National Aeronautics and
Space Administration
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Plum Brook Station
Sandusky, OH 44870

August 29, 2011

Reply to Attn of: QD

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D.C. 20555

Subject: Final Status Survey Report, Attachment 10, Emergency Retention Basin, for the Plum Brook Reactor Facility, Licenses Nos. TR-3, Docket No. 50-30 and R-93, Docket No. 50-185

Enclosed for your review is Attachment 10 to the Final Status Survey Report supporting eventual termination of the licenses for the Plum Brook Reactor Facility.

The complete Final Status Survey Report will consist of a series of Attachments, each addressing an individual survey area or group of survey areas or environmental areas as described in our NRC approved Final Status Survey Plan. The final submission will be the main body of the Final Status Survey Report which will consolidate and summarize the details presented in the Attachments.

This Attachment addresses the Final Status Survey of the Emergency Retention Basin. It supports our conclusion that radiological remediation of the building has been completed and the area meets the criteria for unrestricted release specified in 10 CFR 20.1402.

Should you have any questions or need additional information, please contact me a NASA Plum Brook Station, 6100 Columbus Avenue, Sandusky, Ohio 44870, or by telephone at (419) 621-3277.

Keith M. Peecook
NASA Decommissioning Program Manager

FSME20

Enclosure

1. Plum Brook Reactor Facility Final Status Survey Report, Attachment 10, Emergency Retention Basin, revision 0, dated August 29, 2011.

cc:
USNRC/C. J. Glenn (FSME)
USNRC/J. Webb (FSME)
USNRC/J. Tapp RIII/DNMS/DB
ODH/M. J. Rubadue

Plum Brook Reactor Facility

Final Status Survey Report

Attachment 10

Revision 0

Emergency Retention Basin (ERB)

FINAL STATUS SURVEY REPORT
ROUTING AND APPROVAL SHEET

Document Title: Final Status Survey Report,
Attachment 10
Emergency Retention Basin (ERB)

Revision Number: 0

ROUTING

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NASA PBRF DECOMMISSIONING PROJECT
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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 Reasonably Achievable
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
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
ERB	Emergency Retention Basin
FSS	Final Status Survey
FSSP	Final Status Survey Plan
FSSR	Final Status Survey Report
γ	gamma, denotes gamma radiation
gpm	gallons per minute
g	gram
i	observation counting interval during scan surveys
in.	inch
LMI	Ludlum Measurements, Inc.
LBGR	Lower Bound of the Gray Region
LWDA	Liquid Waste Disposal Authorization
m^2	square meters
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
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
MOU	Memorandum of Understanding
mrem	millirem
MW	Megawatt

LIST OF ACRONYMS & SYMBOLS, Continued

NASA	National Aeronautics and Space Administration
N	Number of FSS measurements or samples established in a survey design
N/A	Not Applicable
NaI	Sodium Iodide
NRC	US Nuclear Regulatory Commission
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
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
SEB	Service Equipment Building
SNL	Sandia National Laboratory
SR	Survey Request
t_b	background count time
t_s	sample count time
TBD	Technical Basis Document
μ	Mean activity concentration
UL	Upper limit of the confidence interval about the mean
VSP	Visual Sample Plan
WEMS	Water Effluent Monitoring System
$Z_{1-\alpha}$	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 Emergency Retention Basin (ERB). It is Attachment 10 of the PBRF Final Status Survey Report (FSSR) [1]. This attachment describes the ERB, its operational history and condition for the Final Status Survey (FSS). It describes the methods used in the FSS and presents the results.

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). Applicable to FSS of the ERB, single radionuclide Derived Concentration Guideline Levels (DCGLs) have been established for PBRF site soils in the FSSP. The principal radionuclides of PBRF origin in ERB soil residual contamination are Cs-137, Co-60 and Sr-90. Their respective DCGLs are: 14.7, 3.8 and 5.4 pCi/g.

The survey measurement results and supporting information presented herein demonstrate that residual contamination levels in each of the ERB survey units are well below the applicable DCGLs. Additionally, it is shown that residual contamination has been reduced to levels that are consistent with the ALARA requirement. Therefore, the land area formerly occupied by the ERB meets the criteria for unrestricted release.

Section 2.0 of the report provides a description of the ERB. This includes its location, layout, relation to other PBRF buildings and facilities, design, construction, modifications, configuration for the FSS and scope of the FSS.

A brief history of operations pertaining to the ERB 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. Results of radiological characterization surveys in support of decommissioning are presented.

Section 4.0 presents the FSS design for the ERB. This section includes applicable FSS Plan requirements, breakdown into survey units and assignment of MARSSIM classifications. The survey design approach, instrumentation and measurement sensitivities are described.

Survey results are presented in Section 5.0. This section includes a summary of the FSS measurements performed in the ERB 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, maps and drawings to supplement the text. Survey design maps and tables of coordinates for each ERB survey unit soil sample location are provided in Appendix B. Soil sample results are provided in Appendix C.

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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).

2.0 PBRF Site and ERB Description

A brief description of the site provides information on the ERB location and function relative to the PBRF. The ERB is described, including as-built and final configuration for the FSS.

2.1 PBRF Site Description

The PBRF site is located near the northern edge of the 6400 acre Plum Brook Station. The site, as described in the NRC license that controls decommissioning activities, comprises 27 acres which contain the Reactor Building, support buildings and water handling facilities.[2] The controlled-access site is bounded on the south by Pentolite Rd., on the west by Line 2 Rd. and on the north and east by a boundary fence. The southwest corner of the site, the intersection of Line 2 and Pentolite Roads is used as a reference location.[3] The coordinates are 41° 23' 03.73" North Latitude and 82° 41' 05.80" West Longitude.[4] Figure 1 shows the principal remaining PBRF buildings and site layout including the ERB, located at the southeast corner of the site.

The site is generally level and was graded to promote surface water drainage to the Water Effluent Monitoring System (WEMS) formerly located at the south east corner of the site [USACE 2004]. The reference grade level at the Reactor Building is 631 ft. above mean sea level [NACA 1956].[5] The ERB as-built floor was at approximately 630 ft. elevation.

2.2 ERB Description

The ERB was a three-acre above ground earthen water storage basin located in the southeast corner of the Plum Brook Reactor Facility site. It was used as emergency storage for radioactively contaminated water that exceeded liquid effluent discharge criteria. The ERB had an effective storage capacity of 5,000,000 gallons. It was constructed of clay/soil with dimensions of approximately 200 x 300 ft. at the floor and about 250 x 350 ft. at the top of the surrounding 10 ft. high berm. See Exhibit 1 of Appendix A for a construction era photo of the PBRF showing the ERB dike nearing completion.

The water management system was designed to divert effluent water from the WEMS to the ERB when radioactivity levels exceeded pre-set release limits. The WEMS gates were

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[2] See Technical Specifications, Section 5, for the License No. TR-3 (Amendment 13) and License No. R-93 (Amendment 9) [NASA 2007].

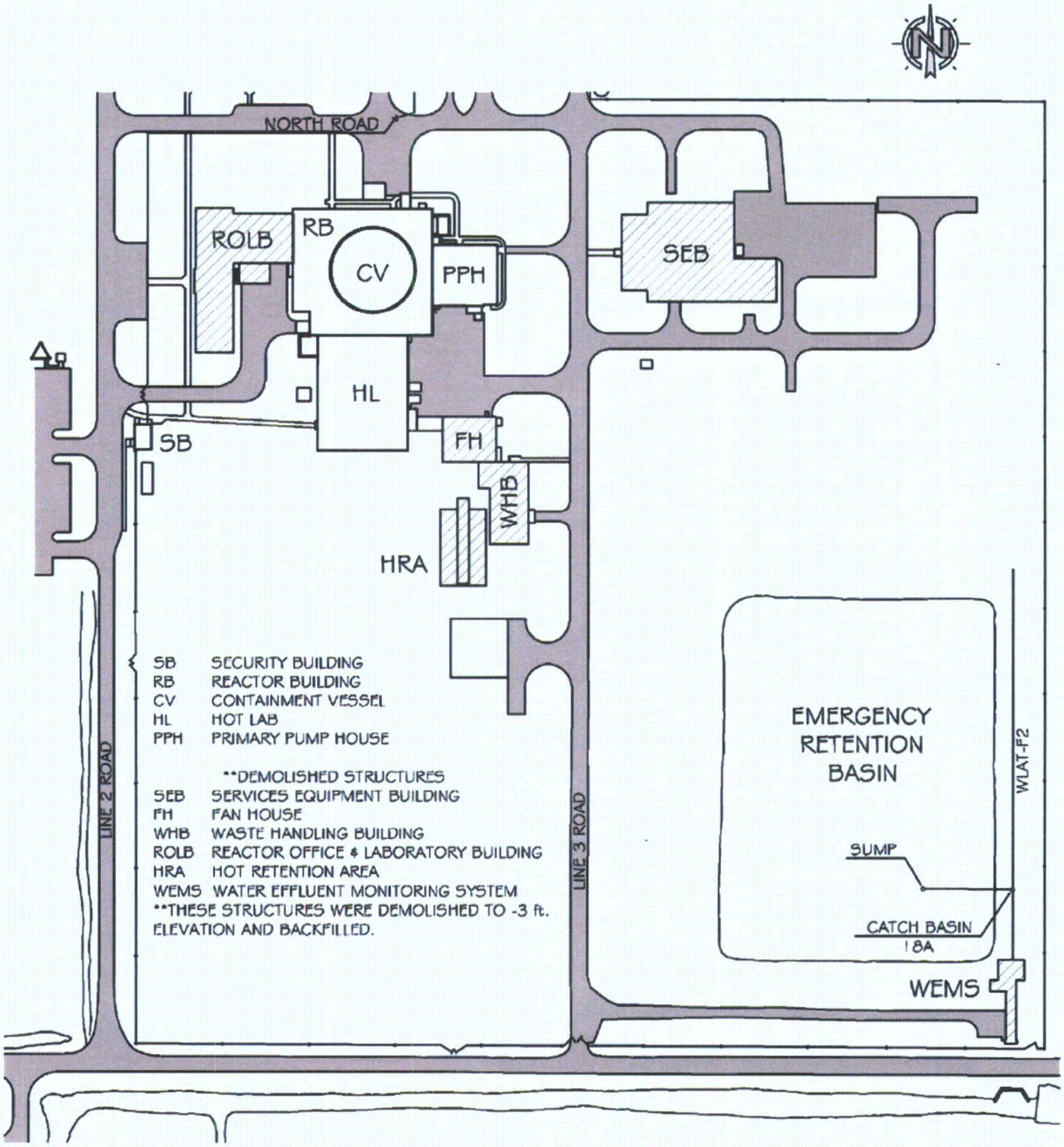
[3] The reference location is a survey monument in the pavement at the center of the intersection of Pentolite and Line 2 Roads. Prior to decommissioning, the Reactor Vessel center was typically used as a local reference location for the PBRF.

[4] Note that the coordinate grid system used for construction of the PBRF was a local coordinate system established by the Army Corps of Engineers in the 1940's for construction of the Plum Brook Ordinance Works. This local grid system has been balanced (tied in) to the Ohio regional state plane coordinate system by NASA to align Glenn Research Center and Plum Brook Station geographic references with modern high-accuracy geo-reference systems. This provides the ability to reference locations specified on historical drawings to global latitude and longitude [Hagelin 2010].

[5] The finished floor elevation of the Reactor Building first floor is designated as the 0 ft. elevation for major PBRF buildings. This is one ft. above grade level at the Reactor Building location.

automatically closed when the in-stream radiation monitors recorded levels in excess of the limits. When this occurred, two electric pumps, rated at 1500 GPM, located on supports over the west side of the WEMS settling basin moved water from the settling basin (via a 14" pipe) into an 8 ft. diameter by 4 ft. deep sump located in the southeast corner of the ERB. In the event of a power failure, emergency power was supplied from diesel generators in the Service Equipment Building (SEB) to power the pumps. A portable diesel powered pump was also available as a backup.

Figure 1, PBRF Site Layout Showing Principal Buildings and the ERB



2.3 Modifications

The ERB was operated as constructed from facility startup until 1968, when the water inlet and drain systems were modified. Effluent water from the WEMS was originally pumped from the main WEMS lateral to the ERB by a gasoline motor-driven pump. Facility Change No. 67-011 covered modifications to the PBRF drainage ditches, including addition of the two electric motor-driven 1500 gpm pumps described in the previous section. These pumps were added to handle potential storm drain overflow from unusually heavy rainfall. The gasoline driven pump was retained as a backup.

