CHARACTERIZATION PLAN
MW-PL-02-004, Rev. 0
September 2002

For

NASA PLUM BROOK REACTOR FACILITY

Prepared By: _____ _____
John L. McGehee, Date
MWH Team FSS/Characterization Design Engineer

Reviewed By: _____ _____
Donald McGee, Date
MWH Team Radiological Protection/Final Status Survey Manager

Reviewed By: _____ _____
Peter G. Huntley Date
MWH Team Project Manager

Prepared By:
Framatome ANP DE&S
Site Restoration Services
400 S. Tryon Street, WC26B
Charlotte, NC 28201-1004

TABLE OF CONTENTS

1.0 GENERAL INFORMATION 1

1.1 INTRODUCTION 1
1.2 OBJECTIVE AND SCOPE OF THE CHARACTERIZATION PLAN 1
1.3 SITE DESCRIPTION 3
1.4 REGULATORY ACTIVITIES 6

2.0 DESCRIPTION OF PLANNED DECOMMISSIONING ACTIVITIES 7

2.1 DECOMMISSIONING PROCESS 7
2.2 DECOMMISSIONING CRITERIA 8
2.3 CHARACTERIZATION ORGANIZATION, TRAINING, PROCEDURES AND PROCESS 9
2.3.1 Training 10
2.3.2 Procedures 10
2.3.3 Decontamination and Decommissioning Phases 11
2.4 DECOMMISSIONING ACTIVITIES AND TASKS 12
2.5 CURRENT ASSESSMENT OF RESIDUAL RADIOACTIVE CONTAMINATION 13
2.5.1 Previous Characterization Efforts 13
2.5.2 Radionuclides of Concern for the PBRF 16
2.5.3 Non-Radiological Waste Characterization of the PBRF 17
2.5.4 Final Environmental Baseline Survey Report for the PBRF 17
2.5.5 Supplemental Historical Site Assessment 18

3.0 DESCRIPTION OF PLANNED CHARACTERIZATION ACTIVITIES 20

3.1 INTRODUCTION 20
3.2 CHARACTERIZATION 20
3.2.1 Site Preparation 21
3.2.2 Underground Utilities 22
3.2.3 Characterization Data Quality Objectives 23
3.2.4 Survey Areas/Unit Classification 24
3.2.5 Selection and Size of Survey Areas and Survey Units 25
3.2.6 Survey Package Development 26
3.2.7 PBRF Survey Data Management System 28
3.2.8 PBRF Survey Measurement Location Codes 29
3.2.9 PBRF Site Survey Areas and Survey Units 32
3.2.10 Derived Concentration Guideline Levels (DCGLs) 33
3.2.11 Survey Design and Implementation 36
3.2.11.1 Number of Measurements/Samples to be Collected 37
3.2.11.2 Sample/Measurement Grid Spacing 39
3.2.11.3 Starting location 39
3.2.11.4 Survey Implementation 40
3.2.12 Instrumentation and Selection 40
3.2.13 Instrument Calibration 43
3.2.14 Sources 43
3.2.15 Survey Protocols/Requirements 43
3.2.16 Minimum Detectable Concentration 47
3.2.17 Survey Records 49

3.2.18 Characterization Survey Package Instructions *50*
3.2.18.1 Structure Surfaces 50
3.2.18.2 Environmental Areas 51
3.2.18.3 Systems 52
3.2.18.4 Sewer and Storm Drain Survey 53
3.2.19 Data Evaluation and Review *53*
3.2.20 Determination of Compliance *54*
3.2.21 Waste Stream Profiling *55*
3.2.21.1 Envirocare of Utah Material Analysis Requirements 58
3.2.21.2 10 CFR Part 61 Radionuclide Sample Analysis 61
3.2.22 Waste Management Operations *63*
3.2.23 Re-Evaluate Decommissioning Assumptions *63*
3.2.24 Characterization and Remediation Survey Methods *63*
3.2.25 Characterization and Remediation Survey Report *63*
3.3 TASK DESCRIPTIONS 64
3.4 REMEDIATION METHODS 64

4.0 HEALTH AND SAFETY AND QUALITY ASSURANCE PROJECT PLAN ELEMENT CONSIDERATIONS 65

4.1 SITE SPECIFIC SAFETY AND HEALTH PLAN 65
4.2 RADIATION PROTECTION PLAN AND PROGRAM 66
4.3 QUALITY CONTROL 66

5.0 PLANNED FINAL RADIATION SURVEY 68

6.0 PHYSICAL SECURITY PLAN AND MATERIAL CONTROL AND ACCOUNTING PLAN PROVISIONS IN PLACE DURING DECOMMISSIONING 69

7.0 REFERENCES 70

8.0 ATTACHMENTS 72

1.0 GENERAL INFORMATION

1.1 Introduction

This Characterization Plan presents the approach and process to be used for further characterization of the National Aeronautics and Space Administration's (NASA's) Plum Brook Reactor Facility (PBRF) at Plum Brook Station near Sandusky, Ohio. This plan was developed to provide guidance and direction, regarding additional characterization, to the decommissioning team responsible for implementing and executing the processes set forth in the *Decommissioning Plan For The Plum Brook Reactor Facility, Revision 2, October 2001* (the decommissioning plan). The processes set forth in the decommissioning plan are explained further and implemented through programmatic plans for the PBRF decommissioning. This characterization plan was developed to work in conjunction with the programmatic plans developed to safely and effectively decontaminate and dismantle the PBRF as described in the decommissioning plan. The PBRF is a NASA Glenn Research Center facility, and existing NASA GRC directives are the overriding procedures and policies for the facility decommissioning. Site specific project plans will meet or exceed GRC requirements.

1.2 Objective and Scope of the Characterization Plan

The objective of the characterization survey is to complete the site characterization process as prescribed in the decommissioning plan, Section 3.2.2.1 Waste Characterization and Section 4.0 Proposed Final Status Survey Plan, according to guidance provided in NUREG-1575, *Multi-Agency Radiation Survey and Site Investigation Manual, September 2000* (MARSSIM). The decommissioning plan, Section 3.2.2.1, states:

> *The Decommissioning Contractor's health physics staff will survey and characterize wastes as they are generated and packaged for shipment and disposal, following procedures approved by the waste disposal sites and/or waste processors, which will receive the waste.*

The decommissioning plan, Section 4.1.1, states:

> *The information currently available to describe the nature and extent of the contamination is described in Section 2.2 of this plan. However, additional information on the general location and extent of residual radioactivity and estimated concentration levels will be gained during the characterization steps of remediation.*

The characterization activities as described in this plan will be implemented and performed prior to performance of decontamination activities on PBRF surfaces, structures and environmental areas. The information from the characterization will provide clear guidance for decontamination and remediation planning such that materials shown to be contaminated with radiological and/or hazardous material will be removed and properly packaged for shipment and disposal in accordance with the Waste Management Plan. As described in the decommissioning plan, Section 3.2.2.1, concrete shown not to be contaminated with radiological and/or hazardous material may be used on site as clean hard fill. Materials that are not clean hard fill and that are

shown not to be contaminated with radiological and/or hazardous material will be removed and properly packaged for shipment and disposal in accordance with the Waste Management Plan.

The scope of the characterization survey of the Plum Brook Reactor Facility site is as follows:

- Identify and quantify full nature and extent all radionuclides, including hard to detect radionuclides, and hazardous materials that may be present at the site in areas that contain radioactive materials contamination;
- Determine the lateral/vertical extent of radioactive material contamination in each area that contains radioactive materials contamination;
- Determine and/or establish a radionuclide mix appropriate for each survey area for the following:
    a. Re-evaluation of the initial pathway analysis contained in the decommissioning plan for applicability to the occupational and public health and safety impacts during decommissioning; and
    b. Re-evaluation of the initial site-specific derived concentration guideline levels (DCGLs) for applicability during final status surveys.
- Obtain the appropriate data to determine PBRF waste acceptability as related to disposal facility waste acceptance criteria (WAC) and to determine PBRF waste stream profiles;
- Obtain the appropriate data to provide guidance to decontamination personnel for waste management planning and decontamination/remediation activities planning; and
- Provide the information needed to develop the Final Status Survey Plan and design FSS for each survey area.

If contamination from hazardous materials is identified in areas as a result of waste stream profile sample analysis, a separate plan will be developed to address any required remedial actions. The plan will also include the method that will be utilized to determine the lateral/vertical extent of the hazardous materials contamination identified. The evaluation and determination of need for further surveys, sampling and analyses to identify and quantify non-radiological contaminants that may be present at the PBRF site will be performed in accordance with the NASA PBRF Environmental Management Plan (EMP).

As stated in Section 1.1 of this plan, during performance of this characterization plan, efforts will be made to accommodate plans developed in accordance with the EMP for further surveys for non-radiological contamination discovered during EMP data gap closure work or from waste stream profile sampling during characterization. This may include collection of split samples or other survey operation to the extent practical, to assist with performance and completion of EMP directed plans.

This characterization plan was developed using the guidance provided in the MARSSIM. The MARSSIM guidance recommends development and use of a *Sampling and Analysis Plan* to guide work activities. The sampling and analysis plan provides a process for obtaining data of sufficient quality and quantity to satisfy data needs. The sampling and analysis plan consists of

two parts: 1) the *Quality Assurance Project Plan* (QAPP) which describes policy, organization, functional activities, the Data Quality Objectives, and measures necessary to achieve adequate data for use in selecting the appropriate remedy; and 2) the *Field Sampling Plan*, which describes the number, type, and location of samples and the type of analyses. This characterization plan was developed to meet the definition of the QAPP part of the sampling and analysis plan as described in the MARSSIM. This characterization plan describes the quality system requirements applicable to the characterization in addition to describing the overall methodology to be utilized for the characterization surveys.

The second component of the MARSSIM *Sampling and Analysis Plan* is the *Field Sampling Plan*, which will be developed as area specific survey package instructions. The survey package instructions that will be developed will meet the MARSSIM definition of a field sampling plan. The survey package instructions will describe the number, type, and location of direct measurements and samples with the analyses to be performed. Specific survey package instructions will be developed for each area to be surveyed in accordance with this characterization plan. Refer to Section 3.2.6, Survey Package Development, and Section 3.2.18, Characterization Survey Package Instructions, for further detail concerning development and content of survey packages.

1.3 Site Description

The PBRF consists of a complex of buildings and includes two reactors. The PBRF is located within a fenced area in the northern portion of NASA's Plum Brook Station (Figure 1-1). The Plum Brook Station is located about 6 km (4 mi) south of Sandusky, Ohio, about midway between Cleveland and Toledo, south of Lake Erie, and just north of the Ohio Turnpike. Farmlands and low density housing surround the Plum Brook Station. Approximately 5400 acres of the Plum Brook Station are enclosed within a high security fence with 1000 acres outside the fence to act as a buffer zone. In addition, an individual security fence surrounds the PBRF.

The PBRF complex of buildings is within a 27-acre fenced area in the northern portion of the 6400-acre Plum Brook Station. The purpose of the PBRF was to perform irradiation testing of fueled and unfueled experiments for space nuclear program application. The PBRF includes: the Reactor Building, which contains a 60-megawatt materials test reactor and a 100-kilowatt swimming-pool type mock-up reactor, both of which have been shut down and defueled; a seven-cell Hot Laboratory complex; reactor and laboratory operations support facilities, which include the Reactor Office and Laboratory Building (Building 1141), the Primary Pump House (Building 1134), the Fan House (Building 1132), the Waste Handling Building (Building 1133), the Hot Retention Area (1155), the Cold Retention Basins (1154), a hot pipe tunnel, and general support facilities, which include the Reactor Services Equipment Building (Building 1131). Other areas of environmental contamination include earthen structures and soil that were contaminated as a result of past operations. These structures are the Emergency Retention Basin, a drainage system, the Water Effluent Monitoring Station (Building 1192), the Pentolite Ditch, and two known past spill areas. Figure 1-1 is a plot plan of the PBRF showing the facilities that comprise it.

NASA currently has two 10 CFR Part 50 facility licenses to "possess but not operate" two reactors within the Reactor Building (Building 1111) at the PBRF. NRC license TR-3 is for the 60-megawatt research test reactor, constructed in 1961 for testing materials to be used in space program applications. NRC license R-93 is for the 100-kilowatt swimming-pool type mock-up reactor constructed in 1960. Refer to the PBRF licenses, respective Technical Specifications and the decommissioning plan for further operational and historical information.

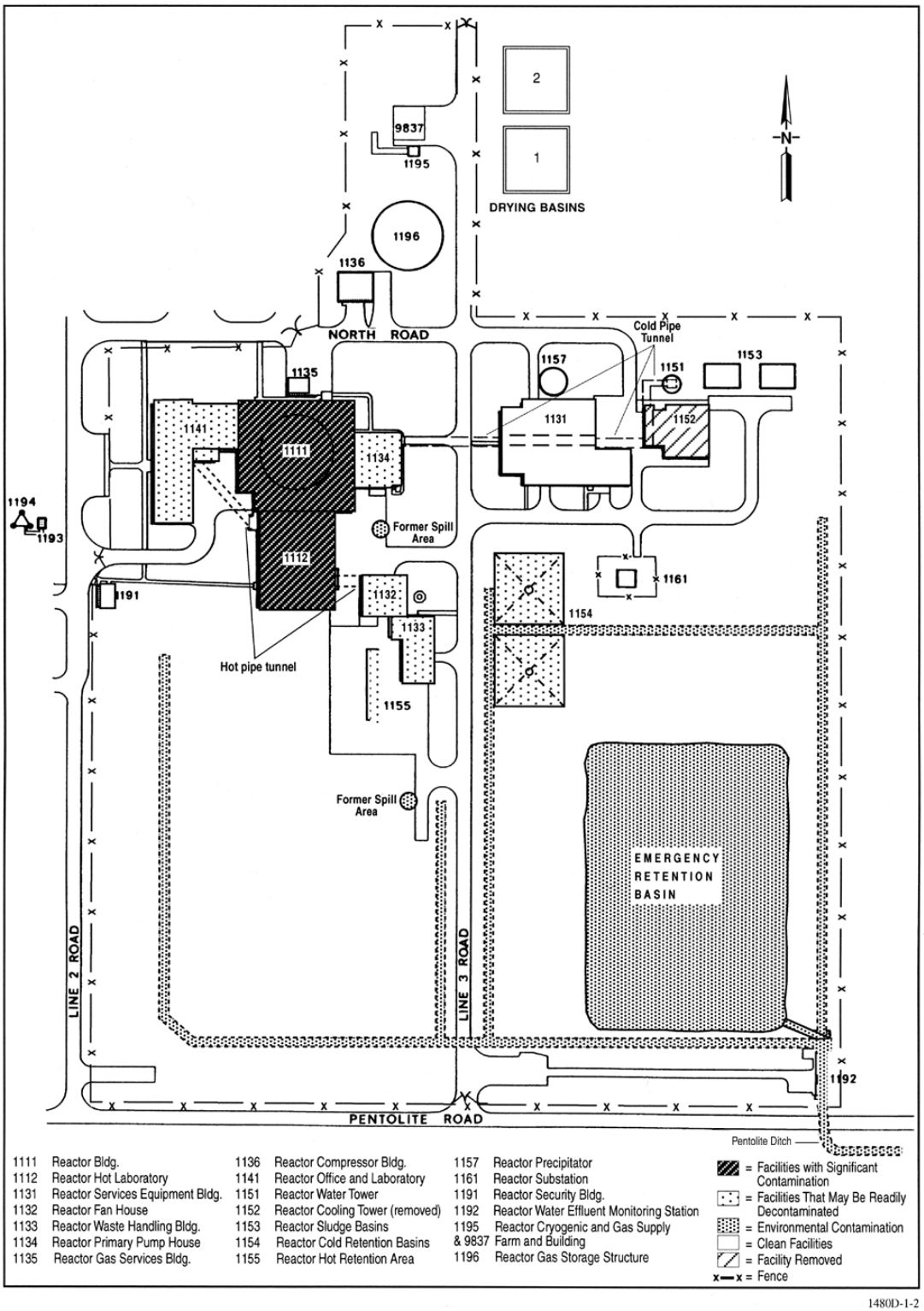

Figure 1-1. Plot Plan of Plum Brook Reactor Facility (modified from NASA 1980b)

1.4 Regulatory Activities

The decommissioning of the PBRF is described in the Decommissioning Plan, Revision 2, October 2001 (decommissioning plan) that was approved by the NRC on March 20, 2002. The approval of the decommissioning plan by the NRC was granted by License No. R-93, Amendment No. 7 and by License No. TR-3, Amendment No. 11, which state specific conditions for the approval. The license amendments also approved the Technical Specifications associated with each of the licenses. As stated in the decommissioning plan, NASA has decided that the PBRF should be decommissioned, remaining radioactive structures and materials properly disposed of, and its NRC licenses terminated.

The objective of decontamination and decommissioning will be to terminate the licenses and allow release of the 27-acre PBRF area for unrestricted use. The radiological criteria for license termination to allow unrestricted use will meet the requirements set forth in 10 CFR Part 20, Subpart E, "Radiological Criteria for License Termination," and will follow the NRC guidance in Draft Regulatory Guide DG-4006, *Demonstrating Compliance with the Radiological Criteria for License Termination* (NRC 1998a). The decommissioning activities will be conducted in accordance with the decommissioning plan and requirements stated in Facility Licenses for the PBRF, License No. TR-3 and License No. R-93 and the approved Technical Specifications associated with each of the licenses.

DG-4006 was issued to describe to the public methods acceptable to the NRC staff for implementing specific parts of the NRC's regulations and to state the NRC regulatory position. One of the regulatory positions stated in DG-4006, position No.2, "Methods for Conducting a Final Status Survey," refers to the use of the MARSSIM as containing acceptable methods for final status surveys. In addition to NUREG-1575, "Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)"; NUREG-1505, "A Nonparametric Statistical Methodology for the Design and Analysis of the Final Status Decommissioning Survey" and NUREG-1507, "Minimum Detectable Concentrations with Typical Radiation Survey Instruments For Various Contaminants and Field Conditions," are also referenced as containing acceptable methods for final status surveys. The use of these guidance documents during characterization planning is consistent with the decommissioning plan Section 2.3.1, Decommissioning Strategy and Section 2.6, Decontamination and Decommissioning Documents and Guides.

Guidance contained in NUREG-1727, *NMSS Decommissioning Standard Review Plan, September 2000* was also used as an information source during characterization plan development. The NUREG-1727 has replaced DG-4006 as the current guidance for implementing requirements set forth in 10 CFR Part 20, Subpart E and contains additional decommissioning guidance and information. However, the decommissioning of the PBRF will be conducted in accordance with DG-4006 as stated in the decommissioning plan.

