Final
CLOSEOUT REPORT

High Flux Beam Reactor
Removal of the Stack Silencer Baffles and Final Status Survey for Remaining HFBR Outside Areas
Area of Concern 31

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Executive Summary

The High Flux Beam Reactor (HFBR) Stack Silencer Baffles and the Remaining HFBR Outside Areas are associated with Area of Concern (AOC) 31 at Brookhaven National Laboratory (BNL). Activities associated with removal of the silencer baffles, the stabilization of the remaining concrete silencer structure, the as-left radiological survey of the remaining concrete silencer structure and the final status survey (FSS) of the remaining HFBR Outside Areas, referred to herein as the HFBR Silencer Baffle Removal Project, are part of the actions described as near-term 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 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) and the *Field Sampling Plan Building 705 (Stack) and Remaining HFBR Outside Areas* (December, 2010).

Remedial activities associated with the HFBR Silencer Baffle Removal Project commenced in June 2011 and were completed in November 2011. Upon completing the removal of the silencer baffles and the stabilization of the remaining concrete silencer structure, an as-left radiological survey of the silencer structure was performed. The as-left radiological survey included the collection of dose rates, a direct frisk of the concrete walls and the collection of smears to determine loose contamination levels on the internal concrete surfaces of the silencer. In addition, an FSS and independent verification survey (IVS) of the remaining HFBR Outside Areas were completed to ensure that soil cleanup objectives were met in accordance with the HFBR ROD. The soil cleanup objectives for radiological contamination 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 United States Department of Energy (DOE), and industrial land use with no decay time (Year 0).

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

- The highest contact dose rate on the silencer concrete was 1.0 milliRoentgens per hour (mR/hr). The highest general area dose rate within the remaining silencer structure, taken at waist level, was 0.8 mR/hr. Direct frisk results of the silencer walls ranged from 5,000 to 6,000 counts per minute (cpm).

- Smear results showed alpha and beta contamination levels were generally below release levels (Table 2-2 of the BNL Radiological Control Manual) on the upper silencer walls and were generally greater than release levels on the lower walls and floor. Alpha results were all less than 20 disintegrations per minute (dpm) on

the above grade upper concrete walls and ledge surfaces with one beta result exceeding 1,000 dpm at 1,221 dpm.

- On the below-grade lower concrete silencer wall and floor surfaces, alpha results exceeded 20 dpm at several locations with the highest level of 164 dpm. The highest beta smear result on the lower concrete silencer surfaces was 35,703 dpm.

- The average cesium (Cs)-137 and strontium (Sr)-90 concentrations detected in the remaining HFBR Outside Areas surface soils were below laboratory detection limits, 0.25 picocuries per gram (pCi/g) and 0.09 pCi/g, respectively. The average radium (Ra)-226 concentration detected in the surface soils was 0.44 pCi/g. The maximum concentrations detected in surface soil samples were as follows: 0.63 pCi/g for Cs-137, 1.32 pCi/g for Sr-90, and 0.67 pCi/g for Ra-226. The maximum concentrations detected in core soil samples (0 to 6 feet below land surface) were as follows: 5.9 pCi/g for Cs-137, less than laboratory detection limits (2.0 pCi/g) for Sr-90, and 0.64 pCi/g for Ra-226. The as-left 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 as-left average concentrations of the chemical contaminants of concern detected in soil samples are below the site cleanup goals (lead = 400 milligrams per kilogram (mg/kg), mercury = 1.84 mg/kg, nickel = 140 mg/kg, copper = 270 mg/kg and zinc = 2,200 mg/kg). The maximum concentrations of lead, mercury, nickel, copper and zinc detected in surface and core soil samples were 91.5 mg/kg, 0.21 mg/kg, 4.6 mg/kg, 13.8 mg/kg and 78.3 mg/kg, respectively.

- For the remaining HFBR Outside Areas, the maximum projected dose to a resident (non-farmer) after 50 years of institutional controls is 0.3 mrem/yr. For a resident with no decay time (Year 0), the maximum projected annual dose is 0.9 mrem/year. The maximum projected dose to an industrial worker with no decay time (Year 0) is 0.2 mrem/yr. The results of the dose assessment are well below the limits established in the HFBR ROD, including the dose objective of 15 mrem/yr and the New York State Department of Environmental Conservation (NYSDEC) cleanup guideline of 10 mrem/yr from Technical and Administrative Guidance Memorandum (TAGM) 4003, which was adopted as an As Low As Reasonably Achievable (ALARA) goal.

- Site restoration for the HFBR Silencer Baffle Removal Project was completed in September 2011. Restoration included backfilling of the silencer to grade, construction of a wood and asphalt roof, and radiological free release and removal of the containment tents.

The HFBR Silencer Baffle Removal Project meets all the completion requirements as specified in OSWER Directive 9320.2-09-A-P, *Closeout Procedures for National Priorities List Sites.*

A surveillance and maintenance (S&M) manual, *Draft Surveillance and Maintenance Manual for the High Flux Beam Reactor (HFBR) Grounds & Stack* (BNL, January 2012) will be finalized and will include the post remediation monitoring and maintenance activities for the HFBR grounds and the Stack. The S&M Manual will include requirements and frequency of monitoring and maintenance for the Stack Drain Tank and associated disposal of collected fluids as well as inspection requirements for the Stack systems (ladder, platforms, lighting, etc.). The S&M manual will include discussion of applicable institutional controls (land use controls, notifications and restrictions, work planning controls such as digging permits, and government ownership).

BSA will perform surveillance and maintenance activities. In addition to maintaining institutional controls for the silencer and remaining HFBR Outside Areas, BSA will ensure that routine monitoring/inspections/maintenance associated with the Stack Drain Tank and other Stack systems (ladder, platforms, lighting, etc.) are performed. DOE will ensure enforcement of all institutional controls.

The following scope of work associated with the Stack and surrounding area has not yet been completed and will be performed before 2020 in accordance with the HFBR ROD:

- Demolition of the Stack;
- Removal of silencer structure and associated contaminated fill material;
- Removal of the Silencer Drain Sump;
- Removal of the remaining section of old Stack Drain Line;
- Removal of the current Stack Drain Tank, associated lines and electrical components;
- Performing a Final Status Survey of the excavation areas;
- Conducting an IVS performed by the Oak Ridge Institute for Science and Education (ORISE);
- Restoring the site to grade.

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ACRONYM LIST

Ac	Actinium
ALARA	As Low As Reasonably Achievable
Am	Americium
ANL	Argonne National Laboratory
AOC	Area of Concern
ARRA	American Recovery and Reinvestment Act
BNL	Brookhaven National Laboratory
BSA	Brookhaven Science Associates
BGD	Below Ground Duct
BGRR	Brookhaven Graphite Research Reactor
C	Carbon
CAC	Community Advisory Council
CDM	CDM Federal Programs Corporation
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFM	Cubic Feet per Minute
cm^2	square centimeter
cpm	counts per minute
Co	Cobalt
Cs	Cesium
DOE	United States Department of Energy
D&D	Decontamination and Dismantlement
DOT IP	United States Department of Transportation
dpm	Disintegrations per Minute
EM	Environmental Management
EPA	United States Environmental Protection Agency
EPD	Environmental Protection Division
ERP	Environmental Restoration Projects
Eu	Europium
F&O	Facilities and Operations
FRDP	Facility Review Disposition Project
FS	Feasibility Study
FSP	Field Sampling Plan
FSS	Final Status Survey
GPS	Global Positioning System
HEPA	High Efficiency Particulate Air
HFBR	High Flux Beam Reactor
HEMO	Heavy Equipment Machine Operator
I	Iodine
IAG	Interagency Agreement
IH	Industrial Hygiene
IP	Industrial Package
IV	Independent Verification
IVS	Independent Verification Survey

JRA	Job Risk Assessment
JSA	Job Safety Analyses (JSAs)
LLRW	Low-Level Radioactive Waste
MARSSIM	Multi-Agency Radiation Survey & Site Investigation Manual
mCi	millicuries
mda	minimum detectable activity
mg/kg	milligrams per kilogram
mR/hr	milliRoentgens per hour
mrem/yr	millirem per year
NaI	Sodium Iodide
Ni	Nickel
NNSS	Nevada National Security Site
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
pCi/g	picocuries per gram
PIC	Person-in-Charge
PCBs	Polychlorinated Biphenyls
PPE	Personal Protective Equipment
PRAP	Proposed Remedial Action Plan
Pu	Plutonium
QA/QC	Quality Assurance/Quality Control
Ra	Radium
RCT	Radiological Controls Technician
RESRAD	Residual Radioactivity Computer Code
RFP	Request for Proposal
RI	Remedial Investigation
ROD	Record of Decision
RWP	Radiological Work Permit
S&M	Surveillance and Maintenance
SOPs	Standard Operation Procedures
SBMS	Standards Based Management System
S&M	Surveillance and Maintenance
Sr	Strontium
SU	Survey Units
TAGM	Technical and Administrative Guidance Memorandum
Th	Thorium
TLDs	Thermoluminescent Dosimeters
U	Uranium
USC	United States Code
WAC	Waste Acceptance Criteria
yd^3	Cubic Yard

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1.0 INTRODUCTION

1.1 Purpose

The purpose of this closeout report is to document the completed actions associated with the removal of the baffles from within the silencer located at the base of the High Flux Beam Reactor (HFBR) Stack (Building 705). This closeout report also documents: 1) the results of an as-left survey of the inside surfaces of the remaining concrete of the silencer structure, backfill of the inside of the silencer to grade, and installation of a new roof, and 2) the results of the Final Status Survey (FSS) for the remaining HFBR Outside Areas. This work is referred to herein as the “HFBR Silencer Baffle Removal Project.” The HFBR is designated as Area of Concern (AOC) 31 at Brookhaven National Laboratory (BNL). The HFBR Silencer Baffle Removal 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).

Remedial activities associated with the HFBR Silencer Baffle Removal 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.

Work was performed in accordance with the HFBR ROD and the *Field Sampling Plan for Building 705 (Stack) and Remaining HFBR Outside Areas* (December, 2010).

The scope of work for the HFBR Silencer Baffle Removal Project included the following:

- Design and installation of a contamination control tent;
- Removal of 12 silencer concrete roof plugs;
- Removal of the 32 silencer baffles;
- Packaging, transport and disposal of the roof plugs and silencer baffles at an off-site permitted facility;
- Application of fixative and performing an as-left survey of the remaining silencer concrete;
- Performing an FSS of the remaining HFBR Outside Areas survey units (SU) (SU-6, SU-7, and SU-8) as identified in the *Field Sampling Plan for Building 705 (Stack) and Remaining HFBR Outside Areas* (December 2010);
- An independent verification survey (IVS) performed by the Oak Ridge Institute for Science and Education (ORISE);
- Backfilling the silencer to grade and installing a new roof;

- Radiological release survey and removal of the containment control tent; and
- Preparation of a closeout report.

The following scope of work associated with Building 705 (Stack) and surrounding area has not yet been completed and will be performed before 2020 in accordance with the HFBR ROD and the *Final Remedial Design/Remedial Action Work Plan for the Decontamination and Dismantlement (D&D) of the Stack and Removal of the HFBR Underground Utilities* (BNL, August 2010):

- Demolition of the Stack;
- Removal of silencer structure and associated contaminated fill material;
- Removal of the Silencer Drain Sump;
- Removal of the remaining section of old Stack Drain Line;
- Removal of the current Stack Drain Tank, associated lines and electrical components;
- Completion of an FSS of the excavation areas;
- Completion of an IVS performed by ORISE ;
- Restoring the site to grade.

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, the 200-acre Long Island Solar Farm, the Former Hazardous Waste Management Area, the Sewage Treatment Plant, firebreaks, and the Former Landfill Area. The terrain is gently rolling, with elevations varying between 40 to 120 feet 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 feet below the land surface. These three water-bearing units are designated as a “sole source aquifer” by the United States 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.

