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Experimental and Sampling Design for the INL-2 Sample Collection Operational Test

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Pacific Northwest National Laboratory
Richland, WA

February 2009

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U.S. Department of Homeland Security
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Executive Summary

This report describes the test events and numbers of samples comprising an experimental and sampling design developed to assess sampling approaches and methods for detecting contamination in a building and clearing the building for use after decontamination. Idaho National Laboratory (INL) identified Building PBF-632 as a test-bed facility for evaluating protocols for response to potential contamination by biological agents. Building PBF-632 is an unoccupied, two-story office building with each floor having an area of 4025 ft^2. The first floor has 11 offices, a reception area (lobby), men's and women's restrooms, and a mechanical room. The second floor has 15 offices, two storage rooms, men's and women's restrooms, and a mechanical room. Building PBF-632 will be contaminated with BG (*Bacillus globigii*, subsequently *Bacillus subtilis var. niger*, and recently renamed *Bacillus atrophaeus*), a simulant for *Bacillus anthracis* (BA). The contamination, sampling, decontamination, and re-sampling will occur as specified by the experimental and sampling design. This study is referred to as the INL-2 Sample Collection Operational Test, which is being planned by the Validated Sampling Plan Working Group (VSPWG). The INL-2 study is a follow-up to the INL-1 Sample Collection Operational Test conducted in 2007.

The VSPWG developed five objectives for the INL-2 study. These objectives are listed in Section 1.2. The primary objectives that influenced developing the experimental and sampling design presented in this report are summarized below.

- Evaluate judgmental and probabilistic sampling for characterization as well as probabilistic and hybrid (judgmental and probabilistic) sampling approaches for clearance.
- Conduct these evaluations for gradient contamination (from low or moderate down to absent or not detectable) for different initial concentrations of the contaminant.
- Explore judgmental composite sampling approaches to reduce sample numbers.
- Collect baseline data to serve as an indication of the actual levels of simulant contamination in the tests.

The hybrid approach is referred to as the *combined judgmental and random* (CJR) approach. The CJR approach uses Bayesian methodology to combine judgmental and random (probabilistic) samples to make clearance statements of the form "X% confidence that at least Y% of an area (or floor of the building) does not contain detectable contamination." These are referred to as X%/Y% clearance statements.[(a)]

The INL-2 experimental design described in this report includes five test events, the first of which is an Operational Readiness Inspection (ORI). The test events 1) vary the floor of the INL building on which the contaminant will be released, 2) provide for varying or adjusting the amount of contaminant released to obtain desired concentration gradients across a floor of the building, and 3) investigate overt as well as covert release of contaminants (i.e., the responders either know or do not know the release point of the contaminant). Desirable contaminant gradients would have moderate to low concentrations

(a) The X%/Y% clearance statements of the CJR method are based on the posterior predictive distribution from a modification of the Beta-Binomial Bayesian model (see Gelman et al. 2003). The X%/Y% clearance statements can also be made using only probabilistic samples with continuous-variable responses based on the statistical theory for X%/Y% tolerance intervals (see Hahn and Meeker 1991).

of contaminant in rooms near the release point, with concentrations down to zero (i.e., not contaminated) in one or more rooms. Such gradients would provide a range of contamination levels (from moderate to low and down to zero) to challenge the sampling, sample extraction, and analytical methods that will be used in the INL-2 study.

For each of the five test events, the specified floor of the INL PBF-632 building will be contaminated with BG. The BG contaminant will be disseminated from a point-release device located in the room specified in the experimental design for each test event. Then quality control (QC), reference material coupon (RMC), judgmental, and probabilistic samples will be collected according to the pre-specified sampling plan for each test event. Judgmental samples will be selected based on professional judgment and prior information. Probabilistic samples were selected with a random aspect and in sufficient numbers to provide desired confidence for detecting contamination or clearing uncontaminated (or decontaminated) areas. Following sample collection for a given test event, the INL PBF-632 building will be decontaminated using Cl_2O gas.

For possibly contaminated areas (which may be individual rooms or a whole floor of the INL PBF-632 building), the numbers of probabilistic samples were chosen to provide 95% confidence of detecting contaminated areas of specified sizes. The numbers of judgmental samples were chosen based on guidance from experts in judgmental sampling. For rooms that may be uncontaminated (or have undetectable contamination) following a contamination event, or for whole floors after decontamination, the numbers of judgmental and probabilistic samples were chosen using the CJR sampling approach. The numbers of samples were chosen to support making X%/Y% clearance statements with X = 95% and Y ~ 98% for clearing a whole floor, and X = 90% and Y = 94 − 96% for clearing a set of two offices. The experimental and sampling design also provides for making X%/Y% clearance statements using only probabilistic samples.

For each test event, the numbers of characterization and clearance samples were selected within limits based on operational considerations while still maintaining high confidence for detection and clearance aspects. The sampling design for all five test events specifies a total of 2085 samples, with 1142 after contamination (characterization and clearance) and 943 after decontamination (clearance). These numbers include QC, RMC, judgmental, and probabilistic samples. The experimental and sampling design specified in this report provides a good statistical foundation for achieving the objectives of the INL-2 Sample Collection Operational Test, despite some limitations of the experimental and sampling design (discussed in Section 6).

In general, it is recommended that statisticians be involved in planning and developing experimental and sampling designs, and conducting data analyses of future validation work as described in the Interagency Strategic Plan.[(a)] Statistical involvement is critical to planning experimental studies and analyzing the data that result from them. Statistical involvement provides for using resources efficiently, accounting for testing and analytical uncertainties, and making conclusions with the desired statistical confidence. Statistical planning combined with proper statistical analysis of data leads to defensible conclusions that satisfy the research objectives.

(a) *Interagency Strategic Plan for Validation of Environmental Sampling Methods Used in Detection and Cleanup of B. Anthracis Contamination in Facilities*, June 29, 2007.

