FINAL

CLOSEOUT REPORT

High Flux Beam Reactor Stabilization
Area of Concern 31

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Upton, New York

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Executive Summary

The High Flux Beam Reactor (HFBR) is designated as Area of Concern (AOC) 31 at Brookhaven National Laboratory (BNL). The HFBR Stabilization Project, which included preparing the HFBR confinement (Building 750) for long-term safe storage and removing localized radiological contamination in areas immediately outside of Building 750, is part of the actions described as near-term decontamination and dismantlement (D&D) in the *Record of Decision – Area of Concern 31, High Flux Beam Reactor* (BNL, February, 2009) (HFBR ROD). The project was performed in part with funding from the American Recovery and Reinvestment Act (ARRA) and in accordance with *Closeout Procedures at National Priority List Sites*, Office of Solid Waste and Emergency Response (*OSWER) Directive 9320.2-09A-P* (EPA, 2000a).

Building 750 stabilization activities associated with this project took place between April 2009 and August 2010. In accordance with the HFBR ROD requirements, preparation of Building 750 for safe storage included the following:

- Modification of the ventilation exhaust system to ensure that the atmosphere in the confinement is safe for personnel access for S&M activities;
- Modification of security system and alarms;
- Installation of a water infiltration detection system with remote alarms;
- Modification of confinement building lighting and electric power distribution to support S&M activities;
- Correction of minor confinement building deficiencies;
- Isolation and drain-down of mechanical systems and tanks;
- Removal of miscellaneous waste and excess combustible materials;
- Improvement to storm water drainage by adjustment of grades so it drains away from Building 750 in four areas (outside the transformer room, north of the east truck lock, adjacent to the air conditioning cooling tower, the entrance to the blower room, and in the cooling tower area); and
- Modification to secure access/entry points from outside.

These activities were completed to achieve the interim end state for the HFBR, as defined by the *High Flux Beam Reactor Decommissioning End Points* (BNL, September 2007).

Localized radiological contamination within the HFBR complex that is outside of the scope of HFBR near-term D&D projects, referred to herein as the "HFBR Outside Areas," was further characterized and removed between April 2010 and September 2010. A subsequent final status survey (FSS) and independent verification survey (IVS) of the

HFBR Outside Areas were completed between July 2010 and September 2010 to ensure that soil cleanup objectives were met in accordance with the HFBR ROD. The soil cleanup objectives for radiological contamination in the HFBR Outside Areas were based on a dose, to a resident (non-farmer) from remaining concentrations of all radionuclides present, of less than or equal to 15 millirem per year (mrem/year) above background after 50 years of institutional control by the Department of Energy (DOE), and industrial land use with no decay time (0 years).

The following summarizes the as-left conditions for Building 750 and the HFBR Outside Areas and how they satisfy the requirements of the HFBR ROD:

- Building 750 is stable, deenergized, and locked for the long-term S&M period (not to exceed 65 years), and only the following systems are operational water infiltration detection; security; building exhaust; and the 480V electrical distribution that is stepped down using transformers to provide 115/120-volt power for use inside of the confinement building.

- General area dose rates inside Building 750 are less than 0.2 mR/hr with the exception of the spent fuel canal (0.2 to 0.5 mR/hr), heat exchanger cells (0.2 to 10 mR/hr), green house (0.2 to 5 mR/hr) and shut down pumps (0.2 to 5 mR/hr).

- General area contamination levels (loose beta/gamma) inside Building 750 are less than 1,000 dpm/100cm^2 with the exception of the spent fuel canal (less than 10,000 dpm/100cm^2).

- The average Cs-137 and Ra-226 concentrations remaining in the HFBR Outside Areas soils are 0.24 picocuries per gram (pCi/g) and 0.47 pCi/g, respectively. Sr-90 concentrations were below laboratory detection limits. The as-left average concentrations are well below the site cleanup goals (Cs-137=23 pCi/g, Sr-90=15 pCi/g and Ra-226=5 pCi/g). The maximum concentrations detected in soil samples were as follows: 2.45 pCi/g for Cs-137, less than laboratory detection limits for Sr-90, and 0.84 pCi/g for Ra-226.

- Chemical results for HFBR Outside Areas soil samples analyzed for mercury, lead, copper, nickel, and zinc also indicated that residual soil concentrations for these contaminants are within the respective cleanup goals, i.e., 1.84 mg/kg for mercury, 400 mg/kg for lead, 270 mg/kg for copper, 140 mg/kg for nickel, and 2,200 mg/kg for zinc.

- For the HFBR Outside Areas, the maximum projected dose to a resident (non-farmer) with no decay time is 0.5 millirem/yr. The maximum projected dose to an industrial worker with no decay time is 0.2 millirem/yr. The results of the dose assessment are below the objectives established in the HFBR ROD, including the dose objective of 15 millirem/yr and the New York State Department of Environmental Conservation (NYSDEC) cleanup guideline of 10 millirem/yr from Technical and Administrative Guidance Memorandum (TAGM) 4003, which was adopted as an ALARA goal.

- Site restoration for the HFBR Outside Areas was completed in October 2010. Restoration included backfilling, re-grading, re-paving and reseeding lawn areas with Long Island native grasses.

Building 750 and the HFBR Outside Areas meet all the completion requirements as specified in OSWER Directive 9320.2-09-A-P, *Closeout Procedures for National Priorities List Sites.*

Post-stabilization surveillance and maintenance (S&M) activities for the HFBR will be performed by BNL in accordance with the *Long-Term Surveillance and Maintenance Plan for the High Flux Beam Reactor (HFBR), Rev 2*, BNL, August 2010 and the *Long-Term Surveillance and Maintenance Manual for the High Flux Beam Reactor (HFBR) latest revision* (BNL, 2010). S&M activities will: ensure adequate containment of radiological materials; provide physical safety and security control; and maintain the facility in a manner that will minimize hazards to workers and the public. S&M activities will include routine inspections, continuous confinement monitoring, radiological monitoring, environmental monitoring (air and groundwater), routine maintenance, and non-routine maintenance/repairs. Both the S&M Plan and the S&M Manual contain the administrative requirement to protect the HFBR remaining inventory during the long-term S&M period (not to exceed 65 years), which began in 2007. Both documents contain the DOE's conditions of approval for the *High Flux Beam Reactor Hazard Assessment Document, latest revision* (BNL, 2010) and both documents require a Nuclear Unreviewed Safety Issue (NUSI) screen if there are changes.

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ACRONYM LIST

ALARA	As Low As Reasonably Achievable
AOC	Area of Concern
ARRA	American Recover and Reinvestment Act
BNL	Brookhaven National Laboratory
BGRR	Brookhaven Graphite Research Reactor
BSA	Brookhaven Science Associates
CDM	CDM Federal Programs
CPM	Counts Per Minute
CERCLA	Comprehensive Environmental Response, Compensation & Liability Act
Ci	Curies
cfm	Cubic Feet Per Minute
CRBs	Control Rod Blades
CY	Cubic Yards
DAC-Hr	Derived Air Concentration-Hour
D&D	Decontamination and Dismantlement
DOE	Department Of Energy
EMCC	Emergency Motor Control Center
EPA	United States Environmental Protection Agency
EPD	Environmental Protection Division
ERE	Exit Readiness Evaluation
ERP	Environmental Restoration Projects
ES	Environmental Solutions
F&O	Facility and Operations
FRDP	Facility Review Disposition Project
FS	Feasibility Study
FSS	Final Status Survey
GPS	Global Positioning System
HASP	Health and Safety Plan
HFBR	High Flux Beam Reactor
HP	Horsepower
IAG	Interagency Agreement
IH	Industrial Hygiene
IVS	Independent Verification Survey
JRA	Job Risk Assessment
JSA	Job Safety Assessment
LLRW	Low-Level Radioactive Waste
LUCMP	Land Use Controls Management Plan
mg/kg	Milligrams per Kilograms
MARSSIM	Multi-Agency Radiological Survey and Site Investigation Manuel
mrem/yr	Millirem Per Year
NaI	Sodium Iodide
NTS	Nevada Test Site
NUSI	Nuclear Unreviewed Safety Issue
NYSDEC	New York State Department of Environmental Conservation
ORISE	Oak Ridge Institute for Science and Education

OSWER	Office of Solid Waste and Emergency Response
OU	Operable Unit
PCB	Polychlorinated Biphenyl
pCi/g	Picocuries per Gram
PRAP	Proposed Remedial Action Plan
PWGC	P.W. Grosser Consulting, Inc.
QA/QC	Quality Assurance/Quality Control
RBA	Radiological Buffer Area
RCRA	Resource Conservation and Recovery Act
RCD	Radiological Controls Division
RCT	Radiological Controls Technician
RESRAD	Residual Radioactivity Computer Code
RI	Remedial Investigation
ROD	Record of Decision
rpm	Revolutions Per Minute
RWP	Radiological Work Permit
SCDHS	Suffolk County Department of Health Services
SBMS	Subject Based Management System
SOP	Standard Operating Procedure
SSCs	Structures, Systems, and Components
SU	Survey Unit
TAGM	Technical and Administrative Guidance Memorandum
TLD	Thermoluminscent Dosimeter
USC	United States Code
V	Volt
WAC	Waste Acceptance Criteria

1.0 INTRODUCTION

1.1 Purpose

The purpose of this of this Closeout Report is to document the completed actions associated with the preparation of the High Flux Beam Reactor (HFBR) confinement building (Building 750) for long-term safe storage to allow for radioactive decay, as well the as-left conditions at the start of long-term safe storage. This Closeout Report also documents the final status survey (FSS) within the HFBR property that is outside of the scope of the HFBR confinement dome near-term decontamination and dismantlement (D&D) projects, referred to herein as the "HFBR Outside Areas." This work is referred to herein as the "HFBR Stabilization Project." The HFBR is designated as Area of Concern (AOC) 31 at Brookhaven National Laboratory (BNL). The HFBR Stabilization Project is part of the actions described as near-term decontamination and dismantlement (D&D) in the *Record of Decision – Area of Concern 31, High Flux Beam Reactor* (BNL, February, 2009) (*HFBR ROD*). The project was performed with funding under the American Recovery and Reinvestment Act (ARRA) and in accordance with *Closeout Procedures at National Priority List Sites*, *OSWER Directive 9320.2-09A-P* (EPA, 2000a). Activities included:

- Physical modifications and stabilization activities to the HFBR facility to prepare it for long-term minimum surveillance and maintenance (S&M), including isolation and drain-down of Building 750 (the confinement dome) mechanical systems and tanks, removal of miscellaneous waste and combustible materials, installation of a building exhaust fan to ensure the atmosphere in the confinement is safe for personnel access, installation of an alternate 480V electrical feed to Building 750, security upgrades/modifications, installation of a water infiltration detection system, removal of hazardous materials, storm water drainage improvements, and confinement repairs;
- Completion of confinement building end state radiological surveys;
- Characterization and removal of localized radiological contamination ("hot spots") in the HFBR Outside Areas soils, as necessary;
- Completion of a FSS of the HFBR Outside Areas, including an independent verification survey (IVS) performed by the Oak Ridge Institute for Science and Education (ORISE);
- Completion of a post-closure dose assessment using the Residual Radioactivity Computer Code (RESRAD); and
- The characterization and disposal of generated waste.

Activities associated with the HFBR Stabilization Project were performed by BNL's Environmental Restoration Projects (ERP), ERP-seconded and task order subcontractors, Brookhaven Science Associates (BSA) Radiological Control Division (RCD), and Environmental Protection Division (EPD) personnel. Verification radiological surveys

and sampling were performed by the Oak Ridge Institute for Science and Education (ORISE).

Work was performed in accordance with the HFBR ROD. The FSS was performed in accordance with the *Field Sampling Plan for the HFBR Outside Areas* (BNL, July 2010).

The scope of work for the HFBR Stabilization Project included the following:

- Complete physical modifications and stabilization activities to the HFBR facility to prepare it for minimum surveillance and maintenance S&M, including isolation and drain-down of Building 750 mechanical systems and tanks, removal of miscellaneous waste and combustible materials, installation of a building exhaust fan to ensure the atmosphere in the confinement is safe for personnel access, installation of an alternate 480V electrical feed to Building 750, security upgrades/modifications, removal of hazardous materials, and confinement repairs;
- Decontamination, survey and release of previously contaminated areas within the confinement building;
- Characterization and removal, if necessary, "hot spots" in the HFBR Outside Areas;
- Packaging, transport, and disposal of radiologically and chemically contaminated project waste at an off-site permitted facility;
- Performing an FSS of the HFBR Outside Areas, including an IVS performed by ORISE; and
- Preparing a dose assessment and a closeout report.

1.2 Site Description and Operational History

The BNL site covers almost 5,300 acres, much of which is wooded. It is an irregular polygon, and each side is approximately 2.5 miles long. The developed portion of the BNL site includes the principal facilities, which are located near the center of the BNL site on relatively high ground. The developed portion is approximately 1,650 acres, 500 acres of which were originally developed for U.S. Army use. Large, specialized research facilities occupy 200 acres and another 400 acres are occupied by roads, parking lots and connecting areas. The remaining 550 acres are occupied by outlying facilities including an apartment area, Biology Field, Former Hazardous Waste Management Area, Sewage Treatment Plant, firebreaks, and the Former Landfill Area. The terrain is gently rolling, with elevations varying between 40 to 120 ft above mean sea level. The land lies on the western rim of the shallow Peconic River watershed, with a tributary of the Peconic River rising in marshy areas in the northern section of the tract. The sole-source aquifer beneath BNL comprises three water-bearing units: the upper glacial deposits, the Magothy Formation, and the Lloyd Sand Member of the Raritan Formation. These units are hydraulically connected and make up a single zone of saturation with varying physical properties extending from a depth of 5 to 1,500 ft below the land surface. These three

water-bearing units are designated as a "sole source aquifer" by the U.S. Environmental Protection Agency (EPA) and serve as the primary source of drinking water for Nassau and Suffolk counties.

A map illustrating the location of the BNL site is presented as Figure 1-1.

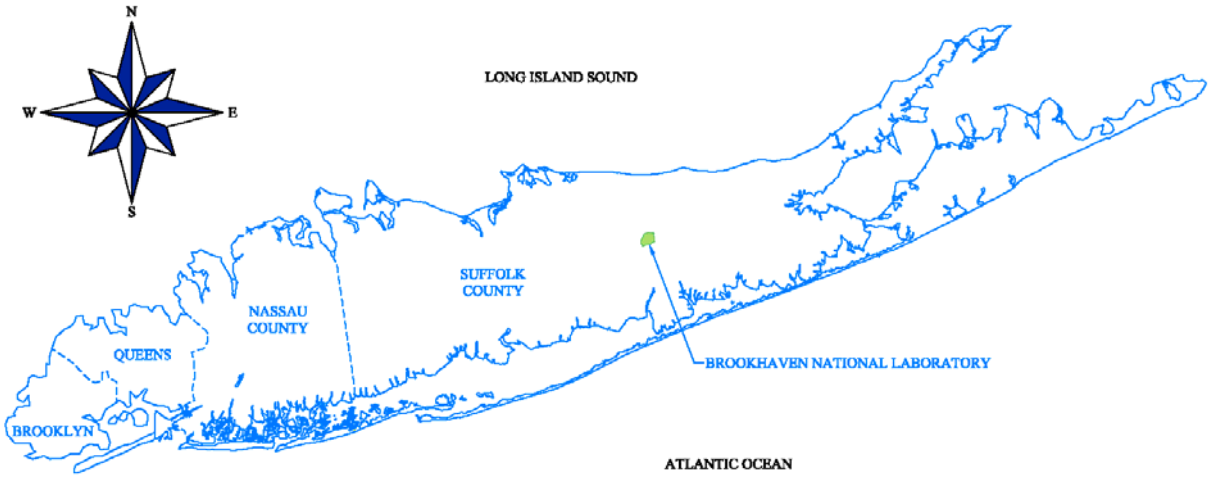


Figure 1-1 Location of Brookhaven National Laboratory

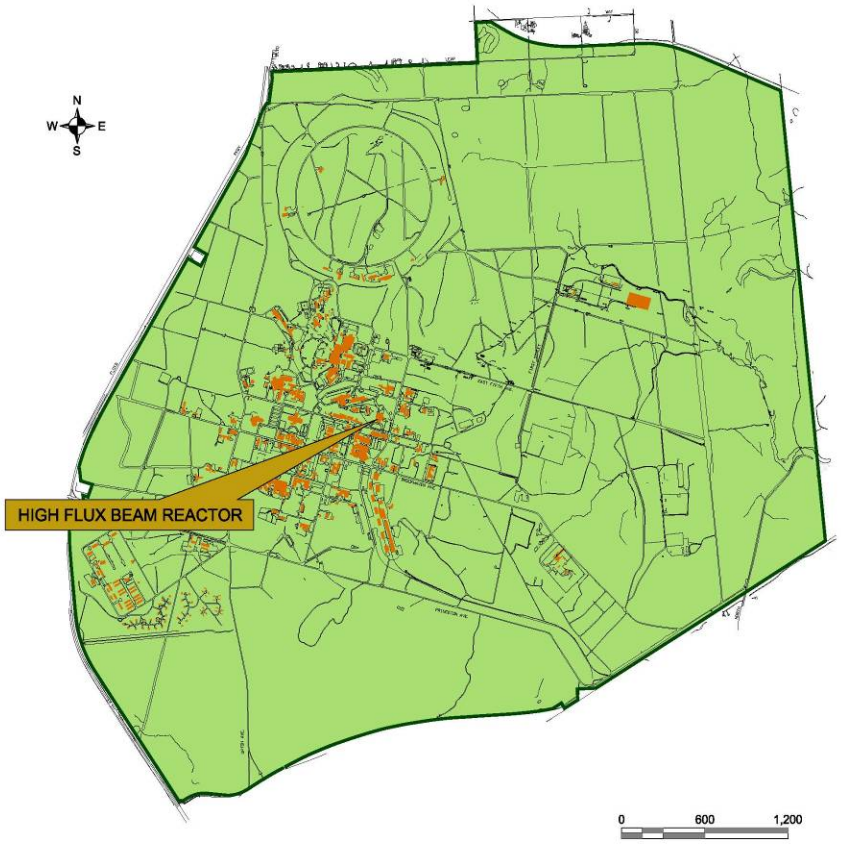


Figure 1-2 HFBR Location at BNL

The HFBR was designed and constructed for basic experimental research particularly in the area of neutron beam research and is centrally located within the BNL site, as shown in Figure 1-2. The most recognizable feature of Building 750 is its steel dome structure in the shape of a hemisphere resting on a cylindrical base. This structure is formed of welded steel plates supported upon an integral I beam framework. The inside diameter of the hemisphere at its base is 176 ft 8 in. The cylindrical base (22 ft 4 in. high) rests upon a bedplate bolted to the reinforced concrete foundation ring. The hemispherical portion of the dome is insulated on the outside, and the insulation is covered with aluminum sheets. The steel plates in the hemispherical section are 0.250 in. thick, and those in the cylindrical base are 0.375 in. thick. The foundation of the building is a reinforced concrete mat bearing on the soil beneath the building. The main portion of Building 750 consists of four levels: the Equipment Level, Experimental Level, Balcony Level, and Operations Level. Additionally, there are three attached sections to the Building 750 confinement dome (a machine shop and truck lock to the north side, a truck lock to the east side, and a lobby area to the south), as shown in Figure 1-3.

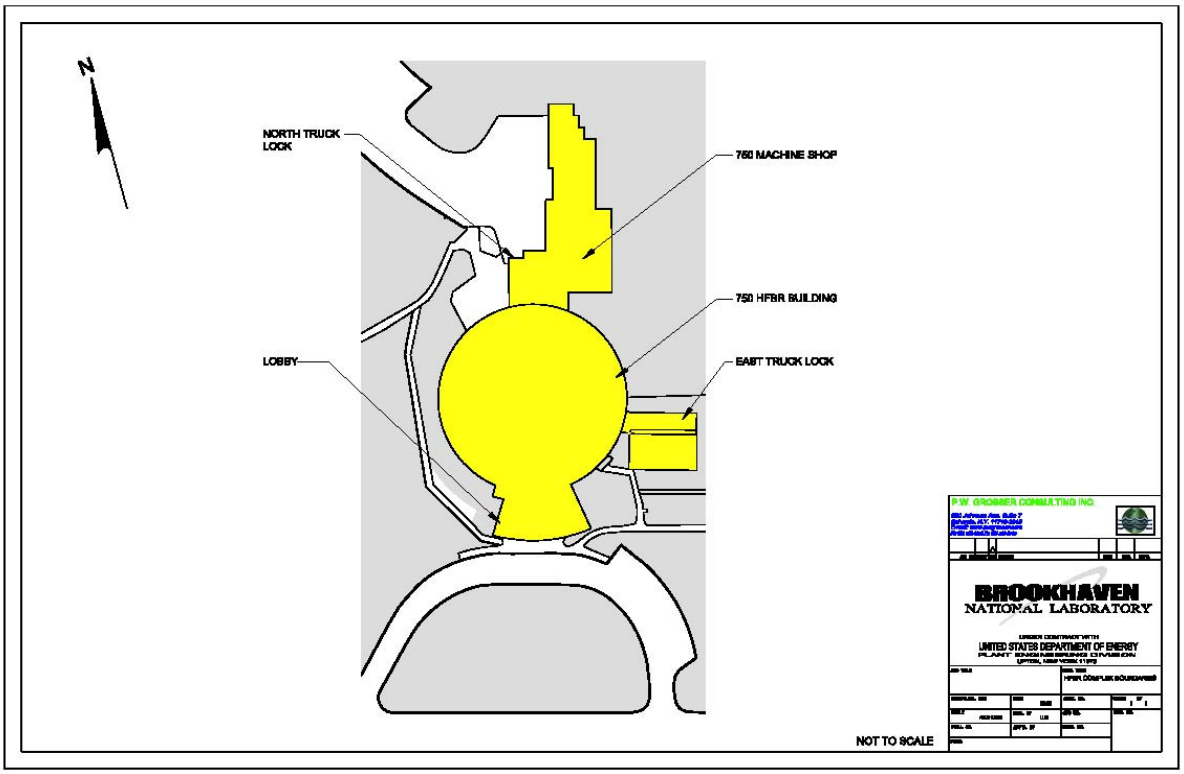


Figure 1-3 Building 750 Site Plan

The HFBR operated from 1965 to 1996. Used solely for scientific research, the HFBR provided neutrons for experiments in materials science, chemistry, biology and physics. During a routine maintenance shutdown in 1996, tritium from the spent fuel canal was found in groundwater south of the reactor. Investigations revealed that the source of the tritium was a small leak in the canal where spent reactor fuel was stored. Operations at the HFBR were suspended while the DOE considered future actions. All of the spent fuel was removed and sent to DOE's Savannah River Site in 1998. In November 1999, the DOE announced it was permanently closing the reactor. A groundwater monitoring program, part of Operable Unit (OU) III, was initiated to address the associated tritium release.

Since the permanent shutdown, a number of actions have been taken to remove contaminated structures, systems, and components (SSCs) from the HFBR including the activated control rod blades, beam plugs, and collimators. The reactor systems and most house systems in the Building 750 dome and lobby area have been taken out of service and prepared for long-term low maintenance. Services remain in the maintenance shop portion of the facility.

Although the HFBR is the remains of a nuclear reactor, it has been defueled and its radionuclide inventory is limited to surface contamination and activation products with

the majority of the inventory located within the biological shield and consisting of cobalt-60 (Co-60). The biological shield is a robust structure that extends from the Equipment Level to the Operations Level of Building 750 and confines approximately 41,800 Curies (Ci) of radiological inventory with the vast majority being activated metal on the Experimental Level. The biological shield is an 8 ft thick, heavy concrete structure. It contains 60% by weight of steel fragments to increase the density. The weight is about 1500 tons for the entire shield. The biological shield is an integral part of the structure and support of Building 750 and was designed to house a nuclear reactor. The cell doors (two loop heat exchanger cells and a shutdown heat exchanger cell) on the Equipment Level are open as well as other smaller instrument port plugs and other miscellaneous penetrations. All current biological shield penetrations are expected to remain open during the remaining life of the facility as they allow for neither streaming radiation from inside the biological shield nor the propagation of a fire into the biological shield where it could impinge on the activated materials on the Experimental Level. A cutaway view of Building 750 is presented below as Figure 1-4.

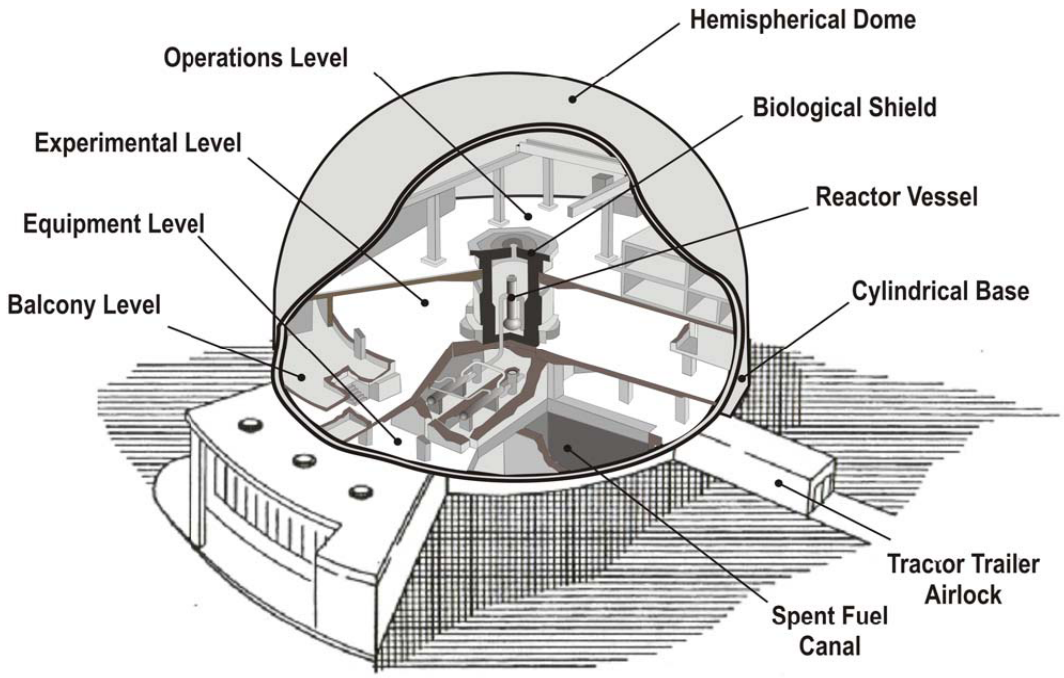


Figure 1-4 Cutaway View of Building 750

1.3 Regulatory and Enforcement History

In 1980, the BNL site was placed on New York State's Department of Environmental Conservation (NYSDEC) list of Inactive Hazardous Waste Sites. On December 21, 1989, the BNL site was included on the U.S. Environmental Protection Agency (EPA) National Priorities List because of soil and groundwater contamination that resulted from BNL's

past operations. Subsequently, EPA, NYSDEC, and DOE entered into a Federal Facilities Agreement (herein referred to as the Interagency Agreement; [IAG]) that became effective in May 1992 (Administrative Docket Number: II-CERCLA-FFA-00201) to coordinate the cleanup.

The IAG identified Areas of Concern (AOCs) that were grouped into OUs to be evaluated for response actions. The IAG required a remedial investigation/feasibility study (RI/FS) for OU I, pursuant to 42 United States Code (USC) 9601 et seq., to meet Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) requirements. OU I consists of areas of soil contamination at the BNL site where waste was historically managed or disposed. The OUs and AOCs identified by the IAG are discussed further in Sections 1.5 and 2.0.

Upon completion and review of the results of a Remedial Investigation (RI) and Feasibility Study (FS) for OU I, the *Record of Decision – Operable Unit I and Radiologically Contaminated Soils (Including Areas of Concern 6, 8, 10, 16, 17, and 18)* (OUI ROD), was signed in August 1999. The OU I ROD specified the excavation and off-site disposal of radiologically and chemically contaminated soils.

In April 2009, the *Record of Decision – Area of Concern 31, High Flux Beam Reactor* (HFBR ROD) was finalized. The HFBR ROD specified stabilization activities that are necessary to prepare the HFBR for long-term safe storage to allow for radioactive decay, as well as the D&D of Building 750 (with the exception of the subsurface concrete structures of the building base mat) after the long-term S&M period (not to exceed 65 years). It also specified the removal of contaminated soil within the HFBR complex utilizing the dose-based cleanup goal and methodology specified in the OU I ROD.

1.4 Site Investigation

Comprehensive sampling and analyses were performed to characterize the HFBR complex between 2000 and 2005. These activities included both radiological and non-radiological characterization inside Building 750 and within the HFBR Outside Areas. Radiological and non-radiological characterization results for the HFBR are summarized further in the following reports:

- *Preliminary Characterization for Brookhaven National Laboratory High Flux Beam Reactor*, WMG Report 9622 Rev.1 (WMG, September 2000);
- *Brookhaven National Laboratory High Flux Beam Reactor Final Characterization Report* (BNL, September 2001);
- *High Flux Beam Reactor & Balance of Plant Supplemental Characterization Summary* (PWGC, June 2005);
- *Brookhaven National Laboratory High Flux Beam Reactor Characterization Summary Report*, Rev. 0, (Cabrera, March 2005);

- *High Flux Beam Reactor and Balance of Plant Structures Preliminary Assessment/Site Inspection Report* (PWGC, January 2005);
- *Brookhaven National Laboratory Building 705 Stack Resolution of End-State* (PWGC, February 2005)
- *High Flux Beam Reactor: Building 751. Portable Structure 549, Interconnecting Ducts, Selected Components, & Soils Sampling and Analysis* (DAQ, December 2005);
- *Feasibility Study, Brookhaven High Flux Beam Reactor, Decommissioning Project* (BNL, 2006);
- *Proposed Remedial Action Plan for the High Flux Beam Reactor at Brookhaven National Laboratory* (BNL, January 2008); and
- *Final Record of Decision for Area of Concern 31, High Flux Beam Reactor* (BNL, February 2009).

1.4.1 Building 750

Radiological characterization of Building 750 included activation analyses of the reactor vessel and its internal components, thermal shield, and biological shield. Radiological characterization also included the reactor building structure, systems, and components. The total of the radioactive material remaining at the HFBR predominantly consists of activated components within the reactor and the surrounding thermal and biological shields. There are also small amounts of contamination contained within the confinement building structure, systems, and components. The HFBR primary piping remains isolated in place, including the original piping in the reactor mat.

Neutron activation of HFBR reactor components and immediately adjacent structures has resulted in a substantial inventory of radioactive material within the reactor and the inner region of the surrounding biological shield. The activated components inventory was calculated to be 65,000 Curies (Ci) as of January 2007, which was more than 99 percent of the total radioactive material remaining at the HFBR complex. This inventory, however, has since been reduced by over a third with the removal of the control rod blades (CRBs) and beam plugs as described further in Section 1.5. Most of the existing activated iron (Fe-55) is in the thermal shield and remaining reactor internals. Most of the cobalt (Co-60) and long-lived nickel (Ni-59 and Ni-63) is in the stainless steel components of the reactor internals. Tritium (H-3) is the primary isotope in the biological shield. The following presents the radiological inventory of the remaining components as of January 2007:

- Reactor Vessel – 380 Ci
- Reactor Internals – 16,387 Ci
- Thermal Shield – 24,876 Ci
- Biological Shield – 125 Ci

The physical form of these components, activated metal and concrete, makes the hazard primarily a direct exposure risk rather than a risk of environmental contamination through dispersal. The reactor vessel, internals, thermal shield, and the activated portion of the biological shield are well shielded in their current configuration. There are no significant exposure hazards from those materials until they are disturbed during dismantling and decommissioning.

The confinement building structure itself is contaminated to a small extent. All of the concrete floors and walls within Building 750 are estimated to contain a total of approximately 0.1 Ci, primarily H-3 and Co-60. While the Co-60 contamination is mostly found on the equipment level, the H-3 contamination is found on all levels of the confinement building. The total contamination inventory inside of the reactor systems within the confinement building is approximately 45 Ci.

Certain chemicals and hazardous materials were used during the construction and operation of the HFBR. They include polychlorinated biphenyls (PCBs), asbestos and lead in materials of construction, organic solvents for degreasing equipment, and elemental mercury in certain instruments used in facility operations. Non-radiological characterization findings included the following:

- Asbestos-containing material (ACM) intrinsic to older floor and ceiling tiles, in gaskets, piping and wiring insulation, switchgear spark arrestors, and roofing materials.
- PCBs intrinsic to original paint for metal constructions and on pipelines, and hydraulic fluids.
- Lead intrinsic to paint, lead blocks and dust, shielding, and batteries.
- Other heavy metals of concern include zinc that was frequently detected and cadmium and beryllium that were found sporadically.
- Sampling for mercury revealed negative results but is intrinsic to capacitors, light ballasts, gearboxes, and in motor-operated valve lubricating oils.
- Solvents, degreasers, lubricants, oils, and petrochemicals intrinsic to equipment such as motors and compressors.
- Sodium hydroxide and sulfuric acid were used for water treatment. Chemical storage tanks were drained and rinsed.
- Lithium arsenite used in the confinement building air conditioning system. .(only trace amounts of this could possibly remain at this time. The brine solution in one of the two A/C units had only 3% Arsenite. It has since been drained and evacuated via vacuum pump)
- Suspected trace amounts of cadmium nitrate and gadolinium nitrate on the operations level due to leaks and spills.

1.4.2 HFBR Outside Areas

Characterization of the HFBR yard included surface and subsurface soils and various underground duct and piping systems. There were also isolated areas of radiologically contaminated soils in the HFBR yard. Figure 1-5 shows the isolated areas of soil contamination that were within the area addressed by the HFBR Stabilization Project (HFBR Outside Areas). The boundaries of the HFBR Outside Areas are further described in Section 3.3 and are illustrated in Figure 3-1.

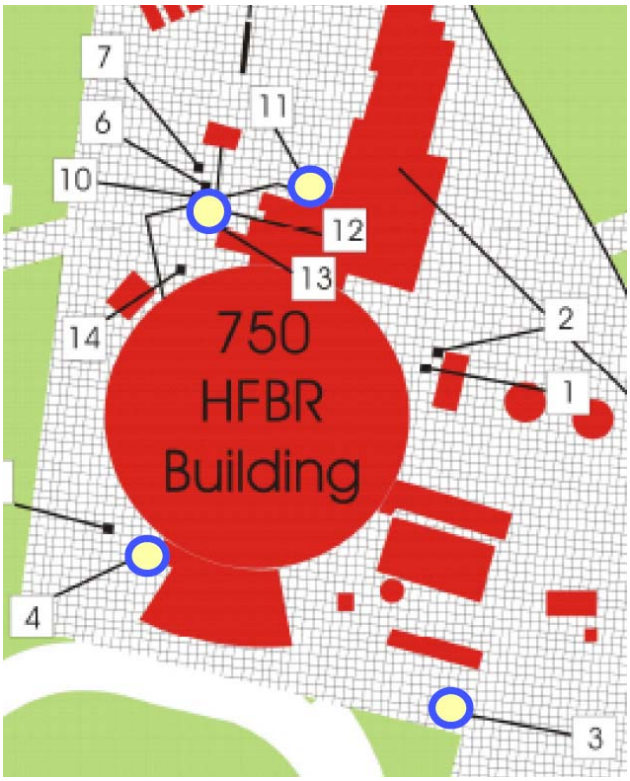


Figure 1-5 – Location of Isolated Soil Contamination within the HFBR Outside Areas

Twenty-one isolated areas of contamination were initially identified during site characterization. As a result of their limited size, many of these areas were actually cleaned up in 2001 through the process of obtaining the samples required for characterization. Eight isolated soil contamination areas (3, 4, 11, 12, 13, 16, 17 and 18) remained after characterization and were posted in accordance with DOE procedures. Locations 16, 17 and 18 were in the previous vicinity of Building 704 and were therefore addressed by the Fan Houses Remediation Project. The soil contamination in the vicinity of the HFBR confinement building, points 3, 4, 11, 12, and 13, was Co-60 and exhibited dose rates ranging from 5 to 11 microrem/hr at 1 ft.

1.5 Previous Remedial and Stabilization Activities

Several measures involving removal of HFBR contaminated structures, components and soils have been completed since 1998. These actions included:

- The primary coolant (heavy water) was removed and sent to an off-site facility in 2001.
- Shielding and chemicals were removed between 2000 and 2005, and are being reused at BNL and other facilities.
- Scientific equipment was removed in 2003 and is being reused or has been sent to an off-site disposal facility.
- The confinement structure and spent fuel canal were modified to meet Suffolk County Article 12 requirements in 2004, under the Tritium Remediation Project.
- The HFBR resin beds and filters were removed in 2009.
- Control rod blades and beam plugs were removed in 2009, as documented by the *Final Completion Report for the Removal of the Control Rod Blades and Beam Plugs* (BNL, January 2010).
- The cooling tower superstructure was dismantled and disposed of as waste in 1999.
- Stack Monitoring Facility (Building 715) was dismantled and removed in 2006.
- Cooling tower basin and pump/switchgear house (Buildings 707/707A) were dismantled and removed in 2006.
- Water Treatment House (Building 707B) was dismantled and removed in 2006.
- Cold Neutron Facility (Building 751) contaminated systems were removed and the clean building has been transferred to another BNL site organization for re-use in 2006.
- Guard House (Building 753) was dismantled and removed in 2006.
- Remediation of the Waste Loading Area was completed in 2008, as documented by *High Flux Beam Reactor Waste Loading Area Soil Remediation Completion Report* (BNL, June 2009).
- Building 801-811 Waste Transfer Lines and associated contaminated soil were removed in 2009, as documented by *Closeout Report for the Removal of the Building 801-811 Waste Transfer Lines (A/B Waste Lines with Co-Located Piping)* (BNL, June 2010).

In addition to the above actions, the removal of the Fan Houses (Buildings 704 and 802), HFBR underground utilities and associated contaminated soils were completed and will be documented in separate closeout reports.

1.6 BNL Operable Units

As part of remedial efforts at BNL, thirty AOCs were identified and grouped into seven OUs. The seven OUs were subsequently reduced to six OUs as a result of combining OU II and OU VII. In February 2009, AOC 31, comprising the HFBR complex was established.

This report documents completion of the stabilization and remedial actions for the HFBR, which is designated as AOC 31. As described in Section 2.1, the cleanup goals established in the OU I ROD were used for the HFBR Stabilization Project.

2.0 OPERABLE UNIT BACKGROUND

2.1 Site Cleanup Criteria

The primary radiological contaminants of concern for the soil within HFBR Outside Areas were specified in the HFBR ROD and are the same as those for OU I radiologically contaminated soils: Cs-137, Ra-226, and Sr-90. The cleanup goals for specific radionuclides were calculated using RESRAD, considering a residential scenario. The dose limit used was 15 millirem per year (mrem/yr) above background (*OSWER Directive 9200.4-1., EPA, 1997*), residential land use with 50 years of institutional control by the DOE, and industrial land use with no decay time (0 years). In addition, the NYSDEC cleanup guideline of 10 mrem/yr, from TAGM 4003, was adopted as an ALARA goal. The primary radiological isotope present at the site was Cs-137; its cleanup goal, as established in the OU I ROD and specified in the HFBR ROD, is 23 pCi/g.

The potential for radiologically contaminated soil to impact groundwater was also considered. A soil cleanup goal of 15 pCi/g was calculated for Sr-90, based on its potential to impact the groundwater. The goal also protects both residential and industrial uses. A cleanup goal of 5 pCi/g was selected for Radium-226 (Ra-226), based on DOE Order 5400.5, *Radiation Protection of the Environment and the Public* (DOE, 1993).

Additional radionuclides that were not addressed in the OU I ROD were also evaluated. As discussed in Section 1.4, previous site investigations indicated detections of Co-60 and H-3 within the HFBR Outside Areas. These radionuclides were considered as additional radiological contaminants of concern and are listed with their respective cleanup goals in Table 2-1.

The primary chemical contaminants of concern for the HFBR Outside Areas are the same as those for OU I chemically contaminated soils: mercury and lead. The cleanup goal established for mercury is 1.84 mg/kg, based on the EPA's soil screening level guidance (*OSWER Directive 9355.4-23*) for protecting groundwater and residential use. The choice of a cleanup goal of 400 mg/kg for lead also was based on the EPA's soil screening level guidance; this level is protective of residential use. The cleanup goals for these chemical contaminants were established in the OU I ROD and specified in the HFBR ROD.

Nickel, copper and zinc were also were also considered chemical contaminants of concern since there were detected above cleanup goals in several areas within the HFBR Outside Areas, as described in *High Flux Beam Reactor and Balance of Plant Structures Preliminary Assessment/Site Inspection Report* (PWGC, January 2005). As specified in Table 2-1, soil cleanup objectives for residential from 6NYCRR Part 375 were used for site cleanup goals for these additional chemical contaminants of concern.

Table 2-1

Radionuclides and Chemical Contaminants of Concern
for the HFBR Stabilization Project

Radionuclides of Concern	Cleanup Value (pCi/g)	Source of Cleanup Goal Value
Cs-137	23	OU I ROD (BNL, 2009)
Sr-90	15	OU I ROD (BNL, 2009)
Ra-226	5	OU I ROD (BNL, 2009)
H-3	424 (2)	N/A
Co-60	1,260 (2)	N/A
Chemical Contaminant	**Soil Cleanup Level**	**Source of Cleanup Goal Value**
Mercury	1.84 mg/kg	OUI ROD (BNL, 2009)
Lead	400 mg/kg	OUI ROD (BNL, 2009)
Nickel	140 ppm	6NYCRR Part 375 Restricted Use – Soil Cleanup Objectives, Residential
Copper	270 ppm	6NYCRR Part 375 Restricted Use – Soil Cleanup Objectives, Residential
Zinc	2,200 ppm	6NYCRR Part 375 Restricted Use – Soil Cleanup Objectives, Residential

Notes:

1. For those nuclides "not referenced," the estimated cleanup levels were not listed in either the OU I ROD nor in other BNL remediation references. If these nuclides were detected, RESRAD was used as described in Section 3.1.3.3 of the project FSP to develop the cleanup levels that will meet the 15 mrem/yr criteria.
2. The value is based on a RESRAD evaluation for a residential scenario with no decay.

2.2 Design Criteria

Technical specifications and design criteria for the HFBR Stabilization Project were established in the HFBR ROD and the *Field Sampling Plan for the HFBR Outside Areas* (BNL, July 2010). The remedial design included:

- Specifications for physical modifications and stabilization activities to prepare the HFBR confinement building for long-term minimum S&M;
- Specifications for institutional controls to protect the health and safety of workers, the public and the environment during long-term minimum S&M;
- A plan and process for ensuring the total exposure from all radioisotopes does not exceed 15 mrem/yr above background following the 50-year period for institutional control for the site;
- Methods to reduce waste volumes that require offsite disposal; and
- An approach for sampling to confirm that cleanup goals have been achieved for the HFBR Outside Areas.

2.3 Community Relations Activities

2.3.1 BNL Community Relations

The BNL Community Involvement Plan was published April 15, 1999. It is supplemented by project-specific plans. In the case of the HFBR, a Communications Plan for the Regulatory Decision-Making Process for Decommissioning the High Flux Beam Reactor was developed. In accordance with these two plans and CERCLA Sections 113 (k)(2)(B)(i-v) and 117, the Community Relations Program focuses on informing and involving the public in the decision-making process to ensure that the views of the internal and external stakeholder communities are considered. A variety of activities are used to provide information and to seek public participation, including distribution of materials to a stakeholders' mailing list; holding community meetings, information sessions, tours, and workshops; and preparing and distributing fact sheets. The Administrative Record, which documents the basis for removal and remedial actions, was established and is maintained at the libraries listed below:

Brookhaven National Laboratory
Research Library
Bldg. 477A
Upton, NY 11973
631-344-3483 or 631-344-3489

Stony Brook University
Melville Library
Special Collections and University Archives
Room E-2320
Stony Brook, NY 11794
Phone: (631) 632-7119

U.S. EPA - Region II
Records Room
290 Broadway, 18th Floor
New York, New York 10007
212-637-4308

2.3.2 Community Involvement

The community involvement activities conducted for the remedy selection process for the HFBR (including stabilization of the confinement building for long-term safe storage) included a formal public review of the HFBR Proposed Remedial Action Plan (PRAP). The public comment period began January 10, 2008 and ended March 17, 2008. Two information sessions and a public meeting were held during the public comment period. Public comments received indicate that there is considerable community support for DOE's preferred remedial alternative identified in the PRAP (Alternative C, Phased Decontamination and Dismantlement with Near-Term Control Rod Blades Removal). DOE's responses to public comments and concerns are included in the HFBR ROD Responsiveness Summary.

The implementation of the HFBR Stabilization Project using ARRA funds was discussed with the BNL Community Advisory Council on April 15, 2009 and November 12, 2009.

3.0 CONSTRUCTION ACTIVITIES

The objective of the HFBR Stabilization Project was to safely prepare the HFBR confinement building (Building 750) for long-term safe storage to allow for radioactive decay, as well as to characterize and remove localized radiological contamination within the HFBR Outside Areas in accordance with the HFBR ROD and project specific plans. Following the characterization and removal of localized radiological contamination, an FSS and a dose assessment were performed for the HFBR Outside Areas by BNL ERP. The FSS was independently verified by ORISE. This work is further discussed in Section 3.2. The FSS was completed using the *Multi-Agency Radiological Survey and Site Investigation Manual* (*MARSSIM*) guidelines.

Building 750 stabilization activities associated with this project took place between April 2009 and August 2010. Localized radiological contamination within the HFBR Outside Areas was further characterized and removed between April 2010 and September 2010, and the subsequent FSS and IVS of the HFBR Outside Areas were completed between July 2010 and September 2010. All pre-construction tasks for each work phase were completed prior to beginning stabilization activities within the associated work area, including equipment mobilization, radiological surveys, site inspections and securing the general work area. In addition, the Building 750 Machine Shop was cleaned out and set up as temporary office space to support the HFBR Stabilization Project.

Job Risk Assessments (JRAs), Radiological Work Permits (RWPs), and project-specific work procedures were developed to address hazards and work steps associated with the HFBR Stabilization Project. The information presented in the project plans was reviewed by the site workers prior to initiating the project work activities. Copies of project plans were available onsite at all times for site workers to thoroughly review.

The *Field Sampling Plan for the HFBR Outside Areas* (BNL, July 2010) detailed the data quality objectives (DQOs) and quality assurance (QA) requirements for the FSS. The plan also presented the field screening value (20,400 cpm with unshielded sodium iodide detector) to be used in guiding the excavation and in determining when the excavation was completed.

3.1 Building 750 Modification and Stabilization Activities

Building 750 physical modifications and stabilization activities were completed to prepare it for long-term minimum S&M. These activities included the isolation and drain-down of Building 750 mechanical systems and tanks, the removal of miscellaneous waste and combustible materials, installation of a building exhaust fan to ensure the atmosphere in the confinement is safe for personnel access, installation of an alternate 480V electrical feed to Building 750, security upgrades/modifications, installation of a water infiltration detection system, removal of hazardous materials, and confinement building repairs. These activities were completed to achieve the interim end state for the

HFBR, as defined by the *High Flux Beam Reactor Decommissioning End Points* (BNL, September 2007).

3.1.1 Ventilation Exhaust System Modification

The original building air exhaust system in Building 750 has been de-energized and abandoned in place. The original system has been replaced with a long-term low maintenance building air exhaust system to prevent the accumulation of condensation, accelerated degradation of metal and concrete and mold growth. The new system will also maintain safe indoor air quality for S&M entries.

The long-term low maintenance building air exhaust system consists of an exhaust fan operating at 4,000 cubic feet per minute (cfm) with a 22'-6" effective stack height with a 10 horsepower (HP) motor at 3,550 revolutions per minute (rpm). The exhaust fan is located outdoors along the west side of the North Truck Lock. Air is drawn through an open Building Vacuum Relief Valve located inside a locked fence cage on the HFBR Balcony Level. To promote air movement throughout the building, floor plugs were removed between the Operations and Experimental Levels, and the doors will remain open in the stairwells between the Experimental and Equipment Levels. There is also in-leakage of air through the truck lock seals.

Operation and maintenance of the long-term low maintenance building air exhaust system will be in accordance with the *Long-Term Surveillance and Maintenance Manual for the High Flux Beam Reactor (HFBR) Brookhaven National Laboratory, New York*, latest revision, (BNL, 2010), referred to herein as the HFBR Long-Term S&M Manual. The building air exhaust blower will initially run continuously. Operation times may be reduced based upon visual inspections and to maintain safe indoor air quality for entries. Should the building air exhaust blower become inoperable, it must be repaired and returned to service prior to any entry into the confinement building.

Photograph 1 – Installation of Building 750 air exhaust system

3.1.2 Outside Access and Security System and Alarms Modification

Building 750 security was modified such that all entry points are now completely locked and alarmed during the long-term low maintenance condition. The confinement alarm system was modified to include remote annunciating alarms on all entryways to prevent unauthorized entry. The alarm system is connected to a central alarm system in Building 50 where it will be monitored on a continuous basis. BNL Security is responsible for monitoring and maintaining the Building 750 alarm system.

3.1.3 Water Infiltration Detection System Installation

A water infiltration detection system, consisting of a panel and five detection sensors, was installed on the Building 750 Equipment Level. The water infiltration detection panel is located on the west side of the Transformer Room within the Equipment Level. The five water infiltration detection sensors are located at the following low points: 1) bottom of the FA-101 tank pit, 2) at the base of the north stairwell, 3) bottom of the freight elevator shaft, 4) at the deep end of the spent fuel canal, and 5) at the base of the south stairwell. The system will be maintained to detect water infiltration into the Building 750 Equipment Level (Elev. 93'). The water intrusion signal alarms remotely in the Chilled Water Facility (Building 600), which is manned 24 hours a day by a site shift supervisor. The exact locations of sensors and instructions on how to maintain, periodically test, inspect the system are provided in the HFBR Long-Term S&M Manual.

Photograph 2 – Water infiltration sensors installed on Equipment Level (This is under the North stairwell)

3.1.4 Electric Power Distribution Modification and Lighting

Utility systems were modified and electrical power was restored to Building 750 to support long-term S&M. The modified electrical power distribution includes two 480-volt feeds from a transformer located on the exterior east side of Building 750. One feed supplies power to the main 480 Volt Bus on the Equipment Level of Bldg 750. That power is stepped down via the Emergency Motor Control Center (EMCC) transformer to 115/120-volt power for use inside the confinement dome, including lighting and duplex receptacles. The duplex receptacles are in place to support S&M activities, including the use of portable lighting and power tools. Their locations are provided in the HFBR Long-Term S&M Manual. Another 480-volt feed from the same transformer also provides electrical power to a main panel in the Machine Shop. The building air exhaust system is powered from this panel. An additional small transformer, located within the North Portal Storage Room adjacent to the north forklift airlock, steps down the 115/120-volt power to 24-volt DC in order to provide power to the water infiltration detection system and the security system. Operation details for the electric power distribution system are provided in the HFBR Long-Term S&M Manual.

In 2010, LiRo Engineers conducted a visual inspection for the light fixtures and found that the connections and hardware were in generally good condition. Given no exposure to the elements or other actions which could otherwise compromise the fixtures fastenings, LiRo Engineers concluded that the light fixtures will remain secure for the long-term low maintenance period. The inspection and associated recommendations are documented in the *Building 750 2010 Follow-up Field Inspection Report* (LiRo, April 2010). Future inspection of the fixtures will be in accordance with the HFBR Long-Term S&M Manual.

3.1.5 Drain-down of Mechanical Systems and Tanks

Stabilization activities included draining and isolating Building 750 mechanical systems and tanks. The status of the inactive systems as of July 2010 is summarized below in Table 3-1.

