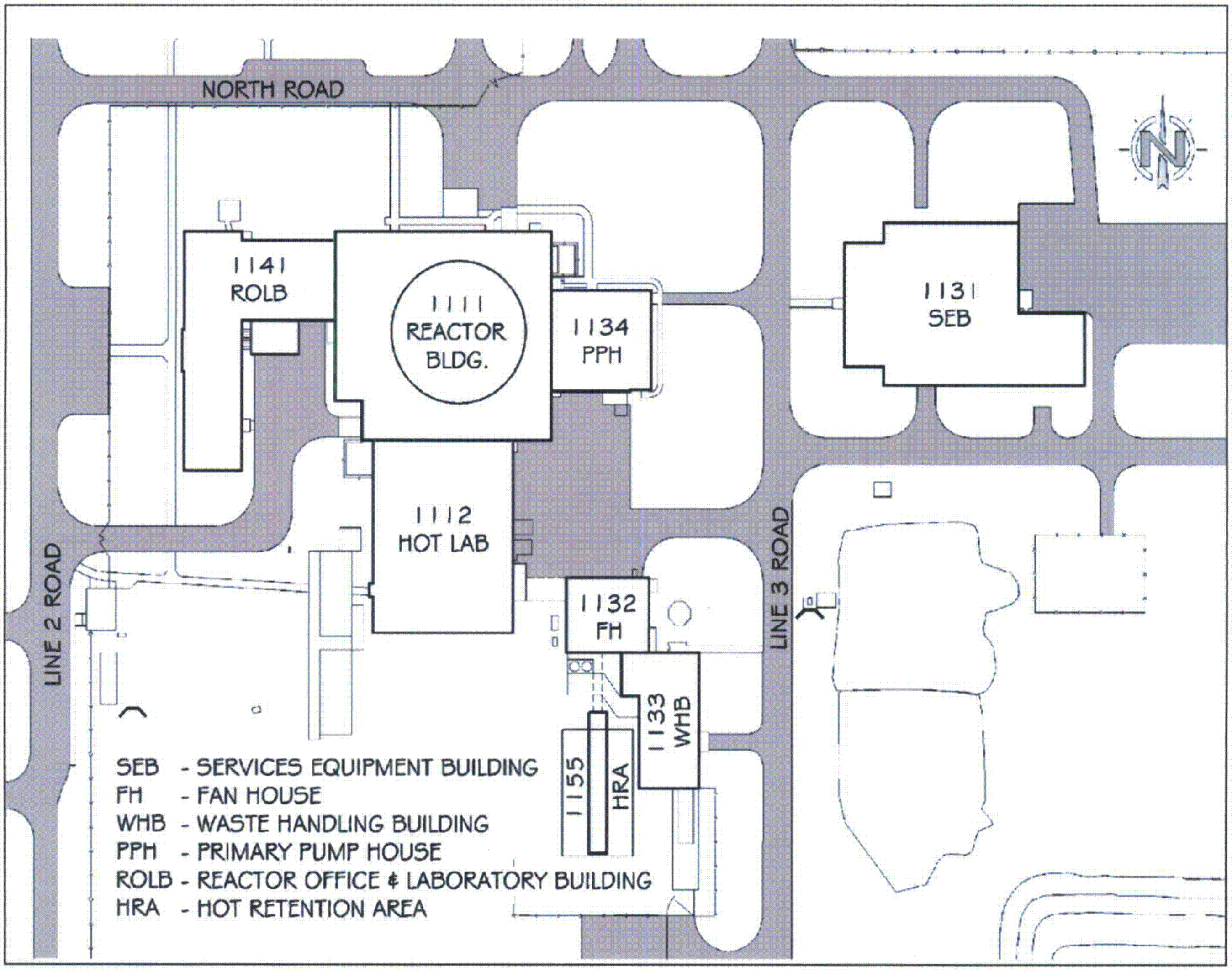
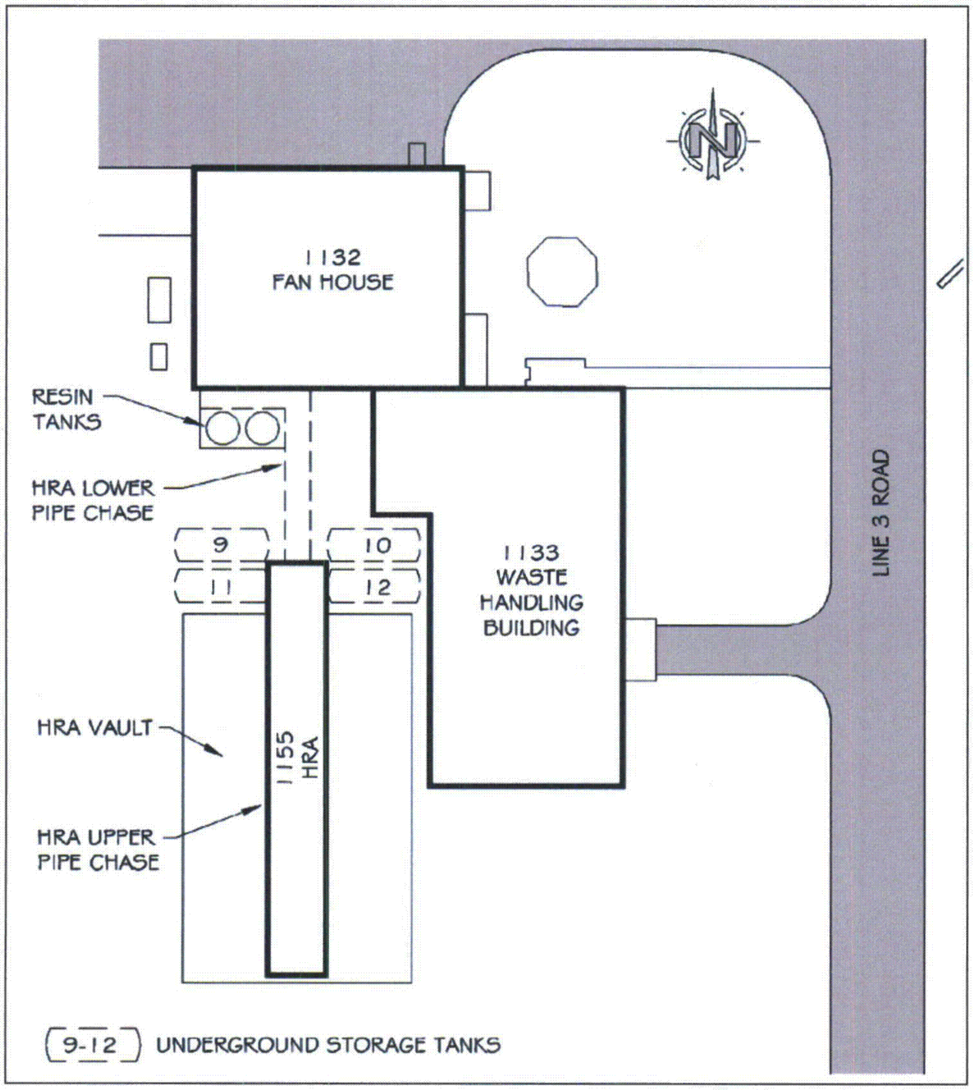


Figure 2, Expanded View Showing HRA Pipe Chase and Underground Tank Arrangement



2.2 Building Systems and Services

Systems and services for the HRA included pumps and valves for water handling, space heaters, air vents and exhaust. Discharge from each tank was provided by a 200-gpm, 7 ½ HP vertical shaft pump that discharged to the waste cleanup supply line. Each pump had a high and low liquid level control cutoff. Continuous level indicators for the HRA tanks were located on a panel in the Fan House (FH).

Ventilation of the upper pipe chase and vault area was via a louvered air inlet and ventilating fan on the south end above the storage tanks. Heating of the upper pipe chase was provided by four unit heaters with intakes and exhausts on the roof of the pipe chase. The HRA lower pipe chase was vented through a 10 in. line that exited the pipe chase through the Fan House south wall. The exhaust air was filtered by a HEPA unit and monitored before exhausting through the PBRF stack.

2.3 Building Modifications

The HRA was operated as designed and built, with minor modifications. Early in reactor full power operations, soaps from laundry operations and decontamination activities fouled the ion exchange resins in the waste cleanup system. Subsequently, to improve water processing, the four underground holdup tanks were used exclusively for laundry and decontamination waste. The high-solids waste water was processed through an evaporator located in the WHB. Modifications were also made to control water intrusion into the vault and pipe chase after the PBRF was shutdown. A pump system was added in 1985 to control groundwater levels in the vault. In 1986, the HRA valve handle extensions were removed and the pipe chase roof sealed to prevent rain water intrusion into the pipe chase.

2.4 Final Configuration and Scope

Configuration of the HRA for the FSS and the period until license termination is controlled by PBRF decommissioning and FSS procedures. The vault structure was intact for the FSS with utilities and services limited to temporary lighting and power. For the FSS, the HRA vault and tunnel areas were essentially stripped and vacant All equipment has been removed except the cold sump in the vault floor.

The four buried HRA tanks located north of the vault were removed in 2010 and staged for survey and disposition as appropriate under PBRF procedures (material to be released must show no detectable activity per Procedure RP-008). Survey results and disposition will be documented in accordance with operational radiological survey procedures. The tank footprint and surrounding soil will be surveyed in accordance with FSS procedures for PBRF open land areas. The pipe chase, connecting tunnel, and vault were also demolished in 2010 to at least 1-meter below grade. Concrete materials will be used as fill. The sump was deactivated and removed prior to backfilling the vault. Exhibits 6 through 14 of Appendix A show the general condition of the HRA vault and pipe chase at the time of the FSS.

The scope of FSS results reported in this attachment includes interior surfaces of the HRA vault and pipe chase, the vault roof-pad and the pipe chase roof and exterior walls. It includes surface attachments, temporary safety covers and embedded fixtures. The concrete vault and pipe chase floors were extensively remediated to remove contamination; particularly around drains, sumps and cracks. This resulted in irregular surfaces including scabbled concrete, remnants of anchors and other attachments, conduit and piping stubs. Examples are shown in Exhibits 15 through 18 of Attachment A.

A drain system comprised of terra cotta (clay) piping is located in and beneath the vault floor. This piping was designed to drain the vault foundation footer. It also received water from the vault floor. The piping remains in place. It was inspected, remediated, surveyed and shown to meet the $DCGL_W$ for the vault structure. The survey results for the drain piping are reported separately from the HRA FSS results.

3.0 History of Operations

A chronology of major milestones is given below. This is followed by a discussion of building operations, post-shutdown and decommissioning activities. Emphasis is on operations with radioactive materials that could affect the final building condition and final status survey.[4]

3.1 Chronology

Major PBRF and HRA milestones are listed below:

1956 – September, groundbreaking for PBRF.

1958 – HRA construction initiated.

1959 – HRA structure completed.[5]

1961 – June, 60 MW Test Reactor critical.

1973- January 5th, Reactor shutdown.

1973 – June 30, PBRF facilities placed in "standby condition

1985 – Initial radiological characterization, Teledyne Isotopes Inc.

1989 – Follow-up radiological characterization, GTS-Duratek.

2002 – Decommissioning Plan approved. Equipment removal and initial building decontamination.

2009 – FSS measurements completed.

2010 – HRA demolished and underground tanks removed.

3.2 Startup and Operations

Construction of the HRA was completed in the 1959-1960 timeframe prior to full power reactor operations in 1963. When HRA systems became operational, they were incorporated as part of routine reactor operations and were utilized throughout the reactor operations period and preparations for reactor standby status in 1973. As radioactive wastewater was generated, it normally was sent to the HRA for decay or cleanup prior to disposal or reuse.

[4] Information sources for the history and pre-decommissioning period include, construction photos, construction drawings, PBRF operating cycle reports, Radiochemistry periodic reports, PBRF Annual Reports, Unusual Occurrence Files, memoranda and other historical files maintained by PBRF Document Control.

[5] Construction photos show that HRA construction was initiated in 1958 and the structure completed in 1959 [PBRF 2009].

As mentioned previously, roving operators and mechanics operated the HRA systems. The valves were operated primarily from the pipe chase roof above the tank vault. The schematic of the pipe chase roof in Exhibit 5, Appendix A shows numerous small penetrations for valve handle extensions. The individual tank level indicators and pump controls were located on the first floor of the FH, as were the tank leakage monitors.

3.3 Radioactive Materials in the HRA

The US Atomic Energy Commission (AEC) authorized operations and use of radioactive materials at the PBRF under several licenses.[6] License No.TR-3 (Docket 50-30) authorized the 60 MW test reactor. The 100 KW mock-up reactor was licensed under License No.R-93. A broad byproduct license (BPL) No. 34-06706-03, authorized possession and use of radioactive materials (byproduct material) produced by the Plum Brook 60MW and Mockup reactors and other radioactive materials. Radioactive materials in the HRA originated mainly from the primary cooling water system, with additional amounts from the radiochemistry laboratories, hot laboratory and contaminated laundry waste. All water entering the hot sumps eventually reached the HRA [PBRF 2009].

The PBRF Health Safety Operations Office reported unplanned incidents in the PBRF Operations Cycle Reports for HRA related activities. These primarily involved WEMS gate closures caused by improper mixing of dilution water and HRA contaminated effluent during planned controlled releases. No events were reported that involved spills or contamination within the HRA itself.

3.4 Disposition of Materials in the Post-Shutdown Period

In the period following termination of reactor operations in January 1973 and June 30th of 1973, the HRA was placed in standby status, as were all PBRF systems and services. The PBRF end condition statements governed the status of each system for the protected safe shutdown mode. The end condition statement called for the exterior of the hot retention tank area to be decontaminated and left as a clean zone. Each HRA tank 1 through 8 and the combined holdup tanks 9-12 were flushed and drained. The tanks were then cleaned, including sludge removal, and left dry. The pumps were deactivated and all valves closed. All access plugs and openings were closed and secured against unauthorized entry except one entrance into the pipe chase tunnel area that was locked. Air inlet louvers to the HRA pipe chase were blanked off and the HRA air was allowed to vent to the PBRF stack. Absolute filters were retained in the HRA vent system to remove particulate airborne contamination. The HRA ground water sump pumps remained in service with water level alarm monitors active.

The completion report, dated July 17, 1973, indicates that the level indicator probes were removed and disposed of. The HRA leakage system was electrically secured. The sump

[6] Authority for the PBRF reactor and radioactive materials licenses was assumed by the US Nuclear Regulatory Commission in 1975.

pump that removed water from below the HRA tank catchments was electrically secured and the discharge valves closed and sealed. The four unit heaters were electrically secured, the gas supply valve closed and vent and flue lines capped for each unit. Check valves were removed and blank flanges installed on four HRA tank discharge lines. The main HRA tanks and the external underground tanks were left in standby condition.

The radiological status of the HRA has been investigated on multiple occasions since the PBRF was shutdown in January 1973. The first of these evaluations was performed by Teledyne Isotopes, Inc. during 1984-86. The results were reported in a 1987 Report [TELE 1987]. The Teledyne Isotopes study reported that all the HRA pumps and piping were contaminated and would require removal and disposal as contaminated waste. Tank and vault residues in the HRA contained primarily Co-60, Sr-90 and Cs-137. Direct radiation levels in the vault ranged from < 0.05 to 2.8 mR/h. Direct radiation levels in the pipe chase were similar. Removable surface contamination levels in the pipe chase ranged from 27 to 1135 beta dpm/100-cm^2. It was reported that no significant removable alpha activity was detected.

3.5 Decommissioning

All equipment housed in the HRA vault and pipe chase was removed and disposed of as contaminated waste or recyclable materials by Montgomery-Watson during 2003 – 2005. All storage tanks, sump liners, piping, fans, electrical cabinets, instrumentation panels, metal gratings, etc. were shipped for disposal. Subsequently, the HRA was characterized to identify remediation requirements for the remaining structure. Analysis of nine samples (floor debris, pipe drain debris and concrete) from the HRA vault was performed [MWH 2005]. Cesium-137 was detected in all samples with activity concentrations ranging from 5 to 187 pCi/g, the latter in drain pipe debris. Cobalt-60 was also detected in all samples, but at lower concentrations, with an average Cs:Co activity ratio of 14.5 ± 2.3 (one standard deviation).

Total surface contamination levels in the vault and pipe chase ranged from < MDA up to 42,000 dpm/100-cm^2, beta and up to 90 dpm/100-cm^2, alpha. Removable surface activity levels were low. The maximum removable surface beta activity measured was 200 dpm/100-cm^2; all alpha smear counting results were < MDA (13 dpm/100-cm^2) [MWH-2005].

Concrete in the vault and pipe chase was remediated by shaving, scabbling and over-coring. Pipe chase roof covering materials were also removed. Radiological surveys were performed in support of HRA decommissioning activities. The objective of the final post-remediation survey was to ensure that the HRA could satisfy the release criteria with a high probability of success. Surveys were performed in 2006 and 2008 by MOTA and Science Applications International Corporation (SAIC), respectively in support of remediation and preparation for FSS.[7]

[7] Surveys performed during decommissioning and post-remediation included Survey Requests, SR-79, 129, 130 and 139.

The radionuclide mixture for development of the HRA gross activity DCGL for the FSS was reported in TBD-07-001 [NASA 2007]. The information used to develop the radionuclide profile was obtained from characterization samples collected in the HRA [MWH, 2005] and other PBRF buildings [MWH 2005a] in 2005.

4.0 Survey Design and Implementation for the HRA

This section describes the method for determination of the number of fixed measurements and samples for the FSS of the HRA. Applicable requirements of the FSS Plan are summarized. These include the $DCGL_W$[8], the gross activity DCGL, scan survey coverage and action-investigation levels, classification of areas and breakdown of the survey units. Radiological instrumentation and detection sensitivities are discussed.

4.1 FSS Plan Requirements

The DCGLs for individual radionuclides were obtained for PBRF structures considering exposure to future site occupants from two potential pathways. Single radionuclide DCGLs were calculated using RESRAD-BUILD Version 3.22 for a building reuse scenario. Single radionuclide volumetric DCGLs were calculated for subsurface structures using RESRAD Version 6.21 for a resident farmer scenario.[9] The volumetric DCGLs (in pCi/g) were converted to "effective surface" DCGLs (in dpm/100-cm^2) using surface-to-volume ratios for the assumed volume of contaminated subsurface concrete. The DCGL calculations are described in the FSSP, Attachment B. To obtain the DCGLs for PBRF structures, the smaller of the two DCGLs calculated for each of the radionuclides of concern were selected.

A gross activity DCGL is used for structural surfaces in the PBRF, where multiple radionuclides are potentially present in residual contamination. The gross activity DCGL accounts for the presence of multiple radionuclides, including beta-gamma and alpha emitters. The gross activity DCGL can also account for so-called hard-to-detect (HTD) radionuclides. The latter are not detected, or detected with very low efficiency, by the beta detectors selected for the FSS of structures.

The gross activity DCGL for the HRA is calculated using equations in the FSSP for gross beta, gross alpha and surrogate DCGLs, based on the radionuclide mixture in residual contamination. Activity fractions and the gross activity DCGLs for the HRA are shown in Table 1.

[8] The convention used in the MARSSIM is to identify the DCGL used as the benchmark for evaluating survey unit measurement results, as the $DCGL_W$. The "W" subscript denotes "Wilcoxon", regardless of the particular test used (Wilcoxon Rank Sum Test, or Sign Test).

[9] Potential exposure to future occupants from subsurface structures could occur from contaminated concrete rubble placed as fill and from contaminated intact structures such as the below-grade portion of the Reactor Bioshield.

Table 1, HRA Radionuclide Activity Fractions and Gross Activity DCGLs

Location	Radionuclides								$DCGL_W$ (dpm/100 -cm^2)
	H-3	Co-60	Sr-90	I-129	Cs-137	Eu-154	U-234	U-235	
	Activity Fractions Assigned to HRA (1)								
Vault & pipe chase	0.1362	0.0522	0.0601	0	0.7346	0	0.0148	0.0021	34,213
Exterior surfaces (2)	0.2707	0.0965	0.0788	0.0142	0.4671	0.0012	0.0698	0.0017	27,166

Table 1 Notes:
1. Activity profiles and gross activity DCGLs for structures are reported in the Technical Basis Document PBRF-TBD-07-001 [PBRF 2007].
2. The default radionuclide mixture and DCGL reported in TBD-07-001 were applied to exterior surfaces in Survey Design 31.

Survey designs incorporate requirements for scan coverage and investigation levels derived from the MARSSIM classification of survey units. The values applicable to the HRA are shown in Table 2.

Table 2, Class-Based Survey Scan Coverage and Action Level Requirements

Classification	Scan Survey Coverage	Scan Investigation Levels	Static Measurement or Sample Result Investigation Levels
Class 1	100%	$>DCGL_{EMC}$	$>DCGL_{EMC}$
Class 2	10 to 100%	$>DCGL_W$ or $>MDC_{scan}$ if MDC_{scan} is $>DCGL_W$	$>DCGL_W$
Class 3	Minimum of 10%	$>DCGL_W$ or $>MDC_{scan}$ if MDC_{scan} is $>DCGL_W$	$\geq$50% of the $DCGL_W$

Table 2 Note:
1. The scan investigation levels shown above are as listed in the FSS Plan. However, as described in Section 4.4, the scan investigation level was set to be equal to the $DCGL_W$ for Class 1 survey units.

4.2 Area Classification and Survey Unit Breakdown

The HRA was identified as a single survey area classified as MARSSIM Class 1 in the FSS Plan. This is shown in Table 2-1 of the FSS Plan. As part of the FSS implementation process, individual survey units were identified and their final MARSSIM classification established. The HRA was divided into 34 Class 1 survey units for the FSS. These are identified in Table 3. Table 4 summarizes the survey unit breakdown by major elevation.[10]

[10] The calculations performed in preparation of this report are documented in a memorandum to the PBRF Decommissioning Project File [PBRF 2010].

Table 3, HRA Survey Units for FSS

Survey Unit (1)	Class	Description	FSSP Classification (2)
HR-1-1	1	HRA Vault – Floor Section 1	1
HR-1-2	1	HRA Vault – Floor Section 2	1
HR-1-3	1	HRA Vault – Floor Section 3	1
HR-1-4	1	HRA Vault – Floor Section 4	1
HR-1-5	1	HRA Vault – Floor Section 5	1
HR-1-6	1	HRA Vault – Floor Section 6	1
HR-1-7	1	HRA Vault – Wall Section 1	1
HR-1-8	1	HRA Vault – Wall Section 2	1
HR-1-9	1	HRA Vault – Wall Section 3	1
HR-1-10	1	HRA Vault – Wall Section 4	1
HR-1-11	1	HRA Vault – Wall Section 5	1
HR-1-12	1	HRA Vault – Wall Section 6	1
HR-1-13	1	HRA Vault – Wall Section 7 & Columns	1
HR-1-14	1	HRA Vault – Ceiling Section 1	1
HR-1-15	1	HRA Vault – Ceiling Section 2	1
HR-1-16	1	HRA Vault – Ceiling Section 3	1
HR-1-17	1	HRA Vault – Ceiling Section 4	1
HR-1-18	1	HRA Vault – Ceiling Section 5	1
HR-1-19	1	HRA Upper Pipe Chase – Floor Section 1	1
HR-1-20	1	HRA Upper & Lower Pipe Chase – Floor	1
HR-1-21	1	HRA Upper Pipe Chase – W & S Wall	1
HR-1-22	1	HRA Upper Pipe Chase – E & N Wall	1
HR-1-23	1	HRA Lower Pipe Chase –Wall Section 3	1
HR-1-24	1	HRA Pipe Chase –Ceiling Section 1	1
HR-1-25	1	HRA Pipe Chase –Ceiling Section 2	1
HR-1-26	1	Exterior - West Pad – South Section	1
HR-1-27	1	Exterior - West Pad – Center Section	1
HR-1-28	1	Exterior - East Pad – South Section	1
HR-1-29	1	Exterior - East Pad – Center Section	1
HR-1-30	1	Exterior - West & East Pads – North	1
HR-1-31	1	Exterior - Roof – South	1
HR-1-32	1	Exterior - Roof - North	1
HR-1-33	1	Exterior - West & South Walls	1
HR-1-34	1	Exterior - East & North Walls	1

Table 3 Notes:

1. The FSSP Table 2-1 identified 1 HRA survey area. For the FSS, this was divided into 34 survey units to meet FSS Plan classification-based size limits.
2. The FSS Plan classification was based on area history and available characterization data.

Table 4, HRA Survey Unit Breakdown by Major Elevation

Major Elevation	No. of Survey Units	Surface Area (m^2)	% of Survey Units	% of Surface Area
Vault	20	1741.2	59	61
Pipe Chase	5	419.9	15	15
OW&R	9	683.8	26	24
Total	34	2844.9	100	100

Table 4 Note:
1. OW&R – outside walls and roof.

4.3 Number of Measurements and Samples

The number of measurements and samples for each survey unit was determined using the MARSSIM statistical hypothesis testing framework as outlined in the FSS Plan. The Sign Test is selected because background count rates of instruments to be used are equivalent to a small fraction of the applicable $DCGL_W$.[11] Decision error probabilities for the Sign Test are set at $\alpha = 0.05$ (Type I error) and $\beta = 0.10$ (Type II error) in accordance with the FSSP.

The Visual Sample Plan (VSP) software was used to determine the number of FSS measurements in the HRA. [12] When the Sign Test is selected, the VSP software uses MARSSIM Equation 5-2 to calculate the number of measurements. Equation 5-2 is shown below:

$$N = 1.2\frac{(Z_{1-\alpha} + Z_{1-\beta})^2}{4\left[\Phi\left(\frac{\Delta}{\sigma}\right) - 0.5\right]^2} \qquad \textbf{(Equation 1)}$$

Where:

1.2 = adjustment factor to add 20% to the calculated number of samples, per a MARSSIM requirement to provide a margin for measurement sufficiency,
N = Number of measurements or samples,
α = the type I error probability,
β = the type II error probability,
$Z_{1-\alpha}$ = proportion of standard normal distribution < $1 - \alpha$ (1.6449 for σ = 0.05),
$Z_{1-\beta}$ = proportion of standard normal distribution < $1 - \beta$ (1.2816 for $\beta = 0.1$),

[11] Background count rates for the LMI 44-116 detector, the instrument of choice for FSS surface beta activity measurements on structures, are in the range of 300 cpm or less for most materials. This is equivalent to about 2500 dpm/100-cm^2; less than 10% of PBRF structure DCGLs (this assumes a detection efficiency of ~ 12%).

[12] The FSS Plan (Section 5.2.4) states that a qualified software product, such as Visual Sample Plan© [PNL 2010], may be used in the survey design process.

Φ (Δ/σ) = value of cumulative standard normal distribution over the interval -∞, Δ/σ,
Δ = the "relative shift", defined as the DCGL – the Lower Bound of the Gray Region (LBGR), and
σ = the standard deviation of residual contamination in the area to be surveyed (or a similar area). This may include the variation in measured "ambient" background plus the material background (for total surface beta measurements).

The MARSSIM module of VSP requires user inputs for the following parameters: α, β, LBGR, the $DCGL_W$ and σ. The numbers of measurements were calculated for the 34 HRA survey units using the parameters established in two survey designs. Table 5 summarizes the HRA survey design calculations and lists the values of the key VSP input parameters.