2.0 DESCRIPTION OF PLANNED DECOMMISSIONING ACTIVITIES

2.1 Decommissioning Process

As discussed in the decommissioning plan, NASA evaluated a range of alternatives for decommissioning the PBRF before selecting decontamination to allow release for unrestricted use according to 10 CFR 20.1402 criteria. The 10 CFR 20.1402 Radiological criteria for unrestricted use states that

> *A site will be considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a TEDE to an average member of the critical group that does not exceed 25 mrem (0.25 mSv) per year, including that from groundwater sources of drinking water, and the residual radioactivity has been reduced to levels that are as low as reasonably achievable (ALARA). Determination of the levels which are ALARA must take into account consideration of any detriments, such as deaths from transportation accidents, expected to potentially result from decontamination and waste disposal.*

The decommissioning plan Section 2.1, Decommissioning Process, describes the process to be used at the PBRF as having three major steps; decontamination, demolition of the remaining facilities and then release of the site.

The first step would be to decontaminate the PBRF to levels that would allow unrestricted release according to the license termination criteria of 10 CFR 20 Subpart E (NRC 1998a). Decontamination will involve removal of the reactor tank and its internals, the MUR, the material in the Hot Dry Storage Area, contaminated equipment and piping in PBRF buildings and structures, and contaminated soil in areas surrounding the PBRF. Waste generated during decontamination will be disposed of offsite. Decontamination will proceed until the residual contamination that is distinguishable from background is below levels that would produce a total effective dose equivalent (TEDE) less than 25 mrem/yr to an average member of the critical group (AMCG) using the appropriate reuse scenario as stated in the decommissioning plan. Decontamination requirements for surface soil, building surfaces, and subsurface material are presented in Section 3.2.10 of this plan. After decontamination, a final status survey will be conducted to verify that decontamination has been completed.

The second step for implementing the process would be to demolish decontaminated buildings and structures, as well as uncontaminated structures, within the PBRF fence and backfill below grade portions of buildings and structures with both demolition rubble having no radiological contamination and clean fill.

The third step for implementing the process would be to prepare documentation (i.e., sampling and analytical information collected during the final status surveys) that demonstrates compliance with the license termination criteria of 10 CFR 20.1402. This documentation will be submitted to the Nuclear Regulatory Commission (NRC) as part of a request to terminate the existing NRC licenses for the PBRF.

The decommissioning plan Section 2.3.5, Facility Demolition, further describes steps involved in the PBRF D&D process. The decommissioning plan Section 2.3.5 states these steps as follows:

> "Facility demolition will begin after buildings are decontaminated (impacted buildings) and following successful lead and asbestos abatement (non-impacted buildings). Once an impacted building is rendered clean through the FSS process the building will be demolished and the construction and demolition (C&D) debris, structural steel, and siding sent off site to the appropriate reprocessor or disposal facility.
>
> In general, the demolition of the building will be performed in the following manner:
>
> - Complete radiological decontamination;
> - Building released for demolition following FSS (impacted areas);
> - Building released following confirmation survey (non-impacted areas);
> - Remove roofing, then siding materials;
> - Remove the superstructure steel;
> - Disassemble and remove additional structural steel;
> - Break, remove, and process remaining concrete for use on-site as clean, hard fill;
> - Reinforcing steel (rebar) will be segregated from the concrete to the extent possible; and
> - All remaining debris will be sized and disposed of at a C&D disposal facility."

2.2 Decommissioning Criteria

The overall objective of the PBRF decommissioning is to remediate retired facilities and soil areas to a condition that corresponds to a calculated dose to the public, or the AMCG, from all applicable pathways of less than 25 mrem/year TEDE from residual radioactivity distinguishable from background. The facilities and land may then be released for unrestricted use. This dose limit appears in 10 CFR 20, Subpart E (10 CFR 20.1402), *Radiological Criteria for Unrestricted Use.*

The DCGL is defined in the MARSSIM as the radionuclide-specific concentration within a survey unit corresponding to the release criterion. The DCGL is dependent upon several factors including the radionuclides of interest, applicable dose pathways, area occupancy and the future use of the facility. DCGLs typically assume a uniform level of residual radioactivity across the survey unit.

The decommissioning plan provides a discussion of the site-specific interim DCGLs developed for the PBRF site and associated ALARA analysis. Additional radionuclides were detected during preliminary radiation protection surveys and were confirmed to be present at the PBRF. These additional radionuclides are discussed further in Section 2.5.2 of this plan. DCGLs for each of these additional radionuclides were developed and are presented in Section 3.2.10 of this plan. The DCGLs for surface contamination at the PBRF were calculated using RESRAD Version 6.0 for soils and RESRAD-BUILD Version 3.0 for building surfaces. DCGLs presented in the decommissioning plan will be verified or revised based upon results of this characterization plan.

Buildings with surface contamination below the established DCGL levels will be deemed acceptable for release for unrestricted use provided that:

1) Residual radioactivity has been reduced to levels that are "as low as is reasonably achievable" (ALARA);
2) The residual radioactivity is contained in the top layer of the building surface (i.e., residual radioactivity above background is contained in less than 1 cm depth of floor surfaces and is in the form of surface residual radioactivity on wall surfaces); and
3) The fraction of removable surface contamination does not exceed 0.1.

Surface soil (top 15 centimeters) with contamination below the established DCGL levels will be deemed acceptable for release for unrestricted use provided that:

1) Residual radioactivity has been reduced to levels that are ALARA;
2) The residual radioactivity is contained in the top layer of the surface soil (i.e., a thickness of approximately 15 cm);
3) The unsaturated zone and the groundwater are initially free of radiological contamination; and
4) The vertical saturated hydraulic conductivity at the specific site is greater than the infiltration rate (i.e., resulting in the water running off the surface rather than purely seeping into the ground).

Dose assessments were performed for subsurface soil contamination as well. The decommissioning plan describes the RESRAD calculations used to determine interim DCGLs for areas with subsurface soil contamination. The numerical release criterion proposed for demonstrating that the dose criterion has been met for soils will be that the sum-of-fractions (quotients of concentrations and DCGLs) of contributing radionuclides shall be less than unity. If a survey unit fails to meet this numerical release criterion, the need for additional sampling or remediation will be evaluated. A Final Status Survey Plan will be developed to describe the process and protocols to be used for the PBRF final surveys. The Final Status Survey Plan will be developed according to the guidance provided in DG-4006, the MARSSIM and NUREG-1727.

2.3 Characterization Organization, Training, Procedures and Process

The decommissioning plan, Section 2.4, Decommissioning Organization and Responsibilities, and the PBRF Decommissioning Project Operations Plan provides a description of the PBRF decommissioning team organization including position descriptions and responsibilities. The Operations Plan functions as a "roadmap" for project execution. Its purpose is to define operating procedures for the Federal Sector Team and the contractors to execute the decommissioning of the PBRF. Refer to the decommissioning plan and the Operations Plan for further information regarding the PBRF D&D project organization, responsibilities and position descriptions.

The Montgomery Watson Harza (MWH) Team will provide the necessary personnel, materials and subcontractors to perform all contracted phases of the D&D work including performance of the characterization survey described in this plan. The MWH Team includes team partners, Framatome ANP DE&S (FANP DE&S) and MOTA Corporation (MOTA). Trained and experienced FANP DE&S personnel will perform the characterization survey in accordance with the protocols and process presented in this plan, using written work instructions and approved procedures. MOTA will provide a variety of tasks in support of the planed characterization activities. All subsequent reference to MWH Team in this plan implies the combined resources and personnel of MWH, FANP DE&S, and MOTA.

2.3.1 Training

The PBRF decommissioning plan Section 2.5, Training Program, provides detailed descriptions of the training requirements for the PBRF decommissioning. These training requirements are a prerequisite for all project personnel performing work during the PBRF decommissioning. As stated in the decommissioning plan, all field personnel (and contractors) assigned to work at the PBRF will meet NASA training and certification requirements and applicable regulatory requirements. NASA employees and contractors will receive training on the decommissioning plan. More specific training for workers will be commensurate with their duties and responsibilities and the magnitude of the potential exposure to direct radiation and contamination.

Specific training to this characterization plan will be provided to personnel who will be performing surveys, collecting samples and/or handling radioactive materials in radiological areas. The training will ensure that characterization personnel have sufficient knowledge to perform work activities in accordance with the requirements of this plan and the PBRF decommissioning plan. The site characterization staff will also receive training in accordance with the requirements of the MWH FSS/Characterization Supervisor and Technician Training Plan, developed in support of this characterization plan.

2.3.2 Procedures

The characterization will be conducted in accordance with written procedures approved for use by the NASA PBRF Project Safety Committee (PSC) to ensure quality and employee and public safety. Procedures will be controlled and implemented to ensure that operations are performed in a safe and technically correct manner. All tasks will require a Job Safety Analysis (JSA) in accordance with the decommissioning plan Section 3.2.4, General Industrial Safety Program.

2.3.3 Decontamination and Decommissioning Phases

The PBRF decontamination and decommissioning (D&D) process will be implemented in phases (or steps) as presented in the outline that follows. These D&D process steps are expanded in respect to the process described in the decommissioning plan and how the characterization activities will be conducted. These steps are consistent with the decommissioning plan section 2.1 and section 2.3.5.

1) Complete planning, includes development, review and approval of the following:
    a. Characterization Plan,
    b. Characterization program procedures,
    c. Waste Management Plan revision, and
    d. Waste management program procedures.
2) Mobilize onsite project personnel and equipment, equipment set-up
3) Training of personnel, includes:
    a. General Employee, Radiation Worker, Hazwoper, and other site-specific requirements,
    b. Characterization program plan and procedures, and
    c. Waste management program plan and procedures.
4) Job Safety Analysis and site preparation activities
5) Perform characterization surveys, includes
    a. Develop characterization survey packages (instructions) for each survey area/unit, (this is on-going operation)
    b. Collecting survey samples and measurements,
    c. Data downloading, processing and analysis, and
    d. Data evaluation and reporting.
6) Perform decommissioning tasks (with direction from characterization findings)
7) Perform waste management operations (with direction from characterization findings)
8) Perform post-remediation surveys, includes:
    a. Development of post-remediation survey packages (instructions) for each survey area/unit, (this is on-going operation), including additional JSAs, as necessary,
    b. Collecting survey samples and measurements,
    c. Data downloading and analysis, and
    d. Data evaluation and reporting.

9) Develop Final Status Survey (FSS) Plan and program, includes development, review and approval (by PSC and NRC as indicated) of the following:
    a. Evaluation and/or development of appropriate DCGLs (PSC and NRC)
    b. FSS plan (PSC and NRC if changes to the conditions in the license are necessary),
    c. FSS procedures, (PSC) and
    d. FSS survey packages (instructions) for each survey area/unit (PSC and NRC review not required, but advised)

Note: steps 4 through 9 may be performed concurrently

10) Perform FSS surveys, includes
    a. Collecting survey samples and measurements,
    b. Data downloading and analysis, and
    c. Data evaluation, reduction and reporting.
11) Develop and issue *Final Status Survey Report*
12) Obtain confirmation and approval required by the NRC that the buildings are suitable for demolition and backfill operations
13) Perform building demolition, backfill operations and site restoration
14) Demobilize project personnel and equipment

Note: steps 10 through 13 may be performed concurrently

2.4 Decommissioning Activities and Tasks

Decommissioning activities for the PBRF will be performed according to defined tasks as described in the PBRF decommissioning plan, Section 2.3, Decommissioning Tasks. The proposed order and schedule for decommissioning activities and tasks takes into account impact on operations and budgetary considerations. The initial mobilization phase includes equipment set-up and site-specific training of personnel and may include readiness reviews by PBRF project management, Health & Safety, and Quality Assurance departments. Characterization will be initiated once the mobilization phase is complete.

During the characterization phase, as areas are fully characterized, remediation of these areas may begin. The remediation phase is expected to take longer than characterization in each area, so once all areas of the site have been fully characterized, the characterization phase personnel will join with the remediation phase, in progress, to complete all necessary decontamination and decommissioning and post remediation survey activities. As contaminated materials and surfaces identified during the characterization are removed and/or decontaminated, post-remediation surveys will be conducted. Post-remediation survey results will be evaluated against site and area specific DCGLs and/or NASA cleanup goals. The success of remediation activities will be determined by evaluation of post-remediation survey results. If residual radionuclide contamination levels are shown to be greater than the DCGLs and/or NASA cleanup goals,

additional remediation and post-remediation surveys will be conducted. This process will be repeated in each survey area until all surfaces and areas are shown to be below DCGLs and/or NASA cleanup goals, ALARA and suitable for final status survey.

2.5 Current Assessment of Residual Radioactive Contamination

The PBRF decommissioning plan, Section 2.2, Facility Radiological Status, presents the operational history of the PBRF and summarizes the radiological status of the PBRF. The decommissioning plan, Section 2.2.1, discusses routine and non-routine events that occurred during the PBRF's operational history that contributed to facility radioactivity and contamination levels. The decommissioning plan, Section 2.2.2, describes the current radiological status of the PBRF and presents information from a characterization survey conducted in 1985 and a confirmatory survey conducted in 1998. The *Final Environmental Baseline Survey Report for the Plum Brook Reactor facility Decommissioning Project, Tetra Tech, Inc. February 2001* (EBS), also summarizes results of the radiological surveys and hazardous material or non-radiological contaminant surveys conducted at the PBRF. Major historical facts stated in the decommissioning plan, relevant to decommissioning were:

1) there is no fuel in the reactors,
2) there were a few suspected fuel cladding leaks during reactor operations, and
3) the PBRF previously underwent a program of waste removal and decontamination following shutdown.

2.5.1 Previous Characterization Efforts

A radiological survey of the PBRF was conducted in 1985 and a confirmatory survey was conducted in September 1998. The major conclusions from the 1985 characterization survey were as follows:

- The majority of the radionuclide inventory at the PBRF is in two locations: (1) the reactor tank and its internals and (2) in stored waste in the Hot Dry Storage Area of the Hot Laboratory.
- Most of the contamination inside the buildings is inside piping and equipment. Other than the internal piping and equipment contamination, residual contamination in the facilities is limited to locations where piping or equipment has leaked (e.g. the hot pipe tunnel and evaporator in the Waste Handling Building).
- In the reactor tank (exclusive of reactor internals) and the primary cooling system, Co-60 was the dominant gamma-emitting nuclide based on analysis of corrosion film samples. Europium isotopes detected were associated with activation of gadolinium from the injection system during reactor operations. The absence of fission products in the primary cooling system is consistent with the historical information.
- The isotope Co-60 and fission products Cs-137 and Sr-90 were detected in the canal and quadrant drains, hot sumps, resin pits, Hot Retention Area, and Cold Retention Basins.
- Areas of environmental contamination contain Co-60 and fission products.

- Residual activity levels in the MUR ranged form 1.5 mrem/hr to 13 mrem/hr with no significant alpha activity.

The 1998 confirmatory radiological survey (presented in the decommissioning plan Appendix A) was only conducted at portions of the PBRF to support the planning for decommissioning and license termination activities. For the confirmatory survey, only the readily detectable radionuclides were analyzed for and quantified. The results from the 1998 confirmatory survey generally confirmed the findings from the 1985 survey for the areas surveyed. However, the 1998 survey identified six additional contaminated areas as follows:

- Four laboratories (Rooms 207, 209, 210 and 213A) in the Reactor Office and Laboratory Building;
- An area of contamination on the -4.6-m (-15-ft) basement level of the Reactor Building; and
- Contamination on the PBRF pavement near the entrance to the Reactor Building.

Within the Emergency Retention Basin, the 1998 confirmatory survey identified a high Cs-137 concentration of 200 pCi/g while the 1985 high concentration of Cs-137 was 90 pCi/g. The gamma characterization information from the 1998 survey shows that the dominant gamma sources Cs-137 and Co-60. However, sampling and analysis to quantify hard to detect radionuclides that may have been present was not performed during either survey. The definitions and locations of these types of residual contamination are summarized in Table 2-1.

Table 2-1. Types of Residual Contamination at the PBRF

Residual Contamination Type	Definition	PBRF Site Areas*
Surface soil	Residual contamination of soil within 15cm (0.5 ft) of the surface that could result in a dose to a residential /agricultural intruder.	• Emergency Retention Basin • Pentolite Ditch • Spill area adjacent to Waste Handling Building (1133) concrete pad • Clean rubble used as fill • Cold Retention Basins (1154)
Building surfaces	Fixed and removable contamination on building floors, walls, or ceilings that could result in a dose to building reuse.	• Reactor Office and Laboratory Building (1141) • Reactor Building (1111) • Hot Laboratory (1112) • Waste Handling Building (1133) • Fan House (1132) • Primary Pump House (1134)
Subsurface structures and building debris	Residual contamination associated with below grade materials that could result in a dose to residential/agricultural intruder.	• Remaining subsurface structures and building debris used as backfill

* Numbers in parentheses are the building numbers (refer to Figure 1-1 for locations).

The characterization surveys indicated that surface soils having residual contamination are present at the Emergency Retention Basin, Pentolite Ditch, Waste Handling Building (Building 1133) concrete pad, and at the entrance to the Reactor Building (1111). Isotopic analysis indicated the radionuclides of concern for surface soil were Co-60, Sr-90, and Cs-137. Low levels of contamination were identified in rooms located on the second floor of the Reactor Office and Laboratory Building (Building 1141), while higher levels were identified in the Reactor Building (Building 1111) subsurface structures. Estimates of the residual contamination levels were based on available PBRF characterization data from the 1985 and 1998 surveys and on measurements at similar facilities.

The measurement results and data from the surveys conducted in 1985 and 1998 were evaluated with regard to the needs of present day regulatory and disposal facility guidance for the PBRF decommissioning. The review showed that the measurement results and data from the surveys conducted in 1985 and 1998 were deficient in several areas. The deficiencies were as follows:

1) The measurements performed and samples collected were not sufficient to determine the nature and lateral/vertical extent of radiological contamination in each survey area. The surveys showed only that contamination was present at various locations. The information provided is similar to a scoping survey as defined in the MARSSIM.

2) The measurements performed and samples collected were not of the type sufficient to provide analytical data to identify and quantify all radionuclides that may be present at the site including hard to detect radionuclides with instrument sensitivities less than 50% of interim site specific DCGLs.

3) The measurements performed and samples collected were not sufficient to provide analytical data to identify and quantify all hazardous materials, except for asbestos, lead and PCBs, that may be present in each survey area at the site with detection sensitivities sufficient to detect potential constituents. The EBS report summarizes results of hazardous material surveys or non-radiological contaminant surveys conducted at the PBRF and includes information regarding asbestos, lead, PCBs and other hazardous materials detected at the site.

4) The measurements performed and samples collected were not sufficient to determine and/or establish a radionuclide mix appropriate for each survey area.

5) The measurements performed and samples collected were not sufficient to provide the information needed to develop the FSS Plan and design FSSs for each survey area and/or unit, and

6) The measurements performed and samples collected were not sufficient to provide analysis data from a State of Utah certified laboratory(s) sufficient to meet disposal waste acceptance criteria, guidance during decontamination and remediation activities and waste management operations.

During planning for the 1985 Teledyne Isotopes characterization survey, current regulatory guidance provided in the MARSSIM and changes in the regulations for decommissioning, license termination and radioactive waste packaging, transportation and disposal were not available. Due to the absence of the current regulations and guidance during planning for the characterization in 1985, the survey could not be designed to satisfy the data quality objectives for present day requirements. The radiological survey conducted in 1998 that was limited to only certain areas at the PBRF, showed contamination was present in areas previously identified

as clean areas. In addition, the recent supplemental Historical Site Assessment (HSA) identified other areas at the PBRF indicating contamination was present in areas identified as clean areas.

