Final Certification of Completion
Columbus Closure Project
West Jefferson North Site
West Jefferson, Ohio

Prepared For:
U.S. Department of Energy
Columbus Closure Project Office

Final
June 29, 2006

Prepared by:
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Contract Number: DE-AC24-04OH20171

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1.0 Executive Summary

The Final Certification of Completion summarizes the performance and results of the final status surveys of the affected and unaffected areas of the West Jefferson North (WJN) site as part of the completion of the Columbus Closure Project (CCP). Final status survey processes adhered to the requirements of the "Radiological Characterization and Final Status Plan for Battelle Columbus Laboratories Decommissioning Project, West Jefferson Site" DD-97-02, Rev. 0 (*hereinafter* DD-97-02), as reflecting the requirements of draft NUREG 5849. Surveys were performed throughout the decommissioning and remediation activities performed at the WJN and documented in Final Status Survey Reports (FSSR). Throughout the project, the CCP activity engaged the oversight of the US Department of Energy (DOE), the Battelle Memorial Institute (BMI), and the Environmental Survey and Site Assessment Program (ESSAP) of the Oak Ridge Institute for Science and Education (ORISE). The ESSAP of the ORISE fulfilled the Independent Verification Contractor (IVC) role for the CCP under contract to the Oak Ridge Office of the DOE. The US Nuclear Regulatory Commission (NRC) also performed independent review of the in-process final status surveys. The FSSR, in conjunction with the IVC Letter Reports and the NRC inspection reports, document that the endpoint criteria objectives of the NRC-approved Decommissioning Plan have been met for WJN site as covered by the CCP.

2.0 Introduction

This Final Certification of Completion summarizes the performance and results of the final status surveys of the affected and unaffected areas of the WJN site as part of the completion of the CCP. Final status surveys were performed using the methods described in draft NUREG 5849, "Manual for Conducting Radiological Surveys in Support of License Termination," as reflected in the Decommissioning Plan, other implementing plans, and work control procedures. Final Status Survey Reports (FSSRs) document the performance and the results of the surveys performed during the decommissioning and remediation activities. Together these actions provide the basis for demonstrating that the criteria for use without radiological restrictions have been met.

Final status survey processes adhered to the requirements of the "Radiological Characterization and Final Status Plan for Battelle Columbus Laboratories Decommissioning Project, West Jefferson Site" DD-97-02, Rev. 0 (*hereinafter* DD-97-02), as reflecting the requirements of draft NUREG 5849. [1, 2] Final status surveys were performed for 100% of the surface of affected areas and 10% of the surface of unaffected areas. The affected areas included the 11.5 acres inside the site security fence, and within the fenced area of the filter beds. The unaffected areas included the parking lot, the site entrance road and margins, area between Darby Creek and the site security fence, the Connecting Area, and the areas between Lake Battelle and the site security fence. Connecting Areas included the piping runs between the fenced areas, various outfalls on the WJN property and the abandoning of existing groundwater monitoring and dewatering wells.

The Final Status Survey Reports were submitted for review to the DOE and BMI, and the ESSAP of the ORISE. The ESSAP fulfilled the IVC role for the project under contract to the Oak Ridge Office of the DOE. The ESSAP performed verification surveys and samplings of the site areas as part of the final release process. The US Nuclear Regulatory Commission (NRC) performed concurrent verification surveys of several affected areas.

The Final Certification Package incorporates the FSSRs documenting the final condition of the affected and unaffected areas, the ORISE Final IVC Reports, and the applicable NRC inspection reports. In total, these document the end-state of the WJN site as meeting the criteria for use without radiological restrictions.

2.1 History

In April 1943, Battelle Memorial Institute (BMI) entered into contract with the Manhattan Engineering District (MED) of the US Army Corps of Engineers (i.e. the "Manhattan Project") to perform atomic energy research and development (R&D) activities. From that time until 1988, BMI performed the R&D activities for the MED and its successor agencies; the Atomic Energy Commission (AEC), the Energy Research and Development Agency (ERDA), and the Department of Energy (DOE) at its privately owned WJN site near West Jefferson, Ohio. Activities at the site involving nuclear materials were carried out under the Nuclear Materials License SNM-7. The NRC has continuously exercised jurisdiction of the licensed activities carried out at the WJN site. [9] The WJN facilities included three buildings that became partially radiologically contaminated as a result of the performance of the R&D activities. Facilities at the WJN site required decontamination and removal to meet the license criteria for release without radiological restrictions. [4]

Decontamination activities at the WJN site were initiated in mid-1970's. The DOE, as the successor agency to the AEC and the Government's earlier work, is the agreed party with predominant liability and

responsibility for decontamination and decommissioning (D&D) of the WJN site. The Assistant Secretary for Nuclear Energy of the DOE accepted the D&D of the WJN site into the DOE's Surplus Facilities Management Program as a major project. The DOE is the agency funding and managing the cleanup of the WJN site. The funded project was referred to as the Battelle Columbus Laboratories Decommissioning Project (BCLDP). [4, 5, 6]

In November 2003, DOE contracted with ECC&E2 Closure Services, LLC (Closure Services) to plan and execute the remaining tasks under the Columbus Closure Project (CCP). The CCP is the successor project of the BCDLP. The purpose of the contract was to safely remove DOE radioactive materials and contamination from the WJN site to levels allowing for future use without radiological restrictions. Site-specific release criteria and technical bases defining unrestricted radiological release are provided in the "Surface Release Criteria Technical Basis Document" (*hereinafter* DD-93-02) and the "Volumetric Release Criteria Technical Basis Document" (*hereinafter* DD-93-03). [2,7,8]

The CCP performed the decommissioning activities under the conditions of the BMI held, NRC Nuclear Materials License No. SNM-7, and the associated documents, revisions, amendments and milestones. [9] In turn, the "Decommissioning Plan, Battelle Memorial Institute Columbus Operations" Decommissioning Plan. define the specific tasks and execution requirements for completing the CCP. [4]

The CCP performed decommissioning and remediation tasks at the WJN site from November 2003 through February 2006.

3.0 Decommissioning Objective and Scope

The overall objective of the CCP was to meet the radiological release criteria by performing decommissioning activities in compliance with the technical requirements detailed in the Decommissioning Plan. [4]

The scope of the CCP included removal and disposal of radiologically contaminated above- and below-grade facilities, equipment, drains, pipes, and contaminated utilities within the WJN site. These included:

- Building JN-1 structure, fuel storage pool, transfer canal, and associated infrastructure down to the 14 feet below grade level. Associated infrastructure included the ground structures, basements, concrete slabs, footings, foundations, and all drains, piping and utility systems within the building's footprint.
- Building JN-2 structure, foundation, and associated below-grade infrastructure. Associated infrastructure included the ground structures, concrete slabs, footings, foundations, source storage wells, and all drains, piping, and utility systems within the building's footprint.
- Building JN-3 structure, foundation, and associated below grade infrastructure; ground structures, basement, external water storage tank, concrete slabs, footings, foundations, and all drains, piping, and utility systems within the building's footprint.
- Filter Bed Area including the structures, piping, and soils in and around the Abandoned North Filter Bed(s), Active North Filter Bed, Abandoned Middle Filter Bed, the Active Middle Filter Bed and the Discharge Line from the Sewage System.
- Connecting Areas including the underground drains and pipe runs between the fenced areas, various outfalls on the WJN property, and abandoning of existing groundwater monitoring and dewatering wells.
- Transuranic (TRU) Waste Staging Pad release survey and demolishing activities.

The Active Middle Treatment System, the section of abandoned sanitary sewer running under the dam on Battelle Lake, the abandoned underground Shell Oil line, and the abandoned natural gas line under Battelle Lake were not included in the scope of work for removal.

Decontamination, removal, waste packaging, and transport activities were conducted according to the Decommissioning Plan, Work Instructions, and an extensive work control process under the license conditions. Final status surveys were performed to demonstrate compliance to the radiological release criteria.

4.0 Description of Facilities

The West Jefferson Site is bounded by the Big Darby Creek, a national scenic and state-protected river on the east, and farm lands to the west, south, and north. Immediately east of the Big Darby Creek are a Girl Scout camp and several residential neighborhoods, all within ½ mile of the site. [10] The CCP consisted of the D&D of the buildings structures as well as remediation and release surveys of associated grounds, and the connecting and filter bed areas of the WJN site located near West Jefferson, Ohio. [4]

Three radiologically contaminated buildings ranging in size from 7,900 sq ft to 31,000 sq ft, were located within the 11.5 acres of the fenced restricted area. The buildings previously contained a reactor, a plutonium test facility and radioactive analysis laboratory, three large hot cells, and a 50-ft fuel pool basin contaminated with fuel residuals. Additionally, extensive sanitary sewer systems of 4,000 linear ft of contaminated underground piping and filter beds were excavated and removed for off-site disposal. The filter beds are located within a fenced area of roughly 2 acres. Buildings JN-6, the former guard house, and the North Site Well House were also surveyed for radiological release. The JN-6 Facility was subsequently demolished and the Well House was left in tact for future use.

CCP project tasks required the completion of D&D activities initiated by the Site Owners (i.e. BMI) under a cost sharing arrangement with the DOE. [3]

Residual radioactive contamination within the WJN facilities and connecting areas resulted from the research and development activities involving special nuclear material, source material, and by-product materials. Decontamination and decommissioning activities typically involved exposures to americium-241 (Am-241), cesium-134 and 137 (Cs-134 and -Cs137), cobalt-60 (Co-60), europium-152 (Eu-152) europium-154 (Eu-154), plutonium 239 and 240 (Pu-239 and –Pu-240), strontium-90 (Sr-90), and a few other individual nuclides. Cs-137, Co-60, and Sr-90 were the prominent isotopes present. [5]

Building JN-1 was the most contaminated building in the WJN site. BMI initiated operation within the building in 1955 and continued its use until 1988. Operational activities focused on nuclear research studies. Work conducted included evaluations of both power and research reactor fuels; post-irradiation examination of fissile, control rod, source, and structural materials and components; and examination of irradiation surveillance capsules. In addition, the facility was the site for radiation source encapsulation and physical and mechanical property studies of irradiated materials and structures. [12]

Constructed in 1955-56, Building JN-2 was a slab-on-grade, two-story concrete building with brick facing. The building housed laboratories and a former vault in which plutonium and enriched uranium were once stored. Initially, the facility was used for reactor criticality experiments, experiment assembly, special nuclear material handling and vault storage, and plutonium research activities. These activities were performed within the large reinforced high bay and adjacent areas from 1957 through 1963, completed in 1970. Decommissioning of the vault and criticality laboratories was conducted during the 1970s. [5] After 1970, a radio-analytical laboratory was operated in the facility providing health physics and environmental analytical services. [4]

Constructed in 1955-56, Building JN-3 housed the first privately owned and licensed nuclear reactor facility of its type in the world. Over a period of 20 years, the reactor was used in irradiation and neutron activation studies for government and industry clients. The 2-megawatt Battelle Research Reactor (BRR) was designed to provide an intense source of neutrons and gamma rays for irradiation of various materials during experimentation. Reactor operations ended in 1974 with the removal and shipment for reprocessing of the reactor fuel in the latter part of 1974. Initial reactor decontamination and dismantling operation took place over a 9-month period beginning in 1975. Final decontamination and removal of the reactor bioshield transpired between 2001 and 2002. [13]

Connecting areas of the site consisted of a sanitary sewer system that supported ongoing operations for each of the three buildings. As such, lines associated with the sanitary sewer system exhibit residual contamination from past site operations. Additionally, the connecting areas include the subsurface and adjacent surface areas of the site.

Two classifications of areas are used in draft NUREG-5849 and are termed *affected* or *unaffected*. [2] **These** classifications are defined as:

> *Affected Areas:* Areas that have potential radioactive contamination (based on plant operating history) or known radioactive contamination (based on past or preliminary radiological surveillance). This would normally include areas where radioactive materials were used and stored, where records indicate spills or other unusual occurrences that could have resulted in spread of contamination, and where radioactive materials were buried. Areas immediately surrounding or adjacent to locations where radioactive materials were used, stored, or buried are included in this classification because of the potential for inadvertent spread of contamination.
>
> *Unaffected Areas:* All areas not classified as affected. These areas are not expected to contain residual radioactivity, based on knowledge of site history and previous information.

The CCP further differentiated affected areas and buildings by assigning one of the following categories based on the history of operations and levels of contamination present: [4]

Category 1 – widely contaminated with low radioactivity levels
Category 2 – high radiation fields and extensive contamination in hot cell areas and lower levels of contamination in operating areas
Category 3 – low level contamination of isolated sections in otherwise uncontaminated facilities.

Building JN-3, the Connecting Areas, and the Filter Bed Area were designated as Category 1, Building JN-2 was designated as Category 3, and Building JN-1 was designated as Category 2. **Table 1** lists the affected and unaffected areas of the WJN site. The category designation for each area is also presented in **Table 1**.

5.0 Unrestricted Release Criteria

The objective of the CCP was to decontaminate or remove residual radioactive contamination so that the WJN site is available for use without radiological restrictions. In order to clearly define the objective, the CCP applied two technical basis documents throughout the decommissioning process.

- Surface Release Criteria Technical Basis Document
- Volumetric Release Criteria Technical Basis Document

These two documents are appendices to the approved Decommissioning Plan. Each provided the quantitative values for decommissioning objectives and defined the technical basis thereof. [7, 8]

5.1 Surface Release Criteria

Table 2 presents the surface release criteria for the CCP. Radiological release criteria for surfaces were first defined in ANSI N13.11 (draft), "Control of Radioactive Surface Contamination on Materials, Equipment, and Facilities to Be Released for Uncontrolled Use" and were later published in US Nuclear Regulatory Commission Regulatory Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors." [15] standards serve as guidance documents when establishing release criteria. The DOE Order 5400.5, "Radiation Protection of the Public and the Environment" also provides release criteria for surface radioactivity. [16] For the CCP, DOE 5400.5 and Reg. Guide 1.86 were utilized to set the upper limits of residual radioactive surface contamination for unconditional release of equipment, materials, and areas. DOE Order 5400.5 requirements were mandatory for the CCP, because the DOE accepted ownership contractually of all radioactive waste generated by the project for purposes of disposal. Reg. Guide 1.86 requirements are mandatory because the CCP was conducted under an NRC Licensee using an NRC-required decommissioning plan. [4]

The CCP performed release surveys of Buildings JN-2, JN-3, JN-6, and TRU Waste Staging Pad Area. and the North Site Well House, areas, material, and equipment to ensure that surface contamination levels were at or below those listed in **Table 2**. Surveys included scanning and static measurements, and smear surveys for removable contamination. Decontamination was performed if surveys indicated residual surface contamination above that listed in **Table 2**.

5.2 Volumetric Release Criteria

Table 3 presents the guidelines for residual radioactivity concentrations for soil and solid volumes as applied to the CCP decommissioning activities. Volumetric release criteria for residual radioactivity concentrations in soils, debris, and other solid media resulting from the decommissioning were from DD-93-03. [8]

DD-93-03 details the development, selection, and application of the volumetric release criteria. As part of the development process, BMI set the volumetric release criteria to reflect a comprehensive review of the guidance given in source documents. Source documents included DOE Order 5400.5, § IV.a.2, for the generic guidelines for residual concentrations of Ra-226, Ra-228, Th-230, and Th-232. NRC guidance received by the Licensee contained soil radioactivity concentration guidelines for Co-60, Sr-90, Cs-137, Ra-226, and Ra-228. Environmental pathway and dose analysis for residual soil radioactivity was conducted using the DOE Residual Radioactivity Material (RESRAD) computer program. Input parameters, including a 100 millirem per year (mrem/y) effective dose equivalent (EDE) to a member of the public, were utilized for the assessment. The technical basis document contains the results of the RESRAD analysis. [8]

The technical basis document included sources drawn from DOE Order 5400.5, NRC guidance documents and regulatory requirements, and limits established through correspondence received from the NRC during the development of the volumetric release criteria. For the CCP, DOE Order 5400.5 requirements were applicable because the DOE accepted ownership contractually of all radioactive waste generated by the project for purposes of disposal. NRC requirements were

applicable because activities were regulated by the NRC license SNM-7 and the Decommissioning Plan. [8]

Criteria presented in **Table 3** are the maximum allowable concentrations of residual radioactive material above background levels that were allowed to be left in soil and solid volumes released for unrestricted use. [8] The CCP applied these limits with consistent ALARA considerations.