Table 5, HRA Survey Design Summary

Design No. (1)	Survey Units	Class	DCGL (2)	LBGR (2)	Δ (2)	σ (2)	Δ/σ	N
28 (3)	HR-1-1 through 1-18 (Vault surfaces)	1	29,423	19,553	9870	3290(5)	3.0	11
31 (3)	HR-1-19 through 1-25 (pipe chase interior surfaces)	1	29,423	17,720	11,703	3901(6)	3.0	11
31 (4)	HR-1-26 through 1-34 (roof and exterior walls	1	24,449	12,746	11,703	3901(6)	3.0	11

Table 5 Notes:
1. The data reported in this table is taken from the Survey Design reports listed. They are maintained in the PBRF Document Control System.
2. Units are dpm/100-cm^2.
3. In HRA vault and pipe chase interior surfaces, the $DCGL_W$ for the survey design, 29,423 dpm/100-cm^2, was obtained by adjusting the DCGL of 34,213 dpm/100-cm^2 published in TBD-07-001, by a factor of 21.5/25 to allocate 1 mrem/y to embedded piping in the HRA vault and 2.5 mrem to account for deselected insignificant radionuclides. It is noted that after the survey designs were prepared and the FSS of the structure completed it was determined that is not necessary to adjust the structure DCGLs in the HRA for embedded piping. The only piping in concrete which remained below grade was the terra cotta floor drain piping in the vault. This was surveyed and satisfied the DCGL for the structure.
4. In the survey design for the HRA exterior surfaces, the $DCGL_W$ for the survey design, 24,449 dpm/100-cm^2, was obtained by adjusting the default value, 27,166 dpm/100-cm^2, by a factor of 22.5/25 to account for deselected insignificant radionuclides.
5. The estimate of σ for vault interior surfaces was obtained from an HRA post-remediation and variability survey (SR-130) and MWH characterization survey material background study (G9000 401B1) measurements collected with LMI 44-116 beta detectors.
6. The estimate of σ was obtained from post-remediation surveys and variability study (SR-129). Data from the MWH characterization survey material background study (G9000 401B1) was also used to obtain the material background component of measurement variability.

Selection of design input parameters followed guidance in the FSS Plan. The Plan states that "the LBGR is initially set at 0.5 times the $DCGL_W$, but may be adjusted to obtain a value for the relative shift (Δ/σ) between 1 and 3." It is seen in Table 5 that a relative shift value of 3.0 was used in the final calculations for determining N.

The VSP software automatically performs an analysis to examine the sensitivity of the number of samples, N, to critical input parameter values. The following is obtained from the VSP report for survey unit HR-1-10 (with modifications). The sensitivity of N was explored by varying the following parameters: standard deviation, lower bound of gray region (as % of DCGL), beta, probability of mistakenly concluding that the survey unit mean concentration, μ, is greater than the DCGL and alpha, probability of mistakenly concluding that the survey unit mean concentration, μ, is less than the DCGL.

Table 6 summarizes this analysis.[13] The region of most interest in the table is for $\alpha = 0.05$ (required to be fixed), $\beta = 0.10$ (may be adjusted) and the LBGR at 60% to 70% of the DCGL. The sensitivity of N to expected measurement variability is examined first. With the LBGR set to 70%, doubling σ increases N from 11 to 16. At this LBGR value, N is sensitive to measurement variability. However, with the LBGR set to 60% of the DCGL, doubling σ increases N only slightly, from 11 to 12. This shows that the number of measurements is not strongly sensitive to measurement variability at LBGR values near 60% of the DCGL, as used in the HRA designs.

The sensitivity of N to an incorrect conclusion that the survey unit will pass (regulator's risk) is low. With the LBGR set at 60% of the DCGL, and increasing α from 0.05 to 0.10 and 0.15 while holding β constant at 0.10, shows that the number of measurements is 12 or fewer in all cases. These results show that N = 11 represents an appropriate number of measurements for FSS of the HRA, in view of parameter values applied to the designs.

Table 6, Sensitivity Analysis for HRA FSS Design

Number of Samples							
DCGL=29,423 (1)		α=0.05 (2)		α=0.10		α=0.15	
		σ= 6580 (1) (3)	σ= 3290	σ=6580	σ=3290	σ=6580	σ=3290
LBGR=80% (1) (4)	β=0.05	34	16	27	12	23	11
	β=0.10	27	12	21	10	17	9
	β=0.15	23	11	17	9	14	8
LBGR=70%	β=0.05	21	14	16	11	14	10
	β=0.10	16	11	12	9	10	8
	β=0.15	14	10	10	8	9	6
LBGR=60%	β=0.05	16	13	12	11	11	9
	β=0.10	12	11	10	8	8	7
	β=0.15	11	9	8	7	7	6

Table 6 Notes:
1. Units of DCGL, σ and LBGR are dpm/100-cm^2.
2. α = alpha, probability of mistakenly concluding that μ < DCGL.
3. σ = Standard Deviation.
4. LBGR = Lower Bound of Gray Region (as % of DCGL)
5. β = beta, probability of mistakenly concluding that μ > DCGL

[13] In this case, the sensitivity analysis was augmented to extend the range of the LBGR to 60% of the DCGL to evaluate the sensitivity of N to changes of key parameters in the region of Δ/σ values near 3.0. This is necessitated by the large estimated value of σ used in the HRA FSS design [PBRF 2010].

Visual Sample Plan was also used to determine the grid size, the random starting location coordinates (for Class 1 and 2 survey units) and to display the measurement locations on survey unit maps drawn to scale. Refer to Appendix B for location coordinate tables and scale VSP maps showing measurement locations for each HRA survey unit.

The survey designs also specify scan survey coverage and action levels based on the MARSSIM classification listed in Table 2 (scan investigation-action levels are discussed further in Section 4.4). If the scan sensitivity of the detectors used in Class 1 survey units is below the $DCGL_W$, the number of measurements in each survey unit is determined solely by the Sign Test. If the scan sensitivity is not below the $DCGL_W$, the number of measurements is increased as determined by the Elevated Measurement Comparison (EMC). As discussed in the next section, the scan sensitivities of instruments used in the FSS of the HRA are below the $DCGL_W$, and no increase in the number of measurements above the value calculated using the Sign Test was required.

4.4 Instrumentation and Measurement Sensitivity

Instruments to be used in the FSS of each survey unit are selected in each survey design. Their detection sensitivities must be sufficient to meet the required action levels for the MARSSIM class of each survey unit. Minimum detection sensitivities for static alpha and beta measurements are calculated using the following equation:

$$MDCstatic = \frac{3 + 3.29\sqrt{B_R t_s (1 + \frac{t_s}{t_b})}}{t_s E_{tot} \frac{A}{100}}, \qquad \textbf{(Equation 2)}$$

where:

MDC_{static} = Minimum Detectable Concentration (dpm/100-cm^2),

B_R = Background Count Rate (cpm),

t_b = Background Count Time (min),

t_s = Sample Count Time (min),

A = Detector Open Area (cm^2) and

E_{tot} = Total Detection Efficiency (counts per disintegration). The total efficiency equals the product of Detector Efficiency, E_i and Surface Efficiency, E_s.

Scan sensitivities for detectors which measure alpha and beta surface activity are determined using the following equation:

$$MDCscan = \frac{d'\sqrt{b_i}\frac{60}{i}}{E_i E_s \sqrt{p}\frac{A}{100}}, \qquad \textbf{(Equation 3)}$$

Where:

MDC_{scan} = Minimum Detectable Concentration (dpm/100-cm^2),

d' = Index of sensitivity related to the detection decision error rate of the surveyor, from Table 6.5 of MARSSIM [USNRC 2000],

i = observation counting interval, detector width (cm) / scan speed (s),

b_i = background counts per observation interval,

E_i = Detector Efficiency (counts per disintegration),

Es = Surface Efficiency, typically 25% for alpha and 50% for beta per ISO 7503-1, Table 2 [ISO 1988],

p = Surveyor efficiency (typically 50%) and

A = Detector Open Area (cm^2).

A summary of the a priori detection sensitivities of instruments used in the FSS of the HRA is provided in Table 7.

Table 7, Typical Detection Sensitivities of Field Instruments

Detector Model	Detector Efficiency (c/d) (1)	MDC_{scan} (dpm/100-cm^2) (2)	Net cpm Equivalent to $DCGL_W$	MDC_{static} (dpm/100-cm^2) (3)
LMI 44-116 (4)	0.140	2,587	3,439	589
LMI 43-37 (5)	0.125	742	3,678	NA
LMI 44-9 (6) (7)	0.145	9,713	512	3,162

Table 7 Notes:

1. The detector efficiencies listed are total efficiency, i. e., $E_t = E_i + E_s$.
2. A priori scan sensitivities are calculated using Equation 3.
3. Static sensitivities are calculated using Equation 2.
4. The scan MDC for the LMI 44-116 is reported in Design No. 28 for background count rate = 200 cpm; scan speed =15 cm/s and E_s = 0.5. An efficiency correction factor = 0.8349 is applied to compensate for concrete roughness (the detector-to-surface distance is 0.5 in.).
5. The static MDC for the LMI 44-116 detector is reported in Design No. 28 for background count rate = 200 cpm, E_s = 0.5 and the detector-to-surface distance = 0.5 in. (one minute count times are assumed for both the background and sample counts).
6. The scan MDC for the LMI 43-37 is from Survey Design No.28. The background count rate is 500 cpm; the scan speed is 27 cm/s, E_s = 0.5 and the detector-to-surface distance is 0.5 in.
7. The scan MDC for the LMI 44-9 is obtained from Survey Design No. 28. The background count rate is 125 cpm with a scan speed of 4.4 cm/s and the detector in contact with the surface.
8. The static MDC for the LMI 44-9 is obtained from Survey Design No. 28. The background count rate is 125 cpm and the detector in contact with the surface (one minute count times are assumed for both the background and sample counts).

The scan investigation level for Class 1 survey units listed in Table 2 is the $DCGL_{EMC}$, as specified in the FSS Plan Section 8.1. However, the scan investigation level is actually set at the $DCGL_W$ established in the survey design for each structure survey unit. This practice was established in early survey designs for conservatism and was continued in subsequent designs. It is also noted the FSS Plan states that technicians are to respond to indications of increased count rates even though scan count rates may not be above the investigation level specified in survey instructions. [14]

Modifications to survey instructions are adjusted to account for unusual measurement conditions. Modified detection sensitivities may be applied taking into account adjustments in detector efficiency. Scan speeds may be reduced to ensure that required scan sensitivities are achieved. The bases for adjustments due to non-standard conditions are provided in PBRF Technical Basis Documents.[15] Examples of areas or locations in HRA survey units where special measurement conditions apply are shown in Exhibits 15 through 18 of Appendix A.

5.0 HRA Survey Results

Results of the HRA FSS are presented in this section. This includes scan survey frequencies (% of areas covered) for each survey unit and occurrence of events where scan investigation levels were exceeded. Investigations performed and the results are summarized. Fixed measurement results for each survey unit and the results of comparison tests of survey unit maximum and average values with the $DCGL_W$ are reported. As discussed below, no statistical tests were required. It is shown that levels of residual contamination have been reduced to levels that are ALARA. This section closes with a summary which concludes that applicable criteria for release of the HRA for unrestricted use are satisfied and all FSS Plan requirements are met.

5.1 Surveys and Investigations

Scan survey results were reviewed to confirm that the scan coverage requirement (as % of survey unit area) was satisfied for all survey units. The results of QC replicate scan surveys were also reviewed to confirm that the minimum coverage requirement of 5% was satisfied. Results of the HRA scan surveys are compiled in Table 8. The table shows that scan coverage requirements were satisfied for all survey units. The table also shows that investigations were performed in three survey units (all HRA survey units are Class 1).

In survey unit HR-1-14, HRA vault ceiling Section 1, elevated counts were observed during the surface beta scan survey. Elevated counts, but less than the action level, were observed over a 1 in. diameter by 7 in. deep anchor hole. It was investigated, however due to the non-standard geometry and concerns about down-hole contamination. This was a hole drilled for

[14] From FSS Plan Section 7.1.1: "Technicians will respond to indications of elevated areas while surveying. Upon detecting an increase in visual or audible response, the technician will reduce the scan speed or pause and attempt to isolate the elevated area. If the elevated activity is verified to exceed the established investigation level, the area is bounded (e.g., marked and measured to obtain an estimated affected surface area). Representative static measurements are obtained as determined by the FSS/Characterization Engineer. The collected data is documented on a Radiological Survey Form."

[15] The PBRF-TBD-07-004 [PBRF 2007a] presents efficiency correction factors developed for the LMI 44-116 detector. The correction factors are presented as a function of detector-to-surface distance. Application of the factors requires empirical measurements of the effective detector-to-surface distance for areas with non-standard surface conditions as part of the survey unit inspection process.

anchoring hoisting equipment during decommissioning. The total surface beta-gamma contamination in the hole was evaluated using a small NaI detector and determined to be less than the applicable $DCGL_W$ (29,423 dpm/100-cm^2). Smears were taken in the anchor holes and counted for beta and alpha activity. The results were less than MDA for both beta and alpha.

The scan investigation level was exceeded in three localized areas during the scan survey of the pipe chase floor in survey unit HR-1-19. Fixed beta measurements and smears were taken at the three locations identified in the scan survey. The highest total surface activity measured was 17,100 dpm/100-cm^2, below the $DCGL_W$ (29,423 dpm/100-cm^2). The highest removable surface beta activity measured was 52 dpm/100-cm^2 (beta), well below 10% of the $DCGL_W$. The alpha activity on all the smears was below the MDA.

An investigation was performed as a result of elevated counts observed during the scan survey of the HRA vault personnel hatch in survey unit HR-1-27. The investigation level was not exceeded, but an investigation was performed due to the non-standard geometry. Static measurements were taken and the highest activity was 12,900 dpm/100-cm^2.

Table 8, Scan Survey Results

Survey Unit	Class	Scan Survey Coverage (%) (1)(2)	Survey Request No.	Investigation Performed	QC Replicate Scan Coverage (%) (2) (3) (4)
HR-1-1	1	100	145	No	5.7
HR-1-2	1	100	145	No	5.7
HR-1-3	1	100	145	No	5.7
HR-1-4	1	100	145	No	5.8
HR-1-5	1	100	145	No	5.7
HR-1-6	1	100	145	No	6.9
HR-1-7	1	100	146	No	5.2
HR-1-8	1	100	146	No	5.2
HR-1-9	1	100	146	No	5.2
HR-1-10	1	100	146	No	5.3
HR-1-11	1	100	146	No	5.6
HR-1-12	1	100	146	No	5.2
HR-1-13	1	100	146	No	5.3
HR-1-14	1	100	147	Yes	5.4
HR-1-15	1	100	147	No	5.2
HR-1-16	1	100	147	No	5.2
HR-1-17	1	100	147	No	5.2
HR-1-18	1	100	147	No	5.2
HR-1-19	1	100	155	Yes	8.1
HR-1-20	1	100	155	No	6.0
HR-1-21	1	100	155	No	12.2
HR-1-22	1	100	155	No	8.4
HR-1-23	1	100	155	No	5.8
HR-1-24	1	100	155	No	6.3
HR-1-25	1	100	155	No	5.4
HR-1-26	1	100	156	No	9.0

Table 8, Scan Survey Results

Survey Unit	Class	Scan Survey Coverage (%) (1)(2)	Survey Request No.	Investigation Performed	QC Replicate Scan Coverage (%) (2) (3) (4)
HR-1-27	1	100	156	Yes	9.0
HR-1-28	1	100	156	No	9.1
HR-1-29	1	100	156	No	12.2
HR-1-30	1	100	156	No	17.7
HR-1-31	1	100	157	No	2.8
HR-1-32	1	100	157	No	9.4
HR-1-33	1	100	157	No	6.0
HR-1-34	1	100	157	No	6.2

Table 8 Notes:

1. One hundred percent of the accessible surface area was scanned. A fraction of the surface area of some survey units is inaccessible for scanning. In most such survey units, it is less than a few percent of the total surface area.
2. Scan % coverage values are rounded to the nearest whole per cent. Values reported with the first decimal as 5, e. g., 5.5, are rounded downward.
3. The % scan coverage is given as the % of the area scanned in the initial survey.
4. Replicate QC scan results are reported for multiple survey units in some Survey Requests. The QC scan percentages are reported as % of the scanned area of the survey units combined. So the same % coverage value is assigned to the survey units whose QC scan areas are reported as a group in a Survey Request.

5.2 Fixed Measurements and Tests

Results of the assessment of HRA FSS total surface beta measurements are presented in Table 9 (individual measurements in each survey unit are reported in Appendix B). Table 9 compares the maximum activity measured in each survey unit to the DCGL. The mean activity of each survey unit is also compared to the DCGL, and as expected, are all less than the DCGL. The DCGL values used for these comparisons are identified as "adjusted DCGLs". As explained in the Table 9 Notes, the adjusted DCGLs are calculated for each survey unit to allow for the dose contribution from deselected radionuclides (2.5 mrem/y) and embedded piping (1 mrem/y) as applicable. The last column of Table 9 shows the results of an additional check. This check is to ensure that the dose from residual surface contamination in each survey unit plus the doses allocated for embedded piping and deselected radionuclides is below 25 mrem/y.

The results of the evaluations reported above and in Table 9 show that the total dose from each HRA survey unit is well below the 25 mrem/y dose criterion.[16] The average of 381

[16] The average estimated dose from residual activity in the HRA survey units is 0.65 mrem/y and the maximum dose is 1.53 mrem/y. Included in this average are the estimated doses from each survey unit obtained from the systematic total surface beta activity measurements on the structure and any contributions from activity measured in localized areas of elevated activity that exceeded the DCGL (there were no localized areas with activity > DCGL in the HRA). For the systematic measurements, the estimated dose is obtained as the ratio of the survey unit average residual surface beta activity (from the systematic measurements only) to the adjusted DCGL, times the dose equivalent to the adjusted DCGL.

systematic total surface beta measurements reported in the HRA release records (interior and exterior surfaces) is: 844 ± 521 dpm/100-cm^2 (one standard deviation) [PBRF 2010]. [17]

Removable surface activity measurements were also performed at each fixed activity measurement location and counted for gross alpha and gross beta activity. A review of the HRA Release records was conducted to ensure that all smear counting results were less than 10% of the gross activity DCGL. The requirement for PBRF laboratory smear counting instruments is that the MDAs be < 10% of the applicable gross activity DCGL[18]. Gross beta and gross alpha counts for all HRA smears were less than MDA.

Table 9, HRA Total Surface Beta Activity Measurement Summary and Test Results

Survey Unit ID	$DCGL_W$ (1) (4)	Adjusted DCGL(2) (4)	N (3)	Maximum (4)	Test Result Maximum < Adj. DCGL	Average (4)	Test Result Average < Adj. DCGL	Total Dose < 25 mrem/y (5)
HR-1-1	34213	30792	11	752	YES	525	YES	YES
HR-1-2	34213	30792	11	1050	YES	607	YES	YES
HR-1-3	34213	30792	11	877	YES	664	YES	YES
HR-1-4	34213	30792	11	1416	YES	722	YES	YES
HR-1-5	34213	30792	11	846	YES	437	YES	YES
HR-1-6	34213	30792	11	781	YES	479	YES	YES
HR-1-7	34213	30792	12	1080	YES	896	YES	YES
HR-1-8	34213	30792	12	1200	YES	884	YES	YES
HR-1-9	34213	30792	12	1308	YES	958	YES	YES
HR-1-10	34213	30792	12	1466	YES	1042	YES	YES
HR-1-11	34213	30792	11	1233	YES	855	YES	YES
HR-1-12	34213	30792	12	1308	YES	965	YES	YES
HR-1-13	34213	30792	11	1169	YES	850	YES	YES
HR-1-14	34213	30792	11	1010	YES	658	YES	YES
HR-1-15	34213	30792	11	1090	YES	697	YES	YES
HR-1-16	34213	30792	11	2120	YES	778	YES	YES
HR-1-17	34213	30792	11	4190	YES	1558	YES	YES
HR-1-18	34213	30792	11	2310	YES	971	YES	YES
HR-1-19	34213	30792	11	3584	YES	1653	YES	YES
HR-1-20	34213	30792	11	4149	YES	2093	YES	YES
HR-1-21	34213	30792	11	1027	YES	850	YES	YES

[17] It is noted that in converting total surface activity measurements in cpm to dpm/100-cm^2, the detector background response from surface materials is not subtracted. As a result, the total surface activity measurement results are biased high.

[18] Typical MDAs for PBRF low background smear counting instruments are 14 dpm for alpha and 18 dpm for beta. Smears cover 100 cm^2, so these MDA values are equivalent to dpm/100-cm^2.

Table 9, HRA Total Surface Beta Activity Measurement Summary and Test Results

Survey Unit ID	$DCGL_W$ (1) (4)	Adjusted DCGL (2) (4)	N (3)	Maximum (4)	Test Result Maximum < Adj. DCGL	Average (4)	Test Result Average < Adj. DCGL	Total Dose < 25 mrem/y (5)
HR-1-22	34213	30792	11	1103	YES	816	YES	YES
HR-1-23	34213	30792	11	959	YES	696	YES	YES
HR-1-24	34213	30792	11	1089	YES	623	YES	YES
HR-1-25	34213	30792	11	1384	YES	808	YES	YES
HR-1-26	27166	24449	12	1120	YES	594	YES	YES
HR-1-27	27166	24449	11	1120	YES	726	YES	YES
HR-1-28	27166	24449	11	1080	YES	698	YES	YES
HR-1-29	27166	24449	12	1170	YES	675	YES	YES
HR-1-30	27166	24449	11	1020	YES	612	YES	YES
HR-1-31	27166	24449	11	1300	YES	877	YES	YES
HR-1-32	27166	24449	11	1340	YES	755	YES	YES
HR-1-33	27166	24449	11	1390	YES	1122	YES	YES
HR-1-34	27166	24449	11	1190	YES	533	YES	YES

Table 9 Notes:

1. The $DCGL_W$ as specified in Table 1 and Table 1 Notes.
2. The $DCGL_W$ is adjusted by a factor of 21.5/25 to account for one mrem/y dose contribution from embedded piping and 2.5 mrem/y from deselected radionuclides. If no embedded piping is associated with the survey unit, the $DCGL_W$ is adjusted by a factor of 22.5/25 to account for the dose contribution from deselected radionuclides only.
3. N = number of measurements. Where the number of measurements is greater than the default design value of 11, it is due to the VSP method of fitting the calculated systematic grid pattern into the survey unit. On occasion, this adds additional measurement locations.
4. Units are dpm/100-cm^2.
5. This column shows the results of a check performed on each survey unit to confirm that the building structure surface activity measured from the systematic measurements plus any activity in localized areas of elevated activity (none observed in the HRA) is less than the adjusted DCGL. This is an additional check to ensure that the total dose from all contributors associated with each survey unit is less than 25 mrem/y.

5.3 ALARA Evaluation

It is shown that residual contamination in the HRA has been reduced to levels that are ALARA, using a method acceptable to the NRC. The NRC guidance on determining that residual contamination levels are ALARA includes the following:

> "In light of the conservatism in the building surface and surface soil generic screening levels developed by the NRC, NRC staff presumes, absent information to the contrary, that licensees who remediate building surfaces or soil to the generic screening levels do not need to provide analyses to demonstrate that these screening levels are ALARA. In addition, if residual radioactivity cannot be detected, it may be presumed that it had been reduced to levels that are ALARA. Therefore the licensee may not need to conduct an explicit analysis to meet the ALARA requirement."[19]

Screening level values published by the NRC for the mix of radionuclides in structural surface residual contamination potentially present in the HRA are shown in Table 10. Since individual radionuclide activity concentrations are not measured in the FSS of structures, a direct comparison of residual contamination levels to individual radionuclide screening level values is not possible. A comparison can be made by converting the nuclide-specific screening level values to an "equivalent" gross activity DCGL. This is accomplished using activity fractions used in development of the HRA gross activity DCGL for the vault and pipe chase interior. A screening level value that is equivalent to the gross activity DCGL was calculated using the equations in Section 3.6 of the FSS Plan.[20] The activity fractions listed in Table 1 (also shown in Table 10) were used in the calculation. The screening level equivalent DCGL for the HRA interior surfaces is calculated to be 4,328 dpm/100-cm^2.[21]

The average total surface beta activity measured in the FSS of the HRA interior surfaces is 885 ± 573 dpm/100-cm^2 (one standard deviation). The upper limit of the 95th % confidence interval of this mean value is 952 dpm/100-cm^2.[22] This value is below the screening level gross activity DCGL of 4,328 dpm/100-cm^2. From this comparison, it is concluded that the ALARA criterion is satisfied.

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[19] This guidance was initially published in Draft Regulatory Guide DG-4006, but has been reissued in NUREG-1757 Volume 2, Appendix N.

[20] The equivalent screening level gross activity DCGL is calculated using an EXCEL template [PBRF 2010]. This template incorporates the equations in section 5.3 of the FSS Plan [NASA 2007].

[21] The screening level equivalent gross activity DCGL was also calculated for the default radionuclide mixture applied to the HRA exterior surfaces. This was calculated to be 1182 dpm/100-cm^2. The upper confidence limit of the FSS measurements on the HRA exterior surfaces is 792 dpm/100-cm^2, also less than the associated screening level equivalent DCGL value.

[22] The upper limit of the confidence interval, 95th percentile value, is calculated as: UL = mean + 1.96 $\sigma/\sqrt{n}$, where n = 381 measurements.

Table 10, Screening Level Values for HRA and Radionuclide Activity Fractions

Radionuclide	Screening Level Value ($dpm/100\text{-}cm^2$)	HRA Activity Fraction (%) [1]
H-3	1.2 E+08 [2]	13.6
Co-60	7.1E+03 [2]	5.2
Sr-90	8.7E+03 [2]	6.0
I-129	3.5E+04[2]	0
Cs-137	2.8E+04 [2]	73.5
Eu-154	1.2E+04[3]	0
U-234	9.1E+01 [3]	14.8
U-235	9.8E+01[3]	0.2

Table 10 Notes:

1. Activity fractions used to develop the $DCGL_W$ for vault and pipe chase interior.
2. Values from NUREG-1757 Vol. 2, Table H.1 [USNRC 2006].
3. Values from NUREG/CR-5512, Vol. 3, Table 5.19 [SNL 1999]. These are 90th percentile values of residual surface activity corresponding to 25 mrem/y to a future building occupant.

5.4 Comparison with EPA Trigger Levels

The PBRF license termination process includes a review of residual contamination levels in groundwater and soil, as applicable, in accordance with the October 2002 Memorandum of Understanding (MOU) between the US NRC and the US Environmental Protection Agency (EPA) [USEPA 2002]. Concentrations of individual radionuclides, identified as "trigger levels" for further review and consultation between the agencies, are published in the MOU. The trigger levels applicable to the PBRF for residual soil concentrations of the radionuclides of concern are:

- Co-60, 4 pCi/g,
- Sr-90 (plus daughter activity), 23 pCi/g and
- Cs-137 (plus daughter activity), 6 pCi/g.

As no soil or groundwater measurement results are reported for the FSS of the HRA, the comparison with EPA Trigger Levels is not applicable.

5.5 Conclusions

The results presented above demonstrate that the HRA satisfies all FSS Plan commitments and meets the release criteria in 10CFR20 Subpart E. The principal conclusions are:

- Scan surveys were performed of 100 % of the accessible surfaces of all 34 HRA survey units – all were Class 1.
- Residual surface contamination levels requiring investigation were observed in only three survey units. No residual contamination levels above the $DCGL_W$ were reported in these investigations.