As initially constructed, the ERB was drained via a siphon system. However, the siphon drain proved to be ineffective during freezing weather. Also, air in-leakage through the siphon gate valves reduced the efficiency. In 1968, a drain line was connected to the sump to improve control and metering of the ERB discharge. It included 4 in. schedule 40 black steel pipe from the ERB sump to a below grade valve pit containing two valves in series (a butterfly valve for fine control and a plug valve). The ERB drain water then discharged through a weir box to a catch basin (18A) on the main WEMS storm and effluent drain lateral located directly east of the ERB.

2.4 Final Configuration and Scope

The ERB sump, inlet and discharge piping and valves have been removed. Initial excavation of the ERB berm and floor soils was performed in 2005. For the FSS, the ERB berm and all remaining non-earthen materials have been removed (see Section 3.5 for a description of ERB excavation and materials disposition). The scope of the FSS includes surface soils in the ERB foot print. Exhibits 2 and 3 of Appendix A show the ERB configuration at the time of the FSS in 2011.

3.0 History of Operations

A chronology of major milestones is given below. This is followed by a discussion of operations, post-shutdown and decommissioning activities. Emphasis is on operations with radioactive materials that could affect the final condition and final status survey of the ERB.[6]

3.1 Chronology

Major PBRF and ERB milestones are listed below:

1956 – September, groundbreaking for PBRF.

[6] 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.

1961 – June, 60 MW Test Reactor critical.

1961 – 1962, ERB completed.

1961- 1964 Reactor and systems testing.

1963 - Full Power 60 MW Test Reactor operations begin.

1973- January, Reactor shutdown (after 152 "cycles").

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

1985 – Initial radiological characterization, Teledyne Isotopes Inc.

2002 – Decommissioning Plan approved.

2005 – Initial excavation of ERB; including sump and soils.

2009 – Temporary repair of ERB for site water management.

2010 – Dismantlement of temporary ERB repairs.

2010 – ERB soil remediation and post-remediation surveys.

2011 – FSS measurements completed.

3.2 Startup and Operations

According to PBRF historical records, the ERB was fully functional upon initiation of full power 60 MW Test Reactor operations in 1963 through June 1973, with the exception of a period during 1968 when the discharge modifications were installed. The ERB was used to receive and store water diverted from the WEMS when radioactive liquid effluent concentration limits were exceeded and during storm drain malfunctions or heavy rains. During normal operations, the ERB water level was maintained below 5 ft. depth (measured from the ERB floor).

The ERB was inspected on a regular basis, especially when in use. Woodchucks would occasionally burrow into the earthen dike walls (berm) and would have to be eradicated. During emergency operations the water level could reach as high as 8 ft. It was required that the berm be inspected at least once a shift when water levels were 8 ft. or greater.

3.3 Radioactive Materials in the ERB

The US Atomic Energy Commission (AEC) authorized operations and use of radioactive materials at the PBRF under several licenses.[7] 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 ERB were those originating from PBRF tests and experiments [PBRF 2009]. Radioactive materials reaching the ERB included fission and activation products and fuel radionuclides in dissolved or suspended form that were transported to the WEMS in effluents from PBRF drains and liquid process systems.

During reactor operations there was only one recorded incident involving the ERB:

> Reactor Cycle 83, 11/12/68. During heavy rains, the ERB dike was breached at the northwest corner allowing water from the basin to flow into the surrounding area. This resulted from the high level of water in the basin and the steadily falling rain over the previous 24-hour period. Grab samples of spillage water showed the radioactivity level to be 1.24 x 10^{-6} μCi/ml (beta-gamma). The water outflow was stopped and NASA personnel continued to reinforce the break with stone fill and earth trucked to the site. The water that had spilled from the break had either entered the effluent conduit through overland flow and the drain systems or had soaked into the ground. Samples taken in the area indicated no activity above acceptable levels. A planned release was then initiated to lower the water level. [8]

3.4 Post-Shutdown Materials Disposition and Characterization

Notification was received on January 5, 1973 that due to budget constraints, NASA was terminating all nuclear related research operations at PBRF. The Test Reactor, Mock-up Reactor, Hot Laboratory and all associated operations were to be shutdown and placed in standby condition and the reactor staff terminated by June 30, 1973. Following notification, the 60 MW test reactor was immediately shutdown. A Master Plan was developed to address activities associated with terminating the operating licenses for PBRF and placing the facility in a standby status. Plum Brook Reactor Facility End Condition Statements for Protected Safe Storage Mode detailed facility final condition status goals for mid-1973; including the ERB.

The ERB remained active during 1973 in the post-shutdown period. It was used for emergency water management in May and June 1973. Large volumes of potentially contaminated water were generated in this period as the major liquid waste processing and hold up systems were flushed and decontaminated in preparation for safe storage mode. Water diverted to the ERB by the WEMS was released under a Liquid Waste Disposal Authorization

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

[8] From background report on the ERB prepared by J. Crooks and D. Young, PBRF-NASA retirees [PBRF 2009].

(LWDA) after analysis for alpha and beta-gamma radioactivity showed that effluent release limits were satisfied.[9]

In July 1973, in accordance with operating procedures and Shift Special Instructions, the ERB was flushed by filling to the 3 ft. level and disposing of the accumulated water per license conditions. These required water radioactivity concentrations to be less than $1x10^{-7}$ μCi/ml beta-gamma and soil or sediment to be less than $5x10^{-4}$ μCi/g gamma and $1x10^{-3}$ μCi/g beta. Once these requirements were satisfied, the ERB was allowed to collect precipitation for a period of up to two months. This water was re-sampled to verify that limit requirements were met and then released though the WEMS. The end condition statement called for the ERB drain valves to be locked in the open condition to allow free draining to the WEMS [PBRF 2009].

From 1973 until the start of decommissioning activities in 2002, the ERB sump water was sampled on a regular basis (once per quarter) to assure that the $1x10^{-7}$ μCi/ml limit was not exceeded. During this period the ERB was also maintained to retain its capability. There was a continuing problem with woodchucks burrowing into the berm so frequent inspections were performed. Vegetation growth inside the basin was controlled by cutting and application of herbicides. Exhibit 5 of Appendix A, an aerial view of the PBRF site shows the ERB condition circa 1970.

The ERB has been characterized on several occasions since PBRF operations were terminated in 1973. The 1984-1985 Teledyne Isotopes study analyzed soil samples including surface soil samples (0 to 6 in.) and cores to 10 ft. depth. The samples were analyzed for gross alpha and gross beta activity. The results indicated that most of the activity was confined to the first 6 in. of soil. Gross beta activity averaged 78 pCi/g. The highest soil activity levels were measured near the south end of the basin. Selected samples were analyzed for individual radionuclide activity. The major contributors were Co-60, Cs-137 and Sr-90. The highest measured concentration was 32 pCi/g Cs-137 [TELE 1987].

During the 1998 GTS-Duratek confirmatory survey, soil samples were collected at 5 locations from the southern portion of the ERB (three on the floor and two on the berm). The samples were analyzed by gamma spectroscopy. The highest measured concentrations (all Cs-137) were: 166 pCi/g (2 in. depth), 114 pCi/g (2 to 6 in. depth) and 11.5 pCi/g (6 to 12 in. depth). The entire ERB was gridded and a walkover gamma scan survey performed using a 1 x 1 in NaI detector. Direct gamma radiation readings (measured at ½" from the surface) ranged from background (10 to 12 μR/hr) to a maximum of 50 μR/hr with an average of approximately 20 to 30 μR/hr [GTS 1998].

3.5 Decommissioning

The PBRF Decommissioning Plan identified the ERB as an environmental area impacted by radioactive contamination from PBRF operations and requiring remediation [NASA 2008]. As part of decommissioning efforts, all components such as piping, valves, sump and pipe

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[9] The LDWA was administered under PBRF operating procedures to control releases of radioactive liquids from the site and to ensure that AEC license conditions and applicable regulations were satisfied.

piers were removed and disposed of as contaminated or recycled materials in accordance with PBRF radiological control procedures (primarily RP-008, Radiological Release of Equipment, Material and Vehicles).

Additional characterization surveys of the ERB were performed by the decommissioning contractor during 2004 and 2005 as part of characterization surveys of PBRF open land areas. Surface samples were collected from 24 locations and subsurface samples (6 in. to 1 ft. depth) from 31 locations. The results are summarized:

- Surface sample average and maximum Cs-137 concentrations were 37.7 and 81.9 pCi/g, respectively,
- Surface sample average and maximum Co-60 concentrations were 2.15 and 7.61 pCi/g, respectively,
- Subsurface sample average and maximum Cs-137 concentrations were 1.22 and 4.46 pCi/g, respectively and
- Subsurface sample average and maximum Co-60 concentrations were 0.14 and 0.70 pCi/g, respectively.

The characterization report concluded that "surface soil remediation and further sampling is necessary from the entire floor of the ERB prior to FSS" [PBRF 2005]. The 2004-2005 characterization surveys included samples sent to a vendor laboratory for gamma spectroscopic and radiochemical analysis. The vendor laboratory reported that the principal constituent was Cs-137, with lesser concentrations of Co-60 and Sr-90 and trace quantities of several of the PBRF deselected radionuclides as described in the PBRF FSS Plan [NASA 2007].

Initial remediation of the ERB commenced in 2005 when approximately 3,400 tons of soil were excavated and shipped for disposal as radwaste by the decommissioning contractor.[10] This work scope included removal of the ERB sump and the underground fill and drain lines.[11] This work also required breaching the north and south berms to provide access for excavation equipment. In 2009, temporary repairs were made to the ERB to enable its use for holdup of storm drain and surface water runoff during excavation and dismantlement of the PBRF storm drains. This work was performed under PBRF Work Execution Package, PBRF-WEP-09-005.[12] The work scope included closing breaches in the ERB berm by installing gravel base, block walls and backfilling to match the adjacent grade. Exhibit 6 of Appendix A shows the condition of the ERB in the spring of 2009 prior to final remediation.

In 2010, demolition of the ERB was completed. This consisted of removal of standing water, vegetative cover and miscellaneous debris and excavation of the remaining potentially

[10] Weights of soil shipped as radwaste from the ERB during 2005 are obtained from PBRF Decommissioning Project waste shipment records.

[11] Plum Brook Reactor Facility Decommissioning Work Package, MW-SWEP-05-22-001, Soil Remediation, July 2005.

[12] Plum Brook Reactor Facility Decommissioning Work Execution Package, PBRF-WEP-09-055, Emergency Retention Basin Repair, April 2009.

contaminated soils.[13] This work was performed under PBRF Work Execution Package, PBRF-WEP-09-025.[14] The work scope included removal of the temporary block walls and berm fill material, excavation of the entire remaining berm and excavation of approximately 6 in. of soil from the basin floor.

4.0 Survey Design and Implementation

This section describes the method for determining the number of fixed measurements and samples for the FSS of the ERB. Applicable requirements of the FSS Plan are summarized. These include the $DCGL_W$[15], the gross activity DCGL, scan survey coverage and action-investigation levels, classification of areas and breakdown of the survey units. The radiological instrumentation used in the FSS of the ERB and their detection sensitivities are discussed.

4.1 FSS Plan Requirements

The DCGLs for individual radionuclides in soil were calculated using RESRAD Version 6.21 for a Resident Farmer occupancy scenario. The DCGL calculations are described in the FSSP, Attachment B. The DCGL values from the FSSP for the three significant PBRF soil contaminant radionuclides are shown in Table 1. These DCGL values are also applied to subsurface soil and to soil-like excavated materials such as sediment and soil-sand-gravel mixtures.

Table 1, Single Radionuclide DCGL Values for Soil

Radionuclide	DCGL (pCi/g)
Co-60	3.8
Sr-90	5.4
Cs-137	14.7

For application to FSS of soil at PBRF, surrogate DCGLs are used to determine scan sensitivities, action levels and sample analysis MDA requirements. They are calculated from the single nuclide soil DCGLs using radionuclide mixtures established for the various outdoor land areas shown in Table 2 as described in TBD-09-001, the Technical Basis Document on radionuclide distributions and DCGLs for site soils [PBRF 2009a]. The following equation from the FSS Plan, Section 3.6.1 is used:

[13] Soil and candidate backfill materials excavated in 2009 and 2010 were removed and staged for evaluation and FSS. The FSS of excavated materials is reported in Attachment 18 of the PBRF Final Status Survey Report.

[14] Plum Brook Reactor Facility Decommissioning Work Execution Package, PBRF-WEP-09-025, Emergency Retention Basin Demolition, October 2009.