Limits are maximum concentrations for individual or mixtures of radionuclides that may be present in solid media. Screening levels for mixtures of radionuclides were developed by summing the individual fraction of the radionuclide to its specific release criteria. Summed fractions less than unit, or 1, were said to meet the release criteria. Unity was calculated as follows: [2]

$$\Sigma (Ci/Gi) \leq 1$$

where
Ci = concentration of the *i*th radionuclide (pCi/g)
Gi = soil guideline of the *i*th radionuclide (pCi/g).

Mixtures of residual radionuclides at levels less than 1.0, or a total fraction thereof, were stated to be less than 100 mrem per year. [8]

5.3 *External Radiation Exposure Limit*

DD-93-03 set the external gamma radiation exposure limit for ground surfaces. The limit of 5 microRoentgen per hour (μR/hr) above mean background, at 1 meter above the ground surface was applied as an additional requirement in determining compliance with the unrestricted release criteria. [8]

In implementing the requirement, exposure rate measurements were compared to the mean background plus 5 μR/hr, at 1 meter above ground surfaces. The calculated mean background exposure rate and the 95-percent confidence intervals used for the CCP open area grounds were 8 ± 2 μR/hr. Initial compliance screening is met if individual exposure rates are ≤ 13 μR/hr. Further assessment of compliance allows for exposure rates to be averaged over a 100-m^2 grid area to meet the limit of less than or equal to 5 μR/hr above background at 1 meter above the ground surface. Additionally, exposure rates over any discreet area may not exceed 5 μR/hr above background. [2]

Data collected from trench-like culverts located on WJN property unassociated with site operations indicate a geometry effect. The geometry effect increased the background exposure rates inside the trenches by 3 to 5 μR/hr. The calculated mean background exposure rate and the 95-percent confidence interval for trench excavations was 13 ± 2 μR/hr. Initial compliance screening of individual exposure rates within the trench were acceptable if ≤ 18 μR/hr. Further assessment of compliance was performed as stated for open ground surveys.

6.0 Actions Completed

Decommissioning activities performed during 2003 were concentrated in Building JN-1 and locations around the site. These tasks were performed primarily by BMI prior to site transition to the CCP. In Building JN-1, BMI crews performed decontamination and stabilization of building areas, removing, packaging, and transporting for disposal excess equipment, packaging remote handled transuranic (TRU) waste, and removing utilities throughout the building. BMI also constructed a TRU waste staging pad, and then removed TRU waste from Building JN-1 to the staging pad. Dewatering wells were also installed in the basement of Building JN-3.

Table 4 presents the major decommissioning activities performed by the CCP from 2004 through 2006. Table 4 summarizes the primary tasks performed for each building, the connecting areas, and the filter bed area.

7.0 Certification Approach and Activities

Final status surveys were performed following remediation control surveys indicating that decommissioning or remediation activities were effective in meeting the radiological release criteria.[19] The exception to this was for Building JN-6 and the North site well house, where the CCP performed only final status surveys. Final status surveys were performed according to the requirements of draft NUREG-5849, as reflected in DD-97-02. [1]

Various surveys were performed during and after the decommissioning and final status survey process. Surveys performed by the CCP included: [1]

- *Background Surveys* – established the levels of naturally occurring radiation/radioactive materials in the environment; including the ambient exposure rate measurements and the influence of building materials in surface contamination surveys.
- *Characterization Survey* – more accurately defined the extent and magnitude of contamination; delineates areas to be decontaminated, demolished, or remediated.
- *Remediation Control Survey* – determined the effectiveness of decontamination or remediation.

- *Final Status Survey* – determined the post-decontamination or post-remediation condition of the area and provided data to demonstrate compliance with the radiological release criteria; data from previous surveys were also utilized to supplement final status survey, if appropriate.
- *Confirmatory Survey* – the IVC performed confirmatory surveys of those performed by the CCP; the NRC performed confirmatory surveys of selected areas.

Appendix A contains an uncontrolled copy of DD-97-02. The CCP adhered to the requirements of DD-97-02 throughout the planning and execution of the decommissioning and final status survey activities.

7.1 Field Instrumentation

The technical basis for field instrumentation selection for the CCP is documented in DD-93-02. [7] Field instrumentation used by the CCP was the same as that listed in DD-93-02. Further, the same make and models of instruments were used by the BCLDP, the predecessor of the CCP.

As required in DD-93-02, field instruments and were calibrated in accordance with ANSI N323, "Radiation Protection Instrumentation Test and Calibration". [14] The CCP maintained the calibration of and the use of the field instrumentation according to health physics administrative and operational procedures. Health physics administrative procedures, or HP-AP, defined the administrative and documentation requirements for the field instruments. Health physics operational procedures, or HP-OP, defined the calibration, maintenance, and operation of the field instruments. Health physics administrative and operational procedures, surveys, and instrument calibrations are retained as part of the project record.

7.2 Background Measurements and Locations

Background measurements were obtained and locations selected according to DD-97-02. Measurements were performed on soils and building materials that contained varying quantities of naturally occurring radionuclides. Mean background activities of materials were determined by surveying areas known or demonstrated to be free of residual activity. The surveys were performed in the same manner and with the same instrumentation used during characterization and final status surveys. Decision Level Values (DLVs) were then calculated to enable identification of surfaces or areas that required additional radiological measurements. [1]

Procedure SC-OP-007, Rev. 0, *Baseline Reference Values for Facility Radiological Characterization Surveys*, provided the basis and survey tasks necessary to set the DLVs. As stated, the DLVs were instrument-specific numerical values that equated to the 95% upper confidence level for a surveyed medium or material. [19] These values were obtained for both building materials and land areas specific to the CCP.

Surface contamination DLVs were obtained for scanning and population surveys for both alpha and alpha/beta measurements of the types of building materials encountered at the CCP. These measurements were obtained from the surveys of Building JN-6; the former guard house located within the restricted area. Extensive surveys and historical evidence demonstrated that the building was free of residual activity. Characterization technicians obtained a minimum of 40 survey measurements for each method and media type. Survey measurements were then statistically evaluated using the Chauvenet's Criterion Test. The Chauvenet's Criterion Test provided an unbiased method for excluding data that were outliers and avoided biasing the measurement data set. [19] Table 5 presents the DLVs used for surface scanning during the CCP.

Soil walkover survey DLVs and mean exposure rate measurements were obtained from surveys performed southwest of Building JN-10, the CCP office trailer complex. Soil walkover DLVs were obtained by utilizing the same statistical method as the surface contamination surveys. Walkover scanning surveys used a Ludlum 44-10 Sodium Iodide Thallium NaI(Tl) gamma scintillator coupled with an Eberline ESP-2 scaler/ratemeter. The DLV for walkover scanning surveys of open grounds and trenches using this radiation instrument was set at 18,374 counts per minute (cpm). The DLV for walkover gamma surveys using a shielded scintillator was set at 4236 cpm for non-suspect materials, materials in the suspect range of 4237 – 4426 cpm, and contaminated materials greater than 4427 cpm.

The mean of the microRoentgen per hour (μR/hr) exposure rate surveys from the same area was 8 ± 2 μR/hr. This value correlates favorably to the background exposure rate values presented in annual environmental reports for the CCP.

7.3 Characterization and Final Status Survey Measurements

Characterization and final status surveys were conducted to verify that decommissioning activities met the radiological release criteria for an area or building and its associated grounds. Surveys were conducted according to site characterization procedures, health

physics procedures, and work instructions specific to the area or building. The same basic methodology for the surveys, instruments, procedures, grid patterns, fixed reference locations, radioanalytical supports, and management review were utilized throughout the project and documented in each FSSR.

Characterization survey procedures were consistently implemented throughout the decommissioning process and performance of the final status surveys. Site characterization operations procedures, or SC-OP procedures, were typically performed in support of or following decommissioning operations. Site characterization sampling procedures, or SC-SP procedures, were conducted when obtaining media specific samples in support of the characterization and final status surveys. Site characterization procedures and surveys conducted in support of the decommissioning and final status surveys have been retained as part of the project records. Individual FSSRs detail the characterization and final status surveys performed for the covered building, excavation, or area of the WJN site.

7.4 Laboratory Instrumentation

The CCP utilized an on-site laboratory for radioanalytical analysis of air, soil, and water samples. The on-site RadioAnalytical Laboratory (RAL) applied several analytical methods and instrumentation in support of the decommissioning and final status survey activities. Instrumentation and methods included:

- A VMS-based Canberra Procount data acquisition system in conjunction with high purity germanium detectors for gamma spectroscopy of soil samples.
- A Tennelec Model LB5100 Simultaneous Alpha and Beta Gas Proportional Counter to count smear samples
- Sr-90 analysis by extraction chromatography

Laboratory personnel and procedures were transitioned from the BCLDP to the CCP. The RAL performed alpha and gamma spectroscopy, gross alpha and beta analysis for various matrices, and limited Sr-90 analysis. Limited processing of soil and debris sample matrices was performed. Capacity for performing wet chemistry separation for sample preparation was maintained throughout the decommissioning and final status survey tasks. Participation in various inter-laboratory comparisons, including the DOE-EML program and comparisons performed by ORISE, and the NRC supported the quality assurance and control for the laboratory.

The RAL provided analytical services under the implementing *Radioanalytical Laboratory Quality Assurance Program Plan*. [20] Radioanalytical laboratory administrative procedures, RL-AP, defined the training, record-keeping, and quality assurance protocol for the laboratory. Calibration procedures, RL-CP, provided calibration requirements for each instrument. Finally, the counting procedures, RL-TP, detailed the steps for performing each of the analysis. All RAL procedures, calibrations, and reported analytical results are retained in project records.

7.5 Surrogate Analysis

7.5.1 Filter Bed Ratio

The CCP developed an area-specific Cs-137 surrogate ratio for all below-grade remediation for Building JN-2 and Building JN-3; as well as the areas associated with the sanitation systems leading to and discharging into and including the filter bed area. The Filter Bed Ratio was developed using characterization samples collected within the filter bed area by BMI. **Table 6** presents the isotopic quantity and activity concentrations of samples collected from the filter bed area by BMI from March, 2000 through September, 2000. [21] These data were not associated with the excavation and removal activities performed by the CCP. Average activities for the multiple samples were calculated for each radiological contaminant of concern (RCOC) prior to setting the ratios against Cs-137. Pu-241 was calculated by applying a ratio to sum of Pu-238 and Pu-239 as obtained from ORIGEN 2.1 derived values, resulting in a Cs-137 to Pu-241 ratio of 2.8. [22] Ratios for the remaining RCOCs were then calculated by dividing the average activity concentration of Cs-137 by the average activity concentration of the specific RCOC.

Table 6 ratios were used to calculate the activity concentration of individual RCOCs, other than those detected by the RAL. Individual concentrations of all RCOCs were calculated using these ratios and the Cs-137 to Pu-241 ratio of 2.8. Derived activity concentrations were then applied to the unity rule to determine compliance to the radiological release limits. Application of the Cs-137 surrogate ratios resulted in a screening criteria of 11 pCi/g for Cs-137. The unity rule was consistently applied to all sample results that were greater than 75% of the modified screening criteria for Cs-137.

7.5.2 Building JN-1 and Bog Area

The CCP developed an area-specific Cs-137 surrogate ratio for the below-grade remediation of Building JN-1; the backyard and bog area. The Building JN-1 and Bog

Area ratio was developed using characterization and remediation data collected by the CCP. **Table 7** presents data utilized from previous characterization samples collected during the excavation of the backyard of Building JN-1 and the Bog Area, to establish a site-specific ratio of Cs-137 to other RCOCs. Analytical results from the samples of the backyard and the bog area were obtained from the excavation during the fall of 2005. Ratios were calculated in the same manner as discussed in the preceding section. JN-1 and bog area samples were collected during pre-remediation characterization activities and are not representative of the final condition of either location. Samples with a range of activity concentrations for Cs-137 were selected in generating the ratios.

Table 7 presents the isotopic activity concentrations of samples collected during the remediation of the Building JN-1 foundation, backyard, and the Bog Area. Remediation samples were collected between October and November of 2005. Characterization Technicians collected the samples according to procedure SC-SP-004.2, "Mechanical Collection of Surface and Subsurface Soil Samples in Support of Site Characterization." [23] Sample integrity protocol and data quality objectives were adhered to throughout the sampling effort. Samples were then screened and transferred to the On-site RAL for analysis. Initially, analysis was for gamma-emitting RCOC was performed according to procedure RL-TP-030, Rev. 5, "Gamma Spectrometric Analysis of Laboratory Samples Using Canberra Procount™ Software." [24] The RAL performed analysis for Sr-90 according to procedure RL-TP-035, Rev. 4, "Strontium-90 Analysis by Extraction Chromatograph." [25]

Ratios presented in **Table 7** were used to calculate the activity concentration of individual RCOCs other than those detected by the RAL. The Pu-241 activity concentration is calculated by using a ratio of Pu-241 to the sum of Pu-238 and Pu-239, as obtained from the ORIGEN 2.1 derived values. [22] The resulting Cs-137 to Pu-241 ratio is 2.8. Using the ratios from **Table 7** and the Cs-137 to Pu-241 ratio of 2.8, the individual concentrations of all RCOCs can be derived. Derived activity concentrations are then applied to the unity rule to determine compliance to **Table 3** values. This results in modified screening criteria of 7.3 pCi/g for Cs-137.

8.0 Description of Final Conditions

Final Status Survey Reports were issued throughout the decommissioning process to reflect the iterative process of reaching unrestricted radiological release of the WJN site. Individual reports contained the final status surveys that stated the end-state condition of the area of consideration within the site.

The intent of the reports was to provide a complete record of the radiological status of the area covered by said report. Sufficient information and data were provided to enable an independent re-creation and evaluation at some future date of both the survey activities and the reported results for the covered decommissioning or remediation activity. Reports referenced technical basis documents, final status survey plans and procedures, and reporting and quality assurance procedures.

To the extent practicable, each report was presented with minimal information incorporated by reference.

Table 8 lists the Final Status Survey Reports for the decommissioning and remediation performed under the CCP. Listed are the title, issue date, and revision of the final report. The IVC report is also identified for each of the plans, along with the NRC inspection reports as appropriate.

Drawing 1 details the current end-state of the WJN facility. Similar call-out boxes as seen in **Drawings 2 and 2**, list the applicable Final Status Survey Report(s), IVC Letter Report(s), and NRC Inspection(s), as appropriate. **Drawing 1** provides a visual expression of the information presented in **Table 8**.

Drawing 2 details the layout of the WJN site as to the above-grade structures demolished during or remaining after the decommissioning task. For each structure, a call-out box lists the applicable Final Status Survey Report(s), IVC Letter Report(s), and NRC Inspection(s), as appropriate. Drawing 1 provides a visual expression of the information presented in **Table 8**.

Drawing 3 details the various below-grade excavations and removals conducted at the WJN site during the decommissioning task. As shown in **Drawing 3**, extensive excavation and removal were performed within the restricted area, the connecting area between the restricted and the fenced filter bed area, and within the fenced filter bed area. **Drawing 3** also details the remaining sub-grade structures that met the radiological release criteria and remain at the WJN site. For each excavation or remaining below-grade structure, a call-out box lists the applicable Final Status Survey Report(s), IVC Letter Report(s), and NRC Inspection(s), as appropriate. **Drawing 2** provides a visual expression of the information presented in **Table 8**.