- All randomly selected (systematic with random start) total surface beta activity measurements are less than the applicable $DCGL_W$.
- All survey unit mean fixed measurement results (total surface beta activity) are below the $DCGL_W$, hence no statistical tests were required.
- All removable surface activity measurements are less than 10% of the $DCGL_W$.
- Residual surface activity concentration measurement results are shown to be less than NRC screening level values - demonstrating that the ALARA criterion is satisfied.
- Only minor changes from what was proposed in the FSS Plan were made – the HRA was divided into 34 survey units, whereas the FSS Plan had not shown a survey unit breakdown.
- There were no changes from initial assumptions (in the FSS Plan) regarding the extent of residual activity in the HRA. No reclassification of survey units was required as a result of FSS measurements and investigations.

6.0 References

ISO 1988 International Organization for Standardization, *Evaluation of Surface Contamination, Part 1: Beta Emitters and Alpha Emitters,* ISO-7503-1, 1988.

MWH 2005 MWH Constructors, Inc., *Characterization Package C1155 101C1 Hot Retention Area Subsurface Structure,* Prepared for US Army Corps of Engineers Under Contract DACW-27-97-0015, August 2005.

MWH 2005a MWH Constructors, Inc., *Investigation of Radioactivity in PBRF Concrete*, Prepared for US Army Corps of Engineers Under Contract DACW-27-97-0015, August 2005.

NASA 2006 NASA Safety and Mission Assurance Directorate, Plum Brook Reactor Facility, *Decommissioning Project Quality Assurance Plan,* QA-01, Revision 2, February 2006.

NASA 2007 NASA Safety and Mission Assurance Directorate, *Final Status Survey Plan for the Plum Brook Reactor Facility,* Revision 1, February 2007.

NASA 2007a NASA Safety and Mission Assurance Directorate, *Decommissioning Plan for the Plum Brook Reactor Facility*, Revision 6, July 2007.

PBRF 1972 Plum Brook Reactor Facility HSS Rad. No. 4, *Radiological Control Zone Criteria,* September 1972.

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PBRF 2009 — Plum Brook Reactor Facility, Memorandum to Project File, J. L. Crooks, Don Young, *Final FSS Report Background –Hot Retention Area (1132),* December 14, 2009.

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PNL 2010 — Battelle Pacific Northwest Laboratories (PNL), *Visual sample Plan*, Version 5.9, 2010.

SNL 1999 — Sandia National Laboratories (SNL), for US Nuclear Regulatory Commission, *Residual Radioactive Contamination From Decommissioning, Parameter Analysis,* NUREG/CR-5512, Vol.3, Oct. 1999.

TELE 1987 — Teledyne Isotopes, *An Evaluation of the Plum Brook Reactor Facility and Documentation of Existing Conditions*, Prepared for NASA Lewis Research Center, December 1987.

USEPA 2002 — Memorandum of Understanding, US Environmental Protection Agency and US Nuclear Regulatory Commission, *Consultation and Finality on Decommissioning and Decontamination of Contaminated Sites*, October 9, 2002.

USNRC 2000 — US Nuclear Regulatory Commission, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*, NUREG-1575, Rev.1, August 2000.

USNRC 2006 — US Nuclear Regulatory Commission, *Consolidated Decommissioning Guidance, Characterization, Survey and Determination of Radiological Criteria*, NUREG 1757, Vol. 2, Rev.1, September 2006.

7.0 Appendices

Appendix A – Exhibits

Appendix B – Survey Unit Maps and Tables Showing Measurement Locations and Results

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Attachment 5

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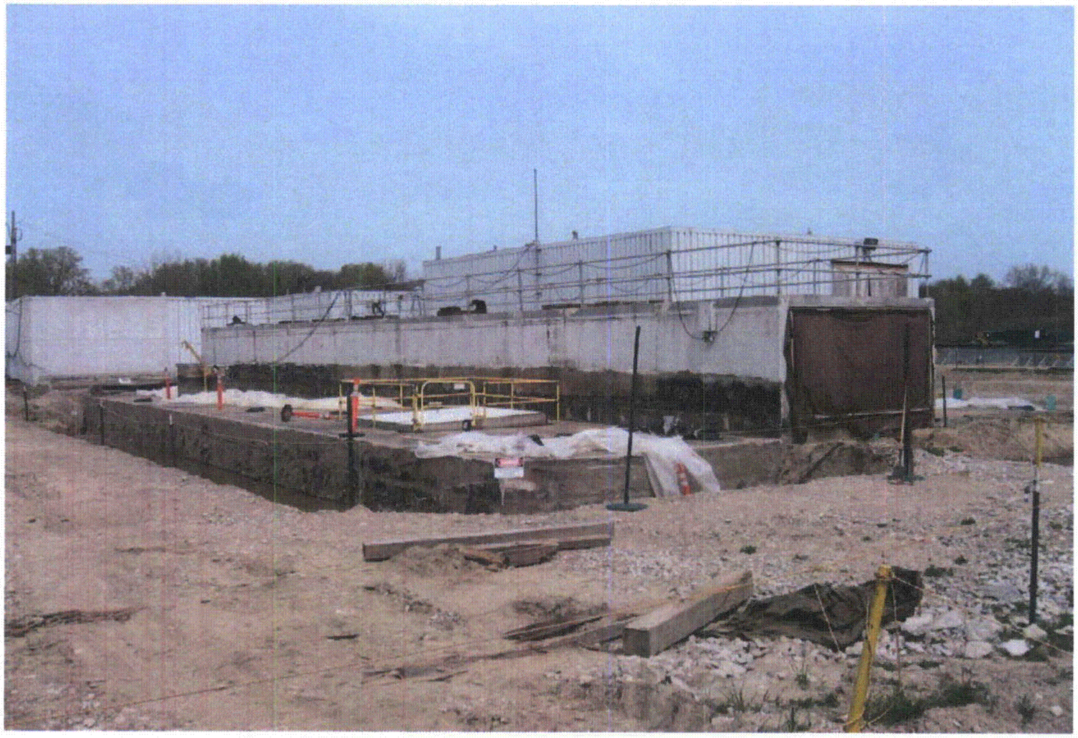
Appendix A

Exhibits

List of Exhibits

Exhibit 1, Views of HRA Exterior

View from Southwest Showing Vault Roof in Foreground and Pipe Chase Structure



HRA Pipe Chase Structure Viewed from Southeast

Exhibit 2, HRA Vault Floor Layout Showing Survey Units

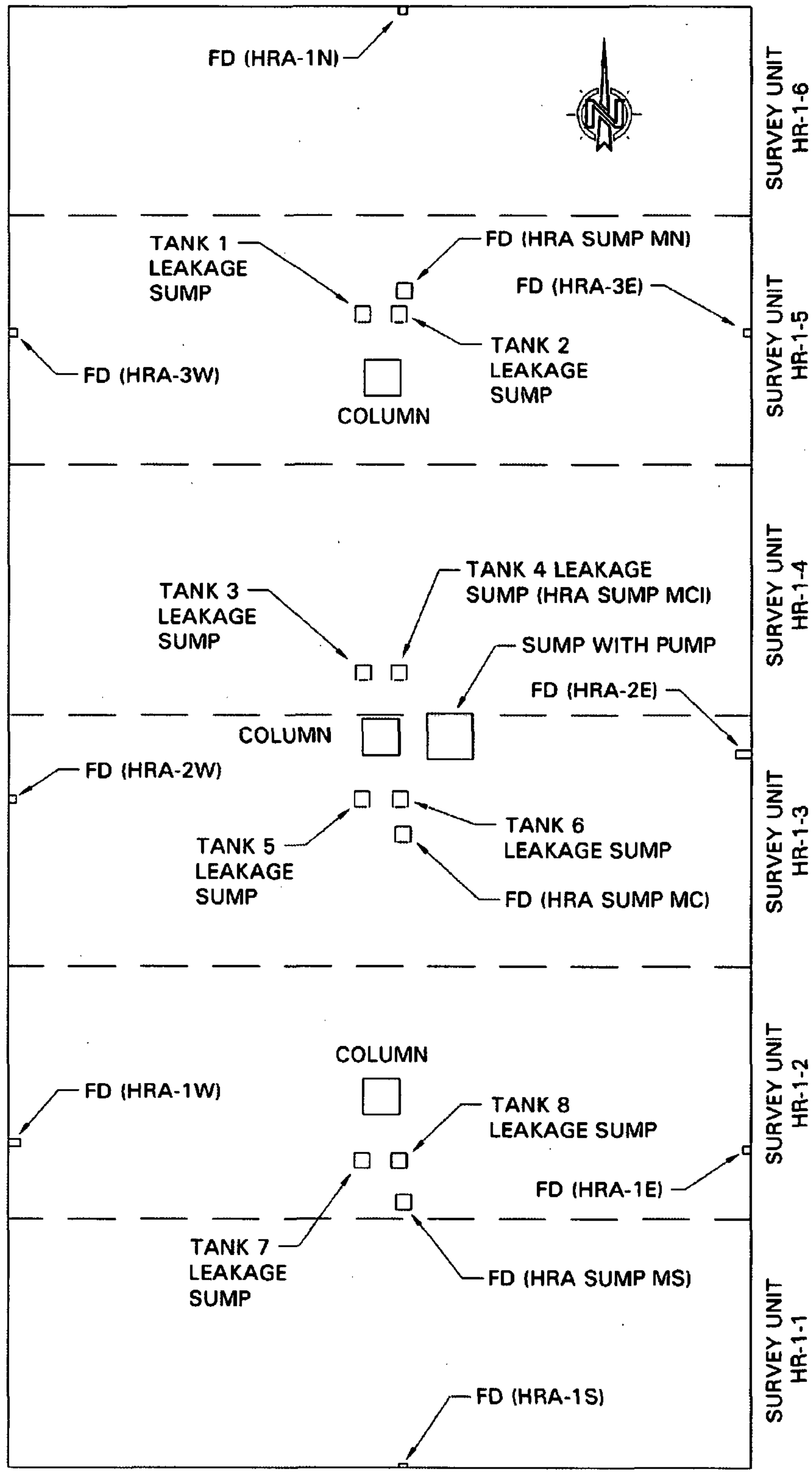


Exhibit 3, HRA Vault Ceiling Showing Survey Units

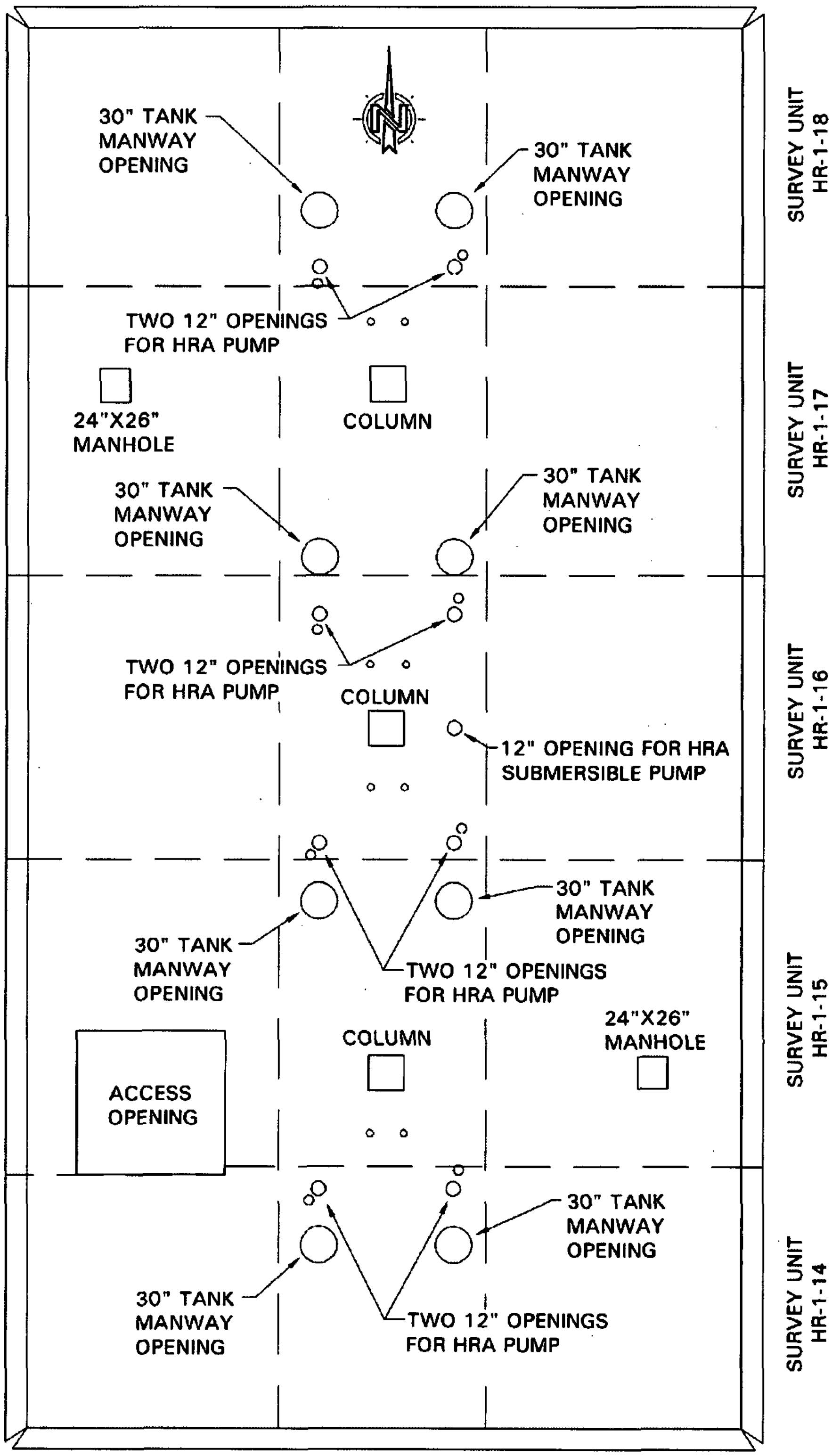


Exhibit 4. HRA Pipe Chase Floor Layout Showing Survey Units

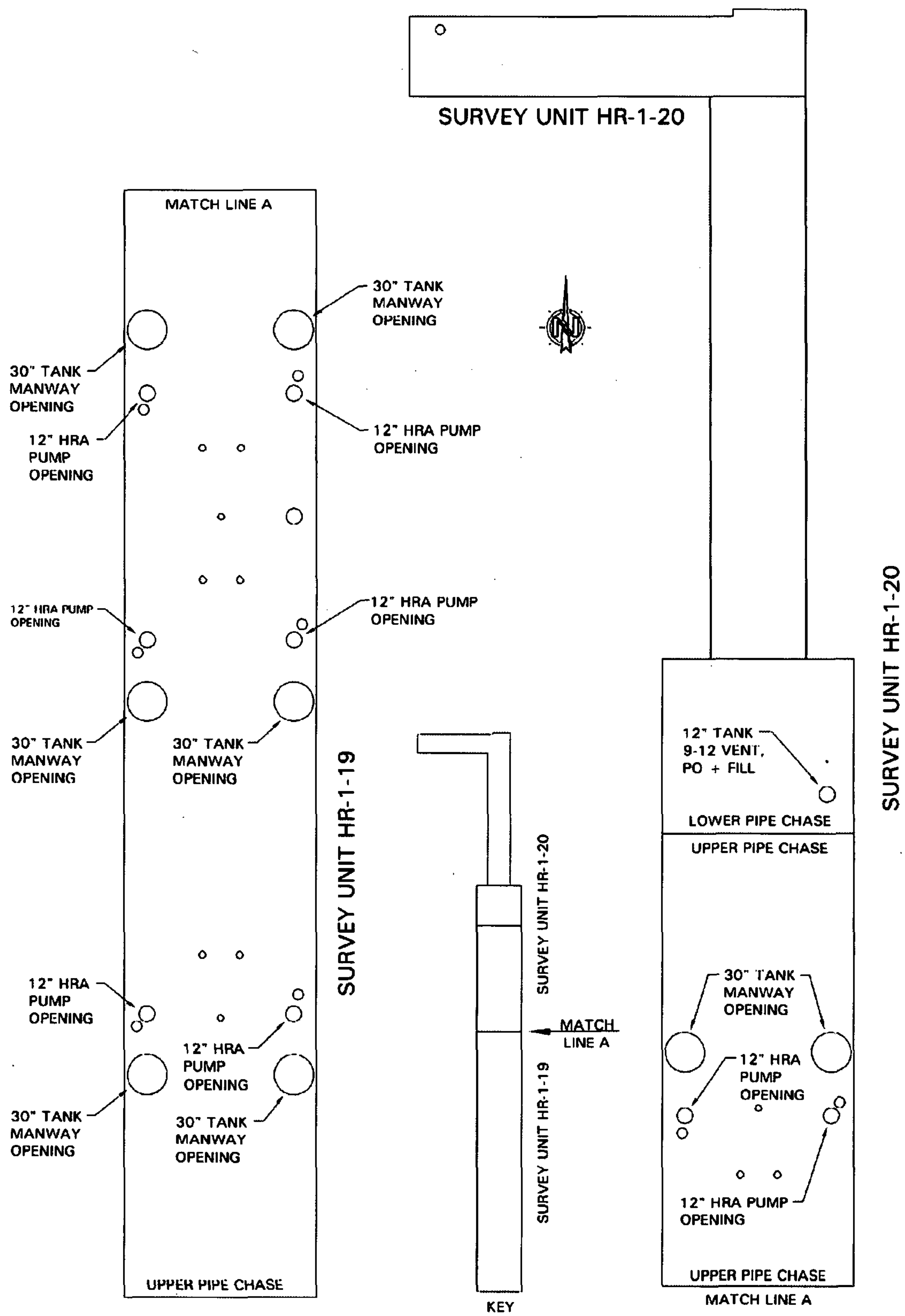


Exhibit 5, HRA Vault and Pipe Chase Roofs Showing Survey Units

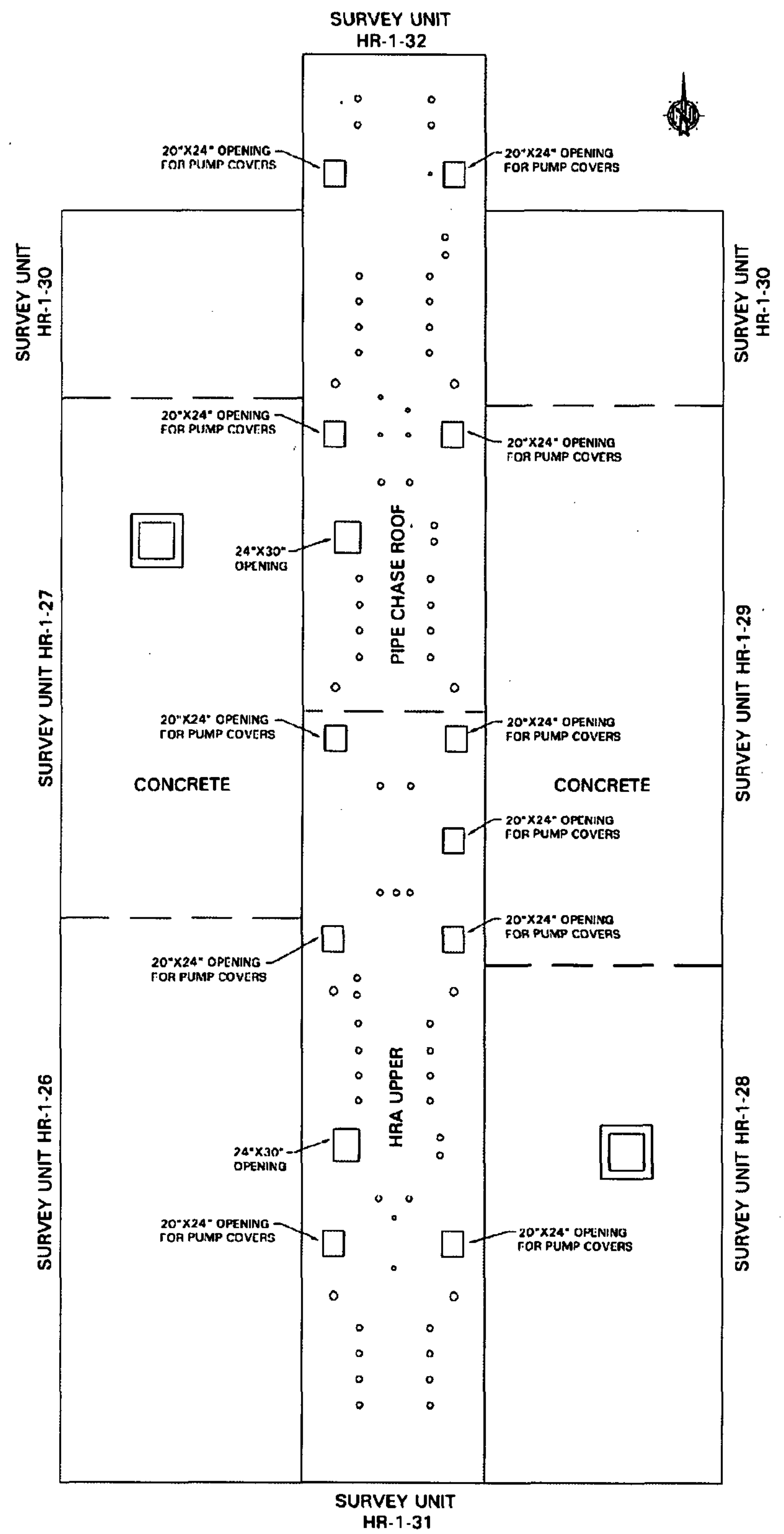


Exhibit 6, Views of HRA Vault Floors

Floor Area and Lower Wall in Vault Center Looking West (Survey Unit HR-1-2)

General View of Vault Floor East Side (Survey Unit HR-1-5)

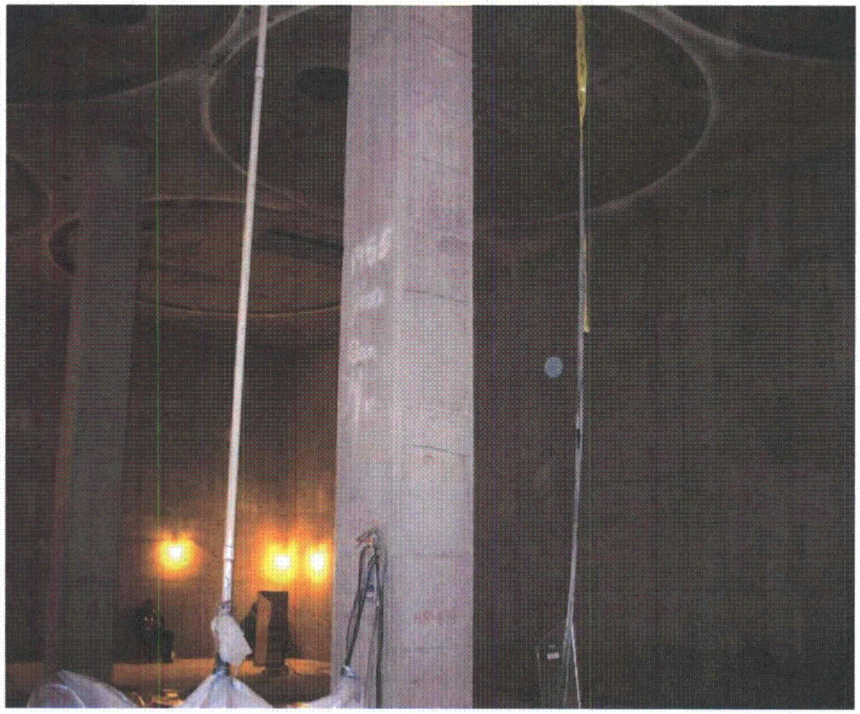
Exhibit 7, HRA Vault Floor Drains

Footer Drain Bowl at South Wall (Survey Unit HR-1-1)

Floor Drain Access near Vault Center Showing Clay Tile Drain Piping (Survey Unit HR-1-5)

Exhibit 8, Support Columns in HRA Vault

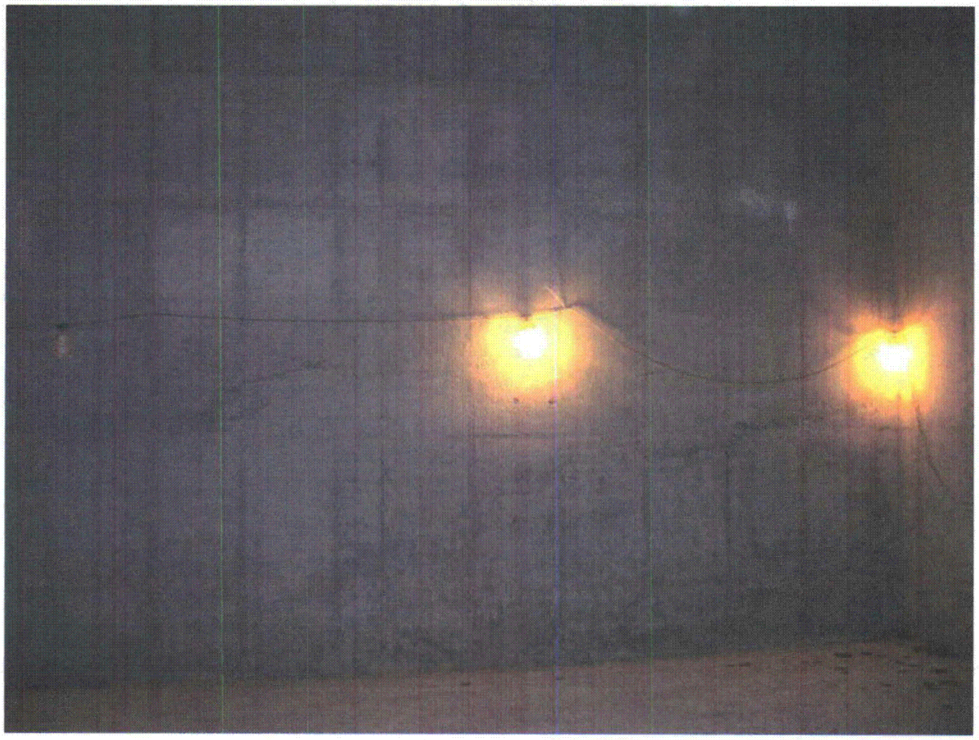
Central Column with North Column in Background (Survey Unit HR-1-13



View of South Column and Ceiling Details (Survey Unit HR-1-13)

Exhibit 9, Views of HRA Vault Walls

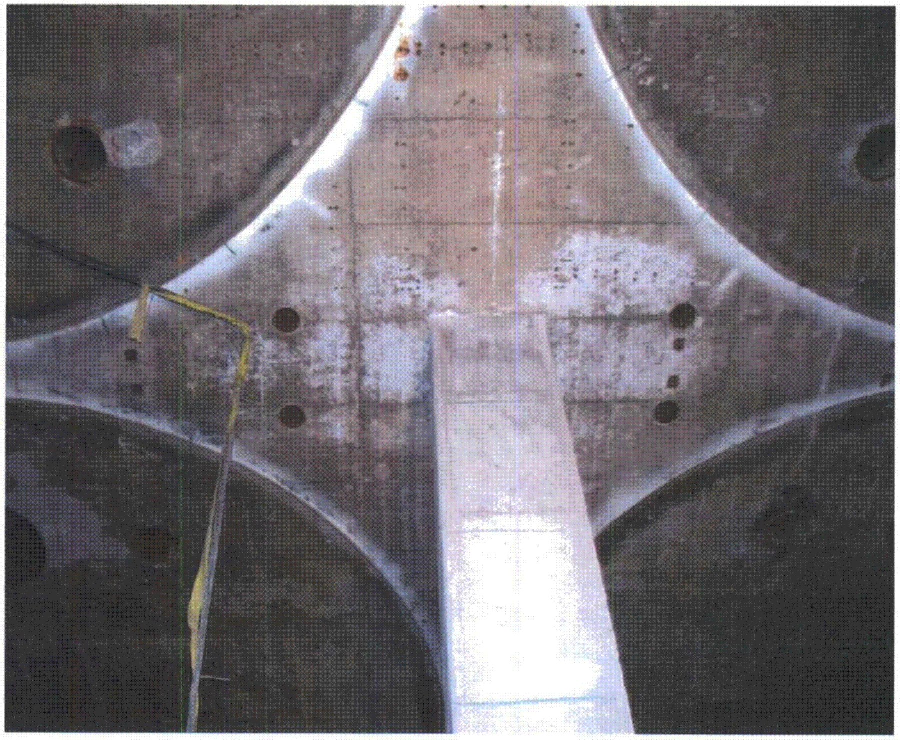
SW Lower Wall (Survey Unit HR-1-12)