Acronyms

BA	*Bacillus anthracis*
BG	*Bacillus globigii*, subsequently *Bacillus subtilis var. niger* (recently renamed *Bacillus atrophaeus*)
CDC	Centers for Disease Control and Prevention
CFU	Colony Forming Unit
CJR	Combined judgmental and random (probabilistic)
DHS	U. S. Department of Homeland Security
DoD	U. S. Department of Defense
DOE	U. S. Department of Energy
EPA	Environmental Protection Agency
FBI	Federal Bureau of Investigation
FNR	False Negative Rate
GAO	Government Accountability Office
HVAC	Heating, Ventilation, and Air Conditioning
INL	Idaho National Laboratory
JHU-APL	Johns Hopkins University, Applied Physics Laboratory
JPEO-CBD	Joint Program Executive Office for Chemical and Biological Defense
NIST	National Institute of Standards and Technology
ORI	Operational Readiness Inspection
PNNL	Pacific Northwest National Laboratory
QC	Quality Control
RMC	Reference Material Coupon
RV-PCR	Rapid Viability Polymerase Chain Reaction
S&T	Science and Technology Directorate
VSP	Visual Sample Plan (software)
VSPWG	Validated Sampling Plan Working Group

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1.0 Introduction

This report describes the final experimental and sampling design for a contamination and decontamination exercise conducted in an unoccupied building at the Idaho National Laboratory (INL). The experimental and sampling design consists of the scenarios for five test events, as well as the numbers of quality control (QC), reference material coupon (RMC), judgmental, and probabilistic samples for characterization and clearance sampling in each test event.

The experimental and sampling design was developed by staff in the Statistics and Sensor Analytics group at Pacific Northwest National Laboratory (PNNL). The specific contributors are listed as authors of this report. Members of the Validated Sampling Plan Working Group (VSPWG) provided guidance and input needed to develop the experimental and sampling design. Specific individuals who provided inputs or guidance are listed in the Acknowledgments.

The PNNL work was funded by the Standards Office of the Test and Evaluation/Standards Division in the Science and Technology Directorate (S&T) of the U.S. Department of Homeland Security (DHS). The work was funded under the prime contract between the U.S. Department of Energy (DOE) and the operator of PNNL for research, testing, evaluation, and/or development activities and pursuant to Section 309(a)(1)(c) of the *Homeland Security Act of 2002* (Public Law 107-296), which authorizes DHS to task the DOE national laboratories on a "work for others" basis.

1.1 Background

The experience with *Bacillus anthracis* (BA) contamination of the Hart Senate office building in Washington, DC and postal facilities that processed the mail containing BA demonstrated weaknesses in the procedures and methods used to characterize and clear buildings contaminated by BA. A congressional inquiry as well as the Government Accountability Office (GAO) identified two main weaknesses (GAO 2005a, 2005b). One weakness was the reliance on sampling specific areas in postal facilities where it was thought BA would be found. This type of sampling approach is referred to as *targeted sampling* or *judgmental sampling*. The GAO reports identified the need to use *probabilistic sampling* so that when all results are negative, a building (or area within a building) can be cleared with a known level of statistical confidence. The second main weakness was that the sample collection and analytical methods used were not validated, which raised questions about the reliability of the negative results from sampling the postal facilities.

The VSPWG was formed in July 2006 in response to the congressional inquiry and GAO reports. The VSPWG is headed by DHS S&T and includes experts from the Department of Defense (DoD), the Environmental Protection Agency (EPA), the Centers for Disease Control and Prevention (CDC), National Institute of Standards and Technology (NIST), and the Federal Bureau of Investigation (FBI). The VSPWG is working towards the overall validation of sampling plans, including 1) sampling approach (e.g., appropriate uses of judgmental and probabilistic sampling), 2) sample collection methods, 3) transportation of samples, 4) sample extraction methods (i.e., extraction of the contaminant from samples), and 5) sample analysis (i.e., analytical methods).

An interagency testing effort led by the DoD, Joint Program Executive Office for Chemical and Biological Defense (JPEO-CBD) and DHS S&T was planned to partially address some of these concerns. This testing effort will consist of a series of contamination, sampling and sample analysis, and decontamination events in an unoccupied two-story office building at INL facilities located outside of Idaho Falls, ID. The study is referred to as the INL-2 Sample Collection Operational Test. The INL-2 testing leverages work performed in 2006–2007 by the Applied Physics Laboratory at Johns Hopkins University (JHU-APL) for the JPEO-CBD to test sample-collection methods in a small-scale operational environment.[(a)] The INL-2 study relied heavily on work and lessons learned in the INL-1 Sample Collection Operational Test performed in late 2007.[(b)] In both the INL-1 and INL-2 studies, BG (*Bacillus globigii*, subsequently *Bacillus subtilis var. niger*, and recently renamed *Bacillus atrophaeus*) was used as a simulant contaminant for BA.

1.2 Objectives

The VSPWG developed five objectives for the INL-2 study, which are listed here verbatim.

- Operationally evaluate judgmental and probabilistic sampling for characterization, as well as evaluate and compare probabilistic and hybrid (judgmental and probabilistic) sampling approaches for clearance, in a building with gradient contamination (from low or moderate down to absent or not detectable) for different initial concentrations of the contaminant.
- Explore judgmental composite sampling approaches as a mechanism to reduce sample numbers but retain the robustness of coverage for characterization.
- Identify operational factors that affect the minimum detectable concentration observed for agreed sampling methods in the field compared to laboratory-validated performance data.
- Operationally compare an alternative analytical method for assessing contamination [Rapid Viability Polymerase Chain Reaction (RV-PCR)] and evaluate the utility of filter-plate and spiral-plate culturing methods.
- Collect baseline data to serve as an indication of the actual levels of simulant contamination in the tests.

The hybrid sampling approach is referred to as the *combined judgmental and random* (CJR) approach. The CJR approach uses Bayesian methodology to combine judgmental and random (probabilistic) samples. This approach provides for making clearance statements of the form "X% confidence that at least Y% of an area (or floor of the building) does not contain detectable contamination." These are referred to as X%/Y% clearance statements[(c)] in the rest of the report.