Photograph 3 – Isolated and empty Tank FA 305

Table 3-1

Status of Inactive HFBR Facility Systems

System	Elevation / Area	Conditions as of July 2010
Primary Cooling Water System	OPS, EXP, EQ	Isolated and drained to RCRA empty requirements.
Primary Purification System	EQ	Isolated and drained to RCRA empty requirements
Primary Acidification System	EQ	Isolated and drained to RCRA empty requirements
Primary Sampling System	EQ	Isolated and drained
Primary Pump Seal Cold Trap System	EQ	Isolated and drained to RCRA empty requirements
DA Drain and D2O Transfer System	OPS, EXP, EQ	Isolated and drained to RCRA empty requirements
Reactor Vessel Cover Gas System	OPS	Isolated and drained
Light Water Make Up System	OPS, EXP, EQ	Isolated, partially disassembled, and drained
Shutdown Cooling Water System	OPS, EXP, EQ	Isolated and drained to RCRA empty requirements
Thermal Shield Cooling Water System	OPS, EXP, EQ	Isolated and drained to RCRA empty requirements
Biological Shield Cooling Water System	OPS, EXP, EQ	Isolated and drained to RCRA empty requirements
Fuel Canal Cooling Water System	EQ	Isolated and drained to RCRA empty requirements
Auxiliary Water Purification System	EQ	Isolated and drained to RCRA empty requirements
Secondary Cooling Water System	OPS, EXP, EQ	Isolated and drained to RCRA empty requirements
Air Conditioning Absorbers	EQ	Isolated and drained to RCRA empty requirements
Chilled Water System	OPS, EXP, EQ	Isolated and drained
Hot Water Heating System	OPS, EXP, EQ	Isolated and drained
Steam Heating System	OPS, EXP, EQ	Isolated and drained
Domestic Water System	OPS, EXP, EQ	Isolated and drained
Sanitary System	OPS, EXP, EQ	Isolated and drained to RCRA empty requirements
Fire Protection System	OPS, EXP, EQ	Deactivated and drained
Carbon Dioxide Gas System	EQ	Isolated and evacuated
Helium Cover Gas System	OPS, EXP, EQ	Isolated and evacuated
Vertical Irradiation Thimbles	OPS	Isolated and drained
Experimental Facilities Cooling Water Sys.	OPS, EXP	Isolated and drained to RCRA empty requirements
Building Compressed Air System	OPS, EXP, EQ	Isolated and evacuated
Liquid D/F Waste System	OPS, EXP, EQ, Outdoors	Interior system isolated and drained to RCRA empty requirements; underground piping removed
Breathing Air System	OPS, EXP, EQ	Isolated and evacuated
Fuel Cladding Failure System	EQ	Removed
Exit Air Monitoring System	EQ	Isolated and evacuated
Break Tank Water Supply System	OPS, EXP, EQ	Isolated and drained to RCRA empty requirements
Condensate Collection System	OPS, EXP, EQ	Isolated and drained to RCRA empty requirements
Reactor Poison Water System	OPS	Isolated and drained to RCRA empty requirements

Notes:

1. OPS – Operations Level,
2. EXP – Experimental Level
3. EQ – Equipment Level
4. In accordance with 40 CFR Part 261.7 (Reference 12), a container holding hazardous waste is defined as "RCRA empty" when:

- All wastes have been removed using practices commonly employed industry-wide to remove wastes from containers or liners, such as pouring, pumping, aspirating, and draining; and,
- No more than 2.5 centimeters (1 inch) of material remains in the container or liner; or,
- No more than 3 percent by weight of the container remains for containers with a capacity of 110 gallons or less, and no more than 0.3 percent by weight remains for containers with a capacity greater than 110 gallons.

All storage tanks registered with the Suffolk County Department of Health Services in accordance with Suffolk County Sanitary Code Article 12 have been rendered inoperable and are permanently closed or exempt from inspection and reporting requirements. Table 3-2 below presents the status of each of the twenty-three (23) tanks and storage areas associated with Building 750.

Table 3-2

Status of HFBR Storage Tanks

BNL Tank No.	SCDHS Tank No.	Cap. (gal.)	Local Designation	Material Stored	Status	Isolation Method
0750-04	154	5,500	FA 101	Empty	Closed	Air gapped inlets and outlets, drilled hole in tank
0750-05	155	5,500	FA 102	Empty	Closed	Air gapped inlets and outlets, drilled hole in tank
0750-06	156	4,400	FA 305: D waste tank	Empty	Closed	Air gapped inlets and outlets, drilled hole in tank
0750-07	157	1,000	FA 311	Empty	Closed	Air gapped inlets and outlets, drilled hole in tank
0750-11	263	68,000	Spent Fuel Canal	Empty	Closed	Leak detection in place
0750-16	491	200	Elevator Tank	Hydraulic oil	Exempt	Leak detection in place
0750-17	492	200	Elevator Tank	Hydraulic oil	Exempt	Leak detection in place
0750-18	485	9,000	Reactor Vessel	Empty	Closed	Air gapped piping
0750-19	486	1,350	Thermal Shield Water System	Empty	Closed	Air gapped via removal of filters and filter vessels
0750-21	488	800	Bio Shield Water System	Empty	Closed	Air gapped via removal of filters and filter vessels
0750-22	489	100	Experimental Facilities Cooling System	Empty	Closed	Air gapped inlets and outlets, drilled hole in tank
0750-23	490	50	D-waste sump	Empty	Closed	Inlets sealed; sump filled with concrete
0750-24	494	2,500	FA 312: Condensate Collection	Empty	Closed	Air gapped inlets and outlets, drilled hole in tank
0750-25	495	78	Thermal Shield Tank	Empty	Closed	Air gapped inlets and outlets, drilled hole in tank
0750-26	496	28	Bio Shield Head Tank	Empty	Closed	Air gapped inlets and outlets, drilled hole in tank
0750-27	497	400	Poison Water Tank	Empty	Closed	Air gapped inlets and outlets
0750-30	493	50	Primary Loop Acid Tank	N/A	Closed	Removed
0750-31	702	55	FA 303 Sump	Empty	Closed	Inlets sealed; sump filled with concrete
0750-32	704	43	DA Drain / Purification Sys	Empty	Closed	Pipes on both ends cut and capped
0750-33	814	15	FA 313 Decon Pump Sump	N/A	Closed	Removed

Table 3-2 cont.

BNL Tank No.	SCDHS Tank No.	Cap. (gal.)	Local Designation	Material Stored	Status	Isolation Method
0750-39	881	600	Exp. Facilities Cooling	Empty	Closed	Air gapped via removal of filters and filter vessels
0750-40	882	250	HAZ-STOR Shed	N/A	Closed	Removed
0750-43	763	250	HAZ-STOR Shed	N/A	Closed	Removed

Notes:

1. "Air gap" is defined as the physical removal of the inlet/outlet piping to the tank or vessel with the open pipe ends capped for contamination control.
2. Drilling holes in tanks is defined as physical removal of the tank or vessel material with a hole saw or equivalent tool in order to render it incapable of holding liquid. Bolted or screwed access or inspection openings in tanks which could be reinstalled are not considered as a method to render tanks out of service. Holes were not drilled in storage tanks not previously registered with the Suffolk County Department of Health Services.
3. Due to concerns of spreading contamination, the holes drilled into tanks were patched with sheet metal and silicon after they were rendered inoperable.
4. Due to personnel hazards, the Poison Water Tank (#497) will not be opened. Inlet and outlets to this tank will be air gapped.
5. Reactor vessel cannot be breached due to radiological hazards. However, all pathways for fluids have been isolated, and system piping to/from vessel will be made inoperable by air-gapping at connection to purification system.
6. Filters/filter vessels have been removed from the system rendering it "air gapped" and inoperable.
7. As part of HFBR stabilization activities prescribed in the HFBR ROD, all systems (domestic water, steam and condensate, sanitary) were drained and permanently isolated by air-gapping at their respective entrances (penetrations) to the building thereby eliminating all pathways for liquids to enter the building. All floor drains and sanitary drains were permanently sealed to prevent any water resulting from rainwater in-leakage from exiting the building.
8. Article 12 de-certification is not an action required by the HFBR Record of Decision (ROD), although this code is "to be considered" guidance (HFBR ROD, 11.2.4). Specifically the HFBR ROD (11.2.4) states that "For the Article 12 registered components remaining, detailed surveillance and maintenance actions will be included in the S&M program." The S&M program is addressed in 10.3.4 of the HFBR ROD and includes "periodic physical examination of the confinement building…including inspection for water infiltration."
9. A leakage detection system is installed in the building low points to detect any liquids which may enter the building. Since the HFBR will not be occupied full time, this system alarms at the BNL Central Energy Facility (Bldg. 600) Control Room.

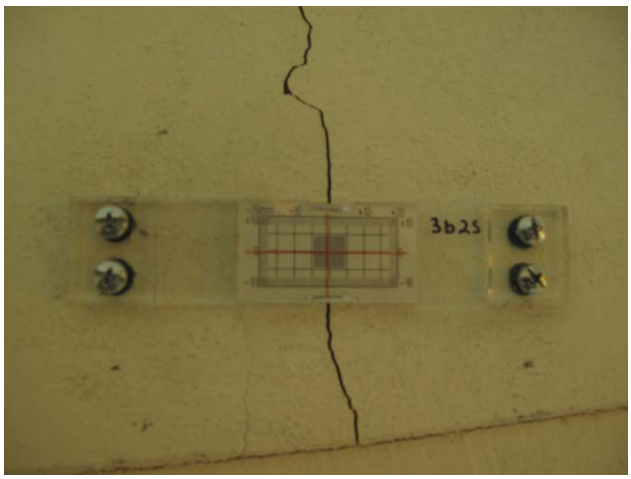
3.1.6 Fire Protection/Detection and Removal of Miscellaneous Combustible Materials

As indicated by Table 3-1, fire protection standpipes and sprinklers within Building 750 have been drained and sections have been removed in several areas. The majority of fire detectors have been removed and the fire detection panel has been de-activated. There is no fire protection/detection for Building 750. Signs indicating that the fire protection/detection system has been de-activated were placed on all fire pull boxes and the fire detection panel. Additionally, there are no fire extinguishers within the building. All combustibles have been removed from Building 750, as practicable.

3.1.7 Correction of Minor Confinement Building Deficiencies

General inspections of Building 750 were performed in 2005 and 2010 by LiRo Engineers, Inc., as documented in the *Building 750 Structural Report on Long Term Building Integrity* (LiRo, August 2005) and the *Building 750 Follow-Up Field Inspection Report* (LiRo, April 2010). In general, the facility is in very good to excellent condition with the exception of minor concrete cracks in concrete structures and other minor deficiencies. Specifically, the LiRo reports identified twelve (12) vertical cracks in the

radial composite girders at the ceiling of the Experimental Level. A subsequent inspection by representatives from ERP in June 2010 identified ninety-eight (98) vertical cracks in these members. Following this inspection and recommendations from BNL Facilities & Operations (F&O) representatives, crack gauges were installed on ten (10) representative cracks for observation. The conditions of the cracks are summarized in Table 3-3.



Photograph 4 – Crack monitoring gauge on radial composite girder on experimental level

Table 3-3

Cracks in Radial Composite Girders on Experimental Level

Location	Width	Extent
2-A-23	Less than 1/32"	Full height
3-B-25	Less than 1/32"	Full height
5-A-26	Less than 1/32"	Full height
6-B-23	Less than 1/32"	Full height
7-A-19	Less than 1/32"	Full height
8-A-23	Less than 1/32"	Full height
9-B-22	Less than 1/32"	Full height
10-A-23	Less than 1/32"	Full height
13-A-12	Less than 1/32"	Full height
15-B-16	Less than 1/32"	Full height

Notes:

Cracks are labeled according to the column / beam number, the side of the beam the crack is located, and the distance from the outside column. Side "A" is towards the numerically smaller beam and Side "B" is towards the numerically larger beam. For example, 2-A-23 is located on Side "A" of beam 2 and is 23 feet inward from the outside column.

During an additional inspection by ERP on the Equipment Level in August 2010, a crack in the ceiling extending radially inward from Column A-1 to the biological shield wall was observed. Based upon expert opinion from an F&O representative, the crack was likely caused by a reduction in weight load as a result of removal of the experimental facilities on the Experimental Level above. The condition of this crack is summarized in Table 3-4. A crack monitoring gauge was installed at this location, as well.

Table 3-4

Crack in Ceiling on Equipment Level

Location	Width	Extent
Ceiling between Column A-1 and Biological Shield Wall	<1/32"	27'-6"

In addition to the installation of crack monitors, minor deficiencies identified in the *Building 750 Follow-Up Field Inspection Report* (LiRo, April 2010) were repaired as part of the HFBR Stabilization Project. The location and description of each minor deficiency is summarized below in Table 3-5. These locations will be monitored in accordance with the HFBR S&M Manual to determine the adequacy of the repairs.

Photograph 5A & 5B – Before/After of concrete repairs on Building 750 exterior wall

Table 3-5

Summary of Repaired Minor Building Deficiencies

Location	Description
Northeast side, 1' above grade	1'x1' area where plaster had cracked and flaked off
East side, 10' above grade	10' long x 4" wide crack in plaster that had flaked off
East side, at grade	Crack in plaster that had flaked off
East side, at grade	Vertical plaster crack

3.1.8 Removal of Hazardous Materials

As discussed in Section 1.4, certain chemicals and hazardous materials were used during the construction and operation of the HFBR. They include PCBs, asbestos, and lead in materials of construction, organic solvents for degreasing equipment, and mercury in certain equipment. The *Final Characterization Report for Brookhaven National Laboratory High Flux Beam Reactor* (BNL, 2001) identified the potential for asbestos-containing materials, PCBs, lead, cadmium, zinc, beryllium, mercury, lithium arsenite, cadmium nitrate, and gadolinium nitrate to be present in the building.

Heavy metal wipe samples were collected from surfaces on the Operations, Experimental, and Equipment Levels in August 2010 and analyzed for beryllium, cadmium, and lead. Locations where lead exceeded 26.9 μg/100 cm^2 and locations where cadmium exceeded 3 μg/100 cm^2 were posted and are provided in Tables 3-6 and 3-7, respectively. Beryllium was not detected in any of the wipe samples. The limits are defined as the housekeeping and general release criteria found in the BNL Industrial Hygiene Group Standard Operating Procedure IH75190, *Surface Wipe Sampling Procedure* (BNL, February 2009).

Table 3-6

Summary of Lead Wipe Sample Exceedances

Level	Location
Operations	V-10 Thimble
Operations	V-11 Thimble
Operations	V-12 Thimble (and adjacent floor)
Operations	V-13 Thimble
Operations	V-14 Thimble
Operations	V-15 Thimble
Operations	Green House Floor and various locations in Green House
Operations	Floor by P-108 Piping
Operations	Demister Area
Experimental	Biological Shield Floor
Experimental	Floor by H-3
Equipment	Thermoshield
Equipment	Primary Equipment Room "A"
Equipment	Floor Outside C-15 Vault
Equipment	Primary Equipment Room "B"
Equipment	Area near Heat Exchanger

Table 3-7

Summary of Cadmium Wipe Sample Exeedances

Level	Location
Operations	Green House
Operations	Demister Area

Much of the lead shielding was removed including from the reactor top, within the Green House, and on the Equipment level around the heat exchangers. The lead shielding remaining inside Building 750 includes lead inside of a trench within the Green House (Operations level) and three lead bricks against the northeast quadrant of the biological shield behind the Positron Experiment (Operations Level).

The Reactor Poison Water System, which contained cadmium nitrate, was rinsed, isolated, and drained to RCRA empty requirements.

The two air conditioning absorbers, which contained lithium bromide, arsenite, and chromates, were drained and evacuated using vacuum pumps to RCRA empty requirements.

All oils which may have contained PCBs were drained from equipment and removed from the facility. A PCB contamination area on the floor of the passenger elevator pit was encapsulated with non-PCB containing paint.

The HFBR reactor vessel and portions of the primary system piping were constructed of an aluminum alloy that could deteriorate by contact with liquid metals such as mercury or gallium. As a result, mercury and gallium were administratively excluded from the confinement building. Therefore, there is a reasonable assurance that there is no liquid mercury or gallium within the confinement building.

Asbestos containing material (ACM) was removed on an as-needed basis to facilitate other stabilization activities. This included the removal of all confirmed and suspect ACM ceiling tiles. Some fixed ACM remains inside Building 750 floor tiles, gaskets and pipe insulation. Locations and descriptions of the remaining confirmed and suspect ACM is provided in the HFBR Long-Term S&M Manual.

3.1.9 Storm Water Drainage Improvement

The grounds surrounding Building 750 were re-graded to divert storm water runoff away from the building. In preparation for re-grading, selected sidewalks and asphalt paving were removed. Re-grading was completed outside of the transformer room, north of the east truck lock, near the entrance to the blower room and in the cooling tower area. In addition to re-grading existing soils surrounding Building 750, an asphalt pavement overlay was placed north of the east truck bay. FSS walkover surveys and soil sampling were completed in these areas prior to initiating re-grading activities. Upon completion, re-graded areas and areas were sidewalks and asphalt paving were removed were re-seeded in accordance with Section 3.5. The boundaries of re-graded areas are illustrated in Appendix A.

Photograph 6 – Re-grading operations outside of Building 750

3.2 HFBR Outside Areas

As discussed in Section 1.4, twenty-one isolated areas of contamination were initially identified during site characterization. As a result of their limited size, many of these areas were actually cleaned up through the process of obtaining the samples required for characterization in 2001. Eight isolated soil contamination areas (3, 4, 11, 12, 13, 16, 17 and 18) remained after characterization and were posted in accordance with DOE procedures. Locations 16, 17 and 18 were in the previous vicinity of Building 704 and were therefore addressed by the Fan Houses Remediation Project. The soil contamination within the HFBR Outside Areas consisted of points 3, 4, 11, 12, and 13. These points surveyed, sampled and released in accordance with BNL Radiological Controls Division (RCD) procedure FS-SOP-1005, Rev. 3, *Radiological Surveys Required for Release of Material from Areas Controlled for Radiological Purposes* (BNL 2007). These isolated areas of contamination were subsequently confirmed to be remediated to below site cleanup criteria by the completion of an FSS and IVS as described below in Section 3.3.

3.3 HFBR Outside Areas Final Status Survey and Sampling

After completion of the HFBR Outside Areas grading and minor remediation, walkover surveys were performed and soil samples were collected and analyzed in accordance with the *Field Sampling Plan for the HFBR Outside Areas* (BNL, July 2010) as specified in Section 3.3.1.

As discussed in Section 2.1, the primary radionuclides of concern, based on exposure potential, were Sr-90, Cs-137, and Ra-226. Although less likely to be present, certain other radionuclides were monitored, including tritium and cobalt-60. The chemical contaminants of concern were mercury, lead, copper, nickel, and zinc.

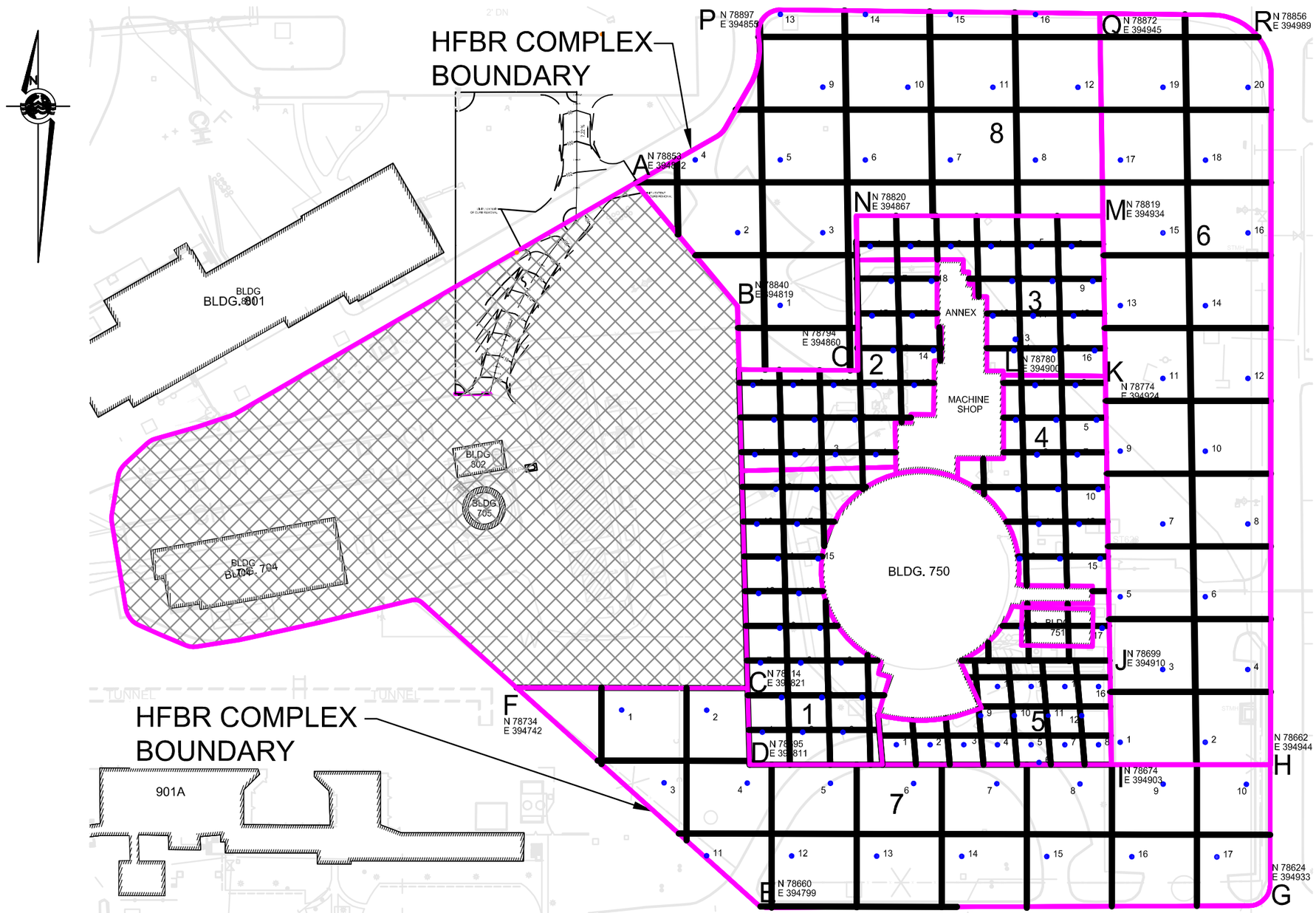
3.3.1 Final Status Survey Design

The HFBR Outside Areas were divided into five Class 1 survey units and three Class 2 survey units as described in Table 3-8. These survey units are shown in Figure 3-1. It should be noted that soils within the shaded area illustrated in Figure 3-1 are being addressed under the HFBR Underground Utilities Project, or the Fan Houses Project. The completion of these projects will be documented in separate closeout reports.

Table 3-8 – HFBR Outside Areas Survey Units and Areas

SU No.	SU Class	Area (ft^2)
1	1	21,700
2	1	17,500
3	1	19,350
4	1	20,930
5	1	12,700
6	2	95,200
7	2	76,400
8	2	79,800
Total Area (ft^2)		**343,580**

Figure 3-1: HFBR Outside Areas – Survey Unit Overview



LEGEND

- 1 — PHASE 1 - HFBR UTILITY REMOVAL
- 2A — PHASE 2A - HFBR UTILITY REMOVAL
- 2B — PHASE 2B - HFBR UTILITY REMOVAL
- 3 — PHASE 3 - HFBR UTILITY REMOVAL
- SURVEY POINT
- AREA TO BE SURVEYED UPON COMPLETION OF UNDERGROUND UTILITIES, FAN HOUSE, 802 AND STACK REMEDIATION
- 4 — AREA REQUIRES FINAL STATUS SURVEY

REFERENCE:

OVERALL SITE PLAN BASED ON SURVEY PREPARED FOR BROOKHAVEN NATIONAL LAB DATED APRIL 2009.

FIGURE 3-1. HFBR OUTSIDE AREAS - SURVEY UNIT OVERVIEW

0 100 200

SCALE: 1" = 100'

P.W. GROSSER CONSULTING INC.
630 Johnson Ave. Suite 7
Bohemia, N.Y. 11716-2618
E-mail: www.pwgrosser.com
Ph: 631 589-6353 Fx: 631 589-8705

JOB NO.	SHEET	NO	REVISION	BASE	DWN.	APP'D.

BROOKHAVEN NATIONAL LABORATORY

UNDER CONTRACT WITH
UNITED STATES DEPARTMENT OF ENERGY
PLANT ENGINEERING DIVISION
UPTON, NEW YORK 11973

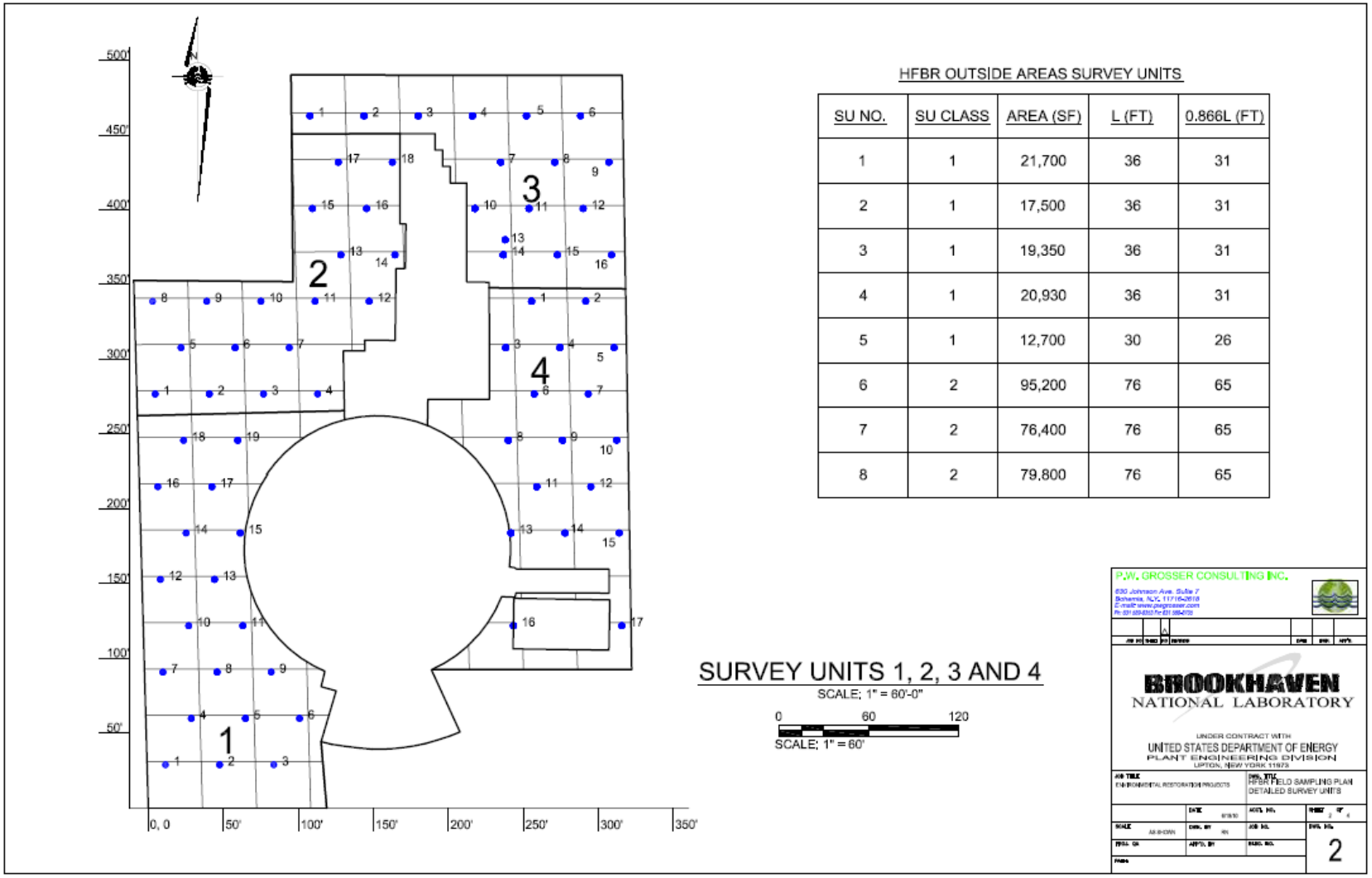
JOB TITLE: ENVIRONMENTAL RESTORATION PROJECTS		FIG. TITLE: HFBR OUTSIDE AREAS - SURVEY UNIT OVERVIEW	
	DATE: 6/18/10	ACCT. NO.	SHEET OF: 1 4
SCALE: AS SHOWN	DWN. BY: RN	JOB NO.	FIG. NO.: 3-1
PROJ. QA	APP'D. BY	BLDG. NO.	
PATH:			

A two-step approach to cleanup confirmation for radiological soil contamination was followed using the MARSSIM approach for the FSS of the HFBR Outside Areas. The first step consisted of a global positioning system (GPS)-based gamma scintillation walkover survey using a 2" by 2" Sodium Iodide (NaI) detector in conjunction with a Ludlum Model 2221 scaler/ratemeters and a PRO XR Satellite Receiver Trimble model TSCe Data Logger (Trimble Unit). The second step involved the collection of soil samples, in accordance with BNL ERP standard operating procedures (SOP) for offsite analysis to verify that residual radiological contamination levels were sufficiently low to meet the cleanup goals established for the site.

In the Class 1 survey units (1, 2, 3, 4 and 5), each sample was analyzed for Cs-137, Ra-226, other gamma emitters, Sr-90 and H-3. Composite samples were analyzed for chemical contaminants.

In the Class 2 survey units (6, 7, and 8), each sample was analyzed for Cs-137, Ra-226 and other gamma emitters. Composite samples were analyzed for Sr-90, H-3, and chemical contaminants.

The approximate soil sample locations are shown in Figures 3-2, 3-3 and 3-4.



HFBR OUTSIDE AREAS SURVEY UNITS

SU NO.	SU CLASS	AREA (SF)	L (FT)	0.866L (FT)
1	1	21,700	36	31
2	1	17,500	36	31
3	1	19,350	36	31
4	1	20,930	36	31
5	1	12,700	30	26
6	2	95,200	76	65
7	2	76,400	76	65
8	2	79,800	76	65

Figure 3-2 – HFBR Outside Areas - Survey Units 1, 2, 3, and 4

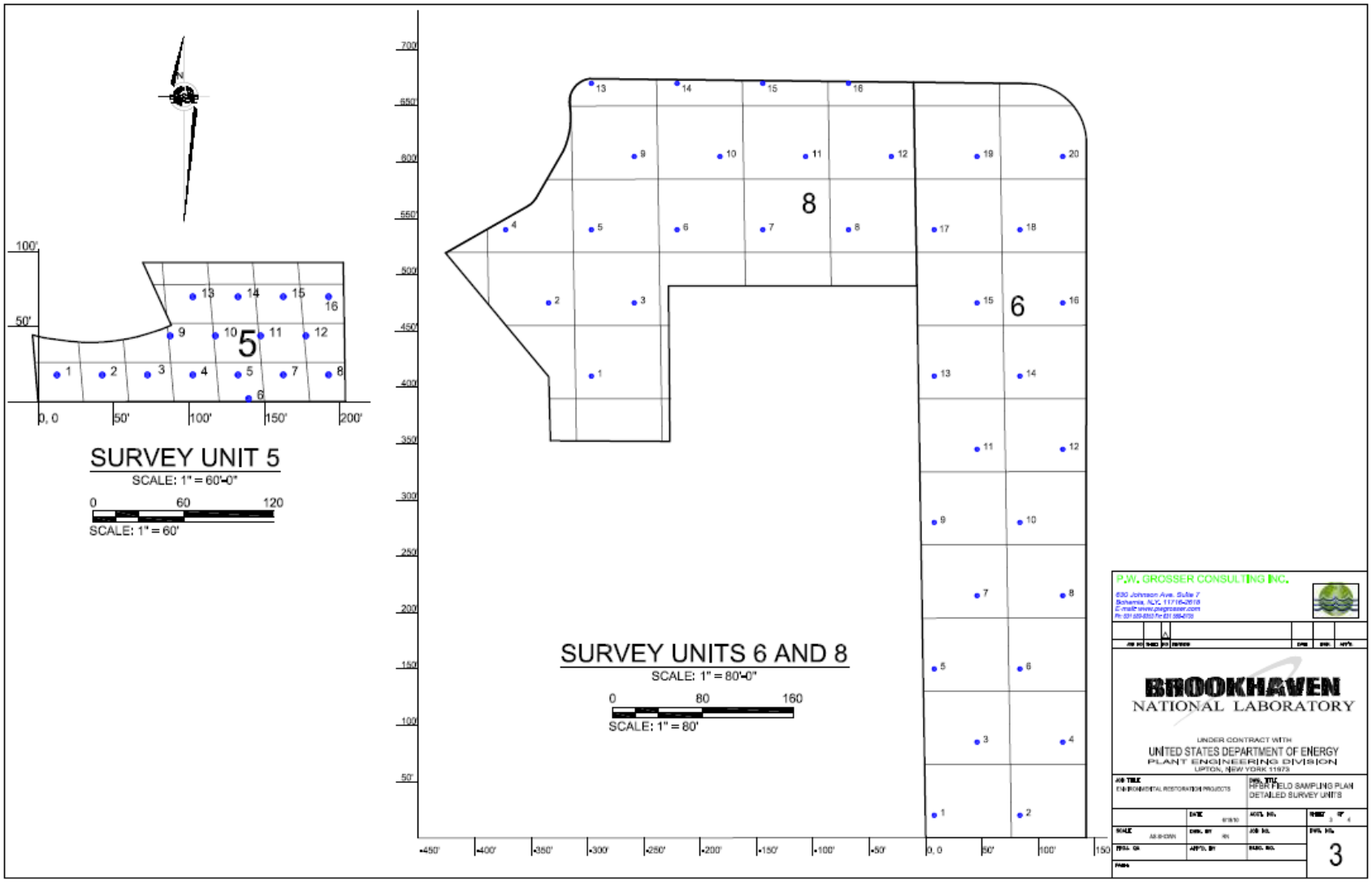


Figure 3-3 – HFBR Outside Areas - Survey Units 5, 6, and 8

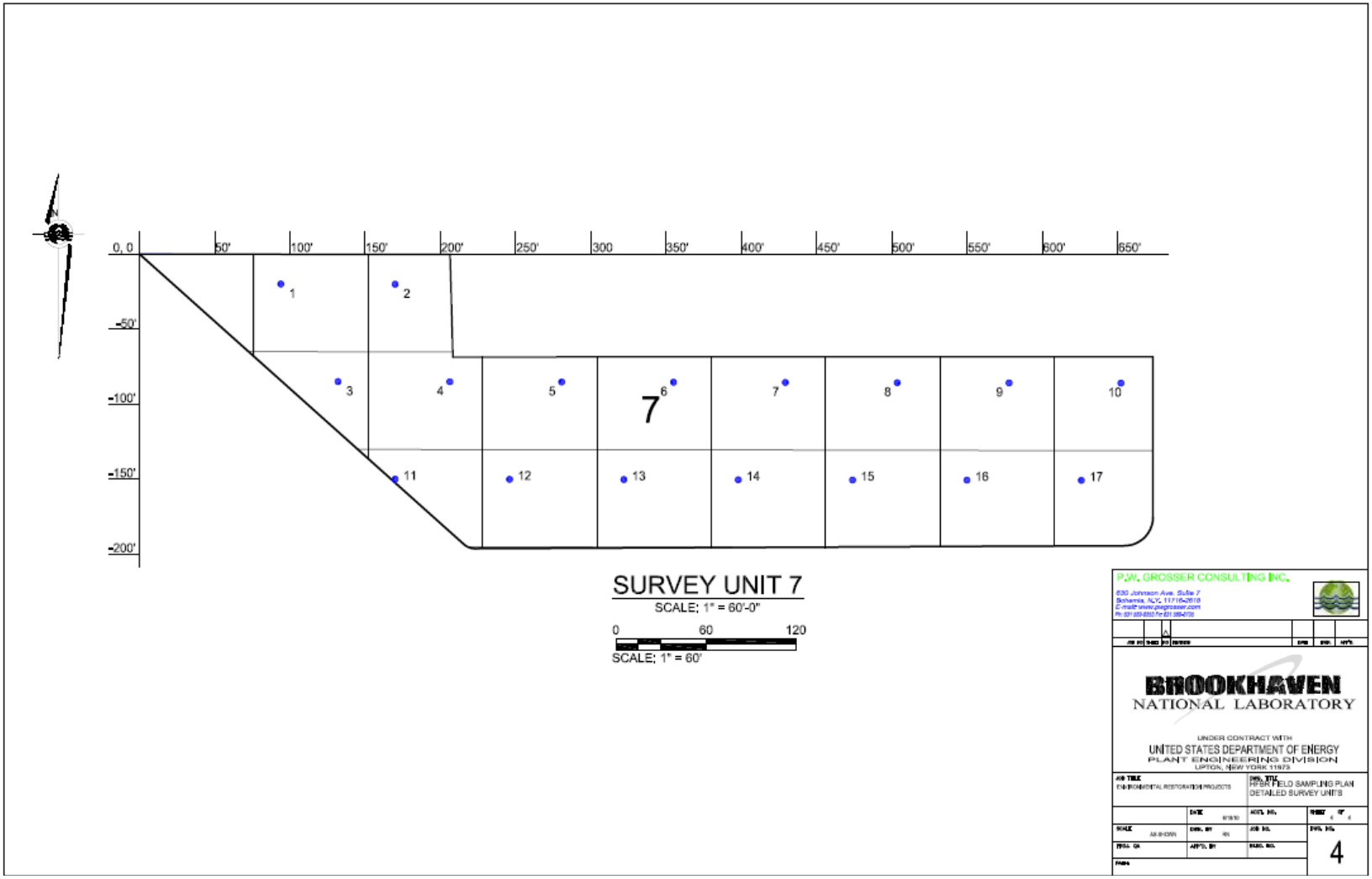


Figure 3-4 - HFBR Outside Areas - Survey Unit 7

3.3.2 Final Status Survey and Sampling Results

The results of the final status radiological walkover survey exhibit count rates below 20,400 cpm for all areas within the SUs, as shown in Figure 3-5. As discussed in Appendix B of the *Field Sampling Plan for the HFBR Outside Areas* (BNL, August 2010), the 20,400 cpm count rate was determined to approximate a Cs-137 concentration of 23 pCi/g in soil when using the unshielded NaI gamma scintillation detector. Radiological walkover surveys indicated that greater than 95% of the area was less than 15,000 cpm.

In addition, individual 1-min. fixed-count measurements were taken with the NaI probe at each of the fixed sample points. The results ranged from 4,348 to 11,292 cpm. Radiological survey forms for gamma walkover and fixed-point readings are provided in Appendix B.

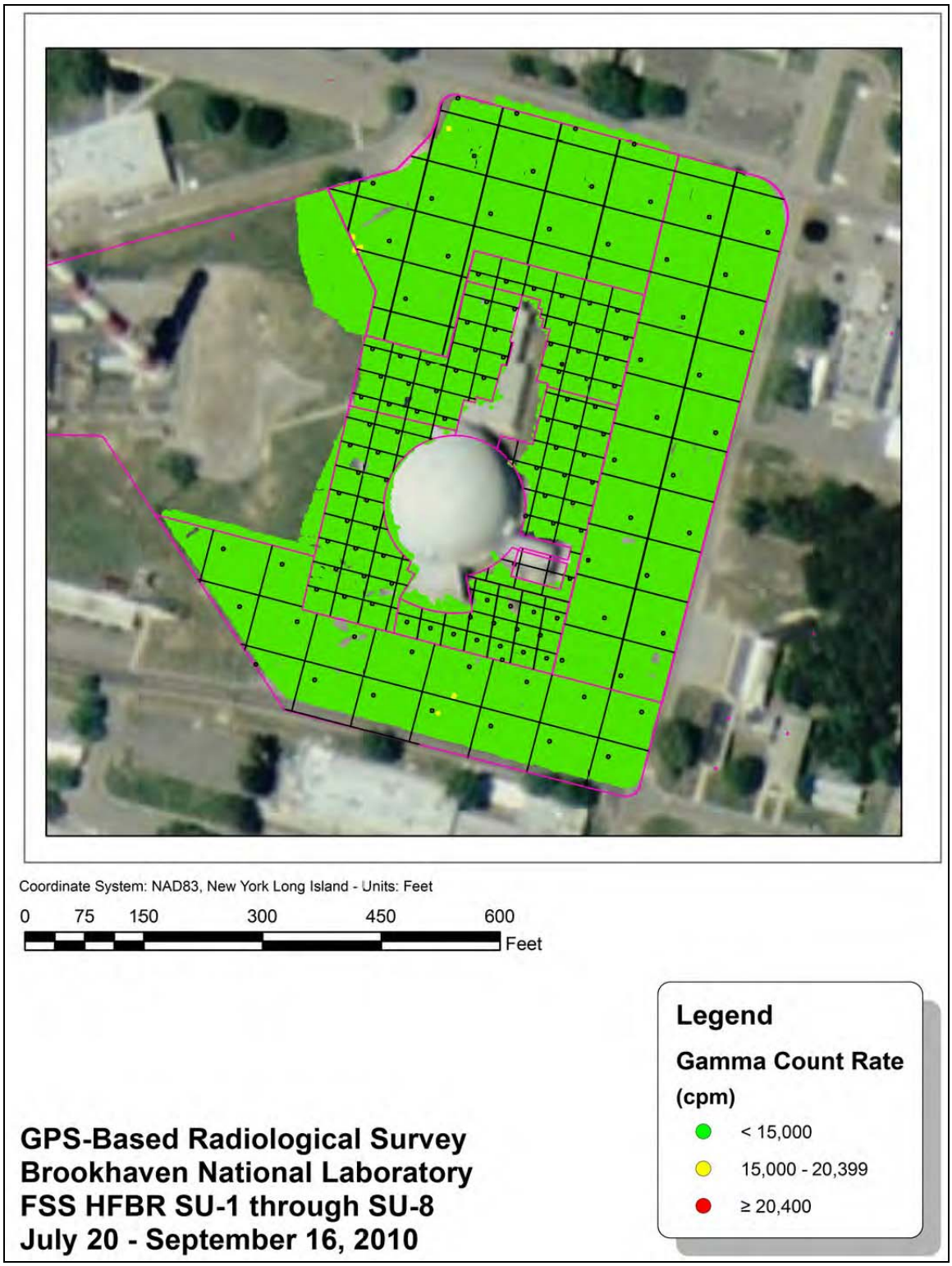


Figure 3-5 – HFBR Outside Areas Gamma Walkover Survey Results

Soil was collected at a minimum of 16 surface soil sample locations per survey unit as specified in the *Field Sampling Plan for the HFBR Outside Areas* (BNL, August 2010). A total of 154 surface soil samples were collected. All soil sample results were below the site cleanup goals for Cs-137, Sr-90 and Ra-226, which are 23 pCi/g, 15 pCi/g, and 5 pCi/g, respectively. A summary of the soil sample results is provided in Table 3-9.

Table 3-9 Summary of HFBR Outside Areas Surface Soil Sample Results for Radionuclides

	Cs-137 (pCi/g)	Sr-90 (pCi/g)	Ra-226 (pCi/g)
Cleanup Goal	23	15	5
Average	0.24	No samples indicated detectable values	0.47
Maximum	2.45	No samples indicated detectable values	0.84

Notes:
Tritium (H-3) and Cobalt-60 were also analyzed, and no samples indicated detectable values of these radionuclides.

Chemical results for soil samples analyzed for mercury, lead, copper, nickel, and zinc also indicated that residual soil concentrations for these contaminants are within their respective cleanup goals. A summary of the soil sample results for chemical contaminants is shown in Table 3-10.

Table 3-10 Summary of HFBR Outside Areas Soil Sample Results for Chemical Contaminants

	Lead (mg/kg)	Mercury (mg/kg)	Copper (mg/kg)	Nickel (mg/kg)	Zinc (mg/kg)
Cleanup Goal	400	1.84	270	140	2,200
Average	26	0.024	9	3.8	33
Maximum	201	0.040	26	7	132

Radiological and chemical results for offsite vendor soil sample analysis are provided in Appendix B.

3.3.3 Sign Test and Elevated Measurement Comparison

Since no samples exceeded the cleanup criteria, the SUs do not require testing with the sign test or the elevated measurement comparison.

3.3.4 Post Remediation Dose Assessment

A dose assessment was conducted to evaluate radiological dose impacts from residual radioactive materials remaining in the HFBR Outside Areas following the completion of the HFBR Stabilization Project. The dose assessment for the soil excavation areas was conducted using RESRAD, Version 6.5 (ANL, 2001). The average concentration for each

radionuclide was used as input to the model in order to determine the projected dose. Note that the Ra-226 background on BNL property had previously been established to be approximately 0.56 pCi/g (CDM, 1996). Therefore, the average Ra-226 value of 0.47 pCi/g from the HFBR Outside Areas is below the established background. For determination of acceptable levels of cleanup, the value of 0.47 pCi/g was used as a conservative measure, with no subtraction of background Ra-226 in the soil. However, when performing the post-remediation dose assessment using RESRAD, Ra-226 background is subtracted to obtain a more accurate result of the dose above background.

The RESRAD model was run with "no background subtract" (Ra-226 = 0.47 pCi/g) and with "full background subtract" (Ra-226 ~ 0 pCi/g). Cs-137 was the only other radionuclide of potential BNL origin detected. The average soil concentration of 0.24 pCi/g Cs-137 was used in all RESRAD calculations.

Two potential radiological dose scenarios were evaluated following remediation. The first assessment considered the radiation dose to a current resident (non-farmer) (no decay). The second assessment considered the radiation dose to a current industrial worker (no decay). The parameters and pathways used in this dose assessment for the HFBR Outside Areas are shown in the RESRAD summary reports (Appendix C).

The results of the dose assessment are shown below in Table 3-11. The maximum projected annual dose to a resident (non-farmer) in Year 0 (0.5 mrem/year) at the HFBR Outside Areas would be below the annual dose objective of 15 mrem/year. For an industrial worker with no decay time, the maximum projected annual dose to an industrial worker at Year 0 (0.2 mrem/year) is also less than 15 mrem/year. The results also indicate that the NYSDEC TAGM 4003 guideline of 10 mrem/yr would be met under each of the two scenarios described above. If background was not subtracted for Ra-226 (use 0.47 pCi/g without background subtract), then the residential and industrial annual doses would be 7.9 and 1.2 mrem/yr, respectively.

Table 3-11 Summary of Post-Remediation Dose Assessment Results

	Resident at 0 years	Industrial Worker at 0 years
Dose (mrem/yr)	0.5	0.2

3.3.5 Final Status Survey Conclusions

As indicated above, results of the FSS following the completion of the grading and spot remediation demonstrates conformance to the site cleanup goals established for the project.

3.3.6 Final Status Survey Independent Verification

During the period between August 18 to 25 and September 24 to 29, 2010, ORISE conducted measurements and sampling of the HFBR "Outside Areas" at the BNL site.

ORISE performed gamma walkover scans in all eight SUs with SUs 2, 4, 6, 7, and 8 receiving high density scans of accessible areas. The remainder of SUs received low density scans. All individual sample concentrations and corresponding mean concentrations evaluated to date were determined to be below the established cleanup goal. A review of the data collected by ORISE has not identified any areas of contamination exceeding cleanup goals.

A copy of the final ORISE verification report is attached to this report as Appendix D.

3.4 Waste Management

3.4.1 Waste Characterization, Handling and Disposal

The waste management strategy, waste characterization, packaging, handling, and storage were performed in accordance with BNL Standards Based Management System (SBMS) waste management procedures. Waste generated during the HFBR Stabilization Project was classified as low-level radioactive waste (LLRW), mixed low-level radioactive waste (MLLRW), or non-contaminated; and included miscellaneous debris, lead, solidified water, deuterated water (D_2O), waste oil, lithium chromate, and metal. Oversized waste was size-reduced to meet the disposal facility's waste acceptance criteria (WAC) prior to being packaged for disposal. Debris characterization data collected during remedial activities were used to characterize the waste in accordance with the BNL SBMS waste management procedures. According to characterization results, the waste shipped met the WAC of the disposal facilities specified below. Waste verification results were submitted to BNL's Waste Management Division.

The specific nature of the waste, as well as waste handling and disposal information is provided below:

- **Miscellaneous Debris -** This included such wastes as building material, light fixtures, loose obsolete items, irradiated hardware, etc. The waste, when practical, was size reduced and packaged within 20-ft sealand containers and 25-cubic yard (CY) intermodal containers. These bulk containers were placed onto ABC Rail cars and shipped to Energy Solutions (ES) of Utah.

- **Lead -** The lead removed from the HFBR was packaged within standard B-6 and B-12 steel boxes. The lead included various sized shielded containers (pigs), lead blankets, sheeting and bricks. There were several boxes filled with lead brick that were able to be reused as shielding for ongoing D&D activities associated with the Brookhaven Graphite Research Reactor (BGRR). The remaining lead waste boxes were shipped via flatbed truck to ES of Utah for macro-encapsulation.

- **Lead Large Components** - There were ten large components within the HFBR that had poured lead throughout. These components were placed into custom fit bags and were sent via flatbed trucks to ES of Utah.

- **Water -** The water removed from the HFBR was from various systems in order to isolate these systems. These systems included the FA-305 tank, condensate, primary and secondary coolant. Small quantities of water (<5 gallons) that were accumulated from isolated systems were solidified into 5 gallon carboys and disposed with the miscellaneous debris in sea land containers. Larger volumes were collected within 250 gallon Intermediate Bulk Containers (IBC) which were transferred to the BNL Waste Management Facility and solidified. The solidified water was shipped via box truck to the Nevada Test Site (NTS) Disposal Facility.

- **Oil -** Oil was drained from the elevators and cranes. The oil was placed into 55 gallon drums and transferred to the BNL Waste Management Facility, and subsequently shipped to PermaFix for disposal as radioactive oil.

- **D_2O Water -** The D_2O water was drained from the primary systems and pumped out of the FA-101 and was placed into a 250 gallon IBC container. Due to its high tritium content, the water was mixed with 19 IBC containers of low-activity waste water that were generated from the Waste Transfer Lines Project. All the waste, once mixed, was solidified and shipped in box trucks for disposal at to NTS Disposal Facility.

- **Lithium Chromate -** The HFBR carrier absorber unit was drained, which generated approximately 440 gallons of a low concentration lithium chromate solution. A treatability study was performed at ES of Utah and a waste profile was drafted and approved. The lithium chromate solution was placed into 55 gallon poly-lined drums and shipped to ES of Utah for treatment and disposal.

- **Metal (non-contaminated)** – Approximately 260 CY of non-contaminated metal waste was removed from the HFBR, placed into 20 CY roll-off containers and shipped via truck to be recycled at Crestwood Metal Corporation of Holbrook, New York.

Waste loading and shipping was initiated on February 17, 2010 and was completed on October 31, 2010. MHF Services (rail), Landstar Ranger (truck), RSB Logistics (truck) and Hittman Transport Services (truck) provided shipping containers/services for transportation of project waste. A project waste summary is provided below in Table 3-12.

Table 3-12

Project Waste Summary

Waste Type	Manifested Volume	Containers	Disposal Facility	Number/Conveyances
Misc. Debris	17,388 ft^3 (LLRW)	(18)-20' Sea-Land Containers (1)-25 yd^3 Intermodal	ES	(5)-ABC Rail Cars
Lead Brig/Pigs	120 ft^3 (MLLRW)	*(2)-B-12 Boxes (1)-B-6 Box	ES	(1)-Truck
Lead Large Components	726 ft^3 (MLLRW)	(10)-Supersacks (custom design)	ES	(4)-Trucks
Water (solidified)	134 (LLRW)	(4)-250 gallon IBC Containers	NTS	(1)-Box Truck
D_2O Water	33 ft^3 (LLRW)	**(1)-250 gallon IBC Container	NTS	(2)-Box Trucks
Waste Oil	60 ft^3 (LLRW)	(8)-55 gallon Drums	PermaFix	(1)-Truck
Lithium Chromate	440 gallons (MLLRW)	(8)-55 gallon Drums	ES	(1)-Truck
Metal	260 (non-contaminated)	(13) 20 yd^3 roll-off containers	Crestwood	(13)-Trucks

Notes:

* (4) Additional B-6 boxes were generated and the lead re-used to shield boxes in support of the BGRR D&D.

** The IBC of D_2O water was mixed with 19 IBC containers that were generated from the Waste Transfer Line Project.

3.4.2 Pollution Prevention and Waste Minimization Opportunities

Waste minimization and pollution prevention methods employed during the HFBR Stabilization Project included the judicious use of consumables (Personal Protection Equipment) as well the reuse of the following HFBR equipment by other BNL divisions:

- Sullaire Air Compressor;
- Two (10' by 10') hazardous waste storage sheds;
- Two large portable air conditioning units;
- Approximately twenty-five gas bottle regulators;
- Plumbing and electrical fittings;
- Approximately twenty personnel lockers;
- Two metal flammable cabinets;
- Six Kevlar blankets;
- Utility poles;
- One 500-gallon SCAT Tank;

- 480/208 step-down transformer, 45 KVA; and
- Shielding.