Table 9 lists the final radiological conditions of the various phases of the decommissioning and remediation

process, as well as the end-state condition of the site. The table lists the facility or area, total alpha and total beta surface contamination, the exposure rate, and the Cs-137 activity concentration.

9.0 Independent Verification

The ESSAP of the ORISE fulfilled the IVC role for the CCP under contract to the Oak Ridge Office of the DOE. The ESSAP performed comprehensive independent verification of the final status survey activities from September, 2004 through April, 2006. The scope of the verification activities included in-process inspections of the CCP's procedures and measurement techniques, verification surveys, document review, and inter-laboratory comparison of project data. Scanning surveys of greater than 50-percent of the open land areas, buildings, and structural surfaces, were performed as part of the IVC activity. Additionally, the ESSAP validated the CCP laboratory analytical methods be performing comparison analysis of several of the CCP's soil samples at the ORISE laboratory in Oak Ridge, TN. The CCP expeditiously and appropriately addressed any identified deficiencies to the satisfaction of the IVC. [26]

The independent verification of all the decommissioning and remediation areas was part of the final release process. The ESSAP documented the findings and results of the independent verification surveys in IVC Letter Reports. The CCP submitted draft FSSRs to the ESSAP for review and comment prior to issuing each document as final. **Table 8** lists the IVC Reports as associated with each of the Final Status Survey Reports. The NRC also performed independent verification surveys. **Table 8** lists the NRC Inspection Reports.

The ESSAP of ORISE concluded that the CCP is suitable for unrestricted radiological release based on the results of the independent verification activities. [26]

10.0 Conclusion

The Final Status Survey Reports, in conjunction with the IVC Letter Reports and the NRC inspection reports, document that the endpoint criteria objectives of the NRC-approved Decommissioning Plan have been met for WJN site as covered by the CCP. **Attachments A** to **CC** contain the final certification documentation for each of the FSSRs. Characterization and final status surveys results for scanning and static measurements of surfaces, including smear samples for removable contamination, were below those listed in **Table 2**. Analytical results for media samples obtained from buildings and soils were below the residual radioactivity concentrations for soil and solid volumes as presented in **Table 3**. Finally, external gamma exposure rate measurements were less than or equal to 5 µR/hr above the mean background level, at 1 meter above ground surface.

Therefore, it is the conclusion of this final certificate of completion, that Columbus Closure Project has completed the mission of safe removal of the Department of Energy (DOE) radioactive materials and contamination from Battelle Memorial Institute's (BMI) West Jefferson North site (WJN) to levels that will allow future use of the site without radiological restrictions.

11.0 References

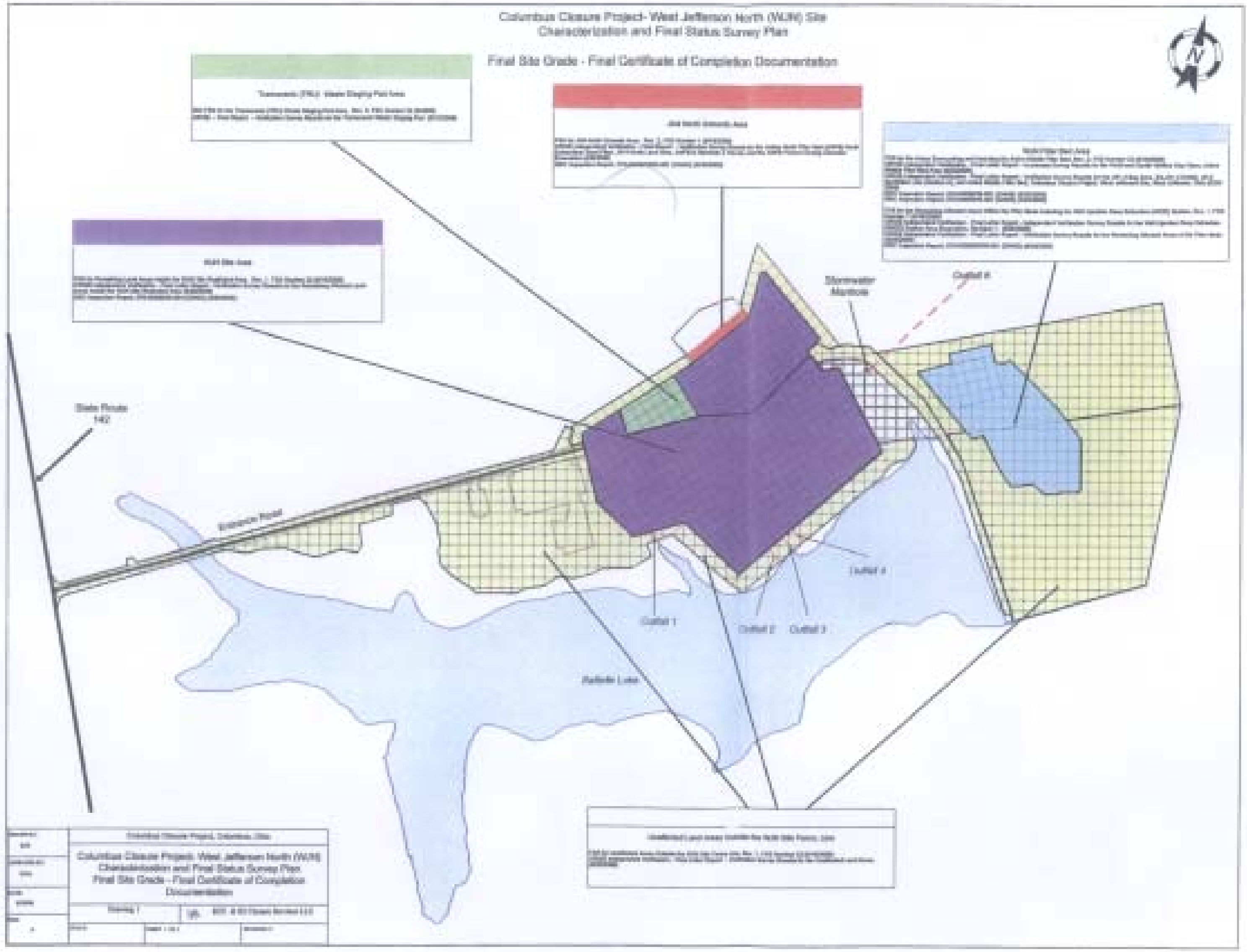
1. Battelle, 2000, "Radiological Characterization and Final Status Plan for Battelle Columbus Laboratories Decommissioning Project, West Jefferson Site", DD-97-02, Rev. 0, March 2000.
2. US Nuclear Regulatory Commission, 1992, "Manual for Conducting Radiological Surveys in Support of License Termination", NUREG/CR-5849, ORAU-92/C57.
3. Battelle, 2003, "Decommissioning Plan, Battelle Memorial Institute Columbus Operations", DD-93-19, Rev. 5, October 16, 2003.
4. U.S. Department of Energy, 1990. "Finding of No Significant Impact, Decontamination and Decommissioning of the Battelle Columbus Laboratories in Columbus and West Jefferson, Ohio."
5. U.S. Department of Energy, 1986, May 29, 1986 memorandum, Voight to Vaughan, approved by Vaughan, June 10, 1986.
6. Battelle, 1992, "Surface Release Criteria Technical Basis Document for Battelle Columbus Laboratories Decommissioning Project (BCLDP)", DD-93-02, Rev. 0, October, 1992.
7. Battelle, 1993. "Volumetric Release Criteria Technical Basis Document for Battelle Columbus Laboratories Decommissioning Project (BCLDP)", DD-93-03, Rev. 0, April, 1993.
8. U.S. Nuclear Regulatory Commission, 1988, "U.S. Nuclear Regulatory Commission Materials License, SNM-7 as renewed, Docket or Reference No. 70-8."
9. Battelle, 2002, "BCLDP Site Environmental Report for Calendar Year 2001 on Radiological and Nonradiological Parameters," September, 2002.
10. Baillieul, T.A. and Ermold, L. F., "Key Considerations for Cost Effective D&D of Nuclear Facilities", www.cemp.doe.gov/lessons/costeffe.pdf

11. Battelle, 2000, "Historical Information on Building JN-1, Project No. G80172909WJ", J. Poliziani to G. Kirsh, June 26, 2000.
12. Battelle, 1975, "Description of Final Survey and Facility Status of the Battelle Research Reactor", September 17, 1975.
13. American National Standards Institute, 1997. ANSI-N323a, "Radiation Protection Instrumentation Test and Calibration."
14. U. S. Nuclear Regulatory Commission, Reg. Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors."
15. U. S. Department of Energy, DOE Order 5400.5, "Radiation Protection of the Public and the Environment."
16. ECC&E2 Closure Services, LLC, 2004, "BCLDP Site Environmental Report for Calendar Year 2003 on Radiological and Nonradiological Parameters," October, 2004.
17. Battelle, 2003, "Site Characterization Operating Procedure, Baseline Reference Values for Facility Radiological Characterization Surveys", SC-OP-007, Rev. 0, March, 2003.
18. Battelle, 2002, "Administrative Operating Procedure for the Radioanalytical Laboratory", RL-AP-1.0, Rev. 10., 2002.
19. Battelle, *Radiological Status of Abandoned Filter Bed Presentation*, http://www.ohio.doe.gov/ccp_seb/, Posted 7/15/2003. Presentation provided by DOE to the CCP website. Page titled "Radioactive Inventory of the Abandoned North Filter Beds & Limit Fractions" contains sampling data obtained from March through September 2000 from the filter beds. Average Cs-137 ratios were utilized to calculate the activity concentrations of the isotopes of concern.
20. Battelle, 2002, "Waste Characterization, Classification, and Shipping Support Technical Basis Document for Battelle Columbus Laboratories Decommissioning Project (BCLDP), West Jefferson North Facility", DD-98-04, Rev. 4, November 2002.
21. Battelle, 2002, "Manual and Mechanical Collection of Surface and Subsurface Soil Samples in Support of Site Characterization", SC-SP-004.3, Rev. 3, November, 2002.
22. Battelle, 2001, "Gamma Spectrometric Analysis of Laboratory Samples Using Canberra Procount™ Software", RL-TP-030, Rev. 5, 2001.
23. Battelle, 2001, "Strontium 90 Analysis by Extraction Chromatography", RL-TP-035, Rev. 4, 2001.

Drawings

Drawing 1

Final Site Grade - Final Certification of Completion Documentation



Columbus Closure Project- West Jefferson North (WJN) Site
Characterization and Final Status Survey Plan
Final Site Grade - Final Certificate of Completion Documentation
State Route
142
Entrance Road
Stormwater
Manhole
Outfall 1
Outfall 2
Outfall 3
Outfall 4
Columbus Closure Project- West Jefferson North (WJN)
Characterization and Final Status Survey Plan
Final Site Grade - Final Certificate of Completion
Documentation

Drawing 2

Above Grade Final Certification of Completion Documentation

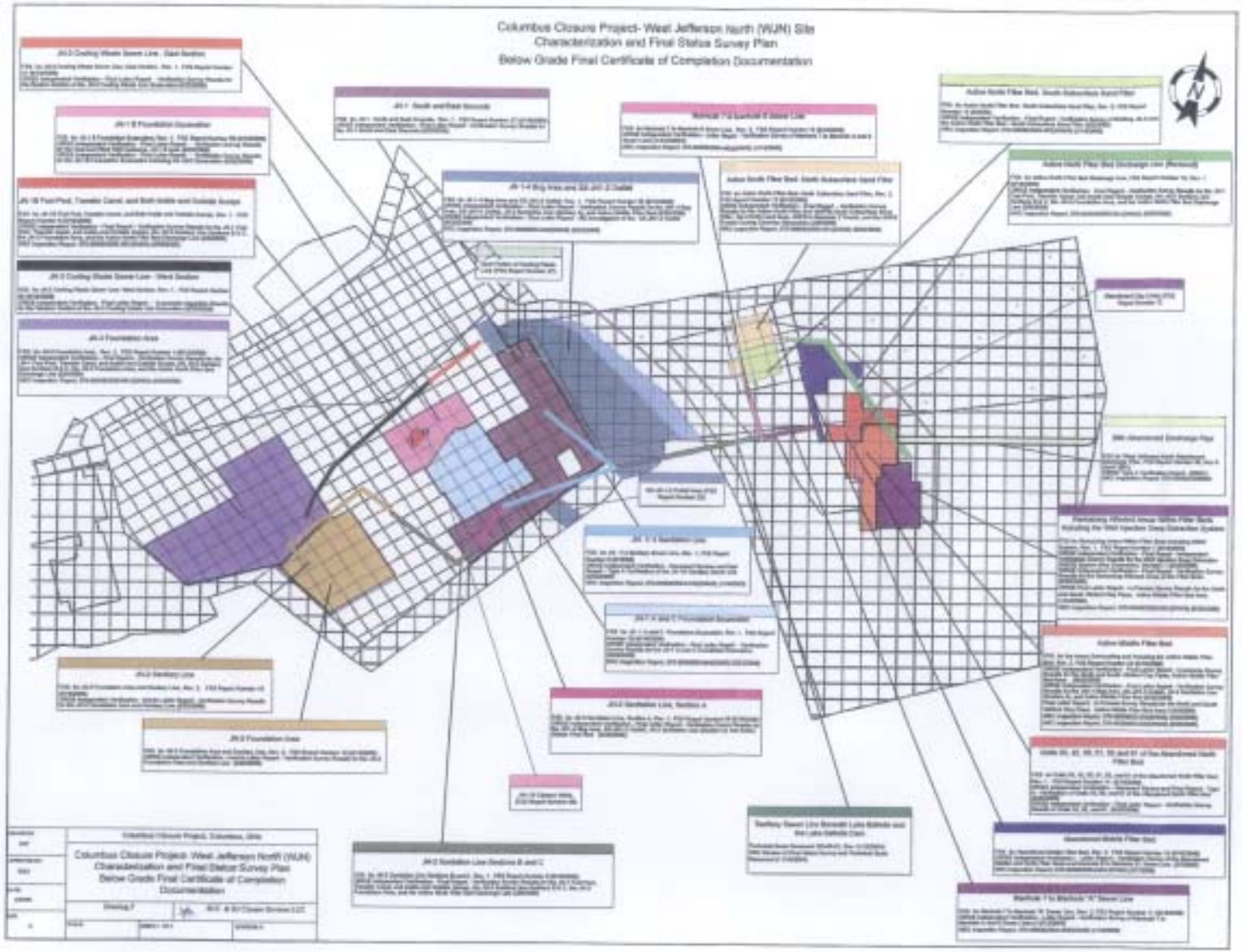
Columbus Closure Project- West Jefferson North (WJN) Site
Characterization and Final Status Survey Plan

Above Grade Final Certificate of Completion Documentation Status Surveys

	Columbus Closure Project, Columbus, Ohio
	Columbus Closure Project- West Jefferson North(WJN) Characterization and Final Status Survey Plan Above Grade Final Certificate of Completion Documentation
	Drawing #

Drawing 3

Below Grade Final Certification of Completion Documentation


Columbus Closure Project- West Jefferson North (WJN) Site
Characterization and Final Status Survey Plan
Below Grade Final Certificate of Completion Documentation
Columbus Closure Project- West Jefferson North (WJN) Site Characterization and Final Status Survey Plan Below Grade Final Certificate of Completion Documentation