(a) *Test and Evaluation of Surface Sampling Approaches Before and After Small-Scale Fumigation-Based Decontamination Events*, NSTD-07-0592 (July 10, 2007 draft), John Hopkins University−Applied Physics Laboratory.

(b) *September 2007: Indoor Field Evaluation of Sample Collection Methods and Strategies at Idaho National Laboratory*, May 2008 (For Official Use Only).

(c) The X%/Y% clearance statements of the CJR method are based on the posterior predictive distribution from a modification of the Beta-Binomial Bayesian model (see Gelman et al. 2003). The X%/Y% clearance statements can also be made using only probabilistic samples with continuous-variable responses based on the statistical theory for X%/Y% tolerance intervals (see Hahn and Meeker 1991).

1.3 Report Organization

The remainder of this report describes the experimental and sampling design of the INL-2 Sample Collection Operational Test and the basis for its development. The report is organized as follows. The five test events that form the main structure for the experimental design are discussed in Section 2. The experimental factors that will be varied or held fixed (constant) in the experimental design are discussed in Section 3. The methods used to determine the numbers of samples required to make statistical detection or clearance statements are presented in Section 4. The experimental and sampling design and the basis for its development are presented in Section 5. The limitations of the experimental and sampling design for the INL-2 Sample Collection Operational Test are discussed in Section 6. The conclusions for the work and recommendations for any future studies are presented in Section 7. The references cited in describing the experimental and sampling design, and the methods used to generate it, are listed in Section 8.

2.0 Test Events

The test events were designed based on the dissemination characteristics of the BG contaminant, a simulant for BA, rather than basing the design on specific terrorist event scenarios. Many contamination motivations or "background stories" could be described to fit the proposed test events. The test-event characteristics include contaminant concentration, point of dissemination, type of dissemination (only aerosol releases will be performed during the INL-2 Sample Collection Operational Test), and knowledge of the point of dissemination.

Section 2.1 briefly introduces the five test events comprising the experimental design for the INL-2 study. Section 2.2 provides some discussion and guidelines regarding the goal of achieving desirable gradients of contamination concentrations over the test events. Section 2.3 discusses the order of performing the test events.

2.1 Experimental Design of Test Events

The experimental design developed for the INL-2 Sample Collection Operational Test includes five test events, the first of which is an Operational Readiness Inspection (ORI). Table 2.1 shows the contamination characteristics for each of the proposed test events. The purpose of the ORI is to provide a complete run that can be used to make any necessary adjustments before the remaining four test events. If the ORI run is completed without any issues, it is possible that its data will be analyzed along with the data from the other four test events. The five test events will each consist of

1. a separate contamination on one of the two floors of the INL building,[(a)]
2. sampling in selected rooms or the complete floor,
3. decontamination, and
4. sampling of the complete floor to determine clearance.

Test Event 1 (the ORI) as well as Test Events 2 and 3 are planned as covert releases in which the response team will not know the room location of the single-source aerosol dissemination. They will only know the floor of the release (first floor for Test Events 1 and 2, second floor for Test Event 3). Test Events 4 and 5 are planned as overt releases in which the response team will know the contaminant release location. In Test Event 4, the release will be in Room 101A on the first floor. In Test Event 5, the release will be in Room 201A on the second floor. The covert test events (1, 2, and 3) make it possible to assess the relative performance of the sampling approaches under different conditions than the overt test events (4 and 5).

2.2 Amounts of Contaminant Released and Resulting Gradients

The five test events in the INL-2 experimental design are intended to provide desirable concentration gradients of contamination across each floor of the building. This will provide a range of contamination conditions (from moderate to low contamination, down to no [or undetectable] contamination). A range

(a) It is assumed that the first and second floors of the INL building will be "sealed" to prevent cross-contamination. Lessons learned from the INL-1 study should enable "sealing" the two floors.

of contamination conditions will challenge the sampling approaches (judgmental, probabilistic, and CJR) as well as the sampling and analytical methods.

Table 2.1. Test Events of the INL-2 Experimental Design for Contamination-Decontamination Testing of the INL PBF-632 Building

	Release				
Test Event	**Contamination Scenario**	**Bldg. Floor**	**Building Room**	**Offices Sealed[c]**	**Initial Amount[d]**
1 (ORI)[a]	Covert Gradient	1	Covert[b]	Covert	A1
2	Covert Gradient	1	Covert[b]	Covert	A2
3	Covert Gradient	2	Covert[b]	Covert	A3
4	Overt Gradient	1	101A[e]	105 & 107	A4
5	Overt Gradient	2	201A[e]	205 − 208	A5

(a) ORI = Operational Readiness Inspection.
(b) Release location has not yet been selected and thus was unknown in choosing the sampling design (both judgmental and probabilistic samples). The release location will also be unknown to the sampling teams.
(c) The indicated offices should have their doors closed and sealed, and any vents in the rooms covered and sealed before the contaminant release. These measures are intended to provide rooms that have no or undetectable contamination. See Section 4 for more discussion.
(d) The initial amounts of contaminant released will be assessed and adjusted for Test Events 2 to 5 based on results of previous test events.
(e) These release locations were chosen based on tracer pre-tests performed at the INL PBF-632 building, which showed that releases from these rooms would give desirable gradients under the pre-test conditions.

An important factor affecting the contamination gradient obtained is the amount of contaminant that is released. Too high of an amount may result in easy detection of contamination in every room on a floor. Too low of an amount may result in too many rooms on a floor being lightly contaminated or not contaminated at all.

At least one test event should have a gradient with contaminant concentrations ranging from moderate to no/undetectable contamination. This gradient should include rooms with low concentrations (between moderate and no/undetectable contamination) that have low false negative rates (FNRs)[a] (e.g., 10%). At least one other test event should have a gradient resulting from a lower amount released so that rooms have concentrations ranging from low to no/undetectable contamination, including very low concentrations that have higher FNRs (e.g., 30 to 50%). Test events with at least one each of these types of contamination gradient would provide an excellent basis for assessing the performance of sampling approaches (judgmental, probabilistic, and CJR), sampling methods, sample extraction methods, and analytical methods.