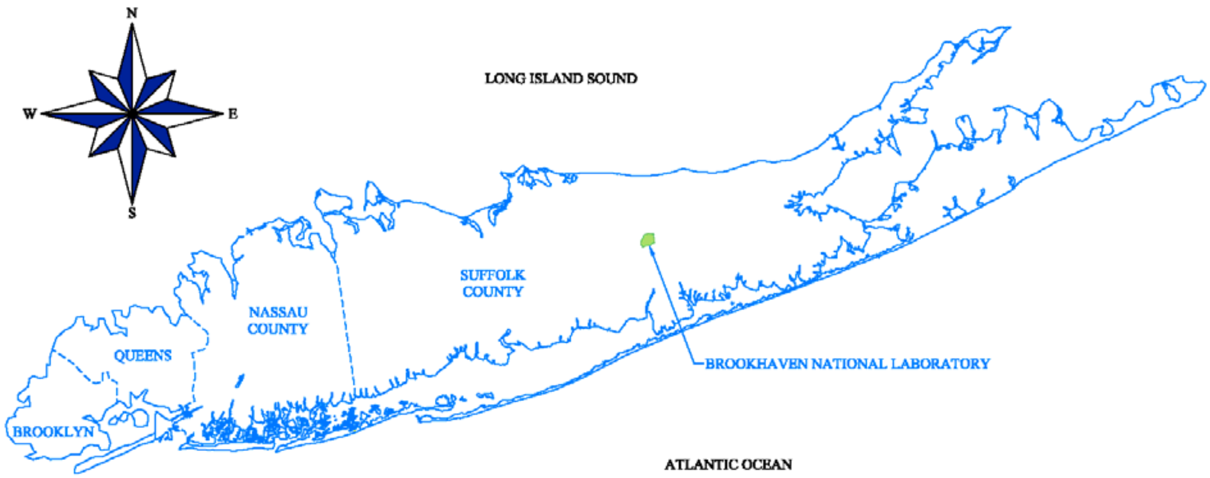


Figure 1-1 Location of Brookhaven National Laboratory

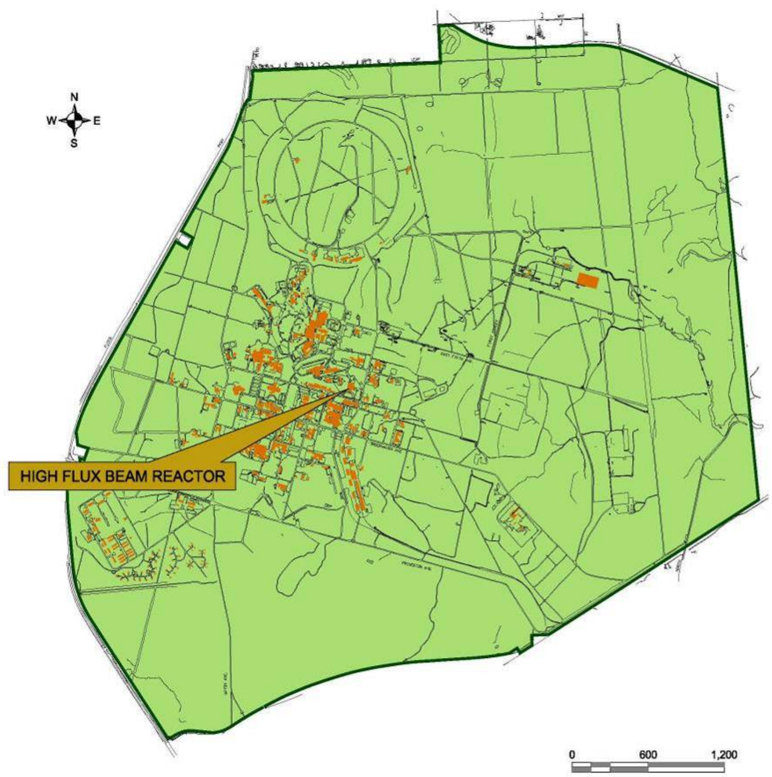


Figure 1-2 HFBR Complex Location at BNL

The HFBR complex is centrally located within the BNL site, as shown in Figure 1-2. The HFBR (Building 750) was designed and constructed for basic experimental research. During its operating lifetime from 1965 to 1996, it provided neutrons for materials science, chemistry, biology, and physics experiments. The Brookhaven Graphite Research Reactor (BGRR) (Building 701) was the first reactor in the United States built solely to perform experiments. It operated from 1950 to 1968. The locations of the HFBR, BGRR, and the Stack are illustrated in Figure 1-3.

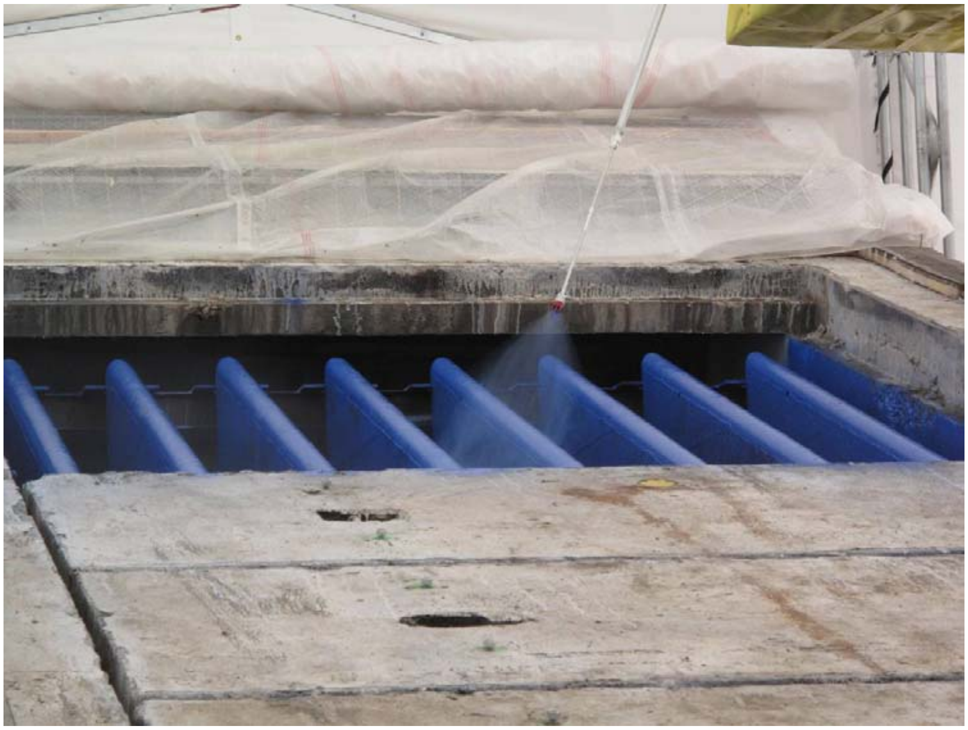
1.2.1 Silencer Description

The silencer is an acoustic filter that was installed at the eastern end of the Below Ground Duct (BGD), connecting the former Fan House (Building 704) and the Stack (Photograph 1). The silencer was constructed of poured reinforced concrete walls and floor with a concrete roof plug system consisting of 11 roof plugs and one key plug. A wood and asphalt secondary roof was installed over the concrete roof plugs.

The silencer is 10 feet wide by 15 feet 10 inches high, and the walls are nine inches thick. The silencer transitions from the BGD to the base of the Stack at an 18.5 degree angle. There were 32 baffles inside the silencer set in four rows of eight. Each baffle had a frame in the form of a parallelogram constructed of 3.5-inch steel pipe. The sides of each baffle were 15 feet 8 inches and the top and bottom were each 10 feet wide. The top and bottom were inclined 18.5 degrees from horizontal. Nine horizontal steel channels were countersunk into the vertical 3.5-inch steel pipe for support. The sides of each baffle were covered with a 0.0625-inch steel sheet with 0.25-inch perforated holes. The inside of each baffle was filled with unbound pink fiberglass insulation.

Photograph 1 – Visible Section of the Silencer prior to Beginning Work

Each set of eight baffles was secured in-place by an I-Beam anchored between the vertical walls of the concrete duct (Photograph 2). A schematic of the HFBR silencer and baffles is provided in Figure 1-4.



Photograph 2 – First Row of Baffles after Roof Plugs are Removed

1.2.2 Remaining HFBR Outside Areas

The HFBR Outside Areas include all grounds around the HFBR, Building 750, as defined by the HFBR Complex Boundary (Figure 1-3). FSS plans were developed and included all the areas within the HFBR Complex Boundary. These FSS's were to be performed at the completion of all remedial activities associated with the HFBR (Underground Utilities Project, Fan Houses Project and Stack Demolition Projects). The HFBR Complex was divided into eleven SUs. The FSS for eight of the SUs (HFBR Outside Areas) was completed in 2010 and is documented in the *Final Closeout Report, High Flux Beam Reactor Stabilization, Area of Concern 31,* (BNL, July 2011). The FSS for the remaining three SUs (remaining HFBR Outside Areas) are documented in Section 3.2 and their location provided on Figure 1-3.