Table

Table 1 CCP Affected and Unaffected Areas			
Facility Grouping	**Surface Type**	**Affected Unaffected Category (1, 2, or 3)**	**Comments**
JN-1	Above/Below Grade	**Affected** (2)	Fuel Pool and Transfer Canal
	Above Grade	**Affected** (2)	Hot Cells
	Below Grade	**Affected** (2)	JN-1 Foundation
	Below Grade	**Affected** (2)	JN-1 Below Grade Infrastructure to 14'feet below surface grade
	Grade	**Affected** (1)	JN-1 Backyard Area
JN-2	Above Grade	**Affected** (3)	Unrestricted Radiological Release of the Building
	Below Grade	**Affected** (3)	JN-2 Foundation
	Grade	**Affected** (3)	JN-2 below Grade Infrastructure and Source Wells
JN-3	Above Grade	**Affected** (1)	Remaining Reactor Wall as LLRW Remaining JN-3 Unrestricted Radiological Release
	Below Grade	**Affected** (1)	JN-3 Foundation and Reactor Wall
	Grade	**Affected** (1)	JN-3 Below Grade Infrastructure, including Tanks
Filter Beds	Below Grade	**Affected** (1)	Abandoned Middle Filter Bed (FB)
	Below Grade	**Affected** (1)	Manhole 7 to A Sewer Line
	Below Grade	**Affected** (1)	North FB-North Sand Filter
	Below Grade	**Affected** (1)	North FB-South Sand Filter
	Below Grade	**Affected** (1)	Abandoned NFB, Old Dosing Chamber, Grids 33, 42, 50, 51, 52, and 61
	Below Grade	**Affected** (1)	Manhole 7 to 8 Sewer Line
	Below Grade	**Affected** (1)	Active NFB Discharge Line
	Grade	**Affected** (1)	Filter Bed and WIDE Area
	Grade	**Affected** (1)	Active Middle Filter Bed Area
	Grade	**Affected** (1)	Inside Filter Bed Area Fence
Connecting Areas	Above Grade	**Affected** (1)	Well House
	Above Grade	Unaffected	Building JN-6, Guard House
	Below Grade	**Affected** (1)	JN-2 Sanitary Line A, B, and C
	Below Grade	**Affected** (1)	JN-1/4 Sanitary Sewer Line
	Below Grade	**Affected** (1)	JN-3 Cooling Line-W
	Below Grade Below Grade Below Grade	**Affected** (1) Affected (1) Affected (1)	JN-3 Cooling Line-E Sewer System Discharge Piping JN-4 Sanitary Piping
Connecting Areas (cont.)	Grade	Unaffected	JN-4 North Grounds
	Grade	**Affected** (1)	Inside WJN Restricted Area
	Grade	Unaffected	Outside WJN Restricted Area
	Grade	**Affected** (1)	Active Middle Filter Bed Area
	Grade	**Affected** (1)	JN-1/4 Bog Area and Outfall 6
	Grade	**Affected** (1)	JN-1 South and East Grounds
	Grade Grade	Unaffected Unaffected	Outfall 1-5 TRU Waste Staging Pad

Table 2 Surface Contamination Guidelines for CCP			
Radionuclides [2]	**Allowable Total Residual Surface Contamination (dpm/100 cm^2)[1]**		
	Average [3,4]	**Maximum [4,3]**	**Removable [4,8]**
Transuranics, 1-125, 1-129, Ra-226, Ac-227, Ra-228, Th-228, Th-230, Pa-231	**Reserved** (100)*	**Reserved** (300)*	**Reserved** (20)*
Th-Natural, Sr-90, 1-126, 1-131, 1-133, , Ra-223, Ra-224, U-232, Th-232	1,000	3,000	200
U-Natural, U-235, U-238, and associated decay product, alpha emitters	5,000	15,000	1,000
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above. [7]	5,000	15,000	1,000

(1)	As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute measured by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.
(2)	Where surface contamination by both alpha-and beta-gamma-emitting radionuclides exists, the limits established for alpha-and beta-gamma-emitting radionuclides should apply independently.
(3)	Measurements of average contamination should not be averaged over an area of more than 1m^2. For objects of less surface area, the average should be derived for each such object..
(4)	The average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/hr and 1.0 mrad/hr., respectively, at 1 cm.
(5)	The maximum contamination level applies to an area of not more than 100 cm^2.
(6)	The amount of removable material per 100 cm^2 of surface area should be determined by wiping an area of that size with dry filter or soft absorbent paper, applying moderate pressure, and measuring the amount of radioactive material on the wiping medium using an appropriate instrument of known efficiency. When removable contamination on objects of surface area less than 100 cm^2 is determined, the activity per unit area should be based on the actual area and the entire surface should be wiped. It is not necessary to use wiping techniques to measure removable contamination levels if direct scan surveys indicate that the total residual surface contamination levels are within the limits for removable contamination.
(7)	This category of radionuclides includes mixed fission products, including the Sr-90 which has been separated from the other fission products or mixtures where the Sr-90 has been enriched.

Table 3
CCP Guidelines for Residual Radioactivity Concentrations for Soil and Solid Volumes

Radionuclide[a]	King Avenue Concentration (pCi/g)[b]	West Jefferson Concentration (pCi/g)[b]
Natural Uranium	10[1]	na[c]
Enriched Uranium	30[1]	30[1]
Depleted Uranium	35[1]	35[1]
Ac-227	19	19
Am-241	na[c]	30[4]
Am-243	na	30[4]
Ce-144	na	2,100
Cm-243	na	0.79
Cm-244	na	1.0
Co-60	8[2]	8[2]
Cs-134	na	33
Cs-137	15[2]	15[2]
C-14	940	940
Eu-152	na	36
Eu-154	na	32
Eu-155	na	1,800
Fe-55	na	2.7E+07
H-3[d]	41,000	38,000
I-129	na	13
Mn-54	na	61
Ni-59	na	1.3E+07
Ni-63	na	4.9E+06
Np-237	na	0.58
Pa-231	18	18
Pb-210	140	na
Pu-238	na	25[4]
Pu-239	na	25[4]
Pu-240	na	25[4]
Pu-241	na	25[4]
Pu-242	na	25[4]
Ra-226 (0-15 cm of soil)	5[2,3]	na
Ra-226 (>15 cm of soil)	15[2,3]	na
Ra-228	5[2,3]	na
Ru-106	na	180
Sb-125	na	118
Sm-151	na	6,700
Sr-90	5[2]	5[2]
Th-228	29	na
Th-230	5[3]	na
Th-232	5[3]	na

Table 3
CCP Guidelines for Residual Radioactivity
Concentrations for Soil and Solid Volumes

Radionuclide[a]	King Avenue Concentration (pCi/g)[b]	West Jefferson Concentration (pCi/g)[b]

Notes:

a. Activity concentrations above natural background concentrations. Where more than one radionuclide is present, the sum of the ratios of the individual radionuclide concentrations to their respective concentration limits shall not exceed 1.
b. Concentrations for which no specific reference is cited have been derived from RESRAD calculations and are the more restrictive values calculated for soil deposition at a depth of 5 meters.
c. Indicates that this radionuclide is not expected to be found at the indicated site.
d. Difference in tritium activity concentrations are due to the difference in depths of the water tables at two sites. The water table depth at King Avenue is deeper than that at West Jefferson.

References:

1. Options 1 and 2 of the Branch Technical Position, "Disposal or Onsite Storage of Thorium or Uranium Wastes from Past Operations" (46 FR 52061, October 23, 1981).
2. NRC Memorandum, "Acceptable Cleanup Criteria and Practices for Decontamination and Decommissioning (License No. SNM-7)" dated April 17, 1992, to Harley L. Toy, License Coordinator and Manager, Nuclear Sciences, Battelle Memorial Institute from J.W.N. Hickey, Chief, Fuel Cycle Safety Branch, Division of Industrial and Medical Nuclear Safety, Office of Nuclear Material Safety and Safeguards.
3. DOE Order 5400.5, "Radiation Protection of the Public and the Environment".
4. NRC Policy and Guidance Directive FC83-23, "Termination of Byproduct, Source, and Special Nuclear Material Licenses".

Table 4 – Summary of CCP Decommissioning and Remediation Activities			
Building JN-1	**Building JN-2**	**Building 3**	**Filter Bed Area & Connecting Areas**
2004 - Modified access control for facility and removed all equipment and materials from JN-1A, B, and C in preparation for interior dismantlement activities. Electrically isolated facility for dismantlement and demolition tasks; Disconnected, removed, and capped the exhaust ductwork from JN-1C; Removed and disposed all equipment in JN-1B Pump Room; Completed the removal of the Stainless Steel Flooring in the JN-1B Fuel Pool; Removed and disposed the FH-1 and FH-2 HEPA Units on top of the HLC/LLC Systems; Competed Operations Room interior dismantlement and Decontamination Room interior dismantlement in JN-1B; Removed and disposed the interior steel liner in HEC/HLC/LLC; Demolition, package, and disposal of JN-1C in November 2004.	2004 - Removed and transferred the RAL equipment and chemicals from JN-2 to the modular lab trailer; completed asbestos abatement of interior Performed interior and exterior FSS and IVC for "clean demo" Completed demolition of JN-2 above ground structure in November 2004.	2004 - Repackaged and transferred the manipulator arm equipment to the University of Michigan; removed all equipment and utilities from JN-3 for preparation of building dismantlement; performed FSS and IVC to allow for portion of facility as "clean demo"; reactor wall isolated as LLRW; initiated demolition of the JN-3 above ground structure on December 10, 2004.	2004 - Completed JN-6 (Security Guard House) building demolition in August 4, 2004; completed removal and remediation of the abandoned middle filter bed system and the original abandoned north filter bed system; Shipped Co-60 and cruciform to Barnwell for disposal.
2005 - Decontaminated and demolished the interior of JN-1A&B; performed final decontamination and wash down of interior; and met the criteria for use without radiological restriction for the JN-1B Pool and Transfer Canal, followed by backfilling of the pool; Demolition of the HEC/HLC/LLC; Completed demolition of JN-1B & C above grade structure, including removal of the 50 ton crane; initiated and completed excavation of the Building JN-1 foundation and subsurface infrastructure; and met the criteria for use without radiological restriction.	2005 - Excavation and removal of foundation and subsurface infrastructure; sent demolition debris to commercial disposal and recycle facility; met the criteria for use without radiological restriction and backfilled the excavation.	Demolition of above grade structure; waste load out of clean construction/demolition debris to a commercial landfill; excavation and removal of foundation and subsurface infrastructure; demolition debris meeting disposal criteria was sent to commercial disposal and recycle facilities; met the criteria for use without radiological restriction and backfilled the excavation.	Installation and adjustment of new and replacement systems; excavation, removal, and restoration of dosing chamber, ANFB, WIDE System; AbNFB, AMFB, and other components; excavation and removal of the cooling water waste line and other underground utilities; initiated and completed site restoration and FSS in 2006.

Table 5 Decision Level Values for Building Materials (CPM)*					
Survey Type	Media				
	Brick	Concrete	Concrete Block	LONAM	Glazed Brick
Alpha – Scan	43	35	33	25	45
Alpha - Population	12	11	9	10	20
Alpha/Beta – Scan	712	545	397	370	1093
Alpha/Beta - Population	587	473	330	339	974

*Units expressed in counts per minute (CPM).

Table 6
Filter Bed Cesium-137 Surrogate Analysis Data & Modified Cs-137 Screening Criteria

Sample ID[a,b]	Cs-137 Activity (pCi/g)	Co-60 Activity (pCi/g)	Eu-152 Activity (pCi/g)	Eu-154 Activity (pCi/g)	Am-241 Activity (pCi/g)	Sr-90 Activity (pCi/g)	Pu-238 Activity (pCi/g)	Pu-239 Activity (pCi/g)
16741	40.1	0.05	<0.096	<0.053	1.36 [b]	<0.172	<0.009	0.053
16746	21.6	0.04	<0.079	<0.051	1.29 [f]	<0.184	0.026	0.9
16747	26.1	0.06	<0.077	<0.046	0.89 [b]	<0.175	<0.011	0.116
16751	8	<0.024	<0.068	<0.047	0.93 [b]	<0.151	0.021	0.496
16752	39.1	0.06	<0.086	<0.046	10.74 [f]	<0.167	0.131	5.822
16607	74.2	0.28	7.26	0.65	1.18 [f]	0.59	0.0213	0.629
16608	18.7	0.07	4.03	0.26	0.47 [f]	<0.180	0.016	0.287
16668	41.6	0.08	<0.098	<0.061	2.59 [f]	NA	0.036	1.846
16686	38.1	0.07	<0.050	<0.031	4.71 [f]	NA	0.135	3.84
19079	11.7	0.17	8.02	0.64	0.018	4.39	<0.016	0.034
19080	32.4	<0.016	0.562	<0.053	<0.016	0.21	<0.019	<0.017
Average	*31.99*	*0.084*	*1.857*	*0.176*	*2.2*	*0.691*	*0.04*	*1.276*

Calculated Cs-137 Surrogate Ratio[c]	
Cs-137/Co-60	381
Cs-137/Eu-152	17
Cs-137/Eu-154	182
Cs-137Am-241	15
Cs-137/Sr-90	46
Cs-137/Pu-238	800
Cs-137/Pu-239	28
Cs-137/Pu-241[d]	2.8

Modified Cs-137 Screening Criteria

Cleanup Criteria (pCi/g)		*Surrogate Activity (pCi/g)*	*Summed Ratio*
Cs-137	15	11	0.73
Co-60	8	0.03	0.00
Eu-152	36	0.64	0.02
Eu-154	32	0.06	0.00
Am-241	30	0.76	0.03
Sr-90	5	0.24	0.05
Pu-238	25	0.01	0.00
Pu-239	25	0.44	0.02
Pu-241	25	3.93	0.16
		Unity Rule[e]	*1.0*

[a] BMI analytical results of samples of filter bed area between March and September 2000; [b] Gamma spectroscopy analysis
[c] Surrogate ratio calculated by dividing average Cs-137 activity by average activity of isotope of concern; [d] Pu-241 is calculated by applying a ratio to sum of Pu-238 and Pu-239 (obtained from ORIGEN 2.1 derived values, Battelle, 2003c), resulting in a Cs-137 to Pu-241 ratio of 2.8; [e] Unity Rule applied to surrogate calculated activity resulting in modified Cs-137 screening level of 11 pCi/g; [f] Alpha spectroscopy analysis