Close-up of Upper Wall and Ceiling Showing Cut Off Anchor (Survey Unit HR-1-9)

Exhibit 10, HRA Vault Ceilings

View of Ceiling in Central Vault Area Showing Support Column (Survey Unit HR-1-16)



Ceiling View Showing Tank Outlines and Penetrations (Survey Unit HR-1-15)

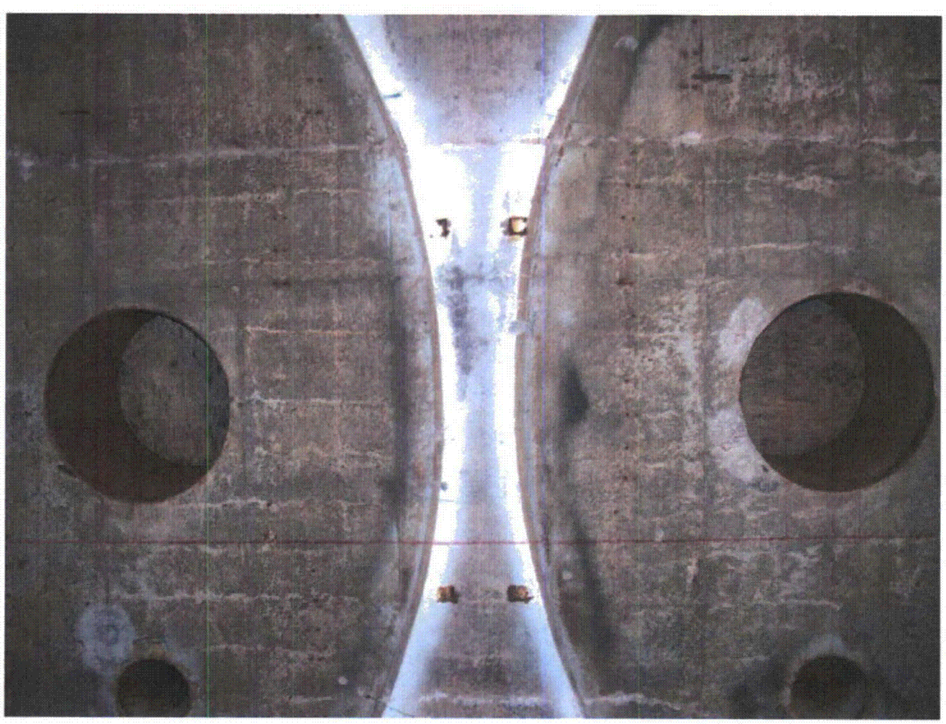


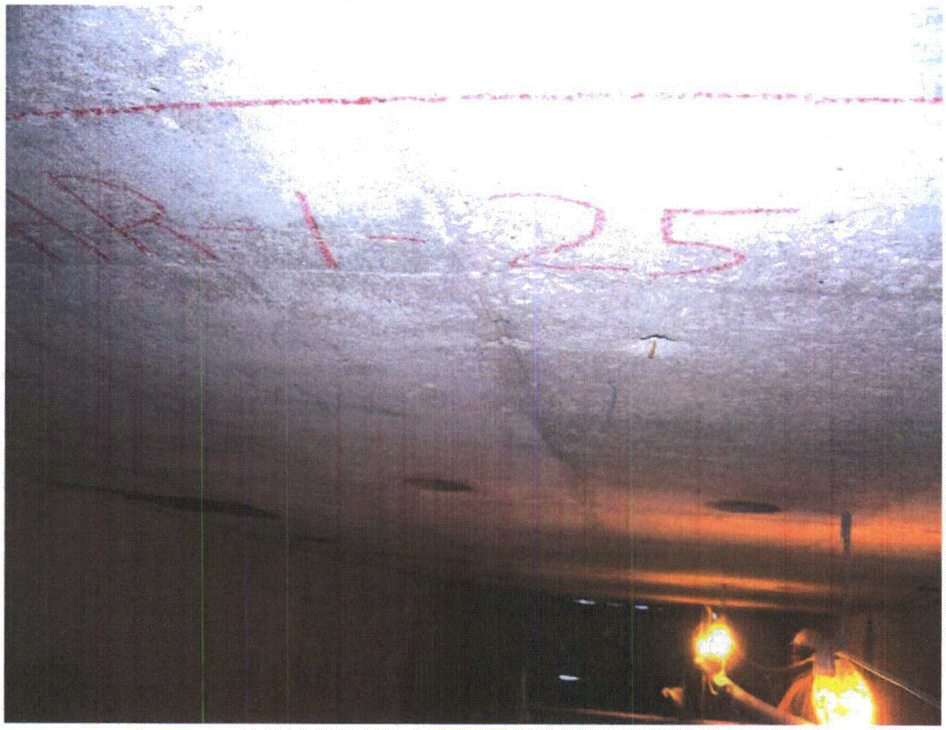
Exhibit 11, Views of HRA Pipe Chase Interior

General View of Main Pipe Chase Looking South (Survey Unit HR-1-19)

Lower Pipe Chase Looking North (Survey Unit HR-1-20)

Exhibit 12, HRA Pipe Chase Walls and Ceiling

General View of Upper Pipe Chase Ceiling Looking North (Survey Unit HR-1-24)



Lower Pipe Chase Looking West

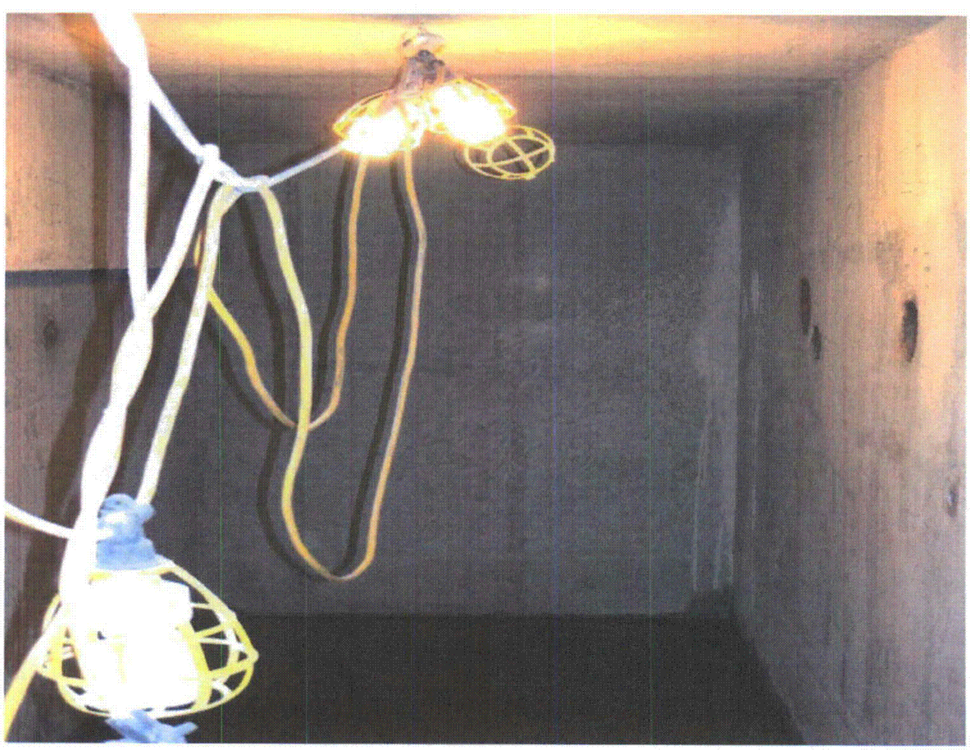


Exhibit 13, Views of HRA Vault Pad Roof

View of Vault Pad East Side Looking North

View of Vault Pad West Side Looking South

Exhibit 14, Pipe Chase Exteriors

Pipe Chase Roof Looking South

Pipe Chase West Wall Exterior Looking North

Exhibit 15, Examples of HRA Unusual Condition Measurement (UCM) Areas

Rough Concrete and Mineral Deposits in SW Corner of Vault Floor (Survey Unit HR-1-1)

Pitted Rough Concrete area in Vault Floor (Survey Unit HR-1-5)

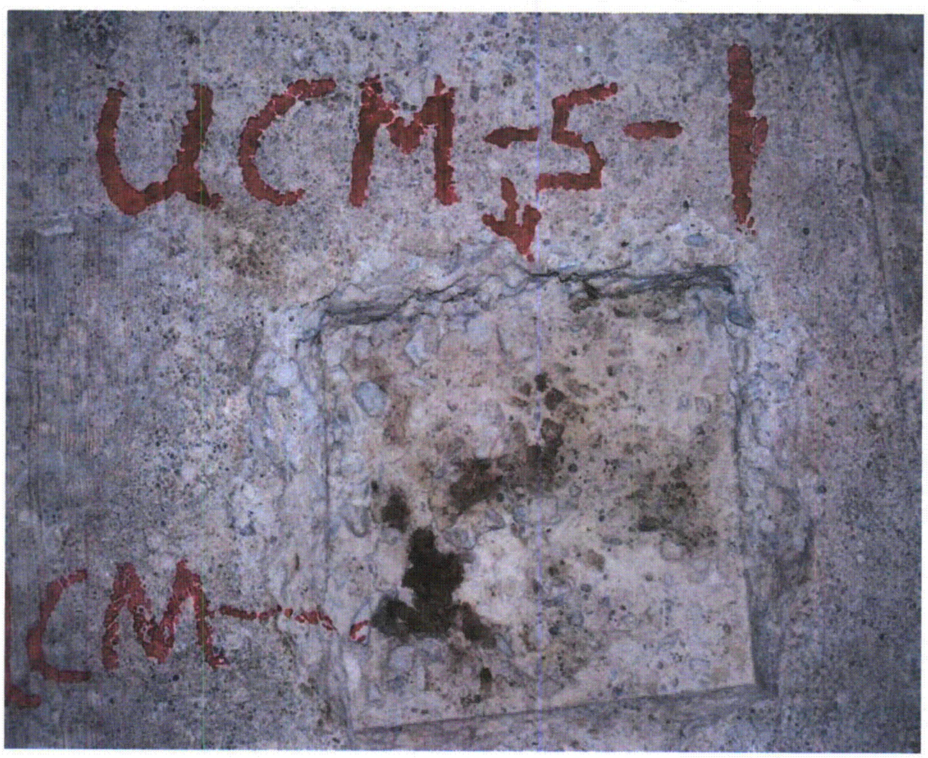


Exhibit 16, Examples of HRA Unusual Condition Measurement (UCM) Areas, Continued

Rough Concrete from Saw Cuts with Exposed Rebar – Vault Equipment Hatch

Chipped Area on Poured Concrete Pipe Chase Roof with Penetration and Anchor Remnants

Exhibit 17, Examples of HRA Surface Measurement Test Areas (SMTA)

Uneven Vault Floor Surface after Decontamination with Concrete Shaver

Pipe Chase Exterior Wall Area with Cracked and Degraded Concrete Coated with Paint & Tar

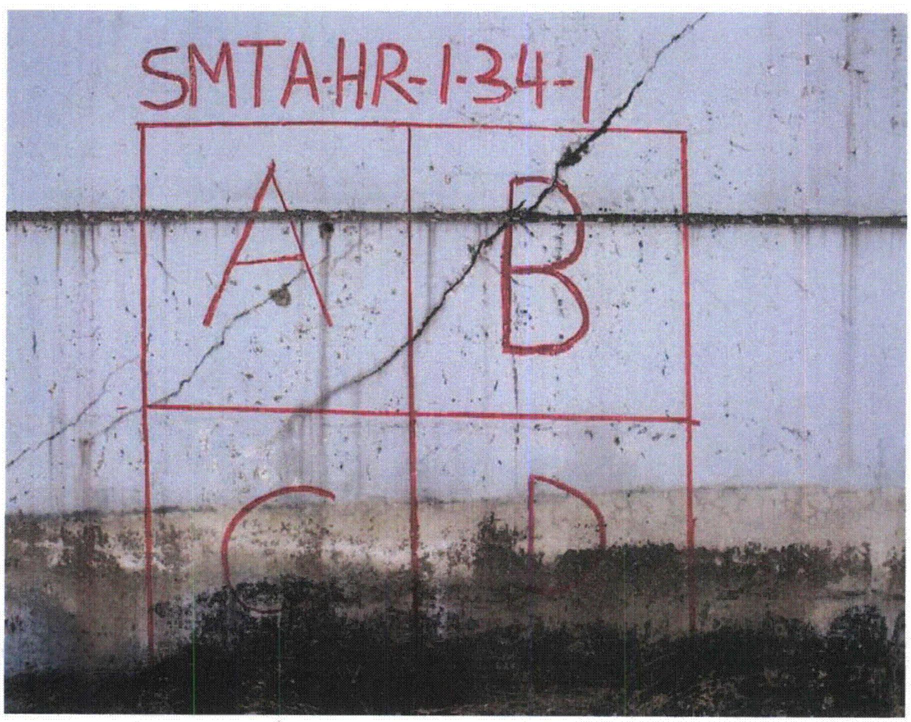


Exhibit 18, Examples of HRA Surface Measurement Test Areas (SMTA), Continued

Rough Concrete Surface on Vault Roof

Chipped Concrete and Roof Coating Remnants on Pipe Chase Roof

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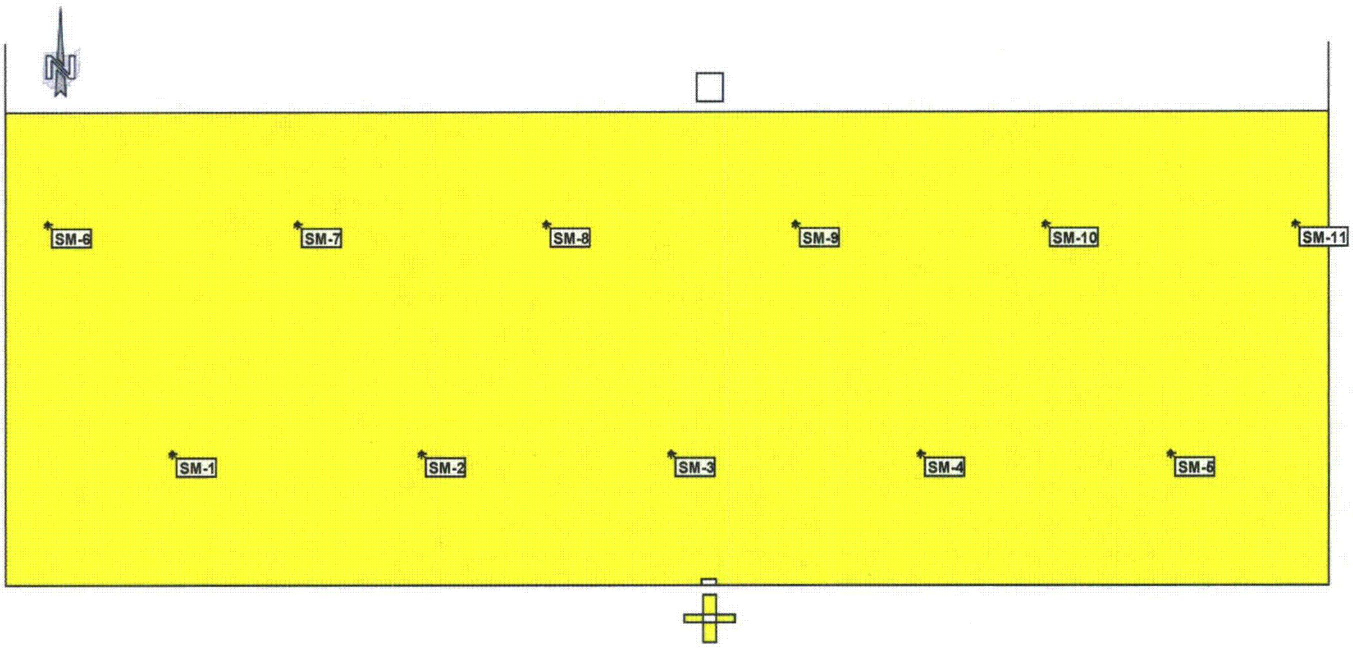
Appendix B

Survey Unit Maps and Tables Showing Measurement Locations and Results

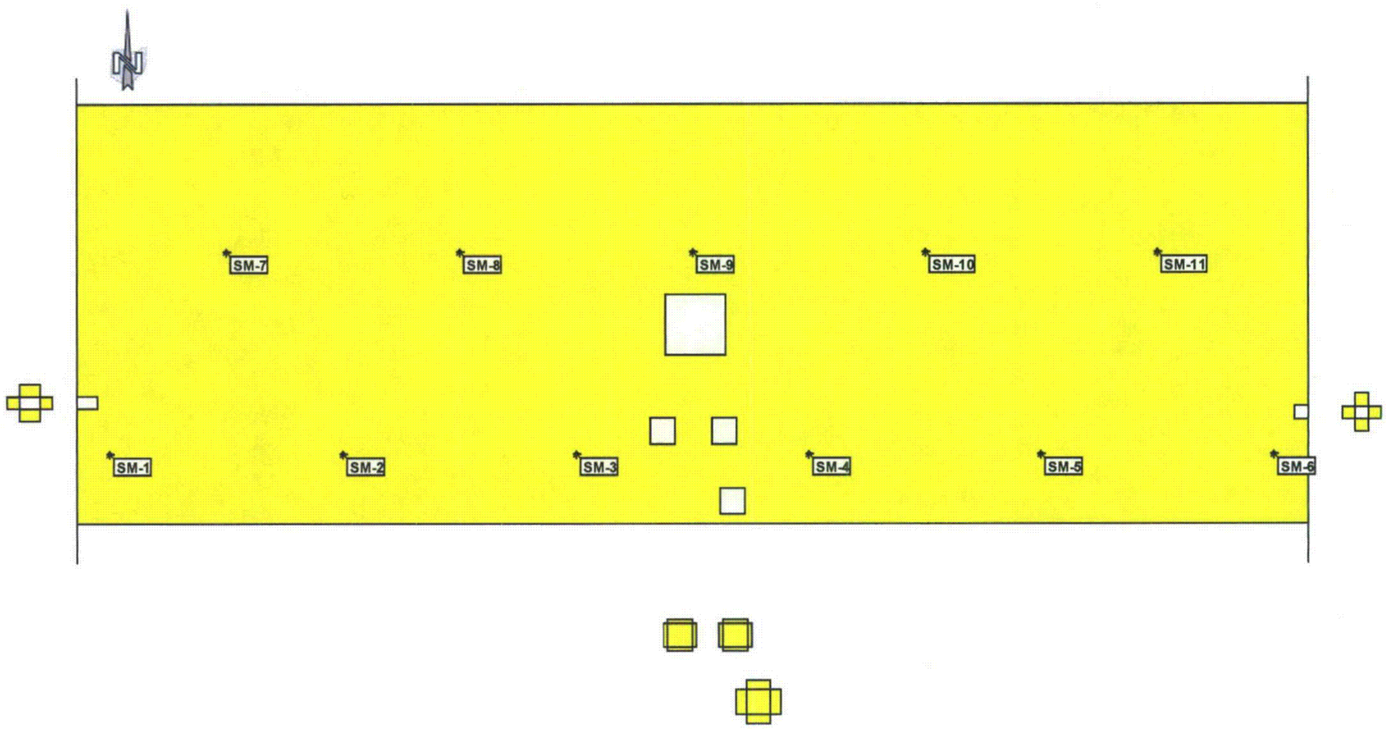
Index of Hot Retention Area Survey Unit Maps and Tables of Coordinates

Survey Unit HR-1-1
Hot Retention Area - Tank Vault - Floor Section 1



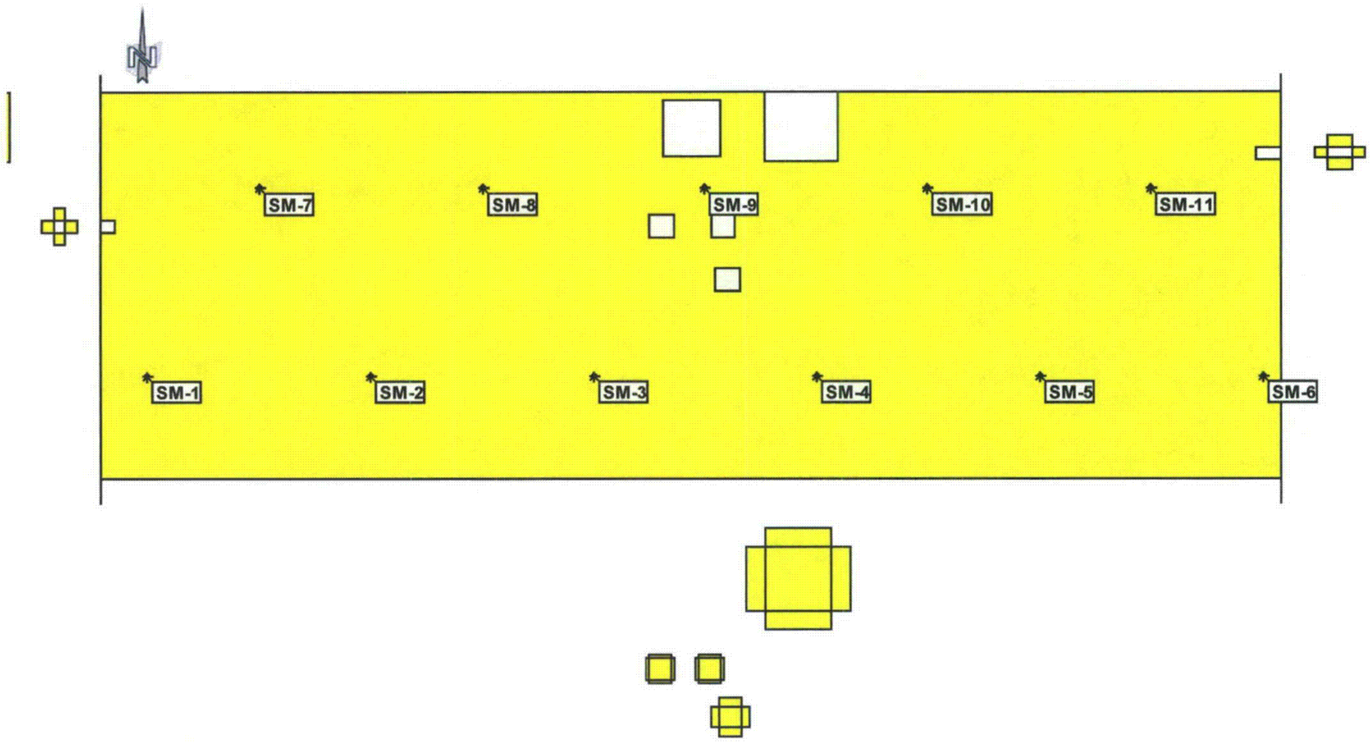
HR-1-1 AREA: Hot Retention Area Tank Vault, Floor Section 1 Measurement Locations and results					
X Co-ord (m)*	Y Co-ord (m)*	Location / dpm/100-cm^2		Type	Notes
1.9	1.4	SM-1	443	Systematic w random start	N/A
4.6	1.4	SM-2	396	Systematic w random start	N/A
7.4	1.4	SM-3	315	Systematic w random start	N/A
10.2	1.4	SM-4	691	Systematic w random start	N/A
13.0	1.4	SM-5	396	Systematic w random start	N/A
0.5	3.8	SM-6	416	Systematic w random start	N/A
3.3	3.8	SM-7	423	Systematic w random start	N/A
6.0	3.8	SM-8	617	Systematic w random start	N/A
8.8	3.8	SM-9	752	Systematic w random start	N/A
11.6	3.8	SM-10	698	Systematic w random start	N/A
14.4	3.8	SM-11	624	Systematic w random start	N/A
* All of the coordinates are measured from the southwest corner of the survey unit					

Survey Unit HR-1-2
Hot Retention Area - Tank Vault - Floor Section 2



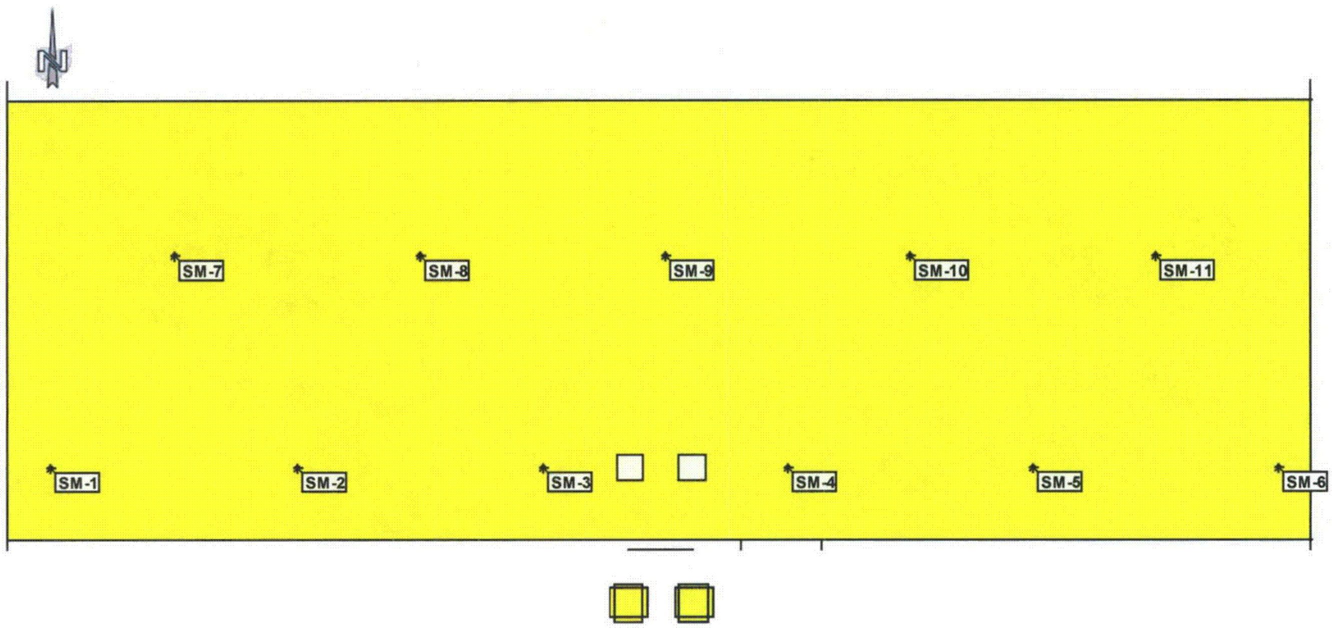
HR-1-2 AREA: Hot Retention Area Tank Vault, Floor Section 2 Measurement Locations and results					
X Co-ord (m)*	**Y Co-ord (m)***	**Location / dpm/100-cm^2**		**Type**	**Notes**
0.4	0.8	SM-1	470	Systematic w random start	N/A
3.2	0.8	SM-2	463	Systematic w random start	N/A
6.0	0.8	SM-3	154	Systematic w random start	N/A
8.8	0.8	SM-4	557	Systematic w random start	N/A
11.6	0.8	SM-5	463	Systematic w random start	N/A
14.4	0.8	SM-6	826	Systematic w random start	N/A
1.8	3.3	SM-7	523	Systematic w random start	N/A
4.6	3.3	SM-8	718	Systematic w random start	N/A
7.4	3.3	SM-9	1050	Systematic w random start	N/A
10.2	3.3	SM-10	638	Systematic w random start	N/A
13.0	3.3	SM-11	819	Systematic w random start	N/A
* All of the coordinates are measured from the southwest corner of the survey unit					