3.5 Site Restoration

Site restoration of the HFBR Outside Areas included the re-grading discussed in Section 3.1.8. In addition to storm water runoff improvements, re-grading activities were also effective in backfilling any small excavations that were necessary during stabilization activities. These included isolated areas where contaminated soil was removed and excavations where underground piping entering Building 750 were cut and capped. In addition, an asphalt pavement overlay was placed north of the east truck bay.

Re-graded areas and areas where concrete walks were removed were seeded with native Long Island grasses. Hydroseeding methods were utilized in accordance with the handling and application requirements provided in project specifications.

Site restoration activities were completed in October, 2010. Future site controls are discussed in Section 7.0.

4.0 CHRONOLOGY OF EVENTS

The following table lists a chronology of the main remedial events associated with the HFBR:

Table 4-1 Chronology of Remedial Events for the HFBR

Date	Remedial Event
1999	The cooling tower superstructure was dismantled and disposed of as waste.
2000-2005	Shielding and chemicals were removed and are being reused at BNL and other facilities
2001	The primary coolant (heavy water) was removed and sent to an off-site facility
2003	Scientific equipment was removed and is being reused or has been sent to an off-site disposal facility
2004	The confinement structure and spent fuel canal were modified to meet Suffolk County Article 12 requirements under the Tritium Remediation Project
2006	Stack monitoring facility (Building 715) was dismantled and removed
2006	Cooling tower basin and pump/switchgear house (Buildings 707/707A) were dismantled and removed
2006	Water treatment house (Building 707B) was dismantled and removed
2006	Cold neutron facility (Building 751) contaminated systems were removed and the clean building has been transferred to another BNL site organization for re-use
2006	Guard house (Building 753) was dismantled and removed
2009	Building 801-811 Waste Transfer Lines and associated contaminated soil were removed and disposed
2009-2010	Stabilization activities for the HFBR confinement building (Building 750) were completed.
2010	FSS and IVS were completed for HFBR Outside Areas.
2010-2011	The Fan Houses (Buildings 704 & 802) were dismantled, the associated contaminated soil was removed and project wastes were disposed
2010	The HFBR underground utilities and associated contaminated soils were removed and disposed.

5.0 PERFORMANCE STANDARDS & QUALITY CONTROL

As discussed in Section 3.3.2, the average concentrations for Cs-137, Sr-90, and Ra-226 in soil were below the cleanup goals of 23 pCi/g, 15 pCi/g, and 5 pCi/g, respectively. The calculated radiological doses from all radioisotopes were also below the levels stipulated in the HFBR ROD. In addition, concentrations of mercury, lead, nickel, copper and zinc in soil were below the cleanup goals of 1.84 mg/kg, 400 mg/kg, 140 mg/kg, 270 mg/kg and 2,200 mg/kg, respectively.

Physical and radiological inspections were conducted on both incoming and outgoing intermodal containers. Inspections were also conducted on storm water control measures during grading operations in the HFBR Outside Areas. Field sampling procedures were reviewed periodically.

Quality control/quality assurance (QA/QC) samples were collected in accordance with the *Field Sampling Plan for the HFBR Outside Areas* (BNL, July 2010). Field duplicates were collected at a frequency of one per twenty soil samples and analyzed for the radiological and chemical contaminants of concern. QA/QC results are summarized with the FSS results provided in Appendix B.

6.0 FINAL INSPECTION AND CERTIFICATIONS

As described in Section 3.3.6, the IVS was performed by ORISE upon the completion of the FSS performed by ERP in the HFBR Outside Areas. Based on the results of the FSS, an evaluation of the dose from the remaining activity in the HFBR Outside Areas was performed using RESRAD; results were within the design criteria described in Section 2.2. Radiological surveys of Building 750, for both contamination and radiation, were conducted to document as-left conditions. The end-state surveys are included as Appendix D. Upon completion of stabilization activities, the Exit Readiness Evaluation (ERE) process was utilized for the transfer of the HFBR from ERP to EPD.

There was strict adherence to industrial safety and radiological safety precautions during the stabilization activities. Work was performed under written and approved procedures, and any potentially hazardous steps were highlighted in the procedure to ensure understanding and compliance. Job Risk Assessments (JRAs) were developed and approved for the stabilization work. Radiological safety and oversight was provided by Radiological Control Technicians (RCTs), and all work was performed under a RWP.

6.1 Industrial Hygiene Oversight & Monitoring

IH oversight and monitoring was conducted by ERP personnel in accordance with ERP procedures. JRAs identified hazards associated with each of the tasks identified and specified the required controls for each hazard. A designated safety professional was onsite during stabilization activities to ensure controls were in place as specified in the JRA, including the use of safety equipment and safe work practices. IH monitoring included confined space monitoring to evaluate levels of carbon monoxide, hydrogen sulfide, oxygen and the lower explosive limit. Wipe and air sampling was performed for heavy metals including, but not limited to, lead, cadmium and beryllium. Additional IH monitoring included air and bulk sampling for asbestos, air sampling for mold and noise evaluations.

6.2 Radiological Oversight & Monitoring

Radiological oversight and monitoring was conducted by BNL RCTs during stabilization activities. Table 6-1 provides the RWPs, radiation exposure estimates and actual radiation exposures for the HFBR stabilization work.

Table 6-1 HFBR Stabilization Project RWP and Dose Summary

RWP Number	RWP Description	Dose Estimate (mrem)	Dose Actual (mrem)
2009-ERP-009	Material, facility and equipment restoration of the HFBR following CRB removal	17	5.7
2009-ERP-018	HFBR Fission chamber removal	10	0.1
2009-ERP-021	Fuel Canal pump down, entry, survey and decontamination	22	13.9
2009-ERP-027	Residual D2O removal	56	44.6
2009-ERP-028	CNF vent line	5	0
2009-ERP-040	Rendering Article 12 tanks inoperable	59	11.8
2009-ERP-041	Capping and isolating radiologically contaminated piping	5	0
2010-ERP-004	Lead removal	19.2	9
2010-ERP-006	Routine RBA entry	10	0
2010-ERP-011	Fuel transfer cask opening and survey	10	0
2010-ERP-018	Irradiated material removal activities	10	0.3
	Total	223.2	85.4

Thermoluminescent dosimeters (TLDs) were worn by each individual entering the HFBR Radiological Buffer Area (RBA). All workers received less than the administrative control level dose value of 100 mrem by TLD while working at the HFBR Stabilization Project.
Radiological monitoring included air sampling as specific by the specific RWP. Tritium continuous air monitoring and tritium grab sampling was conducted on a routine basis. Air sample results were used to estimate airborne radioactivity exposures. All general area and tritium air sample results were below 0.5 derived air concentration (DAC).

Workers entering the contamination areas were also required to have an annual whole body count prior to and upon completion of work on the HFBR Stabilization Project. Workers were also required to complete a whole body monitoring using a PCM-1B or equivalent hand-held instrument each time they exited a contamination area and the HFBR RBA, in accordance with BNL Radiological Control Manual requirements. In addition, workers who performed work where there was a potential for exposure to D_2O were required to submit pre- and post-job urine bioassay samples.

Equipment used during stabilization activities was also monitored for radiological contamination. All equipment that was released from the work zone was surveyed in accordance with FS-SOP-1005, *Radiological Surveys Required For Release of Materials from Areas Controlled For Radiological Purposes* (BNL, November 2007).

7.0 OPERATION AND MAINTENANCE ACTIVITIES

Post-stabilization S&M activities for the HFBR during the long-term S&M period will be performed in accordance with the HFBR Long-Term S&M Manual and the S&M Plan. Specific objectives of the long-term S&M program for the HFBR facility (Building 750) are as follows:

- Ensure adequate containment of radiological materials;
- Provide physical safety and security control; and
- Maintain the facility in a manner that will minimize hazards to workers and the public.

S&M activities will include routine inspections, continuous confinement monitoring, radiological monitoring, environmental monitoring (air and groundwater), routine maintenance and non-routine maintenance/repairs. EPD will perform S&M activities, in addition to maintaining institutional controls for the HFBR.

Both the S&M Plan and the S&M Manual contain the administrative requirement to protect the HFBR remaining inventory during the long-term S&M period, which began in 2007. Both documents contain the DOE's conditions of approval for the *High Flux Beam Reactor Hazard Assessment Document, Rev. 2* (BNL, July 2010) and both documents require a Nuclear Unreviewed Safety Issue (NUSI) screen if there are changes.

8.0 SUMMARY OF PROJECT COSTS

The HFBR Stabilization Project was performed with both ARRA funding and BNL Base funding. The project cost approximately $7,533,700 to complete. The original estimate cost for the HFBR Stabilization Project was $6,931,300. The additional cost was associated with the additional project personnel and equipment that were required to complete the project within ARRA time constraints.

The costs for the HFBR Stabilization Project included the following details:

Engineering and planning	$ 570,787
Stabilization Activities	$ 6,128,670
Waste Transportation and Disposal	$ 822,154
Project Closeout	$ 12,028
Total Cost	$ 7,533,700

9.0 OBSERVATIONS AND LESSONS LEARNED

The following is a summary of the lessons learned from this project and the corrective actions for future projects:

- Sharing of physical resources between two or more projects requires careful coordination to ensure workers are not exposed to hazards that have not been identified or adequately analyzed. As a payload operator from the HFBR Underground Utilities Project prepared to dump metal waste into a 20-yard dumpster that was originally staged for the HFBR Stabilization Project, an HFBR Job Supervisor asked the operator if he had verified the dumpster to be clear of personnel. The operator indicated that he had not. HFBR Stabilization Project personnel regularly entered this dumpster through a walk-in door to deposit scrap office equipment. The HFBR Underground Utilities Project personnel discussed the need to dump their waste into the dumpster with the pay loader at their tailgate safety meeting that morning without being aware that HFBR Stabilization Project personnel periodically entered the dumpster. The HFBR Stabilization Project personnel were immediately briefed regarding the situation and the dumpster was posted with caution tape and a sign reading "Caution, No Entry Without a Spotter." The HFBR Underground Utilities Project Manager participated in the briefing and explained that no dumping would take place into the dumpster without first notifying HFBR Stabilization Project personnel and verifying the dumpster to be clear of personnel. In addition, HFBR JRAs were updated to require the posting at the entry of dumpsters and require a spotter to be present when personnel physically enter a dumpster.
- Demolition of buildings or spaces within buildings often introduces new hazards as walls and ceilings are removed. Examples include trip/fall hazards that are present when a wall along a walking surface is removed and overhead hazards that are present when debris falls from roofs. Job planning for demolition work should anticipate the introduction of new hazards. Frequent site walk-downs during demolition work also help to identify newly introduced hazards and the adequacy of existing controls.
- The BNL Subject Based Management System (SBMS) requires task order contractors to provide BNL with a Health and Safety Plan (HASP) and a separate Phase Hazards Analysis (PHA) that describes the hazards of each proposed task. The PHA is required to be reviewed and accepted by the Safety Engineering Group and the F&O Safety Group. The PHA is usually submitted after the cost estimate (i.e., not in parallel with the cost estimate). Since contractors are generally not experienced at generating work risk analyses, the PHAs need to be revised and resubmitted. This has resulted in ERP experiencing some delays in getting work approved. ERP proposed an equivalency to this process and obtained the Safety Engineering Group's concurrence to use a modified PHA submittal process. When working with a task order contractor, ERP develops a JRA/JSA together with the contractor and submits this, together with the cost quotation, as attachments to the EPP work order. This approach speeds up the

work order request approval process and it strengthens the hazard safety analysis because one or more ERP staff, who is knowledgeable of facility-specific hazards, is involved in writing the JRA/JSA.

- An inadequate number of elevated work options were discussed during the planning for the isolation and abandonment of FA 312 Tank in the HFBR. All options to perform elevated work, including ladders, man lifts, aerial lifts, work platforms, scaffolds and stair platforms, should be evaluated during the work planning process and at tailgate safety meetings before selecting one.
- Workers were observed taping all exposed sharp edges prior to moving furniture to be size reduced. This is an example of good work practices and a fine example of workers paying attention to detail.

10.0 PROTECTIVENESS

Preparation of the HFBR for long term S&M and the removal of isolated soil contamination within the HFBR Outside Areas is protective of human health and the environment. Completion of the HFBR Stabilization Project and the institution of the long-term S&M Program ensures adequate containment of radiological materials, provides physical safety and security control, and minimizes hazards to workers and the public. These actions have also minimized the potential for the migration of contaminants into the underlying groundwater.

10.1 Facility Review Disposition Project Issues

The Facility Review Disposition Project (FRDP) was initiated in 1998 to resolve the issues identified during the preceding BNL Facility Review Project. The completion of the HFBR Stabilization Project satisfies the closure requirements associated with the FRDP issues summarized in Table 10-1.

Table 10-1 HFBR Stabilization FRDP Issues Summary

BNL I.D. #	SCDHS I.D. #	Building	BNL Issue Description	Resolution
836	N/A	750	Cooling tower – Cooling tower basin has several leaks.	Cooling towers were removed. The concrete basin remains below grade cover.
839	N/A	750	Sanitary sink in lab – Radiological samples are processed in a room with a sanitary sink.	The sanitary sinks were surveyed clean. The sanitary system has been sealed and abandoned.
845	N/A	750	Soil contamination – Contamination was found outside of the air handling unit in 1990/91.	Soil contamination has been removed, which has been confirmed by the HFBR Outside Areas FSS and ORISE IVS.
846	N/A	750	Cooling water leaks – The leak tightness of the equipment level floor is unknown.	A leak detection system, consisting of five sensors located in the low points of the Equipment Level, has been installed and is manned at all times.
852	0543	750	Domestic water system – There are water system cross-connections to the sanitary as well as contaminated systems without backflow prevention devices.	The domestic water system has been drained, isolated and gapped.
853	0554	750	Spent fuel pool – The pool is leaking 6-9 gallons/day to groundwater.	The spent fuel pool underwent a secondary containment upgrade to ensure groundwater protection and compliance with Suffolk County Sanitary Code - Article 12. The pool was drained and is currently empty and dry.

11.0 FIVE YEAR REVIEW

Five-year reviews will be conducted to determine whether the remedy implemented continues to be protective of human health and the environment. These reviews will be performed in accordance with the *Comprehensive Five-Year Review Guidance, OSWER No. 9355.7-03B-P* (EPA, June 2001). Remedy implementation at the HFBR, including preparing Building 750 for long-term safe storage, was discussed in the *Five Year Review Report for Brookhaven National Laboratory Superfund Site* (BNL, March 2011). The HFBR complex will be included in the next sitewide five year review in 2016.

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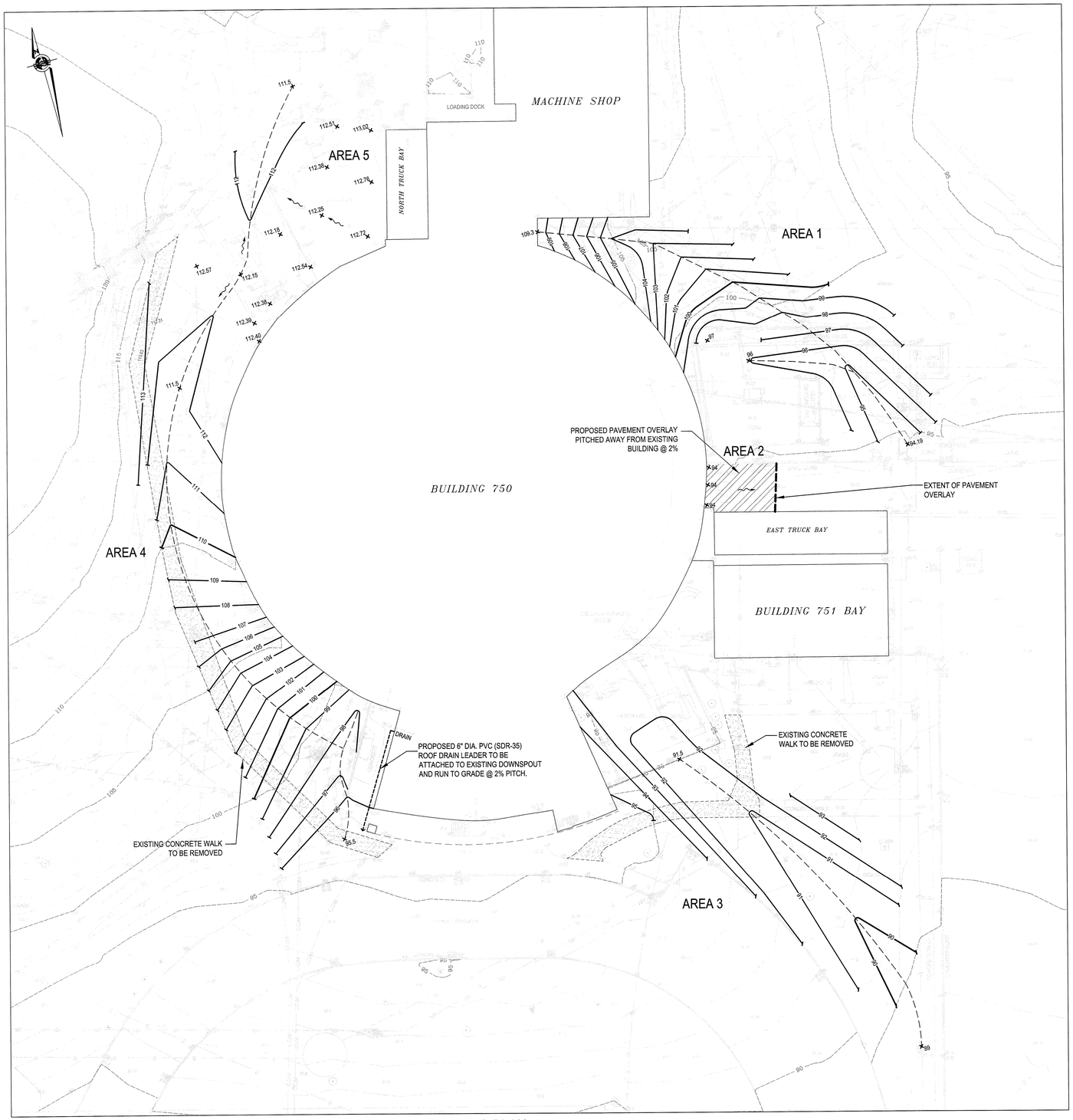
APPENDIX A

HFBR Outside Areas Grading Plan

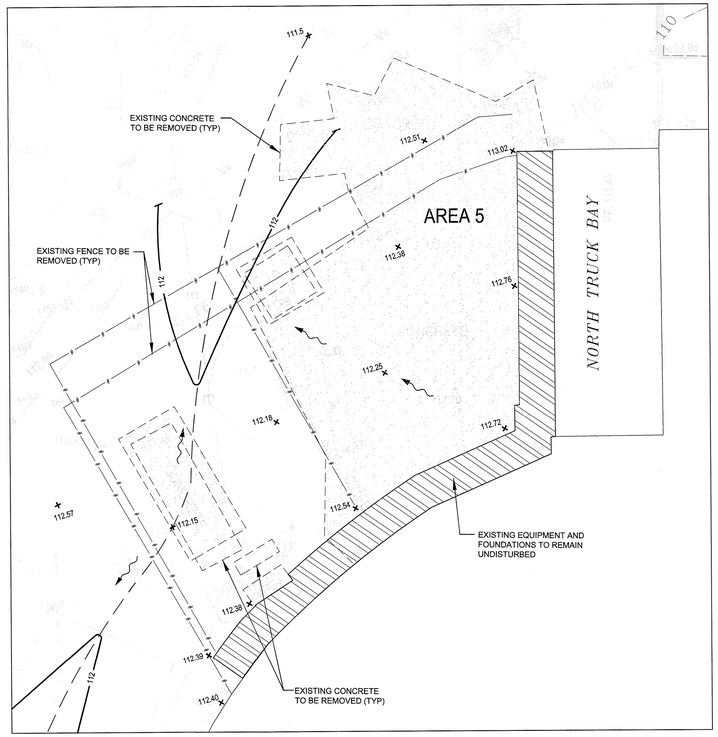


GRADING PLAN

SCALE: 1" = 20'-0"

0 20 40

SCALE: 1" = 20'



AREA 5 DETAIL PLAN

SCALE: 1" = 10'-0"

0 10 20

SCALE: 1" = 10'

LEGEND

- EXISTING MAJOR CONTOUR
- EXISTING MINOR CONTOUR
- EXISTING SPOT ELEVATION
- PROPOSED MAJOR CONTOUR
- PROPOSED MINOR CONTOUR
- PROPOSED SWALE
- PROPOSED SPOT ELEVATION
- PROPOSED DRAINAGE FLOW DIRECTION

GENERAL NOTES:

1. SURVEY INFORMATION AND TOPOGRAPHIC DATA BASED ON SURVEY PREPARED BY MUNICIPAL LAND SURVEY, P.C., DATED MARCH 28, 2010.
2. ALL ROOF DRAINAGE SHALL BE ADJUSTED TO FLOW AWAY FROM THE HFBR BUILDING.
3. BASED ON THE PRELIMINARY STORMWATER INFILTRATION EVALUATION PREPARED BY D.B. BENNETT, P.E., DATED SEPTEMBER 20, 2005, INFILTRATING STORMWATER IS NOT ESTIMATED TO INTERSECT WITH SFP CONTAMINATED VADOSE ZONE BASED ON SIMPLE ESTIMATES OF WETTING WIDTH AND INFORMATION OF EXISTING SOIL CONDITIONS AND CORE BORING SAMPLES TAKEN IN THE AREA.

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DRAWINGS PREPARED FOR

REVISIONS	DATE	INITIAL	COMMENTS

DRAWING INFORMATION

PROJECT: BNL1010	APPROVED BY: PKB
DESIGNED BY: MK	DATE: 5/24/10
DRAWN BY: MK	SCALE: AS SHOWN

SHEET TITLE

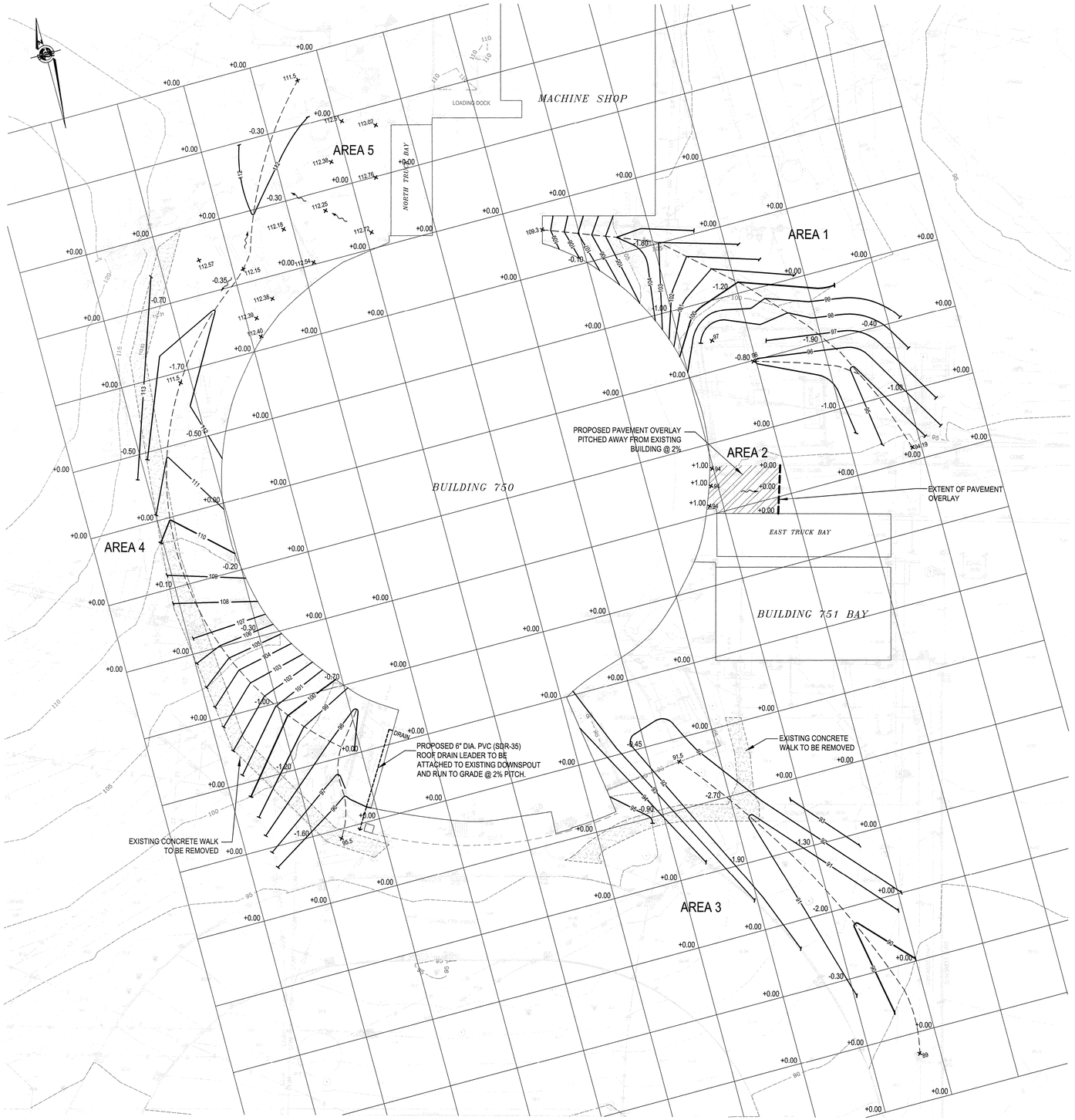
ENVIRONMENTAL RESTORATION PROJECTS

HFBR COMPLEX

GRADING PLAN

FIGURE NO C-100

SHEET 1 OF 2



EARTHWORK ANALYSIS

SCALE: 1" = 20'-0"

0 20 40

SCALE: 1" = 20'

EARTHWORK ANALYSIS

ITEM	QUANTITY
AREA 1	202 CY CUT ±
AREA 3	251 CY CUT ±
AREA 4 & AREA 5	219 CY CUT ±
TOTAL	672 CY CUT ±

ESTIMATE OF QUANTITIES

ITEM	QUANTITY
AREA 2 (ASPHALT PAVEMENT OVERLAY - 445 SF ±)	8.2 CY ±
CONCRETE WALKWAY TO BE REMOVED	2,183 SF ±

LEGEND

- 90 — EXISTING MAJOR CONTOUR
- EXISTING MINOR CONTOUR
- 95.15 — EXISTING SPOT ELEVATION
- 100 — PROPOSED MAJOR CONTOUR
- 101 — PROPOSED MINOR CONTOUR
- PROPOSED SWALE
- 91.5 — PROPOSED SPOT ELEVATION
- PROPOSED DRAINAGE FLOW DIRECTION
- -1.00 — PROPOSED CUT (FT) ±
- +1.00 — PROPOSED FILL (FT) ±

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DRAWINGS PREPARED FOR

REVISIONS	DATE	INITIAL	COMMENTS

DRAWING INFORMATION

PROJECT: BNL1010	APPROVED BY: PKB
DESIGNED BY: MK	DATE: 5/24/10
DRAWN BY: MK	SCALE: AS SHOWN

SHEET TITLE

ENVIRONMENTAL RESTORATION PROJECTS

HFBR COMPLEX

EARTHWORK ANALYSIS

FIGURE NO

C-101

SHEET 2 OF 2

APPENDIX B

HFBR Outside Areas
Final Status Survey Results

HFBR Outside Areas
Final Status Survey
Offsite Soil Radiochemical Analytical Results
Survey Unit - 1

Parameter	Residential Cleanup Value	30424-001 (pCi/g)		30424-002 (pCi/g)		30424-003 (pCi/g)		30424-004 (pCi/g)		30424-005 (pCi/g)		30424-006 (pCi/g)		30424-007 (pCi/g)		30424-008 (pCi/g)		30424-009 (pCi/g)		30424-010 (pCi/g)		30424-011 (pCi/g)		30424-012 (pCi/g)		30424-013 (pCi/g)		30424-014 (pCi/g)		30424-015 (pCi/g)		30424-016 (pCi/g)		30424-017 (pCi/g)		30424-018 (pCi/g)	
Rad Gamma Spec Analysis																																			
Beryllium-7	NA	0.135	U	0.295	U	0.0885	U	0.00767	U	0.104	U	0.0278	U	0.225	U	-0.169	U	0.172	U	0.214	U	0.148	U	0.00889	U	0.0236	U	0.0689	U	0.804		0.0233	U	0.185	U	0.118	U
Cesium-137	23	0.237		0.288		0.0638	J	0.181		0.114		0.0886	J	0.168		0.151		0.138		0.113		0.214		0.199		0.0889	J	0.106		0.0657	J	0.116		0.194		0.198	
Cobalt-57	NA	-0.0148	U	-0.00732	U	0.0115	U	0.00295	U	-0.00139	U	-0.00115	U	-0.00375	U	-0.00677	U	0.00852	U	0.00715	U	0.00183	U	-0.000166	U	-0.00391	U	-0.00515	U	-0.011	U	-0.000499	U	0.00147	U	0.000306	U
Cobalt-60	1,260	-0.000496	U	-0.00412	U	-0.0134	U	0.00172	U	0.00695	U	-0.00787	U	0.00714	U	0.00996	U	-0.00461	U	-0.0113	U	-0.00483	U	0.00763	U	0.0144	U	-0.00451	U	-0.00351	U	0.00679	U	0.0166	U	-0.00804	U
Manganese-54	NA	0.0119	U	0.0113	U	0.0083	U	-0.0101	U	0.000396	U	0.0107	U	0.0127	U	0.00108	U	0.0285	U	0.00331	U	0.00328	U	0.00178	U	0.00705	U	0.00242	U	-0.00878	U	-0.00576	U	0.0157	U	0.025	U
Potassium-40	NA	6.44		6.00		6.24		6.23		5.98		4.89		5.38		6.03		5.37		5.09		5.09		5.58		4.14		3.74		6.14		5.23		5.13		6.17	
Radium-226	NA	0.661		0.526		0.381		0.645		0.504		0.373		0.00	UI-UI	0.382		0.394		0.389		0.385		0.415		0.00	UI-UI	0.00	UI-UI	0.00	UI-UI	0.381		0.427		0.629	
Sodium-22	NA	-0.0294	U	0.00918	U	0.0227	U	0.00135	U	-0.0147	U	0.00153	U	0.0123	U	0.00795	U	0.025	U	0.00514	U	0.0035	U	-0.0114	U	-0.0137	U	0.00742	U	0.00073	U	0.0225	U	0.006	U	0.00825	U
Thorium-228	NA	0.874		0.796		0.610		0.850		0.585		0.484		0.683		0.670		0.649		0.583		0.700		0.623		0.52		0.451		0.519		0.542		0.764		0.776	
Rad Gas Flow Proportional Counting																																			
Alpha	NA	9.58		8.60		12.0		4.21		5.48		10.0		2.99	U	6.22		6.45		5.42		8.68		4.88		3.47	J	5.55		4.36		8.22		6.21		3.99	J
Beta	NA	4.56	J	12.2		12.5		3.51	U	3.55	J	5.77	J	5.88	J	9.01	J	7.38	J	7.67	J	1.86	U	8.11	J	4.00	J	7.82	J	6.76	J	8.93	J	8.72	J	7.25	J
Strontium-90	15	-0.0863	U	0.235	U	0.605	U	0.0829	U	0.0995	U	-0.147	U	0.167	U	0.279	U	0.104	U	0.0141	U	0.0959	U	-0.124	U	-0.116	U	0.0734	U	-0.11	U	0.447	U	-0.154	U	-0.103	U
Rad Liquid Scintillation Analysis																																			
Tritium	NA	-35.2	U	61.3	U	40.3	U	0.00	U	13.9	U	80.2	U	-4.55	U	0.00	U	0.00	U	-18.4	U	82.1	U	40.0	U	72	U	-80.1	U	-37.1	U	-68.9	U	-56.1	U	4.96	U

Notes:
DL - Below the detection limit
NA - Not Applicable
J - Indicates an estimated concentration
U - Indicates that the compound was analyzed for, but was not detected
All units are pCi/g
Gamma Spec results only reported for those parameters that were recorded during the analysis

HFBR Outside Areas
Final Status Survey
Offsite Soil Radiochemical Analytical Results
Survey Unit - 2

Parameter	Residential Cleanup Value	30063-001 (pCi/g)		30063-002 (pCi/g)		30063-003 (pCi/g)		30063-004 (pCi/g)		30063-005 (pCi/g)		30063-006 (pCi/g)		30063-007 (pCi/g)		30063-008 (pCi/g)		30063-009 (pCi/g)		30063-010 (pCi/g)		30063-011 (pCi/g)		30063-012 (pCi/g)		30063-013 (pCi/g)		30063-014 (pCi/g)		30063-015 (pCi/g)		30063-016 (pCi/g)		30063-017 (pCi/g)		30063-018 (pCi/g)	
Rad Gamma Spec Analysis																																			
Beryllium-7	NA	0.0884	DL	-0.0864	DL	0.006	DL	0.43		0.00784	DL	0.0702	DL	0.756		-0.162	DL	0.154	DL	0.261	DL	0.292		0.165	DL	0.22	DL	-0.0598	DL	0.093	DL	0.241	DL	0.444	DL	0.198	DL
Cesium-137	23	0.197		0.325		0.245		0.00882	DL	0.226		0.138		0.00814	DL	0.141		0.162		0.207		0.0746		0.0122	DL	0.0114	DL	-0.0163	DL	-0.078	DL	0.00604	DL	0.0485	DL	-0.0421	DL
Cobalt-57	NA	0.00167	DL	0.0119	DL	0.0031	DL	-0.00755	DL	-0.00155	DL	-0.00525	DL	0.00271	DL	0.00038	DL	-0.00302	DL	0.00166	DL	0.00736	DL	-0.0114	DL	0.00285	DL	-0.00566	DL	-0.0139	DL	-0.0192	DL	-0.00956	DL	3.11E-05	DL
Cobalt-60	1,260	0.000178	DL	0.00586	DL	-0.00467	DL	0.0182	DL	-0.00238	DL	-0.00684	DL	0.0179	DL	-0.0203	DL	-0.00767	DL	0.00737	DL	0.0121	DL	0.0279	DL	0.000796	DL	-0.04	DL	-0.102	DL	-0.0349	DL	-0.0573	DL	0.0242	DL
Manganese-54	NA	-0.0134	DL	0.00161	DL	0.0186	DL	-0.00614	DL	0.0141	DL	0.000347	DL	0.0171	DL	-0.00334	DL	-0.00413	DL	-0.0133	DL	-0.000961	DL	0.0457	DL	0.0246	DL	-0.0157	DL	-0.0635	DL	-0.0214	DL	0.0139	DL	0.0549	DL
Potassium-40	NA	6.81		7.04		7.06		3.25		7.05		6.15		2.93		7.02		7.65		6.27		5.89		3.96		7.25		5.79		6.65		5.52		4.46		4.57	
Radium-226	NA	0.619		0.634		0.577		0.266		0.665		0.612		0.256		0.701		0.704		0.533		0.314		0.308	UI	0.266	UI	0.51	UI	0.357	DL	0.296		-0.0283	DL	0.251	DL
Sodium-22	NA	-0.000418	DL	0.00352	DL	-0.0301	DL	-0.0194	DL	0.00111	DL	-0.00953	DL	-0.0131	DL	-0.0205	DL	-6.20E-06	DL	-0.000887	DL	0.00775	DL	-0.0103	DL	0.0432	DL	0.0438	DL	0.0405	DL	-0.0632	DL	0.0308	DL	-0.0429	DL
Thorium-228	NA	0.995		0.863		0.942		0.343		0.972		0.882		0.313		0.999		1.02		0.802		0.462		0.145	DL	0.354		0.72	UI	0.0593	DL	0.313		0.0162	DL	0.462	
Rad Gas Flow Proportional Counting																																					
Alpha	NA	4.67		3.4	U	6.95		0.30	U	3.41	U	4.11		1.30	U	9.66		6.47		6.40		6.12		1.33	U	2.25	U	2.97	U	1.26	U	1.44	U	2.51	U	3.15	U
Beta	NA	7.45	J	7.22	J	5.47	J	3.31	U	6.51	J	8.59	J	5.30	J	10.80		9.02	J	11.90		22.0		3.83	J	4.88	J	2.98	U	4.90	J	6.50	J	10.10		6.37	J
Strontium-90	15	0.246	U	0.341	U	0.279	U	0.00964	U	-0.0159	U	0.311	U	0.0636	U	-0.219	U	0.502	U	0.6	U	-0.288	U	0.527	U	0.243	U	0.337	U	-0.148	U	0.175	U	0.248	U	0.166	U
Rad Liquid Scintillation Analysis																																					
Tritium	NA	-102	U	46.3	U	-41.6	U	-21	U	59.0	U	40.8	U	-48.6	U	26.0	U	31.9	U	6.83	U	67.1	U	-71.9	U	-26.3	U	13.2	U	49.7	U	-40.7	U	24.5	U	18.4	U

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HFBR Outside Areas
Final Status Survey
Offsite Soil Radiochemical Analytical Results
Survey Unit - 3

Parameter	Residential Cleanup Value	30421-001 (pCi/g)		30421-002 (pCi/g)		30421-003 (pCi/g)		30421-004 (pCi/g)		30421-005 (pCi/g)		30421-006 (pCi/g)		30421-007 (pCi/g)		30421-008 (pCi/g)		30421-009 (pCi/g)		30421-010 (pCi/g)		30421-011 (pCi/g)		30421-012 (pCi/g)		30421-013 (pCi/g)		30421-014 (pCi/g)		30421-015 (pCi/g)		30421-016 (pCi/g)	
Rad Gamma Spec Analysis																																	
Beryllium-7	NA	-0.0864	DL	-0.0151	DL	-0.17	DL	0.0156	DL	0.122	DL	0.165	DL	0.00723	DL	0.162	DL	0.02	DL	0.170	DL	0.245	DL	0.102	DL	0.00643	DL	-0.0628	DL	0.0592	DL	0.0901	DL
Cesium-137	23	0.171		0.298		0.227		0.783		0.379		0.508		0.277		0.257		0.229		0.303		0.212		0.256		0.388		0.331		0.403		0.241	
Cobalt-57	NA	-0.00649	DL	0.00419	DL	0.00117	DL	0.00992	DL	-0.00338	DL	-0.0108	DL	0.000286	DL	-0.00283	DL	0.00271	DL	0.0185	DL	-0.00234	DL	-0.0112	DL	0.00904	DL	-0.00367	DL	0.00742	DL	0.0171	DL
Cobalt-60	1,260	0.00108	DL	-0.0147	DL	-0.00368	DL	0.0058	DL	-0.0281	DL	-0.00068	DL	-0.00268	DL	0.021	DL	0.00607	DL	-0.0155	DL	0.0114	DL	0.00472	DL	-0.00351	DL	-0.0003	DL	-0.027	DL	0.00285	DL
Manganese-54	NA	-0.00899	DL	-0.0019	DL	-0.018	DL	0.00901	DL	0.0387	DL	0.00654	DL	-0.0145	DL	0.00582	DL	-0.00451	DL	0.00486	DL	0.00285	DL	0.0141	DL	0.0153	DL	0.0127	DL	-2.34E-07	DL	0.00784	DL
Potassium-40	NA	6.30		7.13		5.97		6.00		7.12		8.77		7.00		7.43		8.06		7.55		5.92		7.51		6.78		6.58		8.44		8.10	
Radium-226	NA	0.518		0.631		0.436		0.508		0.696		0.835		0.695		0.603		0.546		0.606		0.525		0.651		0.587		0.494		0.611		0.716	
Sodium-22	NA	0.0171	DL	-0.0199	DL	0.00648	DL	0.000995	DL	0.0169	DL	0.00939	DL	0.00122	DL	-0.0193	DL	-0.0013	DL	-0.0107	DL	-0.00803	DL	-0.0184	DL	0.000323	DL	-0.00921	DL	-0.0256	DL	-0.0118	DL
Thorium-228	NA	0.749		0.873		0.689		0.750		0.882		1.37		0.965		0.892		0.836		0.933		0.782		0.896		0.792		0.852		0.951		0.922	
Alpha	NA	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
Beta	NA	NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA		NA	
Strontium-90	15	0.107	U	0.454	U	-0.0415	U	0.324	U	0.066	U	0.0503	U	-0.109	U	0.292	U	0.197	U	-0.168	U	-0.29	U	-0.102	U	0.269	U	0.129	U	0.153	U	-0.222	U
Tritium	NA	-75.5	U	-39.9	U	-46.3	U	-19.6	U	-79.3	U	-20.9	U	-3.44	U	-80.6	U	-58.1	U	-30	U	-38.8	U	14.5	U	-28	U	-23	U	-19.3	U	-23.5	U

Notes:

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HFBR Outside Areas
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Survey Unit - 4

Parameter	Residential Cleanup Value	30062-001 (pCi/g)		30062-002 (pCi/g)		30062-003 (pCi/g)		30062-004 (pCi/g)		30062-005 (pCi/g)		30062-006 (pCi/g)		30062-007 (pCi/g)		30062-008 (pCi/g)		30062-009 (pCi/g)		30062-010 (pCi/g)		30062-011 (pCi/g)		30062-012 (pCi/g)		30062-013 (pCi/g)		30062-014 (pCi/g)		30062-015 (pCi/g)		30062-016 (pCi/g)		30062-017 (pCi/g)	
Rad Gamma Spec Analysis																																			
Beryllium-7	NA	0.206	DL	0.138	DL	-0.0651	DL	-0.033	DL	0.183	DL	0.103	DL	0.0557	DL	0.172	DL	-0.0777	DL	-0.0833	DL	0.767		0.182	DL	1.03		0.0361	DL	-0.000866	DL	0.283		0.324	
Cesium-137	23	0.681		0.409		0.0605		0.373		0.224		0.199		0.262		0.156		0.115		0.0244	DL	0.0649		0.142		0.341		0.212		0.175		0.0282	DL	8.73E-05	DL
Cobalt-57	NA	-0.0103	DL	-0.00533	DL	-0.00183	DL	-0.0061	DL	-0.000286	DL	-0.00602	DL	0.00118	DL	-0.00275	DL	-0.00875	DL	-0.00691	DL	0.00413	DL	-0.00504	DL	0.00439	DL	-0.00619	DL	0.00747	DL	0.00419	DL	-0.00264	DL
Cobalt-60	1,260	-0.00302	DL	-3.25E-05	DL	0.0189	DL	-0.00352	DL	-0.00365	DL	-0.0147	DL	0.00405	DL	0.00479	DL	-0.00497	DL	0.0118	DL	0.000893	DL	-0.00182	DL	-0.00227	DL	-0.0117	DL	0.00343	DL	0.000516	DL	0.0178	DL
Manganese-54	NA	-0.00605	DL	-0.0149	DL	-0.000458	DL	0.00806	DL	-0.0175	DL	0.00655	DL	0.00155	DL	-0.000614	DL	0.00743	DL	-0.00324	DL	0.00091	DL	-0.0522	DL	0.00872	DL	-0.00388	DL	-0.0108	DL	0.00533	DL	-0.00263	DL
Potassium-40	NA	7.29		8.11		4.73		7.17		8.98		6.17		7.97		5.83		4.44		5.77		5.95		5.04		4.87		5.26		4.37		4.13		2.64	
Radium-226	NA	0.552		0.645		0	DLUI	0.580		0.539		0.487		0.613		0.515		0.408		0.49		0.514		0.425		0.400		0.363		0.409		0.21		0.232	
Sodium-22	NA	-0.0133	DL	0.00166	DL	0.00455	DL	-0.0259	DL	0.0277	DL	-0.00629	DL	0.00336	DL	0.00612	DL	-0.00686	DL	-0.00107	DL	-0.00248	DL	-0.00593	DL	-0.000376	DL	-0.0035	DL	-0.0167	DL	-0.0151	DL	0.00308	DL
Thorium-228	NA	0.825		0.956		0.597		0.968		0.896		0.793		1		0.813		0.623		0.704		0.66		0.581		0.757		0.655		0.534		0.33		0.327	
Rad Beta Flow Proportional Counting																																			
Alpha	NA	7.27		15.2		4.98		10.80		11.3		7.35		11.40		7.45		6.67		18.10		4.80		8.61		11.9		2.83	U	1.40	U	3.18	U	0.505	U
Beta	NA	8.60	J	11.6		11.6		11.00		15.5		5.98	J	13.90		11.10		5.18	J	14.30		10.8		11.40		14.4		7.75	J	6.72	J	5.01	J	11.4	
Strontium-90	15	0.387	U	0.988	U	0.501	U	0.103	U	-0.252	U	0.567	U	-0.423	U	0.316	U	0.303	U	0.0718	U	-0.0337	U	0.383	U	0.0219	U	-0.0348	U	-0.309	U	-0.119	U	0.192	U
Rad Liquid Scintillation Analysis																																			
Tritium	NA	19.7	U	-51.8	U	-3.56	U	-14.1	U	-73.7	U	-7.09	U	-34.8	U	-26.2	U	16.3	U	-32.7	U	39.5	U	-18	U	-25	U	-23.7	U	-38.5	U	-46.3	U	49.0	U

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Survey Unit - 5

Parameter	Residential Cleanup Value	30422-001 (pCi/g)		30422-002 (pCi/g)		30422-003 (pCi/g)		30422-004 (pCi/g)		30422-005 (pCi/g)		30422-006 (pCi/g)		30422-007 (pCi/g)		30422-008 (pCi/g)		30422-009 (pCi/g)		30422-010 (pCi/g)		30422-011 (pCi/g)		30422-012 (pCi/g)		30422-013 (pCi/g)		30422-014 (pCi/g)		30422-015 (pCi/g)		30422-016 (pCi/g)	
Rad Gamma Spec Analysis																																	
Beryllium-7	NA	0.529	U	0.591	U	0.0937	U	0.0462	U	0.238	U	0.246	U	0.119	U	-0.0471	U	0.0155	U	0.150	U	-0.117	U	-0.0208	U	0.256	U	0.00241	U	-0.0201	U	-0.0507	U
Cesium-137	23	0.0876	J	0.235	U	0.0215	U	0.000498	U	0.202		0.194		0.199		0.302		0.256		0.199		0.228		0.0781	J	0.127		0.0516	J	0.136		0.150	
Cobalt-57	NA	0.010	U	-0.0227	U	0.00879	U	0.00139	U	-0.0137	U	0.00864	U	0.000925	U	0.00117	U	-0.00485	U	-0.00845	U	-0.00688	U	-0.00844	U	-0.00558	U	0.00557	U	-0.00174	U	-0.0133	U
Cobalt-60	1,260	-0.0367	U	0.0146	U	-0.000897	U	0.0165	U	0.00258	U	0.0312	U	-0.0122	U	0.0019	U	-0.000793	U	-0.00253	U	0.0163	U	-0.0129	U	0.0000962	U	0.0135	U	-0.0077	U	-0.0364	U
Manganese-54	NA	-0.048	U	-0.0104	U	-0.0277	U	-0.0101	U	0.0173	U	-0.00849	U	0.00794	U	-0.00773	U	-0.0191	U	0.000902	U	0.00678	U	-0.0129	U	0.00361	U	-0.00397	U	0.00257	U	-0.00542	U
Potassium-40	NA	5.49		5.74		5.35	UI	5.02		4.95		6.49		6.74	UI	7.91		8.87		6.15		6.66		7.30		5.62		5.79		6.85		6.42	
Radium-226	NA	0.370		0.330	UI	0.204		0.350		0.368	UI	0.688		0.600		0.722		0.622		0.462		0.678		0.519		0.366		0.376		0.481		0.672	
Sodium-22	NA	0.0317	U	0.0079	U	0.0263	U	-0.00239	U	-0.0183	U	-0.00579	U	-0.00696	U	-0.00805	U	0.00684	U	-0.0122	U	0.00423	U	0.00381	U	-0.000805	U	0.00712	U	0.00881	U	0.00816	U
Thorium-228	NA	0.376		0.192		0.171	UI	0.209		0.157		0.721		0.828		0.978		1.01		0.680		0.891		0.685		0.487		0.529		0.759		0.826	
Rad Gas Flow Proportional Counting																																	
Alpha	NA	4.69		1.37	U	1.22	U	2.99	U	3.19	U	4.55		10.50		8.12		13.10		8.56		10.30		12.70		5.3		8.53		6.07		4.74	
Beta	NA	4.25	J	4.63	J	6.28	J	45.2		7.63	J	5.16	J	12.80		10.3		4.94	J	11.0		11.7		15.40		4.98	J	637		14.5		14.30	
Strontium-90	15	0.296	U	0.106	U	0.340	U	-0.175	U	0.277	U	-0.543	U	0.315	U	0.293	U	0.203	U	0.297	U	0.0218	U	0.732	U	0.444	U	0.411	U	0.0627	U	0.176	U
Rad Liquid Scintillation Analysis																																	
Tritium	NA	-66	U	-92.8	J	-85.1	U	-103	U	-101	U	-82	U	-24.5	U	-66.6	U	-108	U	-8.5	U	14.8	U	-95.3	U	-4.93	U	-23.5	U	-43	U	4.96	U

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Survey Unit - 6

Parameter	Residential Cleanup Value	30066-001 (pCi/g)		30066-002 (pCi/g)		30066-003 (pCi/g)		30062-006 (pCi/g)		30066-007 (pCi/g)		30066-008 (pCi/g)	
Rad Gamma Spec Analysis													
Beryllium-7	NA	0.422	DL	0.0911	DL	0.192	DL	0.142	DL	0.152	DL	0.193	DL
Cesium-137	23	-0.000512	DL	0.139		0.187		0.800		0.103		2.45	
Cobalt-57	NA	-0.0103	DL	-0.0138	DL	-0.0101	DL	0.0133	DL	-0.0126	DL	0.0111	DL
Cobalt-60	1,260	0.00282	DL	3.14E-03	DL	-0.00734	DL	-0.0117	DL	0.00903	DL	-0.00435	DL
Manganese-54	NA	0.00244	DL	-0.0184	DL	0.0119	DL	0.0132	DL	0.0125	DL	0.00161	DL
Potassium-40	NA	3.46		6.81		7.04		6.54		6.58		3.98	
Radium-226	NA	0.252	DL	0.505		0.637		0.00	DLUI	0.351		0.288	
Sodium-22	NA	-0.0261	DL	-0.0161	DL	-0.0358	DL	-0.0101	DL	0.00303	DL	-0.0273	DL
Thorium-228	NA	0.00	DLUI	0.899		0.831		0.314		0.344		0.382	
Rad Alpha Spec Analysis													
Plutonium-238	NA	NA		NA		NA		-0.00373	U	-0.012	U	0.0383	U
Plutonium-239/240	NA	NA		NA		NA		0.0273	U	0.013	U	0.0455	U
Plutonium-241	NA	NA		NA		NA		0.687	U	0.261	U	-0.759	U
Uranium-235/236	NA	NA		NA		NA		0.121	U	-0.0326	U	0.0919	U
Uranium-238	NA	NA		NA		NA		0.195	U	0.768	J	0.372	J
Rad Gas Flow Proportional Counting													
Alpha	NA	NA		NA		NA		NA		NA		NA	
Beta	NA	NA		NA		NA		NA		NA		NA	
Strontium-90	15	0.118	U	0.236	U	-0.0238	U	0.539	U	0.159	U	0.541	U
Rad Liquid Scintillation Analysis													
Tritium	NA	-20.9	U	-27.9	U	35.5	U	9.07	U	-9.83	U	-56.2	U

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Survey Unit - 6

Parameter	Residential Cleanup Value	HFBR-6-001 (pCi/g)	HFBR-6-002 (pCi/g)	HFBR-6-003 (pCi/g)	HFBR-6-004 (pCi/g)	HFBR-6-005 (pCi/g)	HFBR-6-006 (pCi/g)	HFBR-6-007 (pCi/g)	HFBR-6-008 (pCi/g)	HFBR-6-009 (pCi/g)	HFBR-6-010 (pCi/g)	HFBR-6-011 (pCi/g)	HFBR-6-012 (pCi/g)	HFBR-6-013 (pCi/g)	HFBR-6-014 (pCi/g)	HFBR-6-015 (pCi/g)	HFBR-6-016 (pCi/g)	HFBR-6-017 (pCi/g)	HFBR-6-018 (pCi/g)	HFBR-6-019 (pCi/g)	HFBR-6-020 (pCi/g)
Rad Gamma Spec Analysis																					
Beryllium-7	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cesium-137	23	ND	ND	ND	ND	ND	ND	0.07780153	ND	0.1724488	ND	0.1695554	0.07210108	0.1148624	0.1169651	ND	0.1471686	0.1512029	ND	0.2415559	0.184312
Cobalt-57	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cobalt-60	1,260	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Lead-212	NA	ND	ND	ND	ND	ND	ND	1.729492	1.889209	ND	1.550891	2.0036	1.784433	2.637814	2.108562	2.47019	2.21288	2.233426	1.553689	2.552608	1.945838
Manganese-54	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Potassium-40	NA	ND	ND	ND	ND	5.16345	ND	ND	ND	ND	ND	ND	4.651174	5.066607	ND	5.420737	ND	5.656927	ND	5.910623	ND
Radium-226	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sodium-22	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thorium-228	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thorium-232	NA	ND	ND	ND	ND	ND	ND	0.483248	0.6238469	0.6039293	0.4625819	0.343844	0.4831829	ND	0.4455164	0.6119848	0.4309906	ND	ND	0.7084493	0.4695394
Uranium-235	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.06970141	ND	ND	ND	0.02906104	0.04997587	ND	0.041298	ND	ND
Uranium-238	NA	ND	ND	ND	ND	ND	ND	0.4314657	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Notes:
NA - Not Applicable
ND - Not detected
All units are pCi/g
Gamma Spec results only reported for those parameters that were recorded during the analysis