[15] 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).

$$DCGL_{SUR} = \frac{1}{\left[\left(\frac{1}{DCGL_1}\right)+\left(\frac{R_2}{DCGL_2}\right)+\left(\frac{R_3}{DCGL_3}\right)+.....+\left(\frac{R_n}{DCGL_n}\right)\right]},\qquad \textbf{(Equation 1)}$$

where: $DCGL_{SUR}$ = Surrogate radionuclide DCGL,

$DCGL_1$ = DCGL for the radionuclide to be used as the surrogate for the other radionuclides,

$DCGL_{2,3...n}$ = DCGL for radionuclides to be represented by the surrogate and

R_n = Ratio of concentration (or nuclide mixture fraction) of radionuclide "n" to surrogate radionuclide.

The activity fractions and the surrogate DCGL for FSS soil scans of the ERB are shown in Table 2. In this portion of the PBRF site, Cs-137 was found to be the predominate radionuclide of PBRF origin in soil. In accordance with TBD-09-001, the $DCGL_{SUR}$ value, 10.31 pCi/g, is used as the basis for scan survey investigation and action levels.

Table 2, Surrogate DCGL for ERB Soil FSS Scan Survey

Location	Activity Fractions			Surrogate Radionuclide	$DCGL_{SUR}$ (pCi/g)
	Cs-137	Co-60	Sr-90		
ERB & Environs Outside Perimeter Fence	0.878	0.037	0.085	Cs-137	10.31

Survey designs incorporate requirements for scan coverage and investigation levels derived from the MARSSIM classification of survey units [USNRC 2000]. The values listed in the FSS Plan applicable to soils are shown in Table 3.

Table 3, Class-Based Survey Scan Coverage and Action Level Requirements

Classification	Scan Survey Coverage	Scan Investigation Levels (1)	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 > $DCGL_W$	≥ 50% of the $DCGL_W$

Table 3 Note.

1. The scan investigation levels shown above are as listed in the FSS Plan. However, the scan investigation level was set below the $DCGL_W$ for Class 1 soil survey units, as discussed below.

4.2 Area Classification and Survey Unit Breakdown

The ERB was identified as an impacted area and initial MARSSIM classification assigned in Table 2-2 of the FSS Plan [NASA 2007]. It was included in two of the environmental areas designated in the Plan. The areas were assigned MARSSIM Class 1/2. The ERB was divided into seven survey units for the FSS. All were designated as MARSSIM Class 1. The ERB FSS survey units are listed in Table 4. They are also shown on a map of the ERB and vicinity in Figure 2.

Table 4, Survey Units for FSS

Survey Unit	Class	Area (m^2)	Survey Design	Survey Request	Description	FSSP Classification
OL-1-26 (1)	1	118	46	277/279	ERB Sump Drain Excavation	1/2
OL-1-27	1	1858	46	277/279	ERB Grids	1/2
OL-1-28	1	1858	46	277/279	ERB Grids	1/2
OL-1-29	1	1858	46	277/279	ERB Grids	1/2
OL-1-30	1	1858	46	277/279	ERB Grids	1/2
OL-1-31	1	1858	46	277/279	ERB Grids	1/2
OL-1-32	1	1858	46	277/279	ERB Grids	1/2

Table 4 Note:

1. The FSS results for Survey Unit OL-1-26 were reported in Attachment 7 of the FSS Report.

Figure 2, ERB Map Showing Survey Units for FSS

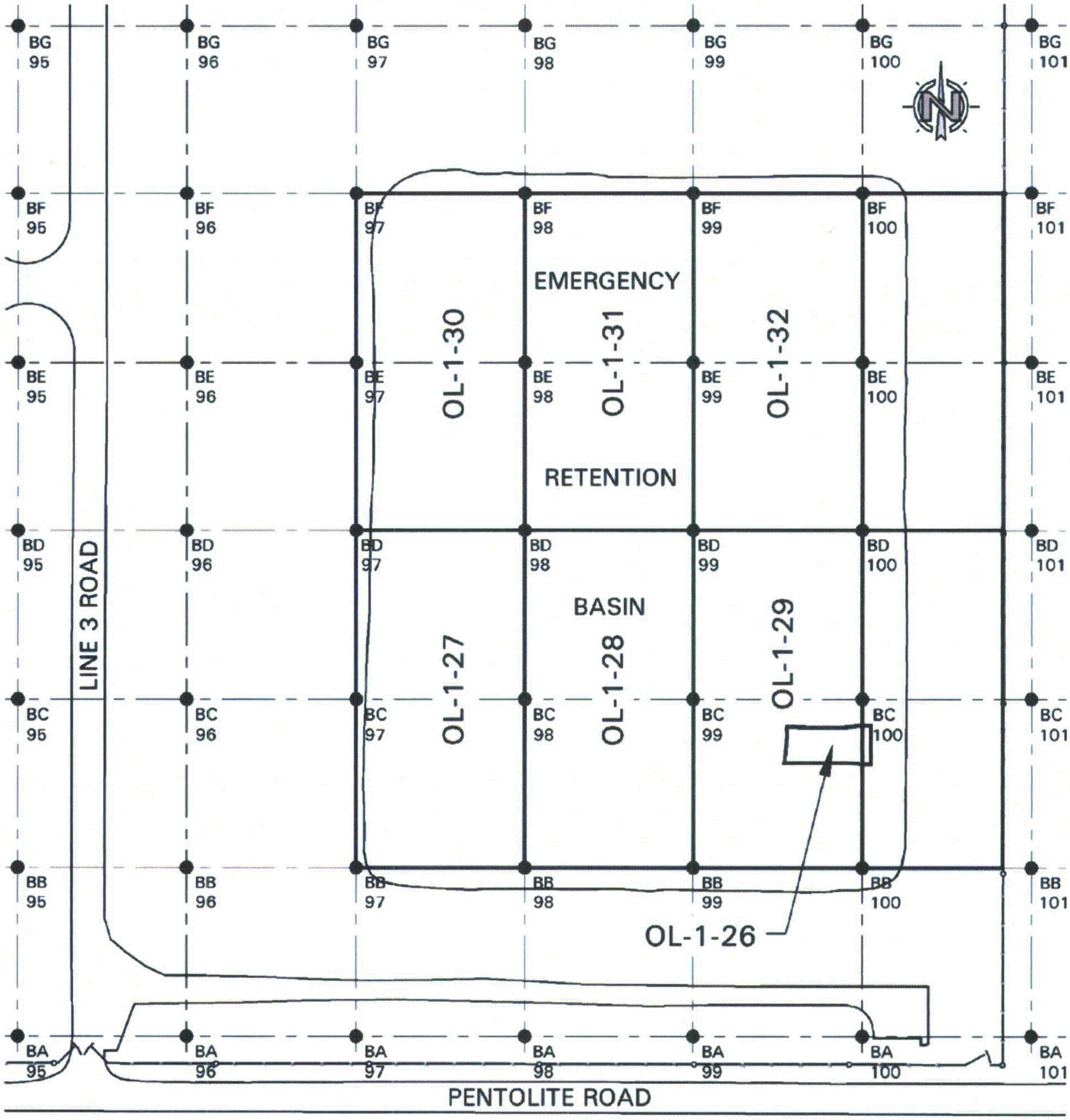

Figure 2 Notes:

1. The ERB survey units are laid out on 100 ft. square grids (except OL-1-26).
2. Reference grid pins (large dots on the map) are in the SW corner of the designated grids.
3. Grid labeling convention is alphabetical characters for N-S direction (increasing northward) and numerical for E-W direction (increasing eastward).
4. Coordinates for ERB SW corner pin (BB97) are: N 34092, E 22505. These coordinates are based on the Plum Brook Station local coordinate system in which the local reference point (intersection of Pentolite and Line 2 Roads) coordinates are: N 33962.27 and E 21790.15 [NASA 2006]. Also, see Section 2.1 for additional discussion of coordinate systems used at the Plum Brook Station.

It is noted that Survey Unit OL-1-26, the ERB Sump and Drain Excavation, was surveyed in the Fall of 2010 and reported in the FSS Report, Attachment 7, *Storm Drains, Pipe Trenches and other Sub-surface Excavations*. At that time the configuration was as shown in Exhibit 4 of Appendix A. Subsequently, the excavated trench was back-filled to the present ERB grade.[16] The backfilled surface is included in the ERB FSS as part of Survey Unit OL-1-29 as shown in Figure 2.

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 soil concentrations of the principal radionuclides are a small fraction of the applicable $DCGL_W$.[17] 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 ERB.[18] 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:

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

(Equation 2)

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 $\beta = 0.1$),
$\Phi(\Delta/\sigma)$ = value of cumulative standard normal distribution over the interval $-\infty$, Δ/σ,

[16] Backfill of the Ol-1-26 area after completion of the FSS was performed with NRC concurrence in accordance with Condition 3.A.4 of the license.

[17] Average soil/sediment concentration of Cs-137 measured in background areas near the PBRF in 2003 was 0.32 ± 0.11 pCi/g (one std. dev.) [PBRF 2005a]. The Sr-90 concentration in northern hemisphere surface soil is reported as "most levels fall between 0.05 and 0.5 pCi/g, with 0.1 pCi/g as a general average" [ANL 2006].

[18] 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.

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 7 ERB survey units using the parameters established in Survey Design No. 46. Table 5 summarizes the survey design and lists the values of the key VSP input parameters.

Table 5, Survey Design Summary

Design No. (1)	Survey Units	Class	$DCGL_W$ (2) (3)	LBGR (2)	Δ (2)	σ (2)	Δ/σ	N
46	OL-1-26 thru OL-1-32	1	11.4	5.7	5.7	2.28	2.5	11

Table 5 Notes:
1. The data reported in this table is obtained from the Survey Design 46. Survey designs are maintained in the PBRF Document Control System.
2. Units are pCi/g.
3. The $DCGL_W$ for determining the number of samples and evaluating soil sample results is derived in Design 46. It is obtained from the Cs-137 DCGL (14.7 pCi/g) published in the FSS Plan Table 3-1 by adjusting for 0.5 mrem/y dose contribution from deselected radionuclides in soil and calculating the DCGL as surrogate for Sr-90.

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 of 2.5 was used in the final calculations for determining N.

The VSP software automatically performs an analysis to examine the sensitivity of N, the number of samples, to critical input parameter values. The following is an example obtained from the VSP report for survey unit OL-1-26 (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.[19] The region of most interest in the table is for α = 0.05 (required to be fixed), β = 0.10 (may be adjusted) and the LBGR at 50% to 70% of the DCGL.

[19] In this case, the VSP sensitivity analysis was modified to set the LBGR range from 50% to 70% of the DCGL to evaluate the sensitivity of N to changes of key parameters in the region of Δ/σ values near 2.5. This is necessitated by the relatively large estimated value of σ used in ERB FSS design. [PBRF 2011]. A retrospective analysis of the ERB soil sample results shows that the standard deviation of the Cs-137 concentration (σ) is only 0.087 pCi/g from systematic samples and 1.54 pCi/g from investigative samples (a biased estimate). From this, it is concluded that 11 samples provided sufficient statistical power and indeed was a conservative design.

The sensitivity of N to expected measurement variability is examined first. With the LBGR set to 60%, doubling σ increases N from 12 to 23. At this LBGR value, N is sensitive to measurement variability. With the LBGR set to 50% of the DCGL, doubling σ increases N from 11 to 17. This shows that the number of measurements is moderately sensitive to measurement variability at LBGR values near 50% of the DCGL, as used in the ERB designs.

The sensitivity of N to the value of α, the probability of an incorrect conclusion that the survey unit will pass (regulator's risk) is low. With the LBGR set at 50% 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 11 or fewer in all cases. These results show that N = 11 represents a reasonable number of measurements for FSS of the ERB soil survey units.

Table 6, Sensitivity Analysis for FSS Design

Number of Samples							
DCGL = 11.4 (1)		α = 0.05 (2)		α = 0.10		α = 0.15	
		σ = 4.56	σ = 2.28 (1) (3)	σ = 4.56	σ = 2.28	σ = 4.56	σ = 2.28
LBGR = 70% (1) (4)	β = 0.05	44	18	35	14	29	12
	β = 0.10	35	14	27	11	22	9
	β = 0.15	29	12	22	9	18	7
LBGR = 60%	β = 0.05	28	15	23	12	19	10
	β = 0.10	23	12	17	9	14	8
	β = 0.15	19	10	14	8	12	6
LBGR = 50%	β = 0.05	21	14	17	11	14	9
	β = 0.10	17	11	13	9	11	7
	β = 0.15	14	9	11	7	9	6

Table 6 Notes:

1. Units of DCGL, σ and LBGR are pCi/g.
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.

Visual Sample Plan was also used to determine the grid size, the random starting location coordinates 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 ERB survey unit.