Based upon further characterization conducted August 2000 in the hot cells, radionuclides in addition to the decommissioning plan radionuclides of concern were detected. The additional radionuclides include Nb-94, Sb-125, Th-230, Th-232/Th-228, Pu-239, Pu-241, Pu-243, Am-241 and possibly uranium (isotopic and depleted uranium). For the reasons stated above, radiological characterization surveys are warranted and will be conducted in each survey area of the PBRF prior to implementing and executing decontamination and remediation actions planned for the facility surfaces and land areas.

2.5.2 Radionuclides of Concern for the PBRF

As stated in the PBRF decommissioning plan, estimates of the residual contamination levels are based on available PBRF characterization data from the 1985 and 1998 surveys and on measurements at similar facilities. Based on these data, the radionuclides of concern for the PBRF are listed in Table 2-2.

Table 2-2. Radionuclides of Concern for the PBRF

Radionuclide	Surface Soil	Building Surfaces	Subsurface Structures
H-3		✓	
C-14			✓*
Fe-55		✓	✓
Co-60	✓	✓	✓
Ni-59			✓
Ni-63		✓	✓
Sr-90	✓	✓	✓
Tc-99			✓*
Cs-137	✓	✓	✓
Eu-152			✓
Eu-154			✓

* Indicates expected nuclides from similar facilities (Abel et al. 1986; Smith et al. 1978).

Based upon additional samples collected in the hot cells and information contained in the supplemental HSA, the radionuclides of concern for the PBRF need to be revised to include Nb-94, Sb-125, Th-230, Th-232/Th-228, Pu-239, Pu-241, Pu-243, Am-241 and possibly uranium (isotopic and depleted uranium). The PBRF radionuclides of concern and where these radionuclides are present will be evaluated once samples from the characterization have been analyzed and the results have been reviewed.

2.5.3 Non-Radiological Waste Characterization of the PBRF

According to the PBRF decommissioning plan, historical data did specify the hazardous materials that may be present at the PBRF. The PBRF decommissioning plan stated that asbestos and asbestos/fiberglass insulation was identified as well as lead paint, lead materials and mercury. Measurements or surveys for other heavy metals and chemicals such as PCBs were not mentioned in the decommissioning plan. During this characterization survey, samples for hazardous materials analysis will be collected according to Section 3.2.21 of this plan. The purpose of the hazardous materials sample analyses is for waste stream profiling for potential contamination from hazardous materials in areas where radioactive contamination will be removed and packaged as radioactive waste. The result of the waste stream profile analyses will be used to determine if the radioactive waste is, or is not, mixed waste that contains a hazardous material component. The EBS report summarizes results of the hazardous material or non-radiological contaminant surveys previously conducted at the PBRF. The conclusions of the EBS report, discussions of data gaps remaining in the PBRF characterization and recommendations for further characterization are presented in Section 2.5.4. In addition, the SAIC report titled *SAIC-FASS Team ACM/LBP/PCB Survey Plum Brook Reactor Facility Buildings, September 25, 2000* provides additional information on the presence and location of asbestos containing material and lead based paint.

2.5.4 Final Environmental Baseline Survey Report for the PBRF

The EBS summarizes results of the hazardous material or non-radiological contaminant surveys conducted at the PBRF. The EBS report concludes (section 5.0) that data gaps exist with regard to the radiological surveys and hazardous material analyses and surveys. The data gaps presented in the EBS that are specific to potential hazardous materials contamination in environmental areas at the PBRF have been addressed or are being addressed via the NASA PBRF EMP. During characterization planning, the information contained in the EBS and the EMP will be referred to as necessary to obtain any details such as historical or "process knowledge" information for waste stream profile purposes, as appropriate.

Data Gap Closure Plans are presented in the EMP and will be evaluated regarding applicability to radiological characterization planning and the need for further surveys, sampling and analyses. The information from the EMP will be utilized, as appropriate, for planning of surveys, measurements and analyses for the radiological characterization survey and as needed for waste stream profile sampling.

The evaluation and determination of need for further surveys, sampling and analyses to identify and quantify non-radiological contaminants that may be present at the PBRF site will be performed in accordance with the EMP. If the potential for non-radiological contamination is identified in an area as a result of waste stream profile sample analysis, a separate plan will be developed in accordance with the EMP to address any required remedial actions. A plan resulting from an EMP directive may include the means to determine the lateral/vertical extent of non-radiological contaminants in areas, or other remedies as determined by the purpose and scope of the investigation or study.

2.5.5 Supplemental Historical Site Assessment

A supplemental HSA was conducted for the PBRF and documented in a report, the *Plum Brook Reactor Facility Supplemental Historical Site Assessment, November 2001.* The purpose of the supplemental HSA was to aid in validating the classifications presented in the PBRF decommissioning plan. The HSA was accomplished by reviewing current survey data from the 1985 and 1998 surveys and performing interviews of current and former employees. The HSA results are summarized as follow.

1) Several areas impacted by former operations involving the use of radioactive materials may be misclassified as non-impacted. Additionally, entire areas have been designated as a Class 1, rather than the more likely scenario of the floor and lower walls being a Class 1 and the upper walls and ceiling being a Class 2.

2) Due to the unavailability of the current regulatory guidance contained in the MARSSIM, data quality objectives (DQOs) had not been established to determine the survey and sampling criteria, as well as the analysis requirements necessary to apply the data toward site release. Characterization surveys and sampling data will be needed for development of a FSS Plan. In the case of classifying an area properly as non-impacted, the MARSSIM classification may be verified to be correct based upon characterization survey results and additional FSS release surveys could be eliminated. In a Class 3 survey area, a successful characterization survey may be used as the FSS assuming adequate controls of the area(s) are in place. It also appears that an adequate evaluation of plant systems and their various interfaces has not been performed. This evaluation will be performed during characterization activities.

3) From the review of system drawings and descriptions, the potential for cross contamination of "clean" systems needs to be determined. It is necessary to perform limited radiological surveys with potentially contaminated "clean" systems to verify that those systems are in fact clean.

4) Based upon limited radiological surveys of selected portions of the site, radioactive contamination is present in areas not previously identified. Numerous discrete areas of high contamination were identified on the asphalt-paved area behind the Reactor Hot Laboratory (Building 1112). On at least one occasion, a PBRF staff member has become contaminated by radioactive material outside a posted contaminated area. In addition, anecdotal evidence obtained in casual conversation with former long-time PBRF employees indicates the presence of radioactive contamination in structures currently classified as non-impacted (e.g., Service Equipment Building [1131]). Subsequent to issuance of the HSA, discrete particles were found by a routine RP survey. The particles were found underneath equipment in Building 1112, Room No.9 that was currently (as of December 2001) being used to dress out.

5) In the mid to late fall of 2001, a component stored within the Reactor Building (1111) was found to be contaminated with what appears to be depleted uranium. The net result of these conditions indicates the need for a comprehensive HSA followed by an adequate characterization.

6) The radiological survey data collected thus far can and will be used as scoping survey data. In some instances where this data is supported by the HSA, and if the DQOs are met, it may be used as characterization data.

7) It was indicated by several retirees that Atomic Energy Commission (AEC) related work was performed at PBRF. The "SNAP" program (System for Nuclear Auxiliary Power) was mentioned and thought it was partially sponsored by the AEC.

8) A suitable background reference area or areas will need to be selected and background study performed. This will be performed during characterization activities.

9) Hazardous material and 10 CFR Part 61 sampling, analysis and evaluation needs to be performed for waste management operations as well as for waste disposal sites' waste acceptance criteria (WAC).

10) Radionuclides other than the ones identified as the Radionuclides of Concern in the decommissioning plan were shown to be present. These include DU, natural thorium and hard to detect radionuclides that were not analyzed for.

11) PCBs are in florescent light ballasts at the facility. Several of these ballasts have leaked onto facility surfaces. The latest occurrence was a ballast in the Reactor Building leaking onto the floor found April 2002.

Based on information from the HSA, additional radiological conditions for the PBRF are listed in Table 2-4.

Table 2-4. Additional Radiological Conditions from the HSA for the PBRF

Area Description	Current Classification	Comments
Reactor Building (1111):		
Inside containment vessel	Class 1	Pipe around CV floor at RB-15 contaminated, Sump pit #4 contaminated, trench beside sump#2 possible contamination
Outside containment vessel	Class 2	J-58 engine stored in truck bay, preliminary indications of depleted uranium (used for ballast), "Black Beauty" sand blast media used outside bldg. 1111
Hot Laboratory (1112):		
Outside Building	Class 2	Contaminated liquid tank stored outside behind bldg. 1112
Waste Handling Building (1133):		
First floor floors	Class 1	Small sludge spill outside Gantry room door
Hot Retention Area (1155)	Class 1	Discovered and removed piece of contaminated Pb outside
Outside Areas		
Areas of past spills	Class 1	Include storm drains
Dress Out Room (1112)	Non-Impacted*	Discrete particles were found underneath equipment
Reactor Service Equipment Building (1131)	Non-Impacted*	DI water line cross contaminated, possible impacted areas to be identified via system drawings

*May be misclassified

3.0 DESCRIPTION OF PLANNED CHARACTERIZATION ACTIVITIES

3.1 Introduction

Current regulatory guidance, NUREG-1727, *NMSS Decommissioning Standard Review Plan, September 2000* and its predecessor DG-4006, prescribes the application of process and protocols contained in the MARSSIM. The MARSSIM recommends a phased approach to the process. Following the MARSSIM guidance and defining the nature and the extent of radiological and non-radiological contaminants at the PBRF decommissioning site is essential for several reasons.

- Protection of the public and the workers requires that all radioactive and/or hazardous material be identified.

- A more thorough knowledge of the depth and extent of contaminated areas at the facility provides guidance for remediation efforts.

- A thorough knowledge of the various waste streams at a site is also a requirement for waste acceptance criteria (WAC) of disposal facilities and for packaging, labeling and transportation of the waste.

- Finally, the final status surveys (FSS) are dependent upon a clear definition of the initial as found site conditions as well as post remediation conditions for appropriate survey unit classification and FSS design.

Preliminary surveys and a HSA have been conducted at the PBRF site. These activities are shown in the MARSSIM as first steps of the site investigation process. By combining characterization survey results with the results of the previous surveys of 1985 and 1998, a complete characterization of the site will be available.

3.2 Characterization

Radiological characterization surveys will be performed prior to decontamination/remediation activities. The purpose of the characterization survey is to complete the site characterization process that was begun, but not completed due to changes in the regulations. As completed for each area, the characterization data obtained will allow finalization of both planned remediation activities and waste management planning, the development of the FSS Plan and design of post remediation and final surveys for each area. The site characterization survey includes surface and subsurface characterization activities for the PBRF site. The subsurface samples will be obtained at locations where contamination was present, but the depth of contamination was not defined. Measurements and samples will also be collected to define the lateral extent of the contamination, based on the results of the initial surveys. The characterization surveys will be designed, performed, evaluated, and documented in accordance with the guidance contained in the MARSSIM, DG-4006 and NUREG-1727.

As stated in Section 1.2 of this plan, during performance of this characterization plan, efforts will be made to accommodate plans developed in accordance with the EMP for further surveys for non-radiological contamination discovered during EBS data gap closure work or from waste stream profile sampling during characterization. This may include collection of split samples or other survey operation to the extent practical, to assist with performance and completion of EMP directed plans.

3.2.1 Site Preparation

Preparation of all areas within the site, structures and outdoor areas, for characterization surveys will be performed, as appropriate. In outdoor areas, prior to excavation or any trenching operations, as a first step to site preparation and performance of the characterization survey, a silt fence will be added to the existing chain link fence, or as appropriate, to reduce the potential for impacting areas outside the PBRF boundary or to reduce the risk of contaminating a non-impacted adjacent area. In order to support the characterization surveys, the facility surfaces and land areas will be cleared of all loose equipment and materials to the maximum extent possible using RP work instructions and existing approved procedures. Characterization survey package instructions will be developed that will include measurements and samples for any remaining loose equipment or materials in an area. However, the characterization survey measurements and/or sample analysis for any remaining loose equipment or materials in an area will be evaluated separately from the characterization survey measurements and/or sample analysis performed for facility surfaces.

Secondly, prior to performing characterization surveys in each environmental survey area or survey unit, the area will be cleared of debris and/or vegetation in the case of outdoor areas to eliminate physical obstructions. The vegetation will be cut as close to the ground surface as possible and left in place. All loose equipment and debris removed from the facility surfaces and land areas that were surveyed using RP work instructions and existing approved procedures will be placed into an appropriate waste container depending upon radiological and/or hazardous status and disposed of in accordance with the PBRF Waste Management Plan. Loose equipment at the facility will be surveyed once an inventory is compiled. This will apply to all materials prior to leaving the PBRF fence (controlled industrial area). If any clean waste materials or loose equipment are to be disposed of at local industrial landfill or archived for historical preservation, these materials will be surveyed in accordance with approved procedures for free release of materials and will show no detectable radioactivity. Materials showing detectable radioactivity will be placed into an appropriate radioactive waste container for disposal at a low level radioactive waste disposal site or sent to a licensed waste processor for further processing in accordance with the Waste Management Plan and procedures.

All physical hazards at the site will be identified and removed or marked as appropriate. Fall hazards will be appropriately marked with caution tape or rope and stanchions. Any structurally unsound structures should be evaluated for safety considerations. Building materials removed due to safety considerations will be surveyed and disposed of as discussed in the previous paragraph.

A grid system will be established such that biased survey measurement locations can be located and marked. The survey reference coordinate system will consist of a grid of intersecting lines, referenced to a fixed site location. The lines will be arranged in a perpendicular pattern, dividing the site into grid squares depending upon survey area and survey unit classification. Class 1 impacted survey areas for structures will be gridded in 1 meter by 1 meter grids for surfaces of structures and in 10 meters by 10 meters grids for outdoor environmental areas. Class 2 impacted survey areas for structures will be gridded in 10 meters by 10 meters grids for surfaces of structures and the same 10 meters by 10 meters grids for outdoor environmental areas. Class 3 impacted survey areas for structures or outdoor environmental areas will not be gridded, each survey measurement location will be appropriately marked at the location and on a drawing depicting the survey area or unit.

The reference coordinate system will provide a level of reproducibility consistent with the objectives of the survey. The site survey areas reference coordinate systems will be marked by paint and/or permanent markers for building surfaces and paved outdoor surfaces. Once concrete floor covering and asphalt pavement is removed during characterization or remediation and soil beneath is exposed, wooden or metal stakes, driven into the surface at reference line intersections will be used to mark survey areas and survey measurement locations.

3.2.2 Underground Utilities

Prior to beginning the characterization, all underground utilities will be marked before performing any boring or digging activities. PBRF characterization supervisor or designee will contact and coordinate with NASA Plum Brook Station personnel and local utility representatives, as appropriate, to locate and appropriately mark the location of any and all underground water, natural gas and/or electric utilities in accordance with the latest revision of the Plum Brook Station Procedure No. GRC-P7030.022.

3.2.3 Characterization Data Quality Objectives

The Data Quality Objectives (DQOs) for the characterization survey of the Plum Brook Reactor Facility site are as follows:

1. Perform measurements and collect samples sufficient to determine the nature and lateral/vertical extent of radiological contamination in each survey area for the following:
   a. Disposal facility WAC and waste stream profiles,
   b. Guidance during decontamination and remediation activities, and
   c. Waste management operations.

2) Provide analysis data to identify and quantify radionuclides including hard to detect radionuclides that may be present at the site with instrument sensitivities less than 50% of interim site specific DCGLs.

3) Provide analysis data to identify and quantify hazardous materials including asbestos, lead and PCBs that may be present in each survey area at the site with detection sensitivities sufficient to detect potential constituents.

4) Determine and/or establish a radionuclide mix appropriate for each survey area.

5) Provide additional information for the pathway analysis re-evaluation of the occupational and public health and safety impacts during decommissioning.

6) Provide additional information for the site-specific DCGLs re-evaluation for applicability during final status surveys.

7) Provide additional information for the pathway analysis and re-evaluate the occupational and public health and safety impacts after decommissioning.

8) Provide additional information to re-evaluate remediation and decontamination technologies to be implemented during remediation and decontamination phase.

9) Provide additional information to re-evaluate waste estimate and remediation and decontamination cost assumptions.

10) Provide the information needed to develop the FSS Plan and design FSS for each survey area and/or unit.

11) Provide analytical data from State of Utah certified laboratory(s) sufficient to meet disposal facility WAC.

3.2.4 Survey Areas/Unit Classification

Depending upon previous site operations and operational histories, the potential for residual contamination varies from survey area to survey area. In order to facilitate characterization surveys to guide decontamination activities and for eventual final surveys, areas are classified based upon their potential, with more extensive final surveys being performed in areas with greater contamination potential. According to MARSSIM, areas are either classified as impacted or non-impacted. Impacted areas have the potential for contamination with levels of detectable radioactivity at or greater than DCGLs while a non-impacted area has no radiological impact from site operations, levels of detectable radioactivity are less than DCGLs and the area does not require surveys.

DCGLs, derived concentration guideline levels, were derived for the PBRF from activity/dose relationships through exposure pathway scenarios presented in the decommissioning plan. The DCGL is a derived, radionuclide-specific activity concentration within a survey unit corresponding to the 25 mrem/year TEDE to the AMCG or release criteria. For areas impacted by multiple radionuclides in a mixture, the $DCGL_W$ is based on the radionuclide mix appropriate for the area and the spatial distribution of the contaminant and is derived for the *nonparametric* statistical test, either the Wilcoxon Rank Sum (WRS) or for the Sign test.

Impacted areas are further classified as either Class 1, Class 2 or Class 3. Class 1 impacted areas are areas which have, or had prior to remediation, a potential for radioactive contamination based on site operating history or known contamination above the $DCGL_W$. Class 2 areas have or had prior to remediation a potential for radioactive contamination or known contamination, which is not expected to exceed the $DCGL_W$. Class 3 areas are any impacted areas that are not expected to contain any residual radioactivity or are expected to contain levels of residual activity at a small fraction of the $DCGL_W$.

Class 1 impacted areas have the greatest potential for contamination and therefore receive the highest degree of survey effort during the final status survey. However, for the characterization surveys, Class 1 survey areas where contamination is known to exist will be surveyed based upon the number of measurements and samples required to bound the lateral and vertical extent of the contamination identified during the 1985 and 1998 surveys. Development of surveys utilizing this methodology, referred to as "bounding surveys," will prescribe biased survey measurement locations and scan areas based upon 1985 and 1998 survey results. Based upon the operational history of the PBRF buildings and the surrounding area, most of the facility is considered to be impacted with a few areas initially classified as non-impacted. All areas known to require decontamination (or remediation) are classified as Class 1 areas. Some of the surrounding support areas are either Class 2 or 3. Non-impacted areas are adjacent to the Class 2 or Class 3 areas. Areas classified as non-impacted or impacted Class 2 or Class 3 will receive surveys developed to include a combination of systematic and biased survey measurement locations and scan areas to supplement what is currently known concerning the condition of the areas with respect to the presence or absence of radiological or non-radiological contamination. Based upon the nature and extent of contamination detected and the areas to be surveyed, some of the survey areas/units floors and lower walls below 2 meters height will be treated as either

Class 1 or Class 2 survey unit. Depending on the area, the upper wall above two meters and the ceiling will be treated as either Class 2 or Class 3 survey unit.