(a) The FNRs are assumed to include false negatives resulting from failure to detect contamination due to sampling method and extraction recovery inefficiencies, sample transportation/aging issues, and analytical uncertainties.

Tracer studies in the INL PBF-632 building were completed to aid in selecting the initial contaminant amount and the rooms in which the contaminant will be released. The results are discussed subsequently at the points where they were factored into the experimental and sampling design. The ORI (Test Event 1) will also be used to determine the contaminant amount and dissemination factors necessary to create the desired gradients. Dissemination factors may include 1) time from dissemination until response, 2) heating, ventilation, and air conditioning (HVAC) being on or off, and 3) the contaminant release location. The experimental design allows for adjustments to be made to the contaminant amount (Table 2.1) or to dissemination factors after each event, based on what is learned from previous events.

2.3 Order of Test Events

The order of test events shown in Table 2.1 is proposed for use during the INL-2 Sample Collection Operational Test. This order will allow using the results of Test Events 1 to 3 to choose the amounts of contaminant to release in Test Events 4 and 5 so as to obtain concentration gradients ranging from moderate to uncontaminated and low to uncontaminated. The sampling designs for the overt events (Test Events 4 and 5) include sampling rooms with a clearance objective during the characterization phase, as discussed subsequently. Hence, it is important for Test Events 4 and 5 to choose the amount of contaminant released and take other measures (such as closing/sealing doors and sealing vents in rooms selected for clearance) to maximize the chance of having the specified rooms be uncontaminated or have undetectable contamination. It would be possible to intersperse the two overt test events among the covert test events, but then this would not allow using the information from previous covert test events to select the "best" amount of contaminant to release to achieve the desired gradients for the objectives of the overt test events. One such objective is to demonstrate the ability to clear an uncontaminated area of a building during the characterization phase of sampling.

3.0 Experimental Factors

The experimental factors are the variables that will be varied or held constant during the experiment. The experiment is designed to determine whether changes to the levels (i.e., values or settings) of the factors that will be varied affect the detection (absence/presence) or the amount (number of colony forming units, CFUs) of the contaminant. One objective of the INL-2 Sample Collection Operational Test is to examine the relative performance of the sampling approaches (judgmental, probabilistic, CJR) when contamination is likely. Characteristics of the test events are allowed to vary so that the relative performance of the sampling approaches can be assessed over a range of conditions. Other factors not varied in the test events should ideally be held as constant as possible.

After contamination, QC, RMC, judgmental, and probabilistic sampling will occur in each room or floor where sampling is planned. In rooms that are expected to have higher contamination (in the overt test events), fewer judgmental and probabilistic samples will be taken. Up to five judgmental samples per room will be taken in rooms where contamination is probable, based on input from experienced samplers concerning rooms of the size in the INL PBF-632 building.

It is of interest to compare the CJR and probabilistic sampling approaches "after decontamination," as well as "after contamination" in rooms that may not be contaminated because of the building airflow patterns and specifics of given test events. The CJR sampling approach, which combines judgmental and probabilistic (random) samples, is an option available in Visual Sampling Plan 5.0 (VSP) software (Matzke et al. 2007). The CJR sampling approach allows for an X%/Y% clearance statement to be made that would be stronger than the clearance statement that could be made from probabilistic sampling alone. This comparison will focus on the advantages of adding judgmental samples to probabilistic samples.

To best study the sampling approaches, the experimental factors should be identified and their roles in the experiment defined as well as possible. Table 3.1 lists the experimental factors and places them into one of four categories (factors controlled during the experiment, factors not controlled but measured, factors fixed during the experiment, and factors used to create the gradient). The Table 3.1 entries in each of these four categories are discussed in Sections 3.1 to 3.4.

3.1 Factors Controlled During the Experiment

The main factors that are varied in the experimental design are 1) the sampling approach (judgmental, probabilistic, and CJR), 2) the floor of the INL PBF-632 building on which the testing will occur, and 3) the type of sampling (covert or overt). Another factor that is varied in the experimental design is the sample area (size). For the majority of samples, the sample area will be constant as specified in the procedure for each sampling method (wipe, swab, vacuum). However, selected judgmental samples will be collected in a "composite" fashion in which larger areas or areas in different locations are sampled. For example, a composite wipe sample could involve wiping the standard area in two or three locations. Other factors that will be controlled during the experiment (which are related to creating a concentration gradient of the contaminant) are discussed in Section 3.4.

Table 3.1. Experimental Factors in the INL-2 Experimental Design for Contamination-Decontamination Testing of the INL PBF-632 Building

Factors Controlled During the Experiment	Factors Not Controlled, but Measured/Recorded	Factors Fixed During the Experiment	Factors Used to Create the Gradient
• Sampling approach • Floor of the building • Type of sampling (covert or overt) • Sampling team collecting samples • Fixed-area (size) and composite samples • Order samples are collected in a room	• Temperature • Humidity • Furniture configuration	• Contaminant release method (aerosol) • Sample collection method for a given sampling surface • Sample area (size) • Sample analytical method • Decontamination method	• Contaminant concentration • Length of HVAC operation after contaminant release • Location of contaminant release • Sealing of doors and/or vents

Another factor that must be controlled is the sampling team. It is important that the judgmental samples are not collected by one sampling team while the probabilistic samples are collected by another sampling team. The same is true for QC and RMC samples. The location of each QC, RMC, judgmental, and probabilistic sample in each of the pre-determined rooms or floors should be selected and included in a test matrix (see Appendix B) to aid the sampling teams in collecting the samples. Only the sample locations should be given to the teams collecting the samples so that they would be "blind" as to whether any given sample is a judgmental or probabilistic sample. This would minimize any bias that could be caused by the teams collecting samples. The specific test matrix (see Appendix B) corresponding to the experimental and sampling design will need to identify the sampling team that is assigned to collect each sample. That way, the sampled rooms can be balanced across the number of sampling teams collecting samples so that any systematic or random differences between sample collectors are spread over the collected samples in a controlled manner. The sampler ID should be recorded with the data so that 1) any systematic or random differences in teams that collected the samples can be assessed and 2) it can be verified that such differences do not impact the comparisons of sampling approaches.