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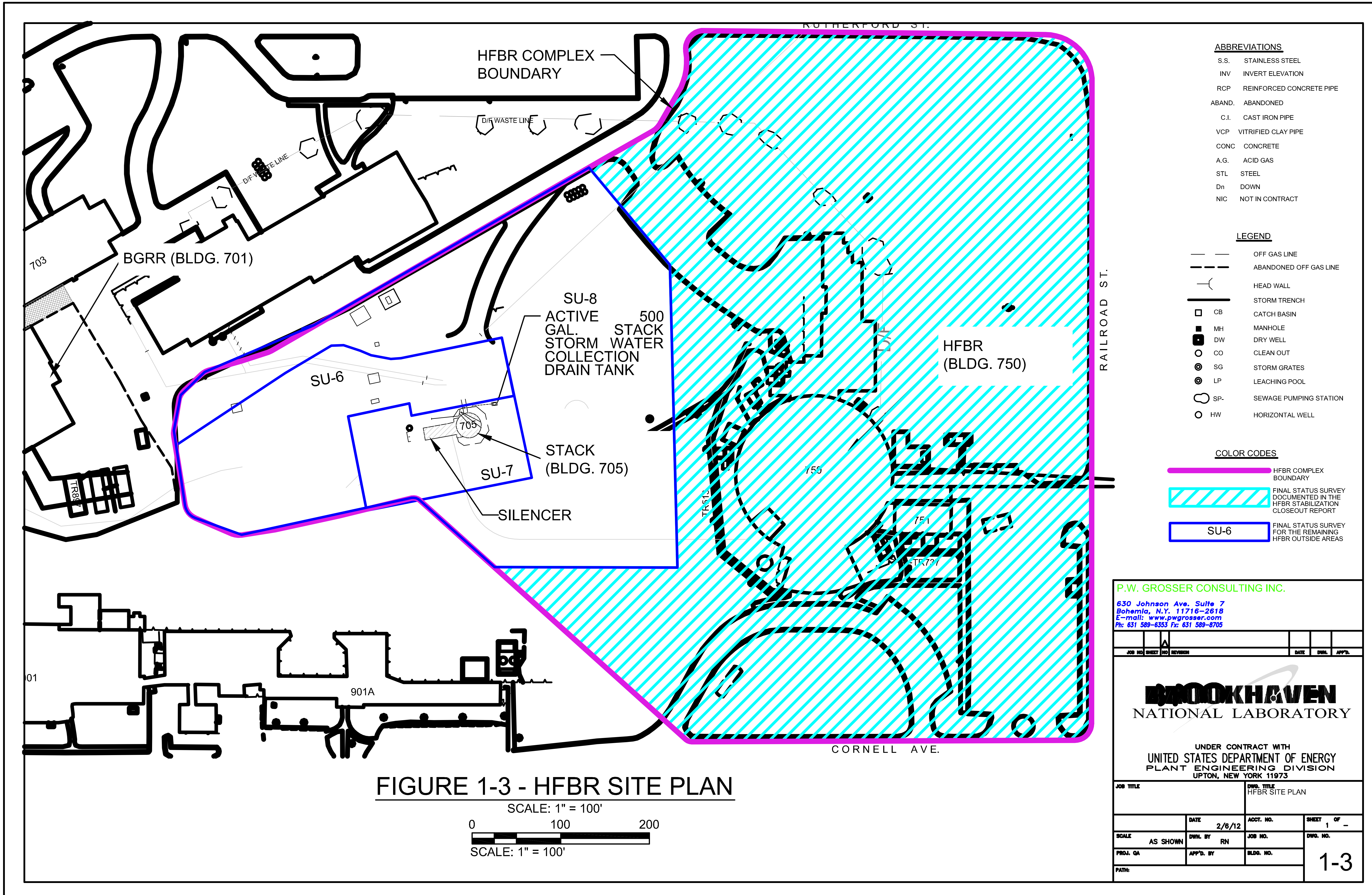
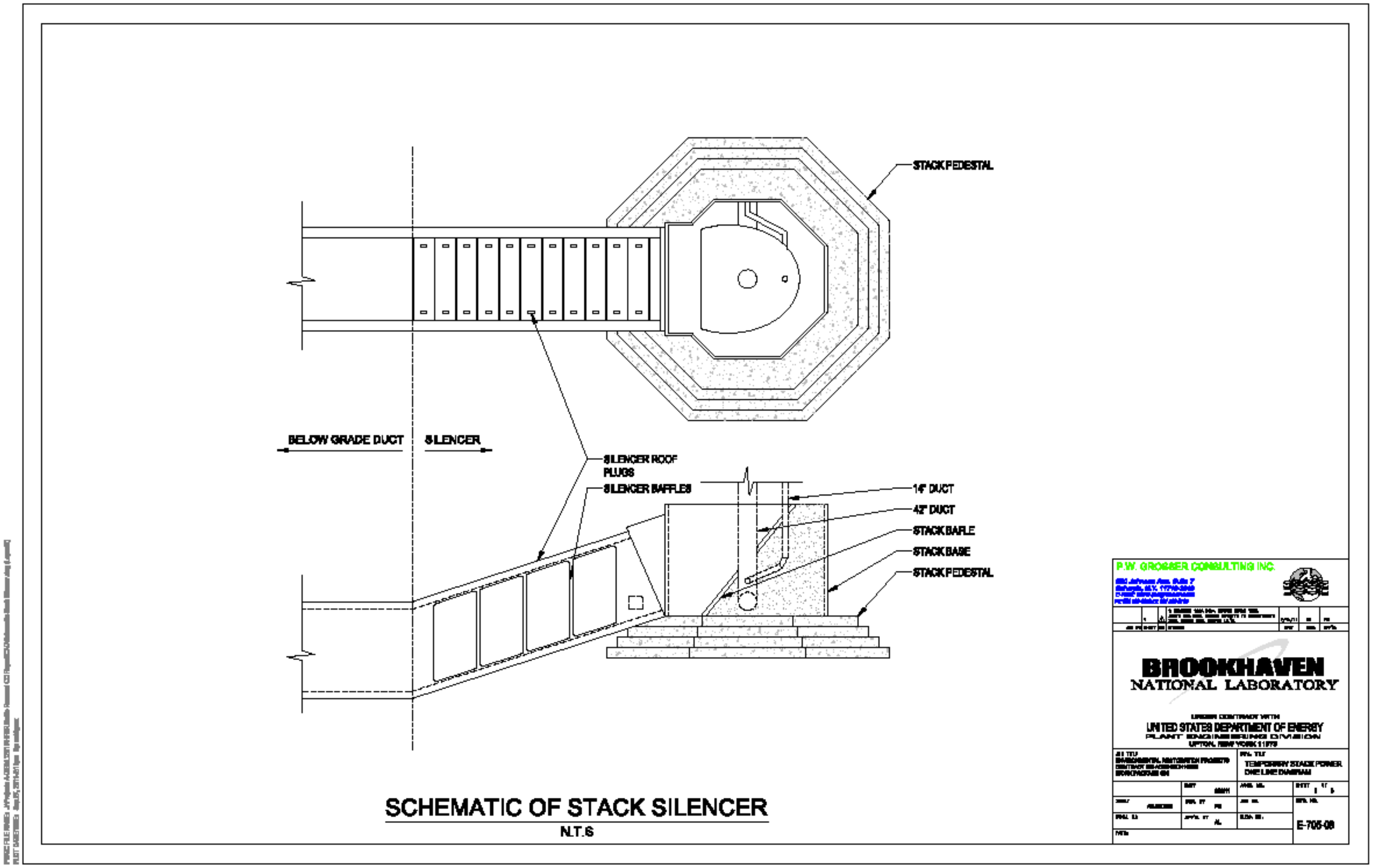


FIGURE 1-3 - HFBR SITE PLAN

Figure 1-4 – HFBR Silencer and Baffle Schematic



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 United States Environmental Protection Agency (EPA) National Priorities List because of soil and groundwater contamination that resulted from BNL's past operations. Subsequently, EPA, NYSDEC, and the U.S. Department of Energy (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 Operable Units (OUs) to be evaluated for response actions. The IAG required a remedial investigation (RI)/feasibility study (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 1.6 and 2.0.

Upon completion and review of the results of the RI/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)* (OU I 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 HFBR ROD (AOC 31) was finalized. The HFBR ROD specified the removal of ancillary buildings and underground utilities, Fan Houses, and Stack as well as 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 Previous Characterization for the Silencer and Remaining HFBR Outside Areas

Sampling and analyses were performed to characterize the HFBR complex between 2000 and 2010. These activities included both radiological and non-radiological characterization of surface and subsurface soils, various underground duct and piping systems and HFBR ancillary buildings. Radiological characterization of the interior surfaces of the Stack and silencer indicated that they were contaminated above the free release criteria specified in Table 2-2 of the BNL Radiological Controls Manual.

Characterization efforts included collection of smear and Maslin samples from the interior lower portion of the Stack (the base near the underground plenum inlet) and silencer, collection and sampling of concrete cores from various elevations of the Stack, sampling of soils near the Stack, sampling of liquids collected from the Stack. The characterization findings and conclusions are summarized below:

- Radiological survey data from the interior of the Stack and silencer demonstrate that the Stack interior is radiologically contaminated with Cesium (Cs)-137, Strontium (Sr)-90 and tritium when compared to the criteria specified in Table 2-2 of the BNL Radiological Controls Manual. Contamination is primarily limited to the first 1/4" of the concrete, with localized contamination up to 3/4". A summary of silencer survey results are included in Table 1-1.

- Soil samples from the vicinity of the Stack and silencer showed minimal presence of Cs-137 and Ra-226 in the soil.

- The Stack and silencer paint samples do not exceed federal hazardous waste level determinations for lead or polychlorinated biphenyls (PCBs).

- The Stack paint samples tested positive for asbestos.

The HFBR ROD identified isolated areas of radiological soil contamination (Cs-137 and Cobalt [Co]-60) within the HFBR property; however these isolated areas were addressed by the HFBR Stabilization Project and the Fan Houses Project.

Characterization of the HFBR soils, structures and underground duct and piping systems is discussed 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).

Table 1-1 Summary of Silencer Radiological Survey Results

	Inside Silencer			
	Pre survey October 2010 (dpm/100 cm²)	**Post fixative October 2010 (dpm/100 cm²)**	**Pre survey July 2010 (dpm/100 cm²)**	**Post fixative April 2010 (dpm/100 cm²)**
Walls and floor	2K – 10K βγ <mda – 25 α	<1K βγ <mda α	2K – 10K βγ	<1K βγ <mda α
On silencer panels	11K – 27K βγ <42 – 140 α	1K – 4K βγ <mda α	80K βγ	<1K βγ <20 α
Exposed inner fiberglass	10K βγ	<1K βγ <mda α	N/A	N/A

Notes:

The contamination on the inside surface of the insulation when the cover was pulled back was 4K – 277K dpm/100cm² βγ and 1K dpm/100 cm² α.
The silencer panels read 8 mR/hr on contact and 3 mR/hr @ 30 cm.
cm^2 = square centimeters
dpm = disintegrations per minute
mda = minimum detectable activity

1.5 Previous Remedial Activities

With the exception of the Stack demolition, all scheduled remedial activities (HFBR Stabilization Project, Underground Utilities Removal Project, and Fan Houses Demolition Project) associated with the HFBR Complex were completed before the Silencer Baffle Removal Project and the FSS for the remaining HFBR Outside Areas were initiated. These activities are documented in separate closeout reports.

1.6 BNL Operable Units

As part of the initial 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, was established.

This report documents completion of the included scope (Section 1.1) associated with 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 remaining HFBR Outside Areas FSS.

2.0 OPERABLE UNIT BACKGROUND

2.1 Site Cleanup Criteria

The primary radiological contaminants of concern for the soil within the remaining HFBR Outside Areas were specified in the HFBR ROD and are the same as those for OU I radiologically contaminated soils: Cs-137, radium (Ra)-226, and Sr-90. The cleanup goals for specific radionuclides were calculated using the Residual Radioactivity Computer Code (RESRAD), Version 6.5 (Argonne National Laboratory (ANL), 2001), 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 after 50 years of institutional control by the DOE, and industrial land use with no decay time (Year 0). In addition, the NYSDEC cleanup guideline of 10 mrem/yr, from Technical and Administrative Guidance Memorandum (TAGM) 4003, was adopted as an As Low As Reasonably Achievable (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 picocuries per gram (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 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. Previous site investigations within the HFBR Complex indicated that the Stack and silencer were contaminated with Co-60. This radionuclide, in addition to europium (Eu)-152, Eu-154, uranium (U)-235, U-238, plutonium (Pu)-238, Pu-239/240 and americium (Am)-241, 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 soil within the remaining 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 considered chemical contaminants of concern since they 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 use 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 remaining HFBR Outside Areas

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)
Tritium	424(2)	(1)
Co-60	1,260 (3)	(1)
Eu-152	51 (3)	(1)
Eu-154	180 (3)	(1)
U-235	4.6 (4)	(1)
U-238	4.7 (4)	(1)
Pu-238	57	(1)
Pu-239/Pu-240	35	(1)
Am-241	34	(1)
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 mg/kg	6NYCRR Part 375 Restricted Use – Soil Cleanup Objectives, Residential
Copper	270 mg/kg	6NYCRR Part 375 Restricted Use – Soil Cleanup Objectives, Residential
Zinc	2,200 mg/kg	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 or in other BNL remediation references. A RESRAD evaluation was used as described in 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.
3. The value is based on a RESRAD evaluation for a residential scenario with 50 years of decay.
4. Values listed for uranium are based on 4 mrem/yr from groundwater consumption.

An as-left survey was completed for the silencer once the baffles were removed. The release levels from the BNL Radiological Control Manual were used as goals for the as-left condition of the silencer. The release levels are provided on Table 2-2.

Table 2-2 Summary of BNL Radiological Control Manual Release Levels for On-Site Surface Contamination*

Nuclide	Removable (dpm/100cm^2)	Total (fixed + removable, dpm/100cm^2)
U-natural, U-235, U-238 and associated decay products	1,000 alpha	5,000 alpha
Transuranics, Ra-226, Ra-228, Thorium (Th)-230, Th-228, Pa-231, Actinium (Ac)-227, Iodine (I)-125, I-129	20	500
Th-natural, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	200	1,000
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above. Includes mixed fission products containing Sr-90.	1,000 beta-gamma	5,000 beta-gamma
Tritium	10,000	10,000

Notes:

* From Table 2-2 of the BNL Radiological Control Manual
cm^2 = square centimeters
dpm = disintegrations per minute

2.2 Design Criteria

Technical procedures and design criteria for the HFBR Silencer Baffles Removal Project were established in the HFBR ROD, the *Field Sampling Plan for Building 705 (Stack) and Remaining HFBR Outside Areas* (December, 2010) and the BNL Standards Based Management System (SBMS). The design included:

- 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 Silencer Baffles Removal Project.

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
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 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 indicated that there was 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 Complex Projects was discussed with the BNL Community Advisory Council (CAC) on April 15, 2009, November 12, 2009 and November 4, 2010. In addition, the HFBR Silencer Baffle Removal Project, as well as removal of the Stack by 2020, were discussed with the BNL CAC on November 10, 2011. Minutes from these meetings are available on the BNL Community Relations website, located at: http://www.bnl.gov/community/cac/meetings.asp.