The survey designs also specify scan survey coverage and action levels based on the MARSSIM classification listed in Table 3. 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 ERB 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

Scan sensitivities for detectors used for walkover gamma scans of soil are determined using the method referenced in the PBRF FSS Plan and described in NUREG-1507 [USNRC 1998]. Scan sensitivities for the Ludlum Model 44-10 NaI detectors used in FSS of soils at PBRF were developed in the technical basis document, PBRF-TBD-09-002 [PBRF 2009b]. The method is summarized and the key equations presented. The scan MDC is calculated using the following equations adapted from NUREG-1507 for walkover gamma scanning with NaI detectors:

$$MDCR_{SURV} = \frac{d' \sqrt{bi}}{\sqrt{p}} \left(\frac{60}{i} \right)$$ **(Equation 3)**

$$MDC_{scan} = \frac{MDCR_{surv}}{Conv * MS_O}$$ **(Equation 4)**

where:

MDC_{SURV} = the minimum detectable count rate in cpm that can be reliably detected by the "surveyor",

d' = index of sensitivity, unitless (MARSSIM default value of 1.38 is assigned),

b_i = background counts observed in the interval i,

i = observation interval (s),

p = surveyor efficiency, unitless (MARSSIM default value of 0.5 for walkover scans is assigned),

MDC_{scan} = the scan MDC, here in units of pCi/g,

Conv = instrument response conversion factor, units of cpm per μR/h and

MS_o = instrument response in units of μR/h per pCi/g (determined empirically or with a shielding algorithm).

Site-specific parameter values for the MDC_{scan} equation are obtained from PBRF-TBD-09-002 [PBRF 2009b]. The instrument response factor for Cs-137 is 0.138 μR/h per pCi/g as calculated using the MicroShield code. The most conservative instrument response conversion factor measured for detectors in the PBRF LMI 44-10 inventory is 232.39 cpm per μR/h for Cs-137. Using these values, detection sensitivities of the instruments used in the FSS of the ERB are provided in Table 7. Minimum detectable count rates and MDC_{scan} values for 44-10 detectors operated in the Cs-137 gamma energy window vs. background count rates are shown in Table 7.

Table 7, Typical Detection Sensitivities of Field Instruments used for ERB Soil Scans

LMI 44-10 with Cs-137 Window [1]		
Background (cpm)	$MDCR_{surveyor}$ (ncpm)	MDC_{scan} (pCi/g) [2]
50	101	3.13
100	142	4.43
150	174	5.42
200	201	6.26
250	225	7.0

Table 7 Notes:

1. Ludlum Model 44-10 NaI detector with Model 2350-1 data logging scaler-rate meter setup to count in Cs-137 energy window. Scan speed = 0.5 m/s, detector to soil surface = 10 cm.
2. The scan investigation level was set at 200 ncpm to ensure that 75% of the scan surrogate DCGL of 10.31 pCi/g (Cs-137) identified in Design 46, can be readily detected in areas with nominal background count rates.

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 for the FSS of ERB soil is actually set at a fraction of the $DCGL_W$ established in the survey design to ensure that areas in excess of the DCGL are identified and investigated. It is also noted that 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. [20] Accordingly, the scan investigation level was set at 7.7 pCi/g, or 75% of the 10.3 pCi/g DCGL for Cs-137.

5.0 Survey Results

Results of the ERB FSS are presented in this section. This includes scan survey frequencies (% of area covered) for each survey unit and description of an instance where the scan investigation level was exceeded. Results of the investigation are summarized. Results of systematic soil samples for each survey unit and the results of comparison tests of survey unit maximum concentration with the DCGL. Unity rule calculated results 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 ERB for unrestricted use are satisfied and all FSS Plan requirements are met.

[20] 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."

5.1 Scan Surveys

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 scan surveys were also reviewed to confirm that the minimum coverage requirement of 5% coverage for replicate QC scans was satisfied. Results of the ERB 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 an investigation was performed in one survey unit (all ERB survey units are Class 1).

In OL-1-27, the survey unit in the SW corner of the ERB, an investigation was performed in an area of about 13 x 14 ft. in the southeast section of the survey unit. During the scan, counts were observed above the scan investigation level (200 ncpm with the LMI 44-10 NaI detector). Four measurement locations were established within the localized area. Static measurements (one minute counts with the 44-10) and samples were collected at each. The static measurement results were: IM-1, 228; IM-2, 442; IM-3, 266 and IM-4, 274 (all ncpm). Investigative sample results are discussed in Section 5.2.

Table 8, ERB Scan Survey Results

Survey Unit	Class (1)	Survey Request No.	Investigation Performed	QC Replicate Scan Coverage (%) (2)
OL-1-27	1	277/279	Yes	6.0
OL-1-28	1	277/279	No	6.0
OL-1-29	1	277/279	No	6.0
OL-1-30	1	277/279	No	6.0
OL-1-31	1	277/279	No	6.0
OL-1-32	1	277/279	No	6.0

Table 8 Notes:
1. The FSS scan coverage of all ERB survey units was 100%.
2. The % QC scan coverage is given as the % of the area scanned in the initial survey.

5.2 Surface Soil Sample Results

Seventy four systematic surface soil samples were collected from the ERB and analyzed by gamma spectroscopy by the PBRF on-site counting laboratory (this total does not include 12 samples collected in OL-1-26). The results are summarized in Table 9. It is seen that all results are < MDA, except in survey units OL-1-27 and OL-1-32 each with one sample Cs-137 concentration > MDA. The maximum measured Cs-137 concentration is 2.73E-01 pCi/g (in OL-1-27). As expected, the sum of the calculated unity fractions for each survey unit is either zero or very small. The individual sample results are presented in Appendix C. Table 10 gives summary statistics for the ERB systematic samples as a whole.

Table 9, Systematic Soil Sample Results for the ERB

Survey Unit ID	No. of Samples (2)	Maximum (1)		Test Result: Maximum < $DCGL_W$
		Cs-137	Co-60 (3)	
OL-1-27 (4)	12	2.73E-01	<MDA	Yes
OL-1-28	12	<MDA	<MDA	Yes
OL-1-29	12	<MDA	<MDA	Yes
OL-1-30	13	<MDA	<MDA	Yes
OL-1-31	12	<MDA	<MDA	Yes
OL-1-32 (4)	13	1.50E-01	<MDA	Yes

Table 9 Notes:
1. The units for maximum sample concentration are pCi/g.
2. In the FSS design calculation for survey units developed using VSP,."extra" fixed measurement locations are sometimes added when "fitting" the calculated grid size onto the survey unit layout.
3. The average Co-60 MDA for these samples was 9.93E-02 pCi/g and the maximum was 1.22E-01 pCi/g (see Table 10).
4. These survey units each had a single sample result > MDA.

Table 10, ERB Systematic Soil Sample Summary Statistics

Summary Statistic (1)	Cs-137 (2)	Co-60	Cs-137 MDA (2)	Co-60 MDA (2)
Number	2	0	72	74
Maximum	2.73E-01	<MDA	1.62E-01	1.22E-01
Minimum	1.50E-01	<MDA	3.43E-02	4.93E-02
Average	2.12E-01	N/A	7.67E-02	9.93E-02
Std. Dev.	8.70E-02	N/A	1.76E-02	2.03E-02

Table 10 Notes:
1. Samples collected under and results reported in SR-279.
2. Units are pCi/g.

Four soil samples were collected during the investigation initiated by the scan survey of Survey Unit OL-1-27. The results of the analysis of these samples are presented in Table 11. Results of the unity rule calculation for each survey unit are also presented. All analysis results were below the DCGL. Cesium-137 concentrations ranged from 1.06 to 4.29 pCi/g and Co-60 concentrations were all <MDA. It is seen in the table that the unity fractions for each sample are much less than 1.

Table 11, Results of Investigative Sample Analysis

Measurement ID (1)	Cs-137 (2)		Co-60 Concentration	Unity Fraction	Co-60 MDA (2)
	Concentration	2σ Uncertainty			
IM-1	4.20E+00	3.77E-01	< MDA	3.68E-01	5.31E-02
IM-2	4.29E+00	3.95E-01	< MDA	3.76E-01	5.25E-02
IM-3	2.53E+00	2.77E-01	< MDA	2.22E-01	8.72E-02
IM-4	1.06E+00	1.66E-01	< MDA	9.30E-02	6.92E-02

Table 11 Notes:

1. All investigative samples were collected in Survey Unit OL-1-27, under SR-277.
2. Units are pCi/g.

5.3 Subsurface Sampling

In late 2010, following ERB remediation in 2009, a post-remediation characterization package was developed and implemented to evaluate subsurface soils. Even though remediation included removal of soil to a depth of up to 24 in. from the ERB floor, the possibility of subsurface contamination existed. Subsurface soils were potentially impacted by heavy equipment operations in loose and muddy soils during remediation. Also, residues from the ERB sump, fill and pump-out lines were possible in the southeastern portion of the ERB.

For this evaluation, a systematic grid was established on a map of the ERB floor. Twenty sampling locations were selected on the grid (with random start) using VSP. The soil column was collected at each location to a depth of 1.15 meters using a manually operated sampling auger. The soil from each location was divided into two samples for analysis comprising the first 0.15 meters (6 in.) and a sample aliquot from the homogenized 0.15 to 1.15 meter depth. All 40 samples were analyzed by gamma spectroscopy at the PBRF counting laboratory.

Sample analysis results show that in all 20 surface and all 20 subsurface soil sample the Cs-137 and Co-60 concentrations were < MDA. The average MDAs for all the samples were 0.07 and 0.11 pCi/g for Cs-137 and Co-60, respectively.[21]

5.4 QC Sample Results

Seven replicate QC soil samples were collected and analyzed by gamma spectroscopy at the PBRF on-site laboratory. This constitutes 9.0% of the 78 collected for the FSS of the ERB (74 systematic plus 4 investigative samples); thus satisfying the FSS Plan 5% QC sample requirement. All but one of the original-replicate sample pair analysis results were < MDA for both Cs-137 and Co-60. The OL-1-27 investigative sample from location IM-1and the QC replicate were > MDA for Cs-137 (and < MDA for Co-60).

The QC and original sample results were compared in accordance with the method in the FSS Plan, Section 12.7.2 [NASA 2007]. In this method the sample resolution is calculated as the quotient of the original sample result and the original sample one-sigma uncertainty. Then the ratios of QC to original sample results are compared to acceptance values specified for each

[21] The ERB subsurface sampling characterization is documented in Survey Request, SR-264, approved for package closure 9/15/2010.

range of resolution given in FSS Plan Table 12.2. All the QC-original sample pair results were found acceptable. The sample results and the comparisons are shown in Table 12. The QC sample evaluation is presented in more detail in Table 3 of Appendix C with supporting information.

Table 12, QC Soil Sample Comparison

Location	Original Result (1)	Replicate Result (1)	Original one Sigma Uncertainty	Resolution (2)	Ratio (3)	Pass (4) (5)
OL-1-27, SP-2 QC	<MDA	<MDA	<MDA	N/A	N/A	Yes
OL-1-28, SP-9 QC	<MDA	<MDA	<MDA	N/A	N/A	Yes
OL-1-29, SP-2 QC	<MDA	<MDA	<MDA	N/A	N/A	Yes
OL-1-30, SP-2 QC	<MDA	<MDA	<MDA	N/A	N/A	Yes
OL-1-31, SP-3 QC	<MDA	<MDA	<MDA	N/A	N/A	Yes
OL-1-32, SP-2 QC	<MDA	<MDA	<MDA	N/A	N/A	Yes
OL-1-27, IM-1 QC	4.20E+00	5.35E+00	1.89E-01	2.23E+01	1.27E+00	Yes

Table 12 Notes:

1. Sample comparison is made for Cs-137 Results. All Co-60 replicate samples are < MDA.
2. The sample resolution is calculated as the quotient of the original sample measured activity concentration and its' one-sigma uncertainty.
3. The ratio of QC to original sample results.
4. See Table 3 in Appendix C for ratio vs. resolution acceptance criteria
5. If both original and QC sample are < MDA, they are considered to be in agreement.

5.5 ALARA Evaluation

It is shown that residual contamination in the ERB 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."[22]

Soil activity concentrations measured in the ERB are compared to NRC surface soil screening level values in Table 13. As shown in the table, soil activity concentrations for Co-60, Cs-137

[22] This guidance was initially published in Draft Regulatory Guide DG-4006, but has been reissued in NUREG-1757 Volume 2, Appendix N [USNRC 2006].

and Sr-90 are well below their respective screening level values. From these comparisons, it is concluded that the ALARA criterion is satisfied.