Table 7 JN-1 and Bog Area Cesium-137 Surrogate Analysis Data & Modified Cs-137 Screening Criteria								
Sample ID[a,b]	Cs-137 Activity (pCi/g)	Co-60 Activity (pCi/g)	Eu-152 Activity (pCi/g)	Eu-154 Activity (pCi/g)	Am-241 Activity (pCi/g)	Pu-238 Activity (pCi/g)	Pu-238 Activity (pCi/g)	Sr-90 Activity (pCi/g)
RL05-2744	10.50	0.20	0.07	0.06	0.27	0.10	0.05	2.29
RL05-2745	16.30	0.46	0.07	0.09	-0.20	0.20	0.17	1.97
RL05-2746	5.52	0.19	0.05	0.03	0.30	0.12	0.05	0.83
RL05-2747	6.43	0.20	0.10	0.03	-0.08	0.05	0.01	1.11
RL05-2748	18.30	0.56	0.14	0.07	0.36	0.14	0.08	1.34
RL05-2749	11.00	0.31	0.10	0.01	0.00	0.05	0.05	0.82
RL05-2750	18.40	1.30	0.11	0.10	0.09	0.80	0.38	10.90
RL05-2751	12.90	0.40	0.07	0.03	-0.10	0.14	0.09	1.73
RL05-2752	104.00	0.10	0.12	0.07	-0.10	0.04	0.01	0.31
RL05-2753	50.40	0.05	-0.03	-0.02	0.22	0.05	0.05	0.23
RL05-3012	16.10	0.19	0.15	0.09	-0.04	1.06	0.32	9.13
RL05-3014	4.40	0.01	0.05	0.04	-0.19	0.05	0.01	0.91
RL05-3015	25.60	0.70	0.22	0.17	0.42	0.77	0.32	13.30
RL05-3017	15.70	0.38	0.04	0.02	-0.33	0.62	0.33	8.15
RL05-3294	15.80	0.45	0.02	0.04	0.28	0.05	0.08	2.34
RL05-3296	8.10	0.27	-0.04	0.01	-0.28	0.03	0.10	2.81
RL05-3297	43.20	0.75	-0.01	0.09	0.05	0.08	0.12	3.10
RL05-3298	20.40	0.46	0.06	0.03	-0.07	0.00	0.06	2.71
RL05-3300	19.50	0.49	0.03	0.04	-0.06	0.07	0.24	2.87
RL05-4049	19.50	0.26	0.11	0.11	0.36	0.98	0.31	1.22
RL05-4084	13.90	0.58	0.08	0.09	0.28	0.17	0.13	2.79
RL05-4085	19.90	0.30	0.09	0.11	0.47	0.36	0.12	5.37
RL05-4100	7.47	0.15	0.05	0.10	0.38	0.22	0.52	1.44
RL05-4101	7.05	0.04	-0.10	0.04	-0.01	0.54	0.93	0.56
RL05-4153	7.15	0.09	-0.02	-0.04	-0.03	0.13	0.53	2.24
RL05-4158	12.80	0.45	0.08	0.02	0.17	0.55	0.28	10.50
RL05-4159	7.56	0.24	0.02	-0.02	0.19	0.80	0.23	10.30
RL05-4161	11.00	0.25	0.08	0.08	0.07	0.77	0.24	9.45
RL05-4162	19.50	0.25	0.10	0.05	0.18	0.31	0.15	5.28
Average	*14.5*	*0.37*	*0.06*	*0.06*	*0.10*	*0.36*	*0.23*	*4.48*

Table 7
JN-1 and Bog Area Cesium-137 Surrogate Analysis Data & Modified Cs-137 Screening Criteria

Sample ID[d,e]	Cs-137 Activity (pCi/g)	Co-60 Activity (pCi/g)	Eu-152 Activity (pCi/g)	Eu-154 Activity (pCi/g)	Am-241 Activity (pCi/g)	Pu-238 Activity (pCi/g)	Pu-238 Activity (pCi/g)	Sr-90 Activity (pCi/g)

Calculated Cs-137 Surrogate Ratio[a]	
Cs-137/Co-60	35.7
Cs-137/Eu-152	76.1
Cs-137/Eu-154	225.1
Cs-137Am-241	78.9
Cs-137/Sr-90	4.1
Cs-137/Pu-238	57.5
Cs-137/Pu-239	83.1
Cs-137/Pu-241[b]	2.8

Modified Cs-137 Screening Criteria

Cleanup Criteria (pCi/g)		*Surrogate Activity (pCi/g)*	*Summed Ratio*
Cs-137	15	7.30	0.487
Co-60	8	0.20	0.026
Eu-152	36	0.10	0.003
Eu-154	32	0.03	0.001
Am-241	30	0.09	0.003
Sr-90	5	1.78	0.356
Pu-238	25	0.13	0.005
Pu-239	25	0.09	0.004
Pu-241	25	2.61	0.104
		Unity Rule[c]	*1.0*

[a] Surrogate ratio calculated by dividing average Cs-137 activity by average activity of isotope of concern.
[b] Pu-241 is calculated by applying a ratio to sum of Pu-238 and Pu-239 (obtained from ORIGEN 2.1 derived values, Battelle, 2003c), resulting in a Cs-137 to Pu-241 ratio of 2.8.
[c] Unity Rule applied to surrogate calculated activity resulting in modified Cs-137 screening level of 7.3 pCi/g.
[d] CS analytical results of samples of the backyard and bog area during the fall of 2005.
[e] Gamma spectroscopy analysis.

Table 8 CCP Final Status Survey Report, ORISE Independent Verification Letter Reports, & NRC Inspection Reports	
FSSR #1	Columbus Closure Project Characterization and Final Status Survey Report for the JN-4 North Grounds Area, Revision 2, Dated June 16, 2006. ▪ ORISE Independent Verification – Final Report – Verification Survey Results for the Active North Filter Bed (ANFB) North Subsurface Sand Filter, JN-4 North Land Area, ANFB to Manhole 2 Trench, and the ANFB Former Dosing Chamber Excavation, Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, February 9, 2006. ▪ NRC Inspection Report, 070-00008/2005-001(DNMS)- Battelle Columbus Laboratories Decommissioning Project NRC, Letter from Jamnes L. Cameron, Chief Decommissioning Branch (NRC) to J. Jacobsen (BMI), June 30, 2005.
FSSR #2	Columbus Closure Project Characterization and Final Status Survey Report for Building JN-2, Revision 0, Dated November 2004. ▪ ORISE Independent Verification- Final Report – Verification Survey of Building JN-2, Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, December 1 2004. ▪ NRC Inspection Report, 070-00008/2004-002(DNMS)- Battelle Columbus Laboratories Decommissioning Project NRC, Letter from Kenneth G. O'Brien, Chief Decommissioning Branch (NRC) to J. Jacobsen (BMI), October 29, 2004.
FSSR #3	Columbus Closure Project Characterization and Final Status Survey Report for Building JN-3, Revision 0, Dated November 2004. ▪ ORISE Independent Verification – Final Report – Verification Survey of Building JN-3 and the Active North Filter Bed – South Subsurface Sand Filter. Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, March 2, 2005. ▪ NRC INSPECTION REPORT, 070-00008/2004-002(DNMS)- Battelle Columbus Laboratories Decommissioning Project NRC, Letter from Kenneth G. O'Brien, Chief Decommissioning Branch (NRC) to J. Jacobsen (BMI), October 29, 2004.
FSSR #4	Columbus Closure Project Characterization and Final Status Survey Report for The JN-3 Foundation Area, Revision 2, Dated June 16, 2006. ▪ ORISE Independent Verification - Final Report – Verification Survey Results for the JN-1 Fuel Pool, Transfer Canal, and Inside and Outside Sumps, the JN-2 Sanitary Line Sections B & C, the JN-3 Foundation Area, and the Active North Filter Bed Discharge Line, Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, February 9, 2006. ▪ NRC Inspection Report, 070-00008/2005-001(DNMS)- Battelle Columbus Laboratories Decommissioning Project NRC, Letter from Jamnes L. Cameron, Chief Decommissioning Branch (NRC) to J. Jacobsen (BMI), June 30, 2005.
FSSR #5	Columbus Closure Project Characterization and Final Status Survey Report for Building JN-6, Revision 1, Dated July 2004. ▪ ORISE Independent Verification - Revised Type A Verification Report – Columbus Project Characterization and Final Status Survey of Building JN-6, Columbus Closure Project, West Jefferson, Ohio, July 22, 2004.
FSSR #6	Columbus Closure Project Characterization and Final Status Survey Report for The JN-1B Fuel Pool, Transfer Canal, and Both the Inside and Outside Sumps, Revision 1, Dated June 16, 2006. ▪ ORISE Independent Verification – Final Report – Verification Survey Results for the JN-1 Fuel Pool, Transfer Canal, and Inside and Outside Sumps, the JN-2 Sanitary Line Sections B & C, the JN-3 Foundation Area, and the Active North Filter Bed Discharge Line, Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, February 9, 2006. ▪ NRC Inspection Report, 070-00008/2005-001(DNMS)- Battelle Columbus Laboratories Decommissioning Project NRC, Letter from Jamnes L. Cameron, Chief Decommissioning Branch (NRC) to J. Jacobsen (BMI), June 30, 2005

Table 8 CCP Final Status Survey Report, ORISE Independent Verification Letter Reports, & NRC Inspection Reports	
FSSR #7	Columbus Closure Project Characterization and Final Status Survey Report for The Remaining Affected Areas Within the Filter Beds Including the Well Injection Deep Extraction (WIDE) System, Revision 1, Dated June 16, 2006. ▪ ORISE Independent Verification – Final Report – Independent Verification Survey Results for the Well Injection Deep Extraction (WIDE) System Area Excavation, Revision 1, Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, June 20, 2006. ▪ ORISE Independent Verification – Final Report – Verification Survey Results for the Remaining Affected Areas of the Filter Beds, Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, June 20, 2006. ▪ NRC Inspection Report, 070-00008/2005-001(DNMS)- Battelle Columbus Laboratories Decommissioning Project NRC, Letter from Jamnes L. Cameron, Chief Decommissioning Branch (NRC) to J. Jacobsen (BMI), June 30, 2005
FSSR #8	Columbus Closure Project Characterization and Final Status Survey Report for The JN-2 Sanitation Line Sections B and C, Revision 1, Dated June 16, 2006. ▪ ORISE Independent Verification - Final Report – Verification Survey Results for the JN-1 Fuel Pool, Transfer Canal, and Inside and Outside Sumps, the JN-2 Sanitary Line Sections B & C, the JN-3 Foundation Area, and the Active North Filter Bed Discharge Line, Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, February 9, 2006.
FSSR #9	Columbus Closure Project Characterization and Final Status Survey Report for JN-1/4 Sanitary Sewer Line, Revision 1, Dated June 16, 2006. ▪ ORISE Independent Verification – Document Review and Final Report - Type A Verification of the JN-1/4 Sanitary Sewer Line, Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, June 20, 2006. ▪ NRC Inspection Report, 070-00008/2004-003(DNMS)- Battelle Columbus Laboratories Decommissioning Project NRC, Letter from Jamnes L. Cameron, Chief Decommissioning Branch (NRC) to J. Jacobsen (BMI), January 18, 2005.
FSSR #10	Columbus Closure Project Characterization and Final Status Survey Report for The Abandoned Middle Filter Bed, Revision 2, Dated June 16, 2006. ▪ ORISE Independent Verification - Letter Report – Verification Survey of the Abandoned Middle and North Filter Beds and Manhole B to Manhole E1 Sewer Line, Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, February 7, 2005. ▪ NRC Inspection Report, 070-00008/2004-004(DNMS)- Battelle Columbus Laboratories Decommissioning Project NRC, Letter from Jamnes L. Cameron, Chief Decommissioning Branch (NRC) to J. Jacobsen (BMI), February 1, 2005.
FSSR #11	Columbus Project Characterization and Final Status Survey Report for Manhole 7 to Manhole "A" Sewer Line, Revision 2, Dated June 16, 2006. ▪ ORISE Independent Verification - Letter Report – Verification Survey of Manhole 7 to Manhole A and 8 Sewer Lines, Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, December 13, 2004. ▪ NRC Inspection Report, 070-00008/2004-003(DNMS)- Battelle Columbus Laboratories Decommissioning Project NRC, Letter from James L. Cameron, Chief Decommissioning Branch (NRC) to J. Jacobsen (BMI), January 18, 2005.
FSSR #12	Columbus Closure Project Characterization and Final Status Survey Report for Active North Filter Bed – North Subsurface Sand Filter, Revision 2, Dated June 16, 2006. ▪ ORISE Independent Verification – Final Report – Verification Survey Results for the Active North Filter Bed (ANFB) North Subsurface Sand Filter, JN-4 North Land Area, ANFB to Manhole 2 Trench, and the ANFB Former Dosing Chamber Excavation, Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, February 9, 2006. ▪ NRC Inspection Report, 070-00008/2005-001(DNMS)- Battelle Columbus Laboratories

Table 8 CCP Final Status Survey Report, ORISE Independent Verification Letter Reports, & NRC Inspection Reports	
	Decommissioning Project NRC, Letter from Jamnes L. Cameron, Chief Decommissioning Branch (NRC) to J. Jacobsen (BMI), June 30, 2005.
FSSR #13	Columbus Closure Project Characterization and Final Status Survey Report for Active North Filter Bed - South Subsurface Sand Filter, Revision 0, Dated August 2005. • ORISE Independent Verification – Final Report – Verification Survey of Building JN-3 and the Active North Filter Bed – South Subsurface Sand Filter. Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, March 2, 2005. • NRC Inspection Report, 070-00008/2004-003(DNMS)- Battelle Columbus Laboratories Decommissioning Project NRC, Letter from Jamnes L. Cameron, Chief Decommissioning Branch (NRC) to J. Jacobsen (BMI), January 18, 2005.
FSSR #14	Columbus Closure Project Characterization and Final Status Survey Report for Grids 33, 42, 50, 51, 52 and 61 of the Abandoned North Filter Bed, Revision 1, Dated June 16, 2006. • ORISE Independent Verification – Document Review and Final Report – Type A – Verification of Grids 42, 50, and 51 of the Abandoned North Filter Bed, Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, June 20, 2006. • ORISE Independent Verification – Final Letter Report – Verification Survey Results of Grids 33, 52, and 61, Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, June 20, 2006.
FSSR #15	Columbus Closure Project Characterization and Final Status Survey report for Manhole 7 to Manhole 8 Sewer Line, Revision 2, Dated June 16, 2006. • ORISE Independent Verification - Letter Report – Verification Survey of Manhole 7 to Manhole A and 8 Sewer Lines, Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, December 13, 2004. • NRC Inspection Report, 070-00008/2004-003(DNMS)- Battelle Columbus Laboratories Decommissioning Project NRC, Letter from Jamnes L. Cameron, Chief Decommissioning Branch (NRC) to J. Jacobsen (BMI), January 18, 2005.
FSSR #16	Columbus Closure Project Characterization and Final Status Survey Report for The Active North Filter Bed Discharge Line, Revision 1, Dated June 16, 2006. • ORISE Independent Verification – Final Report – Verification Survey Results for the JN-1 Fuel Pool, Transfer Canal, and Inside and Outside Sumps, the JN-2 Sanitary Line Sections B & C, the JN-3 Foundation Area, and the Active North Filter Bed Discharge Line, Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, February 9, 2006. • NRC Inspection Report, 070-00008/2005-001(DNMS)- Battelle Columbus Laboratories Decommissioning Project NRC, Letter from Jamnes L. Cameron, Chief Decommissioning Branch (NRC) to J. Jacobsen (BMI), June 30, 2005.
Technical Basis Document DD-05-01	DD-05-01, Technical Basis Document for Unrestricted Release of Sanitary Sewer Line Beneath Lake Battelle and the Lake Battelle Dam, Revision 0, Dated October 2004. • NRC REVIEW OF FINAL STATUS SURVEY AND TECHNICAL BASIS DOCUMENT FOR THE SANITARY SEWER LINE BENEATH LAKE BATTELLE AND THE BATTELLE LAKE DAM, Letter from Kenneth G. O'Brien, Chief Decommissioning Branch (NRC) to J. Jacobsen (BMI), November 10, 2004.
FSSR #19	Columbus Closure Project Characterization and Final Status Survey Report for The JN-2 Foundation Area and Sanitary Line, Revision 2, Dated June 16, 2006. • ORISE Independent Verification - Final Letter Report – Verification Survey Results for the JN-2 Foundation Area and Sanitary Line, Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, March 20, 2006.
FSSR #20	Columbus Closure Project Characterization and Final Status Survey Report for The WJN Well House Building, Revision 1, Dated June 16, 2006. • ORISE Independent Verification - Final Letter Report – Verification Survey Results for the Well House Building, Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, June 20, 2006.