3.0 CONSTRUCTION ACTIVITIES

The objective of the HFBR Silencer Baffle Removal Project was to safely remove the majority of the 331 millicuries (mCi) of radiological activity contained in the Stack structures. This was accomplished by removing the 32 silencer baffles, which contained approximately 301 mCi of activity. The remaining structure was placed in a safe configuration until its removal following demolition of the HFBR Stack, which is scheduled to be completed by 2020. Following the baffle removal, a fixative was applied to the remaining internal silencer surfaces and an as-left radiological survey was performed. The silencer cavity was then backfilled to grade with soil and a new wooden and asphalt roof was constructed.

Project-specific work procedures, Job Safety Analyses (JSAs), and Radiological Work Permits (RWPs) were developed to address hazards and work steps associated with the HFBR Silencer Baffle Removal 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 to site workers at all times.

Completion of the HFBR Silencer Baffle Removal Project was accomplished without any worker injuries categorized as lost time accidents.

3.1 Removal of the Stack Silencer Baffles

Removal of the Stack silencer baffles and the FSS of the remaining HFBR Outside Areas took place between June 2011 and November 2011.

3.1.1 Temporary Wall Construction

A temporary wall was constructed between the silencer and the Stack (Photograph 3). The wall was constructed using wood framing and layers of plastic. The wall created a barrier between the silencer and the Stack, preventing contamination from entering the Stack and isolating the silencer so that a High Efficiency Particulate Air (HEPA) ventilation system could be used to control air flow inside the silencer during baffle removal activities.

3.1.2 Tent Construction

Two connected tents were assembled to support the HFBR Silencer Baffle Removal Project. The larger tent measured 44 feet wide by 80 feet long by 47 feet high (Photograph 4). The tent was oriented east to west with a large roll-up door for equipment access located at the western end. The second smaller tent was located adjacent to and west of the larger tent. This tent measured 32 feet wide by 20 feet long by 20 feet high.

A HEPA ventilation system was installed to ventilate the silencer during baffle removal activities, which consisted of three 2,000 cubic feet per minute (CFM) units.

Photograph 3 – Temporary Wall Construction

Photograph 4 – Containment Tent Construction

3.1.3 Roof Plug Removal

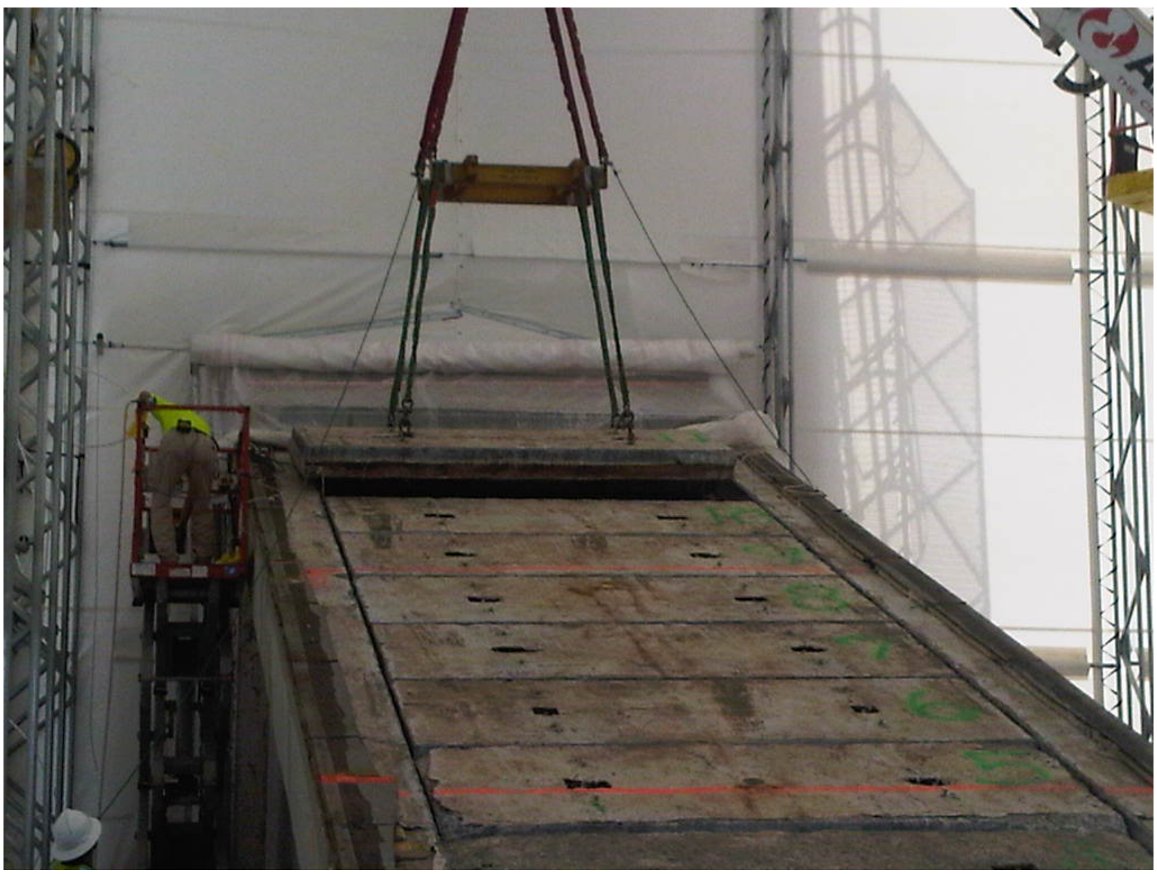
Prior to removing the baffles, the asphalt roofing was removed from the silencer. The lifting points on the concrete roof plugs were inspected and determined to show signs of corrosion; therefore, new lifting points were installed in seven (upper) of the roof plugs and the key plug.

The concrete of the remaining (lower) four roof plugs was degraded to the point that the installation of lifting points was not possible.

The mastic seal located between the roof plugs and the silencer walls, which was sampled and determined to contain asbestos, was removed and packaged for disposal.

The roof plugs were removed in groups of three to four in order to gain access to the baffles beneath (Photograph 5). The upper seven roof plugs and the key plugs were removed using the installed lifting hardware. The lower four roof plugs were removed with an excavator equipped with a thumb.

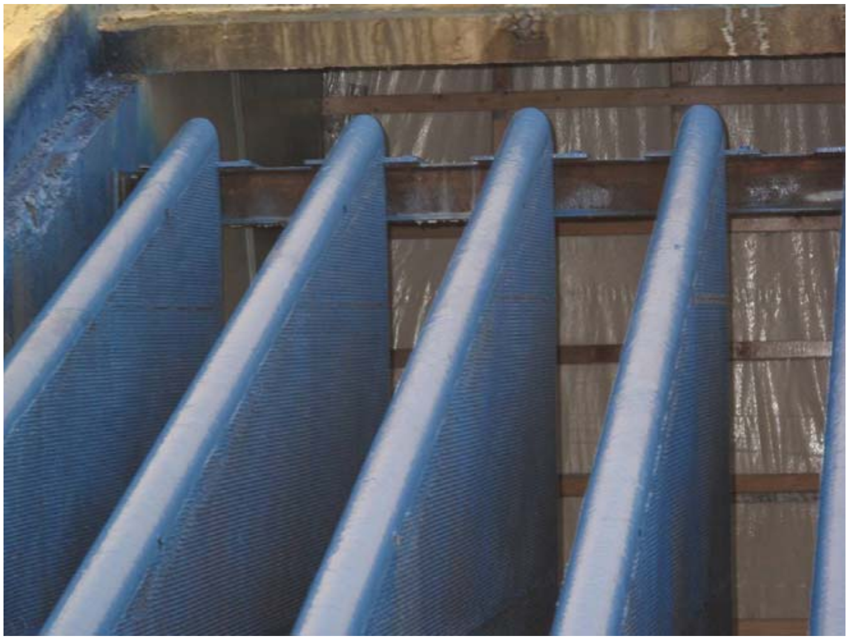
All of the roof plugs were placed into three intermodal containers for off-site disposal.



Photograph 5 – Lifting the First Roof Plug

3.1.4 Baffle Removal

The baffles were removed in four groups of eight, starting from the east and finishing with the western most baffles. A fixative was applied to the surfaces of the baffles before removing them from the silencer for contamination control (Photograph 6).



Photograph 6– Baffles after Application of Fixative

The baffles were lifted from the silencer using the engineered lifting points used during the original baffle installation (Photograph 7).

Photograph 7– First Baffle Removed from Silencer

Once the baffles were lowered to the ground, each was wrapped in plastic and placed into one of four waste packages constructed to United States Department of Transportation (DOT) Industrial Package (IP)-1 specifications (Photograph 8). The four packages were constructed of wood with removable front and top panels.

The remaining walls and floors were secured with construction adhesive and lag bolts. Each container was lined with plastic and eight baffles were placed into each container. After each package was full, the front and top panels were secured in place with construction adhesive and lag bolts. Prior to shipment off-site each of the four containers was placed into a DOT IP-1 rated supersack.

Photograph 8– Placing Baffle into Waste Package

The process of roof plug removal, fixative application, baffle removal and packaging continued until all 32 baffles were removed (Photograph 9).

Photograph 9– Silencer after all Baffles have been Removed and Fixative Applied to Remaining Surfaces

3.2 Stack Silencer As-Left Survey

After completion of the baffle removal, the internal concrete surfaces were sprayed with a fixative. Following the fixative application, an as-left survey of the silencer was performed.

3.2.1 As-Left Survey Design

The as-left survey included collection of dose rates, direct frisk of the concrete walls and the collection of smears to determine loose contamination levels on the internal concrete surfaces of the silencer. The as-left survey results are included in Appendix A.

3.2.2 As-Left Survey Results

The highest contact dose rates were 1.0 milliRoentgens per hour (mR/hr), the highest general area dose rate, taken at waist level, was 0.8 mR/hr. Direct frisk results of the silencer walls ranged from 5,000 to 6,000 counts per minute (cpm). Smear results showed alpha and beta contamination levels were generally below release levels (Table 2-2 of the BNL Radiological Control Manual) on the upper silencer walls and were generally greater than release levels on the lower walls and floor. Alpha results were all less than 20 disintegrations per minute (dpm) on the above grade upper concrete walls and ledge surfaces with one beta result exceeding 1,000 dpm at 1,221 dpm.

On the below-grade lower concrete wall and floor surfaces, alpha results exceeded 20 dpm at several locations with the highest level of 164 dpm. The highest beta smear result on the lower concrete surfaces was 35,703 dpm. Release levels from the BNL Radiological Control Manual are provided on Table 2-2.

3.2.3 Tent Survey

The containment tents were free released in accordance with BNL FS-SOP-1005, *Radiological Surveys Required for Release of Materials from Areas Controlled for Radiological Purposes,* (BNL, November 2007).

3.3 HFBR Remaining Outside Areas Final Status Survey and Sampling

An FSS was performed of the remaining HFBR Outside Areas as detailed in the Field Sampling Plan (FSP), *Field Sampling Plan for Building 705 (Stack) and Remaining HFBR Outside Areas, (BNL,* December 2010). The SUs identified in the FSP included SU-6, SU-7, and SU-8. The SUs are shown in Figure 3-1. An FSS was performed to confirm that the as-left conditions met the project cleanup criteria identified in the HFBR ROD.

The FSS associated with the D&D of Bldg. 802 (SU-6 post demolition and subsurface excavation) and Bldg. 704 (SU-4 and SU-5 post demolition and subsurface excavation) and the associated excavation to remove contaminated piping and structures from beneath and adjacent to the building was included in the *Final Closeout Report, High Flux Beam Reactor Fan Houses (Building 704 and Building 802) Decontamination and Dismantlement (D&D), Area of Concern 31,* (BNL, November 2011). The FSS for SU-1, SU-2, and SU-3 is documented in the *Final Closeout Report, High Flux Beam Reactor Underground Utilities Removal, Area of Concern 31* (August, 2011).

The FSS for eight additional SUs located in the vicinity of Building 750 was documented in the *Final Closeout Report, High Flux Beam Reactor Stabilization, Area of Concern 31* (July, 2011). This area is illustrated on Figure 3-1.