Table 13, NRC Soil Screening Level ALARA Comparison

Radionuclide	NRC Screening Level (pCi/g)	Maximum Measured Concentration (pCi/g)
Co-60	3.8	< MDA (1)
Cs-137	11	4.29 (2)
Sr-90	1.7	0.42 (3)

Table 13 Notes:

1. The maximum Co-60 MDA for four investigative samples is 0.087 pCi/g.
2. The maximum of four investigative samples as reported in Table 11.
3. Maximum Sr-90 concentration inferred from the maximum measured Cs-137 concentration and Sr-90: Cs-137 activity ratio of 0.097 (from Design 46).

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. Maximum activity concentrations of radionuclides of concern measured in the FSS of the ERB are compared to EPA trigger levels. This comparison is shown in Table 14. The table shows that the measured soil activity concentrations are below EPA trigger levels. It is noted that groundwater is not within the scope of the ERB FSS.

Table 14, Comparison of Soil Sample Results with EPA Trigger Levels

Radionuclide	EPA Trigger Level (pCi/g)	Maximum Measured Concentration (pCi/g)
Co-60	4	< MDA (1)
Cs-137 (4)	6	4.29 (2)
Sr-90 (4)	23	0.42 (3)

Table 14 Notes:

1. The maximum Co-60 MDA for four investigative samples is 0.087 pCi/g.
2. The maximum of four investigative samples as reported in Table 11.
3. Maximum Sr-90 concentration inferred from the maximum measured Cs-137 concentration and Sr-90: Cs-137 activity ratio of 0.097 (from Design 46).
4. Specified in the MOU as including daughter activity [USEPA 2002].

5.5 Conclusions

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

- Soil walk-over scan surveys were performed over 100 % of the area of the ERB survey units – all were Class 1.
- Scan surveys of the ERB soil resulted in investigation of a localized area in one survey unit. Static counts and investigative samples were collected at four locations. All investigative soil sample results were well below the DCGL (only Cs-137 was detected).
- All survey unit systematic soil sample results (maximum and average concentrations) are below the $DCGL_W$, hence no statistical tests were required.
- The ERB subsurface soil was evaluated (after remediation) by collection and gamma spectroscopic analysis of soil samples to 1.15 meter depth from 20 locations (selected on a systematic grid with randomly selected start location). All samples were < MDA for both Cs-137 and Co-60.
- Only minor changes from what was proposed in the FSS Plan were made – the ERB was divided into seven survey units, whereas the FSS Plan had identified two survey areas, not divided in to survey units. In the FSS Plan, the environmental areas comprising the ERB and adjacent areas were classified as Class 1 and 2.
- There were no changes from initial assumptions (in the FSS Plan) regarding the extent of residual activity in the ERB. No reclassification of survey units was required as a result of FSS measurements and investigations.

6.0 References

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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

Appendix C – Soil Sample Results

Final Status Survey Report

Attachment 10

Emergency Retention Basin

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Appendix A

Exhibits

List of Exhibits

Exhibit 1, PBRF Construction Era Photo Showing ERB in Foreground

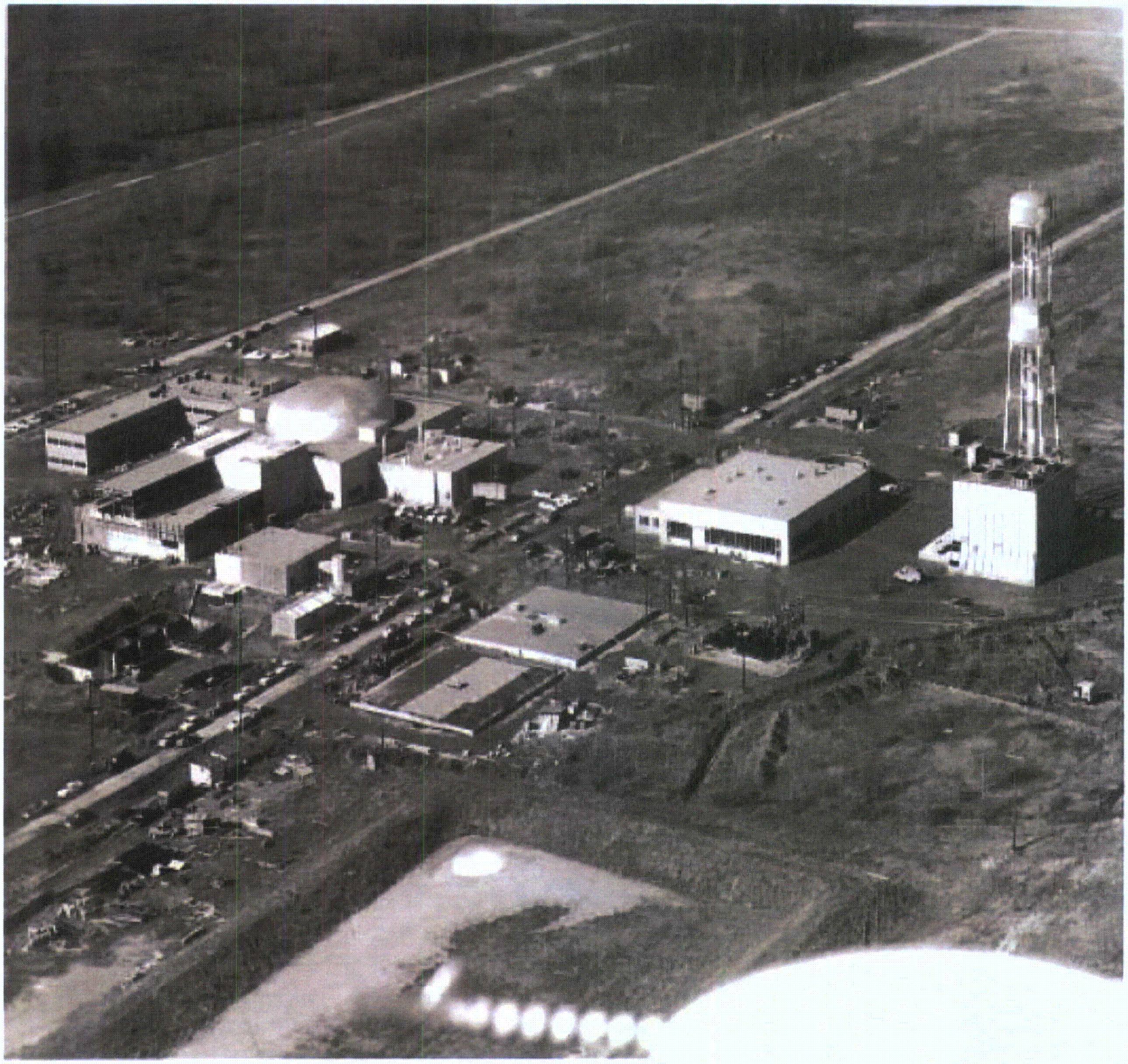

Exhibit 2, View of ERB from Pentolite Rd Looking NW – July 2011
(shows configuration for FSS, but prior to pumping and drying out)

Exhibit 3, View of ERB Looking NE - July 2011
(shows configuration for FSS, but prior to pumping and drying out)

Exhibit 4, View of ERB Sump Drain Excavation – West End Looking East

Exhibit 5, Site Aerial View Circa 1970 Showing ERB at Far Right

Exhibit 6, View of ERB in 2009 Prior to Final Remediation, Looking East

Plum Brook Reactor Facility

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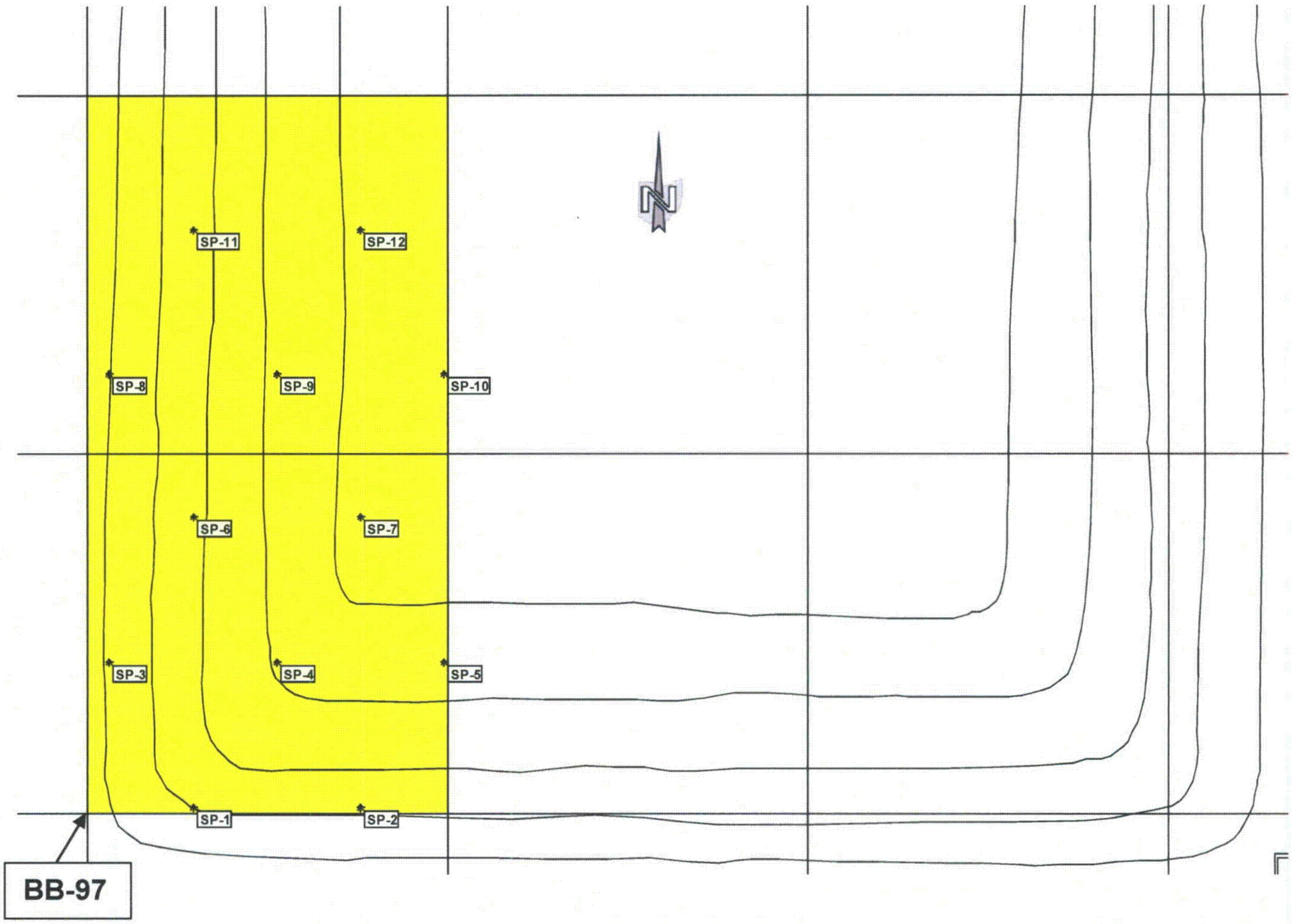
Appendix B