Survey Unit HR-1-3
Hot Retention Area - Tank Vault - Floor Section 3



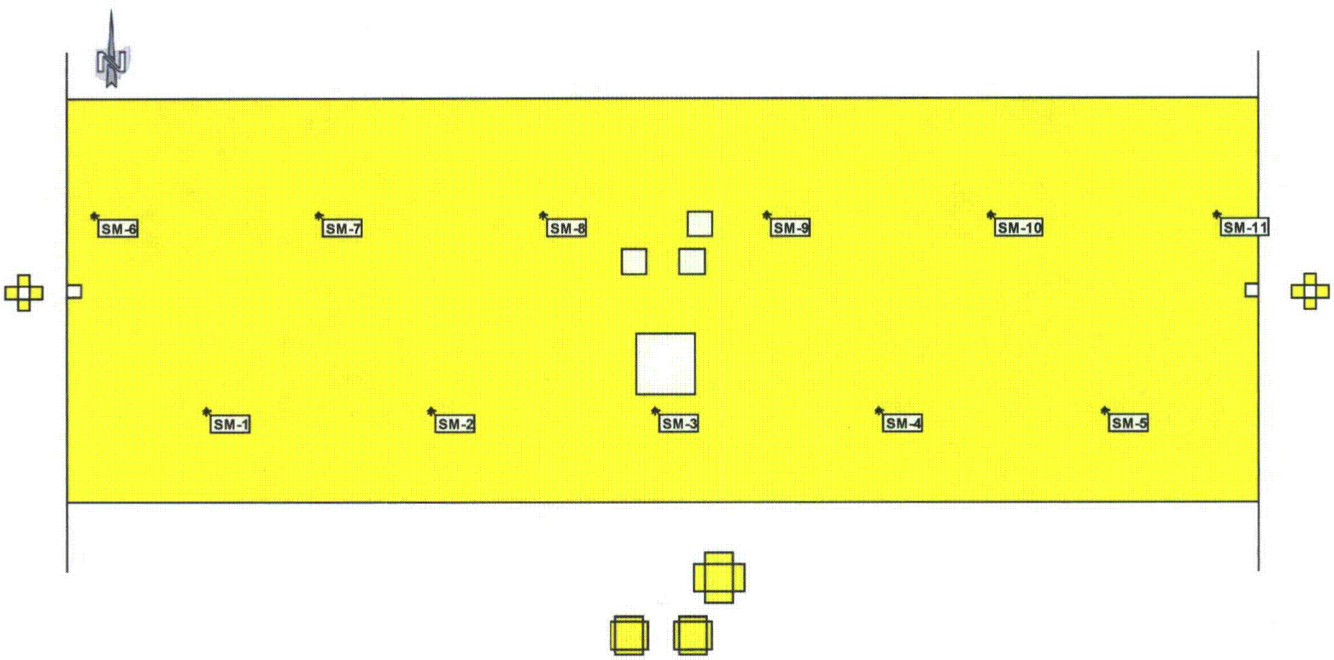
HR-1-3 AREA: Hot Retention Area Tank Vault, Floor Section 3 Measurement Locations and results					
X Co-ord (m)*	**Y Co-ord (m)***	**Location / dpm/100-cm^2**		**Type**	**Notes**
0.6	1.3	SM-1	404	Systematic w random start	N/A
3.4	1.3	SM-2	671	Systematic w random start	N/A
6.2	1.3	SM-3	705	Systematic w random start	N/A
9.0	1.3	SM-4	822	Systematic w random start	N/A
11.8	1.3	SM-5	877	Systematic w random start	N/A
14.5	1.3	SM-6	678	Systematic w random start	N/A
2.0	3.7	SM-7	822	Systematic w random start	N/A
4.8	3.7	SM-8	685	Systematic w random start	N/A
7.6	3.7	SM-9	788	Systematic w random start	N/A
10.4	3.7	SM-10	486	Systematic w random start	N/A
13.2	3.7	SM-11	363	Systematic w random start	N/A
* All of the coordinates are measured from the southwest corner of the survey unit					

Survey Unit HR-1-4
Hot Retention Area - Tank Vault - Floor Section 4



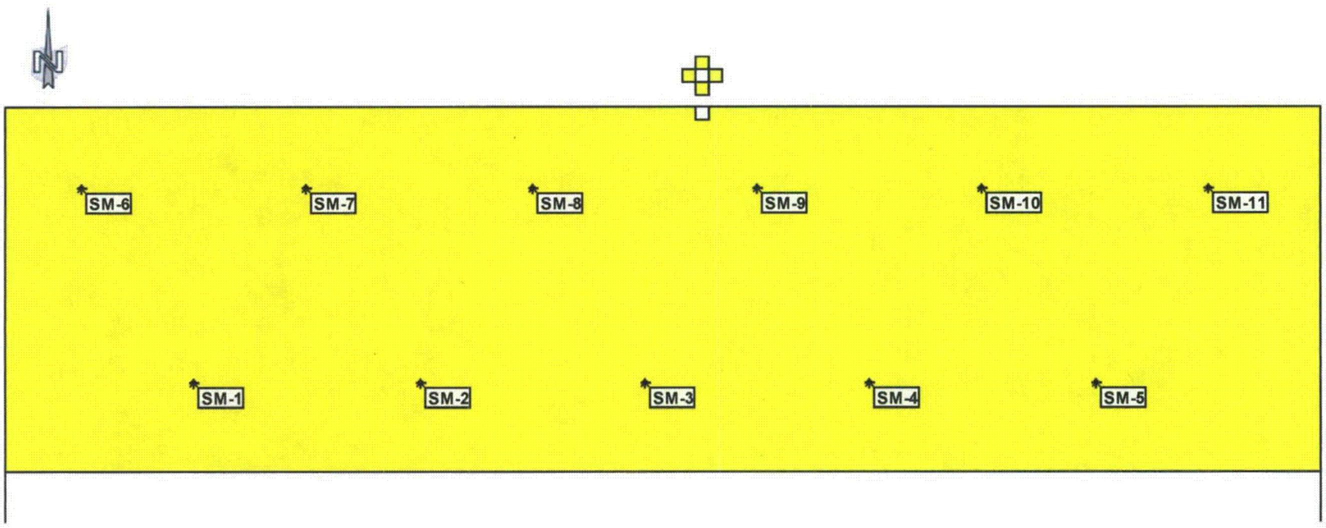
HR-1-4 AREA: Hot Retention Area Tank Vault, Floor Section 4 Measurement Locations and results					
X Co-ord (m)*	Y Co-ord (m)*	Location / dpm/100-cm^2		Type	Notes
0.5	0.8	SM-1	715	Systematic w random start	N/A
3.3	0.8	SM-2	730	Systematic w random start	N/A
6.1	0.8	SM-3	708	Systematic w random start	N/A
8.8	0.8	SM-4	540	Systematic w random start	N/A
11.6	0.8	SM-5	394	Systematic w random start	N/A
14.4	0.8	SM-6	569	Systematic w random start	N/A
1.9	3.2	SM-7	839	Systematic w random start	N/A
4.7	3.2	SM-8	1416	Systematic w random start	N/A
7.5	3.2	SM-9	708	Systematic w random start	N/A
10.2	3.2	SM-10	788	Systematic w random start	N/A
13.0	3.2	SM-11	540	Systematic w random start	N/A
* All of the coordinates are measured from the southwest corner of the survey unit					

Survey Unit HR-1-5
Hot Retention Area - Tank Vault - Floor Section 5



HR-1-5 AREA: Hot Retention Area Tank Vault, Floor Section 5 Measurement Locations and results					
X Co-ord (m)*	Y Co-ord (m)*	Location / dpm/100-cm^2		Type	Notes
0.5	0.8	SM-1	396	Systematic w random start	N/A
3.3	0.8	SM-2	262	Systematic w random start	N/A
6.1	0.8	SM-3	443	Systematic w random start	N/A
8.8	0.8	SM-4	577	Systematic w random start	N/A
11.6	0.8	SM-5	154	Systematic w random start	N/A
14.4	0.8	SM-6	698	Systematic w random start	N/A
1.9	3.2	SM-7	248	Systematic w random start	N/A
4.7	3.2	SM-8	846	Systematic w random start	N/A
7.5	3.2	SM-9	389	Systematic w random start	N/A
10.2	3.2	SM-10	577	Systematic w random start	N/A
13.0	3.2	SM-11	215	Systematic w random start	N/A
* All of the coordinates are measured from the southwest corner of the survey unit					

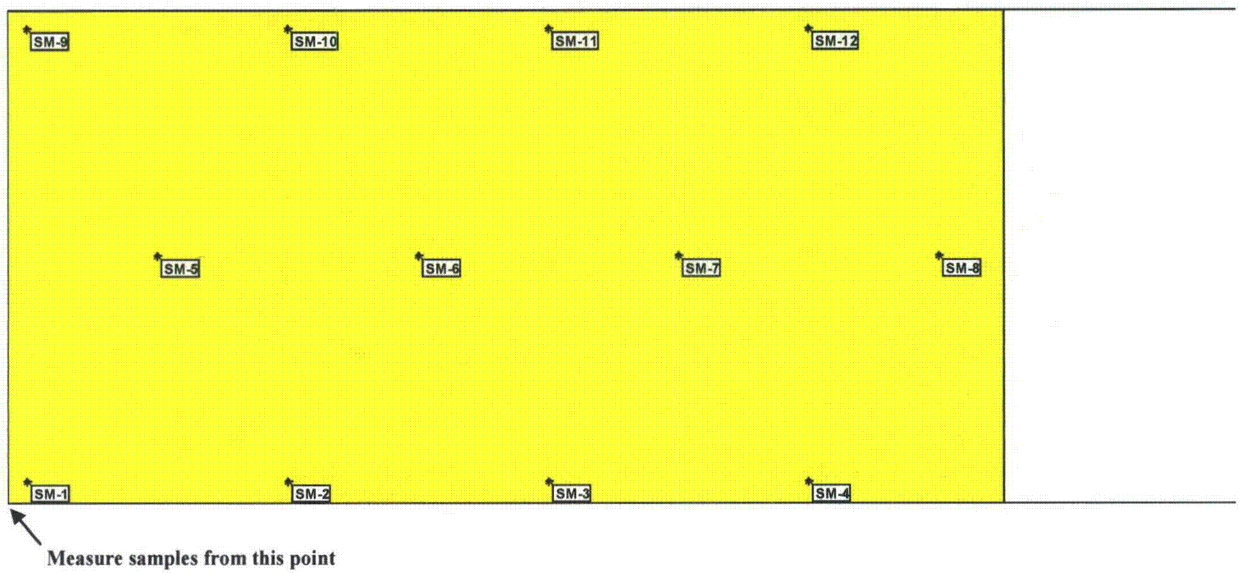
Survey Unit HR-1-6
Hot Retention Area - Tank Vault - Floor Section 6



HR-1-6 AREA: Hot Retention Area Tank Vault, Floor Section 6 Measurement Locations and results					
X Co-ord (m)*	Y Co-ord (m)*	Location / dpm/100-cm^2		Type	Notes
2.1	1.0	SM-1	555	Systematic w random start	N/A
4.7	1.0	SM-2	387	Systematic w random start	N/A
7.2	1.0	SM-3	219	Systematic w random start	N/A
9.7	1.0	SM-4	307	Systematic w random start	N/A
12.2	1.0	SM-5	489	Systematic w random start	N/A
0.9	3.2	SM-6	496	Systematic w random start	N/A
3.4	3.2	SM-7	620	Systematic w random start	N/A
5.9	3.2	SM-8	533	Systematic w random start	N/A
8.5	3.2	SM-9	591	Systematic w random start	N/A
11.0	3.2	SM-10	781	Systematic w random start	N/A
13.5	3.2	SM-11	292	Systematic w random start	N/A
* All of the coordinates are measured from the southwest corner of the survey unit					

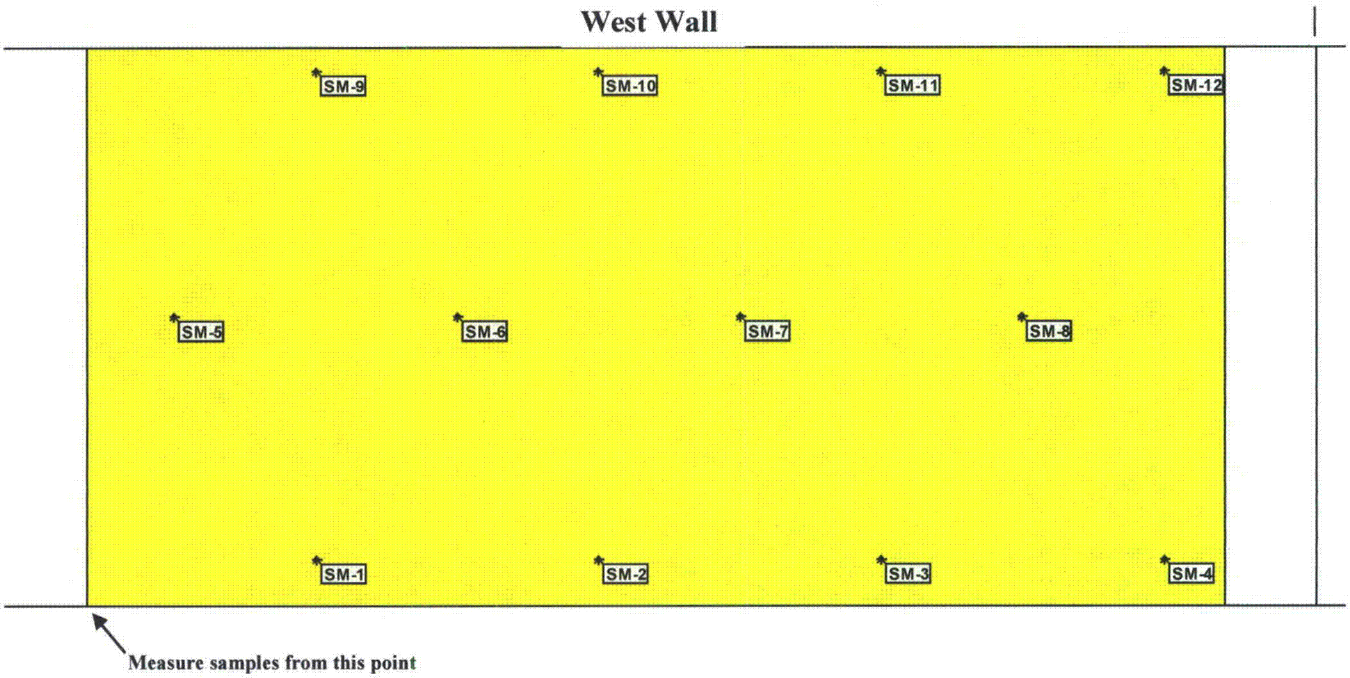
Survey Unit HR-1-7
Hot Retention Area - Tank Vault - Wall Section 1

West Wall



HR-1-7 AREA: Hot Retention Area Tank Vault, Wall Section 1 Measurement Locations and results					
X Co-ord (m)*	Y Co-ord (m)*	Location / dpm/100-cm^2		Type	Notes
0.3	0.3	SM-1	836	Systematic w random start	N/A
4.0	0.3	SM-2	685	Systematic w random start	N/A
7.6	0.3	SM-3	1020	Systematic w random start	N/A
11.3	0.3	SM-4	911	Systematic w random start	N/A
2.1	3.5	SM-5	918	Systematic w random start	N/A
5.8	3.5	SM-6	1080	Systematic w random start	N/A
9.4	3.5	SM-7	945	Systematic w random start	N/A
13.1	3.5	SM-8	1020	Systematic w random start	N/A
0.3	6.6	SM-9	1000	Systematic w random start	N/A
4.0	6.6	SM-10	651	Systematic w random start	N/A
7.6	6.6	SM-11	637	Systematic w random start	N/A
11.3	6.6	SM-12	1050	Systematic w random start	N/A
*All of the coordinates are measured from the location shown on the map.					

Survey Unit HR-1-8
Hot Retention Area - Tank Vault - Wall Section 2

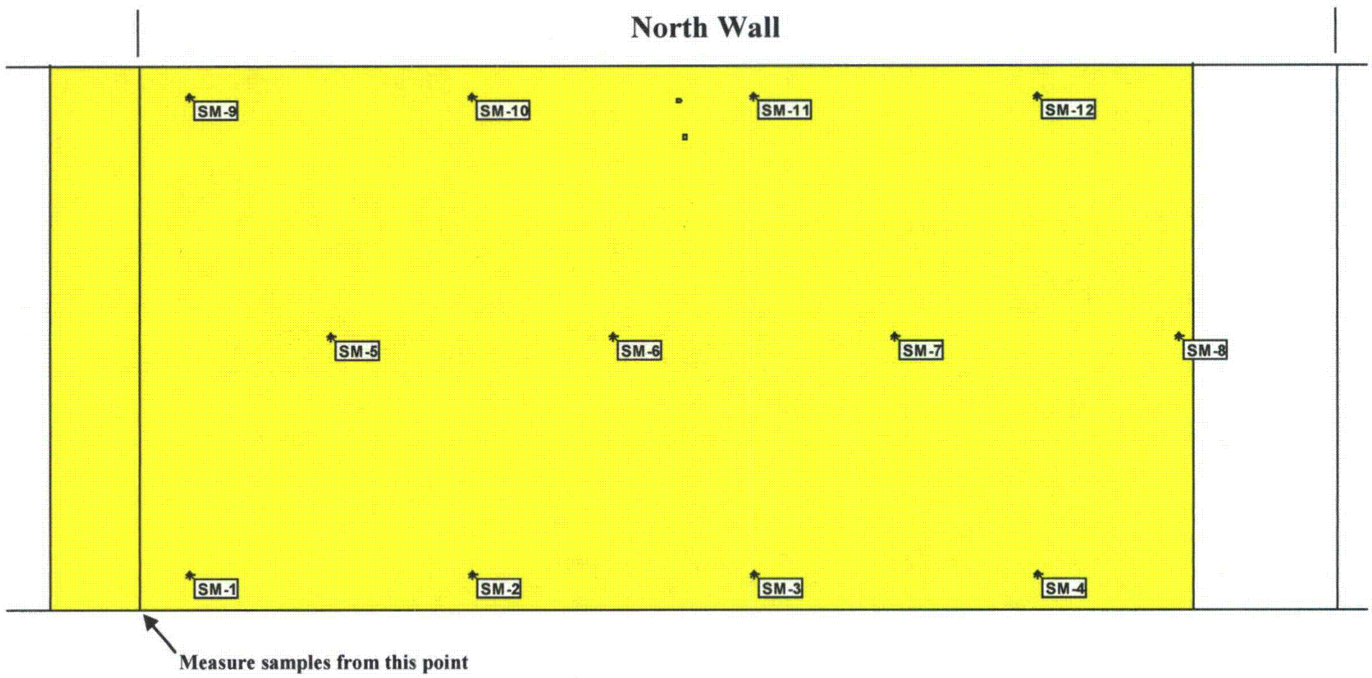


HR-1-8
AREA: Hot Retention Area Tank Vault, Wall Section 2
Measurement Locations and results

X Co-ord (m)*	Y Co-ord (m)*	Location / dpm/100-cm^2		Type	Notes
2.8	0.6	SM-1	1200	Systematic w random start	N/A
6.3	0.6	SM-2	1020	Systematic w random start	N/A
9.8	0.6	SM-3	993	Systematic w random start	N/A
13.2	0.6	SM-4	952	Systematic w random start	N/A
1.1	3.6	SM-5	788	Systematic w random start	N/A
4.6	3.6	SM-6	1080	Systematic w random start	N/A
8.0	3.6	SM-7	678	Systematic w random start	N/A
11.5	3.6	SM-8	856	Systematic w random start	N/A
2.8	6.6	SM-9	740	Systematic w random start	N/A
6.3	6.6	SM-10	637	Systematic w random start	N/A
9.8	6.6	SM-11	863	Systematic w random start	N/A
13.2	6.6	SM-12	795	Systematic w random start	N/A

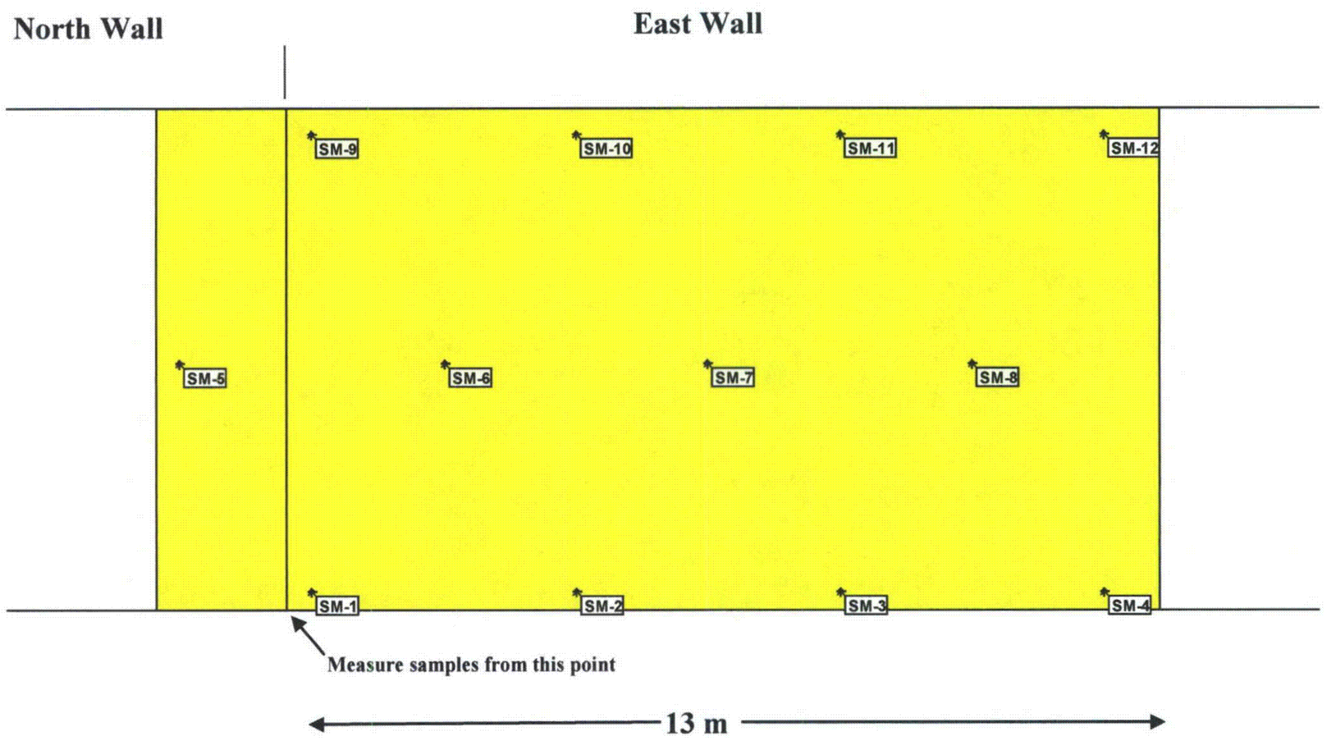
*All of the coordinates are measured from the location shown on the map.

Survey Unit HR-1-9
Hot Retention Area - Tank Vault - Wall Section 3



HR-1-9 AREA: Hot Retention Area Tank Vault, Wall Section 3 Measurement Locations and results					
X Co-ord (m)*	Y Co-ord (m)*	Location / dpm/100-cm^2		Type	Notes
0.6	0.5	SM-1	1308	Systematic w random start	N/A
4.1	0.5	SM-2	1041	Systematic w random start	N/A
7.6	0.5	SM-3	753	Systematic w random start	N/A
11.1	0.5	SM-4	856	Systematic w random start	N/A
2.4	3.5	SM-5	986	Systematic w random start	N/A
5.8	3.5	SM-6	993	Systematic w random start	N/A
9.3	3.5	SM-7	658	Systematic w random start	N/A
12.8	3.5	SM-8	938	Systematic w random start	N/A
0.6	6.5	SM-9	945	Systematic w random start	N/A
4.1	6.5	SM-10	1062	Systematic w random start	N/A
7.6	6.5	SM-11	788	Systematic w random start	N/A
11.1	6.5	SM-12	1170	Systematic w random start	N/A
*All of the coordinates are measured from the location shown on the map.					

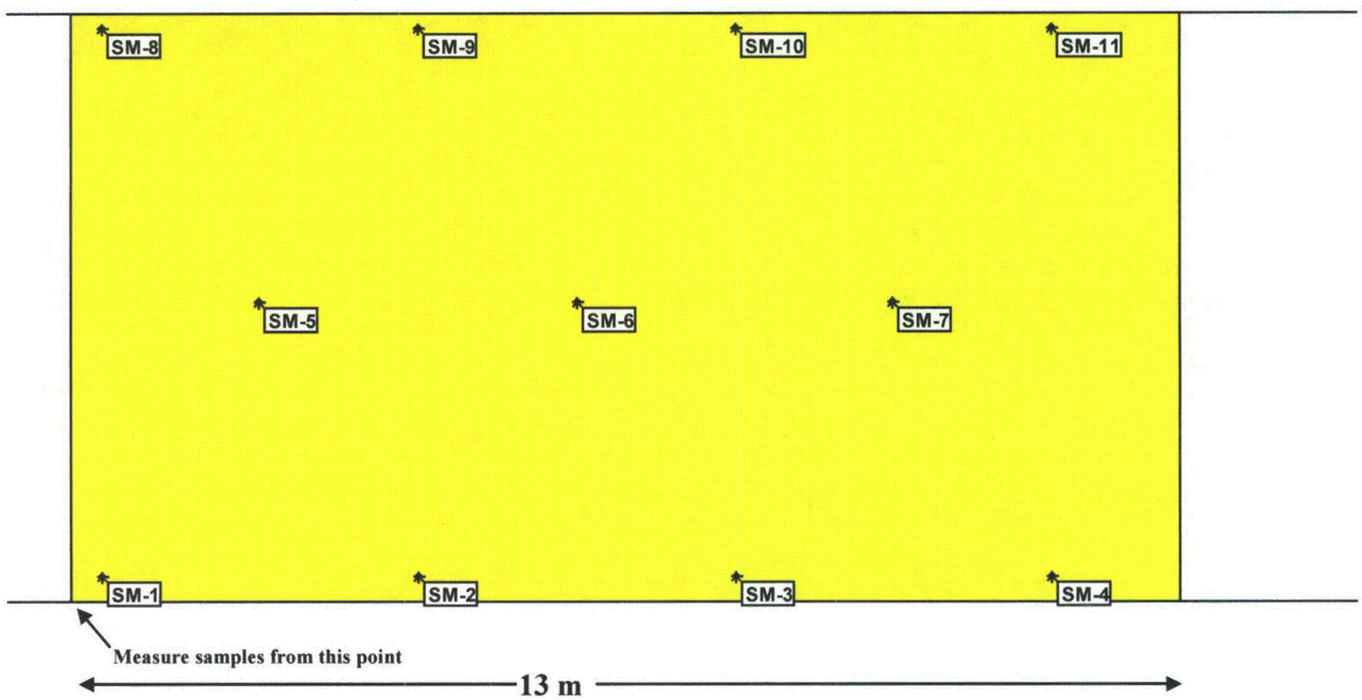
Survey Unit HR-1-10
Hot Retention Area - Tank Vault - Wall Section 4



HR-1-10 AREA: Hot Retention Area Tank Vault, Wall Section 4 Measurement Locations and results					
X Co-ord (m)*	Y Co-ord (m)*	Location / dpm/100-cm^2		Type	Notes
0.4	0.2	SM-1	1466	Systematic w random start	N/A
4.0	0.2	SM-2	1096	Systematic w random start	N/A
7.6	0.2	SM-3	1021	Systematic w random start	N/A
11.2	0.2	SM-4	1096	Systematic w random start	N/A
-1.5	3.4	SM-5	884	Systematic w random start	N/A
2.2	3.4	SM-6	932	Systematic w random start	N/A
5.8	3.4	SM-7	870	Systematic w random start	N/A
9.4	3.4	SM-8	1151	Systematic w random start	N/A
0.4	6.5	SM-9	1041	Systematic w random start	N/A
4.0	6.5	SM-10	979	Systematic w random start	N/A
7.6	6.5	SM-11	973	Systematic w random start	N/A
11.2	6.5	SM-12	1000	Systematic w random start	N/A
*All of the coordinates are measured from the location shown on the map.					