Table 8 CCP Final Status Survey Report, ORISE Independent Verification Letter Reports, & NRC Inspection Reports	
FSSR #22	Columbus Closure Project Final Status Survey Report for Remaining Land Areas Inside the WJN Site Restricted Area, Revision 1, Dated June 16, 2006. ▪ ORISE Independent Verification - Final Letter Report - Verification Survey Results for the Remaining Affected Land areas Inside the WJN Site Restricted Area, Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, June 20, 2006. ▪ NRC Inspection Report, 070-00008/05-004(DNMS)- Battelle Columbus Laboratories Decommissioning Project NRC, Letter from James L. Cameron, Chief Decommissioning Branch (NRC) to J. Jacobsen (BMI), March 23, 2006.
FSSR #23	Columbus Closure Project Final Status Survey Report for Unaffected Land Areas Outside the WJN Site Fence Line, Revision 1, Dated June 16, 2006. ▪ ORISE Independent Verification – Final Letter Report – Verification Survey Results for the Unaffected Land Areas, Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, June 20, 2006.
FSSR #24	Columbus Closure Project Characterization and Final Status Survey Report for The Areas Surrounding and Including the Active Middle Filter Bed, Revision 2, Dated June 16, 2006. ▪ ORISE Independent Verification – Final Letter Report – In-process Survey Results for the North and South Vitrified Clay Pipes, Active Middle Filter Bed Area, Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, June 20, 2006. ▪ ORISE Independent Verification – Final Letter Report – Verification Survey Results for the JN1-4 Bog Area, SS-JN1-2 Outfall, JN-2 Sanitation Line (Section A), and Active Middle Filter Bed, Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, June 20, 2006. ▪ NRC Inspection Report, 070-00008/05-002(DNMS)- Battelle Columbus Laboratories Decommissioning Project NRC, Letter from Jamnes L. Cameron, Chief Decommissioning Branch (NRC) to J. Jacobsen (BMI), September 29, 2005. ▪ NRC Inspection Report, 070-00008/05-004(DNMS)- Battelle Columbus Laboratories Decommissioning Project NRC, Letter from Jamnes L. Cameron, Chief Decommissioning Branch (NRC) to J. Jacobsen (BMI), March 23, 2006.
FSSR #25	Columbus Closure Project Characterization and Final Status Survey Report for The JN1-4 Bog Area and SS-JN1-2 Outfall, Revision 1, Dated June 16, 2006. ▪ ORISE Independent Verification – Final Letter Report – Verification Survey Results for the JN1-4 Bog Area, SS-JN1-2 Outfall, JN-2 Sanitation Line (Section A), and Active Middle Filter Bed, Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, June 20, 2006. ▪ ORISE Independent Verification – Final Letter Report – RE-Investigation of the SS-JN1-2 Outfall, Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, June 20, 2006. ▪ NRC Inspection Report, 070-00008/05-004(DNMS)- Battelle Columbus Laboratories Decommissioning Project NRC, Letter from Jamnes L. Cameron, Chief Decommissioning Branch (NRC) to J. Jacobsen (BMI), March 23, 2006.
FSSR #26	Columbus Closure Project Characterization and Final Status Survey Report for The JN-2 Sanitation Line Section A, Revision 1, Dated June 16, 2006. ▪ ORISE Independent Verification – Final Letter Report – Verification Survey Results for the JN1-4 Bog Area, SS-JN1-2 Outfall, JN-2 Sanitation Line (Section A), and Active Middle Filter Bed, Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, June 20, 2006.
FSSR #27	Columbus Closure Project Characterization and Final Status Survey Report for the JN-1 South and East Grounds, Revision 1, Dated June 16, 2006. ▪ ORISE Independent Verification – Final Letter Report - Verification Survey Results for the JN-1 South and East Grounds, Columbus Closure Project, West Jefferson, Ohio, June 20, 2006.
FSSR #28	Columbus Closure Project Characterization and Final Status Survey Report for the JN-1 A

Table 8 CCP Final Status Survey Report, ORISE Independent Verification Letter Reports, & NRC Inspection Reports	
FSSR #27	Columbus Closure Project Characterization and Final Status Survey Report for the JN-1 South and East Grounds, Revision 1, Dated June 16, 2006. • ORISE Independent Verification – Final Letter Report - Verification Survey Results for the JN-1 South and East Grounds, Columbus Closure Project, West Jefferson, Ohio, June 20, 2006.
FSSR #28	Columbus Closure Project Characterization and Final Status Survey Report for the JN-1 A and C Foundation Excavation, Revision 1, Dated June 16, 2006. • ORISE Independent Verification – Final Letter Report - Verification Survey Results for the JN-1 A and C Foundation Excavation, Columbus Closure Project West Jefferson, Ohio, June 20, 2006. • NRC Inspection Report, 070-00008/05-004(DNMS)- Battelle Columbus Laboratories Decommissioning Project NRC, Letter from Jamnes L. Cameron, Chief Decommissioning Branch (NRC) to J. Jacobsen (BMI), March 23, 2006.
FSSR #29	Columbus Closure Project Characterization and Final Status Survey Report for The JN-1 B Foundation Excavation, Revision 1, Dated June 16, 2006. • ORISE Independent Verification - Final Letter Report - Verification Survey Results for the East and West Well Caissons, JN-1 B Area, Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, June 20, 2006. • ORISE Independent Verification - Final Letter Report - Verification Survey Results for the JN-1B Foundation Excavation Including the HEC Excavation, Columbus Closure Project, West Jefferson Site, West Jefferson, June 20, 2006.
FSSR #30	Columbus Closure Project Characterization and Final Status Survey Report for the JN-3 Cooling Waste Sewer Line – West Section, Revision 1, Dated June 16, 2006. • ORISE Independent Verification – Final Letter Report - In-process Inspection Results for the Western Section of the JN-3 Cooling Waste Line Excavation, Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, June 20, 2006.
FSSR #31	Columbus Closure Project Characterization and Final Status Survey Report for the JN-3 Cooling Waste Sewer Line – East Section, Revision 1, Dated June 16, 2006. • ORISE Independent Verification - Final Letter Report - Verification Survey Results for the Eastern Section of the JN-3 Cooling Waste Line Excavation, Columbus Closure Project, West Jefferson Site, West Jefferson, Ohio, June 20, 2006
FSSR #32	Battelle Columbus Laboratory Decommissioning Project Characterization and Final Status Survey Report -JN-4 Yard and Drainpipe Removal Dated May 2006. • NRC Inspection Report , 070-00008/-5-04
FSSR #33	Battelle Columbus Laboratory Decommissioning Project Characterization and Final Status Survey Report- West Jefferson North Abandoned Discharge Pipe dated April 2001. • NRC Inspection Report, 070-00008/2000003
FSSR #34	Battelle Columbus Laboratory Decommissioning Project Characterization and Final Status Survey Report- TRU Waste Staging Pad Area
FSSR #35	Battelle Columbus Laboratory Decommissioning Project Characterization and Final Status Survey Report- Investigatory Survey Report JN-3 Cooling Waste Sewer Line East * NRC Inspection Report, 070-00008/05-004

Table 9. End-State Radiological Conditions of CCP

Facility	Medium	Total alpha (dpm/100 cm²)			Total beta (dpm/100 cm²)			Exposure Rate (µR/h)			Cs-137 (pCi/g)			Final Status Survey Reports
		Max	Ave	Criteria (Ave/Max)	Max	Ave	Criteria (Ave/Max)	Max	Ave	Criteria	Max	Ave	Criteria	
JN-4 North Grounds	soil	—	—	—	—	—	—	11	7.1	13	0.16	0.19	11	FSSR #1/ FSSR #22 (µR/hr)
JN-2 Building	structure	73	0.21	100/300	460	22	1000/3000	11	7.1	13	—	—	—	FSSR #2/ FSSR #22 (µR/hr)
JN-3 Building	structure	47	3.63	100/300	537	-38.5	1000/3000	11	7.1	13	—	—	—	FSSR#3 / FSSR #22 (µR/hr)
JN-3 Foundation	soil	—	—	—	—	—	—	11	7.1	13	1.80	0.16	11	FSSR #4/ FSSR #22 (µR/hr)
JN-6 Building	structure	26.8	-4.36	100/300	870	321	1000/3000	12	9.5	13	—	—	—	FSSR #5
JN-1 B Fuel Pool and Transfer Canal	structure	—	—	—	776	-70.6	1000/3000	10	8.3	13	—	—	—	FSSR #6
Filter Bed and WIDE Area	soil	—	—	—	—	—	—	13	10.8	13	7.76	0.36	11	FSSR #7 (Average w/in grids)
JN-2 Sanitary Lines B & C	soil	—	—	—	—	—	—	11	7.1	13	0.08	0.03	11	FSSR #8/ FSSR #22 (µR/hr)
JN-1/4 Sanitary Line	soil	—	—	—	—	—	—	11	7.1	13	0.39	0.28	11	FSSR #9/ FSSR #22 (µR/hr)
Abandoned Middle Filter Bed	soil	—	—	—	—	—	—	13	11.4	13	1.02	0.18	11	FSSR #10
Manhole 7 to Manhole A	soil	—	—	—	—	—	—	16	15.5	16	12.3	1.10	11	FSSR #11 (Unity < 1.0)
Active N Filter Bed – N Sand Filter	soil/structure	—	—	—	25.3	-35.6	1000/3000	12	11	13	0.20	0.08	11	FSSR #12 (α + β surface activity)
Active N Filter Bed – S Sand Filter	soil/structure	—	—	—	51.79	122	1000/3000	12	10.6	13	—	—	—	FSSR #13 (α + β surface activity)
Land Areas Inside WJN Restricted Area	soil	—	—	—	—	—	—	11	7.1	13	0.62	0.26	7.3	FSSR #22
JN-3 Cooling Waste Line - West	soil	—	—	—	—	—	—	12	8.2	13	0.12	0.02	7.3	FSSR #30
JN-3 Cooling Waste Line - East	soil	—	—	—	—	—	—	8	5.9	13	0.09	0.01	7.3	FSSR #31
Area Surrounding and Including AMFB	soil	—	—	—	—	—	—	13	9.8	13	20.4	2.17	11	FSSR #24 (< 3X Cs-137 Limit)
Abandoned N Filter Bed Grids 42, 50, 51, 33, 52, and 61	soil	—	—	—	—	—	—	13	11	13	9.24	1.3	11	FSSR #7 (µR/hr) / FSSR #14
Manhole 7 to Manhole 8	soil	—	—	—	—	—	—	11	7.1	13	0.16	0.05	11	FSSR #15/ FSSR #22 (µR/hr)
Active N Filter Bed Discharge Line	soil	—	—	—	—	—	—	11	7.1	13	3.99	0.25	11	FSSR #16 / FSSR #22 (µR/hr)
JN-2 Foundation and Sanitary Line	soil	—	—	—	—	—	—	11	7.1	13	0.08	0.43	11	FSSR #19 / FSSR #22 (µR/hr)
WJN Well House	structure	—	—	—	276	11	1000/3000	13	12	13	—	—	—	FSSR #20 (α + β surface activity)
Remaining Land Areas Inside the WJN Restricted Area	soil	—	—	—	—	—	—	11	7.1	13	5.59	0.81	7.3	FSSR #22 (µR/hr)
Land Areas Outside WJN Restricted Area	soil	—	—	—	—	—	—	13	8	13	1.01	0.22	7.3	FSSR #23
JN-1/4 Bog Area and Outfall SS-JN1-2	soil	—	—	—	—	—	—	10	12	13	3.86	0.43	7	FSSR #25
JN-2 Sanitary Line A	soil	—	—	—	—	—	—	11	10.4	13	0.48	0.26	11	FSSR #26
JN-1 South and East Grounds	soil	—	—	—	—	—	—	13	9.4	13	6.63	0.45	7	FSSR #27
JN-1 A, B, & C Foundation	soil/structure	—	—	—	9440	2170	5000/15000	12	7.3	13	5.59	0.88	7.3	FSSR #28 / FSSR #29

DD-97-02
Revision 0

FINAL PLAN

RADIOLOGICAL CHARACTERIZATION AND FINAL STATUS PLAN FOR BATTELLE COLUMBUS LABORATORIES DECOMMISSIONING PROJECT WEST JEFFERSON SITE

Battelle
. . . Putting Technology To Work

505 King Avenue
Columbus, Ohio 43201

March 2000

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PLAN APPROVAL PAGE

Prepared By:

Michael Rubadue, Characterization Task Leader — 3-27-00 Date

This plan, DD-97-02, "Radiological Characterization and Final Status Plan for the Battelle Columbus Laboratories Decommissioning Project West Jefferson Site," has been reviewed and approved by the following:

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1.0 INTRODUCTION

The Battelle Columbus Laboratories Decommissioning Project (BCLDP) is a remediation project affecting the Battelle Columbus Operations (BCO) King Avenue and West Jefferson sites. Battelle has been a contractor to the U.S. Department of Energy (DOE) since the 1940s, when it was the United States Army Corp of Engineers Manhattan Engineer District. Radioactive materials research activities including metalworking, metallurgy, radiochemistry, and testing continued until the 1980s. The BCLDP was formed in 1984 to decommission and remediate Battelle-owned buildings containing residual radioactive materials. In addition to being a DOE contractor, Battelle is also a Nuclear Regulatory Commission (NRC) licensee. Consequently, both DOE and NRC requirements must be met during the decommissioning process.

Decommissioning is the process of removing a facility from operation, decontaminating the facility, terminating the NRC license and/or returning the facility to unrestricted use. The purpose of the decommissioning process is to "assure that future uses of any licensed facility will not result in individuals being exposed to unacceptable levels of radiation and/or radioactive materials" as stated in NUREG/CR-5849, "Manual for Conducting Radiological Surveys in Support of License Termination" (Reference 1). Radiological surveys are necessary to determine the levels of radiation/radioactive materials at a facility. Guidance regarding the planning and performing of radiological surveys in conjunction with decommissioning is provided in Reference 1 that describes six surveys relating to the decommissioning process:

- Scoping survey - identifies the potential radionuclide contaminants at the facility and the general extent of area and volumetric contamination and preliminarily identifies affected and unaffected areas. Affected areas are those that have potential contamination (based on process knowledge) or known contamination (based on previous radiological surveys). Unaffected areas are not expected to contain radioactive contamination based on process knowledge and previous radiological surveys.

- Background survey - establishes the levels of naturally occurring radiation/radioactive materials in the environment; may include ambient exposure rate measurements, determination of radionuclide concentration in soil or groundwater, and determination of radionuclide concentrations in building materials.

- Characterization survey - more accurately defines the extent and magnitude of contamination; delineates areas to be decontaminated.

- Remediation control survey - determines the effectiveness of decontamination in progress.

- Final status survey - determines the post-decontamination (if decontamination was required) condition of the facility; provides data to demonstrate that unacceptable levels

of radioactive materials have not been left on-site. Data from previous surveys may be used to supplement the final status survey.

- Confirmatory survey - confirms the adequacy of the facility's decontamination and decommissioning process and the accuracy of the final status survey. This survey is performed by an independent third party, usually referred to as the "Independent Verification Contractor (IVC)." This DOE subcontactor satisfies the certification requirements of BCLDP Procedure QA-AP-7.1, "Decontamination and Decommissioning Operations (DDO) Quality Department Administrative Procedure (QD-AP)."

This plan provides general but mandatory guidance for survey activities at the West Jefferson site. It is based upon NUREG/CR-5849, which is committed to in the NRC-approved BCLDP decommissioning plan, "Decommissioning Plan for the Battelle Memorial Institute Columbus Operations" (Reference 2). NUREG-1575 "Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)" (Reference 3) may be used in lieu of Reference 2 if the final status process is determined to be a more efficient and cost-effective survey. Professional judgement will be used to determine the most efficient and effective survey design. Operations not covered by approved procedures will be described in detailed Work Instructions for each area to be characterized, as required by QD-AP-5.2, "Work Instructions."

2.0 OPERATIONAL HISTORY

The West Jefferson North site has five permanent structures included in the scope of this document; JN-1, JN-2, JN-3, JN-6, and the Well house. Three temporary structures, JNT-1, JNT-2, and JNT-3, are also located at the site. Several outfalls, filter beds, and wells are located on the site.