Finally, the order in which the sampling team should collect samples within each room must be controlled. Having the sampling team collect the judgmental samples first, the probabilistic samples next, and finally the RMC and QC samples (or any permutation of these) should be avoided. From a statistical standpoint, it would be ideal to collect all samples (QC, RMC, judgmental, and probabilistic) within a room in a random order. Doing so would protect against confounding the effects of any uncontrolled variables that may change over time with the effects of factors of interest (i.e., probabilistic versus judgmental sampling). However, it is recognized that randomizing the order of all QC, RMC, judgmental, and probabilistic samples in a room is not feasible because of time constraints and the need to minimize movement within a room that might redistribute or transfer contamination from one location to another. Thus, it is recommended that a "sampling path" be determined for each room that minimizes unnecessary movements within the room, but still allows for sufficient intermingling of the order in which QC, RMC, judgmental, and probabilistic samples are collected. All samples that will be taken in a

room should be listed in the test matrix (see Appendix B) in the order they are to be collected so that this factor is controlled.

3.2 Factors Not Controlled but Measured or Recorded

Temperature and humidity should remain constant during the sampling as much as possible. The temperature and humidity should be recorded at selected locations on each floor of the building a few times a day during every day of testing.

One consistent furniture configuration should be used in each room if possible. This could possibly be a chair and desk with a monitor placed on the desk. The chair should be out from under the desk so that the BG contaminant can settle on its whole surface. If there is room, a table, a filing cabinet, or other furniture should also be placed in each room. This would increase the chance that probabilistic samples would select sampling positions with non-porous surfaces. Otherwise, the majority of probabilistic samples may be dominated by vacuum samples of the floors (which are mostly carpeted in the INL PBF-632 building). If it is not possible to use a single furniture configuration in every room, the number of configurations should be limited to two. In that case, the furniture configuration would need to become a controlled factor (the first column of Table 3.1, as discussed in Section 3.1). The two configurations would need to be assigned so as not to confound the effects of this factor with other factors of interest (e.g., the contamination gradient).

The furniture configurations planned for use in each office on the first and second floors of the INL PBF-632 building are shown in Figure 3.1 and Figure 3.2, respectively. The furniture configuration changes from office to office, depending mainly on the size and layout of each office. It is not clear to what extent different furniture configurations may affect the dissemination of contaminant within an office or to what effect it may affect results of data analyses after INL-2 is completed.

3.3 Factors Fixed During the Experiment

Table 3.1 identifies certain factors that will either be held fixed (constant) during the experiment or determined by other factors. These are discussed in the following paragraphs.

The contaminant-release method will be the same for all test events, namely, an aerosol release from a single point (location) on a floor of the INL building. Other contaminant-release methods were discussed and even proposed in early drafts of the experimental design. One such release method was to contaminate only smaller areas (so-called “hot spots”) of varying size in selected rooms, which would pose a much different situation for comparing judgmental and probabilistic samples (see Section 6.1 for more discussion of this). However, it was decided for this real-world contamination exercise to limit the contaminant-release method to an aerosol release from a single location (point release).

Figure 3.1. Furniture Configuration for the First Floor of the INL PGF-632 Building

Figure 3.2. Furniture Configuration for the Second Floor of the INL PGF-632 Building

The sample-collection method (swab, wipe, or vacuum) will be chosen according to the sampling surface that corresponds to each location to be sampled. The appropriate collection method will be applied to the appropriate sampling surface. The test plan should define which collection method should be applied for each of the possible surfaces. The specific test matrix (see Appendix B) for each room should specify the method to be used for each sample (whether judgmental or probabilistic) according to the nature of the surface to be sampled. This will require selecting the locations of judgmental samples in advance so that the sampling method as well as sampling order (see Section 3.1) can be included in the specific test matrix for each room. However, if it is decided to have the sampling team select the locations of judgmental samples at the time they enter a room, there will need to be a system in place to document the specific locations where judgmental samples were collected. This approach would also require the sampling team to be responsible for selecting the intermingling of judgmental and probabilistic samples and documenting the order of sample collection. This latter approach, although possibly more realistic, is far more complicated for the sampling team and could impact the ability to compare judgmental and probabilistic samples.

For probabilistic sampling, it has been assumed that samples will be collected from horizontal surfaces only. Horizontal positions of probabilistic samples selected by the VSP software (Matzke et al. 2007) may allow for the choice of the sample location. For example, a horizontal position might correspond to the floor, a table, or a vent in the ceiling. The specific sample location for a given horizontal sample position will need to be determined and included in the specific test matrix (see Appendix B) for each room. VSP allows for sampling from all surfaces of a room instead of just horizontal surfaces, but that increases the surface area of each room and floor of the building. That in turn increases the number of samples needed to detect contamination or clear a decontaminated floor. However, sampling from horizontal surfaces is the typical practice for BA/BG contamination released as an aerosol. Hence, in constructing the experimental and sampling design for the INL-2 Sample Collection Operational Test, it was assumed that only horizontal surfaces would be sampled.

It is important to note that the size (or area) of each sample should be held constant (per the procedure for each sampling method), independent of whether it is a judgmental or probabilistic sample. If the sampling team determines that a larger area should be sampled with a given sampling method for judgmental samples, then multiple samples should be taken to sample the larger area (rather than collecting a single sample from the larger area). This restriction is removed for some judgmental samples that will be collected using a composite sampling approach.