3.2.5 Selection and Size of Survey Areas and Survey Units

The characterization survey team will divide the impacted PBRF into survey areas and some survey areas will be further divided into survey units based on the classification described above. A survey unit is a portion of a building or site that is surveyed, evaluated, and released as a single unit as a result of the final status survey. The entire survey unit will be given the same area classification according to Section 4.6 of the MARSSIM. The important features of this method are summarized here. For buildings, it would be appropriate to designate each separate room as either 1 or 2 survey units (e.g., floors with the lower half of walls and upper half of walls with ceiling) based on the pattern of potential of residual radioactivity. In accordance with the MARSSIM and NUREG-1727, rooms of normal size (100 m^2 area or less) will not be divided into more than two survey units because the dose modeling is based on the room being considered as a single unit. However, very large spaces may be divided into multiple survey units, as appropriate.

For soil, survey units will be areas with similar operational history or similar potential for residual radioactivity to the extent practical. Survey units will be formed from areas with the same classification to the extent practical, but if areas with more than one class are combined in to one survey unit, the entire survey unit will be given the more restrictive classification. Survey units may have relatively compact shapes and not have highly irregular shapes unless the unusual shape is appropriate for the site operational history or the site topography.

Suggested survey unit areas from MARSSIM for FSS are given in Table 3-1. These areas are suggested in MARSSIM for FSS survey units because they give a reasonable sampling density and they are consistent with most commonly used dose modeling codes. However, the size and shape of a particular survey unit may be adjusted to conform to the existing features of the particular site area and dose modeling specifics. For the characterization surveys, survey area size will be determined based upon the specific area and the most efficient and practical size needed to bound the lateral and vertical extent of contamination identified in the area.

Table 3-1. MARSSIM Suggested Survey Unit Areas

Classification	Survey Unit Areas	
	Structures	Land
Class 1	up to 100 m^2	up to 2,000 m^2
Class 2	100 to 1,000 m^2	2,000 to 10,000 m^2
Class 3	No limit	No limit

3.2.6 Survey Package Development

For each survey area, and/or survey unit, the characterization team will develop a survey package, or portfolio. The survey packages will be the primary method of controlling and tracking the hard copy records of survey results. The characterization survey packages will be developed according to this plan and will be provided as an attachment to this plan, as developed. Records of surveys will be documented and maintained in the survey packages for each area according to approved PBRF procedures. During the survey, the project team will update the survey package(s) with the survey data and results of any special surveys or sample analyses performed.

The survey package development will involve performing walk-downs and preparing a worksheet/tracking sheet. During the walk-down details regarding the physical survey area will be compiled such as type of area (structure, system or environ), surfaces in the area (wall, floor, ceiling, surface soil, etc.,) and metric dimensions in meters. Data from previous surveys will be reviewed and utilized as appropriate. From the walk-down worksheet, the survey package will be developed. The survey package will contain sections for the following types of information:

1) Detailed description of the survey area and/or survey units, as applicable,

2) Photographs, drawing or drawings of the survey area and/or survey units, as applicable,

3) Survey area operational history including summary data from previous surveys,

4) Characterization survey instructions,

5) Location codes developed uniquely for the area,

6) Types and number of survey measurements and/or samples prescribed for the survey.

7) Survey support requirements,

8) Health and safety requirements,

9) RWP requirements,

10) Specific survey instructions for any abnormal conditions that may be encountered within the survey area, and

11) Survey instrument data downloads and sample analysis report hard copies.

A combination of photographs, drawing or drawings will be developed for each survey package depicting each survey area or survey unit. The survey area/unit drawings will be annotated with the grid reference system and the location of the characterization survey measurement locations.

As described in MARSSIM, significant health and safety concerns during any radiological survey include the potential industrial hazards commonly found at a construction site, such as exposed electrical circuitry, excavations, enclosed work spaces, hazardous atmospheres, insects, poisonous snakes, plants and animals, unstable surfaces, heat and cold, sharp objects or surfaces, falling object, tripping hazards, and working at heights. MARSSIM suggests the survey plan(s) incorporate objectives and procedures for identifying and eliminating, avoiding, or minimizing these potential safety hazards.

Prior to and during collection of survey data, a visual inspection by on-site safety personnel will be performed to identify potential industrial safety hazards (step number 8, Health and Safety requirements). This inspection, typically performed as part of the Job Safety Analysis (JSA) development, is intended to identify general safety hazards as well as significant industrial safety hazards that may or may not impact upcoming work in the area described in the survey package. These hazards may include (but are not limited to):

- Potential creation or existence of hazardous atmospheres,
- Exposed electrical circuitry,
- Overhead power lines,
- Overhead piping,
- Underground pipes and power lines,
- Excavations,
- Confined spaces,
- Working at heights,
- Potential load bearing stresses (roofing and flooring),
- Structural integrity (piping, building, etc.),
- Stored energy sources (hydraulic, pressure, potential, etc.),
- Kinetic energy sources and use of power equipment (need for guards, blocks, braces, etc.),
- Open water.

Once these industrial hazards are identified through the JSA process (as will be performed for each survey area) they will be incorporated into the characterization database for each survey area. As part of the JSA process, each hazard identified will be evaluated to determine if the hazard can be eliminated, avoided or minimized, as well as to determine if the need for additional outside support/expertise is necessary to complete further evaluation. If at any time during the inspection or the subsequent survey work, a serious hazard is identified that requires immediate action *(i.e., can not be immediately eliminated, avoided, or minimized), the area will be isolated until an acceptable remedy has been implemented.

A JSA will be performed for each area in accordance with the NASA Plum Brook Reactor Facility Site Specific Safety and Health Plan (SSHP) developed for the project. The JSA documentation records any chemical, structural and/or physical hazards that may be present in an area prior to performance of survey area preparation and surveys.

Implementation, completion and review signature blocks in the survey packages will be used to initiate and track the progress of the characterization surveys. The number of characterization survey measurements and samples prescribed to be performed and/or collected during the characterization survey will be contained in the survey packages. During the survey, the project

team will update the survey package(s) with the survey data and results of any characterization, and post-remediation surveys or sample analyses performed. Prior to implementing the survey package instructions, the characterization team management will review and approve each survey package.

Once the surveys have been completed, data analysis and evaluation will begin. Once data analysis and evaluation is completed for each survey unit and survey area and the data is shown to have satisfied the DQOs of the survey, the survey package will be closed and the spaces provided for survey package closure signed by the data reviewer and the characterization team manager.

3.2.7 PBRF Survey Data Management System

A survey data management system (SDMS) will be developed to assist the PBRF decommissioning team in managing the data generated during site characterization survey, post remediation survey and final status survey operations. The SDMS will be developed based upon data storage and data analysis and reporting requirements to support the PBRF decommissioning processes. The SDMS will be developed using Microsoft Access 2002 (MS Access) computer software or similar software package. The SDMS will have a modular structure that will incorporate a database (DB) storage repository to include folders, file structure and DB tables for each function of the process. Survey data collected during the project will be downloaded from survey instruments into database tables specific for each measurement type for storage, analysis, and reporting. Each of these functions are relevant during characterization, post-remediation and final status surveys. The SDMS modules are described as follows:

1. Lookup Tables – Will contain work breakdown structure (WBS) and survey area/unit information, location code structure, DCGLs, instrument and detector DB and source DB.

2. Package Tables – Will contain Survey package DB tables of developed survey package instructions and drawings for each survey area/unit.

3. Data Tables – Will contain DB tables with survey samples and measurement data downloads from survey instrumentation for each measurement type as a result of performing characterization surveys, post-remediation and/or final status surveys. DB tables for each measurement type will allow queries and preliminary reporting for technician review, supervisor review and means for uploading QC'ed data into a master DB for each measurement type.

4. Data Analysis – Will contain the master DB tables for each measurement type. Queries for data reduction, calculations, summary statistics and reporting will occur for engineering review and data evaluation.

5. Reports – Will contain various reports resulting from data analysis. The reports include:
    a. Characterization survey data report for each survey area/unit for remediation operations and waste management guidance,
    b. Post-remediation survey data reports for measuring success of remediation activities final status survey suitability evaluations and final status survey planning, and
    c. Final Status Survey data reports to show suitability of specific survey areas/units meet criteria for release for unrestricted use.

Information, such as from the JSA concerning metals, VOC's, structural/physical hazards, etc., that may be identified as present in an area prior to commencement of area prep and characterization, will be captured by entry into the survey database tables. During survey package development, JSA and other information will be complied for reporting with the survey package instructions and will be presented in the characterization report once the surveys are completed with all data and analysis summaries. The ability to query the survey database and produce reports concerning health and safety issues identified at the PBRF and other information will also be available.

The survey team will perform survey measurements utilizing data logger type instruments and perform sample analysis utilizing MS Windows based analytical instruments. Upon completion of a survey or sample analysis, the contents of the data logger's memory or analysis instruments' computer will be downloaded to a SDMS Data Table, MS Access database. The SDMS will undergo validation and verification (V&V) testing to show it meets its' design specification and testing to demonstrate it will function as designed. Documentation of the V&V process will be maintained. The survey team will use instrument manufacturer's computer programs to download the measurement or analysis data and generate a survey report that presents all raw data. MS Access program and MS Excel will be used to query and convert raw data and report survey information by survey area and/or survey unit. The survey technician and supervisor will review these reports for completeness, accuracy, suspect entries and compare the data to the survey DCGLs, as appropriate. All computer data produced during the characterization will be backed up daily.

3.2.8 PBRF Survey Measurement Location Codes

To facilitate database queries and reporting utilizing the survey data management system (SDMS), each characterization survey measurement and sample collected will have a unique survey measurement location code associated with the measurement or sample. Table 3-2 presents an example of the survey measurement LC to be used during the PBRF characterization survey.

Table 3-2, PBRF Survey Measurement Location Code Example Sheet

LC 1 **Survey Group and Survey Area ID**	**LC 2** **Survey Unit Class/ Survey Unit ID and Survey Reason**	**LC 3** **Surface Category / Measurement Background Mode**	**LC 4** **Detector Type / Survey Count Type**	**LC 5** **Material Code / Survey Grid ID**	**LC 6** **Survey Point / Measurement Location**
Positions (P) 1 - 5	**Positions (P) 1 - 5**	**Positions (P) 1 - 5**	**Positions (P) 1 - 5**	**Positions (P) 1 - 5**	**Positions (P) 1 - 5**
C 1 1 1 1	**1 0 1 C 1**	**F L 1 S B**	**B 0 4 F C**	**D A C 3 5**	**0 0 0 0 1**
P1 - A 1 character code to identify the survey group. e.g. **A** - Impacted Environs **B** - Non-Impacted Environs **C -** Impacted Structures **D** - Non-Impacted Structures **E** - Impacted Systems **F** - Non-Impacted Systems **G** – Background Structures **H** – Background Environs *P2, 3, 4 & 5 (4 character) code to identify the survey area. e.g.* **C1111** - Reactor Building (Structure) **D1191** – Reactor Security Building (Structure) *The LC1 code is also used to designate the source number during Source Checks. e.g.* **FAD01** – FANP DE&S assigned source number	*P1 - A 1 character code to identify the survey unit classification. e.g.* **1**... – Class 1 **2**... – Class 2 **3**... – Class 3 **4**... – Non-Impacted *P2 & 3 - A 2 character code to identify the survey unit. e.g.* **01**... – Quad A. **12**... – Quad E **21**... – Mock Up Reactor Area. *P ,4 & 5 - A 2 character code to identify the survey reason. e.g.* **Bx** - Background Survey **Cx** – Characterization **Ix** – Investigation **Fx** - Final Status Survey **Px** – Post Remediation **Qx** – QA/QC **Sx** - Scoping Survey **Vx** - Verification Survey **x** will be a numeric sequence starting with **1.**	*P 1, 2 & 3 - A 3 character code to identify the survey surface. e.g.* **FLx** – Floor **WLx** – Wall Lower **WUx** – Wall Upper **LAx** – Open Land Area **SA x–** Surface Soil (0-6") **SB x–** Subsurface Soil (6-12") **SYx –** System **x** will be a numeric sequence starting with **1.** *P4 & 5 - A 2 character code to identify the local area background subtract method for direct measurements. e.g.* **AB –** Average background **NB –** Background not required **SB –** Single background per reading	*P1, 2 & 3 - A 3 character code to identify the survey detector.* e.g. **A01 - 43-68 Alpha** **A02 - 43-106 Alpha** **B01 - 44-40** **B04 - 43-68 Beta** **B05 - 43-106 Beta** **B08 - 43-37** **G03 - 44-2 Gamma** **ZZZ – Not Used** *P4 & 5 - A 2 character code to identify the type of count. e.g.* **Source Check (SC) Types:** **AB** – Pre SC Bkg **AS** – Pre SC Count **BB** – Post SC Bkg **BS** – Post SC Count **Field Count Types:** **FB** – Field Bkg **FC** – Field Count **FS** – Field Scan	*P1 - A 1 character code to identify the type of Material* e.g. **A** – Asphalt **B** – Brick **C** –Concrete (Bare) **D** – Concrete (Painted) **E** – Concrete (Epoxy) **F** – Cinder Block (Bare) **H** – Cinder Block (Painted) **J** – Cinder Block (Epoxy) **G** – Generic **M** – Misc. Material **P** – Porcelain **R** – Sediment **S** – Soil **T** – Ceramic Tile **V** – Vegetation **W** – Water This code would be used if background activity from structural materials is to be subtracted from results. Requires that a background study be performed. *P2, 3, 4 & 5 - A 4 character code to identify the survey grid ID, room number or system number.* If not used, enter ZZZZ	*5 character counter to track measurement or sample numbers as required.*

The survey measurement LC convention provides the ability to uniquely code each surface to be surveyed during the PBRF characterization for each survey area and/or survey unit. The LC system will also provide for measurement traceability back to a specific location on a survey area drawing and a marking at the location of the survey measurement or sample. The thirty character LC was divided into six, 5 character sections as shown in Table 3-2. The sections of the LC provide for expanded capabilities as follows:

1) Section LC 1 position 1 provides a Survey Area/ Survey Package classification and position 2 thru 5 provides the Survey Area/ Survey Package ID. Secondly section LC 1 provides a means to designate a calibration or QC check source number during the performance of pre-survey or post-survey source checks.

2) Section LC 2 position 1 provides a Survey Unit classification as impacted Class 1, 2, or 3 or Non-impacted 4. Section LC 2 position 2 and 3 provides a Survey Unit number from 01 to 99 and position 4 and 5 provides a Survey Reason code to differentiate between types of surveys and number.

3) Section LC 3 position 1 thru 3 provides the Survey Surface Category and number as applicable. Section LC 3 position 4 and 5 provides a Survey Background type code for post processing measurement results.

4) Section LC 4 position 1 thru 3 provides a Detector Type code for prescribing measurement type and for post processing measurement results. Section LC 4 position 4 and 5 provides a Survey Count Type code to differentiate between types of survey measurement types also for post processing measurement results.

5) Section LC 5 position 1 provides a Material Code for post processing measurement results and LC 5 position 2 thru 5 provides space to identify a room number for structures or Survey Grid ID for environs, if needed. For surveys of systems this section may be used to designate system components, or other survey locations as needed. When not used, "ZZZZ" will be entered.

6) Section LC 6 provides a Survey Measurement Location Number for traceability of a measurement or sample back to a location on a drawing and in a survey area or unit.

Each of these LC functions will be relevant during characterization, post-remediation and final status surveys.

3.2.9 PBRF Site Survey Areas and Survey Units

To facilitate the site characterization, the PBRF buildings and site will be divided into survey areas in accordance with the MARSSIM. A survey area may contain one or several survey units depending on size, nature and extent of contamination and physical similarities. The survey areas and preliminary survey units for the PBRF site are listed in Attachment A to this plan. The initial classification associated with each survey area was based upon the decommissioning plan Section 4.1.4.1. For the characterization survey, these survey area classifications will not be changed to meet requirements of Amendment No. 11 of NRC License No. TR-3 dated March 20, 2002. The Amendment No. 11 approves the decommissioning plan for the PBRF and states specific conditions for the approval. The Amendment Section 3, Part A.1.h states that an area classification may not be decreased (i.e., impacted to non-impacted; Class 1 to Class 2; Class 2 to Class 3; or Class 1 to Class 3) without first seeking NRC approval pursuant to 10 CFR 50.59. This requirement is in affect for characterization as well as for final status surveys.

Attachment A – PBRF Survey Areas and Survey Units describes the currently anticipated survey areas and survey units at the PBRF prior to survey package development. The table will be updated periodically to provide information regarding new survey units added to a survey area as survey package instructions are developed. In this since, the table is a "living document." The Attachment A table will undergo periodic review/revision as the PBRF characterization progresses from planning and development stages through completion of the characterization surveys. These reviews will occur as each survey package instruction is developed to assure that the information is updated in a timely manor.

Each survey area is assigned a survey area number to facilitate handling of information and data via SDMS database files. Some survey areas will be further divided into survey units. The initial area classification (i.e., Impacted Class 1, Class 2 or Class 3) is also provided. During and upon completion of the characterization and/or post-remediation surveys of the facility, additional survey areas and/or units may be added, adjusted or some of the areas combined to facilitate final status survey planning. This will depend upon the similarities of the areas (contamination potential) and the facility layout. For the characterization surveys, survey area size will be determined based upon the specific area and the most efficient and practical size needed to bound the lateral and vertical extent of contamination identified in the area.

3.2.10 Derived Concentration Guideline Levels (DCGLs)

Some of the DCGLs used for the characterization will be as presented in Section 2.2.3.1 of the PBRF decommissioning plan. A detailed discussion of DCGL development regarding the reuse scenario for the site-specific DCGLs is also provided in the decommissioning plan section for these radionuclides.

Additional radionuclides were detected during preliminary radiation protection surveys and were confirmed to be present at the PBRF. DCGL values relating to 25 mrem/yr TEDE to AMCG for isotopes not currently in the decommissioning plan but present at the PBRF were added to Table 3-4 and Table 3-5 in this section. The development of the DCGLs for the additional radionuclides at the PBRF was performed using the same protocol and version of RESRAD and RESRAD-BUILD as stated in the decommissioning plan.

Generic screening DCGLs from NUREG-1549 were provided in the decommissioning plan to provide perspective. However, the NRC has provided an update to the generic screening DCGLs in NUREG-1727. These values are presented in this characterization plan for perspective with regard to the current regulatory guidance. The NUREG-1727 values have been approved for use by the NRC as values that would be appropriate for facility surfaces and environmental areas cleanup and final status survey to demonstrate suitability to release for unrestricted use and license termination. Surface soils (0-15 cm depth) and soil like material DCGLs are provided in the decommissioning plan and in Table 3-3 that follows for Co-60, Sr-90 and Cs-137 in pCi/gram.