HFBR Outside Areas
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Survey Unit - 7

Parameter	Residential Cleanup Value	30423-001 (pCi/g)		30423-002 (pCi/g)		30423-003 (pCi/g)	
Rad Gamma Spec Analysis							
Beryllium-7	NA	0.163	U	0.00479	U	0.0434	U
Cesium-137	23	0.162		0.210		0.208	
Cobalt-57	NA	-0.00676	U	-0.00603	U	0.00586	U
Cobalt-60	1,260	0.0083	U	-0.00283	U	-0.0113	U
Manganese-54	NA	0.0135	U	0.00499	U	-0.015	U
Potassium-40	NA	5.56		6.31		7.14	
Radium-226	NA	0.501		0.500		0.487	
Sodium-22	NA	0.0139	U	-0.0234	U	-0.00963	U
Thorium-228	NA	0.736		0.706		0.671	
Rad Gas Flow Proportional Counting							
Alpha	NA	NA		NA		NA	
Beta	NA	NA		NA		NA	
Strontium-90	15	0.114	U	0.213	U	0.139	U
Rad Liquid Scintillation Analysis							
Tritium	NA	42.6	U	109	U	25.5	U

Notes:

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Gamma Spec results only reported for those parameters that were recorded during the analysis

HFBR Outside Areas
Final Status Survey
Onsite Soil Radiochemical Analytical Results
Survey Unit - 7

Parameter	Residential Cleanup Value	HFBR-7-001 (pCi/g)	HFBR-7-002 (pCi/g)	HFBR-7-003 (pCi/g)	HFBR-7-004 (pCi/g)	HFBR-7-005 (pCi/g)	HFBR-7-006 (pCi/g)	HFBR-7-007 (pCi/g)	HFBR-7-008 (pCi/g)	HFBR-7-009 (pCi/g)	HFBR-7-010 (pCi/g)	HFBR-7-011 (pCi/g)	HFBR-7-012 (pCi/g)	HFBR-7-013 (pCi/g)	HFBR-7-014 (pCi/g)	HFBR-7-015 (pCi/g)	HFBR-7-016 (pCi/g)	HFBR-7-017 (pCi/g)
Rad Gamma Spec Analysis																		
Beryllium-7	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cesium-137	23	ND	0.08742931	0.04092314	0.09405831	0.2536931	0.1605961	0.19541130	0.1276442	ND	ND	0.118968	0.1731927	0.1747383	0.1010202	ND	ND	0.1513319
Cobalt-57	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cobalt-60	1,260	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Lead-212	NA	0.3553008	ND	0.2714474	ND	ND	0.6869748	0.825785	0.5778577	ND	ND	0.5269812	0.6395599	0.6065018	0.6962856	ND	ND	ND
Lead-214	NA	41.33987	66.51754	80.9436	ND	ND	351.5389	851.4254	1,276.28	ND	ND	817.7772	ND	ND	ND	ND	ND	ND
Manganese-54	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Potassium-40	NA	ND	3.789082	ND	ND	ND	ND	ND	4.221539	5.341501	3.385789	3.236344	ND	3.842482	4.971319	5.780025	ND	5.82234
Radium-226	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sodium-22	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thorium-228	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thorium-232	NA	ND	0.3297586	ND	0.4268361	ND	0.3998984	0.514721	ND	ND	ND	ND	ND	0.404119	ND	ND	ND	ND
Uranium-235	NA	ND	ND	ND	ND	0.0337706	ND	ND	0.05095266	ND	ND	ND	ND	ND	ND	ND	ND	ND
Uranium-238	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Notes:
ND - Not detected
NA - Not Applicable
All units are pCi/g
Gamma Spec results only reported for those parameters that were recorded during the analysis

HFBR Outside Areas
Final Status Survey
Offsite Soil Radiochemical Analytical Results
Survey Unit - 8

Parameter	Residential Cleanup Value	30420-001 (pCi/g)		30420-002 (pCi/g)		30420-003 (pCi/g)		30539-021 (pCi/g)		30539-022 (pCi/g)		30539-023 (pCi/g)	
Rad Gamma Spec Analysis													
Beryllium-7	NA	-0.0522	DL	0.0556	DL	-0.0258	DL	0.209	U	-0.0224	U	-0.0963	U
Cesium-137	23	0.199		0.327		0.203		0.0991	J	0.0328	U	0.0371	U
Cobalt-57	NA	-0.013	DL	-0.00453	DL	-0.00189	DL	0.00206	U	0.00124	U	-0.00726	U
Cobalt-60	1,260	0.0298	DL	-0.00895	DL	0.00165	DL	-0.0081	U	0.0169	U	-0.00355	U
Manganese-54	NA	0.015	DL	-0.026	DL	0.0182	DL	0.018	U	0.0199	U	-0.0127	U
Potassium-40	NA	7.68		6.69		8.46		8.07		6.91		7.33	
Radium-226	NA	0.632		0.711		0.585		0.701		0.430		0.538	
Sodium-22	NA	-0.0327	DL	-0.00825	DL	-0.00122	DL	-0.00203	U	0.0196	U	-0.0279	U
Thorium-228	NA	0.823		0.961		0.792		0.910		0.618		0.687	
Rad Gas Flow Proportional Counting													
Alpha	NA	NA		NA		NA		NA		NA		NA	
Beta	NA	NA		NA		NA		NA		NA		NA	
Strontium-90	15	0.367	U	0.108	U	0.231	U	0.819	U	0.0798	U	-0.466	U
Rad Liquid Scintillation Analysis													
Tritium	NA	-31.2	U	-75.6	U	-59.2	U	-48.8	U	0.00	U	-18.5	U

Notes:

DL - Below the dectection limit

ND - Not detected

NA - Not Applicable

U - Indicates that the compound was analyzed for, but was not detected

All units are pCi/g

Gamma Spec results only reported for those parameters that were recorded during the analysis

HFBR Outside Areas
Final Status Survey
Onsite Soil Radiochemical Analytical Results
Survey Unit - 8

Parameter	Residential Cleanup Value	HFBR-8-001 (pCi/g)	HFBR-8-002 (pCi/g)	HFBR-8-003 (pCi/g)	HFBR-8-004 (pCi/g)	HFBR-8-005 (pCi/g)	HFBR-8-006 (pCi/g)	HFBR-8-007 (pCi/g)	HFBR-8-008 (pCi/g)	HFBR-8-009 (pCi/g)	HFBR-8-010 (pCi/g)	HFBR-8-011 (pCi/g)	HFBR-8-012 (pCi/g)	HFBR-8-013 (pCi/g)	HFBR-8-014 (pCi/g)	HFBR-8-015 (pCi/g)	HFBR-8-016 (pCi/g)
Rad Gamma Spec Analysis																	
Beryllium-7	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cesium-137	23	ND	ND	0.19077	0.110755	0.07753806	0.1792857	0.27986840	0.266832	0.1857035	0.2254137	0.2122543	0.2636329	0.1028207	0.04231391	0.05116656	0.1320518
Cobalt-57	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cobalt-60	1,260	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Lead-212	NA	ND	ND	ND	0.6904004	1.533613	1.85129	2.169219	2.66241	1.96786	1.368342	2.269109	2.239347	ND	1.975135	ND	ND
Lead-214	NA	ND	ND	ND	486.458	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Manganese-54	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Potassium-40	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Radium-226	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sodium-22	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thorium-228	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thorium-232	NA	ND	ND	ND	ND	0.5646538	ND	ND	0.5015972	0.5358517	ND	0.8915602	ND	0.2809144	ND	ND	ND
Uranium-235	NA	ND	ND	0.02831201	ND	ND	ND	0.00496528	ND	ND	0.05963641	0.02998537	0.04400002	ND	0.0474119	ND	ND
Uranium-238	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Notes:
NA - Not Applicable
ND - Not detected
All units are pCi/g
Gamma Spec results only reported for those parameters that were recorded during the analysis

HFBR Outside Areas
Final Status Survey
Offsite Soil Hazardous Constituent Analytical Results

Parameter	Site Cleanup Criteria	SU-1								SU-2								SU-3								SU-4							
		30424-022		30424-023		30424-024		30424-025		30063-020		30063-021		30063-022				30421-019		30421-020		30421-021				30062-019		30062-020		30062-021			
Lead	400	14.1		12.7		9.23		14.4		21.3		21.5		2.25				27.8		20.4		18.1				15.7		18.5		15.5			
Mercury	1.84	0.0198	J	0.016	J	0.0174	J	0.015	J	0.026		0.0259		ND	U			0.0389		0.036		0.0315				0.0253		0.0117	J	0.0135			
Copper	270	4.44		4.16		4.71		5.11		14.1		10.4		9.6				6.3		7.22		6.01				4.31		7.25		25.7			
Nickel	140	3.00		2.28		2.48		2.82		6.97		4.87		4.07				4.6		3.77		3.47				3.69		4.02		5.04			
Zinc	2,200	16.20		21.2		27.2		32.8		24.1		67.2		13				35.8		21.9		25.1				24.2		49.3		132			

Parameter	Site Cleanup Criteria	SU-5						SU-6						SU-7								SU-8							
		30422-019		30422-020		30422-021		30066-001		30066-002		30066-003		30423-001		30423-002		30423-003				30420-001		30420-002		30420-003			
Lead	400	4.51		28.3		19.7		1.33		25.4		19		37.2		27.2		201				22.4		24.4		21.0			
Mercury	1.84	ND	U	0.0.28		0.0238		ND	U	0.0275		0.0269		0.0144	J	0.0161	J	0.0142	J			0.0201		0.0393		0.0404			
Copper	270	12.1		10.5		8.82		14.2		6.07		16.2		17.4		5.9		8.44				10.0		6.39		5.95			
Nickel	140	1.92		4.45		4.42		2.66		3.8		4.29		3.48		3.42		3.65				3.52		4.56		3.86			
Zinc	2,200	8.37		22.6		28.2		12.4		71.2		20.6		20.4		50.2		23.2				17.5		21.6		25.4			

Notes:
ND - Not detected
J - Indicates an estimated concentration
U - Indicates that the compound was analyzed for, but was not detected
All units are mg/kg

HFBR Outside Areas
Final Status Survey
Offsite Soil Radiochemical Analytical Results
QA/QC

Parameter	Residential Cleanup Value	30424-020 (Field Blank) SU-1 (pCi/g)		30421-021 (Field Dup) SU-1 (pCi/g)		30063-019 (Field Dup) SU-2 (pCi/g)		30063-023 (Field Blank) SU-2 (pCi/g)		30421-017 (Field Dup) SU-3 (pCi/g)		30421-018 (Field Blank) SU-3 (pCi/g)		30062-018 (Field Dup) SU-4 (pCi/g)		30062-022 (Field Blank) SU-4 (pCi/g)		30422-017 (Field Blank) SU-5 (pCi/g)		30422-017 (Field Dup) SU-5 (pCi/g)		30066-004 (Field Dup) SU-6 (pCi/g)		30066-005 (Field Blank) SU-6 (pCi/g)		30423-004 (Field Dup) SU-7 (pCi/g)		30423-005 (Field Blank) SU-7 (pCi/g)		30420-004 (Field Dup) SU-8 (pCi/g)		30420-005 (Field Blank) SU-8 (pCi/g)	
Rad Gamma Spec Analysis																																	
Beryllium-7	NA	-0.0264	U	0.151	U	0.0683	DL	0.224		0.180	DL	0.162	DL	-0.0641	DL	0.208	DL	0.469		-0.0402	U	-0.00143	DL	0.0433	DL	0.191	U	0.240	U	0.0967	DL	0.358	
Cesium-137	23	0.206		0.277		0.229		0.00155	DL	0.305		-0.00831	DL	0.096		0.0128	DL	0.0403	U	0.203		0.0679		0.0683		0.251		0.0384	U	0.185		0.0777	
Cobalt-57	NA	-0.00797	U	0.00475	U	0.00221	DL	0.000865	DL	0.00429	DL	0.000645	DL	-0.00114	DL	0.00139	DL	0.00331	U	0.000855	U	-0.00629	DL	0.022	DL	-0.00757	U	0.00765	U	0.00901	DL	0.0082	DL
Cobalt-60	1,260	0.00426	U	0.000304	U	0.00633	DL	-0.00256	DL	0.00827	DL	-0.00515	DL	0.00484	DL	0.0187	DL	0.0000983	U	-0.00387	U	0.0185	DL	0.0000932	DL	-0.0128	U	-0.0057	U	-0.000291	DL	0.005	DL
Manganese-54	NA	0.0107	U	0.000455	U	0.00409	DL	-0.00137	DL	-0.00904	DL	-0.0061	DL	-0.0241	DL	0.000563	DL	0.0101	U	0.00722	U	0.0095	DL	-0.0103	DL	-0.0201	U	-0.00657	U	0.0163	DL	0.00047	DL
Potassium-40	NA	5.41		5.99		6.51		5.55		6.50		3.98		4.78		7.32		4.97		6.67		7.05		5.33		5.62		4.92		8.16		4.50	
Radium-226	NA	0.525		0.654		0.550		0.305		0.572		0.284		0.348		0.430		0.400		0.558		0.577		0.383		0.547		0.425		0.720		0.337	
Sodium-22	NA	0.0249	U	0.00454	U	-0.0107	DL	-0.000611	DL	0.0134	DL	0.000921	DL	-0.00757	DL	-0.00859	DL	-0.00251	U	-0.00185	U	0.0111	DL	-0.0147	DL	-0.00749	U	-0.0201	U	0.0223	DL	-0.00842	DL
Thorium-228	NA	0.587		0.783		0.896		0.442		0.873		0.355		0.664		0.776		0.487		0.702		0.696		0.529		0.739		0.532		1.12		0.387	
Rad Gas Flow proportional counting																																	
Alpha	NA	3.60	U	4.52		7.08		2.71	U					7.86		14.6		7.33		8.72				0.562	U								
Beta	NA	11.4		8.61	J	9.89	J	4.56	J					11.3		13.7		8.81	J	11.8													
Strontium-90	15	0.631	U	0.181	U	0.201	U	0.336	U	0.0464	U	-0.0395	U	-0.0152	U	0.0738	U	0.229	U	0.00186	U	0.244	U			0.167	U	0.100	U	-0.0604	U	0.235	U
Rad Liquid Scintillation Analysis																																	
Tritium	NA	-9.54	U	-25.7	U	-8.27	U	-28.6	U	-41.1	U	-11	U	-33	U	-72	U	4.32	U	-26.5	U	9.69	U	8.56	U	97.6	U	77.5	U	-66.6	U	-63.2	U

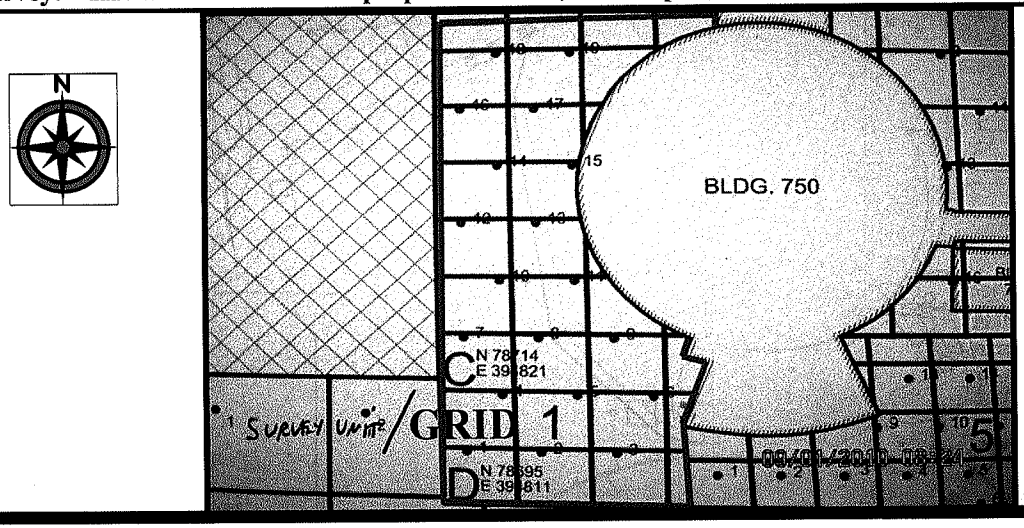
Notes:
DL - Below the dectection limit
NA - Not Applicable
J - Indicates an estimated concentration
U - Indicates that the compound was analyzed for, but was not detected
All units are pCi/g
Gamma Spec results only reported for those parameters that were recorded during the analysis

RADIOLOGICAL SURVEY FORM
FS-SOP-1000

REASON FOR SURVEY
☐ Routine ☒ Special HFBR - FSS
☐ RWP# ☐ WP

Location / Equipment: HFBR Out Side Grounds | D 08/31/10-09/04/10 | Time: 1400

Survey: HFBR FSS Grid #1 sample point location, soil samples, GPS coordinates, one minute static counts.



INSTRUMENTS Model #	Serial #	CAL DUE
LUD-2221/SPA-3	149942/114540	7/22/11
Trimble TSCe	00015842	N/A
LUD-2221/SPA-3	138377/18986	7/28/11
Trimble TSCe	00023998	N/A
N/A		

LEGEND
○ - SMEAR SURVEY LOCATION △ - AIR SAMPLE LOCATION
□ - MASSLINN SURVEY LOCATION # - DIRECT FRISK LOCATION
C̄ - CONTAMINATION * CONTACT
XXXY/ZZZ XXX = contact reading Y = radiation type ZZZ = reading @ 30cm

AIRBORNE ACTIVITY SURVEY

Sample #	Duration	Flow Rate	Field Analysis cpm	Field Analysis µCi/cc	% DAC
N/A					

DOSE RATE (HIGHEST)

CONTACT READING	N/A
GENERAL AREA READING	N/A

MASSLINN SURVEY RESULTS (in dpm)

1.	N/A	5.	N/A
2.		6.	
3.		7.	
4.		8.	

SMEAR SURVEY RESULTS (dpm/100cm²) α, β-γ, ³H

1.	N/A	8.	N/A	15.	N/A
2.		9.		16.	
3.		10.		17.	
4.		11.		18.	
5.		12.		19.	
6.		13.		20.	
7.		14.		21.	

Note:
(A) Sample point locations for soil samples, GPS coordinates and [1 minute] static counts taken:

(1) HFBR FSS SU1 - #1 at 78712 North / 394807 East ; at 8424 cpm.
(2) HFBR FSS SU1 - #2 at 78709 North / 394824 East ; at 8550 cpm.
(3) HFBR FSS SU1 - #3 at 78704 North / 394838 East ; at 11121 cpm.
(4) HFBR FSS SU1 - #4 at 78733 North / 394814 East ; at 8198 cpm.
(5) HFBR FSS SU1 - #5 at 78723 North / 394825 East ; at 6295 cpm.
(6) HFBR FSS SU1 - #6 at 78710 North / 394840 East ; at 10169 cpm.
(7) HFBR FSS SU1- #7 at 78743 North / 394818 East ; at 7096 cpm.
(8) HFBR FSS SU1 - #8 at 78730 North / 394837 East ; at 6342 cpm.
(9) HFBR FSS SU1 - #9 at 78721 North / 394839 East ; at 7802 cpm.
(10) HFBR FSS SU1 - #10 at 78746 North / 394827 East ; at 5972 cpm.
(11) HFBR FSS SU1 - #11 at 78739 North / 394837 East ; at 5767 cpm.
(12) HFBR FSS SU1 - #12 at 78754 North / 394826 East ; at 7854 cpm.
(13) HFBR FSS SU1 - #13 at 78745 North / 394832 East ; at 5713 cpm.
(14) HFBR FSS SU1 - #14 at 78759 North / 394838 East ; at 5559 cpm.
(15) HFBR FSS SU1 - #15 at 78752 North / 394844 East ; at 6127 cpm.
(16) HFBR FSS SU1 - #16 at 78763 North / 394830 East ; at 7038 cpm.
(17) HFBR FSS SU1 - #17 at 78763 North / 394844 East ; at 5861 cpm. Duplicate soil sample.
(18) HFBR FSS SU1 - #18 at 78766 North / 394835 East ; at 6881 cpm
(19) HFBR FSS SU1 - #19 at 78766 North / 394853 East ; at 5338 cpm

Surveyed By: D. Dove, S. Gully, J. Conley Date: 09/04/10 Reviewed By: Date: 9/5/10

FS-SOP-1000
Attachment 9. 2

 9/5/10

RADIOLOGICAL SURVEY FORM
FS-SOP-1000

REASON FOR SURVEY
☐ ROUTINE ☒ SPECIAL FSS
☐ RWP # ☐ WP #

LOCATION & EQUIPT. HFBR Complex

DATE: 7-27-2010 **TIME:** 1400

HFBR Outside FSS Survey

Survey Unit 2

COC # 30063

Sample No.	GPS Coordinate	1 Min. Gamma	Post 1 Min. Gamma
001	78777.10 / 394834.45	9745	N/A
002	78776.02 / 394839.12	9548	N/A
003	78772.63 / 394849.96	8333	N/A
004	78770.60 / 394860.71	6683	6673
005	78785.82 / 394836.51	10461	N/A
006	78783.00 / 394846.31	7214	N/A
007	78779.51 / 394856.94	6743	7575
008	78797.01 / 394832.77	10830	N/A
009	78794.32 / 394843.69	10865	N/A
010	78789.91 / 394854.83	10094	N/A
011	78787.67 / 394865.26	7196	8162
012	78784.36 / 394875.72	7026	7625
013	78795.59 / 394873.33	6898	8014
014	78791.05 / 394883.52	7173	9231
015	78813.02 / 394878.77	7162	7408
016	78802.87 / 394881.62	6997	7328
017	78805.96 / 394871.55	7109	7410
018	78810.87 / 394886.95	7018	8784

Note: "Post 1 min. Counts" were only done on sample locations that were taken on concrete or asphalt.

INSTRUMENT

Model #	Serial #	CAL DUE
Ludlum 2221	149942	2-15-2011
N/A	N/A	N/A

LEGEND
○ - SMEAR SURVEY LOCATION △ - AIR SAMPLE LOCATION
☐ - MASSLINN SURVEY LOCATION # - DIRECT FRISK LOCATION
XXXY / ZZZ XXX = contact reading Y = radiation type ZZZ = reading @ 30cm

AIRBORNE ACTIVITY SURVEY

Sample #	Duration	Flow Rate	Field Analysis cpm	Field Analysis µCi/cc	Field Analysis % DAC
N/A					

DOSE RATE (HIGHEST)

CONTACT READING	N/A
GENERAL AREA READING	N/A

MASSLINN SURVEY RESULTS (in dpm)

1.	N/A	5.	N/A
2.		6.	
3.		7.	
4.		8.	

SMEAR SURVEY RESULTS (dpm/100cm²) α, β-γ, ³H

1.	See	8.	Attached	15.	Results
2.	Batch	9.	Number	16.	N/A
3.		10.		17.	
4.		11.		18.	
5.		12.		19.	
6.		13.		20.	
7.		14.		21.	

Surveyed By Merkel/ Dzvonar/ Schultz **Date:** 7-28-2010 **Reviewed By:** **Date:** 7/28/10

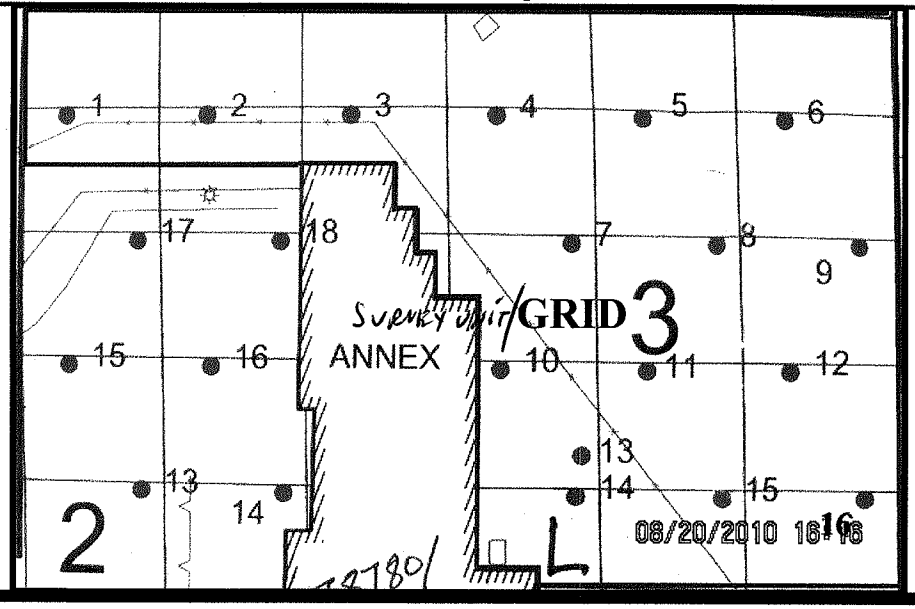
FS-SOP-1000
Attachment 9.2

RADIOLOGICAL SURVEY FORM
FS-SOP-1000

REASON FOR SURVEY: ☐ Routine ☒ Special HFBR - FSS ☐ RWP# ☐ WP

Location / Equipment: HFBR Out Side Grounds | Date: 08/ 21 /10 | Time: 12:00

Survey: HFBR FSS Grid #3 sample point location, soil samples, GPS coordinates, one minute static counts.



INSTRUMENTS Model #	Serial #	CAL DUE
LUD-2221	211786	01/07/11
NaI Probe	2027	01/08/11
Trimble TSCe	45268-00	N/A
N/A		
N/A		

LEGEND
○ - SMEAR SURVEY LOCATION △ - AIR SAMPLE LOCATION
□ - MASSLINN SURVEY LOCATION # - DIRECT FRISK LOCATION
C - CONTAMINATION * CONTACT
XXXY / ZZZ XXX = contact reading Y = radiation type ZZZ = reading @ 30cm

AIRBORNE ACTIVITY SURVEY

Sample #	Duration	Flow Rate	Field Analysis cpm	Field Analysis µCi/cc	Field Analysis % DAC
N/A					

DOSE RATE (HIGHEST)

CONTACT READING	N/A
GENERAL AREA READING	N/A

Note:

(A) Sample point locations for soil samples, GPS coordinates and [1 minute] static counts taken:

(1) HFBR FSS SU3 - #1 at 78826 North / 394873 East ; at 7378 cpm.
(2) HFBR FSS SU3 - #2 at 78823 North / 394882 East ; at 7893 cpm.
(3) HFBR FSS SU3 - #3 at 78821 North / 394892 East ; at 6993 cpm.
(4) HFBR FSS SU3 - #4 at 78818 North / 394903 East ; at 6201 cpm.
(5) HFBR FSS SU3 - #5 at 78816 North / 394912 East ; at 7594 cpm.
(6) HFBR FSS SU3 - #6 at 78813 North / 394921 East ; at 10315 cpm.
(7) HFBR FSS SU3- #7 at 78806 North / 394907 East ; at 7157 cpm.
(8) HFBR FSS SU3 - #8 at 78804 North / 394918 East ; at 8035 cpm.
(9) HFBR FSS SU3 - #9 at 78801 North / 394929 East ; at 8838 cpm.
(10) HFBR FSS SU3 - #10 at 78798 North / 394902 East ; at 6795 cpm. Duplicate soil sample.
(11) HFBR FSS SU3 - #11 at 78796 North / 394913 East ; at 7403 cpm.
(12) HFBR FSS SU3 - #12 at 78793 North / 394923 East ; at 8756 cpm.
(13) HFBR FSS SU3 - #13 at 78790 North / 394907 East ; at 7646 cpm.
(14) HFBR FSS SU3 - #14 at 78787 North / 394906 East ; at 7278 cpm.
(15) HFBR FSS SU3 - #15 at 78785 North / 394917 East ; at 8982 cpm.
(16) HFBR FSS SU3 - #16 at 78783 North / 394926 East ; at 8814 cpm.

MASSLINN SURVEY RESULTS (in dpm)

1.	N/A	5.	N/A
2.		6.	
3.		7.	
4.		8.	

SMEAR SURVEY RESULTS (dpm/100cm²) α, β-γ, ³H

1.	N/A	8.	N/A	15.	N/A
2.		9.		16.	
3.		10.		17.	
4.		11.		18.	
5.		12.		19.	
6.		13.		20.	
7.		14.		21.	

Surveyed By: Aaron Merkel and Sean A. Gully Date: 08/ 23 /10 Reviewed By: Date: 8/23/10

FS-SOP-1000
Attachment 9. 2

RADIOLOGICAL SURVEY FORM
FS-SOP-1000

REASON FOR SURVEY
☐ ROUTINE ☒ SPECIAL FSS
☐ RWP # ☐ WP #

LOCATION & EQUIPT. HFBR Complex

DATE: 7-22-2010 **TIME:** 1300

HFBR Outside FSS Survey

See attached for GPS Walkover Results

Survey Unit 4

COC # 30062

Sample No.	GPS Coordinate	1 Min. Gamma
001	78777.45 / 394906.80	7667
002	78774.17 / 394917.74	7928
003	78769.25 / 394900.24	6695
004	78766.11 / 394909.65	7467
005	78762.19 / 394920.23	5860
006	78758.34 / 394902.77	5965
007	78754.65 / 394913.09	7240
008	78751.55 / 394893.99	5892
009	78747.75 / 394904.44	6145
010	78744.6 / 394915.12	5934
011	78737.61 / 394900.95	4501
012	78737.14 / 394907.55	5242
013	78731.21 / 394893.53	5023
014	78728.6 / 394902.59	5209
015	78726.22 / 394913.20	5051
016	78700.47 / 394884.50	4348
017	78707.57 / 394911.29	3691

INSTRUMENT

Model #	Serial #	CAL DUE
Ludlum 2221	149942	2-15-2011
Ludlum 2221	211786	1-07-2011
N/A		
N/A		

LEGEND
○ - SMEAR SURVEY LOCATION △ - AIR SAMPLE LOCATION
☐ - MASSLINN SURVEY LOCATION # - DIRECT FRISK LOCATION
XXXY / ZZZ XXX = contact reading Y = radiation type ZZZ = reading @ 30cm

AIRBORNE ACTIVITY SURVEY

Sample #	Duration	Flow Rate	Field Analysis cpm	Field Analysis µCi/cc	% DAC
N/A					

DOSE RATE (HIGHEST)

CONTACT READING	N/A
GENERAL AREA READING	N/A

MASSLINN SURVEY RESULTS (in dpm)

1.	N/A	5.	N/A
2.		6.	
3.		7.	
4.		8.	

SMEAR SURVEY RESULTS (dpm/100cm²) α, β-γ, ³H

1.	See	8.	Attached	15.	Results
2.	Batch	9.	Number	16.	N/A
3.		10.		17.	
4.		11.		18.	
5.		12.		19.	
6.		13.		20.	
7.		14.		21.	

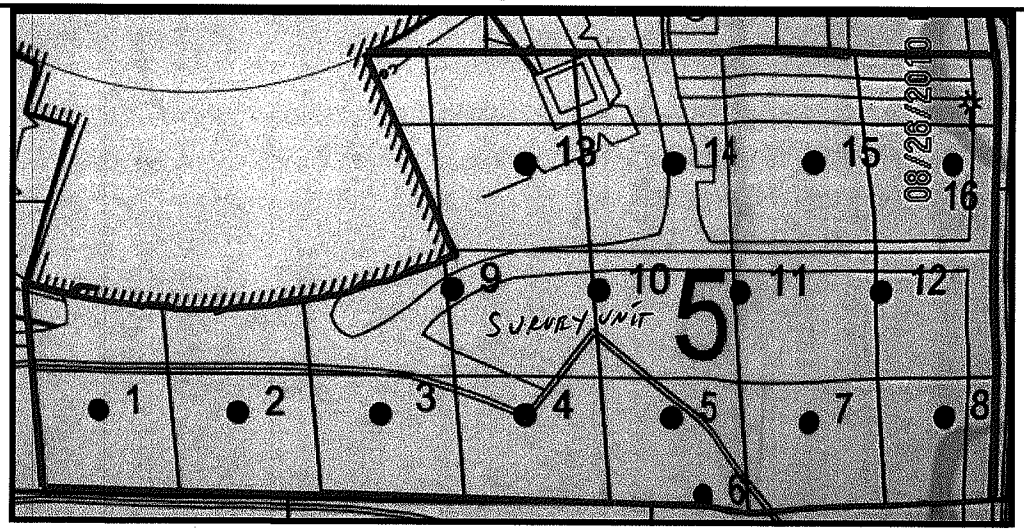
Surveyed By Merkel, Dzionar, Schultz **Date:** 7-22-2010 **Reviewed By:** **Date:** 7/27/10

RADIOLOGICAL SURVEY FORM
FS-SOP-1000

REASON FOR SURVEY: ☐ Routine ☐ RWP# ■ Special HFBR-ESS ☐ WP

Location / Equipment: HFBR outside grounds | Date: 8/25-27/10 | Time: 0900

: HFBR FSS Grid #5 sample point location, soil samples, GPS coordinates, one minute static counts.



Note:

(A) Sample point locations for soil samples, GPS coordinates and [1 minute] static counts taken:

(1) HFBR FSS SU5 - #1 at 78688 North / 394847 East ; at 5655 cpm.
(2) HFBR FSS SU5 - #2 at 78686 North / 394855 East ; at 5658 cpm.
(3) HFBR FSS SU5 - #3 at 78684 North / 394864 East ; at 5792 cpm.
(4) HFBR FSS SU5 - #4 at 78681 North / 394874 East ; at 5175 cpm.
(5) HFBR FSS SU5 - #5 at 78685 North / 394879 East ; at 5251 cpm.
(6) HFBR FSS SU5 - #6 at 78680 North / 394881 East ; at 5290 cpm.
(7) HFBR FSS SU5- #7 at 78679 North / 394886 East ; at 6936 cpm.
(8) HFBR FSS SU5 - #8 at 78675 North / 394898 East ; at 6922 cpm.
(9) HFBR FSS SU5 - #9 at 78695 North / 394872 East ; at 10446 cpm.
(10) HFBR FSS SU5 - #10 at 78693 North / 394878 East ; at 6805 cpm.
(11) HFBR FSS SU5 - #11 at 78690 North / 394887 East ; at 6346 cpm.. Duplicate soil sample
(12) HFBR FSS SU5 - #12 at 78686 North / 394894 East ; at 6360 cpm.
(13) HFBR FSS SU5 - #13 at 78702 North / 394875 East ; at 6604 cpm.
(14) HFBR FSS SU5 - #14 at 78698 North / 394886 East ; at 5361 cpm.
(15) HFBR FSS SU5 - #15 at 78697 North / 394893 East ; at 5936 cpm.
(16) HFBR FSS SU5 - #16 at 78695 North / 394904 East ; at 6027 cpm.

INSTRUMENTS

MODEL#	SERIAL #	CAL.DUE
LUD-2221/SPA-3	138377/118986	7/28/11
Trimble TSCe	00023998	N/A
N/A	N/A	

LEGEND

○ - SMEAR SURVEY LOCATION ▲ - AIR SAMPLE LOCATION
□ - MASSLINN SURVEY LOCATION [#] - DIRECT FRISK LOCATION
C - CONTAMINATION * CONTACT
XXXY / ZZZ XXX = contact reading Y = radiation type ZZZ = reading @ 30cm

AIRBORNE ACTIVITY SURVEY

Sample #	Duration	Flow Rate	Field Analysis cpm	Field Analysis µCi/cc	% DAC
N/A					

DOSE RATE (HIGHEST)

CONTACT READING	N/A
GENERAL AREA READING	N/A

MASSLINN SURVEY RESULTS (in dpm)

1.	N/A	5.	N/A
2.		6.	
3.		7.	
4.		8.	

SMEAR SURVEY RESULTS (dpm/100cm²) α, β-γ, ³H

1.	See	8.	Attached	15.	Results
2.	Batch	9.	Number	16.	N/A
3.	N/A	10.	N/A	17.	
4.		11.		18.	
5.		12.		19.	
6.		13.		20.	
7.		14.		21.	

Surveyed By: J.Dzvonar, J. Conley, S. Gully Date: 8/30/10 Reviewed By: Date: 9/3/10

FS-SOP-1000
Attachment 9. 2

 9/3/10

RADIOLOGICAL SURVEY FORM
FS-SOP-1000

REASON FOR SURVEY
☐ ROUTINE ☒ SPECIAL FSS
☐ RWP # ☐ WP #

LOCATION & EQUIPT. Bldg. 750 HFBR

DATE: 8-11-2010 **TIME:** 1000

HFBR Outside Survey Unit-6 FSS Survey

Survey Unit 6

COC # 30066

Sample No.	GPS Coordinate	1 Min. Gamma	Post 1 Min. Gamma
001	78679.8 / 394906.4	9201	N/A
002	78673.3 / 394928.9	10272	N/A
003	78694.5 / 394922.8	9070	N/A
004	78688.7 / 394945.3	10250	N/A
005	78715.6 / 394915.5	6596	N/A
006	78709.8 / 394939.1	8473	N/A
007	78735.2 / 394928.4	6247	N/A
008	78728.9 / 394950.1	7470	N/A
009	78759.5 / 394924.6	7287	N/A
010	78751.4 / 394946.0	7294	N/A
011	78773.2 / 394942.2	7926	N/A
012	78769.6 / 394961.8	7878	N/A
013	78794.9 / 394933.3	8335	N/A
014	78789.7 / 394957.5	8382	N/A
015	78810.1 / 394949.9	8468	N/A
016	78806.5 / 394970.1	9240	N/A
017	78832.2 / 394942.3	9099	N/A
018	78827.7 / 394966.6	7908	N/A
019	78848.8 / 394957.5	9502	N/A
020	78842.2 / 394980.0	8489	N/A

Performed GPS NaI Walk-Over Survey. See attached results.

INSTRUMENT

Model #	Serial #	CAL DUE
Ludlum 2221	149942	2-15-2011
Ludlum 2221	138377	7-28-11
N/A		
N/A		

LEGEND
○ - SMEAR SURVEY LOCATION △ - AIR SAMPLE LOCATION
☐ - MASSLINN SURVEY LOCATION # - DIRECT FRISK LOCATION
XXXY / ZZZ XXX = contact reading Y = radiation type ZZZ = reading @ 30cm

AIRBORNE ACTIVITY SURVEY

Sample #	Duration	Flow Rate	Field Analysis cpm	Field Analysis µCi/cc	% DAC
N/A					

DOSE RATE (HIGHEST)

CONTACT READING	N/A
GENERAL AREA READING	N/A

MASSLINN SURVEY RESULTS (in dpm)

1.	N/A	5.	N/A
2.		6.	
3.		7.	
4.		8.	

SMEAR SURVEY RESULTS (dpm/100cm²) α, β-γ, ³H

1.	See	8.	Attached	15.	Results
2.	Batch	9.	Number	16.	N/A
3.		10.		17.	
4.		11.		18.	
5.		12.		19.	
6.		13.		20.	
7.		14.		21.	

Surveyed By Merkel/ Dzvonar/ Schultz **Date:** 8-11-2010 **Reviewed By:** **Date:** 8/13/10

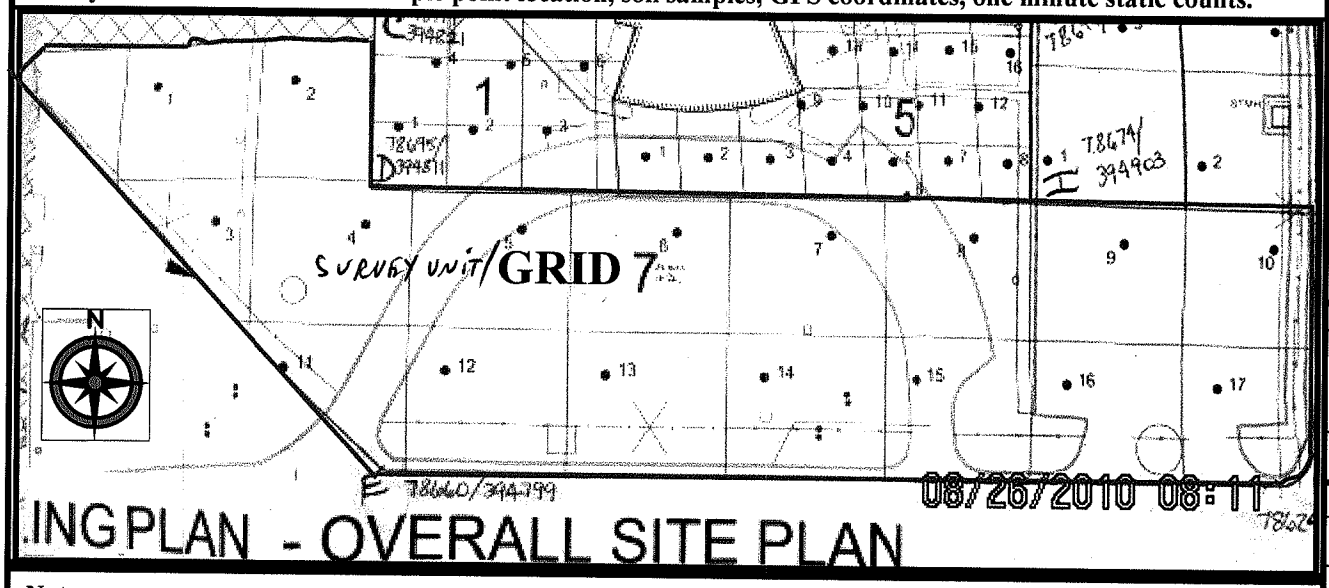
FS-SOP-1000
Attachment 9.2

RADIOLOGICAL SURVEY FORM
FS-SOP-1000

REASON FOR SURVEY
☐ Routine _____ ☒ Special HFBR - FSS
☐ RWP# _____ ☐ WP

Location / Equipment: HFBR Out Side Grounds | **Date:** 08/31/10 | **Time:** 0800

Survey: HFBR FSS Grid #7 sample point location, soil samples, GPS coordinates, one minute static counts.



Note:

(A) Sample point locations for soil samples, GPS coordinates and [1 minute] static counts taken:

(1) HFBR FSS SU7 - #1 at 78712 North / 394874 East ; at 8005 cpm.
(2) HFBR FSS SU7 - #2 at 78710 North / 394802 East ; at 8330 cpm.
(3) HFBR FSS SU7 - #3 at 78686 North / 394792 East ; at 7908 cpm.
(4) HFBR FSS SU7 - #4 at 78680 North / 394804 East ; at 7289 cpm.
(5) HFBR FSS SU7 - #5 at 78674 North / 394829 East ; at 8063 cpm.
(6) HFBR FSS SU7 - #6 at 78668 North / 394851 East ; at 8606 cpm.
(7) HFBR FSS SU7- #7 at 78862 North / 394874 East ; at 8542 cpm.
(8) HFBR FSS SU7 - #8 at 78655 North / 394895 East ; at 9997 cpm. Duplicate soil sample.
(9) HFBR FSS SU7 - #9 at 78659 North / 394917 East ; at 6013 cpm.
(10) HFBR FSS SU7 - #10 at 78648 North / 394935 East ; at 7614 cpm.
(11) HFBR FSS SU7 - #11 at 78672 North / 394792 East ; at 8791 cpm.
(12) HFBR FSS SU7 - #12 at 78667 North / 394805 East ; at 8063 cpm.
(13) HFBR FSS SU7 - #13 at 78657 North / 394834 East ; at 9089 cpm.
(14) HFBR FSS SU7 - #14 at 78654 North / 394858 East ; at 8148 cpm.
(15) HFBR FSS SU7 - #15 at 78653 North / 394879 East ; at 7103 cpm.
(16) HFBR FSS SU7 - #16 at 78646 North / 394901 East ; at 6677 cpm.
(17) HFBR FSS SU7 - #17 at 78641 North / 394922 East ; at 7265 cpm.

INSTRUMENTS

Model #	Serial #	CAL DUE
LUD 2221/SPA-3	138377/118986	7/28/11
Trimble TSCe	00023998	N/A
LUD 2221/SPA-3	149942/114540	7/22/11
Trimble TSCe	00015842	N/A
N/A		

LEGEND
○ - SMEAR SURVEY LOCATION ▲ - AIR SAMPLE LOCATION
□ - MASSLINN SURVEY LOCATION [#] - DIRECT FRISK LOCATION
C̄ - CONTAMINATION * CONTACT
XXXY/ZZZ XXX = contact reading Y = radiation type ZZZ = reading @ 30cm

AIRBORNE ACTIVITY SURVEY

Sample #	Duration	Flow Rate	Field Analysis cpm	Field Analysis µCi/cc	% DAC
N/A					

DOSE RATE (HIGHEST)

CONTACT READING	N/A
GENERAL AREA READING	N/A

MASSLINN SURVEY RESULTS (in dpm)

1.	N/A	5.	N/A
2.		6.	
3.		7.	
4.		8.	

SMEAR SURVEY RESULTS (dpm/100cm²) α, β-γ, ³H

1.	N/A	8.	N/A	15.	N/A
2.		9.		16.	
3.		10.		17.	
4.		11.		18.	
5.		12.		19.	
6.		13.		20.	
7.		14.		21.	

Surveyed By: D. Dove/ J. Conley, J. Dzvonar **Date:** 08/ 31 /10 **Reviewed By:** _____ **Date:** 9/3/10

FS-SOP-1000
Attachment 9. 2

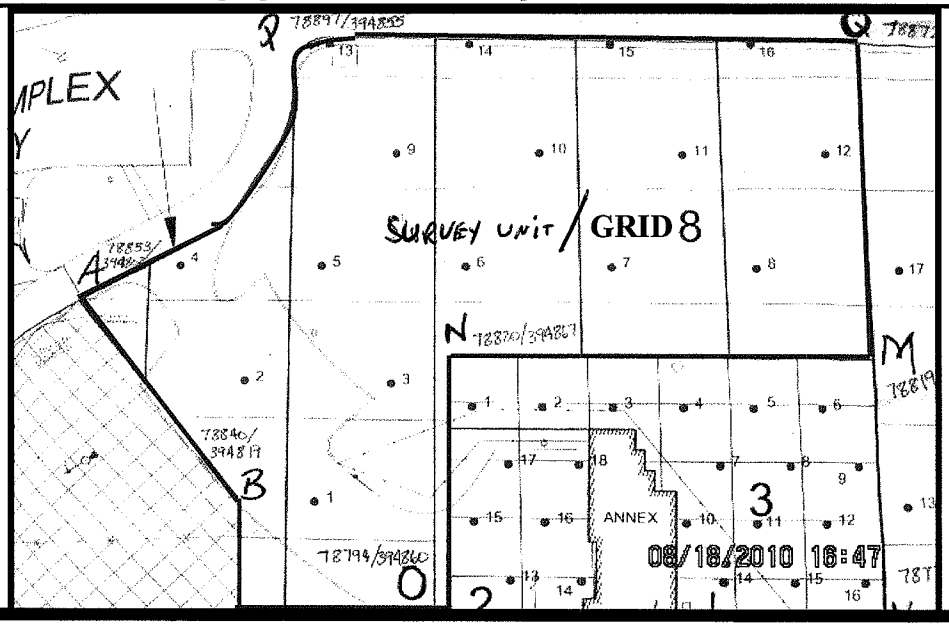
 9/3/10

RADIOLOGICAL SURVEY FORM
FS-SOP-1000

REASON FOR SURVEY: ☐ Routine _____ ☒ Special HFBR - FSS ☐ RWP# _____ ☐ WP

Location / Equipment: HFBR, Outside Grounds | Date: 08/ 18 /10 | Time: 17:00

Survey: HFBR FSS Grid #8 sample point location, soil samples, GPS coordinates, one minute static counts.



INSTRUMENTS

Model #	Serial #	CAL DUE
LUD-2221	138377	07/28/11
NaI Probe	PR118986	07/28/11
N/A		
N/A		
N/A		

LEGEND

○ - SMEAR SURVEY LOCATION ▲ - AIR SAMPLE LOCATION
□ - MASSLINN SURVEY LOCATION # - DIRECT FRISK LOCATION
C̄ - CONTAMINATION * CONTACT
XXXY / ZZZ XXX = contact reading Y = radiation type ZZZ = reading @ 30cm

AIRBORNE ACTIVITY SURVEY

Sample #	Duration	Flow Rate	Field Analysis cpm	Field Analysis µCi/cc	Field Analysis % DAC
N/A					

DOSE RATE (HIGHEST)

CONTACT READING	N/A
GENERAL AREA READING	N/A

MASSLINN SURVEY RESULTS (in dpm)

1.	N/A	5.	N/A
2.		6.	
3.		7.	
4.		8.	

SMEAR SURVEY RESULTS (dpm/100cm²) α, β-γ, ³H

1.	N/A	8.	N/A	15.	N/A
2.		9.		16.	
3.		10.		17.	
4.		11.		18.	
5.		12.		19.	
6.		13.		20.	
7.		14.		21.	

Note:

(A) Sample point locations for soil samples, GPS coordinates and [1 minute] static counts taken:

(1) HFBR FSS SU8 - #1 at 78812 North / 394846 East; at 5986 cpm.
(2) HFBR FSS SU8 - #2 at 78865 North / 394837 East; at 6415 cpm.
(3) HFBR FSS SU8 - #3 at 78831 North / 394859 East ; at 7777 cpm.
(4) HFBR FSS SU8 - #4 at 78854 North / 394826 East ; at 9478 cpm.
(5) HFBR FSS SU8 - #5 at 78849 North / 394850 East ; at 8275 cpm.
(6) HFBR FSS SU8 - #6 at 78846 North / 394872 East ; at 8090 cpm.
(7) HFBR FSS SU8 - #7 at 78841 North / 394896 East ; at 11292 cpm.
(8) HFBR FSS SU8 - #8 at 78837 North / 394917 East ; at 10156 cpm.
(9) HFBR FSS SU8 - #9 at 78870 North / 394867 East ; at 9530 cpm.
(10) HFBR FSS SU8 - #10 at 78863 North / 394890 East ; at 9465 cpm.
(11) HFBR FSS SU8 - #11 at 78860 North / 394913 East ; at 10324 cpm.
(12) HFBR FSS SU8 - #12 at 78852 North / 394934 East ; at 9811 cpm.
(13) HFBR FSS SU8 - #13 at 78891 North / 394864 East ; at 6992 cpm.
(14) HFBR FSS SU8 - #14 at 78886 North / 394883 East ; at 7779 cpm.
(15) HFBR FSS SU8 - #15 at 78880 North / 394906 East ; at 7927 cpm.
(16) HFBR FSS SU8 - #16 at 78874 North / 394928 East ; at 7778 cpm.

Surveyed By: Joan Conley, Dan Dove, Sean A. Gully Date: 08/ 18 /10 Reviewed By: _____ Date: 8/23/10

FS-SOP-1000
Attachment 9.2

Appendix C

HFBR Outside Areas
RESRAD Summary Reports

Summary : HFBR Outside Areas-Residential- Bkg-Subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-RES-BKG-SUBTRACT.RAD

Table of Contents

Part I: Mixture Sums and Single Radionuclide Guidelines

Summary : HFBR Outside Areas-Residential- Bkg-Subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-RES-BKG-SUBTRACT.RAD

Dose Conversion Factor (and Related) Parameter Summary
Dose Library: FGR 12 & FGR 11

Menu	Parameter	Current Value#	Base Case*	Parameter Name
A-1	DCF's for external ground radiation, (mrem/yr)/(pCi/g)			
A-1	Ba-137m (Source: FGR 12)	3.606E+00	3.606E+00	DCF1(1)
A-1	Cs-137 (Source: FGR 12)	7.510E-04	7.510E-04	DCF1(2)
B-1	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Cs-137+D	3.190E-05	3.190E-05	DCF2(1)
D-1	Dose conversion factors for ingestion, mrem/pCi:			
D-1	Cs-137+D	5.000E-05	5.000E-05	DCF3(1)
D-34	Food transfer factors:			
D-34	Cs-137+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(1,1)
D-34	Cs-137+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.000E-02	3.000E-02	RTF(1,2)
D-34	Cs-137+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	8.000E-03	8.000E-03	RTF(1,3)
D-5	Bioaccumulation factors, fresh water, L/kg:			
D-5	Cs-137+D , fish	2.000E+03	2.000E+03	BIOFAC(1,1)
D-5	Cs-137+D , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(1,2)

#For DCF1(xxx) only, factors are for infinite depth & area. See ETFG table in Ground Pathway of Detailed Report.
*Base Case means Default.Lib w/o Associate Nuclide contributions.