The below grade fan discharge plenum was removed up to the Stack silencer during the D&D of Building 704. The FSS for this area was unable to be completed due to the high background readings from the silencer baffles. A separate FSS of this area will be performed at the completion of the Stack and remaining silencer structure D&D, which is scheduled to be completed by 2020.

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 and include tritium, gamma emitters (e.g., Co-60, Eu-152), and alpha emitters, such as isotopes of uranium, americium, and plutonium. The chemical contaminants of concern were mercury, lead, copper, nickel and zinc.

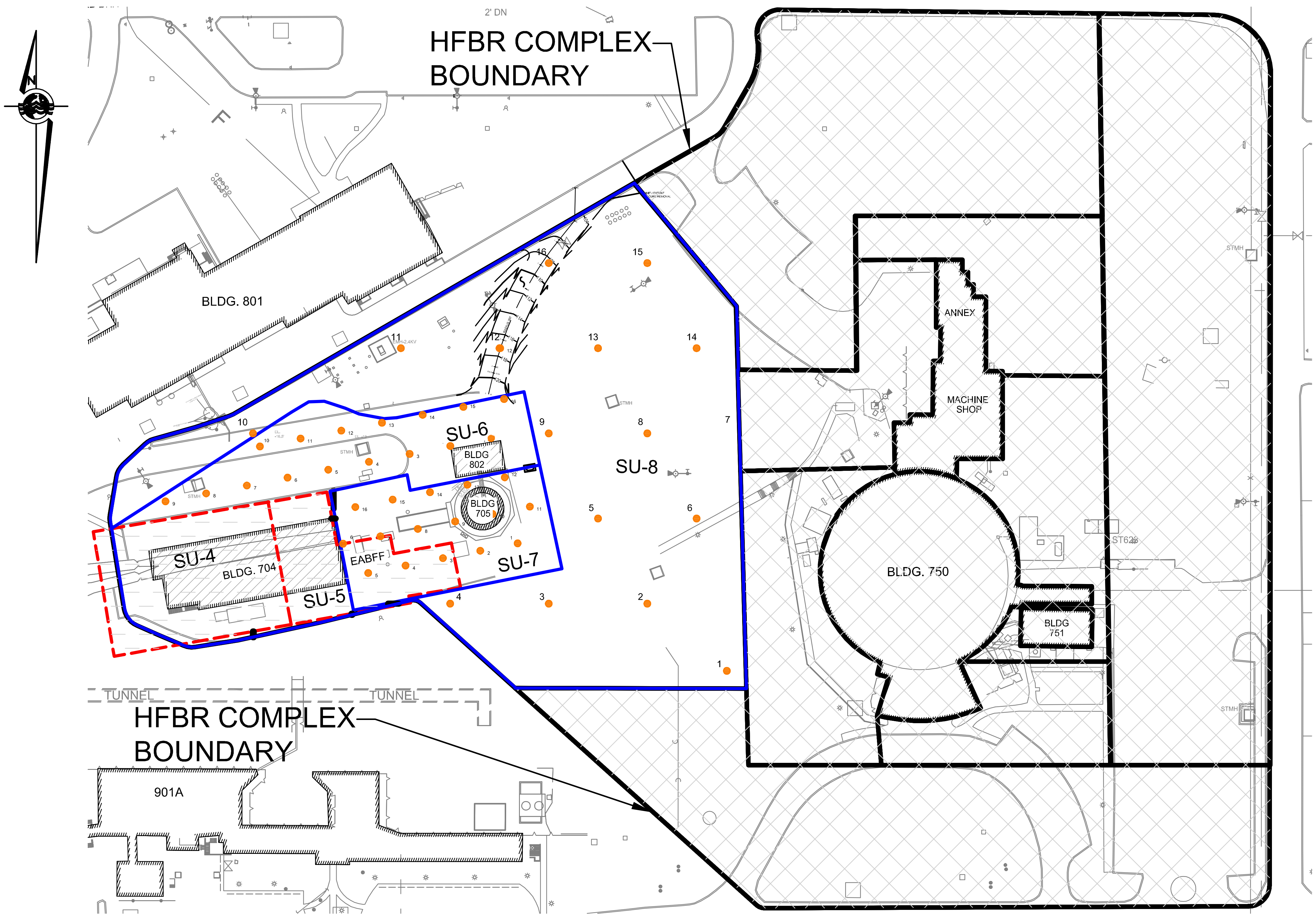
3.3.1 Final Status Survey Design

The FSS was divided into three SUs: SU-6 (19,859 ft^2), SU-7 (18,889 ft^2), and SU-8 (106,433 ft^2). The SUs included the land area after site restoration was completed. SU-6 and SU-7 were considered Class 1 areas and SU-8 was considered a Class 2 area.

A Multi-Agency Radiation Survey & Site Investigation Manual (MARSSIM) survey and sampling approach was followed to confirm cleanup goals for radiological soil contamination were met. The first step consisted of a global positioning system (GPS)-based gamma scintillation walkover survey using a 2-inch by 2-inch 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 Environmental Management (EM) standard operation procedures (SOPs) for offsite analysis to verify that residual radiological contamination levels were sufficiently low to meet the cleanup goals established for the site.

Core samples (from grade to six feet below ground surface) were collected from the SUs to determine if there was residual contamination at depth. Core samples were analyzed by gamma spectroscopy, and for Sr-90 and tritium. Composites of the surface samples were analyzed for gamma emitters, chemical contaminants, alpha emitters, Sr-90, and tritium. Gamma surveys were performed in each SU.

The approximate sample locations for SU-6, SU-7, and SU-8 are shown in Figure 3-2 through 3-4 and the results are summarized in Appendix B.



LEGEND

- SURVEY SAMPLING POINT
- FINAL STATUS SURVEY COMPLETED UNDER THE HFBR FIELD SAMPLING SURVEY
- FINAL STATUS SURVEY DOCUMENTED IN THE FAN HOUSE CLOSEOUT REPORT
- SU-4 — FINAL STATUS SURVEY FOR THE HFBR OUTSIDE AREAS
- BUILDING REMOVED

NOTES::

1. REFERENCE: OVERALL SITE PLAN BASED ON SURVEY PREPARED FOR BROOKHAVEN NATIONAL LAB DATED APRIL 2009.
2. THIS DRAWING DOES NOT REFLECT THE MOST UP TO DATE SITE CONDITIONS (JAN 2012).

P.W. GROSSER CONSULTING INC.
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BROOKHAVEN NATIONAL LABORATORY

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

JOB TITLE: ENVIRONMENTAL RESTORATION PROJECTS		DWG. TITLE: BUILDING 705 STACK AND HFBR OUTSIDE AREAS FIELD SAMPLING PLAN SITE PLAN	
	DATE 9/13/10	ACCT. NO.	SHEET 1 OF 4
SCALE AS SHOWN	DWN. BY RN	JOB NO.	DWG. NO.
PROJ. QA CG	APP'D. BY MP	BLDG. NO. 705	3-1
PATH:			

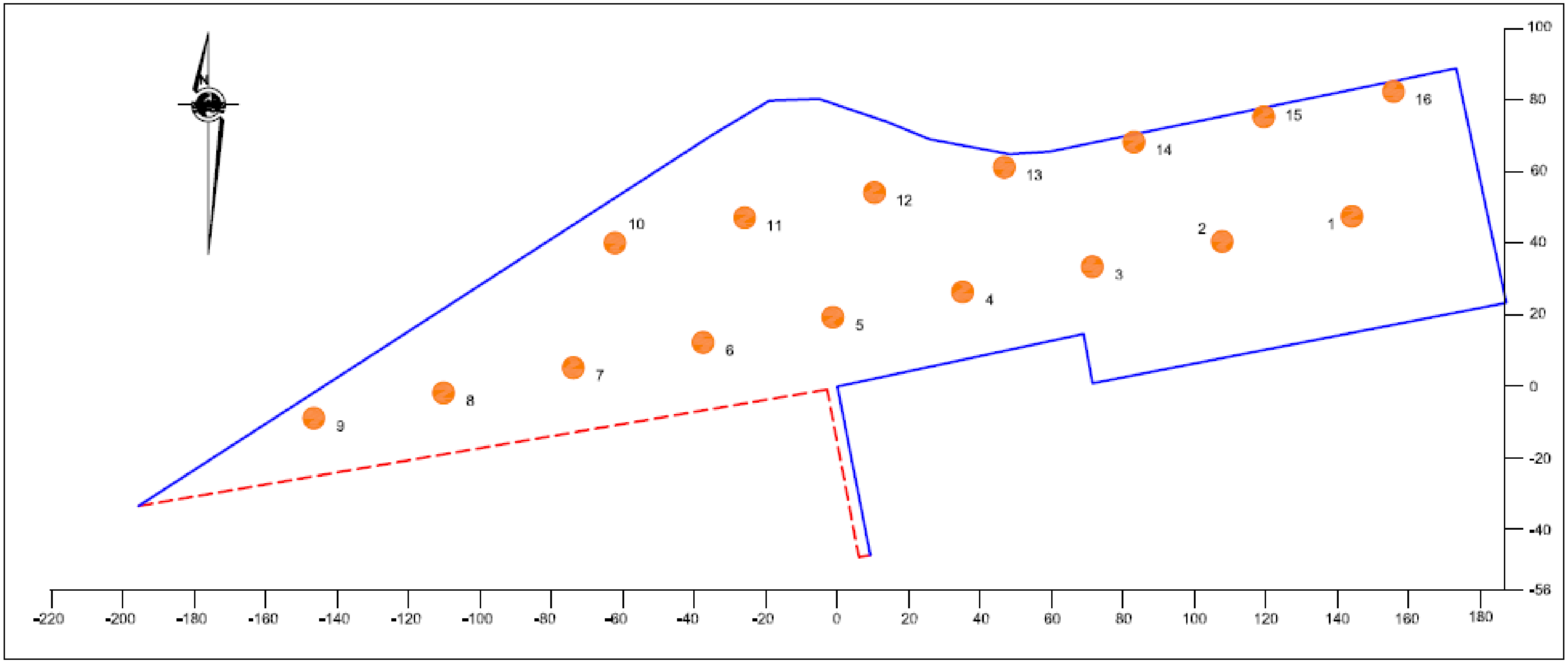
FIGURE 3-1- HFBR OUTSIDE AREAS FINAL STATUS SURVEY SURVEY UNITS AND SAMPLING LOCATIONS

SCALE: 1" = 100'

0 100 200

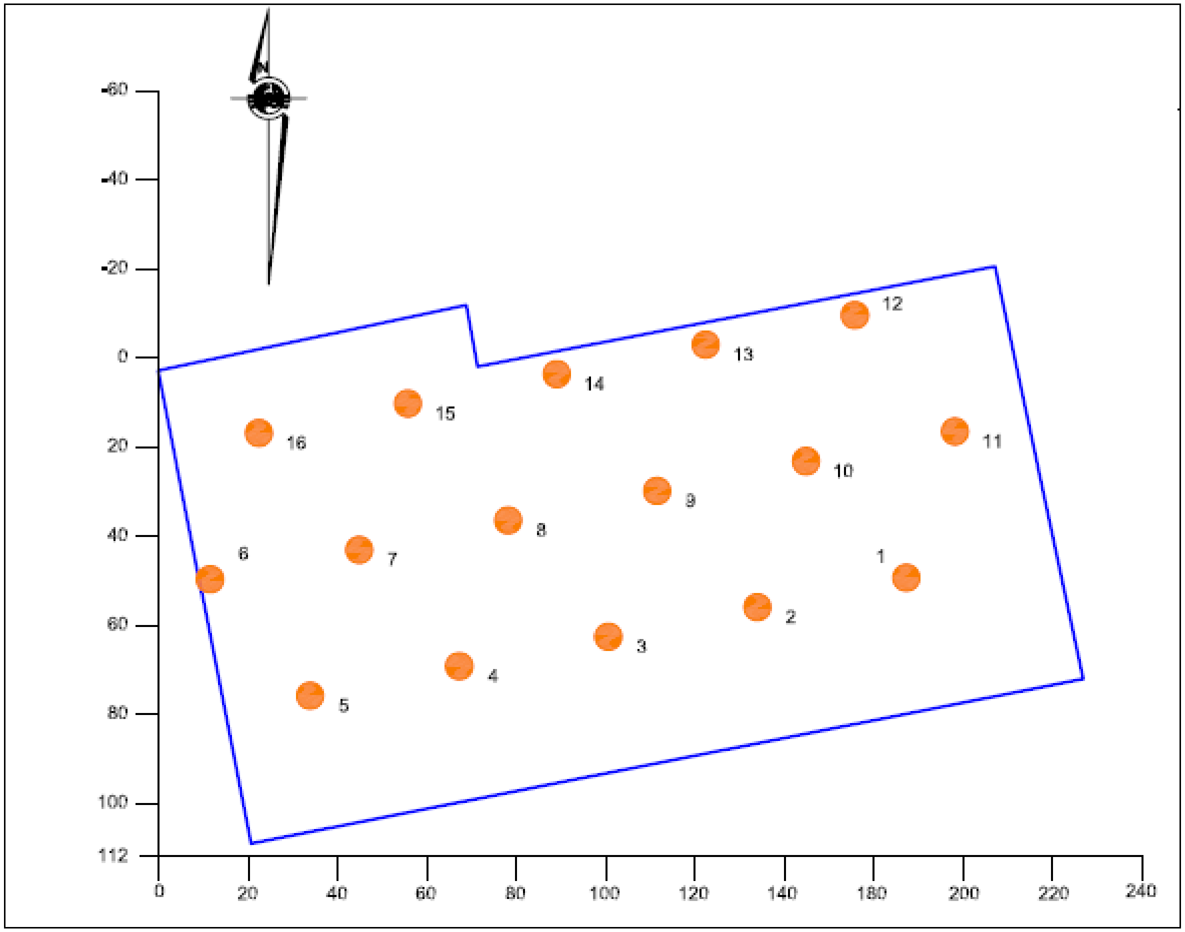
SCALE: 1" = 100'