Culture has been determined to be the only analytical method that will be applied to every sample. It is possible that a few RV-PCR analyses will be made, but it was decided that this would not be factored into the experimental and sampling design. Hence, the choice of samples to be analyzed by RV-PCR is not addressed in this document. It is also assumed that the extraction method will be fixed and performed according to a set procedure for each sampling method, regardless of whether a given sample-collection method is used to collect a judgmental or probabilistic sample. The extraction method also should not change over the gradient of contamination because changes in the extraction method could negate differences due to the contamination gradient.

It is expected that the decontamination method will be aggressive (i.e., the concentration of ClO_2 gas will be sufficient to easily decontaminate contaminated areas). Because contamination will be occurring after all but the last decontamination, it is important to make sure that the decontamination is sufficient so

that there is no residual contamination that could become an uncontrolled factor that affects testing results.

3.4 Factors Used to Create the Gradient

The location of contaminant release, the amount of contaminant released, and the HVAC system will be used to create a gradient of the contaminant across a floor of the INL building. Another factor that can be used to create a gradient is whether rooms are "sealed." This could involve anything from closing the door of a room, sealing around a door, or sealing vents in the room.

Modeling and pre-testing work should be used to determine the amount of time the HVAC should remain on after contaminant release to achieve the desired concentration gradient. If the desired concentration gradient is not achieved in Test Event 1 (the ORI), then adjustments could be made in subsequent test events to the amount of contaminant released while holding constant the post-release running time of the HVAC system. However, the amount of time the HVAC system is run after contaminant release, along with the contaminant amount and within-room location of the contaminant release,[(a)] could be used to improve or vary the concentration gradient.

(a) The room of the INL PBF-632 building floor in which the contaminant will be released is specified as part of each test event. However, if the location of the release within the specified room (e.g., proximity to return air vents) affects the dissemination, the location of release within a room could be modified.

4.0 Required Numbers of Samples

The numbers of samples required to achieve desired statistical detection and clearance statements depends on the sampling goal. This goal is formulated using 1) information that is known about an event and 2) the objectives that must be achieved when responding to the event. In an area where contamination is expected, sampling is performed to confirm/detect that contamination is present. In an area that may not be contaminated initially or after decontamination, sampling can be performed to clear the area. The appropriate numbers of samples for the characterization and clearance situations are discussed in Sections 4.1 and 4.2. Individual room calculations are based on a typical room for the INL PBF-632 building (Room 108), while calculations for a single floor are based on the first floor (considering it as a "typical" floor). Calculations associated with clearing two rooms together are based on typical "full size" offices in INL PBF-632.

The calculations in this section for a single floor (represented by the first floor) of the INL PBF-632 building consider only the rooms that will be sampled as part of the INL-2 study. These include the Lobby and Offices 101, 101A, 102, 103, 104, 105, 106, 107, 108, 109, and 110. The hallway is not included because it will be sampled separately per agreement with one of the sampling teams. Also, hallway samples would consist of only vacuum samples of carpet, and a better of balance of sample types was desired. Because resources were not sufficient to sample all rooms on a floor, it was decided not to sample the men's and women's restrooms and the mechanical room.

Section 4.1 discusses the methods used to calculate the number of samples needed to detect contamination in a possibly contaminated area. Section 4.2 discusses the methods used to calculate the number of samples needed to clear an uncontaminated or decontaminated area.

4.1 Characterization of Contamination in a Possibly Contaminated Area

There are many variables that affect the number of probabilistic samples that should be taken in a room or on a floor to detect contamination in a possibly contaminated area. These variables include the 1) percent confidence of detecting contamination, 2) size of the contaminated area (assumed in this case to be circular, quantified by its diameter)[(a)] one wishes to be able to detect with high confidence, and 3) FNR.[(b)] More samples are required to have a higher confidence, detect a smaller diameter of

(a) Statistical formulas for calculating numbers of samples required to detect a contaminated area with specified confidence exist for circular or elliptical contamination shapes using square, rectangular, and triangular contamination shapes (Sego and Wilson 2007; Gilbert 1987, Chapter 10). The formula for a circular contaminated area is used most frequently in practice and thus was the basis for calculations used to develop the experimental design for the INL-2 study.

(b) The false-negative rate is specified as the percentage of times a contaminated sample is erroneously declared to be "uncontaminated." False negatives can occur because of inefficiencies in (1) recovery of the contaminant by sampling, (2) extraction of the contaminant from samples, (3) sample transportation or aging issues, and (4) the analytical method. However, if the concentration of contaminant is high enough, the FNR can be zero (or near zero) despite sampling-recovery inefficiencies, extraction inefficiencies, sample transportation/aging issues, and analytical uncertainties.

contamination, or when the FNR is higher. Given that the INL-2 study will have smaller amounts of contaminant released than the INL-1 study, it is not clear what sizes of contaminated areas may result. Similarly, there is not much information on the expected FNR. For this reason, the numbers of samples were calculated for confidence levels ranging from 50% to 95%, contaminated areas ranging from 1 foot to 10 feet in diameter, and FNRs ranging from 0% to 50%. Sample sizes were calculated using triangular grid patterns where samples are spread out in a relatively uniform manner. This implies that no two samples are bunched together, and there is no large unsampled portion of the room or floor (Gilbert et al. 2002, Matzke et al. 2007). Results of these calculations are provided in subsequent figures and tables for 95% confidence. The results for the smaller diameters of contaminated areas are not presented because they correspond to unrealistically large numbers of samples. Appendix A contains additional figures displaying the numbers of samples calculated. These figures display realistic numbers of samples for all combinations of contaminated areas (from 1 foot to 10 feet in diameter), FNRs (0% to 50%), and confidence (50%, 75%, 90%, and 95%) for a typical room and for a single floor.

Figure 4.1 summarizes the calculations for the number of probabilistic samples required to sample a typical room and detect contamination with 95% confidence when the diameter of a circular, contaminated area and the FNR are varied. This plot shows that 20 samples provide 95% confidence for detecting a circular, contaminated area of 6 feet in diameter with an FNR of 30%. If a smaller FNR of about 15% is assumed, then 20 samples are required to achieve 95% confidence for detecting a circular, contaminated area with a 5-foot diameter.