Survey Unit Maps Showing Measurement Locations

Index of Emergency Retention Basin FSS Design Maps

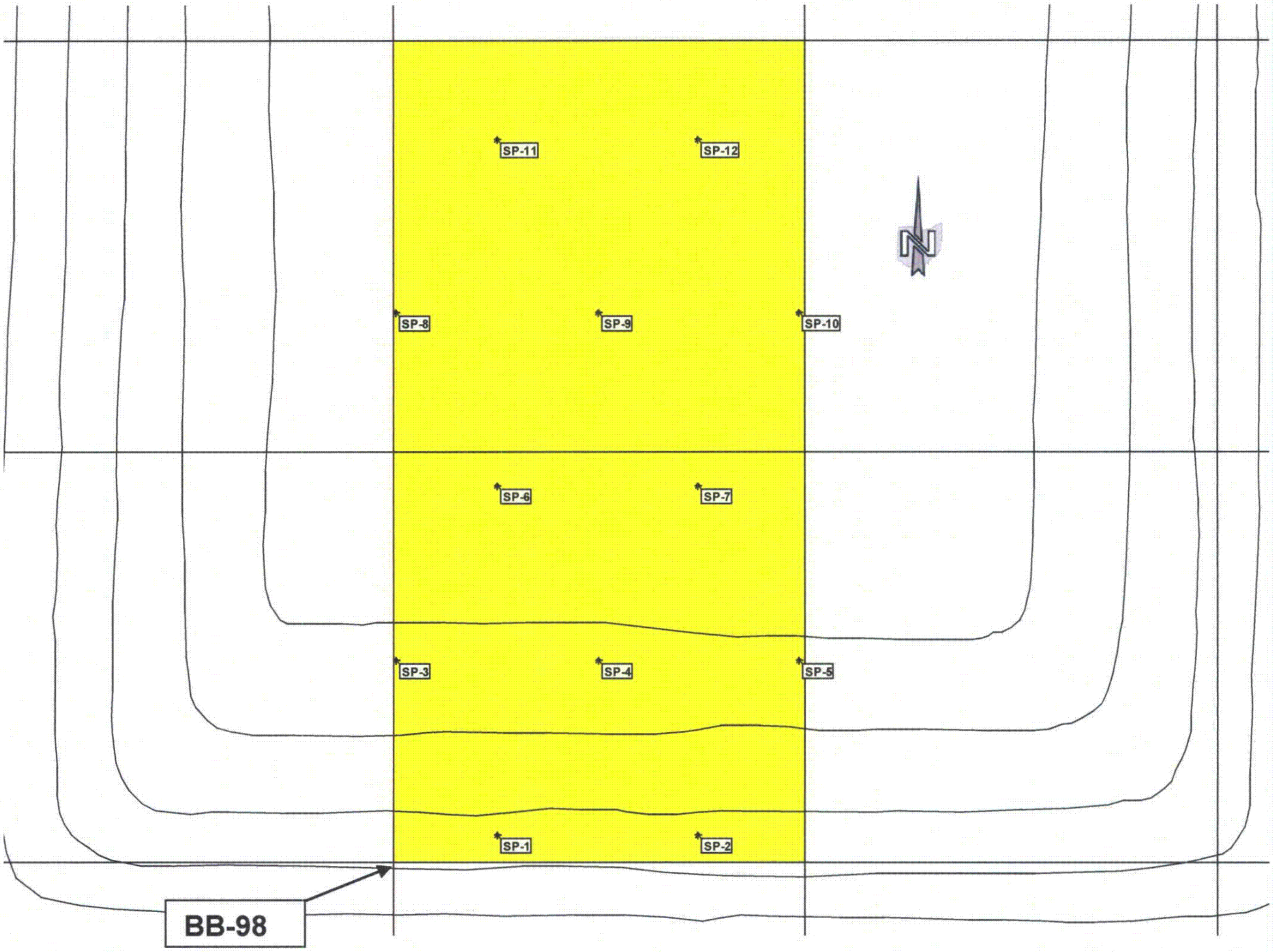
Survey Unit	Description	Page Number	Number of Pages
OL-1-27	ERB Grids BB-97, BC-97	3	1
OL-1-28	ERB Grids BB-98, BC-98	4	1
OL-1-29	ERB Grids BB-99, BC-99	5	1
OL-1-30	ERB Grids BD-97, BE-97	6	1
OL-1-31	ERB Grids BD-98, BE-98	7	1
OL-1-32	ERB Grids BD-99, BE-99	8	1

Survey Unit OL-1-27



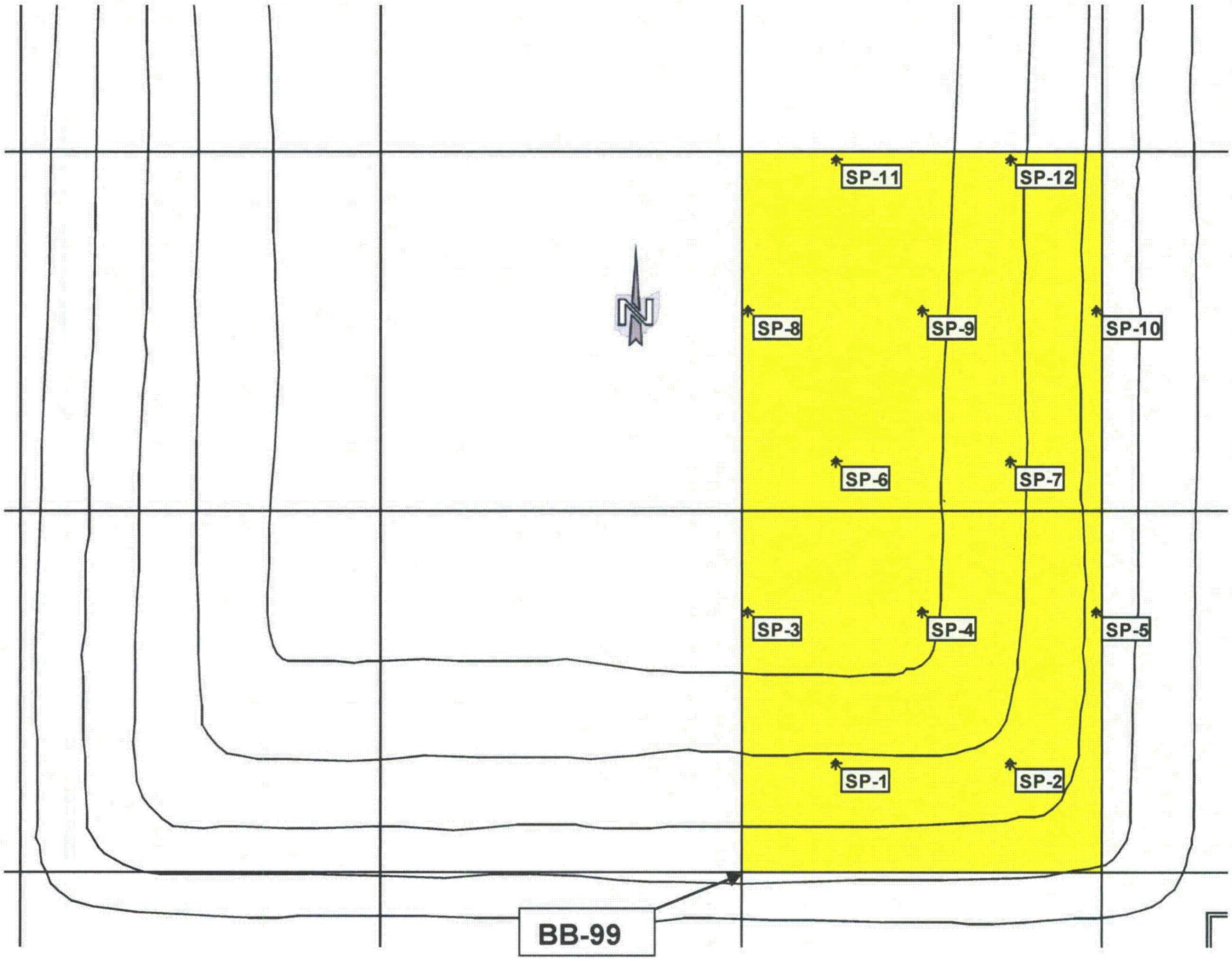
OL-1-27 AREA: ERB Grids BB-97, BC-97 Measurement Locations and Results			
X Coord (ft.)	**Y Coord (ft.)**	**Label**	**Type**
29.1	1.8	SP-1	Systematic
75.6	1.8	SP-2	Systematic
5.9	42.0	SP-3	Systematic
52.4	42.0	SP-4	Systematic
98.8	42.0	SP-5	Systematic
29.1	82.2	SP-6	Systematic
75.6	82.2	SP-7	Systematic
5.9	122.4	SP-8	Systematic
52.4	122.4	SP-9	Systematic
98.8	122.4	SP-10	Systematic
29.1	162.6	SP-11	Systematic
75.6	162.6	SP-12	Systematic
All sample points are measured from the Grid Pin BB-97			

Survey Unit OL-1-28



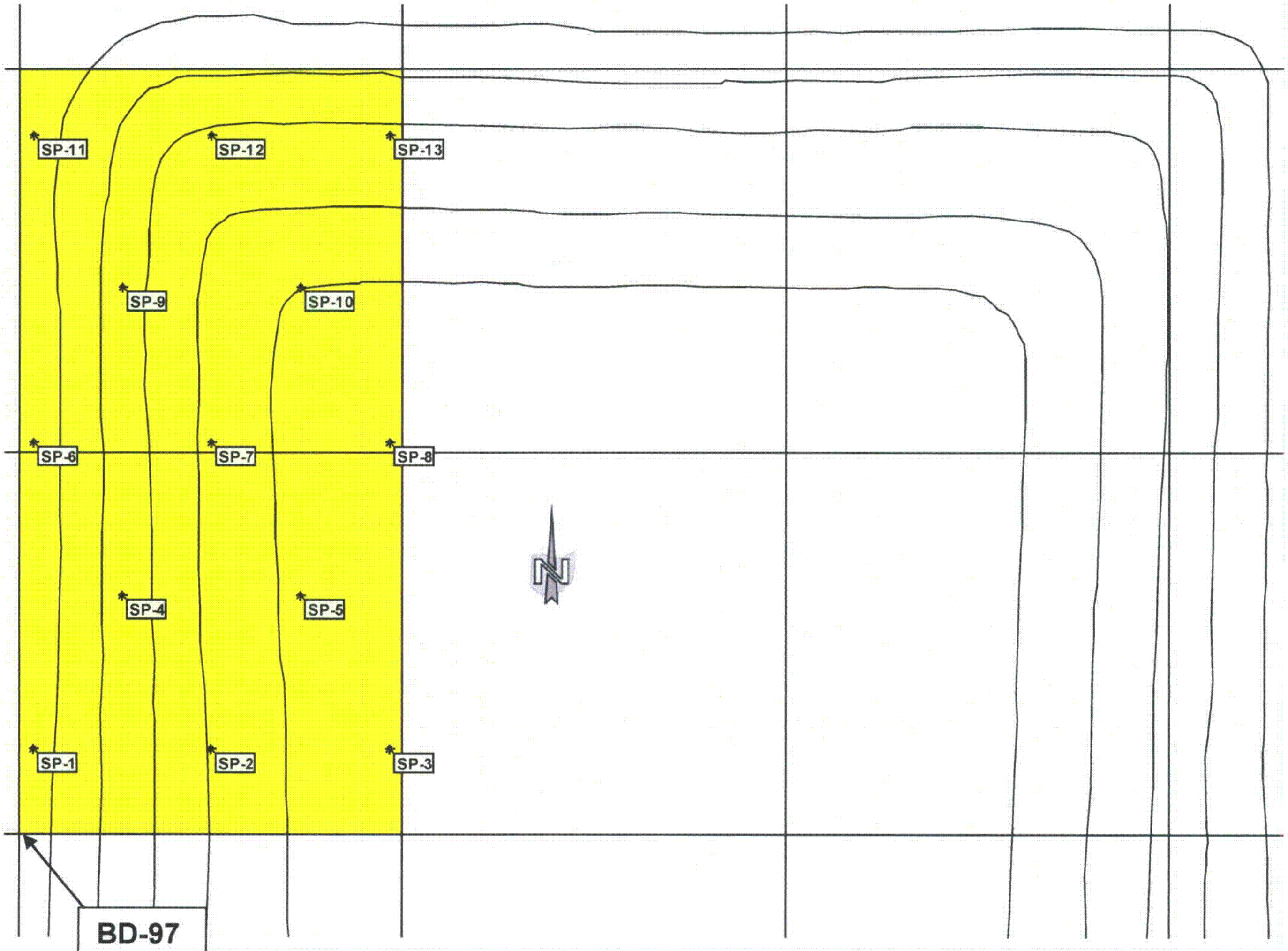
OL-1-28 AREA: ERB Grids BB-98, BC-98 Measurement Locations and Results			
X Coord (ft.)	**Y Coord (ft.)**	**Label**	**Type**
25.2	6.9	SP-1	Systematic
74.1	6.9	SP-2	Systematic
0.8	49.3	SP-3	Systematic
49.6	49.3	SP-4	Systematic
98.5	49.3	SP-5	Systematic
25.2	91.6	SP-6	Systematic
74.1	91.6	SP-7	Systematic
0.8	133.9	SP-8	Systematic
49.6	133.9	SP-9	Systematic
98.5	133.9	SP-10	Systematic
25.2	176.2	SP-11	Systematic
74.1	176.2	SP-12	Systematic
All sample points are measured from the Grid Pin BB-98.			