Figure 3-2 – SU-6 Sampling Locations



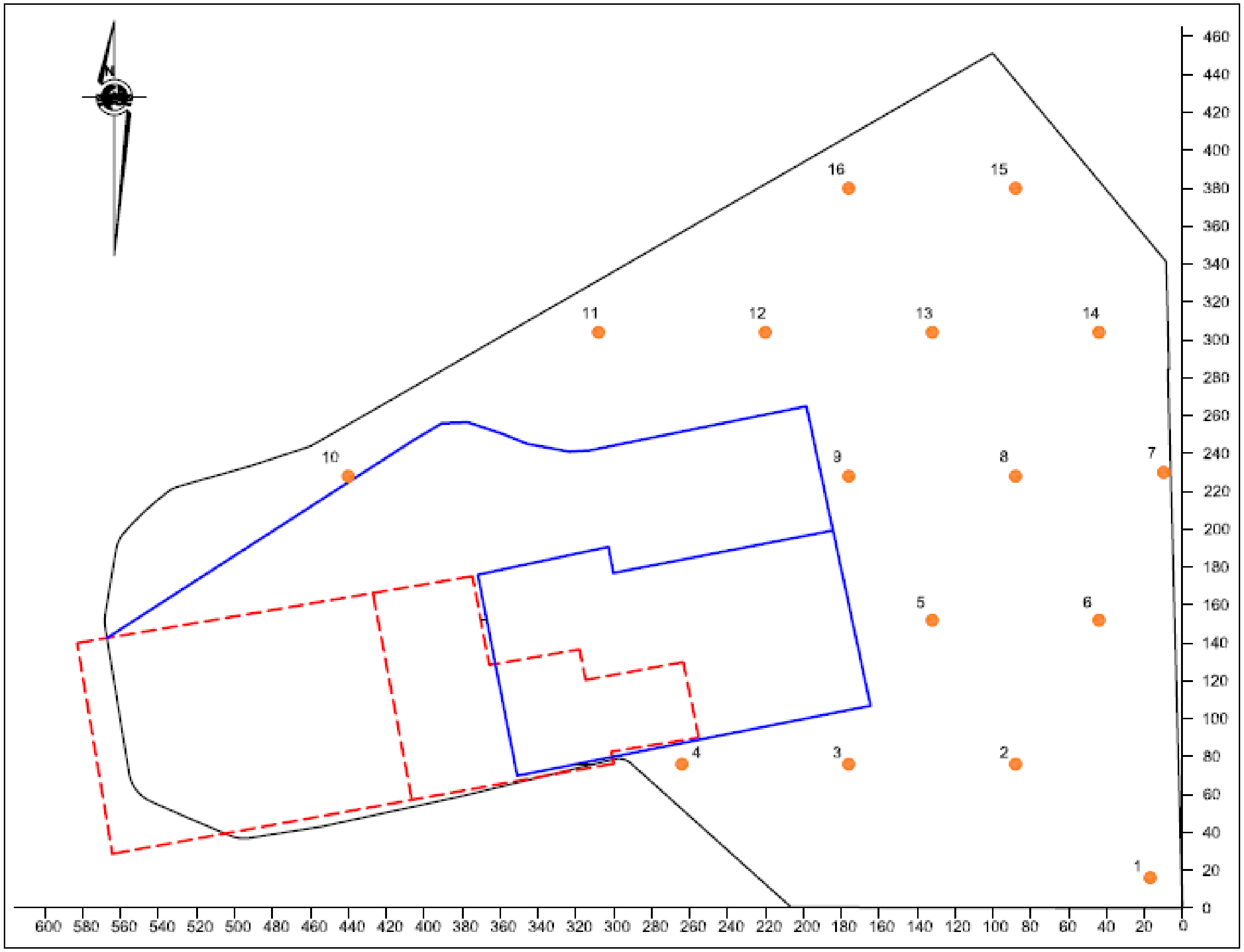
Note: Scales are in feet

Figure 3-3 – SU-7 Sampling Locations



Note: Scales are in feet

Figure 3-4 – SU-8 Sampling Locations



Note: Scales are in feet

3.3.2 Final Status Survey and Sampling Results

The results of the FSS are separated by SU and type of evaluation:

1. **SU-6 and SU-7 Gamma Scans – Class 1 Survey Units**

   Results of the final status radiological walkover survey for SU-6 and SU-7 exhibit count rates below 20,400 cpm using an uncollimated probe and 9,000 cpm using the collimated probe for all areas, as shown in Figure 3-5. As specified in Appendix B of the *Field Sampling Plan Building 705 (Stack) and Remaining HFBR Outside Areas* (December, 2010), the values of 20,400 cpm and 9,000 cpm were determined to approximate a Cs-137 concentration of 23 pCi/g in soil for the uncollimated probe and collimated probe, respectively.

   The collimated probe was necessary at two locations in order to shield elevated background readings from around Building 801 and from a small area adjacent to the Stack. In addition, individual one-minute fixed-point measurements were taken with the NaI probe at each of the fixed sample points. An uncollimated probe was used where possible and a collimated probe was used as described above. The results ranged from 6,409 cpm to 16,488 cpm for the uncollimated probe and 3,249 cpm to 3,759 cpm for the collimated probe. All values were less than 20,400 (uncollimated) and 9,000 cpm (collimated). Radiological survey forms for the gamma fixed-point readings are provided in Appendix B.

2. **SU-8 Gamma Scans – Class 2 Survey Unit**

   Two areas of elevated count rates were identified during the initial final status radiological walkover survey of SU-8. The first area exhibited count rates as high as 50,000 cpm using an uncollimated probe, exceeding the 20,400 cpm field guidance for remediation. The area measured approximately one and a half feet in diameter and one foot deep. On-site analytical results detected Cs-137 at a concentration of 268 pCi/g. The area was excavated using hand tools and generated approximately two cubic feet of soil. Post excavation walkover surveys indicated all count rates less than 15,000 cpm.

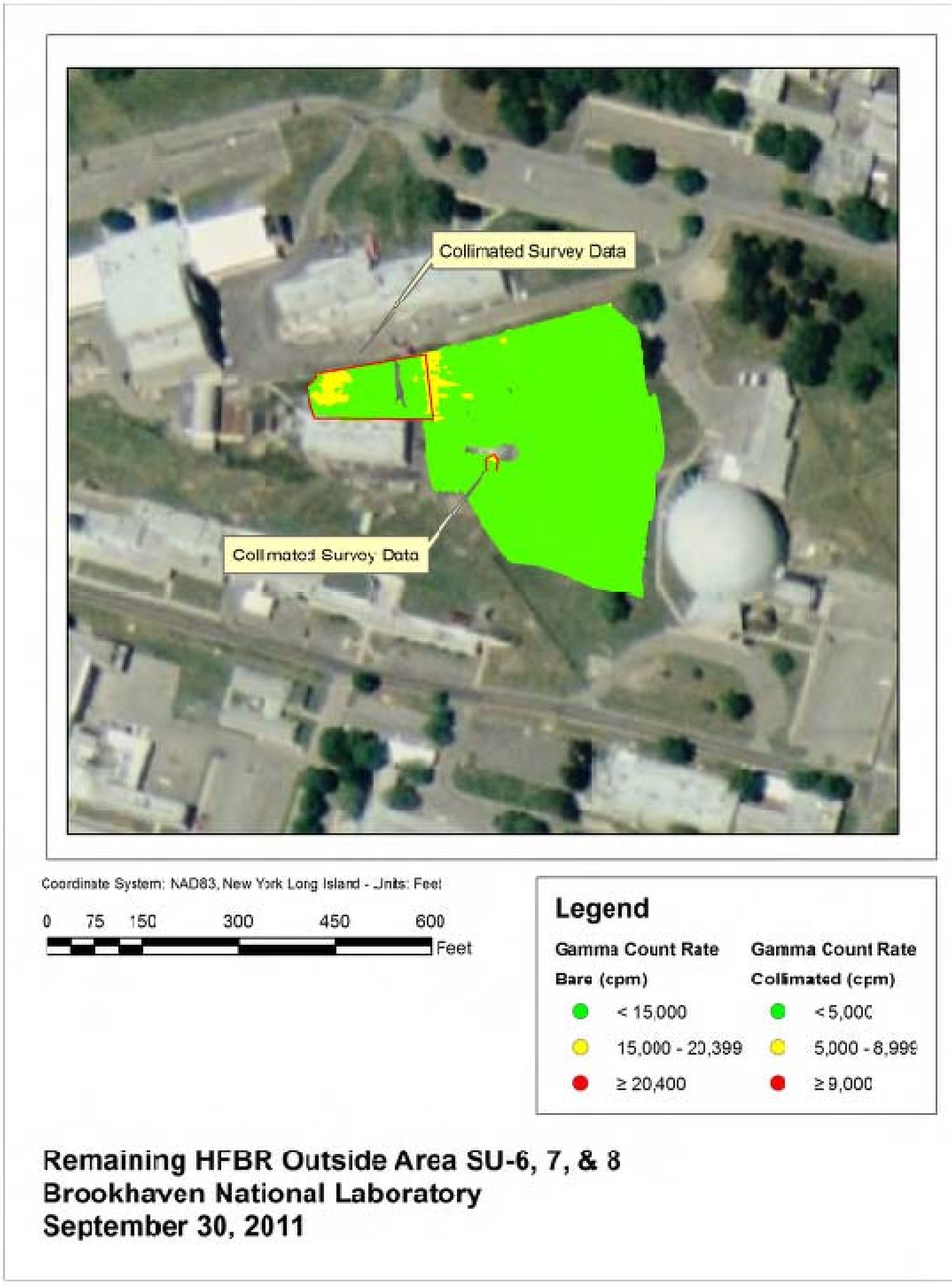
   The second area exhibited count rates as high as 28,000 cpm using an uncollimated probe, exceeding the 20,400 cpm field guidance for remediation. The area was irregularly shaped and consisted of an approximately eight foot circle narrowing to a three foot by 10 foot rectangle. On-site analytical results detected Cs-137 at a concentration of 15 pCi/g. The area was excavated to approximately two feet below grade using heavy equipment and generated approximately three cubic yards (yd^3) of soil. Post excavation walkover surveys indicated all count rates less than 15,000 cpm. The excavated soil from the two areas was placed into an intermodal and shipped to Energy Solutions for disposal as low-level radioactive waste (LLRW) in February 2012, as further discussed in Section 3.4.