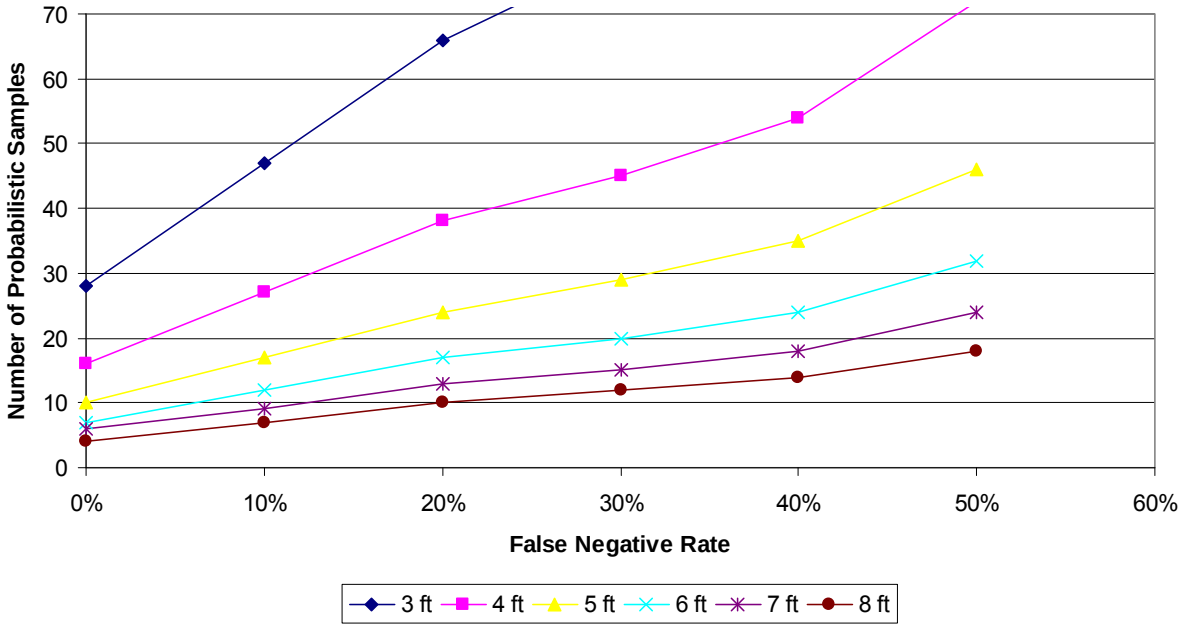

Figure 4.1. Number of Probabilistic Samples Required to Detect with 95% Confidence a Circular Contaminated Area of a Given Diameter (represented by the colored lines) within a Typical Room of the INL PBF-632 Building

Figure 4.2 summarizes these calculations for the number of samples required to sample a single floor and detect contamination with 95% confidence when the contamination diameter and the FNR are varied. This plot shows that 200 samples provide 95% confidence for detecting a 7-foot contamination diameter

with an FNR of about 28%. If a smaller FNR of about 15% is assumed, then 200 samples are required to achieve 95% confidence for detecting a 6-foot contamination diameter.

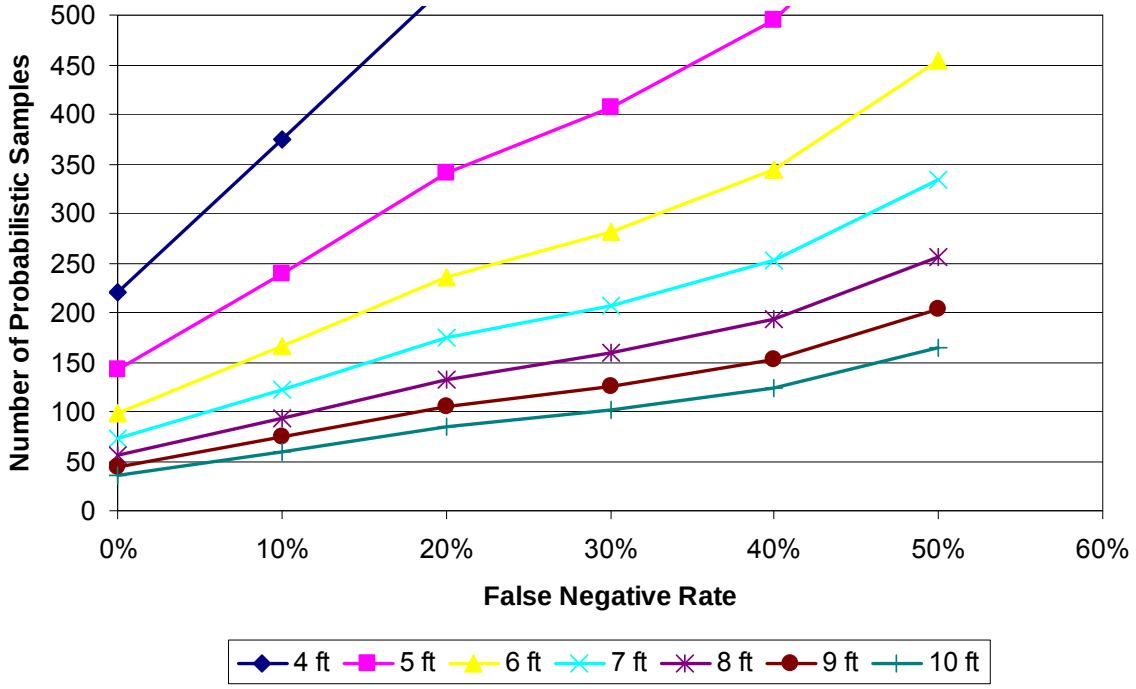

Figure 4.2. Number of Probabilistic Samples Required to Detect with 95% Confidence a Circular Contaminated Area of a Given Diameter (represented by the colored lines) within a Single Floor of the INL PBF-632 Building

Figure 4.1 and Figure 4.2 are intended to show how the numbers of probabilistic samples increase as the FNR increases and size of contaminated area to be detected decreases. In practice, response teams should first identify the FNR appropriate for the sampling, transportation, extraction, and analytical methods to be used and the level of contamination that may be present. They should also identify the area of contamination (e.g., circular diameter) to be detected with specified high confidence (e.g., 95%). Then the number of probabilistic samples required to meet those detection goals can be determined. Sometimes in practice there is a tendency to first determine how many samples are possible (based on time, budget, etc.) and then select values of FNR and area of contamination to yield that number of samples. This is generally considered to be a misuse of the statistical approach.