Summary : HFBR Outside Areas-Residential- Bkg-Subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-RES-BKG-SUBTRACT.RAD

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	3.200E+04	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	5.000E+00	2.000E+00	---	THICK0
R011	Fraction of contamination that is submerged	0.000E+00	0.000E+00	---	SUBMFRACT
R011	Length parallel to aquifer flow (m)	2.500E+02	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	1.500E+01	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	5.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	5.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	5.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Cs-137	2.400E-01	0.000E+00	---	S1(1)
R012	Concentration in groundwater (pCi/L): Cs-137	not used	0.000E+00	---	W1(1)
R013	Cover depth (m)	0.000E+00	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.500E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.660E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	3.300E-01	4.000E-01	---	TPCZ
R013	Contaminated zone field capacity	2.400E-01	2.000E-01	---	FCCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	5.000E+03	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	4.900E+00	5.300E+00	---	BCZ
R013	Average annual wind speed (m/sec)	6.230E+00	2.000E+00	---	WIND
R013	Humidity in air (g/m**3)	not used	8.000E+00	---	HUMID
R013	Evapotranspiration coefficient	4.600E-01	5.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	1.230E+00	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	2.600E-01	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	1.000E+06	1.000E+06	---	WAREA
R013	Accuracy for water/soil computations	1.000E-03	1.000E-03	---	EPS
R014	Density of saturated zone (g/cm**3)	1.660E+00	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	3.300E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	2.400E-01	2.000E-01	---	EPSZ
R014	Saturated zone field capacity	2.000E-01	2.000E-01	---	FCSZ
R014	Saturated zone hydraulic conductivity (m/yr)	2.000E+04	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	4.800E-03	2.000E-02	---	HGWT
R014	Saturated zone b parameter	4.900E+00	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	1.000E-03	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	1.800E+01	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	---	MODEL
R014	Well pumping rate (m**3/yr)	2.500E+02	2.500E+02	---	UW

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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R015	Number of unsaturated zone strata	1	1	---	NS
R015	Unsat. zone 1, thickness (m)	0.000E+00	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	1.660E+00	1.500E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	3.300E-01	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	2.400E-01	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, field capacity	2.000E-01	2.000E-01	---	FCUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	4.900E+00	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	5.000E+03	1.000E+01	---	HCUZ(1)
R016	Distribution coefficients for Cs-137				
R016	Contaminated zone (cm**3/g)	2.800E+02	4.600E+03	---	DCNUCC(1)
R016	Unsaturated zone 1 (cm**3/g)	2.800E+02	4.600E+03	---	DCNUCU(1,1)
R016	Saturated zone (cm**3/g)	2.800E+02	4.600E+03	---	DCNUCS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.889E-04	ALEACH(1)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)
R017	Inhalation rate (m**3/yr)	7.300E+03	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	1.000E-04	1.000E-04	---	MLINH
R017	Exposure duration	3.000E+01	3.000E+01	---	ED
R017	Shielding factor, inhalation	4.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	8.000E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	5.000E-01	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	2.500E-01	2.500E-01	---	FOTD
R017	Shape factor flag, external gamma	1.000E+00	1.000E+00	>0 shows circular AREA.	FS
R017	Radii of shape factor array (used if FS = -1):				
R017	Outer annular radius (m), ring 1:	not used	5.000E+01	---	RAD_SHAPE(1)
R017	Outer annular radius (m), ring 2:	not used	7.071E+01	---	RAD_SHAPE(2)
R017	Outer annular radius (m), ring 3:	not used	0.000E+00	---	RAD_SHAPE(3)
R017	Outer annular radius (m), ring 4:	not used	0.000E+00	---	RAD_SHAPE(4)
R017	Outer annular radius (m), ring 5:	not used	0.000E+00	---	RAD_SHAPE(5)
R017	Outer annular radius (m), ring 6:	not used	0.000E+00	---	RAD_SHAPE(6)
R017	Outer annular radius (m), ring 7:	not used	0.000E+00	---	RAD_SHAPE(7)
R017	Outer annular radius (m), ring 8:	not used	0.000E+00	---	RAD_SHAPE(8)
R017	Outer annular radius (m), ring 9:	not used	0.000E+00	---	RAD_SHAPE(9)
R017	Outer annular radius (m), ring 10:	not used	0.000E+00	---	RAD_SHAPE(10)
R017	Outer annular radius (m), ring 11:	not used	0.000E+00	---	RAD_SHAPE(11)
R017	Outer annular radius (m), ring 12:	not used	0.000E+00	---	RAD_SHAPE(12)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R017	Fractions of annular areas within AREA:				
R017	Ring 1	not used	1.000E+00	---	FRACA(1)
R017	Ring 2	not used	2.732E-01	---	FRACA(2)
R017	Ring 3	not used	0.000E+00	---	FRACA(3)
R017	Ring 4	not used	0.000E+00	---	FRACA(4)
R017	Ring 5	not used	0.000E+00	---	FRACA(5)
R017	Ring 6	not used	0.000E+00	---	FRACA(6)
R017	Ring 7	not used	0.000E+00	---	FRACA(7)
R017	Ring 8	not used	0.000E+00	---	FRACA(8)
R017	Ring 9	not used	0.000E+00	---	FRACA(9)
R017	Ring 10	not used	0.000E+00	---	FRACA(10)
R017	Ring 11	not used	0.000E+00	---	FRACA(11)
R017	Ring 12	not used	0.000E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	1.600E+02	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	1.400E+01	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	not used	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	not used	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	not used	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	not used	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	4.380E+01	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	7.000E+02	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	1.000E+00	1.000E+00	---	FDW
R018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	not used	1.000E+00	---	FLW
R018	Contamination fraction of irrigation water	1.000E+00	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	not used	5.000E-01	---	FR9
R018	Contamination fraction of plant food	-1	-1	0.500E+00	FPLANT
R018	Contamination fraction of meat	not used	-1	---	FMEAT
R018	Contamination fraction of milk	not used	-1	---	FMILK
R019	Livestock fodder intake for meat (kg/day)	not used	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	not used	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	not used	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	not used	1.600E+02	---	LWI6
R019	Livestock soil intake (kg/day)	not used	5.000E-01	---	LSI
R019	Mass loading for foliar deposition (g/m**3)	1.000E-05	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	9.000E-01	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	not used	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	1.000E+00	1.000E+00	---	FGWIR
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	7.000E-01	7.000E-01	---	YV(1)
R19B	Wet weight crop yield for Leafy (kg/m**2)	1.500E+00	1.500E+00	---	YV(2)
R19B	Wet weight crop yield for Fodder (kg/m**2)	not used	1.100E+00	---	YV(3)
R19B	Growing Season for Non-Leafy (years)	1.700E-01	1.700E-01	---	TE(1)
R19B	Growing Season for Leafy (years)	2.500E-01	2.500E-01	---	TE(2)
R19B	Growing Season for Fodder (years)	not used	8.000E-02	---	TE(3)

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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R19B	Translocation Factor for Non-Leafy	1.000E-01	1.000E-01	---	TIV(1)
R19B	Translocation Factor for Leafy	1.000E+00	1.000E+00	---	TIV(2)
R19B	Translocation Factor for Fodder	not used	1.000E+00	---	TIV(3)
R19B	Dry Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	---	RDRY(1)
R19B	Dry Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	---	RDRY(2)
R19B	Dry Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RDRY(3)
R19B	Wet Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	---	RWET(1)
R19B	Wet Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	---	RWET(2)
R19B	Wet Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RWET(3)
R19B	Weathering Removal Constant for Vegetation	2.000E+01	2.000E+01	---	WLAM
C14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	---	C12WTR
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	C12CZ
C14	Fraction of vegetation carbon from soil	not used	2.000E-02	---	CSOIL
C14	Fraction of vegetation carbon from air	not used	9.800E-01	---	CAIR
C14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	---	DMC
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	---	EVSN
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	---	REVSN
C14	Fraction of grain in beef cattle feed	not used	8.000E-01	---	AVFG4
C14	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5
STOR	Storage times of contaminated foodstuffs (days):				
STOR	Fruits, non-leafy vegetables, and grain	1.400E+01	1.400E+01	---	STOR_T(1)
STOR	Leafy vegetables	1.000E+00	1.000E+00	---	STOR_T(2)
STOR	Milk	1.000E+00	1.000E+00	---	STOR_T(3)
STOR	Meat and poultry	2.000E+01	2.000E+01	---	STOR_T(4)
STOR	Fish	7.000E+00	7.000E+00	---	STOR_T(5)
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	---	STOR_T(6)
STOR	Well water	1.000E+00	1.000E+00	---	STOR_T(7)
STOR	Surface water	1.000E+00	1.000E+00	---	STOR_T(8)
STOR	Livestock fodder	4.500E+01	4.500E+01	---	STOR_T(9)
R021	Thickness of building foundation (m)	not used	1.500E-01	---	FLOOR1
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	---	DENSFL
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	not used	1.000E-01	---	TPFL
R021	Volumetric water content of the cover material	not used	5.000E-02	---	PH2OCV
R021	Volumetric water content of the foundation	not used	3.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.000E-06	---	DIFCV
R021	in foundation material	not used	3.000E-07	---	DIFFL
R021	in contaminated zone soil	not used	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	not used	2.000E+00	---	HMIX
R021	Average building air exchange rate (1/hr)	not used	5.000E-01	---	REXG
R021	Height of the building (room) (m)	not used	2.500E+00	---	HRM
R021	Building interior area factor	not used	0.000E+00	---	FAI
R021	Building depth below ground surface (m)	not used	-1.000E+00	---	DMFL
R021	Emanating power of Rn-222 gas	not used	2.500E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	not used	1.500E-01	---	EMANA(2)
TITL	Number of graphical time points	32	---	---	NPTS

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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
TITL	Maximum number of integration points for dose	17	---	---	LYMAX
TITL	Maximum number of integration points for risk	257	---	---	KYMAX

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	active
2 -- inhalation (w/o radon)	active
3 -- plant ingestion	active
4 -- meat ingestion	suppressed
5 -- milk ingestion	suppressed
6 -- aquatic foods	suppressed
7 -- drinking water	active
8 -- soil ingestion	active
9 -- radon	suppressed
Find peak pathway doses	active

Summary : HFBR Outside Areas-Residential- Bkg-Subtract
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Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	32000.00 square meters	Cs-137	2.400E-01
Thickness:	5.00 meters		
Cover Depth:	0.00 meters		

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 1.500E+01 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	5.000E+00	1.000E+01	5.000E+01	1.000E+02	5.000E+02	1.000E+03
TDOSE(t):	5.424E-01	5.298E-01	4.825E-01	4.292E-01	1.684E-01	5.229E-02	4.520E-06	3.768E-11
M(t):	3.616E-02	3.532E-02	3.217E-02	2.862E-02	1.123E-02	3.486E-03	3.013E-07	2.512E-12

Maximum TDOSE(t): 5.424E-01 mrem/yr at t = 0.000E+00 years

Summary : HFBR Outside Areas-Residential- Bkg-Subtract
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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	5.007E-01	0.9232	1.811E-07	0.0000	0.000E+00	0.0000	4.128E-02	0.0761	0.000E+00	0.0000	0.000E+00	0.0000	3.896E-04	0.0007
Total	5.007E-01	0.9232	1.811E-07	0.0000	0.000E+00	0.0000	4.128E-02	0.0761	0.000E+00	0.0000	0.000E+00	0.0000	3.896E-04	0.0007

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	8.007E-07	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.283E-08	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.424E-01	1.0000
Total	8.007E-07	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.283E-08	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.424E-01	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Residential- Bkg-Subtract
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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	4.891E-01	0.9232	1.769E-07	0.0000	0.000E+00	0.0000	4.032E-02	0.0761	0.000E+00	0.0000	0.000E+00	0.0000	3.806E-04	0.0007
Total	4.891E-01	0.9232	1.769E-07	0.0000	0.000E+00	0.0000	4.032E-02	0.0761	0.000E+00	0.0000	0.000E+00	0.0000	3.806E-04	0.0007

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	2.368E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.677E-07	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.298E-01	1.0000
Total	2.368E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.677E-07	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.298E-01	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Residential- Bkg-Subtract
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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	4.454E-01	0.9232	1.611E-07	0.0000	0.000E+00	0.0000	3.672E-02	0.0761	0.000E+00	0.0000	0.000E+00	0.0000	3.466E-04	0.0007
Total	4.454E-01	0.9232	1.611E-07	0.0000	0.000E+00	0.0000	3.672E-02	0.0761	0.000E+00	0.0000	0.000E+00	0.0000	3.466E-04	0.0007

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	7.941E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.782E-07	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.825E-01	1.0000
Total	7.941E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.782E-07	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.825E-01	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Residential- Bkg-Subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-RES-BKG-SUBTRACT.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	3.963E-01	0.9231	1.433E-07	0.0000	0.000E+00	0.0000	3.267E-02	0.0761	0.000E+00	0.0000	0.000E+00	0.0000	3.084E-04	0.0007
Total	3.963E-01	0.9231	1.433E-07	0.0000	0.000E+00	0.0000	3.267E-02	0.0761	0.000E+00	0.0000	0.000E+00	0.0000	3.084E-04	0.0007

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	1.351E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.883E-07	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.292E-01	1.0000
Total	1.351E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.883E-07	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.292E-01	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Residential- Bkg-Subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-RES-BKG-SUBTRACT.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	1.554E-01	0.9230	5.621E-08	0.0000	0.000E+00	0.0000	1.281E-02	0.0761	0.000E+00	0.0000	0.000E+00	0.0000	1.210E-04	0.0007
Total	1.554E-01	0.9230	5.621E-08	0.0000	0.000E+00	0.0000	1.281E-02	0.0761	0.000E+00	0.0000	0.000E+00	0.0000	1.210E-04	0.0007

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	2.567E-05	0.0002	0.000E+00	0.0000	0.000E+00	0.0000	1.886E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.684E-01	1.0000
Total	2.567E-05	0.0002	0.000E+00	0.0000	0.000E+00	0.0000	1.886E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.684E-01	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Residential- Bkg-Subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-RES-BKG-SUBTRACT.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	4.826E-02	0.9229	1.745E-08	0.0000	0.000E+00	0.0000	3.978E-03	0.0761	0.000E+00	0.0000	0.000E+00	0.0000	3.755E-05	0.0007
Total	4.826E-02	0.9229	1.745E-08	0.0000	0.000E+00	0.0000	3.978E-03	0.0761	0.000E+00	0.0000	0.000E+00	0.0000	3.755E-05	0.0007

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	1.599E-05	0.0003	0.000E+00	0.0000	0.000E+00	0.0000	1.176E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.229E-02	1.0000
Total	1.599E-05	0.0003	0.000E+00	0.0000	0.000E+00	0.0000	1.176E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.229E-02	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Residential- Bkg-Subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-RES-BKG-SUBTRACT.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	4.165E-06	0.9216	1.506E-12	0.0000	0.000E+00	0.0000	3.434E-07	0.0760	0.000E+00	0.0000	0.000E+00	0.0000	3.241E-09	0.0007
Total	4.165E-06	0.9216	1.506E-12	0.0000	0.000E+00	0.0000	3.434E-07	0.0760	0.000E+00	0.0000	0.000E+00	0.0000	3.241E-09	0.0007

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	7.353E-09	0.0016	0.000E+00	0.0000	0.000E+00	0.0000	5.409E-10	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	4.520E-06	1.0000
Total	7.353E-09	0.0016	0.000E+00	0.0000	0.000E+00	0.0000	5.409E-10	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	4.520E-06	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Residential- Bkg-Subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-RES-BKG-SUBTRACT.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	3.465E-11	0.9197	1.253E-17	0.0000	0.000E+00	0.0000	2.857E-12	0.0758	0.000E+00	0.0000	0.000E+00	0.0000	2.697E-14	0.0007
Total	3.465E-11	0.9197	1.253E-17	0.0000	0.000E+00	0.0000	2.857E-12	0.0758	0.000E+00	0.0000	0.000E+00	0.0000	2.697E-14	0.0007

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	1.331E-13	0.0035	0.000E+00	0.0000	0.000E+00	0.0000	9.789E-15	0.0003	0.000E+00	0.0000	0.000E+00	0.0000	3.768E-11	1.0000
Total	1.331E-13	0.0035	0.000E+00	0.0000	0.000E+00	0.0000	9.789E-15	0.0003	0.000E+00	0.0000	0.000E+00	0.0000	3.768E-11	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Residential- Bkg-Subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-RES-BKG-SUBTRACT.RAD

Dose/Source Ratios Summed Over All Pathways
Parent and Progeny Principal Radionuclide Contributions Indicated

Parent (i)	Product (j)	Thread Fraction	DSR(j,t) At Time in Years (mrem/yr)/(pCi/g) 0.000E+00	1.000E+00	5.000E+00	1.000E+01	5.000E+01	1.000E+02	5.000E+02	1.000E+03
Cs-137+D	Cs-137+D	1.000E+00	2.260E+00	2.208E+00	2.010E+00	1.788E+00	7.017E-01	2.179E-01	1.883E-05	1.570E-10

The DSR includes contributions from associated (half-life ≤ 180 days) daughters.

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 1.500E+01 mrem/yr

Nuclide (i)	t= 0.000E+00	1.000E+00	5.000E+00	1.000E+01	5.000E+01	1.000E+02	5.000E+02	1.000E+03
Cs-137	6.638E+00	6.795E+00	7.461E+00	8.387E+00	2.138E+01	6.884E+01	7.965E+05	9.554E+10

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
at tmin = time of minimum single radionuclide soil guideline
and at tmax = time of maximum total dose = 0.000E+00 years

Nuclide (i)	Initial (pCi/g)	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Cs-137	2.400E-01	0.000E+00	2.260E+00	6.638E+00	2.260E+00	6.638E+00

Summary : HFBR Outside Areas-Residential- Bkg-Subtract
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Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

Nuclide	Parent	THF(i)	DOSE(j,t), mrem/yr							
(j)	(i)	t= 0.000E+00	1.000E+00	5.000E+00	1.000E+01	5.000E+01	1.000E+02	5.000E+02	1.000E+03
Cs-137	Cs-137	1.000E+00	5.424E-01	5.298E-01	4.825E-01	4.292E-01	1.684E-01	5.229E-02	4.520E-06	3.768E-11

THF(i) is the thread fraction of the parent nuclide.

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide	Parent	THF(i)	S(j,t), pCi/g							
(j)	(i)	t= 0.000E+00	1.000E+00	5.000E+00	1.000E+01	5.000E+01	1.000E+02	5.000E+02	1.000E+03
Cs-137	Cs-137	1.000E+00	2.400E-01	2.345E-01	2.135E-01	1.899E-01	7.451E-02	2.313E-02	1.997E-06	1.661E-11

THF(i) is the thread fraction of the parent nuclide.

RESCALC.EXE execution time = 0.65 seconds

Summary : HFBR Outside Areas-Industrial-Bkg subtract
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Part I: Mixture Sums and Single Radionuclide Guidelines

Summary : HFBR Outside Areas-Industrial-Bkg subtract
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Dose Conversion Factor (and Related) Parameter Summary
Dose Library: FGR 12 & FGR 11

Menu	Parameter	Current Value#	Base Case*	Parameter Name
A-1	DCF's for external ground radiation, (mrem/yr)/(pCi/g)			
A-1	Ba-137m (Source: FGR 12)	3.606E+00	3.606E+00	DCF1(1)
A-1	Cs-137 (Source: FGR 12)	7.510E-04	7.510E-04	DCF1(2)
B-1	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Cs-137+D	3.190E-05	3.190E-05	DCF2(1)
D-1	Dose conversion factors for ingestion, mrem/pCi:			
D-1	Cs-137+D	5.000E-05	5.000E-05	DCF3(1)
D-34	Food transfer factors:			
D-34	Cs-137+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(1,1)
D-34	Cs-137+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.000E-02	3.000E-02	RTF(1,2)
D-34	Cs-137+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	8.000E-03	8.000E-03	RTF(1,3)
D-5	Bioaccumulation factors, fresh water, L/kg:			
D-5	Cs-137+D , fish	2.000E+03	2.000E+03	BIOFAC(1,1)
D-5	Cs-137+D , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(1,2)

#For DCF1(xxx) only, factors are for infinite depth & area. See ETFG table in Ground Pathway of Detailed Report.
*Base Case means Default.Lib w/o Associate Nuclide contributions.

Summary : HFBR Outside Areas-Industrial-Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-BKG-SUBTRACT.RAD

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	3.200E+04	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	5.000E+00	2.000E+00	---	THICK0
R011	Fraction of contamination that is submerged	0.000E+00	0.000E+00	---	SUBMFRACT
R011	Length parallel to aquifer flow (m)	2.500E+02	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	1.500E+01	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	5.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	5.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	5.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Cs-137	2.400E-01	0.000E+00	---	S1(1)
R012	Concentration in groundwater (pCi/L): Cs-137	not used	0.000E+00	---	W1(1)
R013	Cover depth (m)	0.000E+00	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.500E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.660E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	3.300E-01	4.000E-01	---	TPCZ
R013	Contaminated zone field capacity	2.400E-01	2.000E-01	---	FCCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	5.000E+03	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	4.900E+00	5.300E+00	---	BCZ
R013	Average annual wind speed (m/sec)	6.230E+00	2.000E+00	---	WIND
R013	Humidity in air (g/m**3)	not used	8.000E+00	---	HUMID
R013	Evapotranspiration coefficient	4.600E-01	5.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	1.230E+00	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	2.600E-01	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	1.000E+06	1.000E+06	---	WAREA
R013	Accuracy for water/soil computations	1.000E-03	1.000E-03	---	EPS
R014	Density of saturated zone (g/cm**3)	1.660E+00	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	3.300E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	2.400E-01	2.000E-01	---	EPSZ
R014	Saturated zone field capacity	2.000E-01	2.000E-01	---	FCSZ
R014	Saturated zone hydraulic conductivity (m/yr)	2.000E+04	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	4.800E-03	2.000E-02	---	HGWT
R014	Saturated zone b parameter	4.900E+00	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	1.000E-03	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	1.800E+01	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	---	MODEL
R014	Well pumping rate (m**3/yr)	not used	2.500E+02	---	UW

Summary : HFBR Outside Areas-Industrial-Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-BKG-SUBTRACT.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R015	Number of unsaturated zone strata	1	1	---	NS
R015	Unsat. zone 1, thickness (m)	0.000E+00	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	1.660E+00	1.500E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	3.300E-01	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	2.400E-01	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, field capacity	2.000E-01	2.000E-01	---	FCUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	4.900E+00	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	5.000E+03	1.000E+01	---	HCUZ(1)
R016	Distribution coefficients for Cs-137				
R016	Contaminated zone (cm**3/g)	2.800E+02	4.600E+03	---	DCNUCC(1)
R016	Unsaturated zone 1 (cm**3/g)	2.800E+02	4.600E+03	---	DCNUCU(1,1)
R016	Saturated zone (cm**3/g)	2.800E+02	4.600E+03	---	DCNUCS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.889E-04	ALEACH(1)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)
R017	Inhalation rate (m**3/yr)	7.300E+03	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	1.000E-04	1.000E-04	---	MLINH
R017	Exposure duration	2.500E+01	3.000E+01	---	ED
R017	Shielding factor, inhalation	4.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	8.000E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	1.700E-01	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	6.000E-02	2.500E-01	---	FOTD
R017	Shape factor flag, external gamma	1.000E+00	1.000E+00	>0 shows circular AREA.	FS
R017	Radii of shape factor array (used if FS = -1):				
R017	Outer annular radius (m), ring 1:	not used	5.000E+01	---	RAD_SHAPE(1)
R017	Outer annular radius (m), ring 2:	not used	7.071E+01	---	RAD_SHAPE(2)
R017	Outer annular radius (m), ring 3:	not used	0.000E+00	---	RAD_SHAPE(3)
R017	Outer annular radius (m), ring 4:	not used	0.000E+00	---	RAD_SHAPE(4)
R017	Outer annular radius (m), ring 5:	not used	0.000E+00	---	RAD_SHAPE(5)
R017	Outer annular radius (m), ring 6:	not used	0.000E+00	---	RAD_SHAPE(6)
R017	Outer annular radius (m), ring 7:	not used	0.000E+00	---	RAD_SHAPE(7)
R017	Outer annular radius (m), ring 8:	not used	0.000E+00	---	RAD_SHAPE(8)
R017	Outer annular radius (m), ring 9:	not used	0.000E+00	---	RAD_SHAPE(9)
R017	Outer annular radius (m), ring 10:	not used	0.000E+00	---	RAD_SHAPE(10)
R017	Outer annular radius (m), ring 11:	not used	0.000E+00	---	RAD_SHAPE(11)
R017	Outer annular radius (m), ring 12:	not used	0.000E+00	---	RAD_SHAPE(12)

Summary : HFBR Outside Areas-Industrial-Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-BKG-SUBTRACT.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R017	Fractions of annular areas within AREA:				
R017	Ring 1	not used	1.000E+00	---	FRACA(1)
R017	Ring 2	not used	2.732E-01	---	FRACA(2)
R017	Ring 3	not used	0.000E+00	---	FRACA(3)
R017	Ring 4	not used	0.000E+00	---	FRACA(4)
R017	Ring 5	not used	0.000E+00	---	FRACA(5)
R017	Ring 6	not used	0.000E+00	---	FRACA(6)
R017	Ring 7	not used	0.000E+00	---	FRACA(7)
R017	Ring 8	not used	0.000E+00	---	FRACA(8)
R017	Ring 9	not used	0.000E+00	---	FRACA(9)
R017	Ring 10	not used	0.000E+00	---	FRACA(10)
R017	Ring 11	not used	0.000E+00	---	FRACA(11)
R017	Ring 12	not used	0.000E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	not used	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	not used	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	not used	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	not used	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	not used	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	not used	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	3.650E+01	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	3.500E+02	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	1.000E+00	1.000E+00	---	FDW
R018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	not used	1.000E+00	---	FLW
R018	Contamination fraction of irrigation water	not used	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	not used	5.000E-01	---	FR9
R018	Contamination fraction of plant food	not used	-1	---	FPLANT
R018	Contamination fraction of meat	not used	-1	---	FMEAT
R018	Contamination fraction of milk	not used	-1	---	FMILK
R019	Livestock fodder intake for meat (kg/day)	not used	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	not used	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	not used	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	not used	1.600E+02	---	LWI6
R019	Livestock soil intake (kg/day)	not used	5.000E-01	---	LSI
R019	Mass loading for foliar deposition (g/m**3)	not used	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	not used	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	not used	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	not used	1.000E+00	---	FGWIR
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	not used	7.000E-01	---	YV(1)
R19B	Wet weight crop yield for Leafy (kg/m**2)	not used	1.500E+00	---	YV(2)
R19B	Wet weight crop yield for Fodder (kg/m**2)	not used	1.100E+00	---	YV(3)
R19B	Growing Season for Non-Leafy (years)	not used	1.700E-01	---	TE(1)
R19B	Growing Season for Leafy (years)	not used	2.500E-01	---	TE(2)
R19B	Growing Season for Fodder (years)	not used	8.000E-02	---	TE(3)

Summary : HFBR Outside Areas-Industrial-Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-BKG-SUBTRACT.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R19B	Translocation Factor for Non-Leafy	not used	1.000E-01	---	TIV(1)
R19B	Translocation Factor for Leafy	not used	1.000E+00	---	TIV(2)
R19B	Translocation Factor for Fodder	not used	1.000E+00	---	TIV(3)
R19B	Dry Foliar Interception Fraction for Non-Leafy	not used	2.500E-01	---	RDRY(1)
R19B	Dry Foliar Interception Fraction for Leafy	not used	2.500E-01	---	RDRY(2)
R19B	Dry Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RDRY(3)
R19B	Wet Foliar Interception Fraction for Non-Leafy	not used	2.500E-01	---	RWET(1)
R19B	Wet Foliar Interception Fraction for Leafy	not used	2.500E-01	---	RWET(2)
R19B	Wet Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RWET(3)
R19B	Weathering Removal Constant for Vegetation	not used	2.000E+01	---	WLAM
C14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	---	C12WTR
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	C12CZ
C14	Fraction of vegetation carbon from soil	not used	2.000E-02	---	CSOIL
C14	Fraction of vegetation carbon from air	not used	9.800E-01	---	CAIR
C14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	---	DMC
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	---	EVSN
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	---	REVSN
C14	Fraction of grain in beef cattle feed	not used	8.000E-01	---	AVFG4
C14	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5
STOR	Storage times of contaminated foodstuffs (days):				
STOR	Fruits, non-leafy vegetables, and grain	1.400E+01	1.400E+01	---	STOR_T(1)
STOR	Leafy vegetables	1.000E+00	1.000E+00	---	STOR_T(2)
STOR	Milk	1.000E+00	1.000E+00	---	STOR_T(3)
STOR	Meat and poultry	2.000E+01	2.000E+01	---	STOR_T(4)
STOR	Fish	7.000E+00	7.000E+00	---	STOR_T(5)
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	---	STOR_T(6)
STOR	Well water	1.000E+00	1.000E+00	---	STOR_T(7)
STOR	Surface water	1.000E+00	1.000E+00	---	STOR_T(8)
STOR	Livestock fodder	4.500E+01	4.500E+01	---	STOR_T(9)
R021	Thickness of building foundation (m)	not used	1.500E-01	---	FLOOR1
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	---	DENSFL
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	not used	1.000E-01	---	TPFL
R021	Volumetric water content of the cover material	not used	5.000E-02	---	PH2OCV
R021	Volumetric water content of the foundation	not used	3.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.000E-06	---	DIFCV
R021	in foundation material	not used	3.000E-07	---	DIFFL
R021	in contaminated zone soil	not used	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	not used	2.000E+00	---	HMIX
R021	Average building air exchange rate (1/hr)	not used	5.000E-01	---	REXG
R021	Height of the building (room) (m)	not used	2.500E+00	---	HRM
R021	Building interior area factor	not used	0.000E+00	---	FAI
R021	Building depth below ground surface (m)	not used	-1.000E+00	---	DMFL
R021	Emanating power of Rn-222 gas	not used	2.500E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	not used	1.500E-01	---	EMANA(2)
TITL	Number of graphical time points	32	---	---	NPTS

Summary : HFBR Outside Areas-Industrial-Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-BKG-SUBTRACT.RAD

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
TITL	Maximum number of integration points for dose	17	---	---	LYMAX
TITL	Maximum number of integration points for risk	257	---	---	KYMAX

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	active
2 -- inhalation (w/o radon)	active
3 -- plant ingestion	suppressed
4 -- meat ingestion	suppressed
5 -- milk ingestion	suppressed
6 -- aquatic foods	suppressed
7 -- drinking water	active
8 -- soil ingestion	active
9 -- radon	suppressed
Find peak pathway doses	active

Summary : HFBR Outside Areas-Industrial-Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-BKG-SUBTRACT.RAD

Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	32000.00 square meters	Cs-137	2.400E-01
Thickness:	5.00 meters		
Cover Depth:	0.00 meters		

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 1.500E+01 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	5.000E+00	1.000E+01	5.000E+01	1.000E+02	5.000E+02	1.000E+03
TDOSE(t):	1.511E-01	1.476E-01	1.344E-01	1.196E-01	4.692E-02	1.457E-02	1.261E-06	1.052E-11
M(t):	1.007E-02	9.839E-03	8.960E-03	7.971E-03	3.128E-03	9.713E-04	8.404E-08	7.015E-13

Maximum TDOSE(t): 1.511E-01 mrem/yr at t = 0.000E+00 years

Summary : HFBR Outside Areas-Industrial-Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-BKG-SUBTRACT.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	1.510E-01	0.9993	5.150E-08	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.957E-05	0.0007
Total	1.510E-01	0.9993	5.150E-08	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.957E-05	0.0007

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	4.004E-07	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.511E-01	1.0000
Total	4.004E-07	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.511E-01	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Industrial-Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-BKG-SUBTRACT.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	1.475E-01	0.9993	5.031E-08	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.727E-05	0.0007
Total	1.475E-01	0.9993	5.031E-08	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.727E-05	0.0007

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	1.184E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.476E-01	1.0000
Total	1.184E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.476E-01	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Industrial-Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-BKG-SUBTRACT.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	1.343E-01	0.9993	4.581E-08	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.858E-05	0.0007
Total	1.343E-01	0.9993	4.581E-08	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.858E-05	0.0007

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	3.970E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.344E-01	1.0000
Total	3.970E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.344E-01	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Industrial-Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-BKG-SUBTRACT.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	1.195E-01	0.9993	4.076E-08	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.880E-05	0.0007
Total	1.195E-01	0.9993	4.076E-08	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.880E-05	0.0007

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	6.753E-06	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.196E-01	1.0000
Total	6.753E-06	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.196E-01	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Industrial-Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-BKG-SUBTRACT.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	4.687E-02	0.9991	1.599E-08	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.091E-05	0.0007
Total	4.687E-02	0.9991	1.599E-08	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.091E-05	0.0007

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	1.283E-05	0.0003	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.692E-02	1.0000
Total	1.283E-05	0.0003	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.692E-02	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Industrial-Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-BKG-SUBTRACT.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	1.455E-02	0.9988	4.964E-09	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.597E-06	0.0007
Total	1.455E-02	0.9988	4.964E-09	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.597E-06	0.0007

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	7.997E-06	0.0005	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.457E-02	1.0000
Total	7.997E-06	0.0005	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.457E-02	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Industrial-Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-BKG-SUBTRACT.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	1.256E-06	0.9964	4.285E-13	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.284E-10	0.0007
Total	1.256E-06	0.9964	4.285E-13	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.284E-10	0.0007

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	3.677E-09	0.0029	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.261E-06	1.0000
Total	3.677E-09	0.0029	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.261E-06	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Industrial-Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-BKG-SUBTRACT.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	1.045E-11	0.9930	3.565E-18	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.892E-15	0.0007
Total	1.045E-11	0.9930	3.565E-18	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.892E-15	0.0007

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	6.653E-14	0.0063	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.052E-11	1.0000
Total	6.653E-14	0.0063	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.052E-11	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Industrial-Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-BKG-SUBTRACT.RAD

Dose/Source Ratios Summed Over All Pathways
Parent and Progeny Principal Radionuclide Contributions Indicated

Parent (i)	Product (j)	Thread Fraction	DSR(j,t) At Time in Years (mrem/yr)/(pCi/g) 0.000E+00	1.000E+00	5.000E+00	1.000E+01	5.000E+01	1.000E+02	5.000E+02	1.000E+03
Cs-137+D	Cs-137+D	1.000E+00	6.295E-01	6.149E-01	5.600E-01	4.982E-01	1.955E-01	6.071E-02	5.252E-06	4.385E-11

The DSR includes contributions from associated (half-life ≤ 180 days) daughters.

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 1.500E+01 mrem/yr

Nuclide (i)	t= 0.000E+00	1.000E+00	5.000E+00	1.000E+01	5.000E+01	1.000E+02	5.000E+02	1.000E+03
Cs-137	2.383E+01	2.439E+01	2.679E+01	3.011E+01	7.673E+01	2.471E+02	2.856E+06	3.421E+11

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
at tmin = time of minimum single radionuclide soil guideline
and at tmax = time of maximum total dose = 0.000E+00 years

Nuclide (i)	Initial (pCi/g)	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Cs-137	2.400E-01	0.000E+00	6.295E-01	2.383E+01	6.295E-01	2.383E+01

Summary : HFBR Outside Areas-Industrial-Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-BKG-SUBTRACT.RAD

Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	THF(i)	DOSE(j,t), mrem/yr							
		t=	0.000E+00	1.000E+00	5.000E+00	1.000E+01	5.000E+01	1.000E+02	5.000E+02	1.000E+03
Cs-137	Cs-137	1.000E+00	1.511E-01	1.476E-01	1.344E-01	1.196E-01	4.692E-02	1.457E-02	1.261E-06	1.052E-11

THF(i) is the thread fraction of the parent nuclide.

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	THF(i)	S(j,t), pCi/g							
		t=	0.000E+00	1.000E+00	5.000E+00	1.000E+01	5.000E+01	1.000E+02	5.000E+02	1.000E+03
Cs-137	Cs-137	1.000E+00	2.400E-01	2.345E-01	2.135E-01	1.899E-01	7.451E-02	2.313E-02	1.997E-06	1.661E-11

THF(i) is the thread fraction of the parent nuclide.

RESCALC.EXE execution time = 0.48 seconds

Summary : HFBR Outside Areas-Residential- NO-Bkg-Subtract
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Part I: Mixture Sums and Single Radionuclide Guidelines

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Dose Conversion Factor (and Related) Parameter Summary
Dose Library: FGR 12 & FGR 11

Menu	Parameter	Current Value#	Base Case*	Parameter Name
A-1	DCF's for external ground radiation, (mrem/yr)/(pCi/g)			
A-1	At-218 (Source: FGR 12)	5.847E-03	5.847E-03	DCF1(1)
A-1	Ba-137m (Source: FGR 12)	3.606E+00	3.606E+00	DCF1(2)
A-1	Bi-210 (Source: FGR 12)	3.606E-03	3.606E-03	DCF1(3)
A-1	Bi-214 (Source: FGR 12)	9.808E+00	9.808E+00	DCF1(4)
A-1	Cs-137 (Source: FGR 12)	7.510E-04	7.510E-04	DCF1(5)
A-1	Pb-210 (Source: FGR 12)	2.447E-03	2.447E-03	DCF1(6)
A-1	Pb-214 (Source: FGR 12)	1.341E+00	1.341E+00	DCF1(7)
A-1	Po-210 (Source: FGR 12)	5.231E-05	5.231E-05	DCF1(8)
A-1	Po-214 (Source: FGR 12)	5.138E-04	5.138E-04	DCF1(9)
A-1	Po-218 (Source: FGR 12)	5.642E-05	5.642E-05	DCF1(10)
A-1	Ra-226 (Source: FGR 12)	3.176E-02	3.176E-02	DCF1(11)
A-1	Rn-222 (Source: FGR 12)	2.354E-03	2.354E-03	DCF1(12)
A-1	Tl-210 (Source: no data)	0.000E+00	-2.000E+00	DCF1(13)
B-1	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Cs-137+D	3.190E-05	3.190E-05	DCF2(1)
B-1	Pb-210+D	2.320E-02	1.360E-02	DCF2(2)
B-1	Ra-226+D	8.594E-03	8.580E-03	DCF2(3)
D-1	Dose conversion factors for ingestion, mrem/pCi:			
D-1	Cs-137+D	5.000E-05	5.000E-05	DCF3(1)
D-1	Pb-210+D	7.276E-03	5.370E-03	DCF3(2)
D-1	Ra-226+D	1.321E-03	1.320E-03	DCF3(3)
D-34	Food transfer factors:			
D-34	Cs-137+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(1,1)
D-34	Cs-137+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.000E-02	3.000E-02	RTF(1,2)
D-34	Cs-137+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	8.000E-03	8.000E-03	RTF(1,3)
D-34	Pb-210+D , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF(2,1)
D-34	Pb-210+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	8.000E-04	8.000E-04	RTF(2,2)
D-34	Pb-210+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	3.000E-04	3.000E-04	RTF(2,3)
D-34	Ra-226+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(3,1)
D-34	Ra-226+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(3,2)
D-34	Ra-226+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(3,3)
D-5	Bioaccumulation factors, fresh water, L/kg:			
D-5	Cs-137+D , fish	2.000E+03	2.000E+03	BIOFAC(1,1)
D-5	Cs-137+D , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(1,2)
D-5	Pb-210+D , fish	3.000E+02	3.000E+02	BIOFAC(2,1)
D-5	Pb-210+D , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(2,2)
D-5	Ra-226+D , fish	5.000E+01	5.000E+01	BIOFAC(3,1)
D-5	Ra-226+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(3,2)

#For DCF1(xxx) only, factors are for infinite depth & area. See ETFG table in Ground Pathway of Detailed Report.
*Base Case means Default.Lib w/o Associate Nuclide contributions.

Summary : HFBR Outside Areas-Residential- NO-Bkg-Subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-RES-NO-BKG-SUBTRACT.RAD

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	3.200E+04	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	5.000E+00	2.000E+00	---	THICK0
R011	Fraction of contamination that is submerged	0.000E+00	0.000E+00	---	SUBMFRACT
R011	Length parallel to aquifer flow (m)	2.500E+02	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	1.500E+01	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	5.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	5.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	5.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Cs-137	2.400E-01	0.000E+00	---	S1(1)
R012	Initial principal radionuclide (pCi/g): Ra-226	4.700E-01	0.000E+00	---	S1(3)
R012	Concentration in groundwater (pCi/L): Cs-137	not used	0.000E+00	---	W1(1)
R012	Concentration in groundwater (pCi/L): Ra-226	not used	0.000E+00	---	W1(3)
R013	Cover depth (m)	0.000E+00	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.500E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.660E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	3.300E-01	4.000E-01	---	TPCZ
R013	Contaminated zone field capacity	2.400E-01	2.000E-01	---	FCCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	5.000E+03	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	4.900E+00	5.300E+00	---	BCZ
R013	Average annual wind speed (m/sec)	6.230E+00	2.000E+00	---	WIND
R013	Humidity in air (g/m**3)	not used	8.000E+00	---	HUMID
R013	Evapotranspiration coefficient	4.600E-01	5.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	1.230E+00	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	2.600E-01	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	1.000E+06	1.000E+06	---	WAREA
R013	Accuracy for water/soil computations	1.000E-03	1.000E-03	---	EPS
R014	Density of saturated zone (g/cm**3)	1.660E+00	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	3.300E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	2.400E-01	2.000E-01	---	EPSZ
R014	Saturated zone field capacity	2.000E-01	2.000E-01	---	FCSZ
R014	Saturated zone hydraulic conductivity (m/yr)	2.000E+04	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	4.800E-03	2.000E-02	---	HGWT
R014	Saturated zone b parameter	4.900E+00	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	1.000E-03	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	1.800E+01	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	---	MODEL

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R014	Well pumping rate (m**3/yr)	2.500E+02	2.500E+02	---	UW
R015	Number of unsaturated zone strata	1	1	---	NS
R015	Unsat. zone 1, thickness (m)	0.000E+00	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	1.660E+00	1.500E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	3.300E-01	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	2.400E-01	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, field capacity	2.000E-01	2.000E-01	---	FCUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	4.900E+00	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	5.000E+03	1.000E+01	---	HCUZ(1)
R016	Distribution coefficients for Cs-137				
R016	Contaminated zone (cm**3/g)	2.800E+02	4.600E+03	---	DCNUCC(1)
R016	Unsaturated zone 1 (cm**3/g)	2.800E+02	4.600E+03	---	DCNUCU(1,1)
R016	Saturated zone (cm**3/g)	2.800E+02	4.600E+03	---	DCNUCS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.889E-04	ALEACH(1)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)
R016	Distribution coefficients for Ra-226				
R016	Contaminated zone (cm**3/g)	5.000E+02	7.000E+01	---	DCNUCC(3)
R016	Unsaturated zone 1 (cm**3/g)	5.000E+02	7.000E+01	---	DCNUCU(3,1)
R016	Saturated zone (cm**3/g)	5.000E+02	7.000E+01	---	DCNUCS(3)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.618E-04	ALEACH(3)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(3)
R016	Distribution coefficients for daughter Pb-210				
R016	Contaminated zone (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCC(2)
R016	Unsaturated zone 1 (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCU(2,1)
R016	Saturated zone (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCS(2)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	8.082E-04	ALEACH(2)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(2)
R017	Inhalation rate (m**3/yr)	7.300E+03	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	1.000E-04	1.000E-04	---	MLINH
R017	Exposure duration	3.000E+01	3.000E+01	---	ED
R017	Shielding factor, inhalation	4.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	8.000E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	5.000E-01	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	2.500E-01	2.500E-01	---	FOTD
R017	Shape factor flag, external gamma	1.000E+00	1.000E+00	>0 shows circular AREA.	FS

Summary : HFBR Outside Areas-Residential- NO-Bkg-Subtract
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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R017	Radii of shape factor array (used if FS = -1):				
R017	Outer annular radius (m), ring 1:	not used	5.000E+01	---	RAD_SHAPE(1)
R017	Outer annular radius (m), ring 2:	not used	7.071E+01	---	RAD_SHAPE(2)
R017	Outer annular radius (m), ring 3:	not used	0.000E+00	---	RAD_SHAPE(3)
R017	Outer annular radius (m), ring 4:	not used	0.000E+00	---	RAD_SHAPE(4)
R017	Outer annular radius (m), ring 5:	not used	0.000E+00	---	RAD_SHAPE(5)
R017	Outer annular radius (m), ring 6:	not used	0.000E+00	---	RAD_SHAPE(6)
R017	Outer annular radius (m), ring 7:	not used	0.000E+00	---	RAD_SHAPE(7)
R017	Outer annular radius (m), ring 8:	not used	0.000E+00	---	RAD_SHAPE(8)
R017	Outer annular radius (m), ring 9:	not used	0.000E+00	---	RAD_SHAPE(9)
R017	Outer annular radius (m), ring 10:	not used	0.000E+00	---	RAD_SHAPE(10)
R017	Outer annular radius (m), ring 11:	not used	0.000E+00	---	RAD_SHAPE(11)
R017	Outer annular radius (m), ring 12:	not used	0.000E+00	---	RAD_SHAPE(12)
R017	Fractions of annular areas within AREA:				
R017	Ring 1	not used	1.000E+00	---	FRACA(1)
R017	Ring 2	not used	2.732E-01	---	FRACA(2)
R017	Ring 3	not used	0.000E+00	---	FRACA(3)
R017	Ring 4	not used	0.000E+00	---	FRACA(4)
R017	Ring 5	not used	0.000E+00	---	FRACA(5)
R017	Ring 6	not used	0.000E+00	---	FRACA(6)
R017	Ring 7	not used	0.000E+00	---	FRACA(7)
R017	Ring 8	not used	0.000E+00	---	FRACA(8)
R017	Ring 9	not used	0.000E+00	---	FRACA(9)
R017	Ring 10	not used	0.000E+00	---	FRACA(10)
R017	Ring 11	not used	0.000E+00	---	FRACA(11)
R017	Ring 12	not used	0.000E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	1.600E+02	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	1.400E+01	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	not used	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	not used	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	not used	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	not used	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	4.380E+01	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	7.000E+02	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	1.000E+00	1.000E+00	---	FDW
R018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	not used	1.000E+00	---	FLW
R018	Contamination fraction of irrigation water	1.000E+00	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	not used	5.000E-01	---	FR9
R018	Contamination fraction of plant food	-1	-1	0.500E+00	FPLANT
R018	Contamination fraction of meat	not used	-1	---	FMEAT
R018	Contamination fraction of milk	not used	-1	---	FMILK
R019	Livestock fodder intake for meat (kg/day)	not used	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	not used	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	not used	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	not used	1.600E+02	---	LWI6
R019	Livestock soil intake (kg/day)	not used	5.000E-01	---	LSI

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R019	Mass loading for foliar deposition (g/m**3)	1.000E-05	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	9.000E-01	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	not used	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	1.000E+00	1.000E+00	---	FGWIR
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	7.000E-01	7.000E-01	---	YV(1)
R19B	Wet weight crop yield for Leafy (kg/m**2)	1.500E+00	1.500E+00	---	YV(2)
R19B	Wet weight crop yield for Fodder (kg/m**2)	not used	1.100E+00	---	YV(3)
R19B	Growing Season for Non-Leafy (years)	1.700E-01	1.700E-01	---	TE(1)
R19B	Growing Season for Leafy (years)	2.500E-01	2.500E-01	---	TE(2)
R19B	Growing Season for Fodder (years)	not used	8.000E-02	---	TE(3)
R19B	Translocation Factor for Non-Leafy	1.000E-01	1.000E-01	---	TIV(1)
R19B	Translocation Factor for Leafy	1.000E+00	1.000E+00	---	TIV(2)
R19B	Translocation Factor for Fodder	not used	1.000E+00	---	TIV(3)
R19B	Dry Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	---	RDRY(1)
R19B	Dry Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	---	RDRY(2)
R19B	Dry Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RDRY(3)
R19B	Wet Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	---	RWET(1)
R19B	Wet Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	---	RWET(2)
R19B	Wet Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RWET(3)
R19B	Weathering Removal Constant for Vegetation	2.000E+01	2.000E+01	---	WLAM
C14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	---	C12WTR
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	C12CZ
C14	Fraction of vegetation carbon from soil	not used	2.000E-02	---	CSOIL
C14	Fraction of vegetation carbon from air	not used	9.800E-01	---	CAIR
C14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	---	DMC
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	---	EVSN
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	---	REVSN
C14	Fraction of grain in beef cattle feed	not used	8.000E-01	---	AVFG4
C14	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5
STOR	Storage times of contaminated foodstuffs (days):				
STOR	Fruits, non-leafy vegetables, and grain	1.400E+01	1.400E+01	---	STOR_T(1)
STOR	Leafy vegetables	1.000E+00	1.000E+00	---	STOR_T(2)
STOR	Milk	1.000E+00	1.000E+00	---	STOR_T(3)
STOR	Meat and poultry	2.000E+01	2.000E+01	---	STOR_T(4)
STOR	Fish	7.000E+00	7.000E+00	---	STOR_T(5)
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	---	STOR_T(6)
STOR	Well water	1.000E+00	1.000E+00	---	STOR_T(7)
STOR	Surface water	1.000E+00	1.000E+00	---	STOR_T(8)
STOR	Livestock fodder	4.500E+01	4.500E+01	---	STOR_T(9)
R021	Thickness of building foundation (m)	not used	1.500E-01	---	FLOOR1
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	---	DENSFL
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	not used	1.000E-01	---	TPFL

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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R021	Volumetric water content of the cover material	not used	5.000E-02	---	PH2OCV
R021	Volumetric water content of the foundation	not used	3.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.000E-06	---	DIFCV
R021	in foundation material	not used	3.000E-07	---	DIFFL
R021	in contaminated zone soil	not used	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	not used	2.000E+00	---	HMIX
R021	Average building air exchange rate (1/hr)	not used	5.000E-01	---	REXG
R021	Height of the building (room) (m)	not used	2.500E+00	---	HRM
R021	Building interior area factor	not used	0.000E+00	---	FAI
R021	Building depth below ground surface (m)	not used	-1.000E+00	---	DMFL
R021	Emanating power of Rn-222 gas	not used	2.500E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	not used	1.500E-01	---	EMANA(2)
TITL	Number of graphical time points	32	---	---	NPTS
TITL	Maximum number of integration points for dose	17	---	---	LYMAX
TITL	Maximum number of integration points for risk	257	---	---	KYMAX

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	active
2 -- inhalation (w/o radon)	active
3 -- plant ingestion	active
4 -- meat ingestion	suppressed
5 -- milk ingestion	suppressed
6 -- aquatic foods	suppressed
7 -- drinking water	active
8 -- soil ingestion	active
9 -- radon	suppressed
Find peak pathway doses	active

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Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	32000.00 square meters	Cs-137	2.400E-01
Thickness:	5.00 meters	Ra-226	4.700E-01
Cover Depth:	0.00 meters		

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 1.500E+01 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	5.000E+00	1.000E+01	5.000E+01	1.000E+02	5.000E+02	1.000E+03
TDOSE(t):	6.040E+00	6.119E+00	6.404E+00	6.712E+00	7.924E+00	8.129E+00	6.552E+00	4.930E+00
M(t):	4.027E-01	4.079E-01	4.269E-01	4.474E-01	5.283E-01	5.419E-01	4.368E-01	3.287E-01

Maximum TDOSE(t): 8.134E+00 mrem/yr at t = 91.5 ± 0.2 years

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 9.152E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	5.884E-02	0.0072	2.128E-08	0.0000	0.000E+00	0.0000	4.851E-03	0.0006	0.000E+00	0.0000	0.000E+00	0.0000	4.579E-05	0.0000
Ra-226	3.090E+00	0.3799	3.230E-04	0.0000	0.000E+00	0.0000	4.695E+00	0.5773	0.000E+00	0.0000	0.000E+00	0.0000	1.190E-01	0.0146
Total	3.149E+00	0.3871	3.230E-04	0.0000	0.000E+00	0.0000	4.700E+00	0.5778	0.000E+00	0.0000	0.000E+00	0.0000	1.191E-01	0.0146