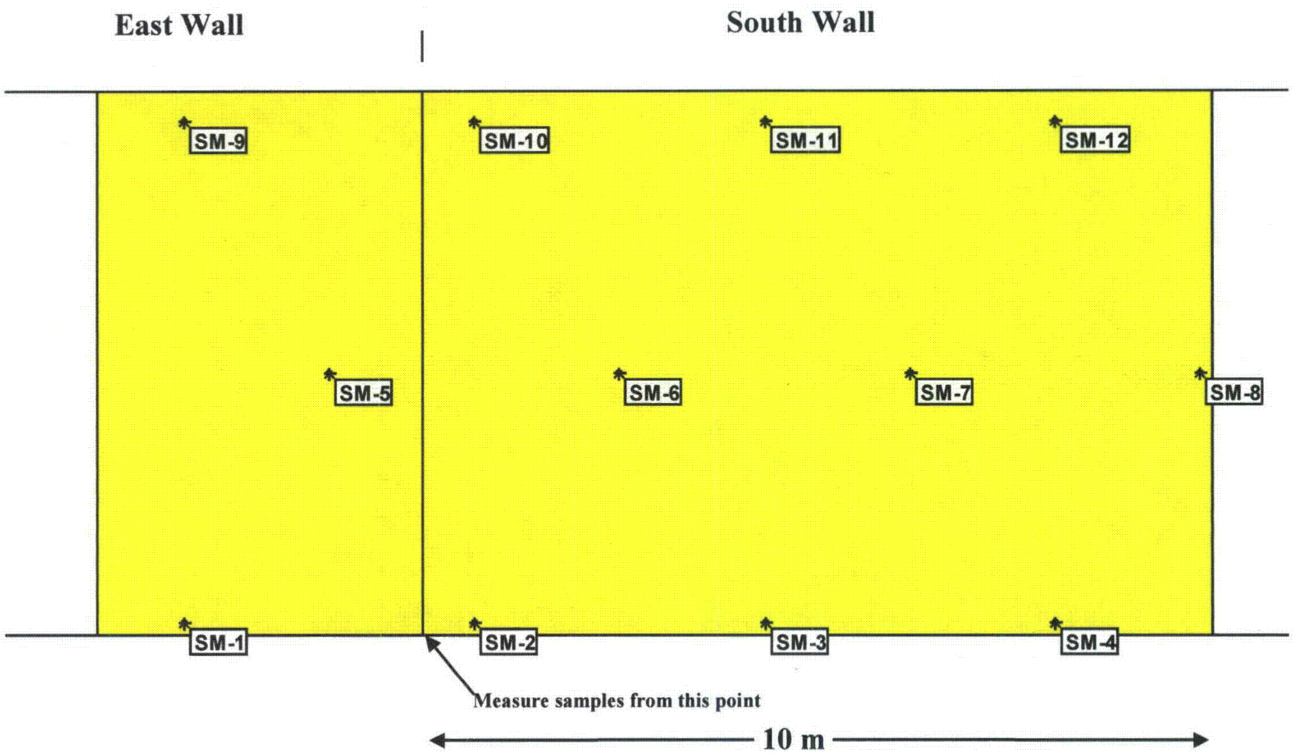
Survey Unit HR-1-11
Hot Retention Area - Tank Vault - Wall Section 5

East Wall



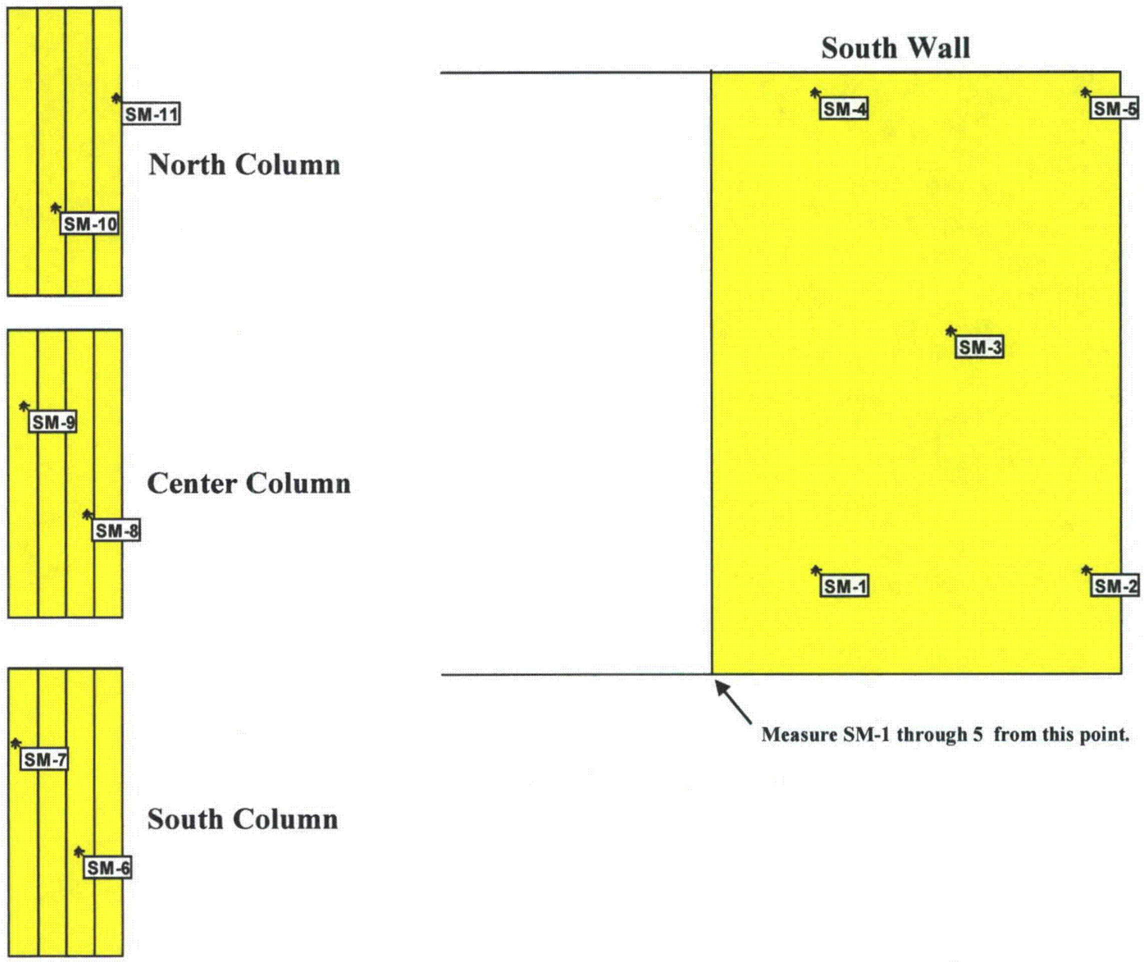
HR-1-11 AREA: Hot Retention Area Tank Vault, Wall Section 5 Measurement Locations and results					
X Co-ord (m)*	Y Co-ord (m)*	Location / dpm/100-cm^2		Type	Notes
0.4	0.3	SM-1	568	Systematic w random start	N/A
4.1	0.3	SM-2	801	Systematic w random start	N/A
7.8	0.3	SM-3	897	Systematic w random start	N/A
11.5	0.3	SM-4	514	Systematic w random start	N/A
2.2	3.5	SM-5	959	Systematic w random start	N/A
5.9	3.5	SM-6	993	Systematic w random start	N/A
9.6	3.5	SM-7	1034	Systematic w random start	N/A
0.4	6.7	SM-8	527	Systematic w random start	N/A
4.1	6.7	SM-9	1014	Systematic w random start	N/A
7.8	6.7	SM-10	863	Systematic w random start	N/A
11.5	6.7	SM-11	1233	Systematic w random start	N/A
*All of the coordinates are measured from the location shown on the map.					

Survey Unit HR-1-12
Hot Retention Area - Tank Vault - Wall Section 6



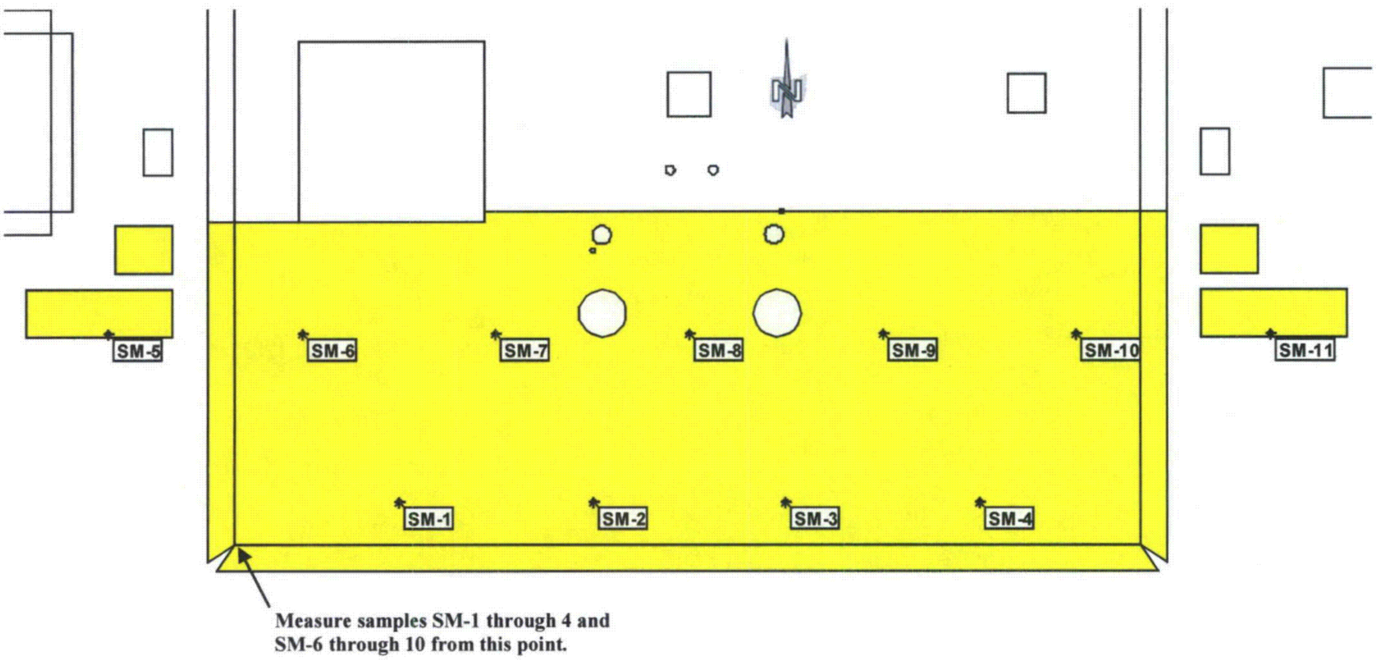
HR-1-12 AREA: Hot Retention Area Tank Vault, Wall Section 6 Measurement Locations and results					
X Co-ord (m)*	Y Co-ord (m)*	Location / dpm/100-cm^2		Type	Notes
-3.0	0.2	SM-1	746	Systematic w random start	N/A
0.7	0.2	SM-2	1192	Systematic w random start	N/A
4.3	0.2	SM-3	1062	Systematic w random start	N/A
8.0	0.2	SM-4	1108	Systematic w random start	N/A
-1.2	3.3	SM-5	885	Systematic w random start	N/A
2.5	3.3	SM-6	1308	Systematic w random start	N/A
6.2	3.3	SM-7	669	Systematic w random start	N/A
9.8	3.3	SM-8	1308	Systematic w random start	N/A
-3.0	6.5	SM-9	1062	Systematic w random start	N/A
0.7	6.5	SM-10	731	Systematic w random start	N/A
4.3	6.5	SM-11	808	Systematic w random start	N/A
8.0	6.5	SM-12	700	Systematic w random start	N/A
*All of the coordinates are measured from the location shown on the map.					

Survey Unit HR-1-13
Hot Retention Area - Tank Vault - Wall Section 7 & Support Columns



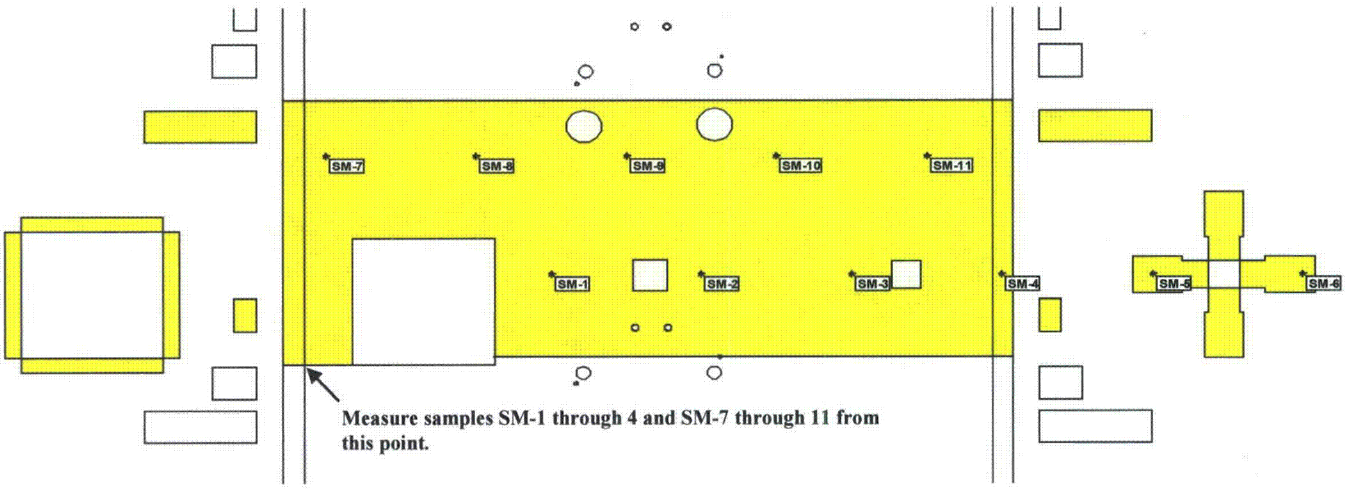
HR-1-13 AREA: Hot Retention Area Tank Vault Wall Section 7 and Support Columns Measurement Locations and results					
X Co-ord (m)*	Y Co-ord (m)*	Location / dpm/100-cm^2		Type	Notes
1.2	1.2	SM-1	992	Systematic w random start	N/A
4.4	1.2	SM-2	692	Systematic w random start	N/A
2.8	3.9	SM-3	1008	Systematic w random start	N/A
1.2	6.7	SM-4	515	Systematic w random start	N/A
4.4	6.7	SM-5	854	Systematic w random start	N/A
0.3	2.6	SM-6	1169	Systematic w random start	N/A
0.2	5.4	SM-7	1100	Systematic w random start	N/A
0.5	2.6	SM-8	569	Systematic w random start	N/A
0.4	5.4	SM-9	869	Systematic w random start	N/A
0.4	2.2	SM-10	646	Systematic w random start	N/A
0.6	5.0	SM-11	938	Systematic w random start	N/A
*Coordinates for SM-1 through 5 are measured from the location shown on the map. SM-6 through 11 are measured from the lower left corner of the column surface on which they rest.					

Survey Unit HR-1-14
Hot Retention Area - Tank Vault - Ceiling Section 1



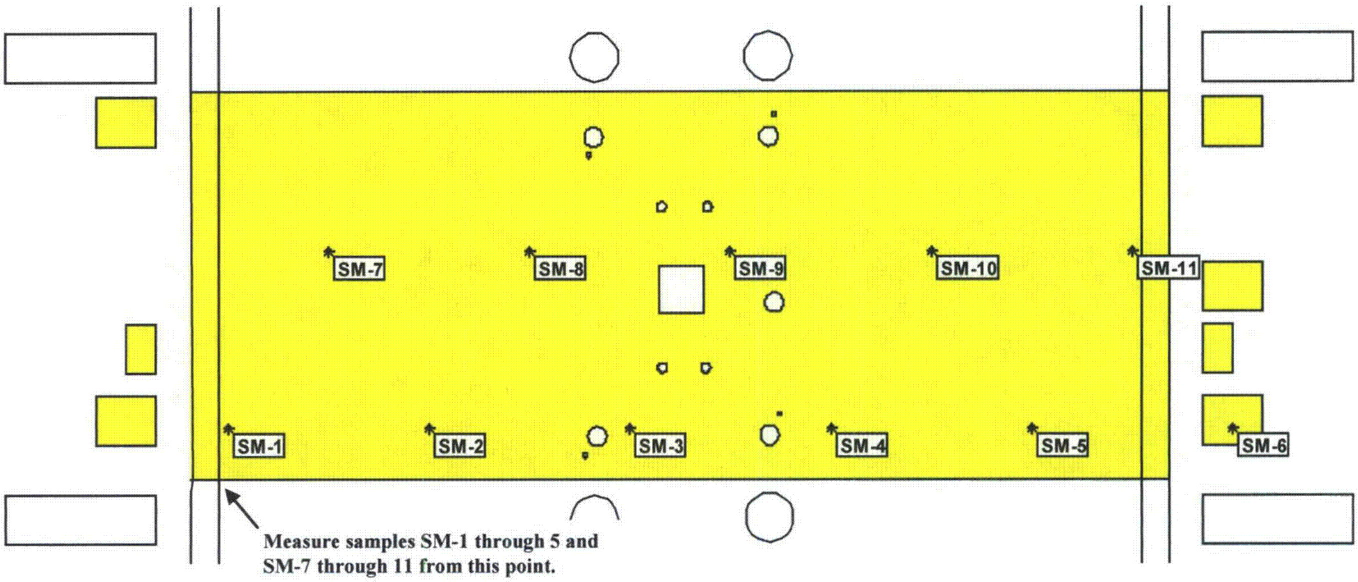
HR-1-14 AREA: Hot Retention Area Tank Vault, Ceiling Section 1 Measurement Locations and results					
X Co-ord (m)*	Y Co-ord (m)*	Location / dpm/100-cm^2		Type	Notes
2.7	0.7	SM-1	726	Systematic w random start	N/A
5.8	0.7	SM-2	808	Systematic w random start	N/A
9.0	0.7	SM-3	1010	Systematic w random start	N/A
12.2	0.7	SM-4	952	Systematic w random start	N/A
1.4	0.1	SM-5	219	Systematic w random start	N/A
1.1	3.4	SM-6	507	Systematic w random start	N/A
4.3	3.4	SM-7	829	Systematic w random start	N/A
7.4	3.4	SM-8	671	Systematic w random start	N/A
10.6	3.4	SM-9	623	Systematic w random start	N/A
13.7	3.4	SM-10	842	Systematic w random start	N/A
1.1	0.1	SM-11	55	Systematic w random start	N/A
* All of sample coordinates, except SM-5 and 11, are measured from the point shown on the map. SM-5 and 11 are measured from the north vertical line of the penetration.					

Survey Unit HR-1-15
Hot Retention Area - Tank Vault - Ceiling Section 2



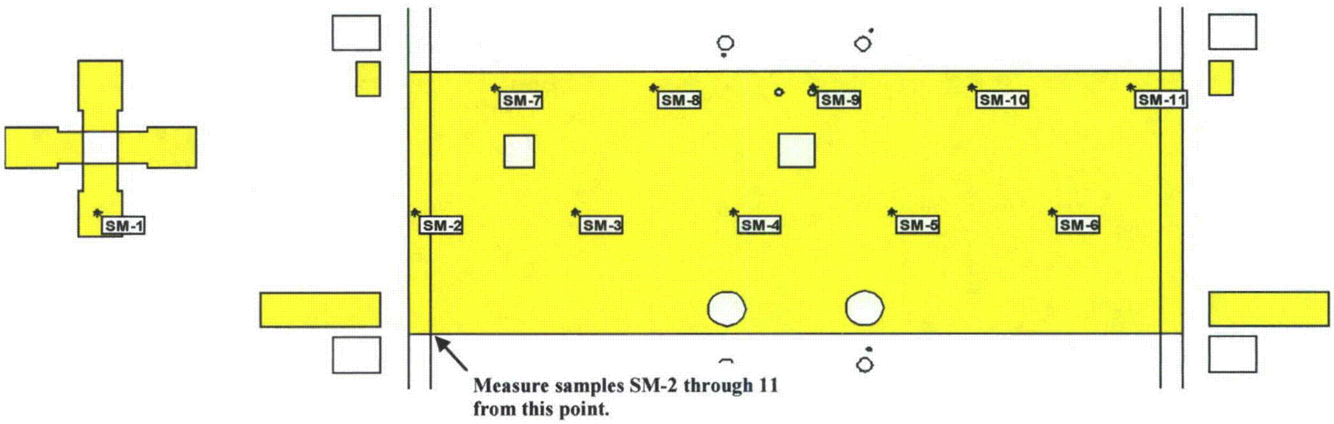
HR-1-15 AREA: Hot Retention Area Tank Vault Ceiling Section 2 Measurement Locations and results					
X Co-ord (m)*	**Y Co-ord (m)***	**Location / dpm/100-cm^2**		**Type**	**Notes**
5.3	2.2	SM-1	377	Systematic w random start	N/A
8.5	2.2	SM-2	585	Systematic w random start	N/A
11.8	2.2	SM-3	1090	Systematic w random start	N/A
15.0	2.2	SM-4	708	Systematic w random start	N/A
0.4	0.6	SM-5	431	Systematic w random start	N/A
0.4	0.8	SM-6	638	Systematic w random start	N/A
0.5	5.0	SM-7	838	Systematic w random start	N/A
3.7	5.0	SM-8	400	Systematic w random start	N/A
6.9	5.0	SM-9	1020	Systematic w random start	N/A
10.1	5.0	SM-10	1060	Systematic w random start	N/A
13.4	5.0	SM-11	523	Systematic w random start	N/A
*All of the coordinates, except SM-5 and 6, are taken from the point shown on the map. SM-5 and 6 are measured from the lower left corner of the surface on which they rest.					

Survey Unit HR-1-16
Hot Retention Area - Tank Vault - Ceiling Section 3



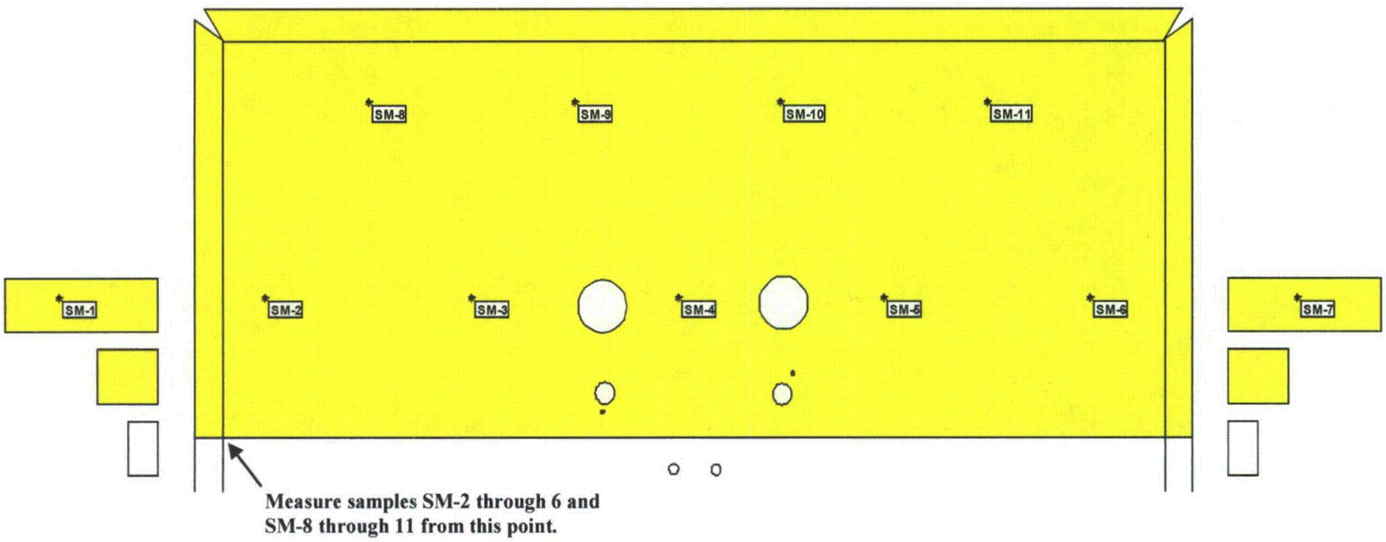
HR-1-16 AREA: Hot Retention Area Tank Vault Ceiling Section 3 Measurement Locations and results					
X Co-ord (m)*	Y Co-ord (m)*	Location / dpm/100-cm^2		Type	Notes
0.1	0.8	SM-1	575	Systematic w random start	N/A
3.4	0.8	SM-2	747	Systematic w random start	N/A
6.6	0.8	SM-3	664	Systematic w random start	N/A
9.8	0.8	SM-4	733	Systematic w random start	N/A
13.0	0.8	SM-5	699	Systematic w random start	N/A
0.5	0.3	SM-6	308	Systematic w random start	N/A
1.7	3.6	SM-7	637	Systematic w random start	N/A
5.0	3.6	SM-8	2120	Systematic w random start	N/A
8.2	3.6	SM-9	479	Systematic w random start	N/A
11.4	3.6	SM-10	712	Systematic w random start	N/A
14.6	3.6	SM-11	884	Systematic w random start	N/A
*All of the coordinates, except SM-6, are measured from the location shown on the map. Point SM-6 is measured from the north vertical line of the penetration.					