JN-1 is a steel frame, concrete block/brick structure containing three large hot cells, a band of ten alpha-gamma cells, a mechanical test cell, and supporting facilities including a large storage and transfer pool. The facility was used for hot cell examination of fuel elements irradiated in the Battelle Research Reactor. Subsequent work in the facility involved examination of fuel from commercial power reactors in support of DOE programs.

JN-2 is a two-story steel frame, concrete block/brick structure with an attached high-bay area. This building contains a vault that was used to store plutonium and highly enriched uranium. The Radioanalytical Laboratory (RAL) is located in the former plutonium lab.

JN-3 is a two-story steel frame, concrete block/brick structure with a basement. The three floors are reinforced concrete and the former reactor pool/containment is also concrete. The research reactor that was located in this building was used in support of fuel development programs. It was partially decommissioned to NRC criteria as indicated and documented in a letter from K.D. Kok and Sam Basham to W. H. Goldthwaite (Reference 4) regarding the report, "Dismantling of

the Battelle Research Reactor (BRR)" (Reference 5), and the letter from Kenneth Kok to Joel Kohler regarding the description of the final survey of the BRR (Reference 6).

JN-6 is a brick building that housed Battelle's West Jefferson security operations.

The Well house is a brick building with a basement that contains the equipment associated with supplying water to the site.

JNT-1, JNT-2, and JNT-3 are mobile home trailers used as office/break areas.

The principal form of material present at the West Jefferson site is irradiated enriched uranium and associated long-lived fission and activation products, which would include all nuclides listed in Table 5 of DD-93-03, "Volumetric Release Criteria Technical Basis Document for Battelle Columbus Laboratories Decommissioning Project (BCLDP)" (Reference 7).

Isolated areas, such as the RAL, may possibly contain nuclides from the King Avenue site. These areas are routinely surveyed under the surveillance and maintenance program and no significant decontamination efforts are expected.

3.0 SCOPING SURVEYS

Scoping surveys were performed at the onset of the BCLDP. Initial baseline areas are listed in "Submission of Report on Facilities for Acceptance Under the DOE Surplus Facilities Management Program" (Blue book, Reference 8), Reference 4, Reference 5, Reference 6, Argonne National Laboratory's "Cursory Radiological Assessment Battelle Columbus Laboratory Decommissioning and Decontamination Project" (Reference 9), and the Stenhouse and Beard report, "Site Characterization West Jefferson North Site Sampling and Analysis" (Reference 10). Additional baseline areas have been added based on radiological surveys and DOE approval. Outdoor areas inside the fenced portion of the site are considered baseline, along with the abandoned filter beds and abandoned discharge pipe. Other outdoor areas will be evaluated individually. The structures on the North site, listed above, are considered baseline.

4.0 BACKGROUND SURVEYS

Background surveys in support of radiological characterization and final status surveys will be performed on materials that contain varying quantities of naturally occurring radionuclides. Surveys may need to be performed in the presence of interfering radiation fields from other natural or contamination sources. Quantification of background sources is required, for both soil and building materials, to accurately report residual radioactive contamination as stated in Reference 7.

Mean background activity for building materials will be determined by surveying areas known to be free of residual activity. These surveys will be performed in the same manner and with the

same instrumentation used during characterization and final status surveys. Chauvenet's criterion for rejection of data (Reference 11) will be applied to ensure a true mean background is acquired. A decision level value (DLV) will be calculated to permit identification, in the field, of surfaces that require additional radiological measurements. Decision level values will be calculated by using the following equation:

$$DLV = \bar{x}_{bkg} + MDA$$

where:

$\bar{x}_{bkg}$ = mean background value (cpm)
MDA = minimum detectable activity (cpm).

MDA values will be calculated using the following:

$$MDA = 3 + 4.65(\sigma_{bkg})$$

where:

σ_{bkg} = standard deviation of background value.

Mean background activity for soil will be determined by taking samples in areas known to be free of residual contamination. These samples will have the same characteristics as the soil in the areas to be characterized and will be analyzed for the known or suspected site contaminants. Soil screening may be used to expedite the survey process and reduce analytical costs. Soil screening is accomplished by placing the soil sample in a known geometry and counting the sample with a scintillation detector. The sample reading is compared to the DLV for soil and is sorted into one of three categories; "clean," "suspect," or "contaminated." The DLV for soil screening is derived by screening several background samples and obtaining the mean using Chauvenet's criterion. All samples whose screening is less than the mean ($\bar{x}_{bkg}$) plus two standard deviations (σ) are "clean." Any samples whose screening is greater than MDA are considered "contaminated." One hundred percent of samples classified as contaminated are sent to the RAL for analysis. Approximately 5 percent of the soil samples that screen as clean will be analyzed for quality control purposes.

5.0 BUILDINGS AND FACILITY SURFACES

For a facility to be released for unrestricted use without radiological controls, characterization, remediation controls, and final status surveys must be performed to ensure that residual radioactive contamination levels are below BCLDP release criteria found in Reference 7 and the "Surface Release Criteria Technical Basis Document for Battelle Columbus Laboratories Decommissioning Project (BCLDP)," (Reference 12).

5.1 Characterization Surveys of Facility Surfaces–Baseline Areas

Radiological characterization surveys are used to determine the quantity and extent of residual radioactive contamination. Areas that exceed acceptable levels of residual contamination, according to Reference 7 and Reference 12, will require decontamination. As Low As Reasonably Achievable (ALARA) considerations may result in the remediation of additional areas that otherwise meet the release criteria. These areas will be evaluated by the Characterization Project Manager or designee, Remedial Action Manager or designated Project Manager, and Safety personnel prior to the beginning of characterization activities.

Preparation of areas for characterization will include equipment removal, floor/ceiling tile removal, or other activities necessary to expose building surfaces and limit the exposure of personnel to hazardous conditions. Characterization surveys will be conducted using BCLDP Procedure DD-CP-004, "Radioactive Contamination Monitoring Requirements for Facility Surface Characterization." DD-CP-004 requires that baseline building areas have exposure rate measurements and direct and indirect surveys conducted as part of the characterization process.

The BCLDP plans to monitor the underground drains using the Pipe Explorer™, which is owned and operated by Science and Engineering Associates, Inc. (SEA). Underground drain lines with activity meeting or exceeding release criteria will be excavated and removed. Soils surrounding the radioactively contaminated drain lines will be surveyed as described in Section 5.2.2 of this document.

5.1.1 Exposure Rate Measurements

Exposure rate measurements will be conducted to ensure that the exposure rate release criterion of 5 μR/hr above the determined mean background level in Reference 1 is satisfied. These measurements will be performed according to DD-CP-004, which states that measurements will be taken at the "corners and center of each room at contact and at 1 meter from the surface." Areas exceeding 10 meters in any direction will be divided into equal segments and exposure rate measurements taken in the center of each segment at contact and at 1 meter from the surface. Each segment shall not exceed 100 m^2.

5.1.2 Gridding

Gridding is used to facilitate systematic selection of measuring/sampling locations, provide a mechanism for identifying areas, and provide a convenient means for determining average activity levels. Gridding will be conducted according to DD-CP-010, "Establishing a Surface Reference Grid for Walls, Floors, and Ceilings for a Detailed Characterization Survey." Grids will be approximately 1 meter by 1 meter.

5.1.3 Scanning and Indirect Surveys

Direct and indirect surveys will be performed on 100 percent of floors, walls (from the floor to 2 meters), and horizontal surfaces after exposure rate measurements and gridding of the area are completed. Any areas suspected to exceed 25 percent of the BCLDP guideline value listed in Reference 7 will be surveyed in the same manner as the floors and walls. Scanning is a survey technique performed by moving a detector at a consistent speed and distance above a surface for

the purpose of detecting elevated levels of radiation. Procedure DD-CP-004 requires direct surveys to be performed at a consistent scanning rate not to exceed 5 cm/sec and with the detector window less than or equal to 0.5 cm above the surface for the purpose of detecting elevated levels of radiation. If a reading above the DLV is indicated while scanning, the following additional data collection will be required:

- 1-minute static alpha + beta measurement at the point of highest activity
- 1-minute static alpha measurement at the point of highest activity
- Smear sample that will be analyzed for gross alpha, beta, and/or gamma activity.

Indirect surveys (smear samples) will be performed on a minimum of 10 percent of the remaining grids that did not have measurements exceeding the DLV.

5.1.4 Additional Samples

Drain, sump, and soil samples will be taken to further define the extent, if any, of residual radioactive contamination in the drainage systems and beneath facility structures. Analysis of samples by gamma spectroscopy will be performed by the BCLDP RAL or an approved outside laboratory. Additional sample analysis (i.e., gross alpha + beta, alpha spectroscopy, etc.) will be performed at the discretion of the Characterization Project Manager.

5.2 Remediation Control Surveys–Baseline Areas

Remediation control surveys will be performed in Buildings JN-1, JN-2, and JN-3, and others as needed. These buildings may be demolished as radiologically contaminated, (Reference 13 and Reference 14), which would negate the need for structural final status surveys. However, ground surveys still will be conducted at the building locations and included as part the site final status documentation. Ground surveys will be conducted in the manner described in Section 6 of this document.

5.2.1 Facility Surfaces

Remediation control surveys for facility surfaces consist of alpha + beta scans in and around the area of decontamination. These scans ensure that decontamination is effective and that radioactive contamination is not being spread to surrounding areas during the decontamination and demolition processes. Scans will be performed in the manner described in Section 5.1.3 of this document.

5.2.2 Soil Remediation Areas/Underground Drains

During the remediation of contaminated underground drains, the surrounding soil must be removed. Remediation control surveys for soil that is or has the potential for radioactive contamination will employ a combination of sampling and screening. Samples will be taken periodically as the soil is being removed. These samples will be screened using the process described in Section 4 of this document. Soil removal will continue until screening indicates that radioactive contamination is bounded and not present. Samples will be taken in the remediated

area and sent to the RAL for analysis to ensure that no radioactive contaminants above the volumetric release criteria in Reference 7 are remaining.

5.3 Final Status Surveys of Facility Surfaces – Baseline Areas

Final status surveys are required to determine the post-decontamination condition of a facility and provide data to demonstrate that unacceptable levels of residual radioactive contamination have not been left on-site. Final status surveys for the BCLDP baseline areas will be performed in accordance with procedure DD-CP-002 and are comprised of both scanning and population surveys.

5.3.1 Gridding

The grid system established during characterization also will be used during final status surveys. Grids in baseline areas will be divided into three categories: designated, adjacent, and non-designated. Designated grids are grids in which contamination was detected during the characterization process and are marked for decontamination and/or grids that were inaccessible during characterization. Adjacent grids are grids that border a designated grid. The remaining grids are considered non-designated.

5.3.2 Scanning

Scan surveys will be performed for designated and adjacent grids. If a reading above the DLV is indicated while scanning, the following additional data collection will be required:

- 1-minute static alpha + beta measurement at the point of highest activity
- 1-minute static alpha measurement at the point of highest activity
- Smear sample that will be analyzed for gross alpha, beta, and/or gamma activity.

The Characterization Project Manager will evaluate grids with activity levels meeting or exceeding 80 percent of the release criteria.

5.3.3 Population Surveys

A large population statistical survey shall be conducted for each designated, adjacent, and non-designated grid category. The statistical survey consists of a static alpha + beta integrated measurement, a static alpha-only integrated measurement, and a smear sample. The number of measurements for large area population surveys are determined by the chart below.

Total Number of Grids	Number of Grids to Receive Static Counts
< 30	100% of total grids
30 to 300	30 grids
> 300	10% of total grids

5.4 Characterization and Final Status Surveys of Facility Surfaces–

Non-Baseline Areas

Non-baseline areas are not expected to contain residual radioactive contamination. The final status surveys performed in support of non-baseline area characterization are designed to statistically show that the area is free from residual radioactive contamination and is suitable for release. Non-baseline building areas will be surveyed in accordance with DD-CP-025, "Facility Non-Baseline Final Status Survey," and Reference 1.

5.4.1 Gridding

Non-baseline areas do not require gridding. However, maps and/or floor plans will be used to identify survey and measurement locations.

5.4.2 Exposure Rate Measurements

Exposure rate measurements will be taken in the center of each room/area at a height of 1 meter above the floor surface. For areas exceeding 10 meters in any direction, the area will be divided into equal segments and a measurement will be taken in the center of each segment. Each segment shall not exceed 100 m^2. A smear sample also will be taken at each exposure rate measurement location.

5.4.3 Scanning

Scans in non-baseline areas will be conducted on a minimum of 10 percent of the floor and lower wall (floor up to 2 meters) surfaces. Scans will be performed in the alpha + beta mode of the instrument. Alpha-only scans may also be required in some areas. Surface activity measurements in excess of 25 percent of the release criteria will be evaluated by the Characterization Project Manager; these areas may require a more detailed survey.

5.4.4 Additional Samples

Samples will be taken from accessible drains and sumps. Analysis of samples by gamma spectroscopy will be performed by the RAL or an approved outside laboratory. Additional sample analysis (i.e., gross alpha + beta, alpha spectroscopy, etc.) will be performed at the discretion of the Characterization Project Manager. Samples with activity levels in excess of 25 percent of the release criteria will be evaluated by the Characterization Project Manager; these areas may require a more detailed survey.

5.4.5 Population Survey

A large population statistical survey also shall be conducted for floor and wall surfaces in each non-baseline area. The statistical survey consists of a static alpha + beta integrated measurement, a static alpha-only integrated measurement, and a smear survey. Static measurements will be taken at a minimum of 30 locations, or at a frequency of 1 measurement every 50 m^2, whichever is greater.

6.0 GROUNDS AND OPEN LAND AREA SURVEYS

The West Jefferson site grounds and open land areas must be surveyed in order to be released from radiological controls. The potential for radiological contamination will be evaluated, and the grounds will be classified as either affected or unaffected areas. The type and extent of radiological surveys will be determined by the area's classification.

Affected areas are those known or suspected to contain residual radioactive contamination. These areas will require characterization surveys, remediation control surveys, and final status surveys. Sample integrity will be maintained by using cross-contamination preventative measures and Chain-of-Custody described in SC-SP-004.2, "Manual Collection of Surface Soil Samples in Support of Site Characterization."

Unaffected areas are not expected to contain residual radioactive contamination. Therefore, a full characterization survey will not be required. Final status surveys will be necessary in order to release the area for unrestricted use. The paragraphs in Section 6.4 of this document describe the requirements for performing these surveys.

Various West Jefferson buildings housed baseline areas that had drain lines connected to exit sumps and piping to the site's sanitary and storm sewers. The BCLDP plans to monitor the underground sanitary and sewer lines using the Pipe Explorer™, which is owned and operated by SEA. Underground lines with activity meeting or exceeding release criteria will be excavated and removed. Soils surrounding the radioactively contaminated lines will be surveyed as described in Section 6.1.4 of this document.

6.1 Characterization Surveys – Affected Areas

For an area to be released from radiological controls, characterization surveys must be conducted to ensure that residual radioactive contamination levels are below BCLDP release criteria. These criteria are specified in Reference 7 and Reference 12. Data generated by previous surveys will be used to assess site conditions and to reduce survey costs. Characterization data will be used to supplement final status surveys.

6.1.1 Reference Grid System

A reference grid system is required by both NUREG/CR-5849 and DD-CP-004. The grid system is established to:

- Facilitate the selection of measurement/sampling locations
- Provide a mechanism for measurement/sampling location identification
- Provide a means for averaging activity levels (Reference 1).

The BCLDP will use a grid spacing for affected grounds of 10 meters by 10 meters. A contractor, approved per BCLDP Procedure QA-AP-7.1 by the DOE and the BCLDP, will perform the gridding.