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 9.152E+01 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	1.783E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.311E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.376E-02	0.0078
Ra-226	1.542E-01	0.0190	0.000E+00	0.0000	0.000E+00	0.0000	1.125E-02	0.0014	0.000E+00	0.0000	0.000E+00	0.0000	8.070E+00	0.9922
Total	1.543E-01	0.0190	0.000E+00	0.0000	0.000E+00	0.0000	1.125E-02	0.0014	0.000E+00	0.0000	0.000E+00	0.0000	8.134E+00	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Residential- NO-Bkg-Subtract
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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	5.007E-01	0.0829	1.811E-07	0.0000	0.000E+00	0.0000	4.128E-02	0.0068	0.000E+00	0.0000	0.000E+00	0.0000	3.896E-04	0.0001
Ra-226	3.261E+00	0.5400	1.006E-04	0.0000	0.000E+00	0.0000	2.214E+00	0.3666	0.000E+00	0.0000	0.000E+00	0.0000	2.212E-02	0.0037
Total	3.762E+00	0.6229	1.008E-04	0.0000	0.000E+00	0.0000	2.255E+00	0.3734	0.000E+00	0.0000	0.000E+00	0.0000	2.250E-02	0.0037

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	8.011E-07	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.321E-08	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.424E-01	0.0898
Ra-226	3.390E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.174E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.498E+00	0.9102
Total	3.470E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.227E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.040E+00	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Residential- NO-Bkg-Subtract
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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	4.891E-01	0.0799	1.769E-07	0.0000	0.000E+00	0.0000	4.032E-02	0.0066	0.000E+00	0.0000	0.000E+00	0.0000	3.806E-04	0.0001
Ra-226	3.259E+00	0.5327	1.084E-04	0.0000	0.000E+00	0.0000	2.304E+00	0.3765	0.000E+00	0.0000	0.000E+00	0.0000	2.548E-02	0.0042
Total	3.749E+00	0.6126	1.086E-04	0.0000	0.000E+00	0.0000	2.344E+00	0.3831	0.000E+00	0.0000	0.000E+00	0.0000	2.586E-02	0.0042

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	2.368E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.677E-07	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.298E-01	0.0866
Ra-226	2.244E-04	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.560E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.589E+00	0.9134
Total	2.268E-04	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.577E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.119E+00	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Residential- NO-Bkg-Subtract
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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	4.454E-01	0.0696	1.611E-07	0.0000	0.000E+00	0.0000	3.672E-02	0.0057	0.000E+00	0.0000	0.000E+00	0.0000	3.466E-04	0.0001
Ra-226	3.252E+00	0.5078	1.372E-04	0.0000	0.000E+00	0.0000	2.629E+00	0.4105	0.000E+00	0.0000	0.000E+00	0.0000	3.791E-02	0.0059
Total	3.697E+00	0.5773	1.373E-04	0.0000	0.000E+00	0.0000	2.666E+00	0.4162	0.000E+00	0.0000	0.000E+00	0.0000	3.826E-02	0.0060

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	7.941E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.782E-07	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.825E-01	0.0753
Ra-226	2.631E-03	0.0004	0.000E+00	0.0000	0.000E+00	0.0000	1.896E-04	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.922E+00	0.9247
Total	2.639E-03	0.0004	0.000E+00	0.0000	0.000E+00	0.0000	1.902E-04	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.404E+00	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Residential- NO-Bkg-Subtract
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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	3.963E-01	0.0590	1.433E-07	0.0000	0.000E+00	0.0000	3.267E-02	0.0049	0.000E+00	0.0000	0.000E+00	0.0000	3.084E-04	0.0000
Ra-226	3.242E+00	0.4831	1.681E-04	0.0000	0.000E+00	0.0000	2.979E+00	0.4439	0.000E+00	0.0000	0.000E+00	0.0000	5.132E-02	0.0076
Total	3.639E+00	0.5421	1.683E-04	0.0000	0.000E+00	0.0000	3.012E+00	0.4488	0.000E+00	0.0000	0.000E+00	0.0000	5.163E-02	0.0077

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	1.351E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.883E-07	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.292E-01	0.0640
Ra-226	8.605E-03	0.0013	0.000E+00	0.0000	0.000E+00	0.0000	6.239E-04	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	6.282E+00	0.9360
Total	8.618E-03	0.0013	0.000E+00	0.0000	0.000E+00	0.0000	6.249E-04	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	6.712E+00	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Residential- NO-Bkg-Subtract
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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	1.554E-01	0.0196	5.621E-08	0.0000	0.000E+00	0.0000	1.281E-02	0.0016	0.000E+00	0.0000	0.000E+00	0.0000	1.210E-04	0.0000
Ra-226	3.167E+00	0.3997	2.934E-04	0.0000	0.000E+00	0.0000	4.383E+00	0.5532	0.000E+00	0.0000	0.000E+00	0.0000	1.058E-01	0.0133
Total	3.323E+00	0.4193	2.935E-04	0.0000	0.000E+00	0.0000	4.396E+00	0.5548	0.000E+00	0.0000	0.000E+00	0.0000	1.059E-01	0.0134

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	2.567E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.886E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.684E-01	0.0213
Ra-226	9.227E-02	0.0116	0.000E+00	0.0000	0.000E+00	0.0000	6.724E-03	0.0008	0.000E+00	0.0000	0.000E+00	0.0000	7.755E+00	0.9787
Total	9.229E-02	0.0116	0.000E+00	0.0000	0.000E+00	0.0000	6.726E-03	0.0008	0.000E+00	0.0000	0.000E+00	0.0000	7.924E+00	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Residential- NO-Bkg-Subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-RES-NO-BKG-SUBTRACT.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	4.826E-02	0.0059	1.745E-08	0.0000	0.000E+00	0.0000	3.978E-03	0.0005	0.000E+00	0.0000	0.000E+00	0.0000	3.755E-05	0.0000
Ra-226	3.075E+00	0.3782	3.246E-04	0.0000	0.000E+00	0.0000	4.708E+00	0.5792	0.000E+00	0.0000	0.000E+00	0.0000	1.198E-01	0.0147
Total	3.123E+00	0.3842	3.246E-04	0.0000	0.000E+00	0.0000	4.712E+00	0.5797	0.000E+00	0.0000	0.000E+00	0.0000	1.198E-01	0.0147

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	1.599E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.176E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.229E-02	0.0064
Ra-226	1.621E-01	0.0199	0.000E+00	0.0000	0.000E+00	0.0000	1.182E-02	0.0015	0.000E+00	0.0000	0.000E+00	0.0000	8.077E+00	0.9936
Total	1.621E-01	0.0199	0.000E+00	0.0000	0.000E+00	0.0000	1.182E-02	0.0015	0.000E+00	0.0000	0.000E+00	0.0000	8.129E+00	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Residential- NO-Bkg-Subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-RES-NO-BKG-SUBTRACT.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	4.165E-06	0.0000	1.506E-12	0.0000	0.000E+00	0.0000	3.434E-07	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.241E-09	0.0000
Ra-226	2.423E+00	0.3699	2.641E-04	0.0000	0.000E+00	0.0000	3.805E+00	0.5808	0.000E+00	0.0000	0.000E+00	0.0000	9.798E-02	0.0150
Total	2.423E+00	0.3699	2.641E-04	0.0000	0.000E+00	0.0000	3.805E+00	0.5808	0.000E+00	0.0000	0.000E+00	0.0000	9.798E-02	0.0150

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	7.353E-09	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.409E-10	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.520E-06	0.0000
Ra-226	2.099E-01	0.0320	0.000E+00	0.0000	0.000E+00	0.0000	1.531E-02	0.0023	0.000E+00	0.0000	0.000E+00	0.0000	6.552E+00	1.0000
Total	2.099E-01	0.0320	0.000E+00	0.0000	0.000E+00	0.0000	1.531E-02	0.0023	0.000E+00	0.0000	0.000E+00	0.0000	6.552E+00	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Residential- NO-Bkg-Subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-RES-NO-BKG-SUBTRACT.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	3.465E-11	0.0000	1.253E-17	0.0000	0.000E+00	0.0000	2.857E-12	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.697E-14	0.0000
Ra-226	1.800E+00	0.3651	1.961E-04	0.0000	0.000E+00	0.0000	2.826E+00	0.5733	0.000E+00	0.0000	0.000E+00	0.0000	7.277E-02	0.0148
Total	1.800E+00	0.3651	1.961E-04	0.0000	0.000E+00	0.0000	2.826E+00	0.5733	0.000E+00	0.0000	0.000E+00	0.0000	7.277E-02	0.0148

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	1.331E-13	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.789E-15	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.768E-11	0.0000
Ra-226	2.154E-01	0.0437	0.000E+00	0.0000	0.000E+00	0.0000	1.571E-02	0.0032	0.000E+00	0.0000	0.000E+00	0.0000	4.930E+00	1.0000
Total	2.154E-01	0.0437	0.000E+00	0.0000	0.000E+00	0.0000	1.571E-02	0.0032	0.000E+00	0.0000	0.000E+00	0.0000	4.930E+00	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Residential- NO-Bkg-Subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-RES-NO-BKG-SUBTRACT.RAD

Dose/Source Ratios Summed Over All Pathways
Parent and Progeny Principal Radionuclide Contributions Indicated

Parent (i)	Product (j)	Thread Fraction	DSR(j,t) At Time in Years (mrem/yr)/(pCi/g) 0.000E+00	1.000E+00	5.000E+00	1.000E+01	5.000E+01	1.000E+02	5.000E+02	1.000E+03
Cs-137+D	Cs-137+D	1.000E+00	2.260E+00	2.208E+00	2.010E+00	1.788E+00	7.017E-01	2.179E-01	1.883E-05	1.570E-10
Ra-226+D	Ra-226+D	1.000E+00	1.158E+01	1.157E+01	1.154E+01	1.151E+01	1.124E+01	1.091E+01	8.603E+00	6.394E+00
Ra-226+D	Pb-210+D	1.000E+00	1.190E-01	3.203E-01	1.056E+00	1.857E+00	5.262E+00	6.274E+00	5.337E+00	4.095E+00
Ra-226+D	∑DSR(j)		1.170E+01	1.189E+01	1.260E+01	1.337E+01	1.650E+01	1.718E+01	1.394E+01	1.049E+01

The DSR includes contributions from associated (half-life ≤ 180 days) daughters.

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 1.500E+01 mrem/yr

Nuclide (i)	t= 0.000E+00	1.000E+00	5.000E+00	1.000E+01	5.000E+01	1.000E+02	5.000E+02	1.000E+03
Cs-137	6.638E+00	6.795E+00	7.461E+00	8.387E+00	2.138E+01	6.884E+01	7.965E+05	9.554E+10
Ra-226	1.282E+00	1.261E+00	1.191E+00	1.122E+00	9.090E-01	8.729E-01	1.076E+00	1.430E+00

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
at tmin = time of minimum single radionuclide soil guideline
and at tmax = time of maximum total dose = 91.5 ± 0.2 years

Nuclide (i)	Initial (pCi/g)	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Cs-137	2.400E-01	0.000E+00	2.260E+00	6.638E+00	2.657E-01	5.646E+01
Ra-226	4.700E-01	100.7 ± 0.2	1.718E+01	8.729E-01	1.717E+01	8.736E-01

Summary : HFBR Outside Areas-Residential- NO-Bkg-Subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-RES-NO-BKG-SUBTRACT.RAD

Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

Nuclide	Parent	THF(i)	DOSE(j,t), mrem/yr							
(j)	(i)	t=	0.000E+00	1.000E+00	5.000E+00	1.000E+01	5.000E+01	1.000E+02	5.000E+02	1.000E+03
Cs-137	Cs-137	1.000E+00	5.424E-01	5.298E-01	4.825E-01	4.292E-01	1.684E-01	5.229E-02	4.520E-06	3.768E-11
Ra-226	Ra-226	1.000E+00	5.442E+00	5.438E+00	5.425E+00	5.409E+00	5.282E+00	5.128E+00	4.044E+00	3.005E+00
Pb-210	Ra-226	1.000E+00	5.593E-02	1.505E-01	4.962E-01	8.730E-01	2.473E+00	2.949E+00	2.509E+00	1.925E+00

THF(i) is the thread fraction of the parent nuclide.

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide	Parent	THF(i)	S(j,t), pCi/g							
(j)	(i)	t=	0.000E+00	1.000E+00	5.000E+00	1.000E+01	5.000E+01	1.000E+02	5.000E+02	1.000E+03
Cs-137	Cs-137	1.000E+00	2.400E-01	2.345E-01	2.135E-01	1.899E-01	7.451E-02	2.313E-02	1.997E-06	1.661E-11
Ra-226	Ra-226	1.000E+00	4.700E-01	4.697E-01	4.686E-01	4.672E-01	4.562E-01	4.428E-01	3.490E-01	2.592E-01
Pb-210	Ra-226	1.000E+00	0.000E+00	1.437E-02	6.742E-02	1.247E-01	3.584E-01	4.206E-01	3.467E-01	2.575E-01

THF(i) is the thread fraction of the parent nuclide.

RESCALC.EXE execution time = 0.58 seconds

Summary : HFBR Outside Areas-Industrial-NO Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-NO-BKG-SUBTRACT.RAD

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Part I: Mixture Sums and Single Radionuclide Guidelines

Summary : HFBR Outside Areas-Industrial-NO Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-NO-BKG-SUBTRACT.RAD

Dose Conversion Factor (and Related) Parameter Summary
Dose Library: FGR 12 & FGR 11

Menu	Parameter	Current Value#	Base Case*	Parameter Name
A-1	DCF's for external ground radiation, (mrem/yr)/(pCi/g)			
A-1	At-218 (Source: FGR 12)	5.847E-03	5.847E-03	DCF1(1)
A-1	Ba-137m (Source: FGR 12)	3.606E+00	3.606E+00	DCF1(2)
A-1	Bi-210 (Source: FGR 12)	3.606E-03	3.606E-03	DCF1(3)
A-1	Bi-214 (Source: FGR 12)	9.808E+00	9.808E+00	DCF1(4)
A-1	Cs-137 (Source: FGR 12)	7.510E-04	7.510E-04	DCF1(5)
A-1	Pb-210 (Source: FGR 12)	2.447E-03	2.447E-03	DCF1(6)
A-1	Pb-214 (Source: FGR 12)	1.341E+00	1.341E+00	DCF1(7)
A-1	Po-210 (Source: FGR 12)	5.231E-05	5.231E-05	DCF1(8)
A-1	Po-214 (Source: FGR 12)	5.138E-04	5.138E-04	DCF1(9)
A-1	Po-218 (Source: FGR 12)	5.642E-05	5.642E-05	DCF1(10)
A-1	Ra-226 (Source: FGR 12)	3.176E-02	3.176E-02	DCF1(11)
A-1	Rn-222 (Source: FGR 12)	2.354E-03	2.354E-03	DCF1(12)
A-1	Tl-210 (Source: no data)	0.000E+00	-2.000E+00	DCF1(13)
B-1	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Cs-137+D	3.190E-05	3.190E-05	DCF2(1)
B-1	Pb-210+D	2.320E-02	1.360E-02	DCF2(2)
B-1	Ra-226+D	8.594E-03	8.580E-03	DCF2(3)
D-1	Dose conversion factors for ingestion, mrem/pCi:			
D-1	Cs-137+D	5.000E-05	5.000E-05	DCF3(1)
D-1	Pb-210+D	7.276E-03	5.370E-03	DCF3(2)
D-1	Ra-226+D	1.321E-03	1.320E-03	DCF3(3)
D-34	Food transfer factors:			
D-34	Cs-137+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(1,1)
D-34	Cs-137+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.000E-02	3.000E-02	RTF(1,2)
D-34	Cs-137+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	8.000E-03	8.000E-03	RTF(1,3)
D-34	Pb-210+D , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF(2,1)
D-34	Pb-210+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	8.000E-04	8.000E-04	RTF(2,2)
D-34	Pb-210+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	3.000E-04	3.000E-04	RTF(2,3)
D-34	Ra-226+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(3,1)
D-34	Ra-226+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(3,2)
D-34	Ra-226+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(3,3)
D-5	Bioaccumulation factors, fresh water, L/kg:			
D-5	Cs-137+D , fish	2.000E+03	2.000E+03	BIOFAC(1,1)
D-5	Cs-137+D , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(1,2)
D-5	Pb-210+D , fish	3.000E+02	3.000E+02	BIOFAC(2,1)
D-5	Pb-210+D , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(2,2)
D-5	Ra-226+D , fish	5.000E+01	5.000E+01	BIOFAC(3,1)
D-5	Ra-226+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(3,2)

#For DCF1(xxx) only, factors are for infinite depth & area. See ETFG table in Ground Pathway of Detailed Report.
*Base Case means Default.Lib w/o Associate Nuclide contributions.

Summary : HFBR Outside Areas-Industrial-NO Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-NO-BKG-SUBTRACT.RAD

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	3.200E+04	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	5.000E+00	2.000E+00	---	THICK0
R011	Fraction of contamination that is submerged	0.000E+00	0.000E+00	---	SUBMFRACT
R011	Length parallel to aquifer flow (m)	2.500E+02	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	1.500E+01	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	5.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	5.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	5.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Cs-137	2.400E-01	0.000E+00	---	S1(1)
R012	Initial principal radionuclide (pCi/g): Ra-226	4.700E-01	0.000E+00	---	S1(3)
R012	Concentration in groundwater (pCi/L): Cs-137	not used	0.000E+00	---	W1(1)
R012	Concentration in groundwater (pCi/L): Ra-226	not used	0.000E+00	---	W1(3)
R013	Cover depth (m)	0.000E+00	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.500E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.660E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	3.300E-01	4.000E-01	---	TPCZ
R013	Contaminated zone field capacity	2.400E-01	2.000E-01	---	FCCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	5.000E+03	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	4.900E+00	5.300E+00	---	BCZ
R013	Average annual wind speed (m/sec)	6.230E+00	2.000E+00	---	WIND
R013	Humidity in air (g/m**3)	not used	8.000E+00	---	HUMID
R013	Evapotranspiration coefficient	4.600E-01	5.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	1.230E+00	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	2.600E-01	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	1.000E+06	1.000E+06	---	WAREA
R013	Accuracy for water/soil computations	1.000E-03	1.000E-03	---	EPS
R014	Density of saturated zone (g/cm**3)	1.660E+00	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	3.300E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	2.400E-01	2.000E-01	---	EPSZ
R014	Saturated zone field capacity	2.000E-01	2.000E-01	---	FCSZ
R014	Saturated zone hydraulic conductivity (m/yr)	2.000E+04	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	4.800E-03	2.000E-02	---	HGWT
R014	Saturated zone b parameter	4.900E+00	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	1.000E-03	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	1.800E+01	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	---	MODEL

Summary : HFBR Outside Areas-Industrial-NO Bkg subtract
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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R014	Well pumping rate (m**3/yr)	not used	2.500E+02	---	UW
R015	Number of unsaturated zone strata	1	1	---	NS
R015	Unsat. zone 1, thickness (m)	0.000E+00	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	1.660E+00	1.500E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	3.300E-01	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	2.400E-01	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, field capacity	2.000E-01	2.000E-01	---	FCUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	4.900E+00	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	5.000E+03	1.000E+01	---	HCUZ(1)
R016	Distribution coefficients for Cs-137				
R016	Contaminated zone (cm**3/g)	2.800E+02	4.600E+03	---	DCNUCC(1)
R016	Unsaturated zone 1 (cm**3/g)	2.800E+02	4.600E+03	---	DCNUCU(1,1)
R016	Saturated zone (cm**3/g)	2.800E+02	4.600E+03	---	DCNUCS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.889E-04	ALEACH(1)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)
R016	Distribution coefficients for Ra-226				
R016	Contaminated zone (cm**3/g)	5.000E+02	7.000E+01	---	DCNUCC(3)
R016	Unsaturated zone 1 (cm**3/g)	5.000E+02	7.000E+01	---	DCNUCU(3,1)
R016	Saturated zone (cm**3/g)	5.000E+02	7.000E+01	---	DCNUCS(3)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.618E-04	ALEACH(3)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(3)
R016	Distribution coefficients for daughter Pb-210				
R016	Contaminated zone (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCC(2)
R016	Unsaturated zone 1 (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCU(2,1)
R016	Saturated zone (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCS(2)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	8.082E-04	ALEACH(2)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(2)
R017	Inhalation rate (m**3/yr)	7.300E+03	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	1.000E-04	1.000E-04	---	MLINH
R017	Exposure duration	2.500E+01	3.000E+01	---	ED
R017	Shielding factor, inhalation	4.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	8.000E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	1.700E-01	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	6.000E-02	2.500E-01	---	FOTD
R017	Shape factor flag, external gamma	1.000E+00	1.000E+00	>0 shows circular AREA.	FS

Summary : HFBR Outside Areas-Industrial-NO Bkg subtract
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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R017	Radii of shape factor array (used if FS = -1):				
R017	Outer annular radius (m), ring 1:	not used	5.000E+01	---	RAD_SHAPE(1)
R017	Outer annular radius (m), ring 2:	not used	7.071E+01	---	RAD_SHAPE(2)
R017	Outer annular radius (m), ring 3:	not used	0.000E+00	---	RAD_SHAPE(3)
R017	Outer annular radius (m), ring 4:	not used	0.000E+00	---	RAD_SHAPE(4)
R017	Outer annular radius (m), ring 5:	not used	0.000E+00	---	RAD_SHAPE(5)
R017	Outer annular radius (m), ring 6:	not used	0.000E+00	---	RAD_SHAPE(6)
R017	Outer annular radius (m), ring 7:	not used	0.000E+00	---	RAD_SHAPE(7)
R017	Outer annular radius (m), ring 8:	not used	0.000E+00	---	RAD_SHAPE(8)
R017	Outer annular radius (m), ring 9:	not used	0.000E+00	---	RAD_SHAPE(9)
R017	Outer annular radius (m), ring 10:	not used	0.000E+00	---	RAD_SHAPE(10)
R017	Outer annular radius (m), ring 11:	not used	0.000E+00	---	RAD_SHAPE(11)
R017	Outer annular radius (m), ring 12:	not used	0.000E+00	---	RAD_SHAPE(12)
R017	Fractions of annular areas within AREA:				
R017	Ring 1	not used	1.000E+00	---	FRACA(1)
R017	Ring 2	not used	2.732E-01	---	FRACA(2)
R017	Ring 3	not used	0.000E+00	---	FRACA(3)
R017	Ring 4	not used	0.000E+00	---	FRACA(4)
R017	Ring 5	not used	0.000E+00	---	FRACA(5)
R017	Ring 6	not used	0.000E+00	---	FRACA(6)
R017	Ring 7	not used	0.000E+00	---	FRACA(7)
R017	Ring 8	not used	0.000E+00	---	FRACA(8)
R017	Ring 9	not used	0.000E+00	---	FRACA(9)
R017	Ring 10	not used	0.000E+00	---	FRACA(10)
R017	Ring 11	not used	0.000E+00	---	FRACA(11)
R017	Ring 12	not used	0.000E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	not used	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	not used	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	not used	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	not used	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	not used	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	not used	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	3.650E+01	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	3.500E+02	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	1.000E+00	1.000E+00	---	FDW
R018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	not used	1.000E+00	---	FLW
R018	Contamination fraction of irrigation water	not used	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	not used	5.000E-01	---	FR9
R018	Contamination fraction of plant food	not used	-1	---	FPLANT
R018	Contamination fraction of meat	not used	-1	---	FMEAT
R018	Contamination fraction of milk	not used	-1	---	FMILK
R019	Livestock fodder intake for meat (kg/day)	not used	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	not used	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	not used	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	not used	1.600E+02	---	LWI6
R019	Livestock soil intake (kg/day)	not used	5.000E-01	---	LSI

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R019	Mass loading for foliar deposition (g/m**3)	not used	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	not used	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	not used	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	not used	1.000E+00	---	FGWIR
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	not used	7.000E-01	---	YV(1)
R19B	Wet weight crop yield for Leafy (kg/m**2)	not used	1.500E+00	---	YV(2)
R19B	Wet weight crop yield for Fodder (kg/m**2)	not used	1.100E+00	---	YV(3)
R19B	Growing Season for Non-Leafy (years)	not used	1.700E-01	---	TE(1)
R19B	Growing Season for Leafy (years)	not used	2.500E-01	---	TE(2)
R19B	Growing Season for Fodder (years)	not used	8.000E-02	---	TE(3)
R19B	Translocation Factor for Non-Leafy	not used	1.000E-01	---	TIV(1)
R19B	Translocation Factor for Leafy	not used	1.000E+00	---	TIV(2)
R19B	Translocation Factor for Fodder	not used	1.000E+00	---	TIV(3)
R19B	Dry Foliar Interception Fraction for Non-Leafy	not used	2.500E-01	---	RDRY(1)
R19B	Dry Foliar Interception Fraction for Leafy	not used	2.500E-01	---	RDRY(2)
R19B	Dry Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RDRY(3)
R19B	Wet Foliar Interception Fraction for Non-Leafy	not used	2.500E-01	---	RWET(1)
R19B	Wet Foliar Interception Fraction for Leafy	not used	2.500E-01	---	RWET(2)
R19B	Wet Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RWET(3)
R19B	Weathering Removal Constant for Vegetation	not used	2.000E+01	---	WLAM
C14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	---	C12WTR
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	C12CZ
C14	Fraction of vegetation carbon from soil	not used	2.000E-02	---	CSOIL
C14	Fraction of vegetation carbon from air	not used	9.800E-01	---	CAIR
C14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	---	DMC
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	---	EVSN
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	---	REVSN
C14	Fraction of grain in beef cattle feed	not used	8.000E-01	---	AVFG4
C14	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5
STOR	Storage times of contaminated foodstuffs (days):				
STOR	Fruits, non-leafy vegetables, and grain	1.400E+01	1.400E+01	---	STOR_T(1)
STOR	Leafy vegetables	1.000E+00	1.000E+00	---	STOR_T(2)
STOR	Milk	1.000E+00	1.000E+00	---	STOR_T(3)
STOR	Meat and poultry	2.000E+01	2.000E+01	---	STOR_T(4)
STOR	Fish	7.000E+00	7.000E+00	---	STOR_T(5)
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	---	STOR_T(6)
STOR	Well water	1.000E+00	1.000E+00	---	STOR_T(7)
STOR	Surface water	1.000E+00	1.000E+00	---	STOR_T(8)
STOR	Livestock fodder	4.500E+01	4.500E+01	---	STOR_T(9)
R021	Thickness of building foundation (m)	not used	1.500E-01	---	FLOOR1
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	---	DENSFL
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	not used	1.000E-01	---	TPFL

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R021	Volumetric water content of the cover material	not used	5.000E-02	---	PH2OCV
R021	Volumetric water content of the foundation	not used	3.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.000E-06	---	DIFCV
R021	in foundation material	not used	3.000E-07	---	DIFFL
R021	in contaminated zone soil	not used	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	not used	2.000E+00	---	HMIX
R021	Average building air exchange rate (1/hr)	not used	5.000E-01	---	REXG
R021	Height of the building (room) (m)	not used	2.500E+00	---	HRM
R021	Building interior area factor	not used	0.000E+00	---	FAI
R021	Building depth below ground surface (m)	not used	-1.000E+00	---	DMFL
R021	Emanating power of Rn-222 gas	not used	2.500E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	not used	1.500E-01	---	EMANA(2)
TITL	Number of graphical time points	32	---	---	NPTS
TITL	Maximum number of integration points for dose	17	---	---	LYMAX
TITL	Maximum number of integration points for risk	257	---	---	KYMAX

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	active
2 -- inhalation (w/o radon)	active
3 -- plant ingestion	suppressed
4 -- meat ingestion	suppressed
5 -- milk ingestion	suppressed
6 -- aquatic foods	suppressed
7 -- drinking water	active
8 -- soil ingestion	active
9 -- radon	suppressed
Find peak pathway doses	active

Summary : HFBR Outside Areas-Industrial-NO Bkg subtract
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Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	32000.00 square meters	Cs-137	2.400E-01
Thickness:	5.00 meters	Ra-226	4.700E-01
Cover Depth:	0.00 meters		

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 1.500E+01 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	5.000E+00	1.000E+01	5.000E+01	1.000E+02	5.000E+02	1.000E+03
TDOSE(t):	1.140E+00	1.137E+00	1.126E+00	1.115E+00	1.075E+00	1.053E+00	8.608E-01	6.690E-01
M(t):	7.601E-02	7.581E-02	7.507E-02	7.432E-02	7.168E-02	7.023E-02	5.739E-02	4.460E-02

Maximum TDOSE(t): 1.140E+00 mrem/yr at t = 0.000E+00 years

Summary : HFBR Outside Areas-Industrial-NO Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-NO-BKG-SUBTRACT.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	1.510E-01	0.1324	5.150E-08	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.957E-05	0.0001
Ra-226	9.834E-01	0.8625	2.862E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.652E-03	0.0050
Total	1.134E+00	0.9949	2.867E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.751E-03	0.0050

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	4.004E-07	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.511E-01	0.1325
Ra-226	1.695E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.891E-01	0.8675
Total	1.735E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.140E+00	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Industrial-NO Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-NO-BKG-SUBTRACT.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	1.475E-01	0.1297	5.031E-08	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.727E-05	0.0001
Ra-226	9.828E-01	0.8644	3.084E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.513E-03	0.0057
Total	1.130E+00	0.9941	3.089E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.610E-03	0.0058

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	1.184E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.476E-01	0.1298
Ra-226	1.122E-04	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.895E-01	0.8702
Total	1.134E-04	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.137E+00	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Industrial-NO Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-NO-BKG-SUBTRACT.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	1.343E-01	0.1193	4.581E-08	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.858E-05	0.0001
Ra-226	9.806E-01	0.8708	3.901E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.688E-03	0.0086
Total	1.115E+00	0.9901	3.906E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.777E-03	0.0087

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	3.970E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.344E-01	0.1194
Ra-226	1.315E-03	0.0012	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.916E-01	0.8806
Total	1.319E-03	0.0012	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.126E+00	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Industrial-NO Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-NO-BKG-SUBTRACT.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	1.195E-01	0.1072	4.076E-08	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.880E-05	0.0001
Ra-226	9.777E-01	0.8771	4.783E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.311E-02	0.0118
Total	1.097E+00	0.9843	4.787E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.319E-02	0.0118

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	6.753E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.196E-01	0.1073
Ra-226	4.302E-03	0.0039	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.952E-01	0.8927
Total	4.309E-03	0.0039	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.115E+00	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Industrial-NO Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-NO-BKG-SUBTRACT.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	4.687E-02	0.0436	1.599E-08	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.091E-05	0.0000
Ra-226	9.550E-01	0.8882	8.346E-05	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.703E-02	0.0251
Total	1.002E+00	0.9318	8.348E-05	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.706E-02	0.0252

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	1.283E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.692E-02	0.0436
Ra-226	4.613E-02	0.0429	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.028E+00	0.9564
Total	4.615E-02	0.0429	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.075E+00	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Industrial-NO Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-NO-BKG-SUBTRACT.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	1.455E-02	0.0138	4.964E-09	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.597E-06	0.0000
Ra-226	9.271E-01	0.8801	9.232E-05	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.061E-02	0.0291
Total	9.416E-01	0.8939	9.232E-05	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.062E-02	0.0291

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	7.997E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.457E-02	0.0138
Ra-226	8.106E-02	0.0769	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.039E+00	0.9862
Total	8.107E-02	0.0770	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.053E+00	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Industrial-NO Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-NO-BKG-SUBTRACT.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	1.256E-06	0.0000	4.285E-13	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.284E-10	0.0000
Ra-226	7.307E-01	0.8489	7.512E-05	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.504E-02	0.0291
Total	7.307E-01	0.8489	7.512E-05	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.504E-02	0.0291

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 5.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	3.677E-09	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.261E-06	0.0000
Ra-226	1.050E-01	0.1219	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.608E-01	1.0000
Total	1.050E-01	0.1219	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.608E-01	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Industrial-NO Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-NO-BKG-SUBTRACT.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	1.045E-11	0.0000	3.565E-18	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.892E-15	0.0000
Ra-226	5.427E-01	0.8111	5.579E-05	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.860E-02	0.0278
Total	5.427E-01	0.8111	5.579E-05	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.860E-02	0.0278

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Cs-137	6.653E-14	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.052E-11	0.0000
Ra-226	1.077E-01	0.1610	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.690E-01	1.0000
Total	1.077E-01	0.1610	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.690E-01	1.0000

*Sum of all water independent and dependent pathways.

Summary : HFBR Outside Areas-Industrial-NO Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-NO-BKG-SUBTRACT.RAD

Dose/Source Ratios Summed Over All Pathways
Parent and Progeny Principal Radionuclide Contributions Indicated

Parent (i)	Product (j)	Thread Fraction	DSR(j,t) At Time in Years (mrem/yr)/(pCi/g) 0.000E+00	1.000E+00	5.000E+00	1.000E+01	5.000E+01	1.000E+02	5.000E+02	1.000E+03
Cs-137+D	Cs-137+D	1.000E+00	6.295E-01	6.149E-01	5.600E-01	4.982E-01	1.955E-01	6.071E-02	5.252E-06	4.385E-11
Ra-226+D	Ra-226+D	1.000E+00	2.103E+00	2.102E+00	2.097E+00	2.091E+00	2.042E+00	1.983E+00	1.564E+00	1.164E+00
Ra-226+D	Pb-210+D	1.000E+00	9.928E-04	3.068E-03	1.253E-02	2.634E-02	1.456E-01	2.278E-01	2.670E-01	2.596E-01
Ra-226+D	∑DSR(j)		2.104E+00	2.105E+00	2.110E+00	2.117E+00	2.188E+00	2.210E+00	1.832E+00	1.423E+00

The DSR includes contributions from associated (half-life ≤ 180 days) daughters.

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 1.500E+01 mrem/yr

Nuclide (i)	t= 0.000E+00	1.000E+00	5.000E+00	1.000E+01	5.000E+01	1.000E+02	5.000E+02	1.000E+03
Cs-137	2.383E+01	2.439E+01	2.679E+01	3.011E+01	7.673E+01	2.471E+02	2.856E+06	3.421E+11
Ra-226	7.128E+00	7.125E+00	7.110E+00	7.084E+00	6.856E+00	6.786E+00	8.190E+00	1.054E+01

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
at tmin = time of minimum single radionuclide soil guideline
and at tmax = time of maximum total dose = 0.000E+00 years

Nuclide (i)	Initial (pCi/g)	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Cs-137	2.400E-01	0.000E+00	6.295E-01	2.383E+01	6.295E-01	2.383E+01
Ra-226	4.700E-01	89.9 ± 0.2	2.212E+00	6.783E+00	2.104E+00	7.128E+00

Summary : HFBR Outside Areas-Industrial-NO Bkg subtract
File : C:\RESRAD_FAMILY\RESRAD\6.5\USERFILES\HFBR-OUTSIDE-AREAS-IND-NO-BKG-SUBTRACT.RAD

Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	THF(i)	DOSE(j,t), mrem/yr							
		t=	0.000E+00	1.000E+00	5.000E+00	1.000E+01	5.000E+01	1.000E+02	5.000E+02	1.000E+03
Cs-137	Cs-137	1.000E+00	1.511E-01	1.476E-01	1.344E-01	1.196E-01	4.692E-02	1.457E-02	1.261E-06	1.052E-11
Ra-226	Ra-226	1.000E+00	9.886E-01	9.881E-01	9.857E-01	9.828E-01	9.598E-01	9.318E-01	7.353E-01	5.470E-01
Pb-210	Ra-226	1.000E+00	4.666E-04	1.442E-03	5.891E-03	1.238E-02	6.845E-02	1.071E-01	1.255E-01	1.220E-01

THF(i) is the thread fraction of the parent nuclide.

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	THF(i)	S(j,t), pCi/g							
		t=	0.000E+00	1.000E+00	5.000E+00	1.000E+01	5.000E+01	1.000E+02	5.000E+02	1.000E+03
Cs-137	Cs-137	1.000E+00	2.400E-01	2.345E-01	2.135E-01	1.899E-01	7.451E-02	2.313E-02	1.997E-06	1.661E-11
Ra-226	Ra-226	1.000E+00	4.700E-01	4.697E-01	4.686E-01	4.672E-01	4.562E-01	4.428E-01	3.490E-01	2.592E-01
Pb-210	Ra-226	1.000E+00	0.000E+00	1.437E-02	6.742E-02	1.247E-01	3.584E-01	4.206E-01	3.467E-01	2.575E-01

THF(i) is the thread fraction of the parent nuclide.

RESCALC.EXE execution time = 0.58 seconds

Appendix D

HFBR Outside Areas
Final ORISE IVS Report

ORISE
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION

December 15, 2010

Ms. Lisa Santoro
U.S. Department of Energy
Brookhaven Site Office
53 Bell Ave., Building 464
Upton, NY 11973

DOE CONTRACT NO. DE-AC05-06OR23100
SUBJECT: FINAL REPORT- INDEPENDENT VERIFICATION SURVEY OF THE HIGH FLUX BEAM REACTOR DECOMMISSIONING PROJECT OUTSIDE AREAS, BROOKHAVEN NATIONAL LABORATORY UPTON, NEW YORK
DCN: 5098-SR-03-0

Dear Ms. Santoro:

The Oak Ridge Institute for Science and Education (ORISE), Independent Environmental Assessment and Verification (IEAV) Program has enclosed the final verification survey report for the "Outside Areas" at the High Flux Beam Reactor decommissioning project at Brookhaven National Laboratory. Should you have any questions please contact me at my information provided below or Evan Harpenau at 865.241.8793.

Sincerely,

Phyllis C. Weaver
Health Physics Project Manager
Independent Environment Assessment
and Verification

PCW:bf

Enclosure

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INDEPENDENT VERIFICATION SURVEY OF THE HIGH FLUX BEAM REACTOR DECOMMISSIONING PROJECT OUTSIDE AREAS BROOKHAVEN NATIONAL LABORATORY UPTON, NEW YORK

P. C. Weaver

Prepared for the
U.S. Department of Energy

ORISE
Oak Ridge Institute for Science and Education

The Oak Ridge Institute for Science and Education (ORISE) is a U.S. Department of Energy facility focusing on scientific initiatives to research health risks from occupational hazards, assess environmental cleanup, respond to radiation medical emergencies, support national security and emergency preparedness, and educate the next generation of scientists. ORISE is managed by Oak Ridge Associated Universities. Established in 1946, ORAU is a consortium of 98 colleges and universities.

NOTICES

INDEPENDENT VERIFICATION SURVEY
OF THE
HIGH FLUX BEAM REACTOR DECOMMISSIONING PROJECT
OUTSIDE AREAS
BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK

Prepared by: _____ Date: 12/14/10
P. G. Weaver, Health Physics Project Manager

Reviewed by: _____ Date: 12/14/2010
T. J. Vitkus, Associate Director of Survey Projects

Reviewed by: _____ Date: 12/14/10
R. D. Condra, Laboratory Manager

Reviewed by: _____ Date: 12/15/10
F. A. Templon, Quality Manager

INDEPENDENT VERIFICATION SURVEY OF THE HIGH FLUX BEAM REACTOR DECOMMISSIONING PROJECT OUTSIDE AREAS BROOKHAVEN NATIONAL LABORATORY UPTON, NEW YORK

Prepared by

P. C. Weaver

Oak Ridge Institute for Science and Education
Oak Ridge, Tennessee 37831-0017

Prepared for the
U.S. Department of Energy

FINAL REPORT

December 2010

This report is based on work performed by the Oak Ridge Institute for Science and Education under contract number DE-AC05-06OR23100 with the Department of Energy.

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The author would like to acknowledge the significant contributions of the following staff members:

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ABBREVIATIONS AND ACRONYMS

AEC	Atomic Energy Commission
BHSO	Brookhaven Site Office
BKG	background
BNL	Brookhaven National Laboratory
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm	centimeter
cpm	counts per minute
Cs-137	cesium-137
DCGL	derived concentration guidelines levels
DOE	U.S. Department of Energy
EPA	Environmental Protection Agency
FIPS	Federal Information Processing Standard
FSP	Field Sampling Plan
FSS	Final Status Survey
GPS	Global Positioning System
HFBR	High Flux Beam Reactor
IAG	Interagency Agreement
IEAV	Independent Environmental Assessment and Verification
ISM	Integrated Safety Management
ITP	Intercomparison Testing Program
IV	independent verification
JHA	job hazard analysis
kg	kilogram
MAPEP	Mixed Analyte Performance Evaluation Program
MDC	minimum detectable concentration
MeV	million electron volt
NaI	sodium iodide
NIST	National Institute of Standards and Technology
NRIP	NIST Radiochemistry Intercomparison Program
NYSDEC	New York State Department of Environmental Conservation
ORAU	Oak Ridge Associated Universities
ORISE	Oak Ridge Institute for Science and Education
pCi/g	picocuries per gram
Ra-226	radium-226
RCRA	Resource Conservation and Recovery Act
ROD	Record of Decision
RSS	ranked set sampling
SOR	sum-of-ratio
SPCS	State Plane Coordinate System
Sr-90	strontium-90
SU	survey unit
TAP	total absorption peak
VSP	Visual Sampling Plan

INDEPENDENT VERIFICATION SURVEY
OF THE
HIGH FLUX BEAM REACTOR DECOMISSIONING PROJECT
OUTSIDE AREAS
BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK

INTRODUCTION

The Brookhaven National Laboratory (BNL) located in Upton, Suffolk County, New York conducts research and development for the Department of Energy's (DOE) Office of Science (Figure A-1). BNL was originally occupied by the U.S. Army as Camp Upton during both World Wars I and II. In 1947, the site was transferred to the Atomic Energy Commission (AEC). The AEC evolved into the Energy Research and Development Administration, which later became the DOE. DOE's Brookhaven Site Office (BHSO) oversees activities at the site including environmental management programs that involve the cleanup and removal of contaminated facilities and soils.

Research operations and processes conducted at the site have produced a variety of radioactive and hazardous wastes that have had an impact on the local site environment. As a result, the BNL site was included on the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) National Priority List on December 21, 1989. In May 1992, the DOE entered into an Interagency Agreement (IAG) with the Environmental Protection Agency (EPA) and New York State Department of Environmental Conservation (NYSDEC) under CERCLA, section 120. The IAG established the framework and schedule for characterizing, assessing, and remediating the site in accordance with requirements of CERCLA and the Resource Conservation and Recovery Act (RCRA) (EPA 1997). In April 2009, the Record of Decision (ROD) – Area of Concern 31 for the High Flux Beam Reactor (HFBR), was finalized. The HFBR ROD defined eight isolated areas of contamination that were present in 2005 and have since been remediated (BNL 2009). Per final status survey (FSS) requirements, BNL will assess the outside grounds around the HFBR to assure that the previous remediation activities remain successful and that no activity at BNL has since affected these areas.

At the request of the DOE-BHSO, the Oak Ridge Institute for Science and Education's (ORISE) Independent Environmental Assessment and Verification (IEAV) program performed independent

verification (IV) of FSS activities associated with the HFBR decommissioning project "Outside Areas". It is the policy of the DOE to perform independent (third party) verification of cleanup activities (DOE 2006). The purpose of IV is to confirm that remedial actions have been effective in meeting established guidelines and that documentation accurately and adequately describes the final site conditions. By using an independent third party, DOE can provide a level of assurance to the stakeholders that the as-left radiological conditions meet the established cleanup goals and is accurately documented.

SITE DESCRIPTION

The HFBR Complex is centrally located within the BNL Site between Cornell Avenue, Renaissance Road, and Rutherford Drive. The HFBR Complex covers approximately 13 acres with multiple structures and systems including the Stack, Building 802, Fan House, and the HFBR Building 750 (Figure A-2). The HFBR designated "Outside Areas" extend from the base of the contoured elevation of the Stack and Fan House area to each bounding road, including approximately eight acres (Figure A-2). The "Outside Areas" were divided into eight survey units (SU), five Class 1 (contiguous to the HFBR and ancillary facilities), and three Class 2 units (BNL 2010).

OBJECTIVES

The objective of the verification survey was to obtain evidence by means of measurements and sampling to confirm that the final radiological conditions meet the established cleanup goals. This objective was achieved via multiple verification components including document reviews, instrument scans, and sample analysis to determine the accuracy and adequacy of FSS documentation.

PROCEDURES

During the periods of August 18 to 25 and September 24 to 29, 2010 ORISE performed visual inspections and independent measurements and sampling of the HFBR "Outside Areas". The verification activities were conducted in accordance with a project-specific verification plan prepared by ORISE, and ORISE-IEAV Survey Procedures and Quality Program Manuals (ORISE 2010a and 2008, and ORAU 2009).

REFERENCE SYSTEM

ORISE used a Global Positioning System (GPS) for documenting measurement and sampling locations, survey unit or area boundaries, and tracking scan data. The specific geographic coordinate system used was the State Plane Coordinate System (SPCS) New York Long Island Federal Information Processing Standard (FIPS) 3104. Coordinate measurements collected using the GPS were accurate to within one meter.

SURFACE SCANS

High density scans in accessible areas for gamma radiation were performed in selected Class 1 and Class 2 SUs at the HFBR "Outside Areas" shown in Figures A-3 to A-7. Low to moderate density gamma scans were performed in remaining SUs 1, 3, and 5 (Figure A-8). Gamma scans were performed using shielded 2 in x 2 in NaI scintillation detectors coupled to ratemeters or ratemeter-scalers with audible indicators. Detectors were coupled to GPS systems that enabled real-time gamma count rate and position data capture. The unshielded surface of the detector was held parallel with the ground surface during scan activities. Locations of elevated direct radiation detected were marked for further investigation and BNL was notified.

SOIL SAMPLING

Visual Sampling Plan (VSP) software was used to generate random coordinates for gamma measurements and soil sampling. These measurement/sample points were down-loaded to the GPS and were based upon the reference grid system established by the site. These predetermined random field assessment and resulting soil sample locations were designed and generated based on the ranked set sampling (RSS) approach (EPA 2002).

RSS provides a methodology to determine the necessary number of soil samples to estimate the mean concentration of a population; however, it does not require the assumption of a normal distribution. The process combines random sampling with the use of professional judgment to select sampling locations. Professional judgment relies upon the ability to assess the relative magnitude of gamma radiation levels between randomly selected locations. In this case, the gamma count rate data collected at randomly selected locations provided the measurable field screening method that correlates with the relative concentrations of the gamma-emitting contaminants of concern. The count rate data obtained were then used to select a specific sampling location.

The RSS systematic planning process uses a replication method on a larger random population from which the locations for the resulting samples can be selected. Replication refers to the number of cycles(*r)* for performing a set size (*m*) of field measurement. The number of field assessment locations per cycle is a function of the set size and is simply m^2. The number of field assessment locations are defined as $m^2 \times r$, or $3^2 \times 2 = 18$ for the HFBR Complex SUs. These measurements are grouped into cycle/sets and distributed in the survey area. The first set identification location is cycle 1 of set 1 at measurement location 1, designated as 1-1-1. Mapping the population of assessment locations uses color coding with a specific geometric shape to correspond to each RSS cycle. The RSS plans designed for selected HFBR "Outside Areas" SUs are provided in Figures A-9 to A-13.

A one-minute static gamma count rate measurement was performed at each of 18 assessment locations determined per SU. The data within a given cycle-set were then ranked as exhibiting either the lowest, medium, or highest gamma count. These data are provided in Tables B-1 through B-5. Six soil samples were collected from each survey unit to satisfy the RSS (Figure A-14).

Six judgmental soil samples were collected from several former hot spot locations identified and remediated by BNL (Table B-8). Judgmental samples were obtained to verify that residual contamination levels were at or below the cleanup objectives (Figure A-14).

SAMPLE ANALYSIS AND DATA INTERPRETATION

Samples and data were returned to the ORISE/IEAV laboratory in Oak Ridge, Tennessee for analyses and interpretation. Sample analyses were performed in accordance with the ORISE Laboratory Procedures Manual (ORISE 2010b). Soil samples were analyzed by gamma spectroscopy for Ra-226 and Cs-137. The spectra were reviewed for other identifiable photopeaks. Sr-90 was quantified by radiochemical separation and counted on a low background proportional counter. Soil sample results were reported in units of picocuries per gram (pCi/g).

APPLICABLE SITE GUIDELINES

The radiological contaminants of concern and the soil cleanup levels are shown in Table 1 as specified in the HFBR- ROD (BNL 2009). Cleanup goals have been met when the radiological contaminants of concern satisfy the unity rule sum–of–ratios (SOR) in accordance with the

following equation: where the sum of the ratio of individual radionuclide concentration divided by the radionuclide derived concentration guideline level (DCGL) must be less than 1.

$$\frac{Conc._{Ra-226}}{DCGL_{Ra-226}} + \frac{Conc._{Cs-137}}{DCGL_{Cs-137}} + \frac{Conc._{Sr-90}}{DCGL_{Sr-90}} \leq 1$$

TABLE 1:
RADIONUCLIDES OF CONCERN IN THE PERIMETER SOILS AREA AND A&B WASTE LINES INDUSTRIAL LAND USE CLEAN-UP GOALS BROOKHAVEN NATIONAL LABORATORY

Radionuclide	AOC-31 ROD (pCi/g)
Cs-137	23
Sr-90	15
Ra-226	5

FINDINGS AND RESULTS

The results of the IV survey components of the "Outside Areas" are discussed below.

SURFACE SCANS

The ambient shielded background count rate averaged about 4,200 counts per minute (cpm) for the NaI detector. Gamma area scan count rates generally ranged from 2,400 to approximately 6,000 cpm; however, up to 8,000 cpm was observed during gamma scans in SU 5. The count rate frequency distributions from real-time data capture of gamma scans are illustrated in Figures A-15 through A-20. Two populations can be clearly delineated in the histograms of SUs 2, 6, and 7. Considerable portions of these SUs were paved with asphalt or covered with concrete.

During gamma scanning in SU 8, the ORISE team observed on both detectors in service at the time, a rapid increase of the gamma radiation count rate, up to 70,000 cpm, in an area where gamma activity previously had been no greater than a few thousand counts above background. The team observed the count rate immediately decrease to the previously observed ambient count rate levels. The ORISE team investigated the area, with no anomalous locations identified. The ORISE team returned to scanning additional measurements in the area, and the count rate was at typical background activity levels. This can be observed in the count rate activity provided in the histogram of the electronic data capture output in Figure A-19.

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES

The range of radionuclide concentrations in soil is provided in Table B-6. ORISE collected 30 random soil samples from six SU and 6 samples from former hot spot locations BNL had identified and remediated. The data for the radionuclide concentrations in individual soil samples and the sum-of-ratios are provided in Table B-7. Cs-137 concentrations ranged from 0.03 to 0.50 pCi/g, Ra-226 ranged from 0.26 to 0.79 pCi/g and Sr-90 ranged from -0.55 to 3.38 pCi/g. The radionuclide concentrations of specific former hot-spots identified by BNL and sampled by ORISE ranged from 0.04 to 0.85 pCi/g for Cs-137, 0.18 to 0.61 pCi/g for Ra-226 and 0.00 to 0.57 pCi/g for Sr-90. Individual sample radionuclide concentrations for hot-spots are provided in Table B-8.

COMPARISON OF RESULTS WITH GUIDELINES

The radionuclide concentration for the "Outside Areas" must meet the guidance per the BNL Field Sampling Plan (FSP) for each individual soil sample and the SOR for the average concentration of each radionuclide of interest must also be less than one. The SORs for individual samples are included with the individual sample analytical results in Table B-7 and Table B-8. The SORs for each SU and hot spot location are well below 1. The highest radionuclide concentration detected was the 3.38 pCi/g of Sr-90 identified in the randomly generated sample 057 location collected in SU7 (Figure A-14). The sample was analyzed again with similar results. The typical observation of analytical results has noted that Sr-90 and Cs-137 have been co-located. The Cs-137 concentration in this location was determined to be 0.03 pCi/g. The Sr-90 concentration was well below the clean-up goal of 15 pCi/g.

SUMMARY

During the period between August 18 to 25 and September 24 to 29, 2010, ORISE conducted measurements and sampling of the HFBR "Outside Areas" at the BNL site. ORISE performed gamma walkover scans in all eight SUs with SUs 2, 4, 6, 7, and 8 receiving high density scans of accessible areas. The remainder of SUs received low density scans. While scanning, ORISE team members observed a significant spike in count rate activity in SU 8. Just as quickly as the count rate increased the count rate decreased. A previous pass in the area did not identify any activity associated with soil contamination. The team determined that both detector instrument electronics functioned normally, and that the increased activity was due to a site activity.