Survey Unit HR-1-17
Hot Retention Area - Tank Vault - Ceiling Section 4



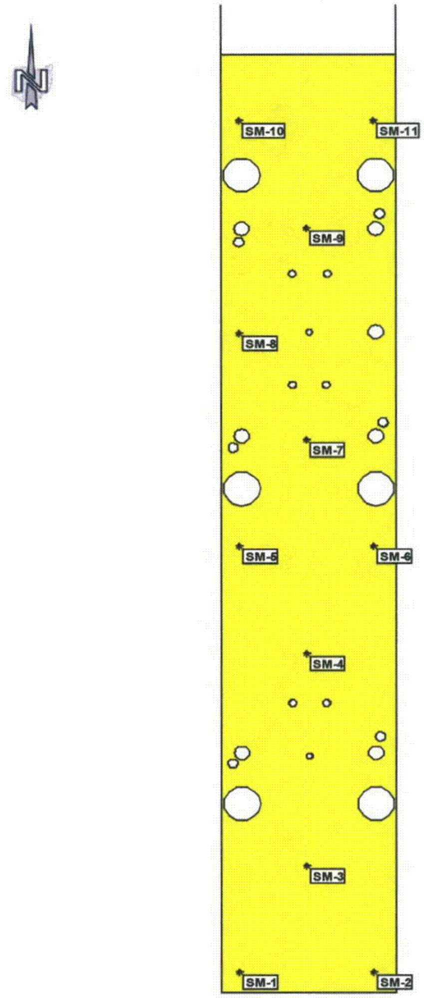
HR-1-17 AREA: Hot Retention Area Tank Vault Ceiling Section 4 Measurement Locations and results					
X Co-ord (m)*	Y Co-ord (m)*	Location / dpm/100-cm^2		Type	Notes
0.5	0.5	SM-1	4190	Systematic w random start	N/A
-0.3	2.7	SM-2	740	Systematic w random start	N/A
2.9	2.7	SM-3	1300	Systematic w random start	N/A
6.1	2.7	SM-4	822	Systematic w random start	N/A
9.4	2.7	SM-5	3440	Systematic w random start	N/A
12.6	2.7	SM-6	1210	Systematic w random start	N/A
1.3	5.5	SM-7	870	Systematic w random start	N/A
4.5	5.5	SM-8	1270	Systematic w random start	N/A
7.7	5.5	SM-9	1160	Systematic w random start	N/A
11.0	5.5	SM-10	1400	Systematic w random start	N/A
14.2	5.5	SM-11	740	Systematic w random start	N/A
*All of the sample coordinates except SM-1 are measured from the point shown on the map. SM-1 is measured from the lower left corner of the surface on which it rests.					

Survey Unit HR-1-18
Hot Retention Area - Tank Vault - Ceiling Section 5



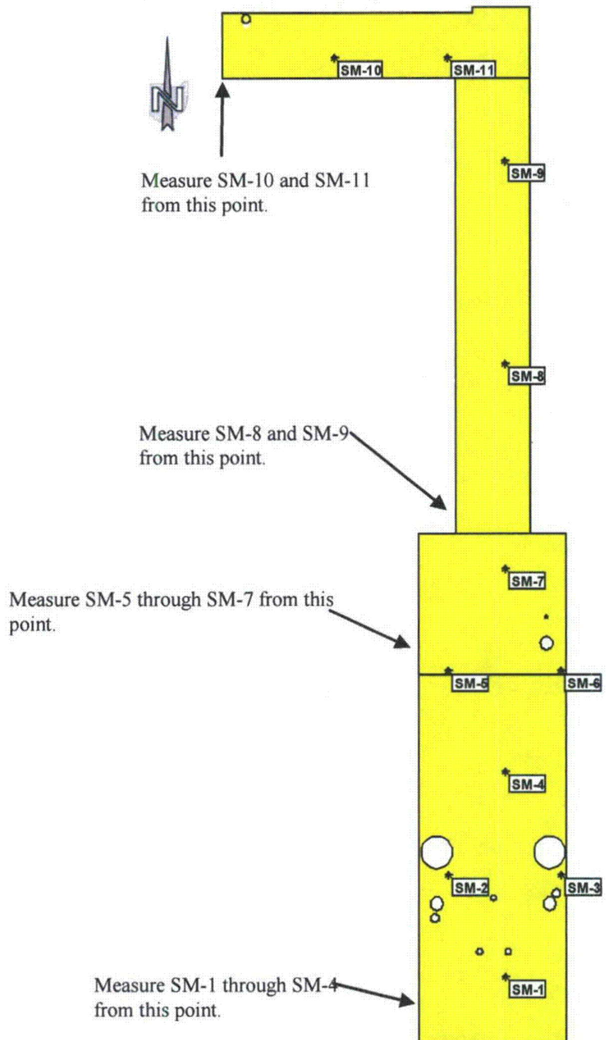
HR-1-18 AREA: Hot Retention Area Tank Vault Ceiling Section 5 Measurement Locations and results					
X Co-ord (m)*	Y Co-ord (m)*	Location / dpm/100-cm^2		Type	Notes
0.8	0.6	SM-1	-34	Systematic w random start	N/A
0.7	2.0	SM-2	753	Systematic w random start	N/A
3.9	2.0	SM-3	836	Systematic w random start	N/A
7.1	2.0	SM-4	863	Systematic w random start	N/A
10.4	2.0	SM-5	1660	Systematic w random start	N/A
13.6	2.0	SM-6	1730	Systematic w random start	N/A
1.1	0.5	SM-7	7	Systematic w random start	N/A
2.3	4.8	SM-8	747	Systematic w random start	N/A
5.5	4.8	SM-9	966	Systematic w random start	N/A
8.8	4.8	SM-10	842	Systematic w random start	N/A
12.0	4.8	SM-11	2310	Systematic w random start	N/A
*All of the sample coordinates, except SM-1 and 7, are measured from the point shown on the map. SM-1 and 7 are measured from the north vertical line of the penetration.					

Survey Unit HR-1-19
Hot Retention Area - Pipe Chase Interior - Floor Section 1



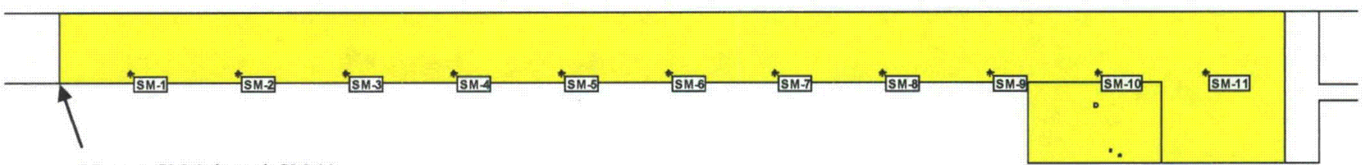
HR-1-19 AREA: Hot Retention Area Pipe Chase Interior - Floor Section 1 Measurement Locations Results					
X Co-ord (m)*	**Y Co-ord (m)***	**Location / dpm/100-cm^2**		**Type**	**Notes**
0.4	0.5	SM-1	786	Systematic w random start	N/A
3.2	0.5	SM-2	1429	Systematic w random start	N/A
1.8	2.9	SM-3	1182	Systematic w random start	N/A
1.8	7.7	SM-4	2513	Systematic w random start	N/A
0.4	10.1	SM-5	753	Systematic w random start	N/A
3.2	10.1	SM-6	1532	Systematic w random start	N/A
1.8	12.6	SM-7	1909	Systematic w random start	N/A
0.4	15.0	SM-8	1188	Systematic w random start	N/A
1.8	17.4	SM-9	3584	Systematic w random start	N/A
0.4	19.8	SM-10	1532	Systematic w random start	N/A
3.2	19.8	SM-11	1779	Systematic w random start	N/A
*All of the coordinates are measured from the southwest corner of the survey unit.					

Survey Unit HR-1-20
Hot Retention Area - Pipe Chase Interior - Floor Section 2



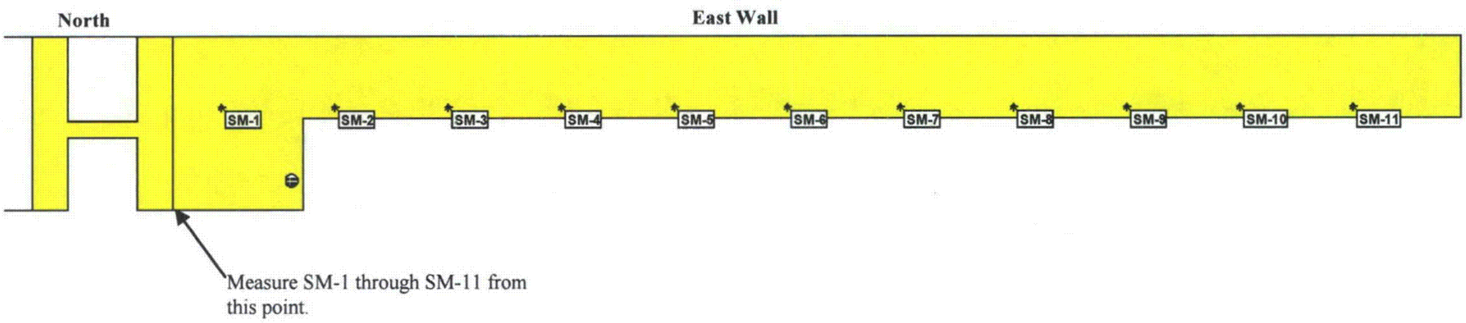
HR-1-20 AREA: Hot Retention Area Pipe Chase Interior - Floor Section 2 Measurement Locations and Results					
X Co-ord (m)*	Y Co-ord (m)*	Location / dpm/100-cm^2		Type	Notes
2.1	1.6	SM-1	1318	Systematic w random start	N/A
0.7	4.0	SM-2	4149	Systematic w random start	N/A
3.5	4.0	SM-3	1974	Systematic w random start	N/A
2.1	6.4	SM-4	3097	Systematic w random start	N/A
0.7	0.1	SM-5	4052	Systematic w random start	N/A
3.5	0.1	SM-6	1916	Systematic w random start	N/A
2.1	2.6	SM-7	1019	Systematic w random start	N/A
1.2	4.0	SM-8	1318	Systematic w random start	N/A
1.2	8.8	SM-9	2825	Systematic w random start	N/A
2.8	0.5	SM-10	857	Systematic w random start	N/A
5.6	0.5	SM-11	494	Systematic w random start	N/A
*The sample coordinates are measured taken from the locations shown on the map.					

Survey Unit HR-1-21
Hot Retention Area - Pipe Chase Interior - West & South Wall - Section 1



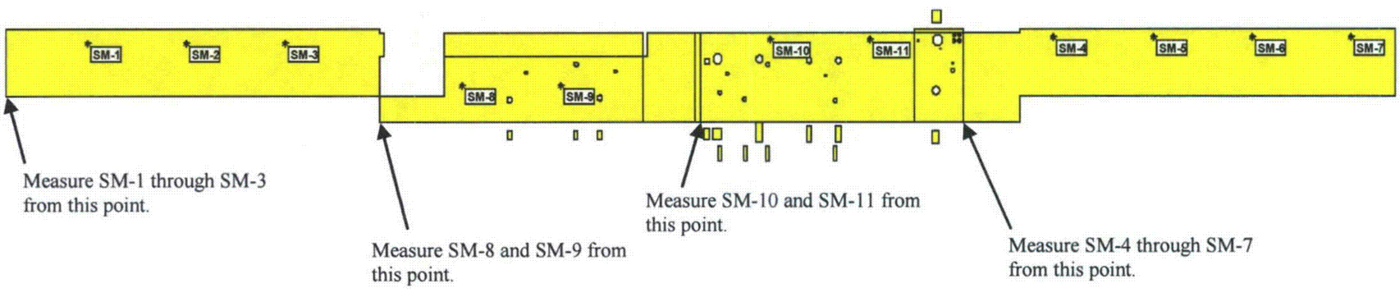
HR-1-21 AREA: Hot Retention Area Pipe Chase Interior West & South Wall Section 1 Measurement Locations and Results					
X Co-ord (m)*	Y Co-ord (m)*	Location / dpm/100-cm^2		Type	Notes
1.9	0.3	SM-1	932	Systematic w random start	N/A
4.9	0.3	SM-2	795	Systematic w random start	N/A
7.8	0.3	SM-3	671	Systematic w random start	N/A
10.7	0.3	SM-4	1007	Systematic w random start	N/A
13.6	0.3	SM-5	1027	Systematic w random start	N/A
16.6	0.3	SM-6	836	Systematic w random start	N/A
19.5	0.3	SM-7	911	Systematic w random start	N/A
22.4	0.3	SM-8	863	Systematic w random start	N/A
25.3	0.3	SM-9	664	Systematic w random start	N/A
28.3	0.3	SM-10	1014	Systematic w random start	N/A
31.2	0.3	SM-11	630	Systematic w random start	N/A
*The sample coordinates are measured from the location shown on the map.					

Survey Unit HR-1-22
Hot Retention Area - Pipe Chase Interior - East & North Wall - Section 2



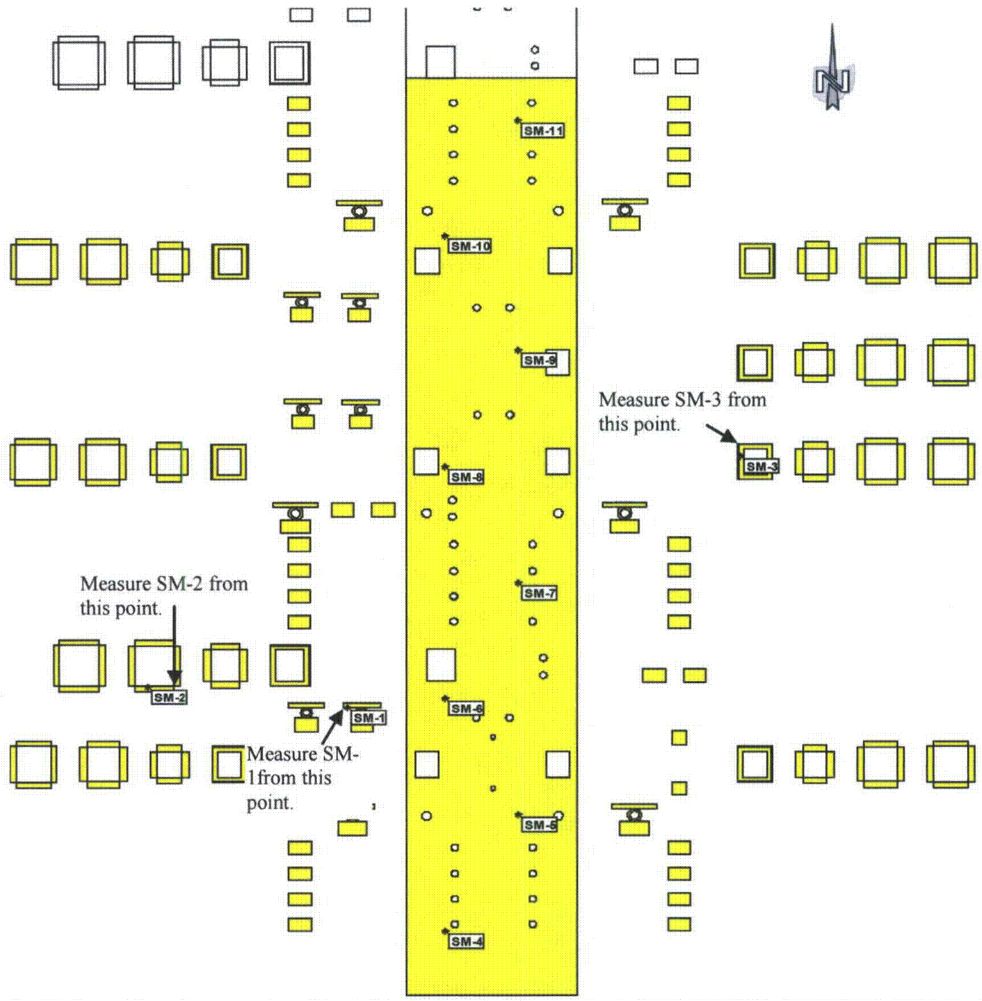
HR-1-22 AREA: Hot Retention Area Pipe Chase Interior East & North Wall Section 2 Measurement Locations and results					
X Co-ord (m)*	Y Co-ord (m)*	Location / dpm/100-cm^2		Type	Notes
1.9	0.3	SM-1	445	Systematic w random start	N/A
4.9	0.3	SM-2	986	Systematic w random start	N/A
7.8	0.3	SM-3	753	Systematic w random start	N/A
10.7	0.3	SM-4	856	Systematic w random start	N/A
13.6	0.3	SM-5	726	Systematic w random start	N/A
16.6	0.3	SM-6	815	Systematic w random start	N/A
19.5	0.3	SM-7	1103	Systematic w random start	N/A
22.4	0.3	SM-8	781	Systematic w random start	N/A
25.3	0.3	SM-9	712	Systematic w random start	N/A
28.3	0.3	SM-10	897	Systematic w random start	N/A
31.2	0.3	SM-11	897	Systematic w random start	N/A
*The sample coordinates are measured from the location shown on the map.					

Survey Unit HR-1-23
Hot Retention Area - Lower Pipe Chase - Wall Section 3



HR-1-23 AREA: Hot Retention Area Lower Pipe Chase - Wall Section 3 Measurement Locations and results					
X Co-ord (m)*	Y Co-ord (m)*	Location / dpm/100-cm^2		Type	Notes
2.4	1.4	SM-1	938	Systematic w random start	N/A
5.2	1.4	SM-2	890	Systematic w random start	N/A
8.1	1.4	SM-3	726	Systematic w random start	N/A
2.6	1.5	SM-4	514	Systematic w random start	N/A
5.5	1.5	SM-5	651	Systematic w random start	N/A
8.3	1.5	SM-6	616	Systematic w random start	N/A
11.2	1.5	SM-7	788	Systematic w random start	N/A
2.3	1.0	SM-8	959	Systematic w random start	N/A
5.2	1.0	SM-9	671	Systematic w random start	N/A
2.0	2.1	SM-10	247	Systematic w random start	N/A
4.9	2.1	SM-11	658	Systematic w random start	N/A
*Tthe sample coordinates are measured from the locations shown on the map.					

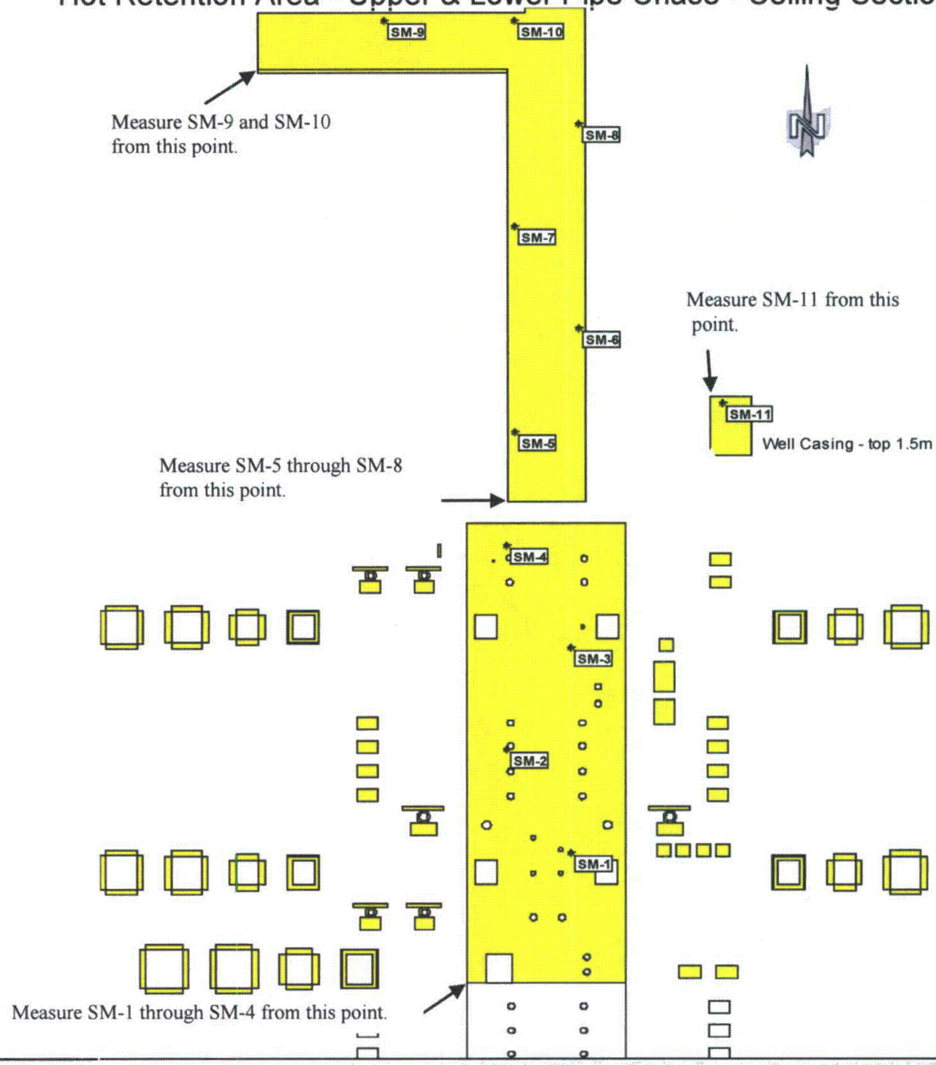
Survey Unit HR-1-24
Hot Retention Area - Upper Pipe Chase - Ceiling Section 1



HR-1-24 AREA: Hot Retention Area Upper Pipe Chase - Ceiling Section 1 Measurement Locations and results					
X Co-ord (m)*	Y Co-ord (m)*	Location / dpm/100-cm^2		Type	Notes
0.1	0.05	SM-1	110	Systematic w random start	N/A
0.5	0.05	SM-2	68	Systematic w random start	N/A
0.3	0.05	SM-3	171	Systematic w random start	N/A
0.8	1.5	SM-4	473	Systematic w random start	N/A
2.4	4.3	SM-5	973	Systematic w random start	N/A
0.8	7.0	SM-6	1089	Systematic w random start	N/A
2.4	9.8	SM-7	884	Systematic w random start	N/A
0.8	12.5	SM-8	760	Systematic w random start	N/A
2.4	15.3	SM-9	815	Systematic w random start	N/A
0.8	18.0	SM-10	685	Systematic w random start	N/A
2.4	20.8	SM-11	829	Systematic w random start	N/A

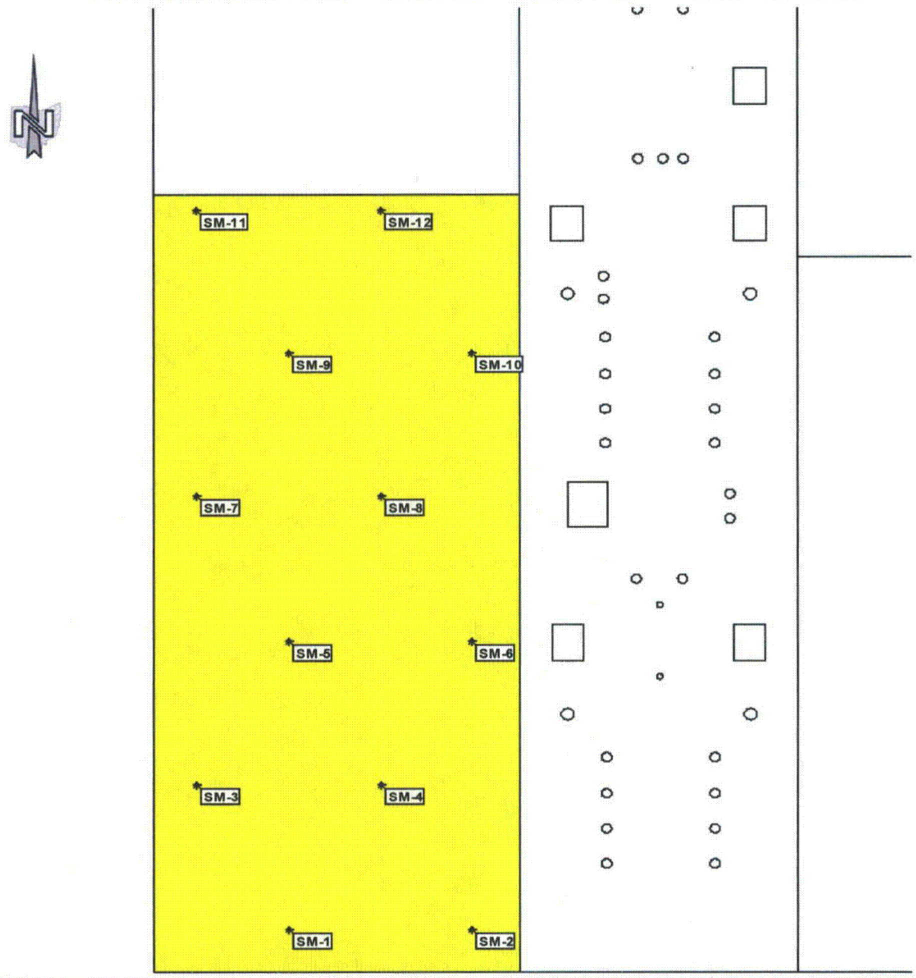
*Coordinates for SM-1 through SM-3 are measured from the location shown on the map. Coordinates for SM-4 through SM-11 are measured from the southwest corner of the survey unit.

Survey Unit HR-1-25
Hot Retention Area - Upper & Lower Pipe Chase - Ceiling Section 2



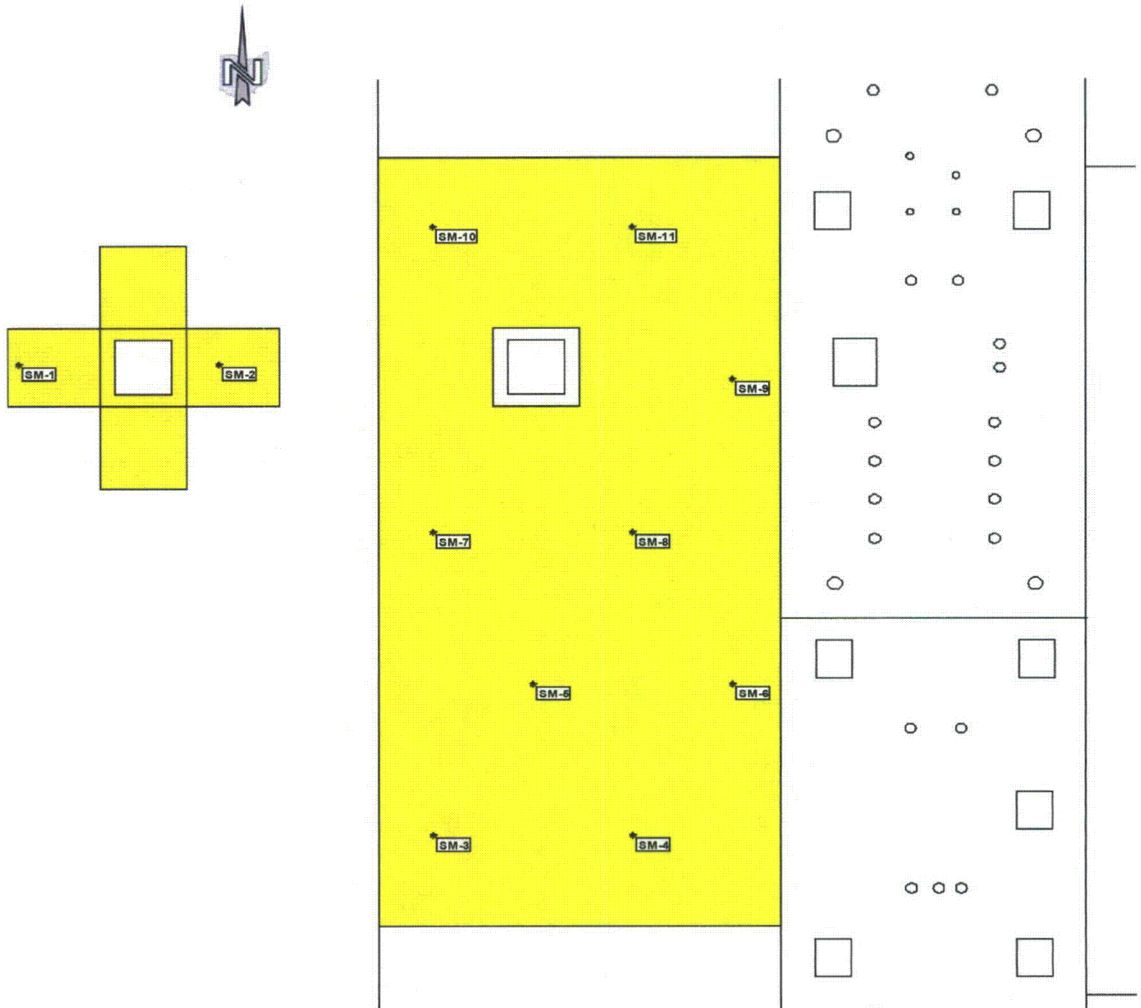
HR-1-25 AREA: Hot Retention Area Upper & Lower Pipe Chase - Ceiling Section 2 Measurement Locations and results					
X Co-ord (m)*	**Y Co-ord (m)***	**Location / dpm/100-cm^2**		**Type**	**Notes**
2.4	3.3	SM-1	479	Systematic w random start	N/A
0.9	5.9	SM-2	397	Systematic w random start	N/A
2.4	8.5	SM-3	1384	Systematic w random start	N/A
0.9	11.1	SM-4	911	Systematic w random start	N/A
0.2	1.8	SM-5	445	Systematic w random start	N/A
1.6	4.4	SM-6	767	Systematic w random start	N/A
0.2	7.0	SM-7	274	Systematic w random start	N/A
1.6	9.6	SM-8	1322	Systematic w random start	N/A
2.9	1.2	SM-9	829	Systematic w random start	N/A
5.9	1.2	SM-10	829	Systematic w random start	N/A
0.3	- 0.2	SM-11	1247	Systematic w random start	N/A
*Coordinates are measured from the locations shown on the map.					