Table 3-3, DCGLs for Surface Soils

Radionuclide	D-Plan Site-Specific DCGL (pCi/g)	NUREG-1727 Generic Screening DCGL (pCi/g)
Co-60	4.6	3.8
Sr-90	32	1.7
Cs-137	18	11.0

Additionally, the decommissioning plan provides subsurface structures DCGLs for some radionuclides expected to be present at the site. DCGLs for these and for the additional radionuclides identified at the PBRF are presented as follows in Table 3-4.

Table 3-4, DCGLs for Subsurface Structures

Radionuclide	D-Plan Site-Specific DCGL (pCi/g)	NUREG-1727 Generic Screening DCGL (pCi/g)
H-3*	144	110
C-14	39	12
Fe-55	71,320	10,000
Co-60	4.1	3.8
Ni-59	4,240	5,500
Ni-63	4,700	2,100
Sr-90	5.5	1.7
Nb-94*	6.7	5.8
Tc-99	37	19
Ag-108m*	6.5	**
Ba-133*	33.5	**
Cs-134*	7.2	5.7
Cs-137	16	11
Eu-152	9.5	8.7
Eu-154	8.7	8.0
U-234*	16.3	13
U-235*	14.4	8
U-238*	16.7	14
Np-237*	0.06	**
Pu-238*	70.7	2.5
Pu-239*	14.4	2.3
Pu-240*	14.4	2.3
Pu-241*	1,680	72
Pu-242*	14.7	**
Am-241*	58.6	2.1
Cm-242*	***	160
Cm-243*	50.5	3.2
Cm-244*	116	**
Cm-245*	23	**
Cm-246*	62	**

*Note: This radionuclide is in addition to the radionuclides listed in the decommissioning plan.
**Note: Value not provided.
***Note: Radionuclide not in RESRAD library.

The decommissioning plan also presents DCGLs for building and facility surfaces in dpm/100cm^2 for some radionuclides expected to be present at the site. DCGLs for these and for the additional radionuclides identified at the PBRF are presented as follows in Table 3-5.

Table 3-5, DCGLs for Building Surfaces

Radionuclide	D-Plan Site-Specific DCGL (dpm/100 cm^2)	NUREG-1727 Generic Screening DCGL (dpm/100 cm^2)
H-3	1.3×10^8	1.2×10^8
C-14*	1.1×10^8	3.7×10^6
Fe-55	1.0×10^8	4.5×10^6
Co-60	1.6×10^4	7.1×10^3
Ni-59*	1.0×10^8	**
Ni-63	4.2×10^7	1.8×10^6
Sr-90	1.99×10^5	8.7×10^3
Nb-94*	2.18×10^4	**
Tc-99*	3.1×10^7	1.3×10^6
Ag-108m*	2.1×10^4	**
Sb-125*	8.31×10^4	**
Cs-134*	2.4×10^4	**
Cs-137	6.55×10^4	2.8×10^4
Eu-152*	2.38×10^4	**
Eu-154*	2.8×10^4	**
U-234*	2.08×10^3	**
U-235*	2.23×10^3	**
U-238*	2.32×10^3	**
Np-237*	5.06×10^2	**
Pu-238*	6.97×10^2	**
Pu-239*	6.4×10^2	**
Pu-240*	6.4×10^2	**
Pu-241*	3.33×10^4	**
Pu-242*	6.66×10^2	**
Am-241*	6.17×10^2	**
Cm-243*	8.88×10^2	**
Cm-244*	1.11×10^3	**

*Note: This radionuclide is in addition to the radionuclides listed in the decommissioning plan.
**Note: Value not provided.

To facilitate initial characterization surveys for measurements of gross contamination, non-radionuclide specific analysis, the DCGL from the most conservative radionuclide for direct gross beta measurements (Co-60) or the most conservative radionuclide for direct gross alpha measurements (Am-241) will be selected, as appropriate. Alternately, the radionuclide mix estimated in the PBRF decommissioning plan will be utilized to determine $DCGL_W$ prior to beginning characterization surveys. Based on the decommissioning plan, an activity distribution of 63% Cs-137, 30% Co-60, and 7% Sr-90 was estimated. This will be used primarily for setting instrument sensitivities and operating parameters for characterization instrumentation. These DCGLs will also be used to guide characterization efforts with regard to bounding the vertical and lateral extent of detected radionuclide contamination. These interim DCGLs will be updated and re-evaluated as more data is made available as a result of characterization data analysis.

3.2.11 Survey Design and Implementation

The purpose of the characterization survey is to collect sufficient survey data to complete the site characterization for the PBRF. The primary purpose of the characterization is to guide remediation and decontamination activities at contaminated areas of the site and aid in waste management operations. Once these areas are remediated and decontaminated and shown to be radiologically below DCGLs as shown by post-remediation survey results, the areas of the facility and site will receive a final status survey to be shown suitable for release for unrestricted use and the Facility Licenses terminated. The project team will perform surveys according to project specific PBRF approved procedures and this characterization survey plan.

Class 1 impacted areas were shown during the 1985 and 1998 surveys to contain areas of radiological contamination and will be decontaminated to levels that would be suitable for subsequent final status survey for release. Therefore, the characterization surveys of Class 1 survey areas where contamination is known to exist will receive bounding surveys. The bounding survey design will based upon the number of measurements and samples required to bound the lateral and vertical extent of the contamination in the survey area. Instructions for the bounding surveys will prescribe biased survey measurement locations and scan areas based upon the 1985 and 1998 survey results. Post-remediation surveys to be performed following decontamination activities will be designed based upon the number of measurements and samples required to verify the decontamination actions were successful and to show no further residual radioactivity above the DCGLs, DCGLs that have been verified to be appropriate, is present in the survey area or survey unit.

The areas surrounding the Class 1 survey areas are either Class 2 or 3 support areas. Non-impacted areas are adjacent to the Class 2 or Class 3 areas. Areas classified as non-impacted or impacted Class 2 or Class 3 will receive surveys developed to include a combination of systematic and biased survey measurement locations and scan areas to supplement what is currently known concerning the condition of the areas with respect to the presence or absence of radiological or non-radiological contamination. Based upon the nature and extent of contamination detected and the areas to be surveyed, some of the survey areas/units floors and lower walls below 2 meters height will be treated as either Class 1 or Class 2 survey unit. Depending on the area, the upper wall above two meters and the ceiling will be treated as either Class 2 or Class 3 survey unit.

3.2.11.1 Number of Measurements/Samples to be Collected

As previously discussed, a survey unit is a discrete area consisting of surfaces with the same potential for contamination, similar physical boundaries and/or dimensions for which a separate decision will be made as to whether or not the area meets the criteria for release for unrestricted use, or suitable for release for restricted use. The survey units to be surveyed as part of this characterization survey will be classified as either a Class 3, Class 2 or a Class 1 survey unit.

According to the MARSSIM, Section 5, for FSS of open land areas there is no size or area limit associated with Class 3 survey units, Class 2 survey units are limited to 10,000 m^2 and Class 1 survey units are limited to 2,000 m^2. For FSS of structures (surfaces) there is no size or area limit associated with Class 3 survey units, Class 2 survey units are limited to 1,000 m^2 and Class 1 survey units are limited to 100 m^2. For the characterization surveys, survey area size will be determined based upon the specific area and the most efficient and practical size needed to bound the lateral and vertical extent of contamination identified in the area.

For a given survey unit the MARSSIM provides direction on how to determine the minimum number of measurement or sample locations to be collected based on the nonparametric statistical test to be used to evaluate the data. Statistical tests are not needed in survey units where survey measurement results show contamination above DCGLs is present. These areas will be marked for decontamination and post-remediation survey. However, surveys conducted in areas that are shown to be suitable for release for unrestricted use will be evaluated in accordance with requirements contained in Section 3.2.20, Data Evaluation and Review and a final status survey plan to be developed for the PBRF. This number is based on the desired power of the statistical test (confidence levels), the expected variation in the sample or measurement results, the width of the gray region which impacts the probability of incorrectly failing to release a survey unit that meets the criteria for release for unrestricted use, and in some cases the sensitivity of the scans to be performed. Measurements performed during previous characterization surveys will be used to identify facilities, equipment and systems impacted by former licensed operations. Remediation activities and waste management operations will be initiated following the characterization surveys conducted according to this plan. The characterization survey results will be used to assess the presence or absence of radiological contamination in each survey area or unit. Following remediation activities, post-remediation surveys will be conducted and used to assess the relative success of the remediation activities in each survey area or unit.

To determine the number of measurements needed in an impacted Class 2, impacted Class 3 or non-impacted survey area or unit, for the characterization surveys, settings recommended in Appendix E, Section 7 of NUREG-1727 and the MARSSIM Section 5.5 will be used. The settings to determine the number of measurements in a survey unit will be as follows:

1) The null hypothesis (H_0) will be that residual radioactivity in the survey area and/or units exceeds the release criterion.

2) For the purpose of the characterization and post-remediation surveys, Type I error (α) will be set at 0.05 or 5 percent and Type II error (β) will be set at 0.10 or 10 percent.

3) The lower bound of the gray region (LBGR) will be conservatively set at 50% of the DCGL, but could be adjusted later to provide a value for the relative shift between the range of 1 to 3.

4) The relative shift will be conservatively set to 1.3.

The number of measurements will be taken from the MARSSIM Table 5.5. This will result in a value of "N" (prescribed number of measurements) equal to 21 for each survey area and/or unit. For added conservatism, the minimum number of measurements for each survey area/unit will be set to thirty (30). For Class 3 survey units, the measurement and sample locations will be random and judgmental (biased), for Class 2 survey areas/units, the measurement and sample locations will be a combination of systematic and judgmental (biased) and for Class 1 survey areas/units, the measurement and sample locations will be systematic. In addition to the systematic measurements to be collected or performed in Class 1 survey areas/units, biased measurements may be collected at locations with potential for contamination.

For the characterization and post-remediation surveys of building, facility and equipment surfaces, beta scans and direct measurements for total beta surface contamination and smear samples for removable alpha and beta surface contamination will be performed. Areas of elevated count rate identified during the scans will receive direct measurements and samples as directed by survey package instructions. Direct measurements for total alpha surface contamination will be performed as directed by survey package instructions. An alpha/beta ratio may be developed to aid in determining when a direct alpha measurement should be performed. For open land survey areas/units within the impacted portion of the site, scanning will follow Section 4.1.3.2 of the decommissioning plan and Appendix E, Section 6 of NUREG-1727. Class 3 survey areas/units will receive judgmental scans, Class 2 survey areas/units will receive 10 to 100% judgmental and/or systematic scans and Class 1 survey areas/units will receive 100% systematic scans. For the post/final remediation surveys, approximately 5 to 10 % of the accessible surface area within Class 3 survey units will be scanned, approximately 10 to 100% of the accessible surface area within Class 2 survey units will be scanned and 100% of the accessible surface area within Class 1 survey units will be scanned. The scans for Class 3 and Class 2 survey units will be performed in the immediate vicinity of each sample or measurement location.

3.2.11.2 Sample/Measurement Grid Spacing

The grid spacing for the measurement and samples is estimated in two ways depending upon the shape of the grid (either triangular or rectangular grid). If a triangular grid is used, the grid spacing is estimated as follows:

$$L = \sqrt{\frac{A}{0.866N}}$$

Where A = Survey unit Area
N = Number of measurements

If a square grid is used, the spacing is estimated as follows:

$$L = \sqrt{\frac{A}{N}}$$

3.2.11.3 Starting location

Once the number of measurements and the grid spacing are determined, a starting point for the survey must be established for each survey unit. This will be performed by selecting a reference point for the survey unit, such as the corner of the room, and using a random number generator to provide a random number between 0 and 1, for an initial offset from the reference point in both the x and y coordinates. The random number pair will be multiplied by the calculated grid spacing, providing the offset from the reference point for the first grid location.

Upon establishing the first grid location, the calculated grid spacing will be used to establish a grid system throughout the survey unit. If the survey unit includes the floor, walls and ceiling, the grid will be extended to all surfaces from the initial point.

Once gridded, a check to ensure that the number of grid locations satisfies the calculated number of measurements will be performed. If not, a smaller grid spacing will be used to ensure the minimum number of measurements/samples are obtained.

3.2.11.4 Survey Implementation

The implementation of this survey plan will include the following:

- Survey instrumentation will be set up and source checked to ensure proper operation.
- The Survey Supervisor will perform preliminary inspections of the areas to identify additional specific survey requirements.
- The Survey Supervisor will review for applicability the survey packages developed for the survey areas.
- The project team will establish the survey area grid by following survey protocols and map the survey locations as applicable.
- The project team will take survey measurements and analyze samples using appropriate calibrated instruments and perform daily source and background checks before and after each day's work.
- Survey measurements and sample analysis data collected during the characterization will be downloaded from the survey and analysis instrumentation into a database for storage and processing.
- The Survey Supervisor will review the completed survey packages to ensure that all required surveys have been performed.
- The Survey Supervisor will review the survey results to identify any areas exceeding the specified characterization criteria.

In order to support the characterization surveys of the building, the facility will be cleared of all loose equipment and materials to the maximum extent possible.

3.2.12 Instrumentation and Selection

Selection and use of survey instrumentation will ensure sensitivities are sufficient to detect the radionuclides of concern at or below minimum detection requirements. Table 3-6 presents a list of the instruments, types of radiation detected and calibration sources, which may be utilized.

The characterization survey team will use Data Logger instrumentation such as a Ludlum Model 2350 or equivalent instrument with a variety of detectors for direct measurements of alpha and beta surface contamination as well as exposure rate measurements. The Data Logger is a portable micro-processor computer based counting instrument capable of operation with NaI(Tl) gamma scintillation, gas-flow proportional, GM and ZnS scintillation detectors.

Detector selection will depend upon the type of survey, surface contour and survey area size. The project team will typically use 126 cm^2 gas-flow proportional detectors such as a Ludlum Model 43-68 or equivalent detector for direct alpha and for direct beta measurements in most areas. The 15.5 cm^2 GM detector will be used for direct beta measurements for smaller areas in

which the gas-flow proportional detector will not fit. Exposure rate measurements and gamma scans will be performed using 2"x 2" NaI (Tl) gamma scintillation detector such as a Ludlum Model 44-10 or equivalent.

The majority of smear sample counting and analysis for removable alpha and beta contamination will be performed using a low background automatic gross alpha/beta counter such as a Tennelec or Protean counter. Some smear sample counting and analysis for removable alpha contamination will be performed using a manual gross alpha counter such as the Eberline Model SAC-4 scaler counter or equal. Some smear sample counting and analysis for removable beta will be performed using a manual gross beta counter such as the Eberline Model BC-4 scaler counter or equivalent.

Tritium smear sample counting and analysis will be performed using a quench corrected liquid scintillation counter such as a Packard Model 2900 or equivalent. The liquid scintillation counter could also be setup, calibrated and utilized for counting other hard to detect radionuclides suspected or known to be present at the PBRF, such as C-14, Ni-63 or pure beta emitters, such as Sr-90. The need and/or requirement for using the liquid scintillation counter for measurement of radionuclides other than tritium will be evaluated as the characterization survey progresses.

Samples for gamma spectrometry analysis will be counted and analyzed using a Canberra Inspector reverse electrode, "N" type high purity germanium (HPGe) detector based gamma spectroscopy system or detector with equal performance. Samples to be analyzed by gamma spectroscopy may include soil, sediment, water, filters or smears and various other bulk materials such as concrete and asphalt.

Table 3-6, Survey Instrumentation

Instrument/ Detector	Detector Type	Radiation Detected	Calibration Source	Use
Ludlum Model 2350-1 with 44-116 detector or equal	Plastic Scintillator (126 cm^2)	Beta	^{99}Tc (β)	Direct beta measurements and beta scan surveys.
Ludlum Model 2350-1 with 43-90 detector or equal	ZnS Scintillator (126 cm^2)	Alpha	^{230}Th (α)	Direct alpha measurement surveys.
Ludlum Model 2350-1 with 43-37 detector or equal	Large area gas-flow proportional (580 cm^2)	Alpha and/or beta	^{99}Tc (β) ^{230}Th (α)	Floor Monitor detector for beta scan survey.
Ludlum Model 2350/ SP-113-3m or SP-175-3m or equal	GM Pipe Detector	Beta	^{99}Tc (β)	Direct beta pipe survey.
Ludlum Model 2350 with. 44-40 detector or equal	Shielded GM (15.5cm^2)	Beta	^{99}Tc (β)	Direct beta surveys; Beta scans.
Ludlum Model 2350 with. 44-10 detector or equal	NaI (Tl) Scintillator	Gamma	^{137}Cs (γ)	Gamma exposure rate and gamma scans.
Eberline SAC-4 Scaler Counter	ZnS Scintillator	Alpha	^{230}Th (α)	Smear counting
Eberline BC-4 Scaler Counter	Shielded GM	Beta	^{99}Tc (β)	Smear counting
Protean Planchet Counter or Equal	Shielded Gas-flow proportional	Alpha and Beta	^{99}Tc (β), ^{230}Th (α)	Smear counting
Packard Liquid Scintillation Counter or Equal	Photo-multiplier tube (PMT) and Liquid Scintillator	Low Energy Beta, including Tritium and C-14	^{3}H (β), ^{14}C (β)	Tritium Smear counting
ORTEC HPGe detector based Gamma Spectrometer or Equal	HPGe	Gamma energy and intensity	Mixed gamma	Nuclide identification and quantification of media samples.

3.2.13 Instrument Calibration

The data loggers, associated detectors and all other portable instrumentation will be calibrated on an annual basis using National Institute of Standards and Technology (NIST) traceable sources and calibration equipment. Calibration typically includes:

- High Voltage calibration,
- Discriminator/threshold calibration,
- Window calibration,
- Alarm operation verification, and
- Scaler calibration verification

The detector calibration includes:

- Operating voltage determination,
- Calibration constant determination, and
- Dead time correction determination

Calibration labels showing the instrument identification number, calibration date and calibration due date will be attached to all portable field instruments.

The gamma spectroscopy system will be calibrated on an annual basis using National Institute of Standards and Technology (NIST) traceable sources. Quality control documentation for the gamma spectroscopy system and all portable or semi-portable instrumentation is maintained at the PBRF project location.

3.2.14 Sources

All sources used for calibration or efficiency determinations for the survey will be representative of the instrument's response to the identified radionuclides and are traceable to NIST. The sources that will be used during the surveys will include ^{99}Tc, ^{230}Th, ^{137}Cs and mixed gamma sources.

Health Physics Technicians will control the radioactive sources used for instrument response checks and efficiency determination in accordance with approved procedures for possessing and using check sources at the PBRF site. Sources will be stored securely and signed out when needed in the field. A source sign-out log will track the location of all sources when they are removed from the source storage area.