All individual sample concentrations and corresponding mean concentrations evaluated were determined to be below the established cleanup goal. A review of the data collected by ORISE has not identified any areas of contamination exceeding cleanup goals.

REFERENCES

Brookhaven National Laboratory (BNL). Final Record of Decision for AOC 31, High Flux Beam Reactor. Upton, NY; April, 2009.

Brookhaven National Laboratory. High Flux Beam Reactor Decommissioning Project Field Sampling Plan HFBR Outside Areas. Upton, New York; July, 2010.

Oak Ridge Associated Universities (ORAU). Quality Program for the Independent Environmental Assessment and Verification Program. Oak Ridge, TN; June 30, 2009.

Oak Ridge Institute for Science and Education (ORISE). Survey Procedures Manual for the Independent Environmental Assessment and Verification Program. Oak Ridge, TN; May 1, 2008.

Oak Ridge Institute for Science and Education. Project-Specific Verification Plan for the Upton, New York. Oak Ridge, Tennessee; September 3, 2010a.

Oak Ridge Institute for Science and Education. Laboratory Procedures Manual for the Independent Environmental Assessment and Verification Program. Oak Ridge, TN; October 8, 2010b.

U.S. Department of Energy (DOE). Environment, Safety and Health Bulletin: A Guide to Good Practices for the Control and Release of Property. DOE/EH-0697. Washington, DC. July 2006.

U.S. Environmental Protection Agency (EPA). Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination (OSWER Directive 9200.14-18), US Environmental Protection Agency, August, 1997.

U.S. Environmental Protection Agency. Guidance on Choosing a Sampling Design for Environmental Data Collection. US Environmental Protection Agency, December 2002.

APPENDIX A

FIGURES

Figure A-1: Location of Brookhaven National Laboratory, Upton, New York

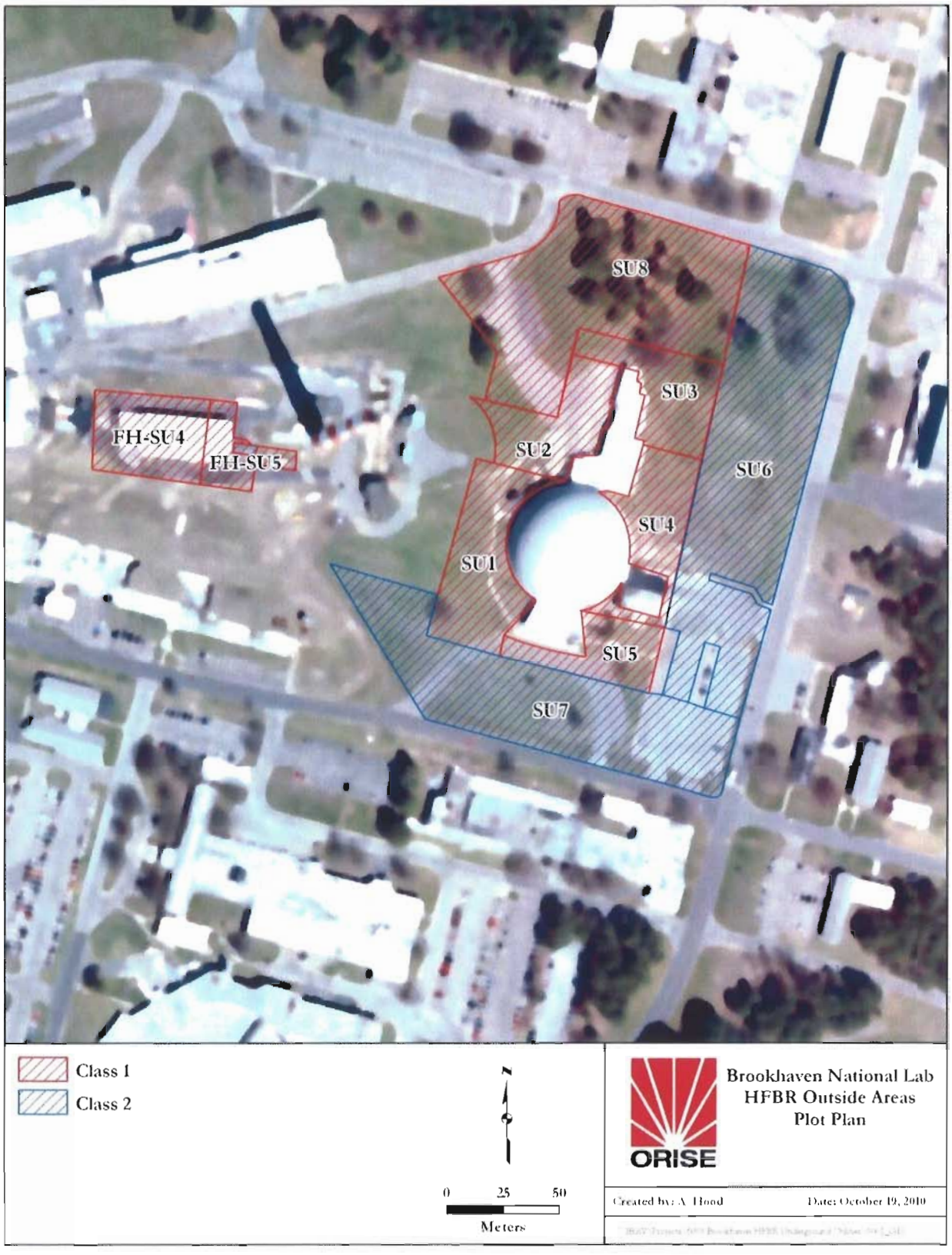


Figure A-2: Plot Plan of the High Flux Beam Reactor Complex "Outside Areas"