Survey Unit HR-1-26
Hot Retention Area - Exterior - West Pad - South Section



HR-1-26 AREA: Hot Retention Area Exterior - West Pad, South Section Measurement Locations and results					
X Co-ord (m)*	**Y Co-ord (m)***	**Location / dpm/100-cm^2**		**Type**	**Notes**
2.1	0.7	SM-1	979	Systematic w random start	N/A
4.9	0.7	SM-2	336	Systematic w random start	N/A
0.6	3.2	SM-3	1120	Systematic w random start	N/A
3.5	3.2	SM-4	192	Systematic w random start	N/A
2.1	5.6	SM-5	1007	Systematic w random start	N/A
4.9	5.6	SM-6	96	Systematic w random start	N/A
0.6	8.1	SM-7	671	Systematic w random start	N/A
3.5	8.1	SM-8	904	Systematic w random start	N/A
2.1	10.6	SM-9	342	Systematic w random start	N/A
4.9	10.6	SM-10	-212	Systematic w random start	N/A
0.6	13.0	SM-11	856	Systematic w random start	N/A
3.5	13.0	SM-12	842	Systematic w random start	N/A
*All of the coordinates are measured from the southwest corner of the survey unit.					

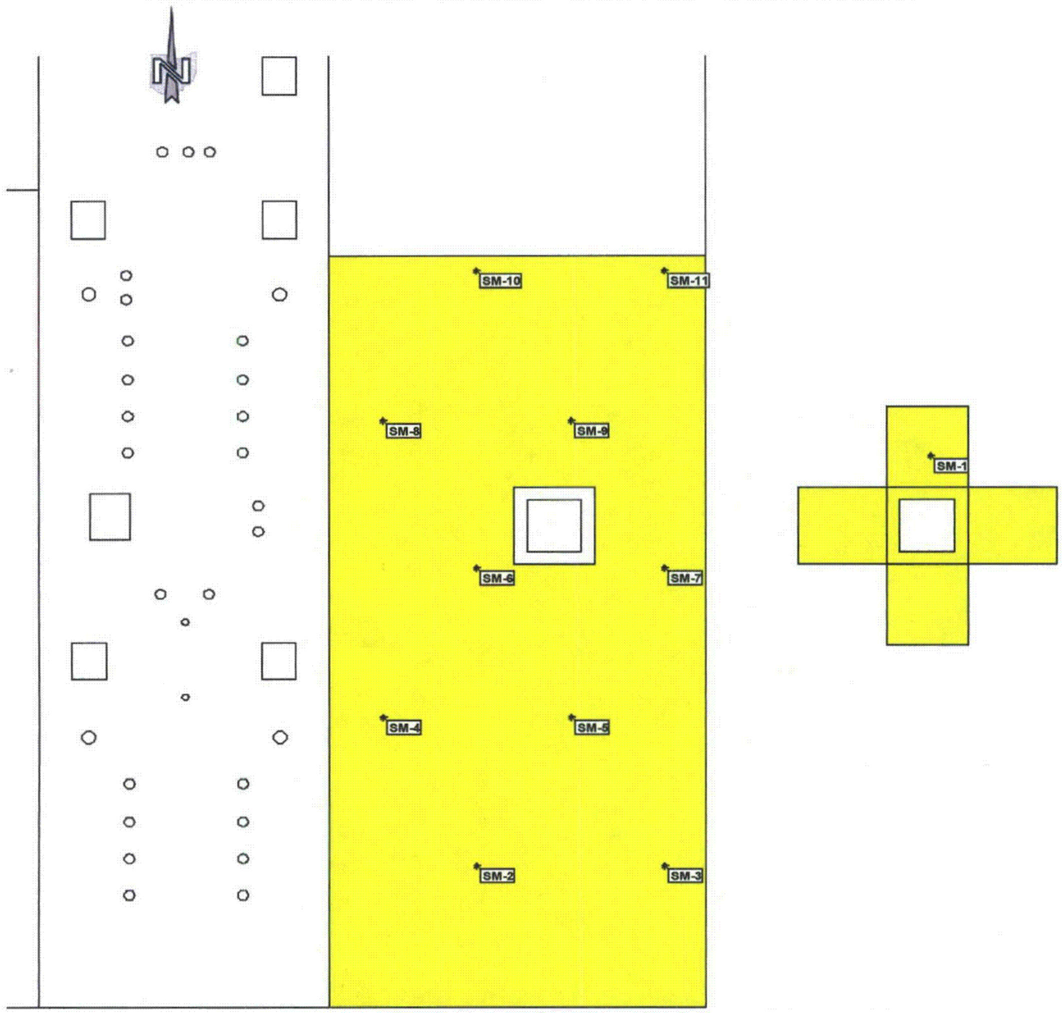
Survey Unit HR-1-27
Hot Retention Area - Exterior - West Pad - Center Section



HR-1-27 AREA: Hot Retention Area Exterior - West Pad, Center Section Measurement Locations and results					
X Co-ord (m)*	Y Co-ord (m)*	Location / dpm/100-cm^2		Type	Notes
0.6	0.2	SM-1	911	Systematic w random start	N/A
0.7	0.8	SM-2	562	Systematic w random start	N/A
0.8	1.4	SM-3	753	Systematic w random start	N/A
3.6	1.4	SM-4	623	Systematic w random start	N/A
2.2	3.9	SM-5	1021	Systematic w random start	N/A
5.0	3.9	SM-6	1120	Systematic w random start	N/A
0.8	6.3	SM-7	1089	Systematic w random start	N/A
3.6	6.3	SM-8	288	Systematic w random start	N/A
5.0	8.7	SM-9	527	Systematic w random start	N/A
0.8	11.2	SM-10	356	Systematic w random start	N/A
3.6	11.2	SM-11	740	Systematic w random start	N/A

*Coordinates for SM-1 and SM-2 are measured from the lower left corner of the surface on which they rest. Coordinates for SM-3 through SM-11 are measured from the southwest corner of the survey unit.

Survey Unit HR-1-28
Hot Retention Area - Exterior - East Pad - South Section

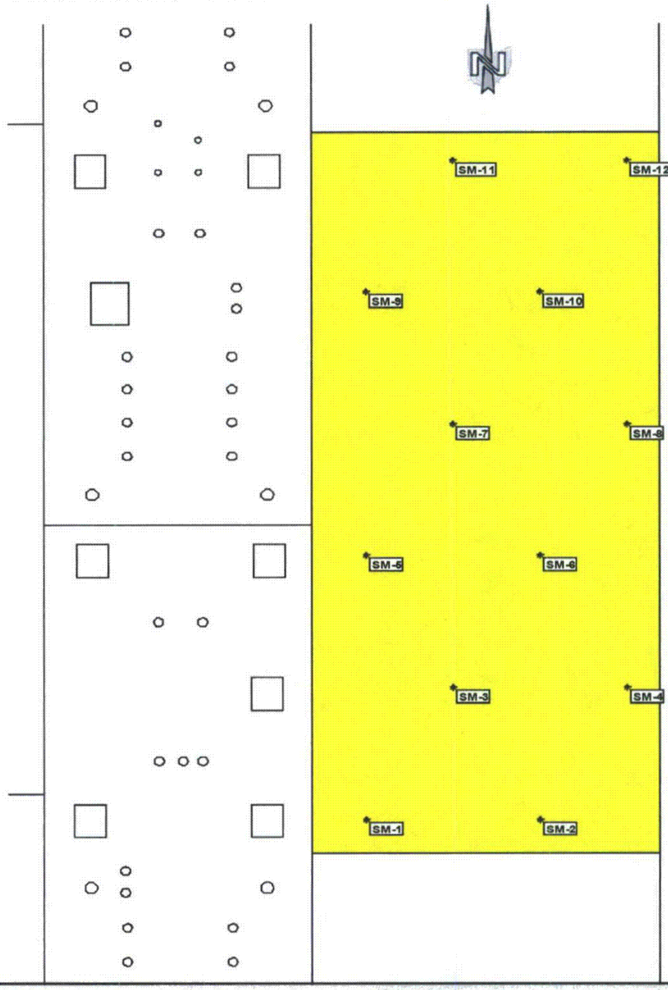


HR-1-28
AREA: Hot Retention Area Exterior - East Pad, South Section
Measurement Locations and results

X Co-ord (m)*	Y Co-ord (m)*	Location / dpm/100-cm^2		Type	Notes
0.6	0.8	SM-1	1080	Systematic w random start	N/A
2.2	2.3	SM-2	589	Systematic w random start	N/A
5.0	2.3	SM-3	610	Systematic w random start	N/A
0.8	4.7	SM-4	568	Systematic w random start	N/A
3.6	4.7	SM-5	575	Systematic w random start	N/A
2.2	7.1	SM-6	836	Systematic w random start	N/A
5.0	7.1	SM-7	829	Systematic w random start	N/A
0.8	9.5	SM-8	671	Systematic w random start	N/A
3.6	9.5	SM-9	527	Systematic w random start	N/A
2.2	12.0	SM-10	651	Systematic w random start	N/A
5.0	12.0	SM-11	747	Systematic w random start	N/A

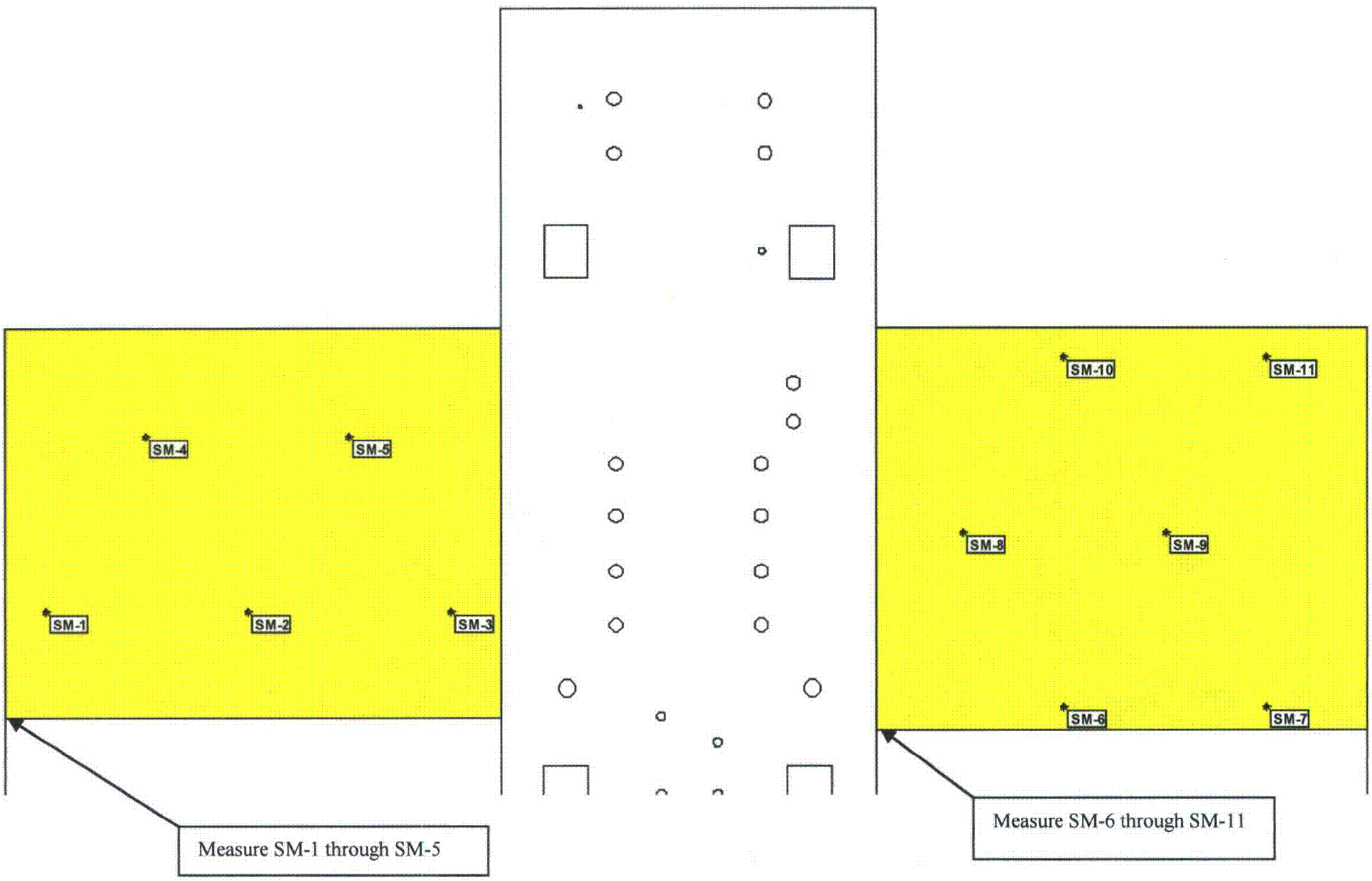
*Coordinates for SM-1 are measured from the lower left corner of the surface on which it rests. Coordinates for SM-2 through SM-11 are measured from the southwest corner of the survey unit.

Survey Unit HR-1-29
Hot Retention Area - Exterior - East Pad - Center Section



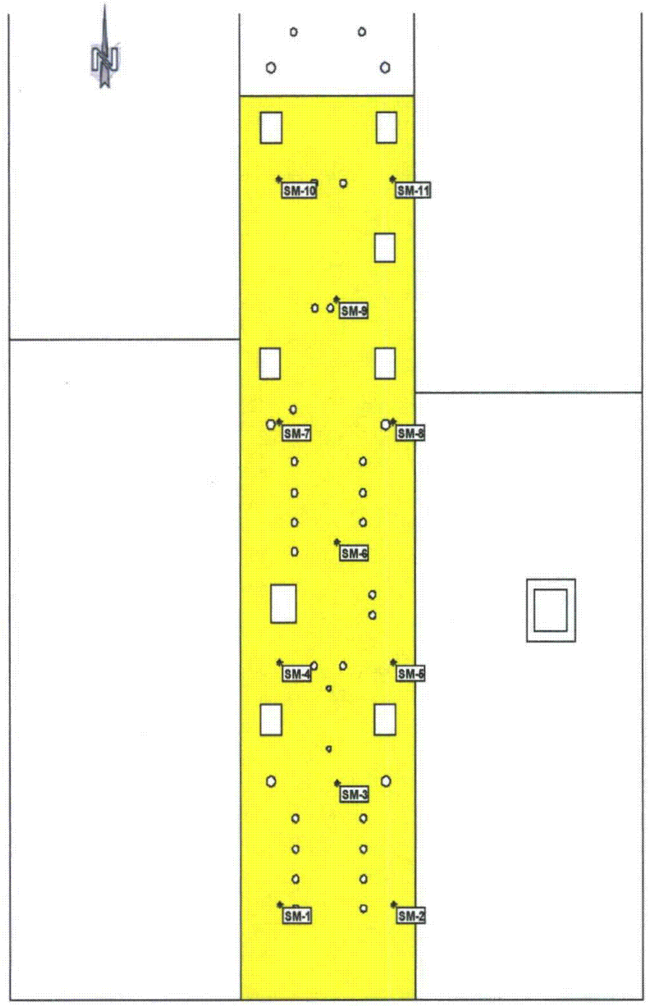
HR-1-29 AREA: Hot Retention Area Exterior - East Pad, Center Section Measurement Locations and results					
X Co-ord (m)*	Y Co-ord (m)*	Location / dpm/100-cm^2		Type	Notes
0.9	0.6	SM-1	418	Systematic w random start	N/A
3.7	0.6	SM-2	459	Systematic w random start	N/A
2.3	3.0	SM-3	904	Systematic w random start	N/A
5.1	3.0	SM-4	96	Systematic w random start	N/A
0.9	5.5	SM-5	644	Systematic w random start	N/A
3.7	5.5	SM-6	870	Systematic w random start	N/A
2.3	7.9	SM-7	877	Systematic w random start	N/A
5.1	7.9	SM-8	788	Systematic w random start	N/A
0.9	10.3	SM-9	582	Systematic w random start	N/A
3.7	10.3	SM-10	473	Systematic w random start	N/A
2.3	12.7	SM-11	815	Systematic w random start	N/A
5.1	12.7	SM-12	1170	Systematic w random start	
*All of the coordinates are measured from the southwest corner of the survey unit.					

Survey Unit HR-1-30
Hot Retention Area - Exterior - West & East Pad - North Section



HR-1-30 AREA: Hot Retention Area Exterior - West & East Pads, North Sections Measurement Locations and results					
X Co-ord (m)*	Y Co-ord (m)*	Location / dpm/100-cm^2		Type	Notes
0.5	1.2	SM-1	1020	Systematic w random start	N/A
2.8	1.2	SM-2	151	Systematic w random start	N/A
5.1	1.2	SM-3	678	Systematic w random start	N/A
1.6	3.2	SM-4	432	Systematic w random start	N/A
4.0	3.2	SM-5	432	Systematic w random start	N/A
2.1	0.3	SM-6	534	Systematic w random start	N/A
4.4	0.3	SM-7	849	Systematic w random start	N/A
1.0	2.3	SM-8	753	Systematic w random start	N/A
3.3	2.3	SM-9	726	Systematic w random start	N/A
2.1	4.3	SM-10	493	Systematic w random start	N/A
4.4	4.3	SM-11	664	Systematic w random start	N/A
*Coordinates are measured from the locations shown on the map.					

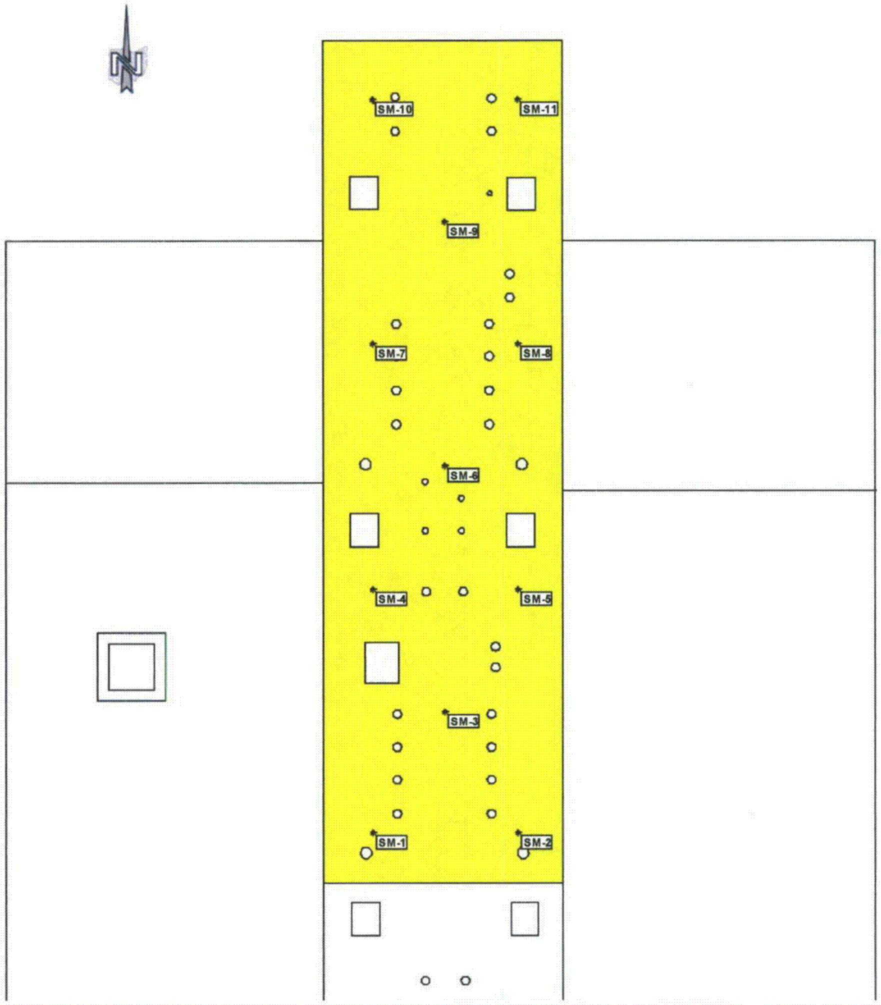
Survey Unit HR-1-31
Hot Retention Area - Exterior - Roof - South Section



HR-1-31 AREA: Hot Retention Area Exterior - Roof, South Section Measurement Locations and results					
X Co-ord (m)*	Y Co-ord (m)*	Location / dpm/100-cm^2		Type	Notes
1.0	1.9	SM-1	959	Systematic w random start	N/A
3.8	1.9	SM-2	836	Systematic w random start	N/A
2.4	4.4	SM-3	507	Systematic w random start	N/A
1.0	6.8	SM-4	815	Systematic w random start	N/A
3.8	6.8	SM-5	699	Systematic w random start	N/A
2.4	9.2	SM-6	1300	Systematic w random start	N/A
1.0	11.7	SM-7	596	Systematic w random start	N/A
3.8	11.7	SM-8	1014	Systematic w random start	N/A
2.4	14.1	SM-9	815	Systematic w random start	N/A
1.0	16.5	SM-10	1123	Systematic w random start	N/A
3.8	16.5	SM-11	979	Systematic w random start	N/A

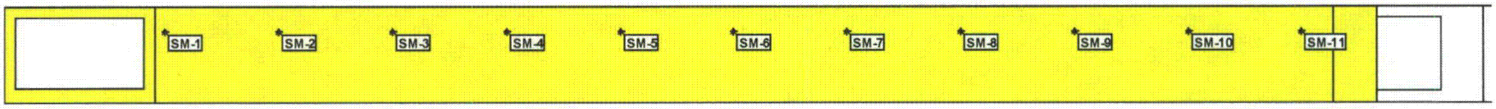
*All of the coordinates are measured from the southwest corner of the survey unit.

Survey Unit HR-1-32
Hot Retention Area - Exterior - Roof - North Section



HR-1-32 AREA: Hot Retention Area Exterior - Roof, North Section Measurement Locations and results					
X Co-ord (m)*	Y Co-ord (m)*	Location / dpm/100-cm^2		Type	Notes
0.9	0.9	SM-1	1340	Systematic w random start	N/A
3.5	0.9	SM-2	753	Systematic w random start	N/A
2.2	3.2	SM-3	596	Systematic w random start	N/A
0.9	5.4	SM-4	986	Systematic w random start	N/A
3.5	5.4	SM-5	993	Systematic w random start	N/A
2.2	7.7	SM-6	370	Systematic w random start	N/A
0.9	9.9	SM-7	767	Systematic w random start	N/A
3.5	9.9	SM-8	822	Systematic w random start	N/A
2.2	12.2	SM-9	685	Systematic w random start	N/A
0.9	14.4	SM-10	473	Systematic w random start	N/A
3.5	14.4	SM-11	521	Systematic w random start	N/A
*All of the coordinates are measured from the southwest corner of the survey unit.					

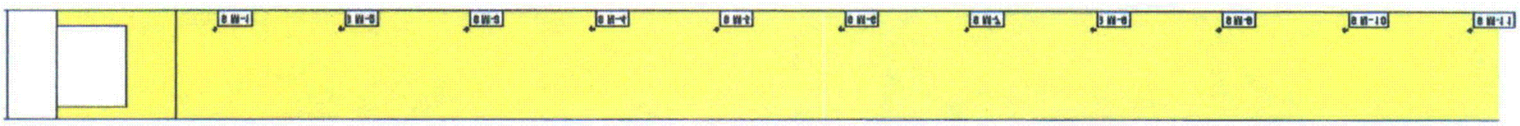
Survey Unit HR-1-33
Hot Retention Area - Exterior - West & South Walls



HR-1-33 AREA: Hot Retention Area Exterior - West & South Walls Measurement Locations and results					
X Co-ord (m)*	Y Co-ord (m)*	Location / dpm/100-cm^2		Type	Notes
0.3	2.1	SM-1	846	Systematic w random start	N/A
3.5	2.1	SM-2	931	Systematic w random start	N/A
6.8	2.1	SM-3	1280	Systematic w random start	N/A
10.0	2.1	SM-4	931	Systematic w random start	N/A
13.3	2.1	SM-5	969	Systematic w random start	N/A
16.5	2.1	SM-6	1390	Systematic w random start	N/A
19.7	2.1	SM-7	1162	Systematic w random start	N/A
23.0	2.1	SM-8	1008	Systematic w random start	N/A
26.2	2.1	SM-9	1290	Systematic w random start	N/A
29.4	2.1	SM-10	1210	Systematic w random start	N/A
32.7	2.1	SM-11	1330	Systematic w random start	N/A

*All of the sample coordinates are measured from the lower left corner of the surface on which they rest.

Survey Unit HR-1-34
Hot Retention Area - Exterior - East & North Walls



HR-1-34 AREA: Hot Retention Area Exterior - East & North Walls Measurement Locations and results					
X Co-ord (m)*	**Y Co-ord (m)***	**Location / dpm/100-cm^2**		**Type**	**Notes**
1.0	0.4	SM-1	267	Systematic w random start	N/A
4.2	0.4	SM-2	288	Systematic w random start	N/A
7.4	0.4	SM-3	911	Systematic w random start	N/A
10.6	0.4	SM-4	158	Systematic w random start	N/A
13.7	0.4	SM-5	363	Systematic w random start	N/A
16.9	0.4	SM-6	486	Systematic w random start	N/A
20.1	0.4	SM-7	740	Systematic w random start	N/A
23.3	0.4	SM-8	308	Systematic w random start	N/A
26.5	0.4	SM-9	1190	Systematic w random start	N/A
29.7	0.4	SM-10	534	Systematic w random start	N/A
32.9	0.4	SM-11	616	Systematic w random start	N/A
*All of the sample coordinates are measured from the lower left corner of the surface on which they rest.					