3.2.15 Survey Protocols/Requirements

The characterization survey of building surfaces will consist of surface scans (beta and gamma); direct alpha and direct beta measurements, and smears for removable gross alpha, removable gross beta and tritium analysis. The characterization survey of the asphalt-paved areas will consist of surface scans (beta and gamma), direct alpha and direct beta measurements. The facility ground areas, interior and exterior to the buildings where the surface covering has been

removed to the underlying soil, for characterization activities, will be surveyed as facility grounds. The survey of the facility grounds will consist of gamma scans and soil sampling for gamma spectroscopy analysis. Surveys will be performed as follows:

1) Beta Surface Scans

Beta scans will be performed as instructed in each survey package over accessible floor, wall and ceiling interior surfaces and exterior walls, roof and asphalt and concrete paved areas using a gas-flow proportional detector or detector with equal capability while listening to instrument audible output and observing the instrument readout. For characterization, the scan areas will be as needed for bounding contamination for Class 1 survey units, 10% to 100% for Class 2 survey units, and as needed or judgmental for Class 3 survey units. The beta scans will be performed using large area (126 cm^2) gas flow proportional detector or equivalent in combination with the data logger such as the Ludlum Model 2350. Beta scans of surfaces will be performed holding the detector approximately ¼ inch to ½ inch (0.6 cm to 1.2 cm) from the surface and moving the detector at a rate of one detector width per second over the area. The scan speeds will be verified such that contamination at levels of less than the $DCGL_W$ will be detected if present. During the scanning process, the data logger instruments' audible output will be monitored and the digital display readout observed for any elevated counts detected. Beta scans will be performed around and including each direct measurement location. All areas of elevated contamination will be identified for further investigation and potential decontamination. Any area exceeding the $DCGL_W$ will be identified and marked for decontamination.

2) Gamma Surface Scans

Gamma scans will be performed as instructed in each survey package in some inside areas and in all outdoor soil areas of the PBRF, above the surfaces of soils, floor, as well as outside the building around the asphalt and concrete paved areas and immediately around the buildings. For characterization, the scan areas will be, as needed to bound contamination for Class 1 survey units, 10% to 100% for Class 2 survey units, and as needed or judgmental for Class 3 survey units. A 2"x 2" NaI (Tl) gamma scintillation detector will be used with a data logger such as the Ludlum Model 2350 to help identify any areas of residual contamination in the soil or the building interior. When scanning, the detector will be moved in a serpentine manner in close proximity with the surface while listening to the audible output of the instrument. The digital display readout will also be observed for any elevated counts detected. Any areas where a noticeable increase in the count rate is determined will be flagged for further investigation and/or sampling.

3) Exposure Rate Measurements

Exposure rate measurements will be performed as instructed in each survey package inside the facility structures above the floor, as well as outside the building around the asphalt and concrete paved areas and around the buildings. A 2"x 2" NaI (Tl) gamma scintillation detector will be used with the data logger such as the Ludlum Model 2350 to help identify any areas of residual contamination in the soil or the building interior. The exposure rate measurements will be performed at survey measurement location on building floor and the

grounds with the detector 1 meter above the surface and no closer to 1 meter proximity with any other surface. The exposure rate measurement count time will be integrated for 15 to 60 seconds as required by survey package instructions.

It is important to note that exposure rate measurements are not required measurements to demonstrate clean up goals have been achieved. Sampling and analysis of materials with analysis results in pCi/g and measurements for direct and removable surface contamination with results in dpm/100cm^2 are the primary measurements. These primary measurements will be used to demonstrate that clean up goals have been achieved and that a survey area or unit is suitable for release for unrestricted use in accordance with current regulations and regulatory guidance. Therefore, the primary measurements are the only measurements that will be compared to DCGLs relating to release criteria. Exposure rate measurements will be collected for "information only" and only as an indication that contamination may or may not be present in a survey area, unit or location.

4) Direct Surface Contamination Measurements/Sampling

Direct surface contamination measurements, for total alpha contamination and for total beta contamination, will be taken on the structural surfaces of the buildings and on concrete or asphalt paved areas within each survey area/unit as instructed in each survey package. The direct alpha and direct beta measurements will be performed using large area (126 cm^2) gas flow proportional detectors or detector with equal capability in combination with a data logger instrument such as the Ludlum Model 2350 survey meter. The alpha and beta measurements are performed with the same data logger and detector, but with alpha specific or beta specific set-up for the detector high voltage. Due to the different set-up for alpha and for beta, the surveys will be performed in two distinct surveys. However, the direct alpha measurements may be performed at a fraction of the same locations as the direct beta measurements in the survey unit as directed by survey package instructions.

5) Removable Contamination Measurements

Smears will be taken at each direct alpha and beta contamination measurement location for removable gross alpha and gross beta analysis as instructed in each survey package. Smear samples for the measurement of removable gross alpha and gross beta surface contamination will be performed by applying pressure to the smear sample and wiping the smear over an area approximately equal to 100 cm^2. Smears will be taken as directed at direct alpha and beta contamination measurement locations for removable tritium analysis as instructed in each survey package. Smear samples for the measurement of removable tritium contamination will be performed by applying pressure to a smear, solely for tritium measurement and analysis moistened with DI water (or water shown to be free of radioactivity) and wiping the smear over an area approximately equal to 100 cm^2. The smear will then be placed into a 20 ml scintillation vial for subsequent preparation according to approved procedures.

6) Core bore Sampling

Core bore sampling will be performed as needed for depth of contamination type measurements. Core bore sampling for concrete covered surfaces may involve the use of a core drill with a 4 or 6-inch diameter diamond bit and a forklift to stabilize the unit. The cutting of the concrete is performed with water applied to the cutting bit as not to overheat and preserve the cutter. The wet operation also reduces the possibility of airborne contamination of concrete dust and radionuclide contamination. A berm will be placed around the area where core bore operations are performed and the water used during the operation will be collected by a wet vacuum. Core bore sampling for asphalt covered surfaces may involve the use of an electric powered jackhammer. Once removed from the borehole, the material (asphalt or concrete) covering the soil surface will be analyzed to determine if the contamination is present on the top or bottom of each concrete core by performing direct alpha and/or direct beta measurements on each side. If contamination is determined to be present in or on the core, the depth of radionuclide contamination will be determined. This will involve slicing concrete core bores into ½" (1.3 cm) slices and performing direct alpha and/or direct beta measurements on the top and bottom of each slice until contamination is shown to be less than the clean up goal. There will be a consideration for contamination levels increasing with depth due to activation during core bore evaluations. On asphalt, subsequent layers may be separated to reveal and measure contamination between the layers.

7) Material Sampling

Material samples including soil, sediment and sludge will be collected as instructed in each survey package. An adequate amount of material will be collected at each location to allow for split sample analysis on 5% of the samples collected. If obtainable, approximately one to two liters of material will be collected, dried, homogenized and sieved to minus 1/4-inch mesh to remove debris from the sample. A high purity germanium (HPGe) gamma spectroscopy system will be used for the onsite gamma spectral analysis of soil samples. During the characterization, depth profiles will be performed and samples collected at depth intervals (i.e., vertical depths) specified in the instructions for each survey package. This operation will use a 3 to 4 inch diameter stainless steel auger or with motorized sampling equipment such as a Geoprobe with a split spoon sampler.

8) Liquid Sampling

Liquid samples will be collected as instructed in each survey package. If present, an adequate amount of liquid will be collected from monitoring wells, sumps, drain traps and liquid storage tanks for a one liter sample. Liquid samples will be taken as directed for gamma spectral analysis, tritium and pure alpha/beta emitters analysis as instructed in each survey package.

Laboratory analyses, including gamma spectrometry, liquid scintillation counting and low background alpha/beta counting, will be performed onsite by trained PBRF characterization survey personnel. In addition, 10 CFR Part 61 and split sample analyses will be performed by an

offsite laboratory, as necessary, to measure all radionuclides including hard to detect radionuclides and/or for the presence of non-radiological constituents for selected samples according to the guidance provided in Section 3.2.21 of this plan. Analyses will also be performed by an offsite laboratory to validate the PBRF characterization onsite lab results according to the guidance provided in Section 4.3 of this plan to satisfy quality assurance requirements.

3.2.16 Minimum Detectable Concentration

Minimum Detectable Concentration (MDC) is defined as the smallest amount or concentration of radioactive material that will yield a net positive count with a 5% probability of falsely interpreting background responses as true activity from contamination. The MDC is dependent upon the counting time, geometry, sample size, detector efficiency and background count rate. As a Data Quality Objective, the MDCs will be set to approximately equal to or less than 50% of the applicable Derived Concentration Guideline Level. There are two different MDCs that will be utilized, one for direct alpha and beta surface contamination measurements, MDC_{Static} and one for field beta scanning of surfaces, MDC_{Scan}. These are calculated differently and each will be incorporated into the operating procedures as appropriate. The equation to be used for calculating the MDC_{Static} for direct alpha and direct beta measurements using field instrumentation is as follows:

$$MDCstatic = \frac{\frac{2.71}{t_s} + 3.29\sqrt{\frac{R_b}{t_s} + \frac{R_b}{t_b}}}{E\left(\frac{A}{100}\right)}$$

Where:	MDC_{Static}	=	Minimum Detectable Concentration (dpm/100 cm^2)
	R_b	=	Background Count Rate (cpm)
	t_b	=	Background Count Time (min)
	t_s	=	Sample Count Time (min)
	A	=	Detector Area (cm^2)
	E	=	Detector Efficiency (c/d)

The equation that will be used to calculate the beta scan MDC_{Scan} for surfaces is as follows:

$$MDCscan = \frac{d' * \sqrt{b_i} * \frac{60}{i}}{E_i * E_s * \sqrt{p} * \frac{A}{100}}$$

Where:	MDC_{Scan}	=	Minimum Detectable Concentration (dpm/100 cm^2)
	d’	=	Decision error taken from Table 6-5 of MARSSIM
	i	=	Observation counting interval (scan speed divided by the detector width)
	b_i	=	Background count per observation interval
	E_i	=	Detector Efficiency (c/d)
	E_s	=	Surface Efficiency (typically around 50% for beta contamination on concrete)
	p	=	Surveyor Efficiency (typically 50%)
	A	=	Detector Area (cm^2)

For scanning soil with a sodium iodide gamma detector, the MDC_{Scan} values presented in Table 6.7 of MARSSIM will be used. According to NUREG-1727, the MDC_{Scan} values presented in Table 6.7 of MARSSIM provide an acceptable estimate of MDC_{Scan} for the survey.

The MDC for the gamma spectral analysis of soil will be based on sample count times sufficient to detect at 50% or less of the DCGLs for the radionuclides of concern or for best sensitivity achievable. The gamma spectroscopy system will be operated such that for Co-60 and Cs-137, a MDC of less than 0.5 pCi/g will be maintained. The calculation of the MDC for the gamma spectroscopy system is a function of the analysis software. The gamma spectroscopy system planned for the project may include an ORTEC HPGe detector based system with GammaVission™ software. The daily verification that 0.5 pCi/g MDC for Co-60 and Cs-137 will be maintained will be provided in conjunction with daily system background checks.

The MDC for the alpha/beta counter for analysis of removable alpha/beta contamination during characterization will be based on sample count times sufficient to detect at 5% or less of the $DCGL_W$ for the radionuclide mix appropriate for the survey area or for best sensitivity achievable. The daily verification that 5% or less of the $DCGL_W$ for the radionuclide mix appropriate for the survey area will be maintained will be provided in conjunction with daily system background checks.

The MDC for the liquid scintillation counter for analysis of tritium contamination during characterization will be based on sample count times sufficient to detect at 5% or less of the DCGL for tritium or for best sensitivity achievable. The daily verification that 5% or less of the DCGL for tritium will be maintained will be provided in conjunction with daily system background checks.

3.2.17 Survey Records

The project team will maintain records of surveys in the survey packages for each area according to project procedures. The survey package will include the following records depending upon the survey design and protocols:

1) Survey Package Worksheet giving the package identification, survey location information, general survey instructions and any specific survey instructions
2) Survey Unit Diagram or drawing of the area to be surveyed as available
3) Photographs of the survey area, as necessary, to show special or unique conditions
4) Printout of laboratory gamma spectroscopy analysis results, if performed, and in appropriate units, i.e., pCi/gram
5) Data logger (Ludlum Model 2350) data files with measurement results converted to appropriate units (i.e., dpm/100 cm^2) for all direct surface contamination measurements
6) Alpha/beta smear counter data files with measurement results converted to appropriate units (i.e., dpm/100 cm^2) for all removable surface contamination measurements
7) Tritium counter data files with measurement results converted to appropriate units (i.e., dpm/100 cm^2) for all tritium contamination measurements

The PBRF survey team will use instrument vendor provided computer programs to download the contents and survey data from the data logger memory and from analytical instrument computers to SDMS measurement specific databases. Survey reports that present all raw data, converted data, and information by survey location will then be generated. The survey technician and supervisor will review these reports for completeness, accuracy, suspect entries and compare the data to appropriate characterization DCGLs.

Any changes to the database tables such as detector efficiency and background, that could affect survey results, will require approval by the characterization survey supervisor. In addition, changes to data in the primary table will require a written explanation on a change request. The change request will be attached to the survey report and maintained as a permanent record.

Data and document control will include the maintenance of the raw data files, translated data files and documentation of all corrections made to the data. The databases will be backed up on a daily basis.

3.2.18 Characterization Survey Package Instructions

These survey package instructions will be developed according to the guidance provided in the MARSSIM regarding field sampling plans for radiological surveys. The survey package instructions will describe the number, type, and location of direct measurements and samples with the analyses to be performed. Specific survey package instructions will be developed for each area to be surveyed in accordance with this characterization plan for structure surfaces, systems and environmental areas.

3.2.18.1 Structure Surfaces

Specific survey package instructions will be developed to provide guidance to characterization survey personnel with regard to performance of measurements and collection of samples for structure surfaces survey areas and/or units. Once the survey area or unit has been prepared for surveying, grid reference system installed and/or survey measurement locations (SMLs) marked, survey personnel will begin the characterization survey by performing beta scans of asphalt, concrete areas and building interiors or exteriors as directed by the survey package instructions. The scans are necessary to reacquire elevated areas identified in the previous characterization report. These surveys will confirm prior characterization results and aid in delineating radiologically contaminated areas from clean areas. For surfaces and structures, prior to core boring or surface removal, the measurements that follow may be performed as directed by survey package instructions:

- Beta scans at ¼ inch to ½ inch (0.6 cm to 1.2 cm) above the surface
- Direct measurements for total alpha contamination
- Direct measurements for total beta contamination
- Smear samples for removable alpha and beta contamination
- Smear samples for removable tritium contamination
- Exposure rate measurements at 1 meter above the floor surfaces

The beta scans will be followed by direct measurements for total alpha and beta contamination, smear samples for removable alpha and beta contamination, smear samples for tritium contamination and exposure rate measurements at 1 meter above floor surfaces. The beta scans at each sample location covering a specified square meter area will be performed with the detector approximately ¼ inch to ½ inch (0.6 cm to 1.2 cm) above the surface for structure surfaces and paved areas as directed in survey package instructions. Locations with readings of two times background or higher count rate during the scan will be marked for further measurements. Direct measurements for total alpha contamination, direct measurements for total beta contamination, and smear samples for removable alpha, beta and tritium contamination will be performed as directed in the survey package and at location of highest count rate above background from the beta scan. If no areas of high count rate are identified during the scan, the direct measurements will be performed at the approximate center of the scanned area.

Once the surface radiation measurements have been completed for surfaces of structural areas, if contamination is detected and depth profiling is needed, borehole sampling will be performed in the area as directed by the survey package instructions. Borehole sample locations will be biased and based upon the need for further characterization. If contamination is detected at levels greater than the DCGL, the depth of contamination will be investigated. Once removed from the borehole, the material (asphalt or concrete) covering the surface will be analyzed to determine if the contamination is present on the top or bottom of each concrete core by performing direct alpha and/or direct beta measurements on each side. If contamination is determined to be present in the core, the depth of radionuclide contamination will be determined. For concrete core bores, this will involve slicing the core into ½" (1.3 cm) slices and performing direct alpha and/or direct beta measurements on the top and bottom of each slice until contamination is shown to be less than the clean up goal. On asphalt, subsequent layers may be separated to reveal and measure contamination between the layers.

3.2.18.2 Environmental Areas

Specific survey package instructions will be developed to provide guidance to characterization survey personnel with regard to performance of measurements and collection of samples for environmental survey areas and/or units. Once the survey area or unit has been prepared for surveying, grid reference system installed and/or SMLs marked, survey personnel will begin the characterization survey by performing gamma scans of soil areas as directed by survey package instructions. The scans are necessary to reacquire elevated areas identified in the previous characterization report and will aid in delineating radiologically contaminated areas from clean areas. The surface soil radiation measurements that follow will be performed at locations indicated in survey package instructions:

- Gamma scans at 15 cm above the surface for soil areas and as directed for surfaces,
- Exposure rate measurements at 1 meter above sample locations of soil surfaces, and
- Surface soil samples (0-15 cm depth) for gamma spectrometry analysis.

The gamma scans will be followed by exposure rate measurements at 1 meter above the surface and surface soil samples (0-15 cm depth) for gamma spectrometry analysis. Once, the surface soil radiation measurements have been completed, if contamination is detected at levels greater than the soil DCGL, the depth of contamination will be investigated. Soil borehole sampling will be performed at intervals at the SML as directed by the survey package instructions. Borehole sample locations will be biased and based upon the need for further characterization.

If contamination continues to be detected and further depth profiling is needed, successive depth soil samples will be collected at the SML until concentrations of contamination are below the cleanup goals as determined by gamma spectrometry analysis. The intervals for further depth profile samples may include the sample depths as follows or until refusal is met.

- Subsurface soil samples from 15-30 cm depth
- Subsurface soil samples from 30-60 cm depth
- Subsurface soil samples from 60-90 cm depth
- Subsurface soil samples from 90-120 cm depth
- Subsurface soil samples from 0-1 meter depth
- Subsurface soil samples from 1-2 meter depth
- Subsurface soil samples from 2-3 meter depth
- Subsurface soil samples from 3-4 meter depth
- Subsurface soil samples from 4-5 meter depth

Liquid samples will be collected as instructed in each survey package. If present, an adequate amount of liquid will be collected from monitoring wells, drainage areas and/or water accumulation areas for a one liter sample. The liquid samples will be analyzed by gamma spectral analysis, liquid scintillation counting for tritium or other pure alpha/beta emitters analysis or other analyses as instructed in the survey package.

3.2.18.3 Systems

Specific survey package instructions will be developed to provide guidance to characterization survey personnel with regard to performance of measurements and collection of samples for PBRF systems survey areas and/or units. Equipment associated with the system may be surveyed as a part of the system survey unit or could be surveyed within a room or space as an "Equipment" surface and as part of a structures survey unit. Once the survey area or unit has been prepared for surveying, the system opened and/or SMLs identified or marked, survey personnel will begin the characterization survey by performing direct contamination measurements within the system on accessible surfaces and collecting smear samples for removable contamination. The direct measurements and smears samples will be followed by collecting liquid and/or media samples from within the system, if available. If present in a system, an adequate amount of sediment and/or liquid will be collected from sumps, drain traps and liquid storage tanks for gamma spectrometry analysis and/or liquid scintillation counting to complete the system characterization.