SU-8 was on the outskirts of areas where radioactive work was being performed, and there was not a high probability of widespread contamination. These elevated areas were relatively small in area, additional samples were taken in the surrounding area, and no additional contamination was identified. In addition, a 100% gamma scan was conducted for the entire SU. For these reasons, the SU was not reclassified as a Class 1 area.

Results of the 100% gamma scan of SU-8 exhibited count rates below 20,400 cpm using an uncollimated probe for all areas, as shown in Figure 3-5.

In addition, individual one-minute fixed-point measurements were taken with the uncollimated NaI probe at each of the fixed sample points. The results ranged from 5,444 cpm to 12,681 cpm. All values were less than 20,400 cpm. Radiological survey forms for the gamma fixed-point readings are provided in Appendix B.

Figure 3-5 – Final Radiological Walkover Survey Results for SU-6, SU-7 & SU-8



3. SU-6, SU-7 and SU-8 Surface Soil Samples

Surface soil samples were collected at 47 locations, as illustrated on Figures 3-2 through 3-4. It should be noted that a total of 48 sample locations are shown on these figures; however, one location within SU-7 was a core location, not a surface soil sample location. Core samples are further described below in Item 4.

All surface soil sample results were below the site cleanup goals for Cs-137, Sr-90 and Ra-226. A summary of the soil sample results is provided in Table 3-1, and the individual sample results are provided in Appendix B. Composite samples indicated no detection of tritium, Carbon (C)-14, Nickel (Ni)-63, Sr-90, or alpha emitters (Pu-238, Pu-239/240, U-235/236, and U-238). The required detection limits are approximately as follows: Tritium: 300 pCi/g; Ni-63: 4 pCi/g; C-14: 2 pCi/g, Sr-90: 2 pCi/g; Cs-137: 2.3 pCi/g, alpha emitters: 1 pCi/g.

Table 3-1 Summary of SU-6, SU-7 & SU-8 Soil Sample Results for Radionuclides

	Cs-137 (pCi/g)	**Sr-90 (pCi/g)**	**Ra-226 (pCi/g)**
Cleanup Goal	23	15	5
Average	0.15*	0.11*	0.43
Maximum	0.63**	1.32*	0.67

Notes:

* Cs-137 and Sr-90 did not indicate any values that were detected without a qualifier, with the exception of two sample intervals and a single core location (SU-8 – 5.9 pCi/g Cs-137 at 2'-4' and 3.4 pCi/g Cs-137 at 4'-6'). That is, they were either not detected (<MDA), or were estimated, because the result was less than the required detection limit. All sample results were used in the average.

** The maximum Cs-137 in a surface sample was 0.63 pCi/g; however, one core sample indicated 5.9 pCi/g.

Chemical results for soil samples also indicated that residual soil concentrations for these contaminants are within their respective cleanup goals, as shown in Table 3-2.

Table 3-2 Summary of SU-6, SU-7 and SU-8 Soil Sample Results for Chemicals

	Mercury (mg/kg)	**Lead (mg/kg)**	**Copper (mg/kg)**	**Nickel (mg/kg)**	**Zinc (mg/kg)**
Cleanup Goal	1.84	400	270	140	2200
Maximum	0.21	91.5	13.8	4.6	78.3

Notes:

The above sample result summary includes the maximum from surface samples, composite samples, and core samples.

A summary of radiological and chemical results for offsite soil sample analysis is provided in Appendix B.

4. SU-6, SU-7 and SU-8 Core Sample Results

Core samples from surface to six feet below existing grade indicated one biased location with a maximum concentration of 5.9 pCi/g of Cs-137 within SU-8. Ra-226 was detected up to 0.64 pCi/g within SU-8, and Sr-90 was not detected above its detection limit of about 2 pCi/g. All results were less than the cleanup goals.

Metals were analyzed up to six feet in depth, and indicated the maximum values shown in Table 3-2 above. All results were less than the cleanup goals.

Radiological and chemical results for core sample results 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 following the completion of the FSS for the HFBR Outside Areas. The dose assessment was conducted using RESRAD, Version 6.5 (ANL, 2001). The average concentration for each radionuclide from SU-6, SU-7 and SU-8 was used as input to the model in order to determine the projected dose. The average concentrations (see Table 3-1) are as follows:

- Cs-137: 0.25 pCi/g
- Ra-226: 0.44 pCi/g
- Sr-90: 0.09 pCi/g

Note that Ra-226 background on the BNL property had previously been established at approximately 0.56 pCi/g (CDM Federal Programs Corporation [CDM], 1996). Therefore, the average Ra-226 value of 0.44 pCi/g from the affected survey units is below established background. For determination of acceptable levels of cleanup, the value of 0.44 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, background is subtracted to obtain a more accurate result of the dose above background.

Two potential radiological dose scenarios were evaluated following remediation. The first assessment considered the radiation dose to a hypothetical future resident (non-farmer) assuming 50 years of institutional control. 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 area enveloped by SU-6, 7, and 8 are shown in the RESRAD summary reports, provided in Appendix C.

The results of the dose assessment are shown in Table 3-3 below. The maximum projected dose to a resident after 50 years of institutional controls (0.3 mrem/yr) would be below the dose objective (non-farmer) of 15 mrem/yr. For a resident with no decay time (Year 0), the maximum projected annual dose (0.9 mrem/yr) is also less than 15 mrem/yr. In addition, the maximum projected dose to an industrial worker at Year 0 (0.2 mrem/yr) is less than 15 mrem/yr. The results also indicate that the NYSDEC Technical and Administrative Guidance Manual 4003 guideline of 10 mrem/yr would be met under each of the three scenarios described above. If background was not subtracted for Ra-226 (use 0.44 pCi/g without background subtracted), then the residential dose would be 7.6 mrem/yr at year 50, and the industrial dose would be 1.1 mrem/yr at Year 0.

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

	Resident at 50 years	Resident at 0 years	Industrial Worker at 0 years
Dose (mrem/yr)	0.3	0.9	0.2

Note: Dose rates shown are dose rates above background

3.3.5 Final Status Survey Conclusions

The results of the FSS and sampling following the completion of remedial activities and associated restoration activities within the remaining HFBR Outside Areas demonstrate conformance to the site cleanup goals established for the project.

3.3.6 Final Status Survey Independent Verification

The independent verification (IV) for the HFBR Outside Areas was performed by ORISE. ORISE performed Type A IV for SU-6, SU-7, and SU-8 of the remaining HFBR Outside Areas. Type A IV includes a review of project plans and procedures, as well as a review of FSS radiological walkover survey and soil sampling results. ORISE IV for the HFBR Outside Areas was performed between June 2011 and September 2011. ORISE determined that project cleanup goals were met. The results of the IV for the HFBR Outside Areas are documented in the *Type A Verification Report for the High Flux Beam Reactor Stack and Grounds, Brookhaven National Laboratory, Upton, New York* (ORISE, January 2012), provided in 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 the BNL SBMS waste management procedures. Waste generated during the HFBR Silencer Baffle Removal Project was characterized as LLRW and included concrete, steel, soil, non-friable asbestos, and personal protective equipment (PPE).

The waste shipped met the Waste Acceptance Criteria (WAC) of the disposal facilities specified below. Waste verification results were submitted to BNL's Waste Management Group. The baffle LLRW was shipped to the Nevada National Security Site (NNSS). The concrete roof plug LLRW and asbestos containing mastic were shipped to Energy Solutions. The approximately 3 yd^3 of soil that was excavated from SU-8, as described in Section 3.3.2, was comingled with waste from the BGRR Biological Shield Project and shipped to Energy Solutions in February 2012.

Photograph 10 – Loaded Shipping Container Holding 8 Baffles

Waste loading and shipping was initiated in July 2011 and was completed in February 2012. MHF Services provided shipping containers and railcars for transportation of the concrete LLRW (roof plugs) and Hitman Transport Services provided trucks to transport the wooden containers with the baffles (Photograph 10).

A project waste summary is provided below in Table 3-4.

Table 3-4 Project Waste Summary

Waste Type	Manifested Volume	Containers	Disposal Facility	Number/Conveyances
Radiologically Contaminated Demolition Concrete	48 yd^3 (LLRW)	3 Intermodals	Energy Solutions	0.5 ABC Railcars
Radiologically Contaminated asbestos containing mastic (non-friable)	8 ft^3 (LLRW)	Sealand Container	Energy Solutions	1 Truck
Radiologically Contaminated Demolition Steel (Baffles)	124 yd^3 (LLRW)	4 Wooden Containers	Nevada National Security Site	2 Trucks
Radiologically Contaminated Soil	3 yd^3 (LLRW)	1 Intermodal	Energy Solutions	ABC Railcar (BGRR Biological Shield Project)

3.4.2 Pollution Prevention and Waste Minimization Opportunities

Waste minimization and pollution prevention methods employed during the HFBR Silencer Baffle Removal Project included the judicious use of consumables (PPE).

In addition the containment tents used during the project were free released and will be re-used for equipment storage by the BNL Facilities and Operations (F&O) Directorate.

3.5 Site Restoration

Site restoration included the backfilling of the silencer to grade; construction of a wood and asphalt roof, and free release and removal of the containment tents (Photographs 11 and 12). In addition, disturbed grassed areas were seeded using hydroseeding methods in accordance with project plans. Site restoration activities were completed in September 2011.

Approximately 150 yd^3 of clean backfill material was placed inside the silencer to grade to prevent cave-in of soil from the open western end of the concrete BGD.

Photograph 11 – Backfilling Silencer to Grade

After backfilling was completed, a wood and asphalt roof was constructed over the silencer to prevent rainwater intrusion and a new entry hatch was installed on the south face of the silencer.

Photograph 12 – Silencer Roof Construction

Once the roof was completed the containment tents were removed from the site. A schematic of the as-left condition of the silencer is provided on Figure 3-6.

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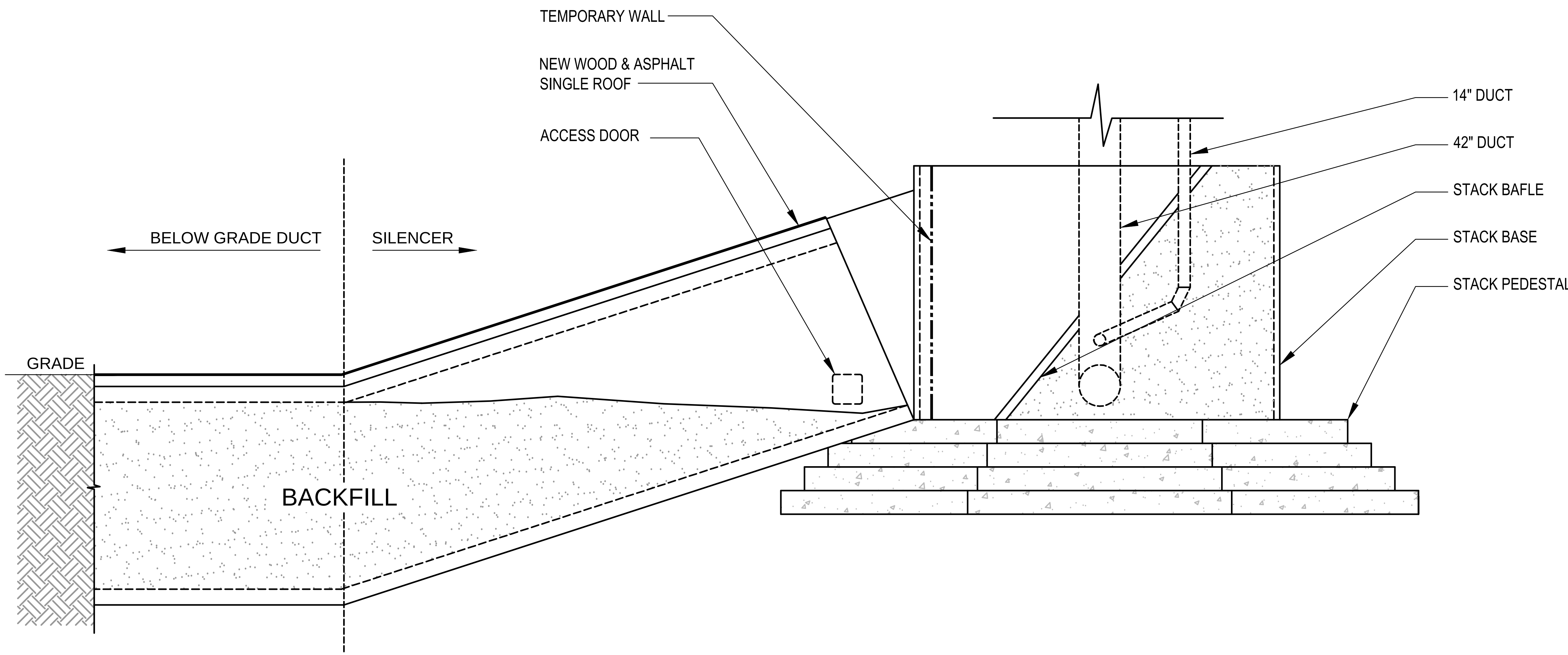

FIGURE 3-6
SILENCER AS-LEFT SCHEMATIC
NOT TO SCALE

4.0 CHRONOLOGY OF EVENTS

Table 4-1 lists a chronology of the main remedial events associated with the HFBR Silencer Baffle Removal Project:

Table 4-1 Chronology of Remedial Events for the HFBR Silencer Baffle Removal Project

Date	Remedial Event
April 2009	HFBR ROD finalized
December 2010	Field Sampling Plan for Building 705 (Stack) and Remaining HFBR Outside Areas finalized
July 2011 – November 2011	Removal of the silencer baffles and securing the silencer until completion of the Stack demolition. The FSS and IVS for the remaining HFBR Outside Areas were performed.