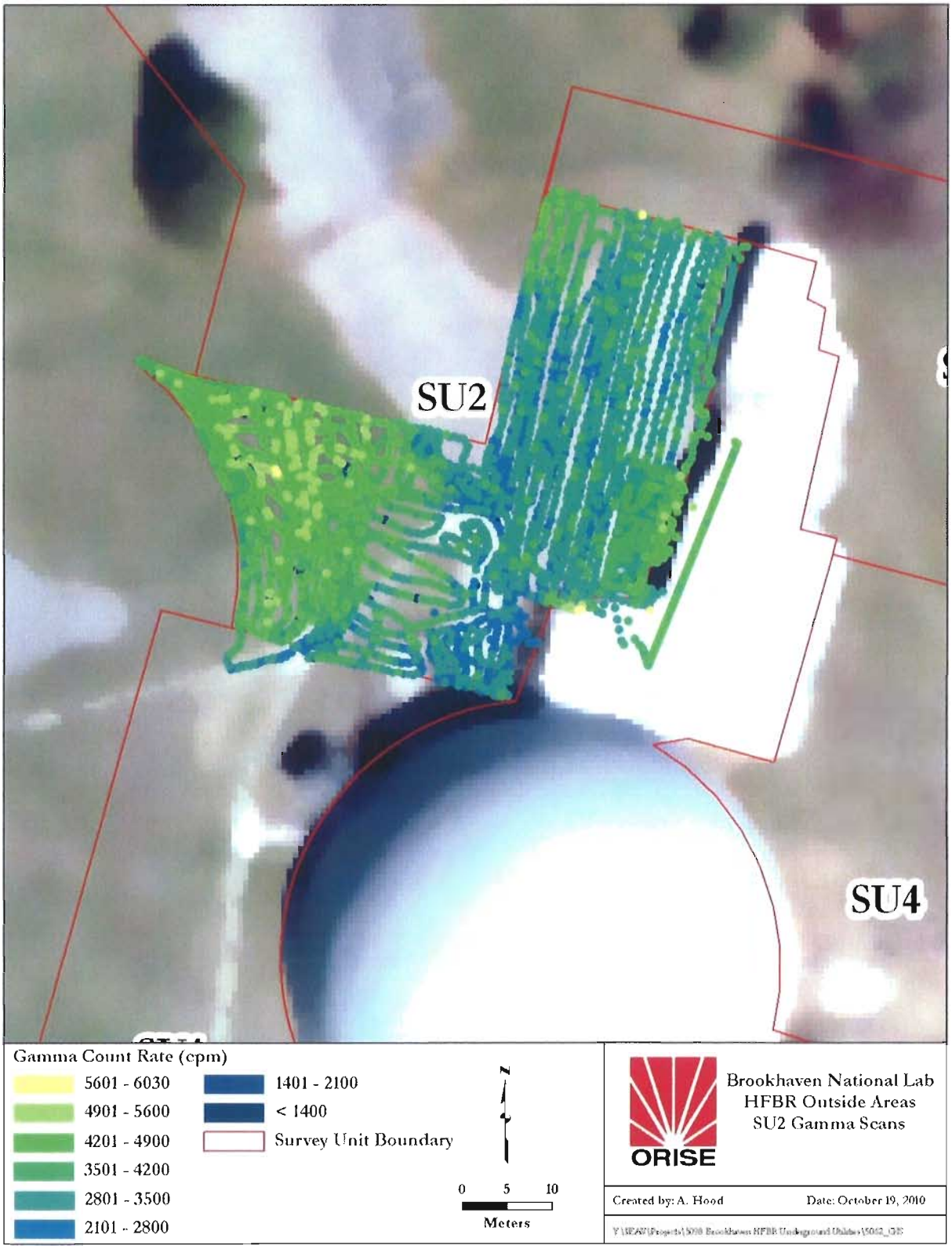


Figure A-3: High Flux Beam Reactor Gamma Scan Survey Unit 2

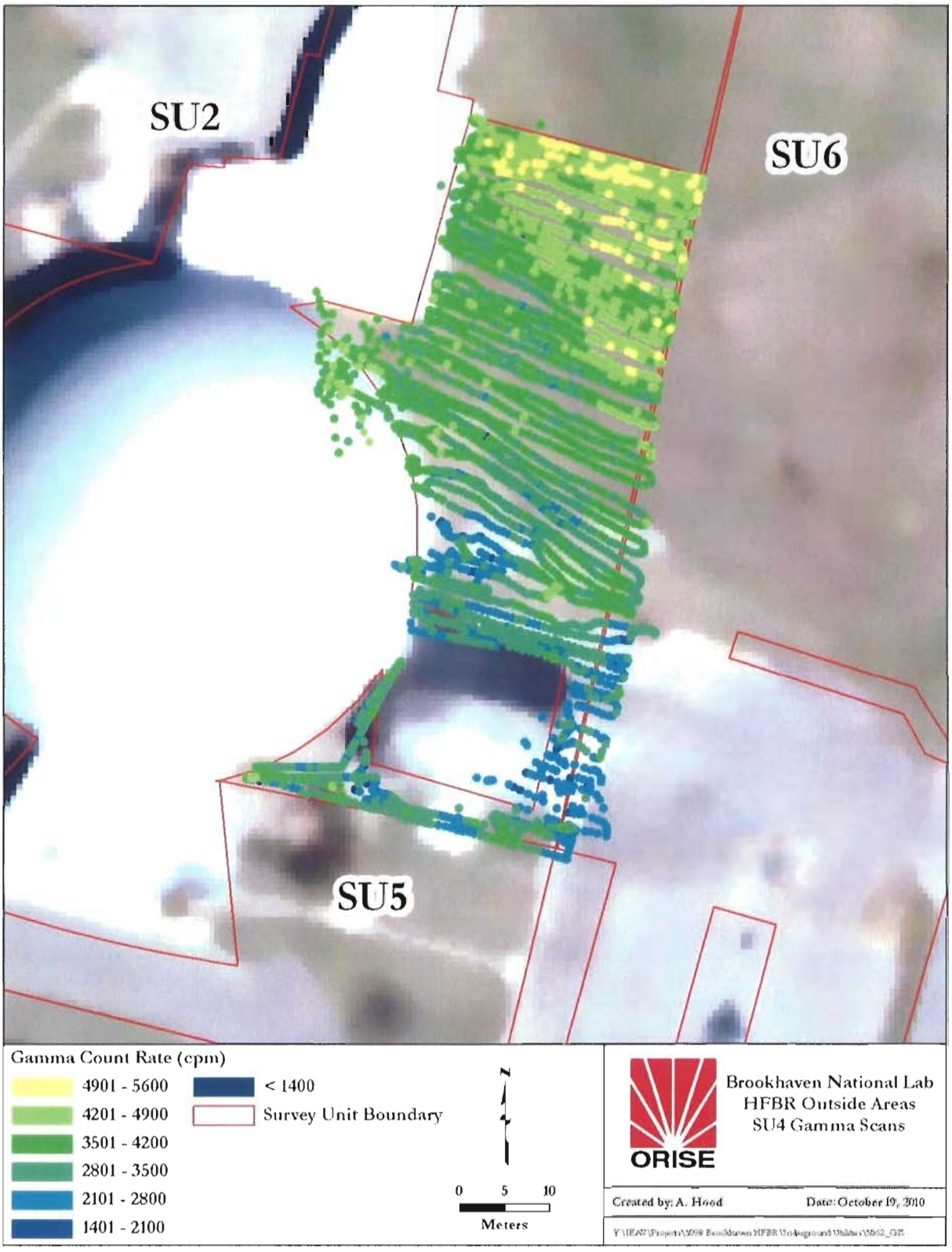


Figure A-4: High Flux Beam Reactor Gamma Scan Survey Unit 4

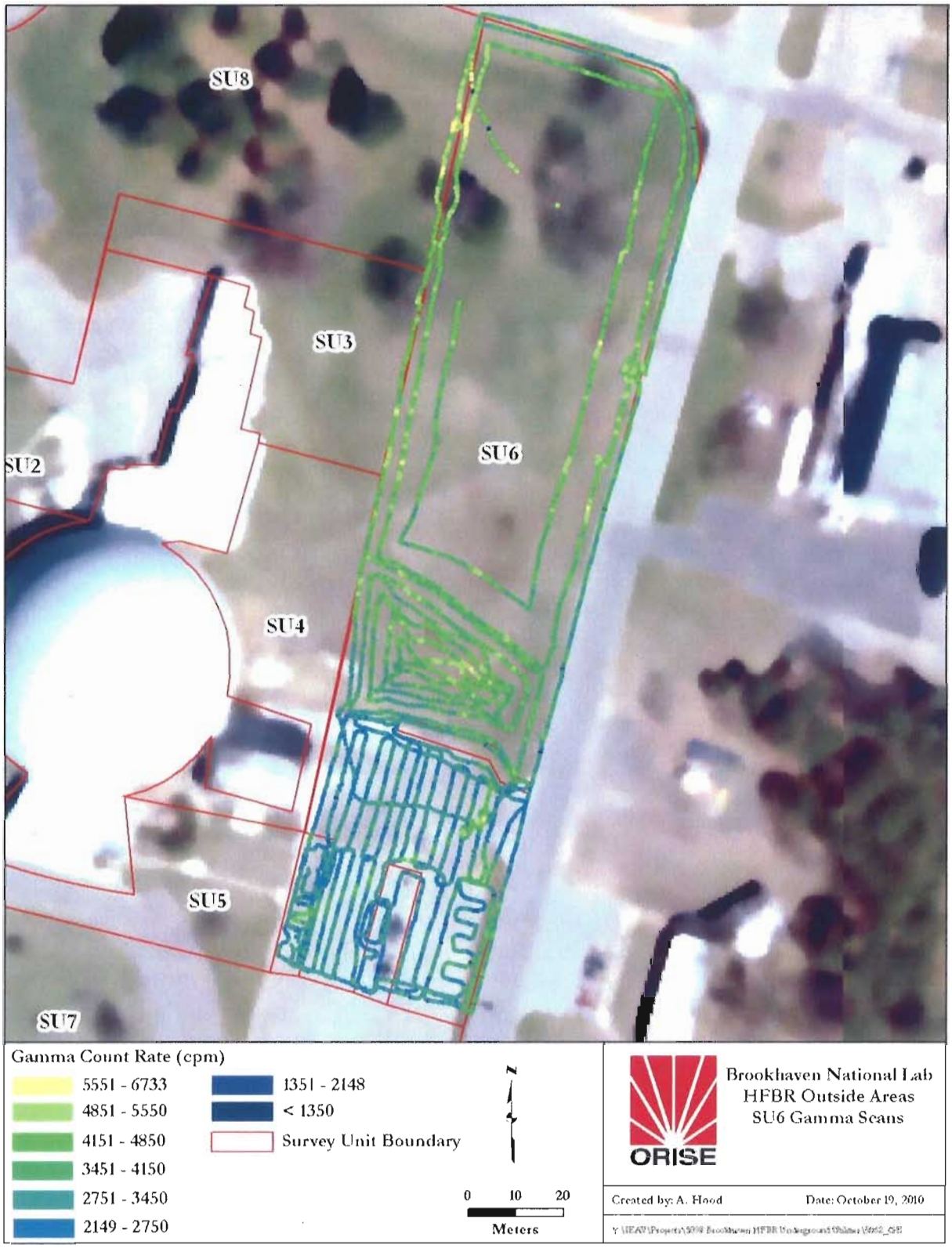


Figure A-5: High Flux Beam Reactor Gamma Scan Survey Unit 6

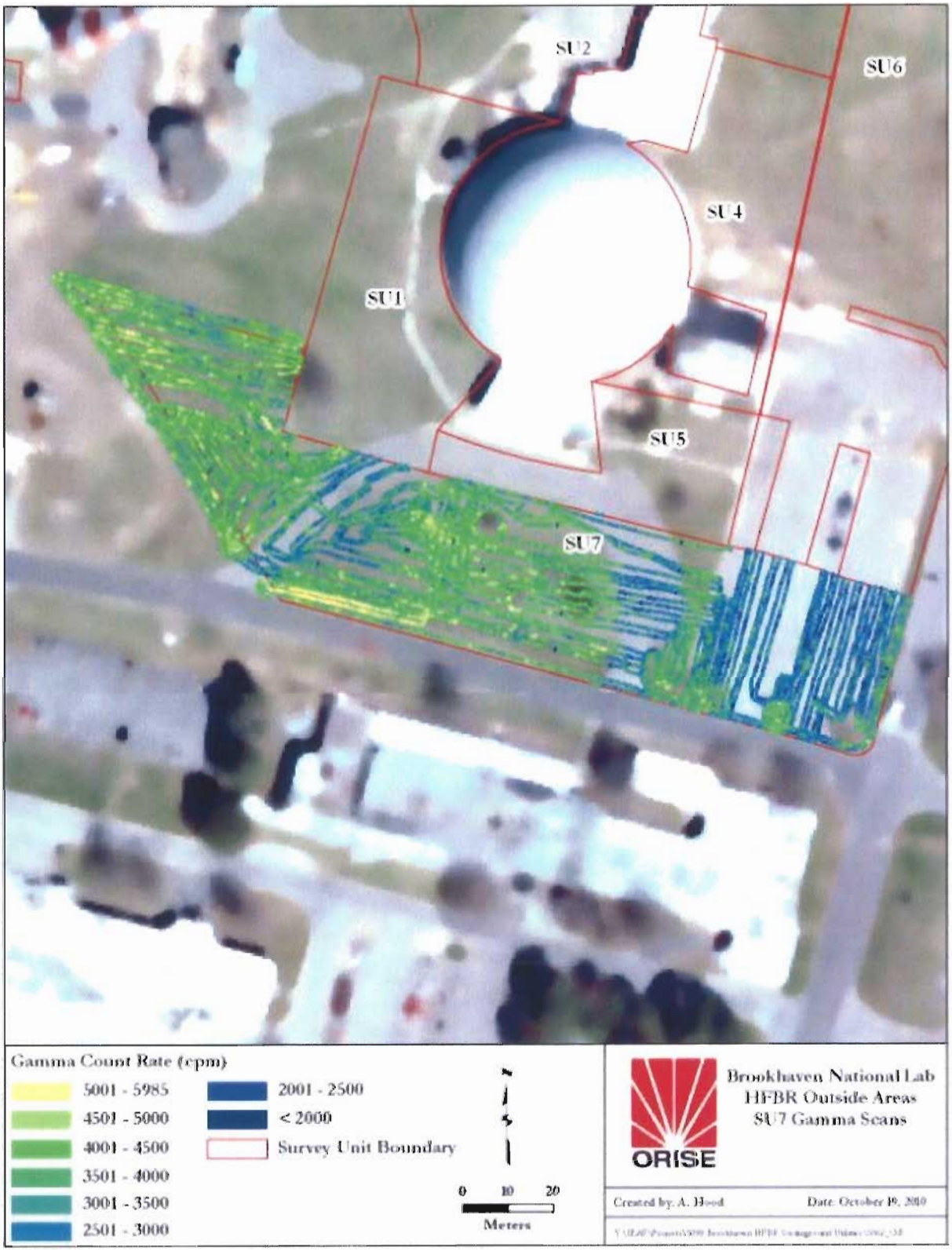


Figure A-6: High Flux Beam Reactor Gamma Scan Survey Unit 7

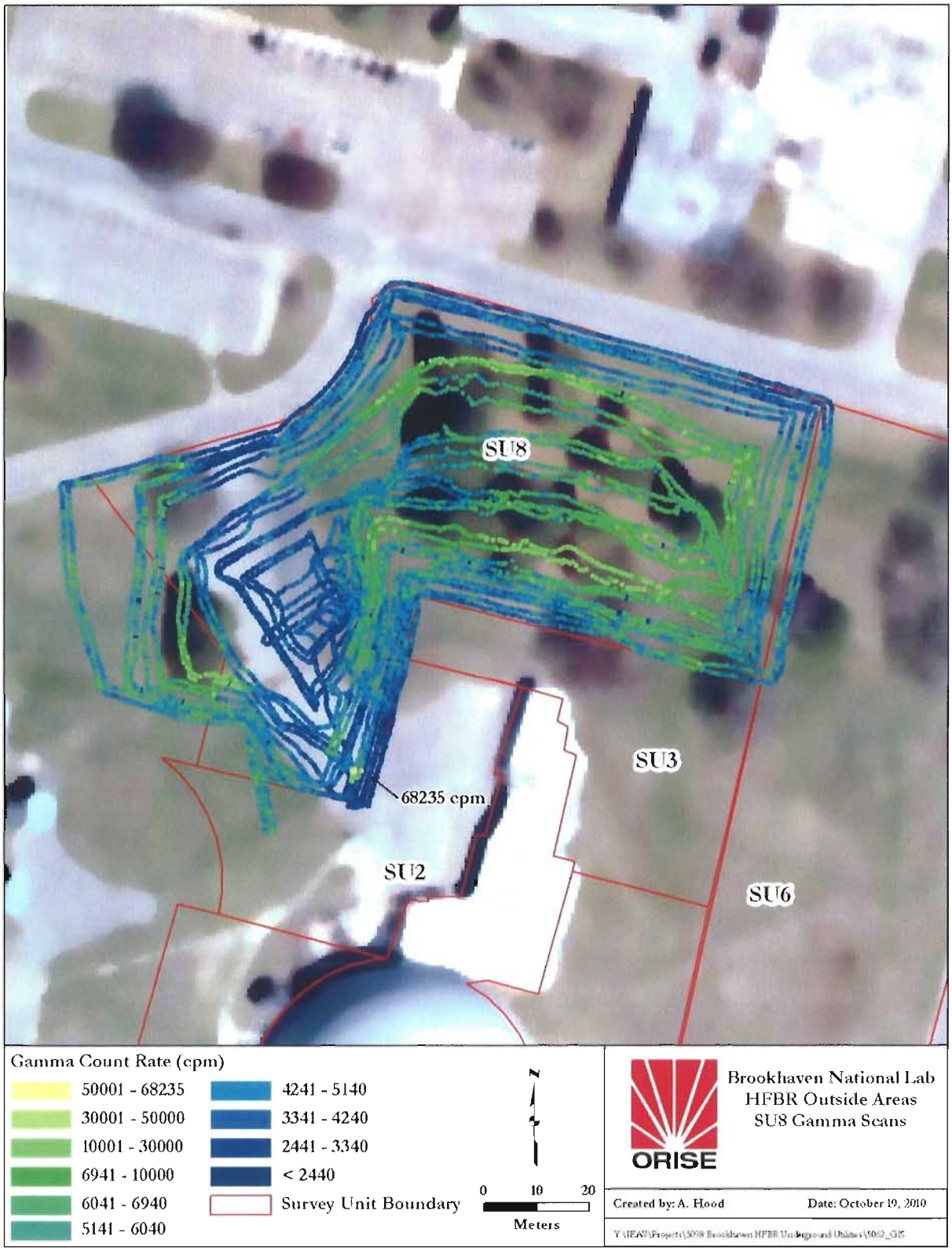


Figure A-7: High Flux Beam Reactor Gamma Scan Survey Unit 8

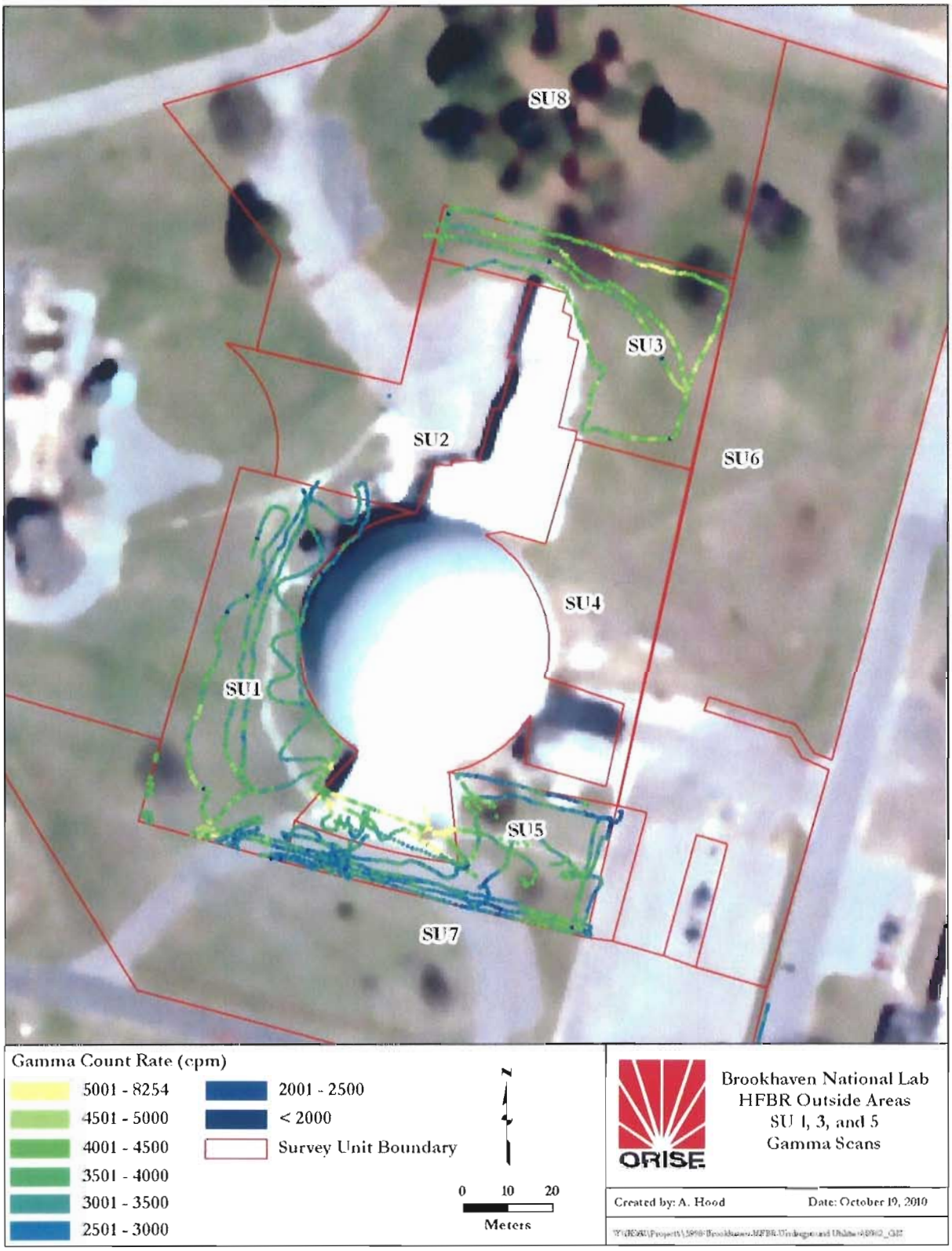


Figure A-8: High Flux Beam Reactor Gamma Scan Survey Units 1, 3, and 5

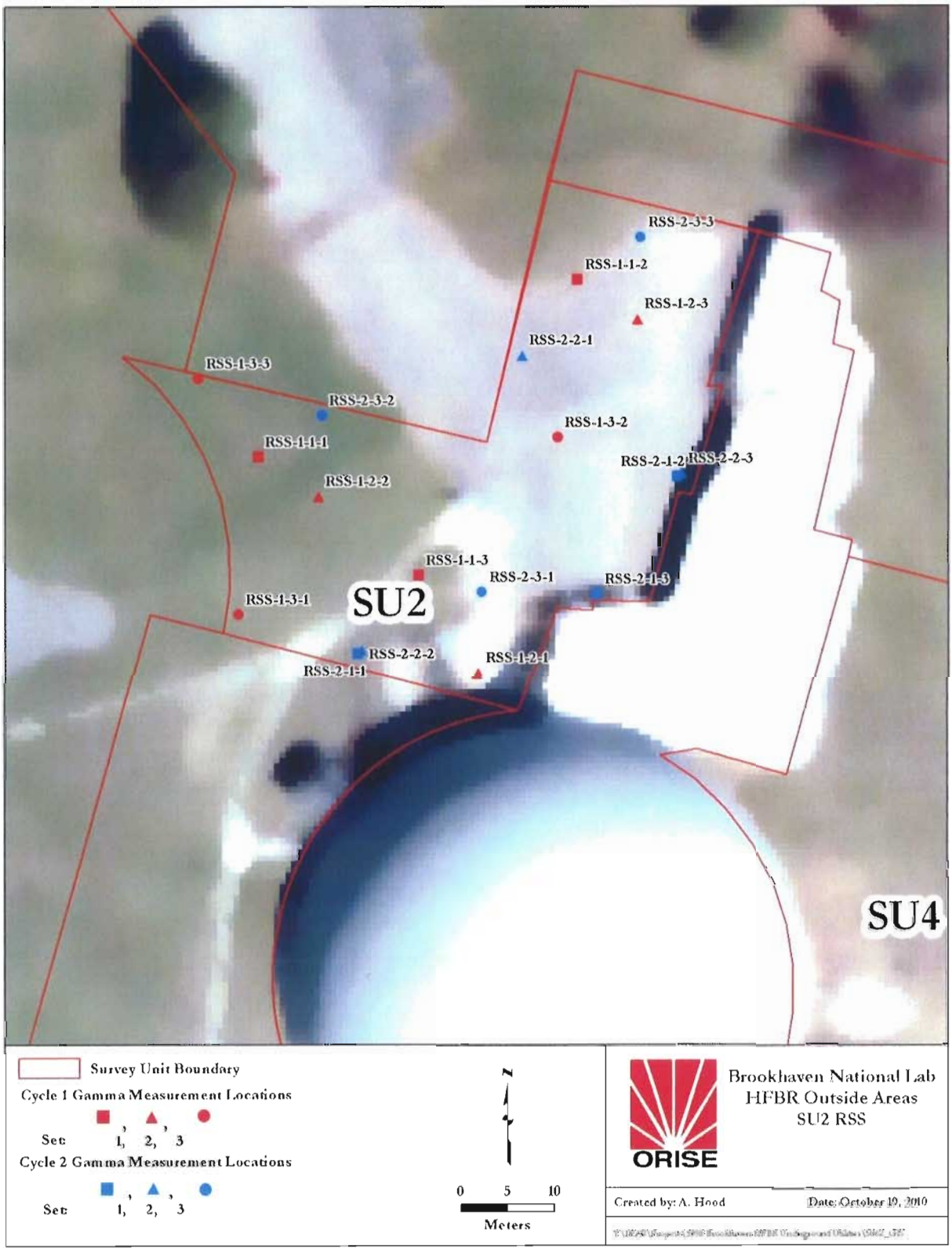


Figure A-9: Survey Unit 2 Ranked Set Sample Locations

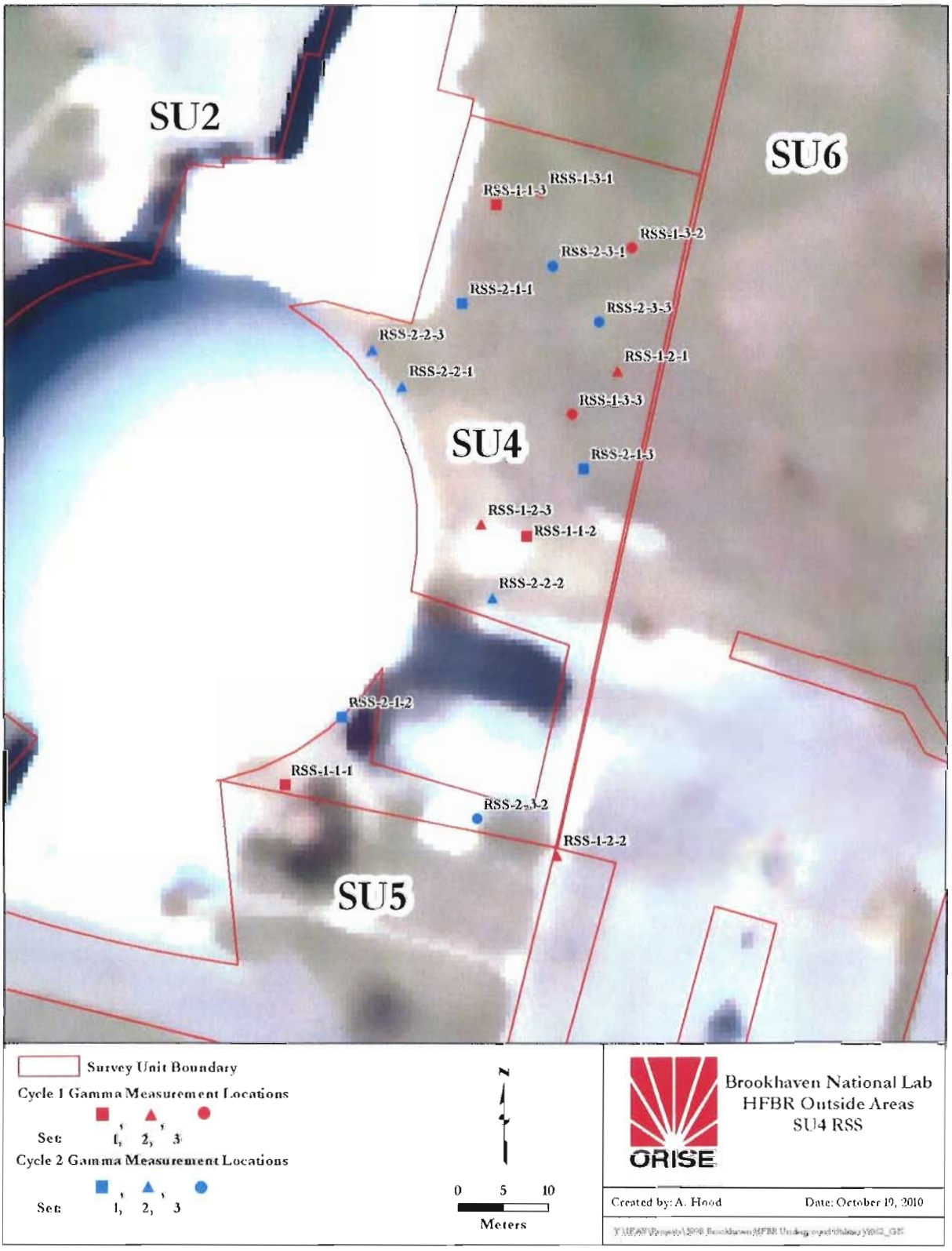


Figure A-10: Survey Unit 4 Ranked Set Sample Locations

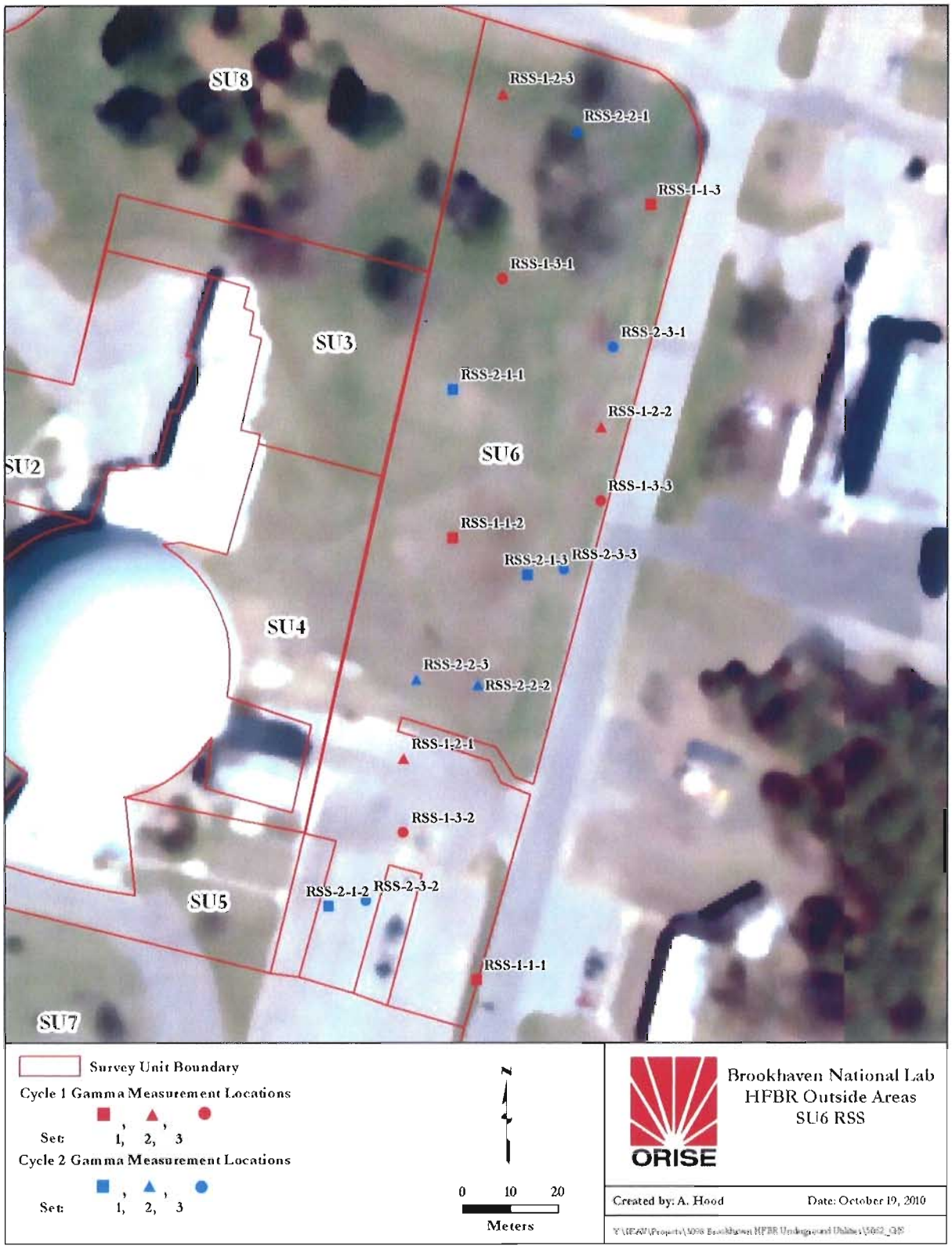


Figure A-11: Survey Unit 6 Ranked Set Sample Locations

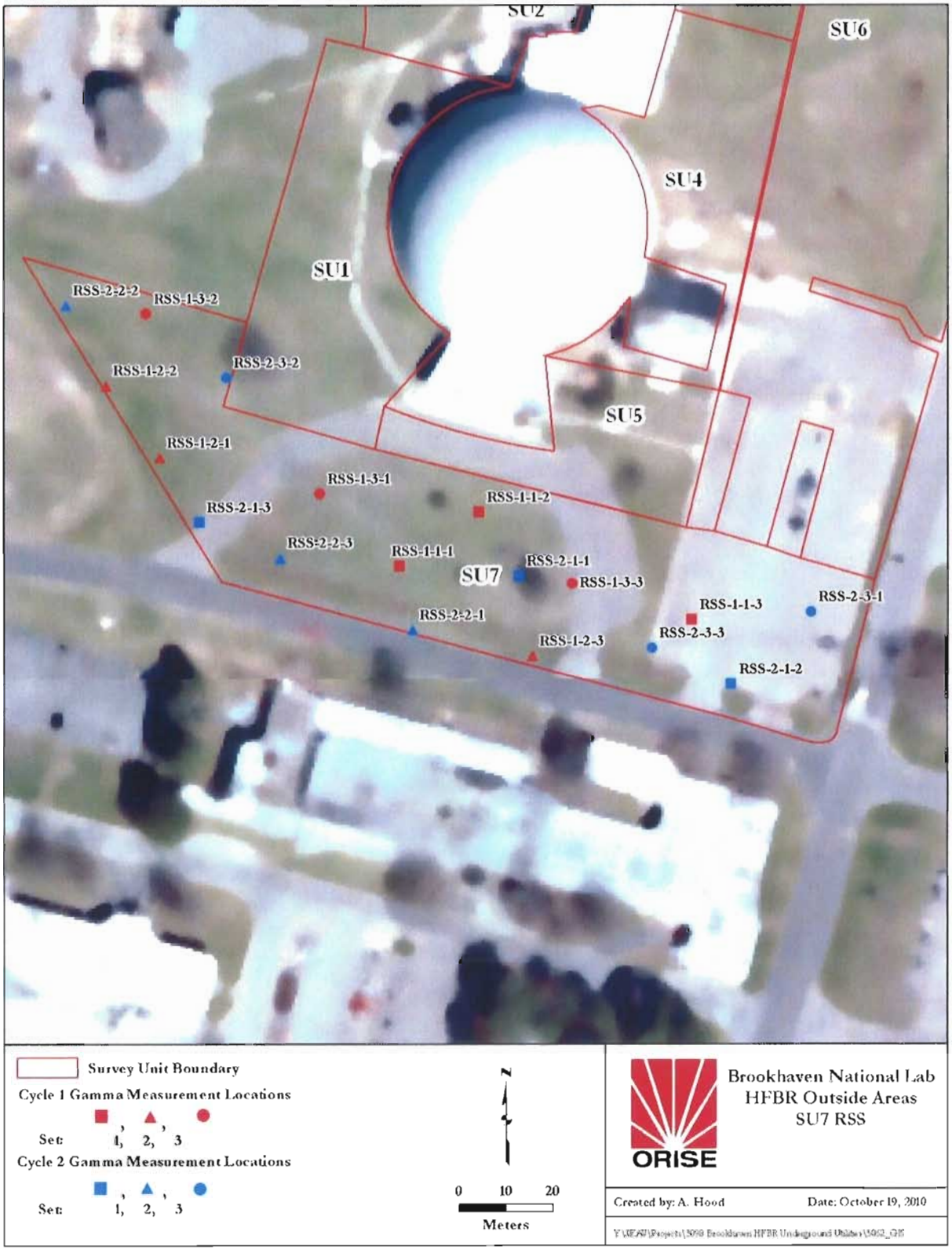


Figure A-12: Survey Unit 7 Ranked Set Sample Locations

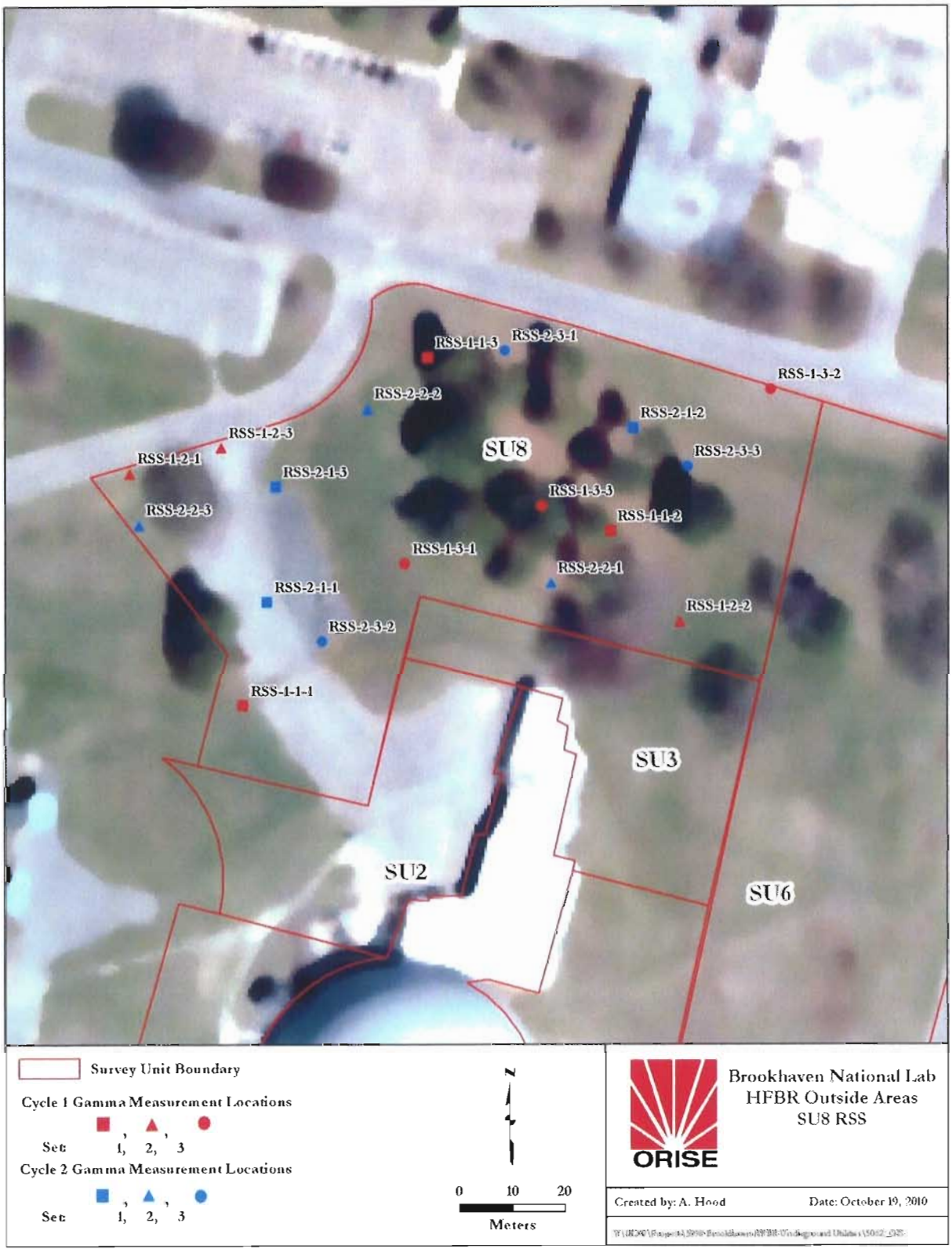


Figure A-13: Survey Unit 8 Ranked Set Sample Locations

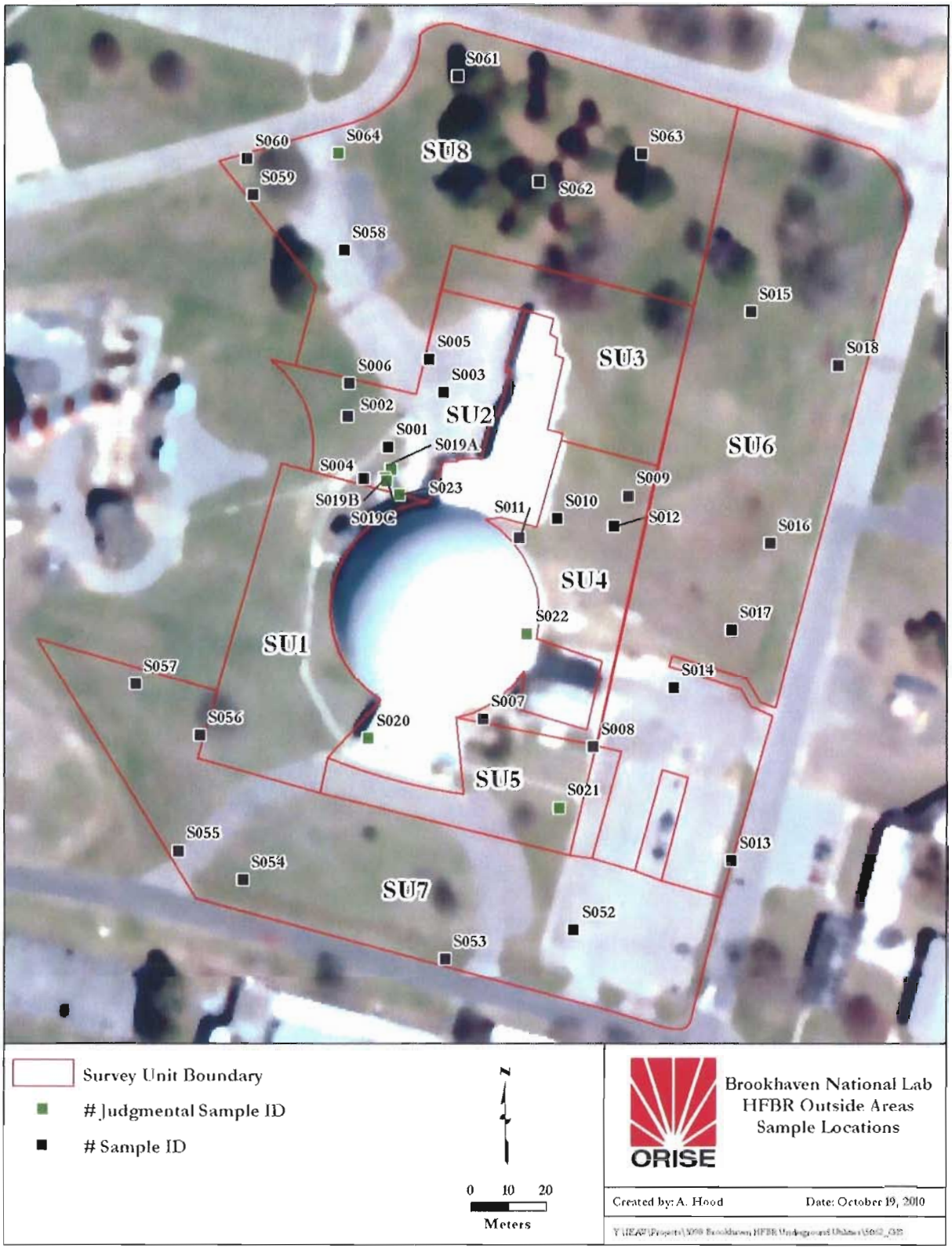


Figure A-14: Soil Sample Locations

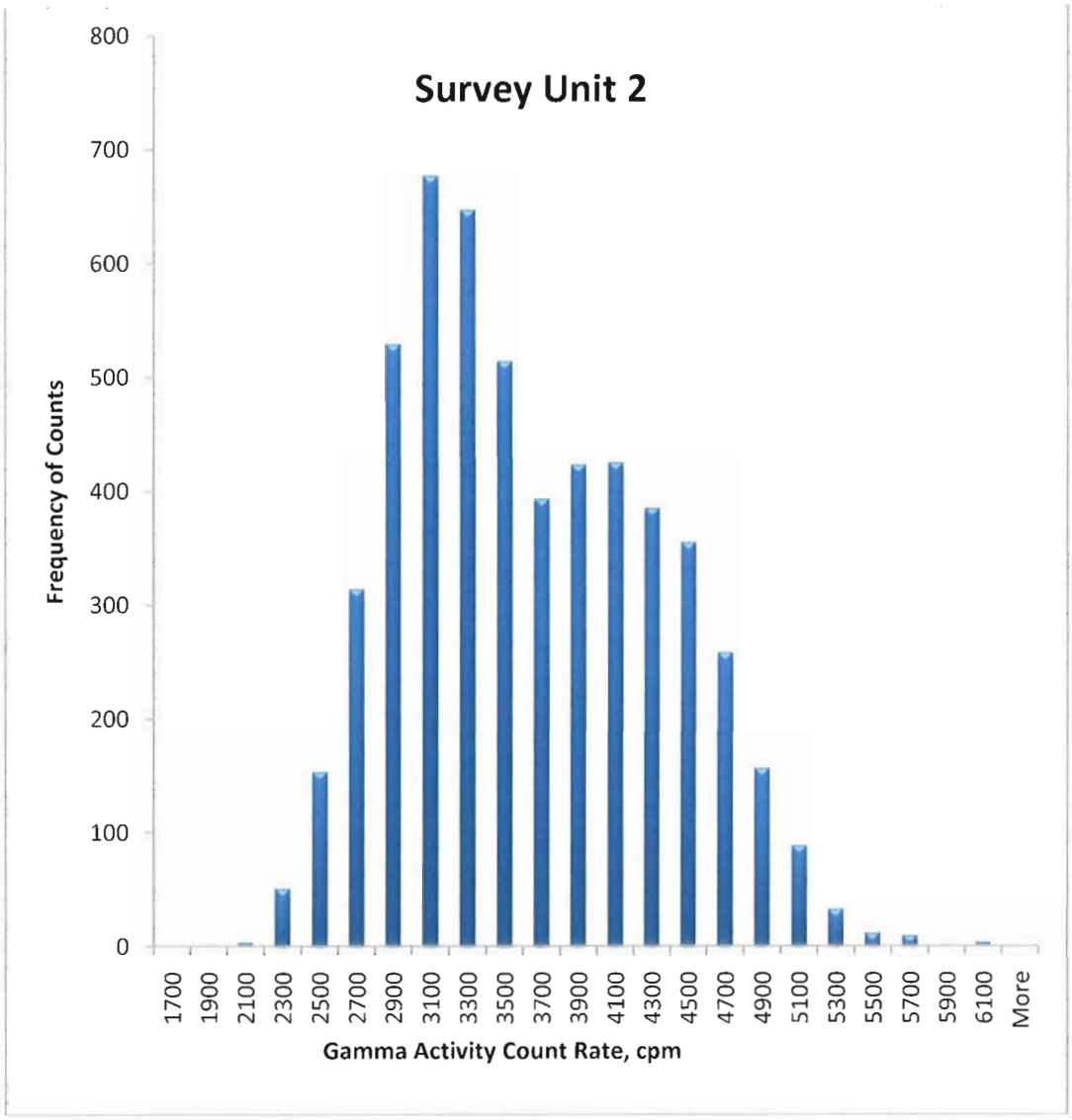


Figure A-15: Gamma Activity Histogram Survey Unit 2

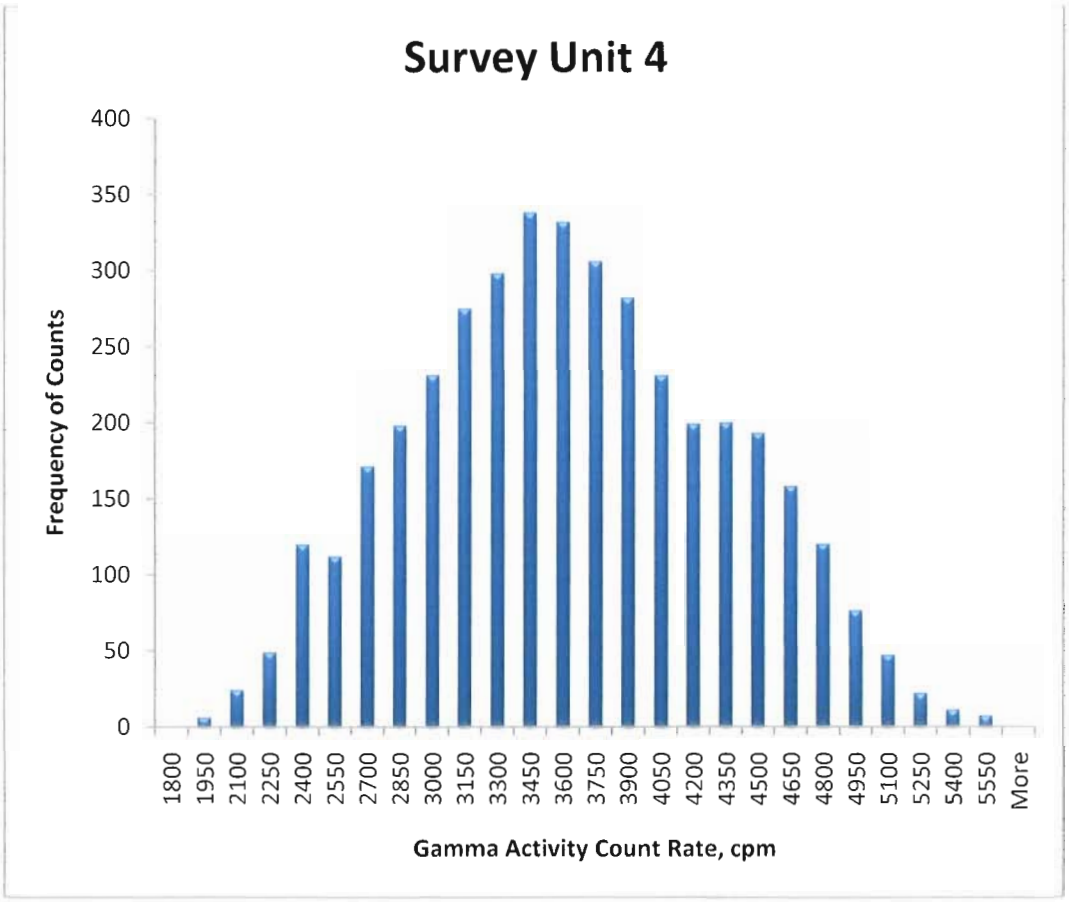


Figure A-16: Gamma Activity Histogram Survey Unit 4

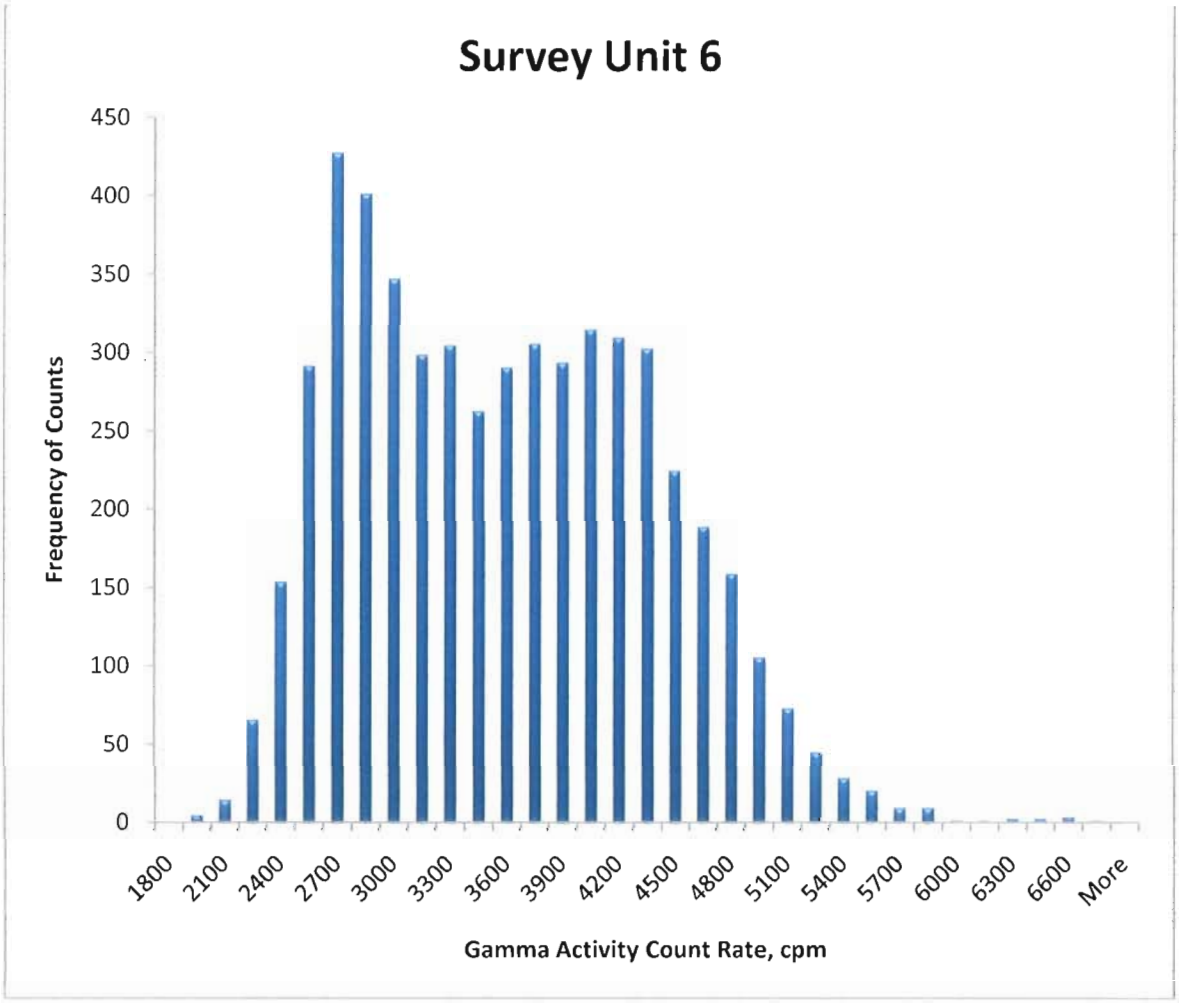


Figure A-17: Gamma Activity Histogram Survey Unit 6

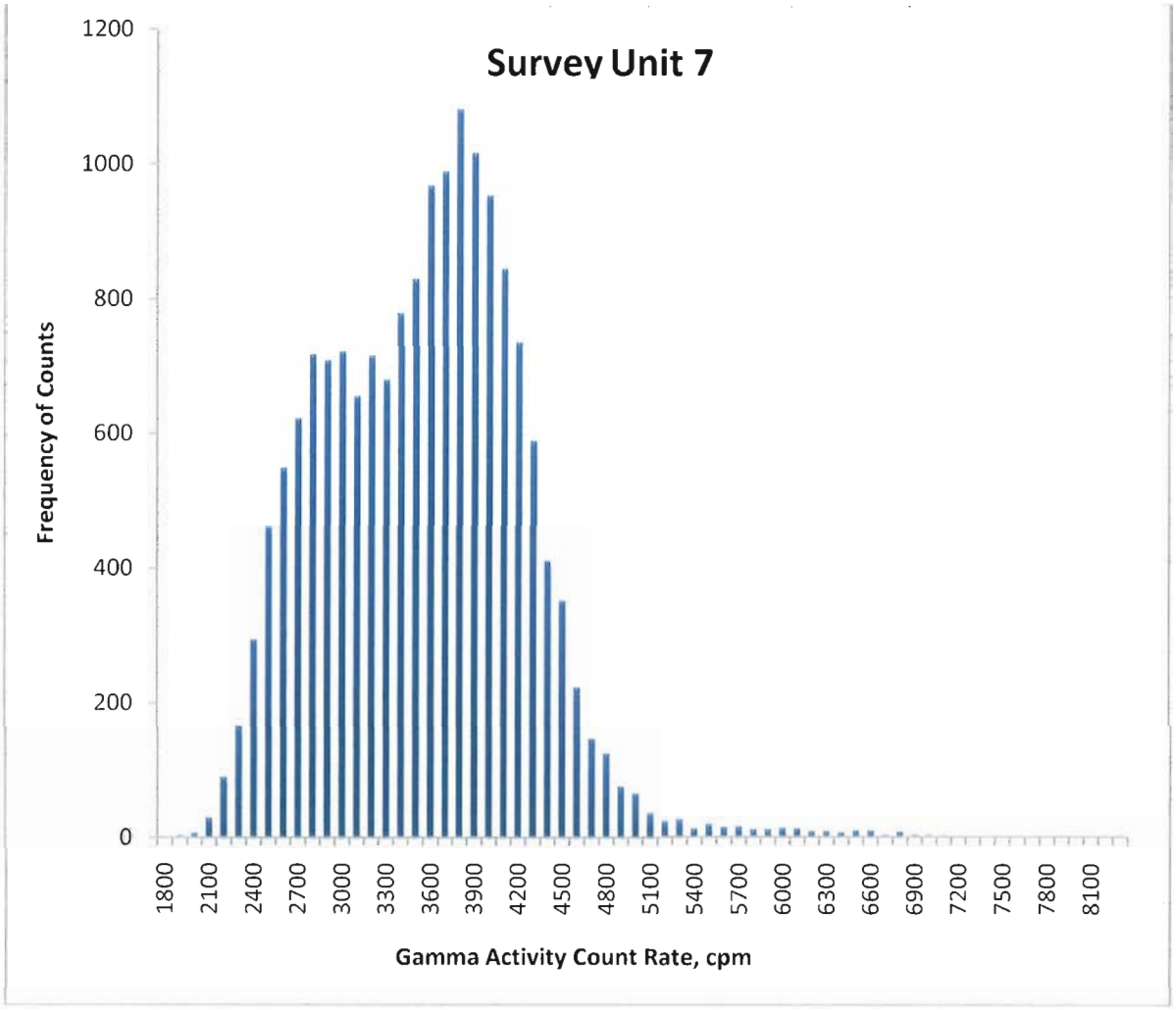


Figure A-18: Gamma Activity Histogram Survey Unit 7

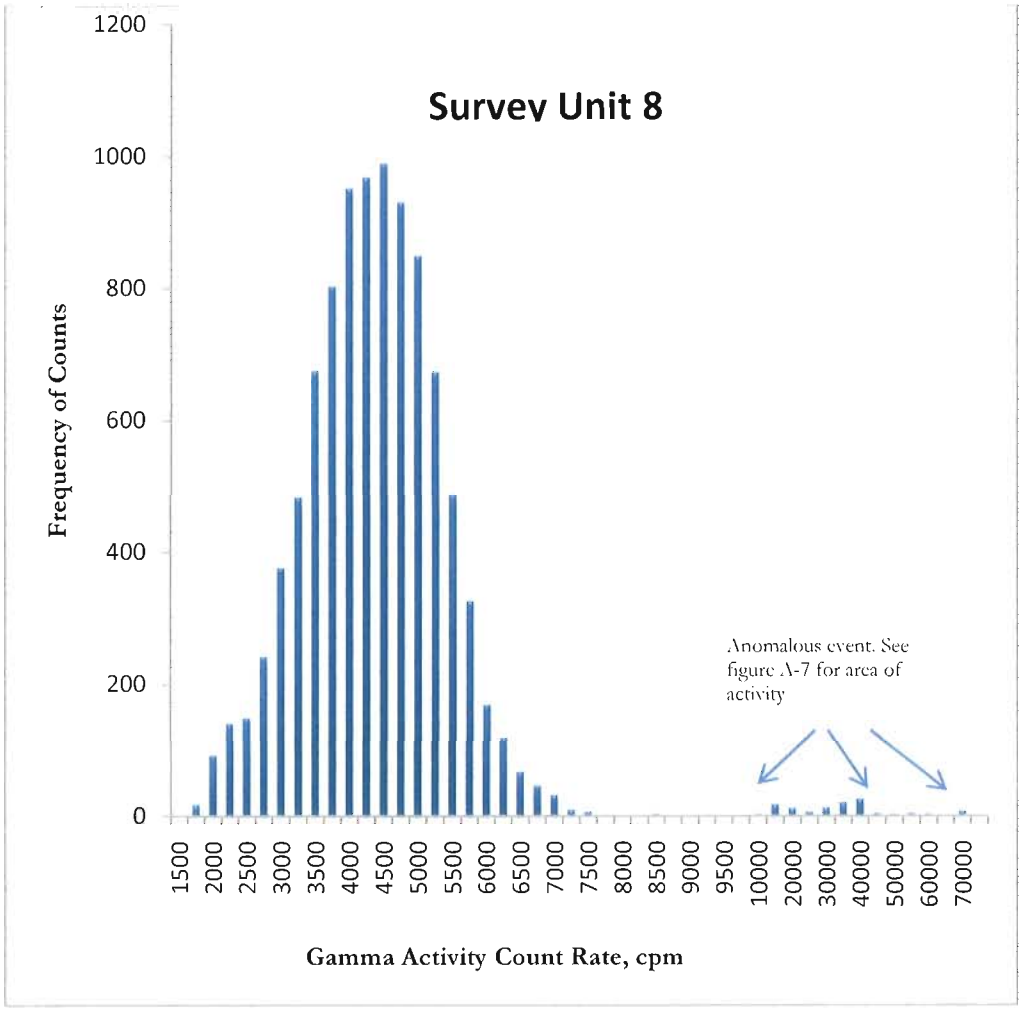


Figure A-19: Gamma Activity Histogram Survey Unit 8

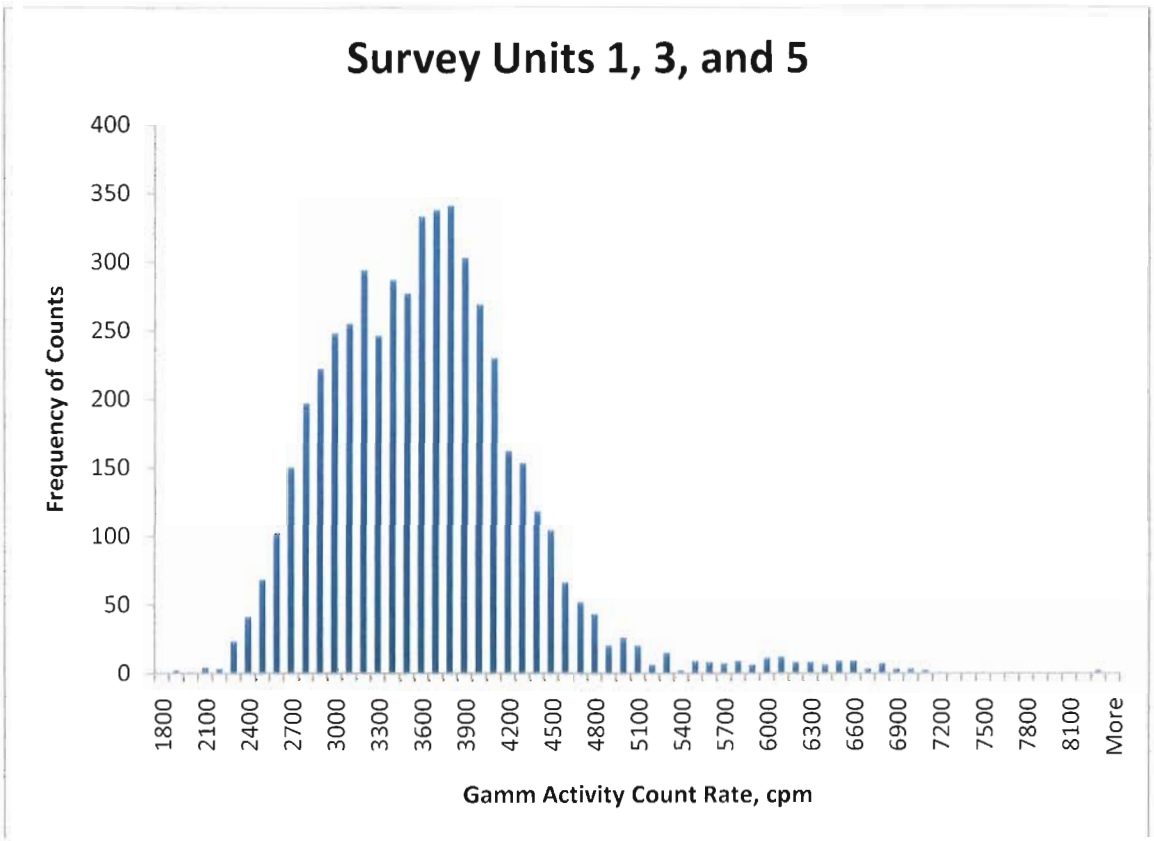


Figure A-20: Gamma Activity Histogram Survey Units 1, 3, and 5

APPENDIX B

TABLES

TABLE B-1:
RANKED SET SAMPLING GAMMA MEASUREMENTS
SURVEY UNIT 2
HIGH FLUX BEAM REACTOR "OUTSIDE AREAS"
BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK

LOCATION GPS NAD 83 SPCS NY Long Island FIPS 3104 Northing[a]	Easting[a]	RSS Cycle	RSS Set	RSS #	Gamma Gross cpm[b]	Notes and Observations L=Low M=Medium H=High	SOIL SAMPLE
258499.98	1295392.86	1	1	1 ■	4725	L	
258561.42	1295504.62	1	1	2 ■	3664	L	
258459.03	1295448.74	1	1	3 ■	3557	L	001
258424.89	1295469.69	1	2	1 ▲	2458	M	
258486.33	1295413.81	1	2	2 ▲	4482	M	002
258547.77	1295525.57	1	2	3 ▲	2965	M	
258445.37	1295385.87	1	3	1 ●	4328	H	
258506.81	1295497.63	1	3	2 ●	3182[c]	H	004
258527.29	1295371.91	1	3	3 ●	4388	H	
258431.72	1295427.78	2	1	1 ■	3246	L	006
258493.16	1295539.54	2	1	2 ■	4198	L	
258452.20	1295511.60	2	1	3 ■	3089	L	
258535.13	1295484.97	2	2	1 ▲	3014[c]	M	003
258432.73	1295429.09	2	2	2 ▲	2949	M	
258494.17	1295540.85	2	2	3 ▲	4276	M	
258453.21	1295471.0	2	3	1 ●	2547	H	
258514.65	1295415.12	2	3	2 ●	4584	H	005
258576.08	1295526.88	2	3	3 ●	2884	H	

[a]Refer to Figure A-9.

[b]Material specific backgrounds were subtracted from the static measurement to determine sample locations.

[c]Static measurement was collected on asphalt surface. The asphalt background was subtracted to rank the data set to determine the sample location. The asphalt was removed and soil underneath was collected.

TABLE B-2:
RANKED SET SAMPLING GAMMA MEASUREMENTS
SURVEY UNIT 4
HIGH FLUX BEAM REACTOR "OUTSIDE AREAS"
BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK

LOCATION GPS NAD 83 SPCS NY Long Island FIPS 3104 Northing Easting[a]		RSS			Gamma	Notes and Observations L=Low M=Medium H=High	SOIL SAMPLE
		Cycle	Set	#	Gross cpm[b]		
258222.98	1295532.11	1	1	1 ■	2943	L	007
258312.76	1295620.2	1	1	2 ■	2695	L	
258432.46	1295609.19	1	1	3 ■	3673	L	
258372.61	1295653.23	1	2	1 ▲	4604	M	
258197.48	1295631.21	1	2	2 ▲	2615[c]	M	008
258317.19	1295603.68	1	2	3 ▲	2283	M	
258436.89	1295625.7	1	3	1 ●	4620	H	
258416.94	1295658.73	1	3	2 ●	4692	H	009
258357.09	1295636.71	1	3	3 ●	3736	H	
258396.99	1295596.8	2	1	1 ■	3491	L	010
258247.36	1295552.76	2	1	2 ■	3905	L	
258337.14	1295640.84	2	1	3 ■	3533	L	
258367.07	1295574.78	2	2	1 ▲	3347	M	
258290.59	1295607.81	2	2	2 ▲	3474	M	
258380.37	1295563.77	2	2	3 ▲	3396	M	011
258410.29	1295629.83	2	3	1 ●	4223	H	
258210.79	1295602.3	2	3	2 ●	3370	H	
258390.34	1295646.34	2	3	3 ●	4617	H	012

[a]Refer to Figure A-10.
[b]Material specific backgrounds were subtracted from the static measurement to determine sample locations.
[c]Static measurement was collected on concrete surface. The concrete background was subtracted to rank the data set to determine the sample location. The concrete was removed and soil underneath was collected.

TABLE B-3:
RANKED SET SAMPLING GAMMA MEASUREMENTS
SURVEY UNIT 6
HIGH FLUX BEAM REACTOR "OUTSIDE AREAS"
BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK

LOCATION GPS NAD 83 SPCS NY Long Island FIPS 3104 Northing[a]	Easting[a]	RSS Cycle	RSS Set	RSS #	Gamma Gross cpm[b]	Notes and Observations L=Low M=Medium H=High	SOIL SAMPLE
258100.22	1295749.43	1	1	1 ■	3368	L	013
258401.00	1295732.50	1	1	2 ■	3669	L	
258626.58	1295867.96	1	1	3 ■	4648	L	
258250.61	1295698.63	1	2	1 ▲	2833[c]	M	014
258476.19	1295834.10	1	2	2 ▲	4425	M	
258701.77	1295766.37	1	2	3 ▲	5268	M	
258576.45	1295766.56	1	3	1 ●	4475	H	015
258200.48	1295698.83	1	3	2 ●	2641	H	
258426.06	1295834.30	1	3	3 ●	4123	H	
258501.26	1295732.70	2	1	1 ■	4008	L	
258150.35	1295648.03	2	1	2 ■	3926	L	
258375.93	1295783.50	2	1	3 ■	3682	L	016
258676.71	1295817.36	2	2	1 ▲	4945	M	
258300.74	1295749.63	2	2	2 ▲	4789	M	017
258304.45	1295707.30	2	2	3 ▲	3318	M	
258530.03	1295842.76	2	3	1 ●	4538	H	018
258154.07	1295673.43	2	3	2 ●	2716	H	
258379.65	1295808.90	2	3	3 ●	3971	H	

[a]Refer to Figure A-11.
[b]Material specific backgrounds were subtracted from the static measurement to determine sample locations.
[c]Static measurement was collected on asphalt surface. The asphalt background was subtracted to rank the data set to determine the sample location. The asphalt was removed and soil underneath was collected.

TABLE B-4:
RANKED SET SAMPLING GAMMA MEASUREMENTS
SURVEY UNIT 7
HIGH FLUX BEAM REACTOR "OUTSIDE AREAS"
BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK

LOCATION GPS NAD 83 SPCS NY Long Island FIPS 3104 Northing Easting[a]		RSS			Gamma	Notes and Observations L=Low M=Medium H=High	SOIL SAMPLE
		Cycle	Set	#	Gross cpm		
258078.12	1295406.33	1	1	1 ■	3805	L	
258115.81	1295462.40	1	1	2 ■	3956	L	
258040.42	1295611.89	1	1	3 ■	2992	L	052
258153.51	1295238.15	1	2	1 ▲	3828	M	
258203.76	1295200.78	1	2	2 ▲	4271	M	
258015.29	1295499.77	1	2	3 ▲	3831	M	053
258128.38	1295350.27	1	3	1 ●	3101	H	
258254.02	1295228.81	1	3	2 ●	3361	H	057
258065.55	1295527.80	1	3	3 ●	2858	H	
258071.14	1295490.43	2	1	1 ■	4100	L	
257995.75	1295639.92	2	1	2 ■	4158	L	
258108.83	1295266.18	2	1	3 ■	3685	L	055
258033.44	1295415.68	2	2	1 ▲	3521	M	
258259.61	1295172.75	2	2	2 ▲	4438	M	
258083.70	1295322.24	2	2	3 ▲	4043	M	054
258046.01	1295695.98	2	3	1 ●	2695	H	
258209.35	1295284.87	2	3	2 ●	3364	H	056
258020.88	1295583.86	2	3	3 ●	2711	H	

[a]Refer to Figure A-12.

TABLE B-5:
RANKED SET SAMPLING GAMMA MEASUREMENTS
SURVEY UNIT 8
HIGH FLUX BEAM REACTOR "OUTSIDE AREAS"
BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK

LOCATION GPS NAD 83 SPCS NY Long Island FIPS 3104 Northing[a]	Easting[a]	RSS Cycle	RSS Set	RSS #	Gamma Gross cpm	Notes and Observations L=Low M=Medium H=High	SOIL SAMPLE
258566.86	1295395.84	1	1	1 ■	4447	L	
258673.82	1295622.67	1	1	2 ■	6117	L	
258780.78	1295509.26	1	1	3 ■	4255	L	061
258709.47	1295324.95	1	2	1 ▲	4377	M	060
258618.36	1295665.21	1	2	2 ▲	5061	M	
258725.32	1295381.66	1	2	3 ▲	2814	M	
258654.01	1295495.08	1	3	1 ●	4479	H	
258760.97	1295721.92	1	3	2 ●	3058	H	
258689.66	1295580.14	1	3	3 ●	5023	H	062
258630.24	1295410.01	2	1	1 ■	3342	L	058
258737.20	1295636.85	2	1	2 ■	4847	L	
258701.55	1295415.33	2	1	3 ■	3381	L	
258642.13	1295585.46	2	2	1 ▲	5044	M	
258749.09	1295472.04	2	2	2 ▲	4276	M	
258677.78	1295330.27	2	2	3 ▲	4971	M	059
258784.74	1295557.10	2	3	1 ●	3713	H	
258606.48	1295443.69	2	3	2 ●	3379	H	
258713.43	1295670.52	2	3	3 ●	4943	H	063

[a]Refer to Figure A-13.

TABLE B-6: RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES SUMMARY SAMPLE RANGE CONCENTRATION HIGH FLUX BEAM REACTOR "OUTSIDE AREAS" BROOKHAVEN NATIONAL LABORATORY UPTON, NY			
Survey Unit	**Cs-137 (pCi/g)**	**Ra-226 (pCi/g)**	**Sr-90 (pCi/g)**
SU-2	0.03 to 0.28	0.26 to 0.60	-0.55 to -0.03
SU-4	0.04 to 0.32	0.28 to 0.56	-0.32 to 0.04
SU-6	0.05 to 0.50	0.29 to 0.55	-0.31 to 0.36
SU-7	0.03 to 0.29	0.29 to 0.54	0.03 to 3.38
SU-8	0.06 to 0.28	0.38 to 0.79	0.09 to 0.76

TABLE B-7: RADIONUCLIDE CONCENTRATIONS IN SOIL HIGH FLUX BEAM REACTOR "OUTSIDE AREAS" BROOKHAVEN NATIONAL LABORATORY UPTON, NY				
Sample ID/Location[a]	Radionuclide Concentration (pCi/g)			
	Cs-137	Ra-226	Sr-90	SOR
SU 2				
001	0.16 ± 0.03[b]	0.37 ± 0.05	-0.35 ± 0.46	0.06
002	0.17 ± 0.03	0.60 ± 0.06	-0.45 ± 0.48	0.10
003	0.03 ± 0.02	0.37 ± 0.04	-0.03 ± 0.46	0.07
004	0.18 ± 0.03	0.41 ± 0.05	-0.05 ± 0.46	0.09
005	0.04 ± 0.01	0.26 ± 0.04	-0.55 ± 0.46	0.02
006	0.28 ± 0.04	0.50 ± 0.06	-0.16 ± 0.37	0.10
SU 4				
007	0.04 ± 0.01	0.28 ± 0.03	-0.19 ± 0.43	0.05
008	0.15 ± 0.02	0.42 ± 0.05	-0.28 ± 0.40	0.07
009	0.26 ± 0.04	0.56 ± 0.06	-0.17 ± 0.45	0.11
010	0.14 ± 0.02	0.36 ± 0.04	-0.32 ± 0.44	0.06
011	0.19 ± 0.03	0.40 ± 0.05	-0.08 ± 0.43	0.08
012	0.32 ± 0.04	0.37 ± 0.05	0.04 ± 0.48	0.09
SU6				
013	0.26 ± 0.03	0.29 ± 0.04	-0.31 ± 0.48	0.05
014	0.50 ± 0.05	0.30 ± 0.04	0.15 ± 0.58	0.09
015	0.05 ± 0.01	0.54 ± 0.05	-0.11 ± 0.42	0.10
016	0.06 ± 0.02	0.38 ± 0.05	0.13 ± 0.45	0.09
017	0.22 ± 0.03	0.55 ± 0.06	0.20 ± 0.44	0.13
018	0.37 ± 0.05	0.54 ± 0.06	0.36 ± 0.45	0.15
SU7				
052	0.03 ± 0.03	0.29 ± 0.04	0.03 ± 0.41	0.06
053	0.24 ± 0.03	0.52 ± 0.05	0.05 ± 0.46	0.12
054	0.29 ± 0.04	0.54 ± 0.05	0.18 ± 0.46	0.13
055	0.15 ± 0.02	0.49 ± 0.05	0.36 ± 0.44	0.13
056	0.10 ± 0.02	0.41 ± 0.05	0.05 ± 0.42	0.09
057	0.03 ± 0.01	0.34 ± 0.04	3.38 ± 0.63	0.29
SU 8				
058	0.09 ± 0.02	0.38 ± 0.04	0.33 ± 0.45	0.10
059	0.28 ± 0.04	0.65 ± 0.07	0.29 ± 0.43	0.16
060	0.08 ± 0.02	0.57 ± 0.06	0.30 ± 0.42	0.14
061	0.06 ± 0.01	0.48 ± 0.04	0.76 ± 0.46	0.15
062	0.28 ± 0.04	0.71 ± 0.07	0.09 ± 0.39	0.16
063	0.25 ± 0.04	0.79 ± 0.08	0.26 ± 0.40	0.19

[a]Refer to Figure A-14

[b]Uncertainties are at the 95% confidence level based on total propagated uncertainties.

TABLE B-8:
RADIONUCLIDE CONCENTRATIONS IN SOIL
HIGH FLUX BEAM REACTOR "OUTSIDE AREAS"
HOT SPOTS
BROOKHAVEN NATIONAL LABORATORY
UPTON, NY

Sample ID/Location[a]	Coordinates Northing/Easting		Radionuclide Concentration (pCi/g)			
			Cs-137	Ra-226	Sr-90	SOR
019[b]	258437.9	1265147.6	0.85 ± 0.09[c]	0.38 ± 0.04	0.51 ± 0.88	0.15
020	258209.8	1295423.9	0.19 ± 0.03	0.26 ± 0.04	0.57 ± 0.47	0.10
021	258147.1	1295598.5	0.11 ± 0.02	0.61 ± 0.06	0.39 ± 0.43	0.15
022	258296	1295587.3	0.64 ± 0.07	0.21 ± 0.04	0.27 ± 0.67	0.09
023	258421.2	1295457.6	0.04 ± 0.01	0.18 ± 0.03	0.00[d] ± 0.44	0.04
064	258714	1295405	0.24 ± 0.04	0.51 ± 0.06	0.15 ± 0.40	0.12

[a]Refer to Figure A-14
[b]Composite of 3 samples (also includes 258434.3 N/1295446.5 E and 258429.5 N/1295447.5 E)
[c]Uncertainties are at the 95% confidence level based on total propagated uncertainties.
[d]"Zero" reported is due to rounding.

APPENDIX C

MAJOR INSTRUMENTATION

APPENDIX C

MAJOR INSTRUMENTATION

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

SCANNING INSTRUMENT/DETECTOR COMBINATIONS

Ludlum NaI Scintillation Detector Model SPA-3, Crystal: 2 inch x 2 inch
(Ludlum Measurements, Inc., Sweetwater, TX)
Coupled to
Ludlum Ratemeter-Scaler Model 2221
Coupled to
Trimble GeoXH Receiver and Data Logger (Trimble Navigation Limited, Sunnyvale, CA)

LABORATORY ANALYTICAL INSTRUMENTATION

High Purity Extended Range Intrinsic Detector
CANBERRA/Tennelec Model No: ERVDS30-25195
(Canberra, Meriden, CT)
Used in conjunction with:
Lead Shield Model G-11
(Nuclear Lead, Oak Ridge, TN)
Multichannel Analyzer
Dell Workstation and Canberra's Apex
Gamma Software (Canberra, Meriden, CT)

High Purity Extended Range Intrinsic Detector
Model No. GMX-45200-5
(AMETEK/ORTEC, Oak Ridge, TN)
used in conjunction with:
Lead Shield Model SPG-16-K8
(Nuclear Data)
Multichannel Analyzer
Dell Workstation and Canberra's Apex
Gamma Software (Canberra, Meriden, CT)

High-Purity Germanium Detector
Model GMX-30-P4, 30% Eff.
(AMETEK/ORTEC, Oak Ridge, TN)
Used in conjunction with:
Lead Shield Model G-16
(Gamma Products, Palos Hills, IL) and
Multichannel Analyzer
Dell Workstation and Canberra's Apex
Gamma Software (Canberra, Meriden, CT)

APPENDIX D

SURVEY AND ANALYTICAL PROCEDURES

APPENDIX D

SURVEY AND ANALYTICAL PROCEDURES

PROJECT HEALTH AND SAFETY

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

Pre-survey activities included an overview of potential health and safety issues. Representatives with the Brookhaven National Laboratory provided site-specific safety awareness training for each individual ORISE survey effort. In-process and verification surveys were performed according to the ORISE generic health and safety plan, site-specific integrated safety management (ISM) pre-job hazard checklist, and safety procedures discussed during the on-site training.

QUALITY ASSURANCE

Analytical and field survey activities were conducted in accordance with procedures from the following Oak Ridge Associated Universities (ORAU) and ORISE documents:

- Survey Procedures Manual
- Laboratory Procedures Manual
- Quality Program Manual

The procedures contained in these manuals were developed to meet the requirements of 10 CFR 830 Subpart A, *Quality Assurance Requirements*, Department of Energy Order 414.1C *Quality Assurance*, and the U.S. Nuclear Regulatory Commission *Quality Assurance Manual for the Office of Nuclear Material Safety and Safeguards* and contain measures to assess processes during their performance.

Quality control procedures include:

- Daily instrument background and check-source measurements to confirm that equipment operation is within acceptable statistical fluctuations.
- Participation in Mixed-Analyte Performance Evaluation Program (MAPEP), NIST Radiochemistry Intercomparison Program (NRIP), and Intercomparison Testing Program (ITP) Laboratory Quality Assurance Programs.
- Training and certification of all individuals performing procedures.
- Periodic internal and external audits.

CALIBRATION

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

SURVEY PROCEDURES

Surface Scans

Scans for elevated gamma radiation were performed by passing the detector slowly over the surface. The distance between the detector and surface was maintained at a nominal distance of about 1 to 5 cm. NaI scintillation detectors were coupled to GPS units that enabled real-time recording of position in one-second intervals. Identification of elevated radiation levels was based on increases in the audible signal from the instrument. Positioning data files were downloaded from field data loggers for plotting using commercially available software (http://trl.trimble.com/docushare/dsweb/Get/Document-261826/GeoExpl2005_100A_GSG_ENG.pdf).

The scan minimum detectable concentrations (MDC) for the NaI scintillation detector for the contaminants of concern in surface soil are typically obtained directly from NUREG-1507 when

available or can be estimated using the calculational approach described in NUREG-1507[1]. A typical NaI 2 inch by 2 inch detector MDC for Cs-137 is 6.4 pCi/g. Audible increases in the activity rate are investigated by ORISE. It is standard procedure for the ORISE staff to pause and investigate any locations where gamma radiation is distinguishable from background levels.

Soil Sampling

Approximately 0.5 to 1 kg of soil was collected at each sample location. Collected samples were placed in plastic bags, sealed, and labeled in accordance with ORISE survey procedures.

RADIOLOGICAL ANALYSIS

Detection Levels

Detection limits, referred to as MDC, were based on 3 plus 4.65 times the standard deviation of the background count [$3 + (4.65\ (BKG)^{1/2})$]. Because of variations in background levels, measurement efficiencies, and contributions from other radionuclides in samples, the detection limits differ from sample to sample and instrument to instrument.

Strontium Analysis

Soil samples were dissolved by a combination of potassium hydrogen fluoride and pyrosulfate fusions. The fusion cake was dissolved and strontium was coprecipitated on lead sulfate. The strontium was separated from residual calcium and lead by reprecipitating strontium sulfate from ethylenediaminetetraacetic acid at a pH of 4.0. Strontium was separated from barium by complexing the strontium in diethylene triamine pentaacetic acid while precipitating barium as barium chromate. The strontium was ultimately converted to strontium carbonate and counted on a low-background gas proportional counter. The typical MDC of the procedure is 0.4 pCi/g for a one hour count time.

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

Gamma Spectroscopy

Samples of soil were dried, mixed, crushed, and/or homogenized as necessary, and a portion sealed in a 0.5-liter Marinelli beaker or other appropriate container. The quantity placed in the beaker was chosen to reproduce the calibrated counting geometry. Net material weights were determined and the samples counted using intrinsic germanium detectors coupled to a pulse height analyzer system. Background and Compton stripping, peak search, peak identification, and concentration calculations were performed using the computer capabilities inherent in the analyzer system. All total absorption peaks (TAP) associated with the radionuclides of concern were reviewed for consistency of activity. Total absorption peaks used for determining the activities of radionuclides of concern and the typical associated MDCs for a one-hour count time were:

Radionuclide	TAP (MeV)	MDC (pCi/g)
Cs-137	0.662	0.05
Ra-226 (from Pb-214)	0.351	0.08

Spectra were also reviewed for other identifiable TAPs.

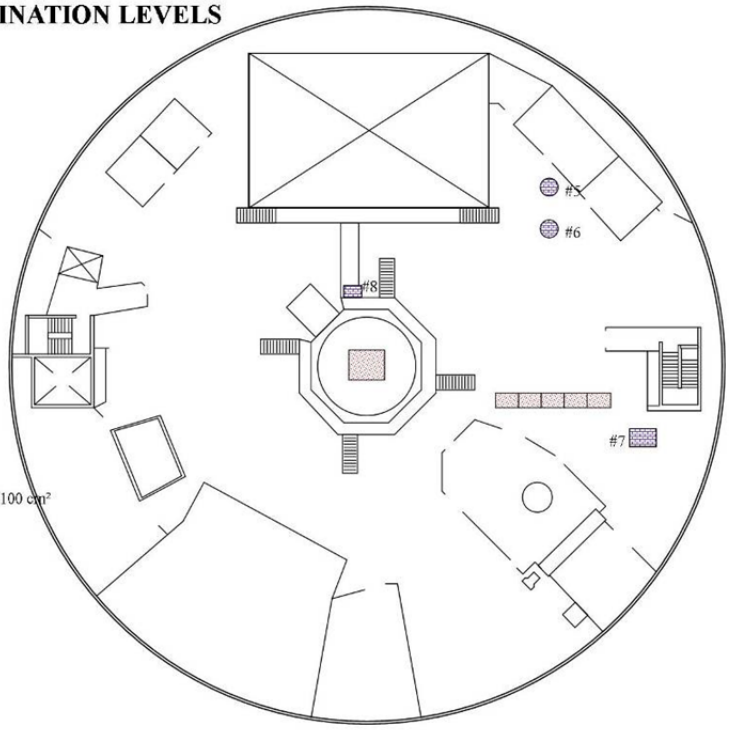
Uncertainties

The uncertainties associated with the analytical data presented in the tables of this report represent the total propagated uncertainties for those data. These uncertainties were calculated based on both the gross sample count levels and the associated background count level.

Appendix E

Building 750
End-State Radiological Surveys

HFBR OPERATIONS LEVEL
END-STATE CONTAMINATION LEVELS



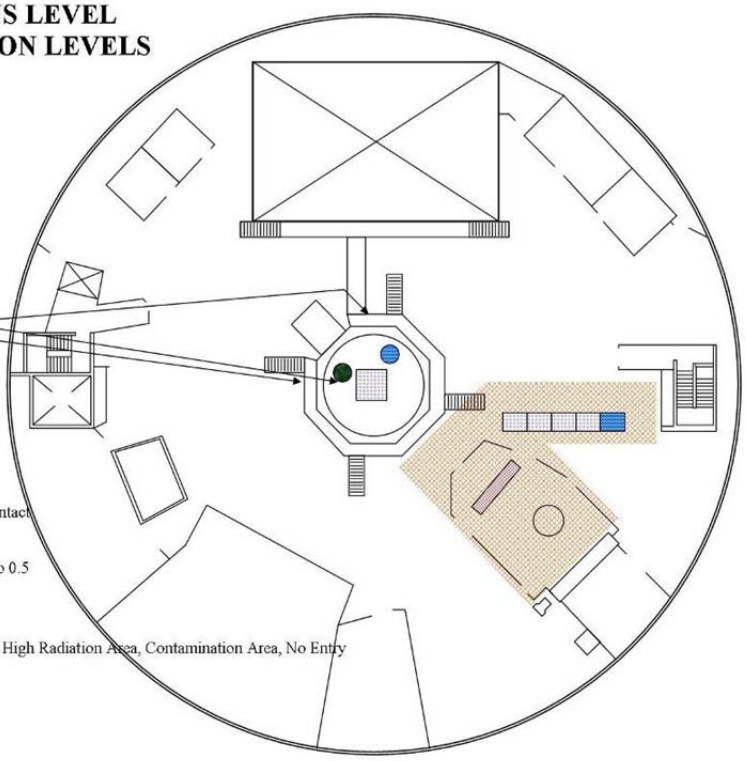
= Contamination levels <1000 dpm/100 cm²

= Contamination Areas

= Fixed Contamination Areas

#5 ~3500 cpm with LUD 3 frisker
#6 ~600 cpm with LUD 3 frisker
#7 ~3000 cpm with LUD 3 frisker
#8 ~500 cpm with LUD 3 frisker

HFBR OPERATIONS LEVEL
END-STATE RADIATION LEVELS



Bio-Shield verification survey locations

= tank #750-39 25 mR/hr on contact 5 mR/hr at 30 cm

= 1 to 2 mR/hr on contact 0.4 to 0.5 mR/hr at 30 cm

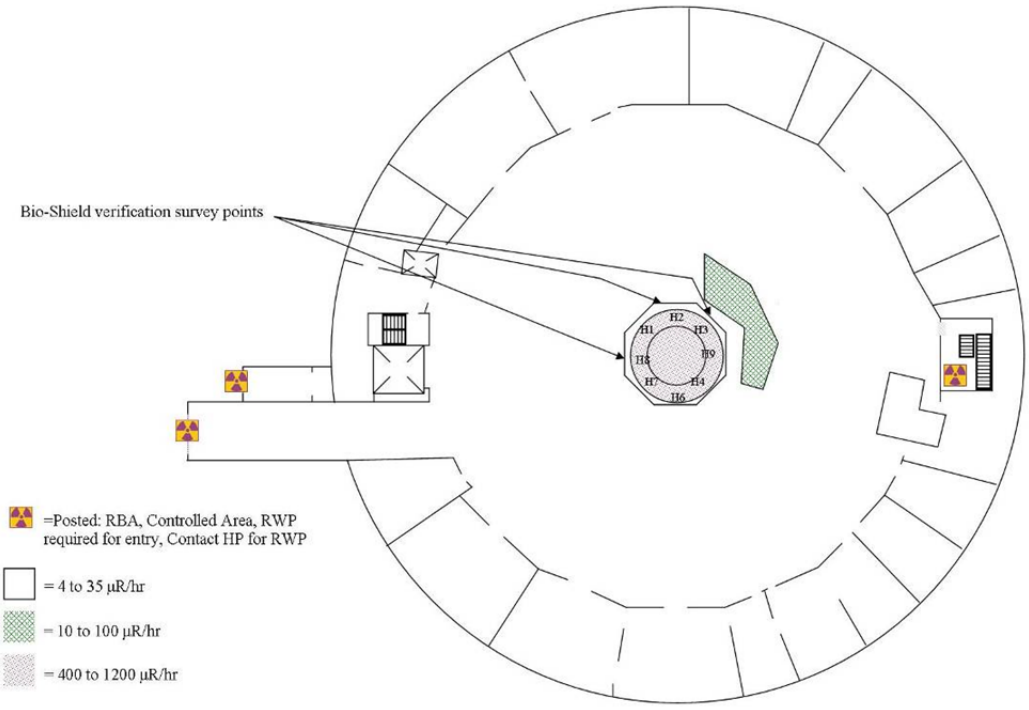
= Contamination Area

= Rx plug Grave Danger, Very High Radiation Area, Contamination Area, No Entry

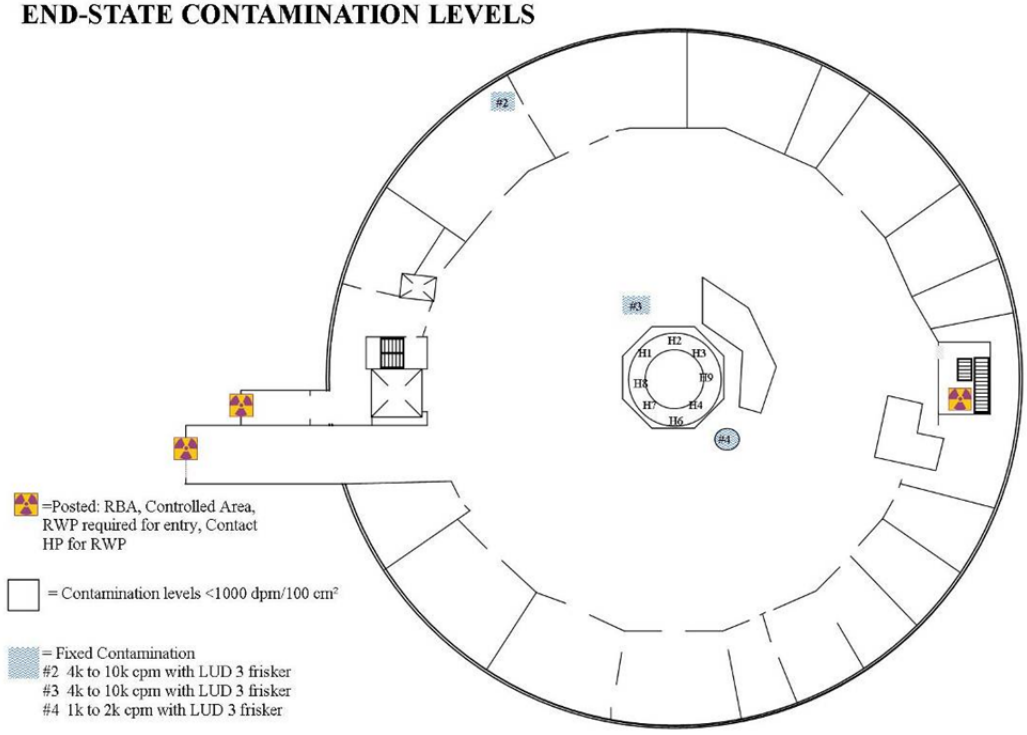
= 25 to 150 µR/hr

= 3 to 10 µR/hr

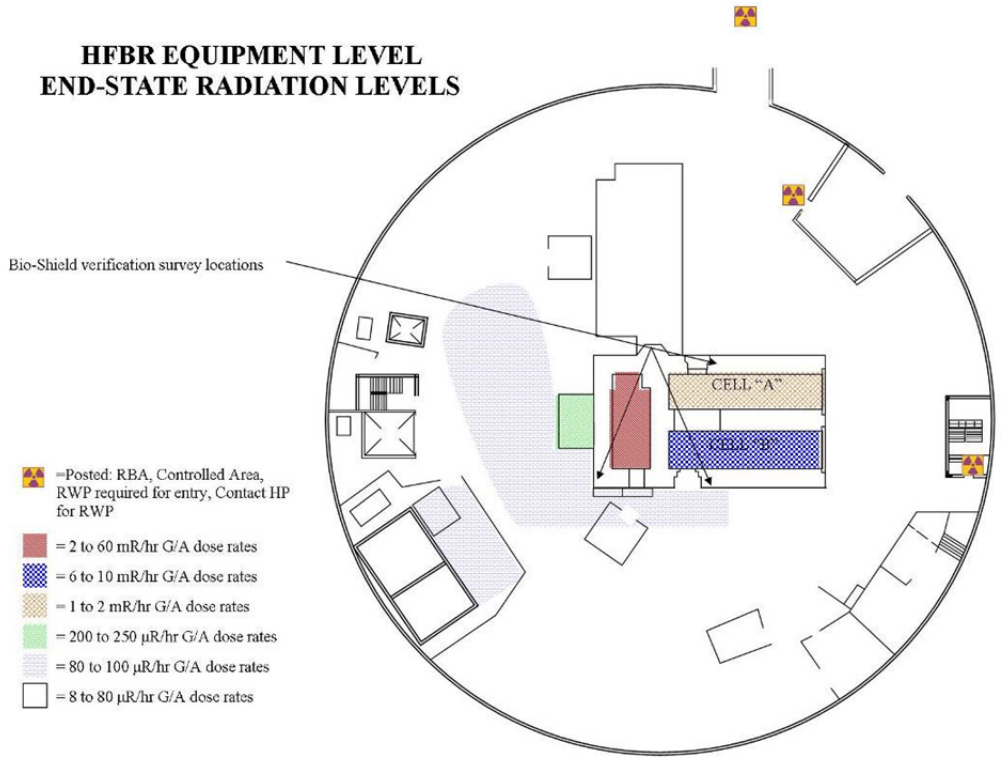
HFBR EXPERIMENTAL LEVEL
END-STATE RADIATION LEVELS



HFBR EXPERIMENTAL LEVEL
END-STATE CONTAMINATION LEVELS



HFBR EQUIPMENT LEVEL
END-STATE RADIATION LEVELS



HFBR EQUIPMENT LEVEL
END-STATE CONTAMINATION LEVELS