Liquid samples will be collected as instructed in each survey package. If present, an adequate amount of liquid will be collected from sumps, drain traps and liquid storage tanks for a one liter sample. The liquid samples will be analyzed by gamma spectral analysis, liquid scintillation counting for tritium or other pure alpha/beta emitters analysis or other analyses as instructed in the survey package.

3.2.18.4 Sewer and Storm Drain Survey

Pipe surveys will be performed at sewer and storm drain access locations as directed by instructions contained in the survey package for each survey area or survey unit containing a sewer or storm drain. If the sewer or storm drain traverses a survey area or unit, measurement results from the accessible openings will be used to assess the radiological condition and status of the sewer or storm drain. The pipe surveys will be performed where accessible to a maximum distance of 10 feet. If contamination above the cleanup goal is detected in the sewer or storm drain, the results will be evaluated and actions to correct the condition will be developed, as appropriate.

3.2.19 Data Evaluation and Review

Direct alpha and direct beta measurements collected during the characterization surveys will be compared against the DCGLs. The soil sample analysis results will also be compared against the soil DCGL values. If multiple radionuclides attributable to licensed activities were identified in the soil, the sum of the fraction rule will apply. Individual survey results exceeding 50 % of the DCGL criteria will be identified. Survey results that approach or exceed the DCGL will be considered cause for additional investigation or decontamination and/or remediation actions.

A detailed background study will be performed at the beginning of the characterization surveys. The background study will be used to determine the contribution of naturally occurring radioactivity (NORM) in building materials. The study will determine the effect on the survey results for concrete, concrete block, asphalt, ceramic tile and any other commonly used materials used during the PBRF construction. The following equation will be used to convert direct alpha and direct beta measurement results to activities per unit area for comparison to the DCGL.

$$X_i = \frac{\left(\frac{C_{s+b}}{t_s} - \frac{C_b}{t_b} \right)}{E_T \left(\frac{A}{100} \right)}$$

Where:

X_i	=	individual measurement result in units of activity per unit area, dpm/100 cm2
C_{s+b}	=	direct beta measurement result, counts
C_b	=	backgrounds, counts
t_s	=	sample count time, minutes
t_b	=	background count time, minutes
E_T	=	total detector efficiency (MARSSIM Section 6.6.1)
A	=	detector area, cm2

The mean activity level or mean counts for the scan surveys, and the standard deviation in the mean activity level or mean counts for the scan surveys will be calculated using all available measurement results for the surface surveyed and the following equations.

$$\overline{X} = \frac{\sum x_i}{n}$$

Where:

$\overline{X}$ = the mean activity level, dpm/100 cm^2 or counts,
x_i = individual measurement result i, dpm/100 cm^2
n = the number of measurement results, unitless.

and

$$s_x = \sqrt{\frac{\sum \left(\overline{X} - x_i\right)^2}{n-1}}$$

Where:

S_x = the standard deviation of the mean activity level, in dpm/100 cm^2 or counts,

$\overline{X}$ = the mean activity level, dpm/100 cm^2 or counts,
x_i = individual measurement result i, dpm/100 cm^2
n = the number of measurement results, unitless.

At the completion of the surveys conducted in each survey area or survey unit of the site, measurement results will be obtained and evaluated according to the characterization DQOs. If the lateral extent of contaminated areas has not been determined by the measurements prescribed in the survey package instructions, more measurements may be prescribed to delineate where surface contamination is no longer present. If the vertical extent of contaminated areas has not been determined by core bore samples prescribed in the survey package instructions, subsequent depth core bore samples will be prescribed to delineate where subsurface contamination is no longer present. The guidance provided in the MARSSIM of survey, measure, analyze data and data evaluation according to the survey DQOs will be repeated during the characterization. Once all DQOs have been achieved, the characterization will be considered complete.

3.2.20 Determination of Compliance

Once the characterization has been completed for some survey areas where remediation was not needed, survey team personnel may review the survey report to determine if the survey could be used as final status survey data. This will involve evaluation of the measurement data to confirm that the survey units were properly classified in accordance with the MARSSIM Section 8.2.2 and that the survey meets the requirements of a final status survey plan developed for the PBRF. If the evaluation of the survey shows that an area was misclassified with a less restrictive

classification, the area will receive the correct classification and the final status survey for the area will be performed. If the survey area or unit required decontamination during remediation operations, area will receive the correct classification and the final status survey for the area will be performed.

If the evaluation of the survey shows that an area was properly classified and requirements of a final status survey plan were met, an evaluation will be performed to determine whether the measurement results demonstrate that the survey unit meets the radiological criteria to release for unrestricted use. The PBRF decommissioning plan has established a requirement for the decontamination that would relate levels of residual radioactivity above background of less than 25 mrem/year TEDE to an AMCG. To achieve this clean up goal, any measurements greater than the DCGL would require further decontamination. If a survey area or unit was surveyed and shown to meet the decontamination goal, this survey area or unit will also meet the radiological criteria for license termination and considered a candidate to release for unrestricted use.

If a survey area or unit was surveyed and shown to not meet the decontamination limit, this survey area or unit will be evaluated further in accordance with Section 8.3 and Section 8.5 of the MARSSIM. The Sign test is described in Section 8.3 of the MARSSIM and the elevated measurement comparison is described in Section 8.5 of the MARSSIM. The elevated measurement is applied to all sample measurements and all scanning results that exceed the $DCGL_W$. From this evaluation if the survey area or unit requires decontamination, the area will receive the correct classification and the final status survey for the area will be performed. From this evaluation if the survey area or unit does not require decontamination, the area will be considered meeting the radiological criteria for license termination and considered a candidate to release for unrestricted use.

Analytical data for survey areas or units considered candidates for release for unrestricted use will be presented to NASA for review and approval. NASA will make a determination if the analytical data for survey areas or units considered candidate for release for unrestricted use will be presented to the NRC for concurrence.

3.2.21 Waste Stream Profiling

As stated in the decommissioning plan Section 3.2.2.1, Waste Characterization, proper waste characterization is required by the NRC, U.S. EPA, Ohio EPA, and U.S. Department of Transportation (DOT); the states in which the disposal facilities are located; and the license that regulates each disposal facility. Proper characterization is also important for waste minimization because improper identification and characterization can result in increasing the volume of low-level waste requiring disposal. Waste characterization is required by 10 CFR Part 61 for near surface burial of radioactive waste. Waste characterization data are also needed to (1) comply with the shipping regulations in 49 Parts CFR 172 and 173 for radioactive and other hazardous materials, (2) demonstrate compliance with the waste acceptance criteria at each disposal facility, (3) comply with temporary storage requirements until the waste leaves the PBRF site and/or (4) determine that the waste is not hazardous and therefore not considered a hazardous or mixed-waste in accordance with 40 CFR 266.

The D&D of the PBRF will result in the conversion of radioactive and/or hazardous material contaminated structural materials, loose equipment, fixed equipment, soil, debris and other contents of the PBRF into properly characterized waste. The PBRF materials to be removed will be categorized into a waste stream to facilitate dispositioning the material after it is removed. The material status, whether for re-use, processing or for disposal as waste, will be determined in accordance with the Waste Management Plan. Waste streams are defined by the physical property of the material or materials that comprise the waste stream and will be further subdivided into waste classifications due to contaminants present in the waste. Table 3-7 that follows represents waste streams that may be encountered during the PBRF decommissioning. Sampling and analysis will be performed to further determine classification of each of the waste streams as radioactive, hazardous and/or mixed waste (radioactive and hazardous combined) or other regulated wastes (such as polychlorinated biphenyls containing wastes).

Table 3-7, PBRF Waste Streams

Waste Stream
Soil
Building Debris
Miscellaneous Metals
Hot Dry Storage Materials
Hot Cells
Reactor Vessel
Concrete
Asbestos
Scabble/Decontamination Debris
Hazardous substances and materials (not regulated as hazardous wastes)
Liquids
Sludges
Lab Packs (for small quantities of compatible wastes)
DAW

Once these materials have been removed from the PBRF, the materials from each waste stream will require packaging suitable for accumulation, storage and transportation to an approved waste processor or directly to a disposal facility. As discussed previously in this plan, to identify applicable regulatory and disposal facility requirements, characterization of the facility must occur to determine what materials are contaminated as well as the nature and extent of the contamination. Knowledge of the radiological and/or hazardous constituents present and the range of contaminant concentration present in a waste stream is a requirement of disposal facilities and is needed by NASA and the decommissioning team to determine disposal options. Depending on the waste stream and nature and extent of the contamination present, some of the waste may be eligible to be sent to a waste processor. A waste processor may be able to apply cost saving processes to reduce the cost for subsequent disposal such as volume reduction by incineration, compaction, and melting or further decontamination. For each option available to NASA for the disposition of the PBRF materials, the applicable waste stream will be tested as needed by the chosen facility acceptance criteria.

Guidance provided in Federal Register Notice, November 20, 1997, Volume 62, Number 224, Page 62079-62094, *Joint NRC/EPA Guidance on Testing Requirements for Mixed Radioactive and Hazardous Waste*, emphasizes the use of process knowledge, whenever possible, to determine if a waste is hazardous as a way to avoid unnecessary exposures to radioactivity. This guidance also states that RCRA regulations do not require testing and that it is the responsibility of the generator to determine if a material is a RCRA hazardous waste in accordance with 40 CFR 262.11 (c). However, historical data were not available to specify the presence of all hazardous materials that may be present at the PBRF. In this case, the NRC/EPA guidance prescribes testing for hazardous materials, but recommends "that the frequency of such testing be held to a minimum, in order to avoid duplicative testing and repeated exposure to radiation." This guidance also allows for testing of surrogate, chemically identical material with significantly less or no radioactivity to determine the presence or absence of hazardous material contaminants.

The waste stream profile sampling and analysis will be conducted in accordance with this plan, the Quality Assurance Plan, the Waste Management Plan, the Environmental Management Plan, specific disposal site waste acceptance criteria and according to approved survey package instructions specific for survey areas or units at the PBRF and implementing procedures developed for that purpose. To determine waste stream profile sample locations, results will be used from the previous characterization surveys conducted in 1985 and 1998 along with recommendations from the EBS report and, as needed, measurements conducted during characterization.

All efforts will be made to adequately profile a specific waste stream prior to any structure demolition or dismantlement, to ensure worker protection, as well as provide data needed for waste acceptance at the disposal site chosen by NASA. Wastes must be adequately characterized for disposal by identifying any characteristic or listed waste identities, as well as any parameter set forth by the disposal facility as part of their waste acceptance criteria. The identification of regulated substances sufficient to change the waste identity, shipping requirements or disposal of the wastes must be determined prior to disposal.

In addition to samples for hazardous characteristic analysis, samples will be collected such that an adequate determination of radionuclide contamination can be made. Samples will be collected that are representative of the waste and will be analyzed for all radionuclides associated with the PBRF including hard-to-detect radionuclides. The information obtained by performance of this characterization plan will guide both remediation and waste management operations and provide for waste stream profiling for processor or disposal facility acceptance criteria. Waste stream sampling and analysis requirements for radioactive and mixed-waste to be sent to Envirocare of Utah for disposal is discussed in the following section.

3.2.21.1 Envirocare of Utah Material Analysis Requirements

If contamination from hazardous materials is identified in areas as a result of waste stream profile sample analysis, a separate plan may be developed to address any required remedial actions. The plan will also include the method that will be utilized to determine the lateral/vertical extent of the hazardous materials contamination identified. The evaluation and determination of need for further surveys, sampling and analyses to identify and quantify non-radiological contaminants that may be present at the PBRF site will be performed in accordance with the EMP.

To qualify PBRF waste for disposal at Envirocare of Utah, samples obtained during characterization will be sent to an offsite laboratory and analyzed, as appropriate, for the Envirocare disposal facility WAC parameters. As required by the Envirocare WAC, the samples will be sent to a State of Utah certified laboratory, for the Envirocare Suite of hazardous materials analyses. The purpose of performing the Envirocare Suite of analysis is to begin the qualification process to send PBRF waste streams such as low level radionuclide contaminated soils from the site to Envirocare for disposal. The analyses required by Envirocare for evaluation with regard to their WAC and depending on the physical properties of the waste as presented for disposal may include the following:

- TCLPs for 10 metals and 32 organics
- Totals for metals and organics
- Total Organic Halides (TOX)
- Hydrogen sulfide
- Hydrogen cyanide
- Soil pH and Paint Filter Liquids Test
- Pesticides
- Standard Proctor Test
- Radionuclide analyses

Based on generator knowledge, a review of previous analytical and field instrument data, site specific constituents of concern, physical properties of the waste, and another information known about the waste stream, one or more laboratory analyses may be performed in order to accurately characterize the waste. Laboratory analysis will be performed in accordance with U.S. EPA methods as presented in SW-846, DOE EML-HASL, ASTM or other industry acceptable method.

Characterization survey data will be reviewed and locations identified for the Envirocare profile samples. From each of the selected survey sample locations, a specified depth sample utilizing approved sampling equipment will be collected. The characterization survey design engineer will indicate the approved method for collection of the samples in the survey package instructions. The samples will be comprised of materials representative of the specific waste stream (or waste category). The waste stream (or waste category) may include various materials such as painted or unpainted concrete, metal, tile and mastic for the building debris waste stream

and wood, paper and plastic for the dry active waste (DAW) waste stream. Care will be taken to ensure the sample matrix is representative of the waste stream (or waste category).

In accordance with this plan and in cooperation with the EMP, environmental samples may be collected in accordance with the Environmental Media Sampling and Analysis Plan, USACE/NASA 2002 (Environmental SAP). Specific sampling procedures and analytical protocols not identified in the Environmental SAP may be incorporated as an addendum to the plan. The sample collection process for collecting the samples may include the following steps as appropriate for type of material.

1) Locate and mark selected survey sample location (SSL)
2) Perform qualitative gamma and/or beta scan, as appropriate for elevated count rate locations
3) Ensure sampling tools and containers are cleaned between sample campaigns
4) At each SSL, sample to specified depth utilizing approved equipment
5) Ensure a minimum volume of material is recovered at each sample location
6) Collect the core sample and deposit into stainless steel mixing bowl
7) Homogenize sample utilizing stainless steel implements
8) Collect appropriate volume of sample media from the homogenized sample,
9) Adhere to sample preservation requirements provided by the laboratory,
10) Record sample collection as appropriate in survey work package and chain of custody

During the sampling campaign, sample preservation requirements will be observed as appropriate. The samples, requiring preservation, will be transferred from a field cooler to a locked refrigeration unit and maintained at or below 4°C until prepared and ready to ship to the offsite laboratory for analysis. Hold times will also be observed for samples that require preservation. Once all samples are collected, the media will be homogenized in stainless steel implements and placed into sample containers provided by the offsite laboratory, marked and sealed.

Sample bottles, preservation, and hold times for wastes undergoing hazardous component evaluation will be as presented in the Environmental SAP or other state/federal approved methodology.

Once samples are prepared, a chain of custody form will be completed, samples will be placed in a cooler provided by the offsite laboratory with ice packs, shipping paper work will be prepared, the offsite laboratory will be notified regarding the sample shipment, and samples will be shipped by Federal Express priority overnight to the offsite laboratory. Analytical reports for sample analyses will be provided from the offsite laboratory in an approved format with acceptable reporting limits shown on the final report. The results of the analyses will be evaluated against the Envirocare WAC, as well as the hazardous characteristics provided in 40 CFR part 260. Analytical methods shall be as listed in Table 3-8 that follows.

Table 3-8, Sample Analysis Requirements for Envirocare WAC

Item	Analysis	Method	Comments
1	**Reactive Cyanide/Sulfide**	Chapter 7	mg/kg
	IF reactive cyanide > 20 mg/kg then total Cyanide & Sulfide	SW-846 9010 or 9012	mg/kg
2	**Soil pH**	SW-846 9045	
3	**Paint Filter Liquids test**	SW-846 9095	
4	**Asbestos**	TLM, TEM or SEM	
5	**Radiological**		See10 CFR 61 Radiological Sample Analysis Requirements.
6	**TOX** (Total Organic Halides)	SW-846 9020/9022	mg/kg
	IF TOX > 200 mg/kg then total Volatile and Semi-volatile analysis	SW-846 8240 and 8270	mg/kg
7	**Standard Proctor Test, (Physical/Geotechnical Testing)**		
	Moisture content; high, low and average levels		
	Optimum Moisture Content	ASTM D-698	
8	**Full Characteristic TCLP 32 organics and 8 heavy metals plus Cu, Zn and PCB**		
	Metals Arsenic	Non ZHE/6010/7470	mg/l
	Lead	Non ZHE/6010/7470	mg/l
	Barium	Non ZHE/6010/7470	mg/l
	Mercury	Non ZHE/6010/7470	mg/l
	Cadmium	Non ZHE/6010/7470	mg/l
	Selenium	Non ZHE/6010/7470	mg/l
	Chromium	Non ZHE/6010/7470	mg/l
	Silver	Non ZHE/6010/7470	mg/l
	Copper	Non ZHE/6010/7470	mg/l
	Zinc	Non ZHE/6010/7470	mg/l
	Organics Herbicides	Non ZHE/8151	mg/l
	PCB	Non ZHE/8151	mg/l
	Pesticides	Non ZHE/8081	mg/l
	Semi volatiles	Non ZHE/8270C	mg/l
	Volatiles	ZHE/8260B	mg/l
9	**Total Metals**		
	Arsenic	6010/7470	mg/kg
	Lead	6010/7470	mg/kg
	Barium	6010/7470	mg/kg
	Mercury	6010/7470	mg/kg
	Cadmium	6010/7470	mg/kg
	Selenium	6010/7470	mg/kg
	Chromium	6010/7470	mg/kg
	Silver	6010/7470	mg/kg
	Copper	6010/7470	mg/kg
	Zinc	6010/7470	mg/kg

3.2.21.2 10 CFR Part 61 Radionuclide Sample Analysis

Composite samples from the site will be collected and sent to an offsite laboratory for radionuclide analysis. The samples will be collected in accordance with approved work instructions and procedures to satisfy requirements of 10 CFR Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste;" and the disposal or processing facility license conditions. The samples will be comprised of materials from sample locations exhibiting the highest contamination levels from the previous and current characterization survey results.

Offsite laboratory instruments used for analyses shall be calibrated with industry recognizable standards such as NIST and operated utilizing approved procedures. The offsite laboratory shall provide a QC package with analysis results and the laboratory's QA program shall be in effect for these analyses.

The offsite laboratory shall provide sample containers and information regarding specific analytes and/or analyses container types, preservation requirements, minimum sample volume/weight, maximum hold time required and sample chain of custody. Analysis results will be provided to PBRF characterization survey supervision. The offsite laboratory shall archive samples for three months and then dispose of the samples as appropriate.

The radionuclide analysis is to analyze for all alpha (including transuranics with half life > 5 years) and beta, gamma and x-ray emitting radionuclides. The laboratory will resolve and quantify all unidentified peaks with 2 sigma error < 60% and provide totals for Uranium, Radium and Thorium. The Laboratory shall perform gross alpha and gross beta counting and provide results. The instruments used for radionuclide analyses shall be operated such that a minimum detectable concentration (MDC) as indicated in the following table or less is achieved. All radionuclides detected including the ones listed in Table 3-9 that follows will be quantified and reported.