Survey Unit OL-1-29



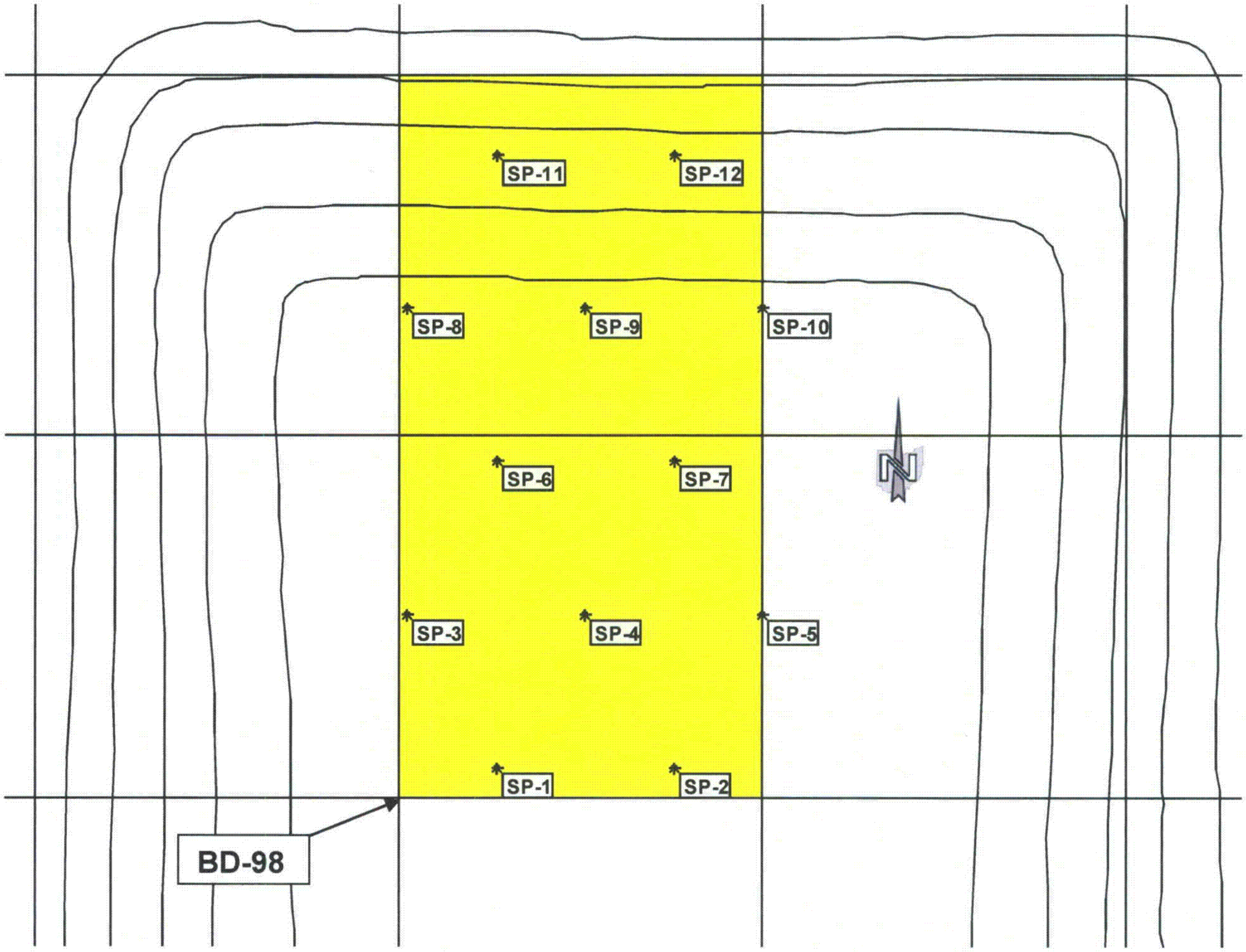
OL-1-29 AREA: ERB Grids BB-99, BC-99 Measurement Locations and Results			
X Coord (ft.)	**Y Coord (ft.)**	**Label**	**Type**
26.1	29.9	SP-1	Systematic
74.5	29.9	SP-2	Systematic
1.9	71.8	SP-3	Systematic
50.3	71.8	SP-4	Systematic
98.6	71.8	SP-5	Systematic
26.1	113.7	SP-6	Systematic
74.5	113.7	SP-7	Systematic
1.9	155.5	SP-8	Systematic
50.3	155.5	SP-9	Systematic
98.6	155.5	SP-10	Systematic
26.1	197.4	SP-11	Systematic
74.5	197.4	SP-12	Systematic
All sample points are measured from the Grid Pin BB-99.			

Survey Unit OL-1-30



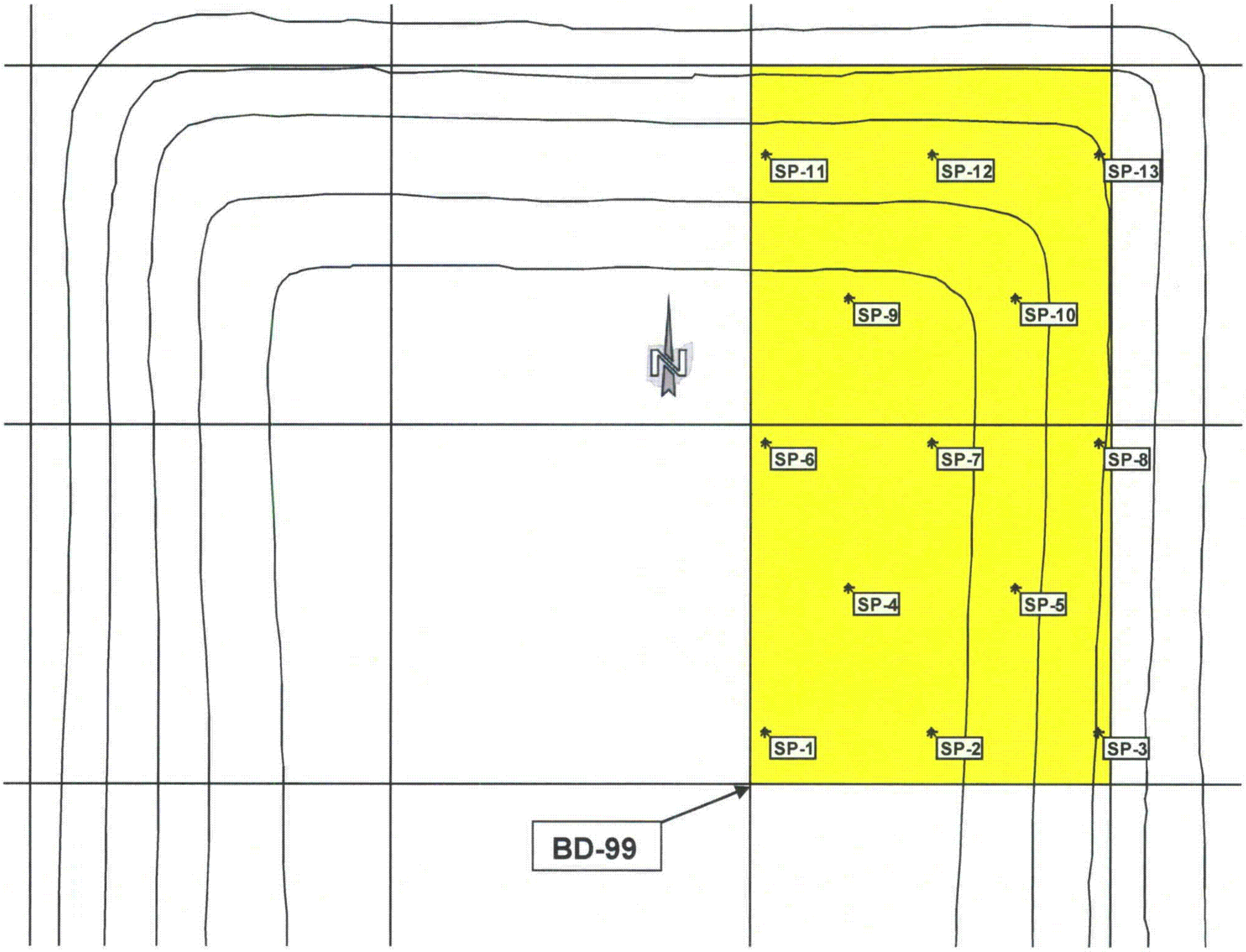
OL-1-30 AREA: ERB Grids BD-97, BE-97 Measurement Locations and Results			
X Coord (ft.)	**Y Coord (ft.)**	**Label**	**Type**
3.8	22.3	SP-1	Systematic
50.3	22.3	SP-2	Systematic
96.7	22.3	SP-3	Systematic
27.0	62.5	SP-4	Systematic
73.5	62.5	SP-5	Systematic
3.8	102.7	SP-6	Systematic
50.3	102.7	SP-7	Systematic
96.7	102.7	SP-8	Systematic
27.0	142.9	SP-9	Systematic
73.5	142.9	SP-10	Systematic
3.8	183.1	SP-11	Systematic
50.3	183.1	SP-12	Systematic
96.7	183.1	SP-13	Systematic
All sample points are measured from the Grid Pin BD-97.			

Survey Unit OL-1-31



OL-1-31 AREA: ERB Grids BD-98, BE-98 Measurement Locations and Results			
X Coord (ft.)	**Y Coord (ft.)**	**Label**	**Type**
26.6	8.7	SP-1	Systematic
75.4	8.7	SP-2	Systematic
2.1	51.0	SP-3	Systematic
51.0	51.0	SP-4	Systematic
99.9	51.0	SP-5	Systematic
26.6	93.3	SP-6	Systematic
75.4	93.3	SP-7	Systematic
2.1	135.6	SP-8	Systematic
51.0	135.6	SP-9	Systematic
99.9	135.6	SP-10	Systematic
26.6	178.0	SP-11	Systematic
75.4	178.0	SP-12	Systematic
All sample points are measured from the Grid Pin BD-98.			

Survey Unit OL-1-32



OL-1-32 AREA: ERB Grids BD-99, BE-99 Measurement Locations and Results			
X Coord (ft.)	Y Coord (ft.)	Label	Type
3.8	14.5	SP-1	Systematic
50.2	14.5	SP-2	Systematic
96.6	14.5	SP-3	Systematic
27.0	54.7	SP-4	Systematic
73.4	54.7	SP-5	Systematic
3.8	94.9	SP-6	Systematic
50.2	94.9	SP-7	Systematic
96.6	94.9	SP-8	Systematic
27.0	135.1	SP-9	Systematic
73.4	135.1	SP-10	Systematic
3.8	175.3	SP-11	Systematic
50.2	175.3	SP-12	Systematic
96.6	175.3	SP-13	Systematic
All sample points are measured from the Grid Pin BD-99			