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, 270 mg/kg, 140 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 during baffle removal operations. Field sampling procedures were reviewed periodically.

Quality Assurance/Quality Control (QA/QC) samples were collected in accordance with the *Field Sampling Plan for Building 705 (Stack) and Remaining HFBR Outside Areas* (BNL, December 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 3.3.4, IV was performed by ORISE upon the completion of the remaining HFBR Outside Areas FSS performed by ERP. Based on the results of each FSS, an evaluation of the dose from the remaining activity in the vicinity of the remaining HFBR Outside Areas was performed using RESRAD; results were within the design criteria described in Section 2.2.

There was strict adherence to industrial safety and radiological safety precautions during the HFBR Silencer Baffle Removal Project. 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. Completion of the HFBR Silencer Baffle Removal Project was accomplished without any worker injuries categorized as lost time accidents.

6.1 Industrial Hygiene Oversight & Monitoring

Industrial hygiene (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 Site Health and Safety Officer was onsite during cleanup activities to ensure controls were in place as specified in JRAs, including the use of safety equipment, safe work practices, excavation safety and asbestos controls. IH monitoring included confined space monitoring, mercury vapor monitoring and carbon monoxide monitoring inside the confinement tent.

6.2 Radiological Oversight & Monitoring

Radiological oversight and monitoring for the HFBR Silencer Baffle Removal Project was conducted by BNL ERP RCTs in accordance with the project RWP (2010-ERP-022. Thermoluminescent dosimeters (TLDs) and Electronic Personal Dosimeters were worn by each individual entering the posted Radiation Area/Contamination Area. The radiation exposure estimate was 104 mrem and actual radiation exposures for the project was 36 mrem, In addition, radiological monitoring included air sampling as specified by the RWP and the National Emissions Standards for Hazardous Air Pollutants (NESHAPs) Assessment. All general area air sample and all personal lapel air samples results were below 0.5 derived air concentrations (DAC). Workers entering the posted contamination areas were also required to have a whole body count prior to and upon completion of work on the HFBR Silencer Baffle Removal Project. All workers in the containment tent during silencer removal and packaging were required to have urine bioassay monitoring prior to and upon completion of the work.

Due to the extent and nature of the radioactive contamination within the Stack silencer baffle panels, a containment tent with ventilation was utilized for contamination control purposes, as previously described in Section 3.1.2. Additionally, fixatives were applied to the Stack silencer baffles prior to removal and packaging, as previously described in Section 3.1.4. The contamination control techniques were very effective and resulted in the containment tents and all equipment used during the HFBR Silencer Baffle Removal Project being surveyed and radiologically free released. Results of the release survey satisfied the requirements of the BNL Radiological Control Manual, specifically Table 2-2 and the requirements of FS-SOP-1005*, Radiological Surveys Required for Release of Materials from Areas Controlled for Radiological Purposes* (BNL, November 2007).

There were no occurrences of personnel contamination or spread of contamination beyond the established boundaries.

As discussed in Section 3.4, the Stack silencer baffles were loaded into four wooden boxes with eight in each. The individual baffle panels read 2 to 5 mR/hr with contamination of 1,000 to 12,000 dpm/100 square centimeters (cm^2) beta-gamma and <100 dpm/100 cm^2 alpha. Radiological surveys of a loaded box showed ~5 mR/hr at 30 cm and ~3.5 mR/hr at one meter.

As discussed in Section 3.2, the Stack silencer vault was radiologically surveyed following the application of fixatives with the following results;

- Radiation levels on the walls - 1 mR/hr on contact and 0.8 mR/hr at 30 cm;
- Removable contamination on the walls - <1,300 dpm/100 cm^2 beta-gamma and <10 dpm/100 cm^2 alpha;
- Removable contamination on the floor – 2,000 to 35,000 dpm/100 cm^2 beta-gamma and <150 dpm/100 cm^2 alpha.

7.0 OPERATION AND MAINTENANCE ACTIVITIES

The BNL Land Use Controls Management Plan will be revised to include the HFBR Outside Areas and the Stack, and the BNL site utility drawings will be updated.

A surveillance and maintenance (S&M) manual, *Draft Surveillance and Maintenance Manual for the High Flux Beam Reactor (HFBR) Grounds & Stack* (BNL, January 2012) will be finalized and will include the post remediation monitoring and maintenance activities for the HFBR grounds and the Stack. The S&M Manual will include requirements and frequency of monitoring and maintenance for the Stack Drain Tank and associated disposal of collected fluids as well as inspection requirements for the Stack systems (ladder, platforms, lighting, etc.). The S&M manual will include discussion of applicable institutional controls (land use controls, notifications and restrictions, work planning controls such as digging permits, and government ownership).

BSA will perform operation and maintenance activities. In addition to maintaining institutional controls for the HFBR grounds and Stack, BSA will ensure that routine monitoring/inspections/maintenance associated with the Stack Drain Tank and other Stack systems (ladder, platforms, lighting, etc.) are performed. The DOE will ensure enforcement of all institutional controls.

8.0 SUMMARY OF PROJECT COSTS

The HFBR Silencer Baffle Removal Project was performed with ARRA funding. The project cost approximately $1,074,892 to complete.

The costs for the HFBR Silencer Baffle Removal Project included the following:

Engineering and planning	$ 39,018
D&D/Remediation & Site Restoration	$ 945,874
Waste Transportation and Disposal	$ 75,000
Project Closeout	$ 15,000
Total Cost	$ 1,074,892

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:

- Failure to call a work time out resulted in lift limit violation and near miss to an injury – Workers were using a mobile crane to rig out concrete roof plugs from the silencer plenum roof in order to facilitate removal and disposal of radiologically contaminated baffles. The work procedure prescribed a lift limit of 2,000 pounds as indicated by the crane load cell for the first and smallest of the plugs to be removed. The concrete roof plugs were interlocking and the seams contained mastic to prevent water intrusion into the plenum. The rigging supervisor (i.e., Person-in-Charge or [PIC]) stationed himself in a man-lift behind the crane which, together with the noise of the crane, hampered communication with the crane operator. While attempting to lift the first block several workers, including the PIC, heard the crane alarm sound intermittently. Two workers also noticed that one of the crane outriggers began to lift several inches off its pad. Others noticed that the boom appeared to be under considerable strain. After several minutes of trying to lift the block free from the mastic sealant, the concrete around the two embedded lifting bolts failed and the bolts were ejected from the concrete block. The slings recoiled violently, striking the railing on the nearby man-lift where the PIC and one other worker were positioned. Several fist-sized chunks of concrete were expelled from around the anchor points. The concrete chunks landed near workers approximately 50 feet away. Recommended Action - Stay alert to unexpected equipment and/or material conditions in the work place. If something does not look right, question it by calling a work pause or time out to investigate.

- Alternate rigging hardware made baffles easier to rig and workers spent less time near baffles – The initial rigging configuration consisted of a threaded bolt with washers and wing nuts to secure the shackles at two lifting points on each baffle. The installation of the hardware took several minutes and placed the worker in an awkward position during installation. The installation also increased the time spent in an elevated dose rate area. After discussion with the workers a new approach was proposed that included a u-shaped shackle and threaded pin, which eliminated the need to install the multiple bolts, washers, wing nuts and second shackle. The equipment was purchased and the simpler, quicker hardware installation was utilized.

- HFBR silencer baffle box closure - BNL riggers removed the first box of eight baffles from the tent at the HFBR Silencer Baffle Removal Project in order to install the box cover. The box was fully loaded with the baffles as well as blocking and bracing. The front panel had been placed on the box by using lag bolts and construction adhesive. During removal of the box, it was noted by the ERP Waste Manager that there was a gap in a seam of the box between the front panel and the bottom of the box. After the box was landed outside the tent, the HFBR D&D workers screwed additional lag bolts into the wood to close the gap. F&O Heavy Equipment Machine Operators (HEMO), riggers and HFBR D&D workers then replaced the box cover. The cover was sealed with construction adhesive, and screwed in place with lag bolts. While fastening the front right corner of the box, the side panel bulged out approximately one and a half inches. Work was paused and the ERP Waste Manager, Project Engineer, and D&D Manager were notified. The box cover was removed in order to determine the cause of the corner separation. Initial inspection indicated that the box was slightly racked and not sitting level on the ground. Recommended Action: Place waste packages on a level surface before securing side or top panels to ensure a proper fit.

- Consider having a vendor representative on site for construction activities - In the preceding 10 years ERP has purchased and installed several large tents for various cleanup projects. In some cases, such as for the BGRR Canal remediation, ERP decided to install the tent without vendor assistance. In the case of the tent being installed for HFBR Silencer Baffle Removal Project, the decision was made to have the vendor representative on site to oversee construction of the tent. The result was a much faster construction period for the tent frame assembly and erection. The tent frame assembly and erection under vendor representative direction took four times less time than the BGRR Canal tent, which was about a third of the size of the silencer tent. The vendor's tent erection manual for the Stack silencer tent was sometimes difficult to follow but the vendor was able to clarify the sequence of steps as questions arose. For assembly of large structures and/or components, it is highly advisable to arrange to have a knowledgeable vendor representative on site for consultation and to help oversee the work. The additional cost is more than offset by gains in work efficiency. Safety is also enhanced.

- Proper verification of as-built conditions during pre-demolition activities can mitigate cost and schedule changes - The characterization report prepared prior to the issuance of the request for proposal (RFP) for Stack demolition, which was provided to the Stack contractor, did not identify the nature and extent of the radiological hazards associated with the Stack silencer panels. The technical manual and drawings identified the silencer as composed of solid fiberglass panels. When entries were made into the Stack to survey and validate the characterization, it was determined that the silencer panels contained fiberglass batting (insulation), which contained significant amounts of readily dispersible contamination. This resulted in a contractual change order, a change in methodology to remove the silencer panels, and a schedule delay of weeks. As-built conditions for older DOE facilities often contradict what is contained in technical manuals. In order to avoid schedule delays, verify assumptions used in characterizations are accurate by validating the as-built material status to documented drawings and technical specifications.

10.0 PROTECTIVENESS

Removal of the HFBR silencer baffles and securing the silencer are protective of human health and the environment. These actions have removed the majority of the radioactivity from the Stack. The surveillance and maintenance activities and institutional controls put in place will insure protectiveness of human health and the environment until the final D&D of the Stack is completed.

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. There are no FRDP issues to be resolved in association with the HFBR Silencer Baffle Removal Project.

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). The HFBR complex will be included in the next sitewide five year review scheduled to be completed in 2016.

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