Table 3-9
10 CFR Part 61 and Envirocare Radionuclide Sample Analysis

Item	Radionuclide	MDC (pCi/g)
1	Tritium (H-3)	10
2	Carbon – 14 (C-14)	2
3	Iron-55 (Fe-55)	500
4	Cobalt –60 (Co-60)	0.5
5	Nickel –59 (Ni-59)	10
6	Nickel –63 (Ni-63)	10
7	Strontium-90 (Sr-90)	0.2
8	Niobium-94 (Nb-94)	1
9	Technetium-99 (Tc-99)	5
10	Antimony -125 (Sb-125)	1
11	Iodine-129 (I-129)	0.2
12	Cesium –137 (Cs-137)	1
13	Europium –152 (Eu-152)	1
14	Europium –154 (Eu-154)	1
15	Europium –155 (Eu-155)	1
16	Radium-226 (Ra-226)	0.1
17	Thorium-230 (Th-230)	0.5
18	Thorium-232/ Thorium-228 (Th-232/Th-228)	0.5
19	Neptunium-237 (Np-237)	0.1
20	Plutonium-238 (Pu-238)	1
21	Plutonium-239 (Pu-239)	1
22	Plutonium-241 (Pu-241)	2
23	Americium-241 (Am-241)	1
23	Curium-242 (Cm-242)	10
24	Curium-243/ 4/ 5 (Cm-243,4,5)	1
25	Uranium, isotopic	0.5

The MDC values presented in Table 3-9 are a fraction (1 to 50%) of the values presented in NUREG-1727 Appendix C, Table C2.3 Interim Screening Values (pCi/g) of Common Radionuclides for Soil Surface Contamination Levels or an MDC value based upon best achievable MDC for sample and analysis method. The concentrations of individual radionuclides listed in NUREG-1727 Table C2.3 would be deemed in compliance with the 25 mrem/y unrestricted release dose limit in 10 CFR 20.1402. For radionuclides in a mixture, the "sum of fractions" rule would apply in accordance with 10 CFR Part 20, Appendix B, Note 4.

3.2.22 Waste Management Operations

The PBRF survey team will collect, package, label, and store for later disposal all wastes generated during the characterization survey in accordance with the PBRF Waste Management Plan and approved procedures developed for the purpose.

3.2.23 Re-Evaluate Decommissioning Assumptions

As characterization surveys are completed, the decommissioning waste and cost estimates, pathway analysis and interim site-specific DCGLs will be re-evaluated for the known radiological conditions at the site and in each survey area. As information is obtained, plans will be re-evaluated and adjusted as appropriate, to prepare for the remediation phase of the process within each survey area at the PBRF.

3.2.24 Characterization and Remediation Survey Methods

The instrumentation and the process, protocols and procedures used during the characterization and post-remediation surveys will be the same as used for the final status survey. The survey designs and intensities used for post-remediation surveys may meet the same requirements for final status survey designs. All information concerning each survey is collected and stored in a survey package portfolio. Detailed descriptions of survey instruments, procedures and survey design used for all surveys of this characterization will be documented in a report and will be used to develop the Final Status Survey Plan.

3.2.25 Characterization and Remediation Survey Report

Following the completion of all measurements and sample analyses, the survey package for each survey area will be updated with results of the characterization survey results. The survey package will continue to be updated as remediation occurs and as post-remediation survey results are added to the survey package. Once the initial characterization activities have been completed, a Characterization Survey Report will be prepared and submitted to the MWH Team management for review and approval. The report will be transmitted to NASA for review once the MWH Team has approved the report. The report will document the as found results for each survey area and/or survey unit and will provide information needed to guide decontamination activities and waste management operations. Once all decontamination activities have been completed and verified to be successful by the results of the post-remediation survey, a Post-Remediation Survey report will be prepared and submitted to NASA and the NRC for review. The report will document the results of the decontamination up through completion of post-remediation surveys. This will identify each survey area of the Plum Brook Reactor Facility site that is ready for the final status survey. The final status survey plan will be developed and evaluated during the characterization and remediation phases of the project, and any revisions will be submitted to NASA and the NRC for review and approval. Once concurrence is obtained from the NRC, the final status survey plan will be implemented and the surveys performed in accordance with the plan provisions. At completion of the final status surveys, a complete final

status survey report will be prepared and submittal to NASA and the NRC. The report will show that the site and facility is suitable to release for unrestricted use.

3.3 Task Descriptions

The major activities and facilities at the site during the licensed activities during operations are summarized in the PBRF decommissioning plan. Tasks presented in the decommissioning plan and specific work plans describe the general approach for decontamination and remediation of contamination identified in each of the areas of the PBRF.

3.4 Remediation Methods

Remediation methods are dependent on the facility to be remediated, type and extent of the radionuclides, and the remediation objective. Contaminated facilities and soils will fall into one or more of the following categories for remediation:

1) Remove and dispose of as radioactive waste
2) Decontaminate for unrestricted release
3) No action, since radiological conditions meet acceptance criteria

Once characterization is completed for each survey area at the PBRF, these areas will be re-evaluated to determine the best method for remediation. Criteria that were used in the evaluation include: availability of a burial facility, the cost of decontamination versus the cost of burial, radiological and occupational hazards involved, and site operations in progress or planned.

4.0 HEALTH AND SAFETY AND QUALITY ASSURANCE PROJECT PLAN ELEMENT CONSIDERATIONS

In accordance with the guidance provided in the MARSSIM Section 9.2, Development of a Quality Assurance Project Plan and the MARSSIM Section 4.10, Health and Safety, this section of the characterization plan is provided to show that the guidance for development of a QAPP have been met for the characterization plan development. Subsections that follow describe how this characterization plan interfaces and/or works in conjunction with some of the NASA programmatic plans developed for the PBRF decommissioning. Some elements of a QAPP have been addressed in these programmatic plans. It is not the intent of this plan to repeat information that is already provided in existing documents, but to show where these QAPP elements exist and how they relate to the characterization activities. In addition, this section serves to communicate to management and to the characterization staff that the programmatic plans will be observed during implementation of the activities described in this characterization plan.
to the project in these areas.

4.1 Site Specific Safety and Health Plan

The NASA Plum Brook Reactor Facility Site-Specific Safety and Health Plan (SSHP) was developed to identify health and safety features to be used while performing characterization, D&D and support activities at the PBRF. The document serves as the general SSHP for the D&D project site, however, because of the nature of the subject site, there are multiple health and safety documents that comprise the complete health and safety program for the PBRF D&D project.

The SSHP and implementing procedure for job safety analysis meet the MARSSIM Section 4.10, Health and Safety, recommendation for health and safety evaluation prior to commencement of work in areas at the PBRF. The PBRF Health and Safety Program include the following:

1. NASA Glenn Research Center Safety Manual
2. NASA Glenn Research Center Environmental Programs Manual
3. NASA Glenn Research Center Emergency Preparedness Plan
4. NASA PBRF Emergency Response Plan
5. Montgomery Watson TERC Safety and Health Program (TERC SHP).
6. Radiation Protection Plan, Decommissioning and Decontamination, NASA Plum Brook Reactor Facility.
7. Plum Brook Reactor Facility Procedures Manual
8. USACE Safety and Health Requirements Manual, EM 385-1-1

The SSHP emphasizes that the PBRF is a NASA GRC facility, that the existing NASA GRC Safety and Environmental plans provide the overriding procedures and policies for the site, and that GRC's requirements will be met or exceeded by any project specific plans. The SSHP and the characterization plan documents are not intended to provide information or direction in conflict with any NASA-established guidance, policies or procedures deemed applicable to the PBRF D&D. In addition, generic reference to NASA involvement in safety issues and oversight is intended to include all pertinent and relevant groups within NASA at Plum Brook Station and Glenn Research Center.

All sampling and surveys described in this plan will be performed in accordance with the SSHP. All sampling and surveys will also be conducted under an approved Job Safety Analysis describing the sampling activities in sufficient detail to identify health and safety requirements. Refer to the decommissioning plan and the SSHP for further information and details regarding the health and safety program that will be in effect during characterization and D&D of the PBRF.

4.2 Radiation Protection Plan and Program

All sampling and surveys described in this plan will be performed in accordance with the NASA PBRF Radiological Protection Plan For The Decontamination and Decommissioning of The Plum Brook Reactor Facility, RP-100 (RP Plan). All sampling and surveys will also be conducted under approved Radiation Work Permit describing the sampling activities in sufficient detail to identify radiation protection requirements. The RP Plan was developed under the cognizance of the NASA Project Radiation Safety Officer. The RP Plan presents the program that will be implemented by trained and experienced supervisory, technical, and service contractor personnel. Radiation protection (RP) personnel will be present at the site when characterization and decommissioning activities are in progress to provide complete support and health physics supervision. Refer to the decommissioning plan and the RP Plan for further details regarding the ALARA program and health physics program that will be in effect during characterization and D&D of the PBRF.

4.3 Quality Control

This characterization plan was developed according to the essential elements of the quality assurance and quality control (QA/QC) program for the PBRF decommissioning and is subject to the PBRF Quality Assurance Plan, QA-01. The QA/QC program elements for the PBRF D&D are as follows:

1) Establishment/implementation of plans, procedures, and protocols for the field operations,
2) Actions to assure that the procedures are understood and followed by the implementing staff, and
3) Documentation of the data collected.

The specific QA/QC program components for the characterization are as follows:

1) Selection of personnel,
2) Establishment of project plans and procedures
3) Documentation of survey data and sample analyses,
4) Personnel training,
5) Selection of appropriate instruments to perform the surveys,
6) Proper instrument calibration and daily functional checks, and
7) Management oversight of characterization activities relative to the adherence to procedures, protocols, and documentation requirements.

Details of these elements are set forth in this plan and the procedures used during characterization. The characterization operations and the associated data acquisition and recording will be guided and conducted in compliance with these QA/QC requirements.

All sampling and analysis described in this plan will be conducted in accordance with this plan, the Quality Assurance Plan and according to approved survey package instructions specific for survey areas or units at the PBRF and implementing procedures developed for that purpose. The procedures include a procedure for onsite laboratory quality control (QC). Sufficient duplicates, trip blanks and spike samples will be collected for quality purposes as described in the onsite laboratory QC procedure. A separate procedure will address quality control for offsite laboratory analysis. The offsite laboratory QC procedure will specify hold time and preservative requirements necessary for analytical methods to be used such as EPA method SW-846 when applicable.

5.0 PLANNED FINAL RADIATION SURVEY

A Final Status Survey Plan will be developed for the release for unrestricted use of the PBRF site and the immediate grounds. The surveys conducted according to the plan will consist of surface scans (beta and gamma), direct beta measurements fixed, and smears for gross alpha and gross beta analysis on structural surfaces while the survey of the facility grounds will consist of gamma scans and soil sampling for gamma spectroscopy analysis. The plan and surveys conducted will be developed and performed in accordance with the MARSSIM while applying site specific DCGL based upon the future use of the facility and the grounds and the results of the characterization surveys completed under this plan. The Final Status Survey will be used to support PBRF intent to terminate their license and release the facility for unrestricted use.

The initial site specific DCGLs for the survey of the building and grounds, as documented in the decommissioning plan section 2.2.3 and subsection 2.2.3.1, will be re-evaluated and updated as necessary during the site characterization. The re-evaluation of the DCGLs may result in updating and/or development of new site-specific release criteria (DCGLs) for use during the final status survey of the building and grounds. The application of the final site-specific DCGLs during final status surveys will ensure that residual radioactivity above background will not exceed the 25 mrem/yr TEDE to the AMCG and that the PBRF will be suitable to release for unrestricted use.

The PBRF survey team will develop the PBRF Final Survey Plan based on the guidance provided in current regulations including the MARSSIM, 10CFR20 Subpart E, *Radiological Criteria for License Termination*, DG-4006, the current RESRAD Version 6.0 and RESRAD-Build Version 3.0. The criteria and survey protocols specified in the plan will be designed to meet the intent of the current regulations for release for unrestricted use and are intended to support termination of the PBRF Facility Licenses.

In addition to the MARSSIM, guidance contained in NUREG-1505, "A Nonparametric Statistical Methodology for the Design and Analysis of the Final Status Decommissioning Survey" and NUREG-1507, "Minimum Detectable Concentrations with Typical Radiation Survey Instruments For Various Contaminants and Field Conditions," will be used for final status survey plan development. The use of these guidance documents during final status survey planning is consistent with the decommissioning plan Section 2.3.1, Decommissioning Strategy and Section 2.6, Decontamination and Decommissioning Documents and Guides.

Guidance contained in NUREG-1727 will also be used as an information source during final status survey plan development. The NUREG-1727 replaces DG-4006 as the current guidance for implementing requirements set forth in 10 CFR Part 20, Subpart E and contains additional decommissioning guidance and information. However, the decommissioning of the PBRF will be conducted in accordance with DG-4006 as stated in the decommissioning plan.

6.0 PHYSICAL SECURITY PLAN AND MATERIAL CONTROL AND ACCOUNTING PLAN PROVISIONS IN PLACE DURING DECOMMISSIONING

PBRF is not required to have an NRC-approved special nuclear material control and accounting plan, since it does not possess a special nuclear material license.

According to the decommissioning plan Section 6.0, Physical Security Plan, the existing security system is adequate to handle any contingency that may arise during decommissioning. There is no cause in the decommissioning plans, as written, for which the existing security should be modified.

7.0 REFERENCES

10 CFR Part 20, *Standards for Protection Against Radiation*

10 CFR Part 61. *Licensing Requirements for Land Disposal of Radioactive Waste*.

Draft Regulatory Guide DG-4006, *Demonstrating Compliance with the Radiological Criteria for License Termination*

NUREG-1575, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*

NUREG-1505, *A Nonparametric Statistical Methodology for the Design and Analysis of the Final Status Decommissioning Survey*

NUREG-1507, *Minimum Detectable Concentrations with Typical Radiation Survey Instruments For Various Contaminants and Field Conditions*

NUREG-1727, *NMSS Decommissioning Standard Review Plan, September 2000*

Federal Register Notice, November 20, 1997, Volume 62, Number 224, Page 62079-62094*, Joint NRC/EPA Guidance on Testing Requirements for Mixed Radioactive and Hazardous Waste*

Decommissioning Plan For The Plum Brook Reactor Facility, Revision 2, October 2001

Teledyne Isotopes, "An Evaluation of the Plum Brook Reactor Facility and Documentation of Existing Conditions, Volume 3: Physical Characterization of Radioactive/Contaminated Areas of the PBRF," December 1987.

NASA PBRF Radiological Protection Plan For The Decontamination and Decommissioning of The Plum Brook Reactor Facility, RP-100, Rev. 1

NASA Plum Brook Reactor Facility Quality Assurance Plan, QA-01, Revision 0

NASA Plum Brook Reactor Facility Site Specific Safety and Health Plan

NASA Plum Brook Reactor Facility Low-Level Radioactive and Hazardous Waste Management Plan

NASA Plum Brook Reactor Facility Environmental Management Plan

SAIC-FASS Team ACM/LBP/PCB Survey Plum Brook Reactor Facility Buildings, September 25, 2000

Environmental Media Sampling and Analysis Plan, USACE/NASA 2002

Duke Engineering & Services, Inc., Plum Brook Reactor Facility Supplemental Historical Site Assessment, November 2001

Tetra Tech, Inc., Final Environmental Baseline Survey Report for the Plum Brook Reactor Facility Decommissioning Project, February 2001

MWH FSS/Characterization Supervisor and Technician Training Plan, MW-PL-02-007, Revision 0

8.0 ATTACHMENTS

Attachment A - PBRF Survey Areas and Survey Units

Attachment A - PBRF Survey Areas and Survey Units

Survey Area ID	Survey Unit ID	Survey Area Description	Initial Classification
C1111		**Reactor Building (1111):**	
C1111	01 to	Inside containment vessel	Class 1
C1111	20 to	Outside containment vessel	Class 2
C1111	50 to	Canals	Class 1
C1112		**Hot Laboratory (1112):**	
C1112	01 to	Cold work area floors, walls, and ceiling	Class 2
C1112	05 to	Hot Work Area floor	Class 1
C1112	09 to	Hot Work Area walls and ceiling	Class 2
C1112	13 to	Decon Room floors and walls	Class 1
C1112	17 to	Decon Room ceiling	Class 2
C1112	21 to	Repair Shop floors and walls	Class 1
C1112	25 to	Repair Shop ceiling	Class 2
C1112	29 to	Storage room floors, walls, and ceiling	Class 2
C1112	33 to	Mezzanine floors	Class 1
C1112	37 to	Mezzanine walls and ceiling	Class 2
C1112	41 to	Hot handling floors and walls	Class 1
C1112	45 to	Hot handling ceiling	Class 2
C1112	49 to	Hot pipe tunnel	Class 1
C1112	53 to	Canals	Class 1
C1132		**Fan House (1132):**	
C1132	01 to	First floor floors	Class 1
C1132	20 to	First floor walls and ceiling	Class 2
C1132	50 to	Basement floors, walls, and ceiling	Class 1
C1133		**Waste Handling Building (1133):**	
C1133	01 to	First floor floors	Class 1
C1133	20 to	First floor walls	Class 2
C1133	30 to	First floor walls	Class 1
C1133	40 to	First floor ceilings	Class 2
C1133	50 to	Basement floors, walls, and ceiling	Class 1
C1134	01 to	**Primary Pump House (1134) floors walls and ceilings**	Class 2
C1141	01 to	**Reactor Office and Laboratory Building (1141) all areas**	
		(exclusive of lab hoods and hood filter housings)	Class 2
C1192	01 to	**Water Effluent Monitoring Station (1192) all areas**	Class 2
C1154	01 to	**Cold Retention Basins (1154)**	Class 1
C1155	01 to	**Hot Retention Area (1155)**	Class 1
A2100	01 to	Emergency Retention Basin	Class 1
A2200	01 to	Drainage System	Class 1
A2300	01 to	Pentolite Ditch	Class 1
A2400	01 to	Areas of past spills	Class 1

Attachment A - PBRF Survey Areas and Survey Units

Survey Area ID	Survey Unit ID	Survey Area Description	Initial Classification
A2500	01 to	Cold pipe tunnel	Class 3
C1153	01 to	**Reactor sludge basins (1153)**	Class 3
C1157	01 to	**Reactor precipitator (1157)**	Class 3
D1131	01 to	**Reactor Service Equipment Building (1131)**	Non-Impacted*
D1135	01 to	**Reactor Gas Services Building (1135)**	Non-Impacted
D1151	01 to	**Reactor Water Tower (1151)**	Non-Impacted*
D1161	01 to	**Reactor Substation (1161)**	Non-Impacted
D1191	01 to	**Reactor Security Building (1191)**	Non-Impacted
D1136	01 to	**Reactor Compressor Building (1136)**	Non-Impacted
D1195	01 to	**Reactor Cryogenic & Gas Supply Farm & Building (1195 & 9837)**	Non-Impacted
D1196	01 to	**Reactor Gas Storage Structure (1196)**	Non-Impacted
D9999	01 to	**Background Reference Area**	Non-Impacted

* May be misclassified based on the Supplemental Historic Site Assessment.