Plum Brook Reactor Facility

Final Status Survey Report

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Appendix C

Soil Sample Results

Table of Contents

Table 1, SR-279 (ERB) Sample Results

Sample #	Location	Weight (g)	Cs-137		Co-60		Unity Fraction	Cs-137	Co-60
			$DCGL_{(eff)}$	11.4	DCGL	3.7		MDA	MDA
			pCi/g	2σ	pCi/g	2σ		pCi/g	pCi/g
SR-279-14	OL-1-27, SP-1	405.7	<MDA	<MDA	<MDA	<MDA	0.00	5.05E-02	5.36E-02
SR-279-15	OL-1-27, SP-2	423.5	<MDA	<MDA	<MDA	<MDA	0.00	5.85E-02	5.41E-02
SR-279-17	OL-1-27, SP-3	434.6	<MDA	<MDA	<MDA	<MDA	0.00	8.13E-02	5.27E-02
SR-279-18	OL-1-27, SP-4	422.0	<MDA	<MDA	<MDA	<MDA	0.00	3.43E-02	6.39E-02
SR-279-19	OL-1-27, SP-5	445.8	<MDA	<MDA	<MDA	<MDA	0.00	7.99E-02	5.06E-02
SR-279-20	OL-1-27, SP-6	428.1	<MDA	<MDA	<MDA	<MDA	0.00	6.59E-02	6.18E-02
SR-279-21	OL-1-27, SP-7	430.2	<MDA	<MDA	<MDA	<MDA	0.00	7.20E-02	6.22E-02
SR-279-22	OL-1-27, SP-8	419.8	<MDA	<MDA	<MDA	<MDA	0.00	8.62E-02	5.18E-02
SR-279-23	OL-1-27, SP-9	428.9	<MDA	<MDA	<MDA	<MDA	0.00	6.78E-02	5.34E-02
SR-279-24	OL-1-27, SP-10	411.3	<MDA	<MDA	<MDA	<MDA	0.00	7.58E-02	5.48E-02
SR-279-25	OL-1-27, SP-11	454.8	<MDA	<MDA	<MDA	<MDA	0.00	6.83E-02	4.93E-02
SR-279-26	OL-1-27, SP-12	389.4	2.73E-01	9.40E-02	<MDA	<MDA	0.02		5.88E-02
SR-279-27	OL-1-28, SP-1	400.9	<MDA	<MDA	<MDA	<MDA	0.00	6.82E-02	1.09E-01
SR-279-28	OL-1-28, SP-2	412.1	<MDA	<MDA	<MDA	<MDA	0.00	7.82E-02	1.11E-01
SR-279-29	OL-1-28, SP-3	436.5	<MDA	<MDA	<MDA	<MDA	0.00	6.50E-02	1.04E-01
SR-279-30	OL-1-28, SP-4	442.7	<MDA	<MDA	<MDA	<MDA	0.00	7.05E-02	9.84E-02
SR-279-31	OL-1-28, SP-5	418.4	<MDA	<MDA	<MDA	<MDA	0.00	8.29E-02	1.10E-01
SR-279-32	OL-1-28, SP-6	372.2	<MDA	<MDA	<MDA	<MDA	0.00	7.34E-02	1.17E-01
SR-279-33	OL-1-28, SP-7	392.3	<MDA	<MDA	<MDA	<MDA	0.00	9.77E-02	1.17E-01
SR-279-34	OL-1-28, SP-8	391.1	<MDA	<MDA	<MDA	<MDA	0.00	1.33E-01	1.16E-01
SR-279-35	OL-1-28, SP-9	401.3	<MDA	<MDA	<MDA	<MDA	0.00	8.28E-02	1.09E-01
SR-279-37	OL-1-28, SP-10	404.6	<MDA	<MDA	<MDA	<MDA	0.00	8.69E-02	1.12E-01
SR-279-38	OL-1-28, SP-11	418.0	<MDA	<MDA	<MDA	<MDA	0.00	7.47E-02	1.04E-01
SR-279-39	OL-1-28, SP-12	376.5	<MDA	<MDA	<MDA	<MDA	0.00	8.07E-02	1.22E-01
SR-279-40	OL-1-29, SP-1	392.6	<MDA	<MDA	<MDA	<MDA	0.00	8.78E-02	1.11E-01
SR-279-41	OL-1-29, SP-2	443.7	<MDA	<MDA	<MDA	<MDA	0.00	6.85E-02	1.03E-01
SR-279-43	OL-1-29, SP-3	406.3	<MDA	<MDA	<MDA	<MDA	0.00	6.73E-02	1.07E-01
SR-279-44	OL-1-29, SP-4	399.5	<MDA	<MDA	<MDA	<MDA	0.00	8.06E-02	1.15E-01

Table 1, SR-279 (ERB) Sample Results

Sample #	Location	Weight (g)	Cs-137		Co-60		Unity Fraction	Cs-137	Co-60
			$DCGL_{(eff)}$	11.4	DCGL	3.7		MDA	MDA
			pCi/g	2σ	pCi/g	2σ		pCi/g	pCi/g
SR-279-45	OL-1-29, SP-5	407.9	<MDA	<MDA	<MDA	<MDA	0.00	6.95E-02	1.11E-01
SR-279-46	OL-1-29, SP-6	415.8	<MDA	<MDA	<MDA	<MDA	0.00	6.57E-02	1.05E-01
SR-279-47	OL-1-29, SP-7	436.1	<MDA	<MDA	<MDA	<MDA	0.00	6.97E-02	1.05E-01
SR-279-48	OL-1-29, SP-8	388.0	<MDA	<MDA	<MDA	<MDA	0.00	1.17E-01	1.16E-01
SR-279-49	OL-1-29, SP-9	399.8	<MDA	<MDA	<MDA	<MDA	0.00	7.44E-02	1.09E-01
SR-279-50	OL-1-29, SP-10	418.0	<MDA	<MDA	<MDA	<MDA	0.00	6.79E-02	1.08E-01
SR-279-51	OL-1-29, SP-11	410.7	<MDA	<MDA	<MDA	<MDA	0.00	6.65E-02	1.06E-01
SR-279-52	OL-1-29, SP-12	452.3	<MDA	<MDA	<MDA	<MDA	0.00	6.27E-02	9.99E-02
SR-279-53	OL-1-30, SP-1	459.1	<MDA	<MDA	<MDA	<MDA	0.00	6.61E-02	1.00E-01
SR-279-54	OL-1-30, SP-2	462.3	<MDA	<MDA	<MDA	<MDA	0.00	7.88E-02	9.77E-02
SR-279-56	OL-1-30, SP-3	459.1	<MDA	<MDA	<MDA	<MDA	0.00	7.51E-02	9.84E-02
SR-279-57	OL-1-30, SP-4	453.6	<MDA	<MDA	<MDA	<MDA	0.00	1.14E-01	1.01E-01
SR-279-58	OL-1-30, SP-5	458.6	<MDA	<MDA	<MDA	<MDA	0.00	5.96E-02	9.50E-02
SR-279-59	OL-1-30, SP-6	411.7	<MDA	<MDA	<MDA	<MDA	0.00	6.84E-02	1.06E-01
SR-279-60	OL-1-30, SP-7	451.4	<MDA	<MDA	<MDA	<MDA	0.00	6.92E-02	9.65E-02
SR-279-61	OL-1-30, SP-8	459.4	<MDA	<MDA	<MDA	<MDA	0.00	9.79E-02	9.99E-02
SR-279-62	OL-1-30, SP-9	451.8	<MDA	<MDA	<MDA	<MDA	0.00	6.05E-02	9.65E-02
SR-279-63	OL-1-30, SP-10	444.6	<MDA	<MDA	<MDA	<MDA	0.00	8.14E-02	1.03E-01
SR-279-64	OL-1-30, SP-11	413.8	<MDA	<MDA	<MDA	<MDA	0.00	9.90E-02	1.05E-01
SR-279-65	OL-1-30, SP-12	458.6	<MDA	<MDA	<MDA	<MDA	0.00	6.62E-02	1.00E-01
SR-279-66	OL-1-30, SP-13	459.8	<MDA	<MDA	<MDA	<MDA	0.00	6.60E-02	9.99E-02
SR-279-67	OL-1-31, SP-1	440.8	<MDA	<MDA	<MDA	<MDA	0.00	6.20E-02	9.89E-02
SR-279-68	OL-1-31, SP-2	401.5	<MDA	<MDA	<MDA	<MDA	0.00	7.57E-02	1.14E-01
SR-279-69	OL-1-31, SP-3	403.1	<MDA	<MDA	<MDA	<MDA	0.00	8.56E-02	1.12E-01
SR-279-71	OL-1-31, SP-4	393.1	<MDA	<MDA	<MDA	<MDA	0.00	9.02E-02	1.17E-01
SR-279-72	OL-1-31, SP-5	403.2	<MDA	<MDA	<MDA	<MDA	0.00	7.03E-02	1.12E-01
SR-279-73	OL-1-31, SP-6	414.0	<MDA	<MDA	<MDA	<MDA	0.00	7.71E-02	1.05E-01
SR-279-74	OL-1-31, SP-7	412.0	<MDA	<MDA	<MDA	<MDA	0.00	1.62E-01	1.11E-01
SR-279-75	OL-1-31, SP-8	384.1	<MDA	<MDA	<MDA	<MDA	0.00	7.38E-02	1.18E-01
SR-279-76	OL-1-31, SP-9	416.1	<MDA	<MDA	<MDA	<MDA	0.00	7.83E-02	1.05E-01

Table 1, SR-279 (ERB) Sample Results

Sample #	Location	Weight (g)	Cs-137		Co-60		Unity Fraction	Cs-137	Co-60
			$DCGL_{(eff)}$	11.4	DCGL	3.7		MDA	MDA
			pCi/g	2σ	pCi/g	2σ		pCi/g	pCi/g
SR-279-77	OL-1-31, SP-10	423.9	<MDA	<MDA	<MDA	<MDA	0.00	9.20E-02	1.08E-01
SR-279-78	OL-1-31, SP-11	415.7	<MDA	<MDA	<MDA	<MDA	0.00	6.82E-02	1.09E-01
SR-279-79	OL-1-31, SP-12	400.8	<MDA	<MDA	<MDA	<MDA	0.00	8.29E-02	1.09E-01
SR-279-80	OL-1-32, SP-1	398.5	<MDA	<MDA	<MDA	<MDA	0.00	7.12E-02	1.13E-01
SR-279-81	OL-1-32, SP-2	415.5	<MDA	<MDA	<MDA	<MDA	0.00	7.51E-02	1.05E-01
SR-279-83	OL-1-32, SP-3	401.2	<MDA	<MDA	<MDA	<MDA	0.00	7.07E-02	1.13E-01
SR-279-84	OL-1-32, SP-4	380.7	<MDA	<MDA	<MDA	<MDA	0.00	7.18E-02	1.14E-01
SR-279-85	OL-1-32, SP-5	402.6	<MDA	<MDA	<MDA	<MDA	0.00	9.17E-02	1.14E-01
SR-279-86	OL-1-32, SP-6	412.9	<MDA	<MDA	<MDA	<MDA	0.00	6.87E-02	1.09E-01
SR-279-87	OL-1-32, SP-7	421.6	1.50E-01	7.32E-02	<MDA	<MDA	0.01		1.03E-01
SR-279-88	OL-1-32, SP-8	408.8	<MDA	<MDA	<MDA	<MDA	0.00	7.43E-02	1.12E-01
SR-279-89	OL-1-32, SP-9	420.9	<MDA	<MDA	<MDA	<MDA	0.00	6.74E-02	1.07E-01
SR-279-90	OL-1-32, SP-10	416.3	<MDA	<MDA	<MDA	<MDA	0.00	6.57E-02	1.05E-01
SR-279-91	OL-1-32, SP-11	386.3	<MDA	<MDA	<MDA	<MDA	0.00	7.86E-02	1.19E-01
SR-279-92	OL-1-32, SP-12	427.6	<MDA	<MDA	<MDA	<MDA	0.00	6.63E-02	1.06E-01
SR-279-93	OL-1-32, SP-13	380.6	<MDA	<MDA	<MDA	<MDA	0.00	7.18E-02	1.15E-01

Table 2, Summary of ERB Soil Sample Results

Statistic	Weight (g)	Cs-137		Co-60		Cs-137 MDA	Co-60 MDA
		pCi/g	2σ	pCi/g	2σ	pCi/g	pCi/g
Total Number	74	2	2	0	0	72	74
Maximum	462.3	2.73E-01	9.40E-02	<MDA	<MDA	1.62E-01	1.22E-01
Average	418.3	2.12E-01	8.36E-02	N/A	N/A	7.67E-02	9.93E-02
Std. Dev.	23.45	8.70E-02	1.47E-02	N/A	N/A	1.76E-02	2.03E-02

Table 3, QC Soil Sample Comparison

Sample #	Location	Original Result [1]	Replicate Result [1]	Original one Sigma Uncertainty	Resolution [2]	Ratio [3]	Pass [4] [5]
SR-279-16	OL-1-27, SP-2 QC	<MDA	<MDA	<MDA	N/A	N/A	Yes
SR-279-36	OL-1-28, SP-9 QC	<MDA	<MDA	<MDA	N/A	N/A	Yes
SR-279-42	OL-1-29, SP-2 QC	<MDA	<MDA	<MDA	N/A	N/A	Yes
SR-279-55	OL-1-30, SP-2 QC	<MDA	<MDA	<MDA	N/A	N/A	Yes
SR-279-70	OL-1-31, SP-3 QC	<MDA	<MDA	<MDA	N/A	N/A	Yes
SR-279-82	OL-1-32, SP-2 QC	<MDA	<MDA	<MDA	N/A	N/A	Yes
SR-277-2	OL-1-27, IM-1 QC	4.20E+00	5.35E+00	1.89E-01	2.23E+01	1.27E+00	Yes

Table 3 Notes:

1. Sample comparison is made for Cs-137 Results. All Co-60 replicate samples are also < MDA.
2. The sample resolution is calculated as the original sample measured activity concentration divided by its' one-sigma uncertainty.
3. The ratio of QC to original sample results.
4. See the table below for ratio vs. resolution acceptance criteria.
5. If both original and QC sample are < MDA, they are considered to be in agreement.

QC Sample Comparison
Acceptance Criteria

Resolution	Ratio
< 4	0.4 - 2.5
4 – 7	0.5 – 2.0
8 – 15	0.6 – 1.66
16 – 50	0.75 – 1.33
51 - 200	0.8 – 1.25
> 200	0.85 – 1.18

Acceptance Criteria Notes:

1. Acceptance Criteria are per FSS Plan Section, Section 12.7.2.
2. When comparing a positive result to a <MDA result, assume that the sample result is positive at the MDA and use the MDA value to determine the ratio.