6.1.2 Exposure Rate Measurements

Ambient external penetrating radiation measurements will be performed prior to characterization surveys. Outside areas require four measurements at 1 meter from the ground/surface per 100 m^2. Exposure rate measurements greater than two standard deviations above the mean value for background will require further evaluation by the Characterization Project Manager or designee.

6.1.3 Scanning

Scanning is a survey technique performed by moving a detector at a consistent speed and distance above a surface for the purpose of detecting elevated levels of radiation. BCLDP procedures require a survey rate not exceeding 5 cm/sec for paved outside areas. Alpha + beta scans of structural and paved surfaces will be performed with detector window less than or equal to 0.5 cm above the paved surface. Outside area scans of paved surfaces will be performed on all roads, parking lots, and walkways consistent with NUREG requirements. Scans will be conducted in accordance with DD-CP-004, which requires scanning 100 percent of the surveyable area. Stationary measurements will be taken in the alpha-only and alpha + beta modes for paved areas that exceed the DLV. If additional data indicate residual contamination levels above release criteria, the area of elevated activity will be bounded and marked for decontamination.

Walkover gamma scans of outside areas, paved and unpaved, will follow the NUREG/CR-5849 guidance of 50 cm/sec survey rate. Soil samples will be taken at each gamma walkover location that exceeds the DLV in unpaved areas. Soil samples will be taken under paved surfaces at the discretion of the Characterization Project Manager. Walkover and scanning surveys will be performed as part of characterization and final status surveys.

6.1.4 Soil Sampling

Soil sampling locations will be selected using the guidance in NUREG/CR-5849. Soil samples will be taken, by means of cross-contamination preventative measures, using 1-meter continuous core intervals, starting from the surface, down to 1 meter below the suspected or potential region of elevated activity. Samples will be taken in both paved and unpaved areas. Soil screening will be used to expedite the sampling process and to reduce analytical costs. Sample integrity will be maintained by using Chain-of-Custody described in SC-SP-004.2. Analysis of samples by gamma spectroscopy will be performed by the RAL or an approved outside laboratory. Additional sample analysis (i.e., gross alpha + beta, alpha spectroscopy, etc.) will be performed at the discretion of the Characterization Project Manager. If analyses indicate the presence of elevated levels of radioactive contamination in the soil, remediation may be required. Analysis that does not show elevated levels of radioactive contamination may be used during final status. All soil sampling will be performed in accordance with BCLDP Procedures SC-SP-004.2 and SC-SP-004.1, "Mechanical Collection of Surface and Subsurface Soil Samples in Support of Site Characterization."

6.2 Remediation Control Surveys – Affected Areas

6.2.1 Paved Surfaces

Remediation control surveys for paved surfaces consist of alpha + beta scans in and around the area of decontamination. These scans will be used to ensure that decontamination is effective and that radioactive contamination is not being spread to surrounding areas.

6.2.2 Soil Remediation Areas

Remediation control surveys for radioactively contaminated soil will employ a combination of sampling and screening. Samples will be taken periodically as the soil is being removed. These samples will be screened using the process described in Section 4 of this document. Soil removal will continue until screening indicates that radioactive contamination is adequately bounded and not present. Samples will be taken in the remediated area and sent to the RAL for analysis to ensure that no radioactive contaminants above the volumetric release criteria in Reference 7 are remaining.

6.3 Final Status Surveys – Affected Areas

Final status surveys provide data to demonstrate that unacceptable levels of radioactive materials have not been left on-site. The final status surveys performed in support of affected area characterization will be designed to statistically show that the specified area is free of residual radioactive contamination and suitable for release. Sample integrity will be maintained by using cross-contamination preventative measures and Chain-of-Custody described in SC-SP-004.2. These surveys will be planned and monitoring strategies detailed using NUREG/CR-5849, Section 4.2.3. The monitoring strategies are described in the following paragraphs. Data from previous surveys may be used to supplement the final status surveys.

6.3.1 Scanning

Outside area scans of paved surfaces will be performed where decontamination has occurred. Scans will be conducted in accordance with DD-CP-002, which requires scanning 100 percent of the remediated area. Stationary measurements will be taken in the alpha-only and alpha + beta modes for paved areas that exceed the DLV. If additional data indicate residual contamination levels above release criteria, the area of elevated activity will be bounded and marked for further decontamination.

Walkover gamma scans of outside areas, paved and unpaved, will follow the NUREG/CR-5849 guidance of 50 cm/sec survey rate. Soil samples will be taken at each gamma walkover location that exceeds the DLV in unpaved areas.

Scans conducted during characterization may be used for final status.

6.3.2 Static Measurements – Paved Surfaces Only

Static measurements are 1-minute counts performed with the detector stationary and less than or equal to 0.5 cm from the surface. Static measurements are part of the statistical aspect of the final status survey. This type of measurement technique is used in final status surveys to more accurately determine the residual activity levels in grids. Static measurements are performed in the alpha + beta and alpha-only modes for paved surfaces. Guidelines in NUREG/CR-5849 for affected areas state that measurements should be performed at a frequency of one measurement per 2 m^2 or 30 total measurements for each 100 m^2 survey unit.

6.3.3 Soil Samples

Final status soil samples will be taken in remediated areas at a frequency of one sample per square (or linear) meter. Analysis of samples by gamma spectroscopy will be performed by the RAL or an approved outside laboratory. Affected grids will be sampled to satisfy NUREG/CR-5849 by dividing the 10-meter by 10-meter grid into four quadrants. Samples will be obtained from the center of each of these quadrants.

6.4 Characterization and Final Status Operations–Unaffected Areas

Unaffected areas are not expected to contain residual radioactive contamination. Therefore, a full characterization will not be required. Final status surveys will be necessary in order to release the area for unrestricted use. The final status surveys performed in support of non-baseline area characterization will be designed to statistically show that the specified area is free of residual radioactive contamination and suitable for release. Sample integrity will be maintained by using cross-contamination preventative measures and Chain-of-Custody described in SC-SP-004.2. These surveys will be planned and monitoring strategies detailed using NUREG/CR-5849, Section 4.2.3, as guidance. These monitoring strategies recommended are detailed in the following paragraphs.

Unaffected areas will be reclassified as affected areas if activity levels exceed 25 percent of the applicable release criteria.

6.4.1 Exposure Rate Measurements

Ambient external penetrating radiation measurements will be performed prior to walkover surveys. Measurements for outside areas will require one measurement at 1 meter from the ground per 100 m^2. The specific location of the measurement will be determined by the layout of the area being characterized. Exposure rate measurements greater than two standard deviations above the mean background will require further evaluation by the Characterization Project Manager or designee.

6.4.2 Scanning

In NUREG/CR-5849, Section 4.2.3 recommends that gamma scans of unaffected areas cover a minimum of 10 percent of the outside ground areas. If scanning data indicate readings above the

DLV, samples will be taken at that location. The sample data will then be evaluated by the Characterization Project Manager or designee. If data indicate residual contamination levels that exceed 25 percent of the BCLDP release criteria, the area will be reclassified as affected and undergo full "affected area" characterization.

6.4.3 Unaffected Area Soil Sampling

To reduce sampling costs and maximize cost effectiveness, the BCLDP has complied with the DOE request to perform statistical sampling for groups of grids that did not have contaminated soils identified during the scoping survey (i.e., unaffected areas). Sampling populations will be defined for each unique area. The BCLDP will use the guidance in Section 8.5 of NUREG/CR-5849 which utilizes the comparison of the $\mu\alpha$ value (EPA 1989) to relate to a given limit value (C_G) at a desired confidence level (i.e., 95 percent) for demonstrating release. This statistical process can be performed only once. If it fails, the area must be remediated and the process must be redone. Given the guidance in Section 8.6, Equation 8-21 and Table B-2, if the scoping survey results are near background, six to ten samples per population area will be necessary to demonstrate the areas statistically satisfy release criteria at the 95 percent confidence level.

7.0 POST-CHARACTERIZATION OPERATIONS

The recorded results of all characterization and final status-related surveys will be compiled into related work instruction packages and retained by BCLDP Project Records. The accumulated work instruction data will be incorporated into a characterization and/or final status report. This report will serve as the documentation, supporting decontamination operations and ultimate release of the area from radiological controls. All documentation generated is reviewed and approved by characterization supervision or qualified designee.

8.0 TRAINING/QUALITY ASSURANCE

The performance of work in the field is overseen by a Certified Health Physicist and several National Registry of Radiological Protection Technologists (NRRPTs). Characterization personnel involved in surveying, monitoring, and/or data collection shall receive at a minimum:

- Basic radiation worker training in accordance with Section 8.0 of the BCLDP Radiation Protection Program (Reference 15)

- Task-specific training and qualification for the performance of BCLDP procedures.

Procedural training will be documented in accordance with BCLDP Procedure TD-AP-2.0, "Indoctrination, Training and Qualification." In addition, industrial safety and industrial hygiene

orientation and training will be provided on specific topics such as the use of ladders, scaffolding, and elevated access equipment, as appropriate.

All data generated during survey performance are documented as required by the applicable procedure. These procedures include such steps as data review, audits, custody control of samples, and project records requirements.

9.0 INSTRUMENTATION

Monitoring instrumentation is calibrated using National Institute of Standards and Technology (NIST) traceable sources and controlled in accordance with ANSI-N323a, "Radiation Protection Instrumentation Test and Calibration" (Reference 16). Thorium-230 is used for α calibrations, Technicium-99 is used for β calibrations, and a commercially available mixed gamma source is used for λ calibrations. The emission energies of these isotopes are in the range of the energies from the expected nuclides, or in the case of Tc-99 are below, resulting in conservative calibration coefficients. Dose rate instruments are calibrated at an accredited off-site facility.

Survey instrumentation is performance tested for proper operation, within calibration ranges, at least once per day, as suggested in NUREG/CR-5849. These tests are documented on DDO-380, "Field Instrument Source Check," as part of procedure utilized for the work.

The following types of instruments may be employed in survey efforts:

- Gas proportional detectors and associated electronics sensitive to alpha and beta/gamma radioactivity and equipped with an aural indicator. These instruments may be operated in gas flow or static gas configuration and will be capable of detecting alpha-only and alpha + beta activity. Some electronics also may allow beta-only readings. Examples of gas proportional detectors are the Ludlum 239-1F floor monitor and the Eberline ESP-2 meter with a Ludlum 43-20 detector.
- Scintillation detectors and associated electronics sensitive to alpha, beta, or gamma radiation. These instruments may be capable of detecting both alpha and beta activity and discriminating between them. Examples of scintillation type instruments are the Delta 3/DP6 combination for alpha and beta detection/discrimination and a sodium iodide (NaI) crystal (Ludlum 12S Micro R meter) for gamma detection.
- A pressurized ionization chamber, MicroSpec, Micro R meter, or Geiger-Mueller instrument may be used to measure external penetrating radiation (gamma).
- A NaI detector (e.g., MicroSpec) and associated electronics may be used in the field for isotopic identification of contamination.
- A high purity germanium (HPGe) detector and associated electronics may be used in the laboratory for quantitative identification of contaminant isotopes in samples.

10.0 RADIOANALYTICAL SERVICES

The majority of samples collected in support of characterization activities will be analyzed at the Battelle RAL located in West Jefferson, Ohio. Gross alpha and gross beta analyses of smear and solid material samples will be performed using a simultaneous alpha and beta gas proportional counter. Gamma spectroscopy will be performed using a Canberra ProCount data acquisition system in conjunction with a HPGe detector. Alpha spectroscopy will be performed using Canberra Alpha Management System (AMS) in conjunction with a Canberra 7401 Passivated Implanted Planar Silicon (PIPS) detector. Analyses of samples with complex matrices or samples considered mixed waste will be performed by an approved off-site laboratory. Prior to solicitation, all outside vendor programs used for sample analysis are reviewed, approved, accredited, and placed on the DDO Approved Suppliers List in accordance with BCLDP Procedure QA-AP-7.1. Currently, General Engineering, in Charleston, South Carolina, is being utilized for off-site sample analysis.

11.0 PROCEDURES TO BE EMPLOYED FOR CHARACTERIZATION AND FINAL STATUS AT THE WEST JEFFERSON SITE

HS-OP-001	Completion of the Industrial Safety Check List
DD-CP-002	Facility Post-Decontamination Final Status Survey
DD-CP-004	Radioactive Contamination Monitoring Requirements for Facility Surface Characterization
DD-CP-007	Baseline Reference Values for Facility Radiological Characterization Surveys
DD-CP-010	Establishing a Surface Reference Grid for Walls, Floors, and Ceilings for a Detailed Characterization Survey
DD-CP-015	Use of a Gamma Scintillation Detector
DD-CP-020	Field Isotopic Identification with a High Purity Germanium Detector
DD-CP-025	Facility Non-baseline Final Status Survey
DD-CP-030	Exposure Measurement Instrumentation Calibration, Performance Testing, and Use
RL-AP-01.0	Administrative Operating Procedure for the Radioanalytical Laboratory (JN-2)
TD-AP-02.0	Indoctrination, Training and Qualification

QA-AP-7.1 Decontamination and Decommissioning Operations (DDO) Quality Department Administrative Procedure (QD-AP)

QD-AP-5.2 Work Instructions

SC-SP-004.1 Mechanical Collection of Surface and Subsurface Soil Samples in Support of Site Characterization

SC-SP-004.2 Manual Collection of Surface Soil Samples in Support of Site Characterization

SC-SP-006 Sampling of Sediment and Sludge for Chemical and Radiological Characterization

12.0 REFERENCES

1. Oak Ridge Associated Universities (ORAU), 1992. "Manual for Conducting Radiological Surveys in Support of License Termination, Draft Report for Comment," NUREG/CR-5849, ORAU-92/C57, prepared for the Nuclear Regulatory Commission by the Environmental Survey and Site Assessment Program, Energy/Environmental Systems Division, ORAU, 1992.

2. Battelle, 1993. "Decommissioning Plan for the Battelle Memorial Institute Columbus Operations," Report No. DD-93-19.

3. Department of Defense (DOD), DOE, EPA, and NRC, December 1997. "Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)," NUREG-1575, Report No. EPA 402-R-97-016.

4. Battelle, 1975. "BRR Dismantling Status," letter from K. D. Kok and S. Basham to W. H. Goldthwaite.

5. Battelle, 1975. "Dismantling of the Battelle Research Reactor."

6. Battelle, 1975. "The dismantling of the Battelle Research Reactor has been completed as described in the Dismantling Plan," letter from Kenneth Kok to Joel Kohler.

7. Battelle, 1993. "Volumetric Release Criteria Technical Basis Document for Battelle Columbus Laboratories Decommissioning Project (BCLDP)," Report No. DD-93-03.

8. Battelle, 1983. "Submission of Report on Facilities for Acceptance Under the DOE Surplus Facilities Management Program" (Blue book).

9. Argonne National Laboratory, 1988. "Cursory Radiological Assessment Battelle Columbus Laboratory Decommissioning and Decontamination Project," Report No. ANL-ESH/TS-88-102.

10. Battelle, 1989. "Site Characterization West Jefferson North Site Sampling and Analysis."

11. Beers, Y., 1953. *Introduction to the Theory of Error*, pp. 23-25, Addison-Wesley.

12. Battelle, 1993. "Surface Release Criteria Technical Basis Document for Battelle Columbus Laboratories Decommissioning Project (BCLDP)," Report No. DD-93-02.

13. U.S. Department of Energy, Columbus Environmental Management Project, 2000. "Supplemental Baseline Guidance," letter from Thomas A. Ballieul to N. Joseph Gantos.

14. Battelle, 1997. "Items for Consideration for Characterization Approach and Cost Saving Improvements for West Jefferson," memo to Len Ermold from J. F. Poliziani.

15. Battelle, 1990. "Radiation Protection Program for the BCLDP," Report No. DD-90-02.

16. ANSI N323a, 1997. "Radiation Protection Instrumentation Test and Calibration."