Table 4.1 lists *statistical statements*[(a)] given the number of probabilistic samples and holding constant two of the three variables (contamination diameter and FNR) used to calculate the numbers of samples. In each set of statistical statements, 95% confidence was used. In the first column of statistical statements, the FNR was set at 10% so that the size of the contaminated area could be calculated. In the second column of statistical statements, the diameter of the circular, contaminated area was set at 10 feet

(a) A *statistical statement* indicates the confidence, false-negative rate, and size of contaminated area to be detected that are associated with a given number of samples.

so that the FNR could be calculated. These calculations were made to quantify what is gained by increasing the number of probabilistic samples.

Table 4.1. Statistical Statements Given the Number of Probabilistic Samples Per Room and Per Floor for Characterizing the INL PBF-632 Building

# of Probabilistic Samples	Statistical Statement 1[(a)]	Statistical Statement 2[(b)]
	Per Room	
3	95% conf/11.8 ft diameter/10% FNR	95% conf/10 ft diameter/0% FNR
6	95% conf/8.3 ft diameter/10% FNR	95% conf/10 ft diameter/14.2% FNR
7	95% conf/7.7 ft diameter/10% FNR	95% conf/10 ft diameter/20.9% FNR
9	95% conf/6.8 ft diameter/10% FNR	95% conf/10 ft diameter/36.8% FNR
12	95% conf/5.9 ft diameter/10% FNR	95% conf/10 ft diameter/49% FNR
17	95% conf/4.9 ft diameter/10% FNR	95% conf/10 ft diameter/>50% FNR
	Per Floor	
65	95% conf/9.6 ft diameter/10% FNR	95% conf/10 ft diameter/11.5% FNR
82	95% conf/8.6 ft diameter/10% FNR	95% conf/10 ft diameter/18.1% FNR
101	95% conf/7.7 ft diameter/10% FNR	95% conf/10 ft diameter/29.3% FNR

(a) Statistical Statement 1 lists the calculated circular diameter of the contamination that can be detected, given the number of probabilistic samples, 95% confidence, and 10% FNR.

(b) Statistical Statement 2 lists the calculated FNR, given the number of probabilistic samples, 95% confidence, and detecting a 10-foot-diameter area of contamination.

There are other assumptions that were not allowed to vary because of limitations in the VSP software (Matzke et al. 2007). VSP performs probabilistic sampling using a grid approach and assumes an equal probability of contamination within each grid cell. With the exception of CJR sampling designs, VSP does not (at this time) allow for different areas of the sampling grid to have different probabilities of detectable contamination. Another assumption not included in the calculations is the sample area (i.e., the physical area that is swabbed, wiped, or vacuumed for a single sample). VSP is able to factor in the sample area when 0% FNR is assumed (a value of 1 ft^2 was used for the work in this report, based on input from experts on the VSPWG). However, VSP does not yet have the capability to vary the sample area and FNR for a grid-sampling approach. Further, the VSP capability to address the sample area assumes that the area is the same for every sample. Thus, VSP does not currently have the capability to account for the smaller area sampled by a swab versus the larger areas sampled by a wipe or vacuum. When the FNR is greater than zero, VSP assumes point sampling (i.e., samples cover a negligible area). This results in conservative estimates for the numbers of samples, meaning that the statistical statements are actually better than stated for point samples. On the other hand, the number of samples is conservative (i.e., larger than what would otherwise be needed) by basing calculations on point samples rather than actual areas covered by samples.

4.2 Clearance of a Non-Contaminated or Decontaminated Area

In a situation where decontamination has occurred, or in an area of the INL PBF-632 building expected not to have been contaminated, sampling may be performed to clear the area (i.e., declare that there is no detectable contamination). When sampling an area for clearance, probabilistic samples are

typically used because they allow making an X%/Y% clearance statement (see Section 1.2). The CJR sampling approach that combines judgmental and probabilistic samples (Sego et al. 2007) also provides for making an X%/Y% clearance statement. The CJR sampling approach is implemented in the VSP Version 5 software (Matzke et al. 2007). Both options (probabilistic samples only and the CJR sampling approach) will be examined in this study. Samples were placed using an adaptive fill algorithm (Gilbert et al. 2002; Matzke et al. 2007) to spread out the probabilistic samples.

There are many parameters that affect the number of probabilistic samples taken using the CJR sampling approach to clear an area or a floor of the INL PBF-632 building that has been decontaminated or is expected to be uncontaminated. These parameters include 1) the percent confidence (X%) desired, 2) the minimum percent (Y%) of the room or floor that can be stated to not contain detectable contamination,[(a)] 3) the number of judgmental samples taken, 4) how much more likely it is that a judgmental sample location contains detectable contamination than a probabilistic sample location, and 5) the expected *a priori* probability that a judgmental sample will detect contamination. The clearance statement only holds true if none of the samples (judgmental or probabilistic) indicate the presence of contamination. More probabilistic samples are necessary to achieve higher values of X and/or Y.

An important assumption of the mathematical model used in the CJR approach is that the decision area can be divided into areas of higher and lower risk (the high risk area and low risk areas need not be contiguous). The higher risk areas have a higher likelihood of being contaminated than the lower risk areas. The CJR model assumes that all of the high risk areas are sampled judgmentally. In essence, the judgmental sample locations *define* the high risk areas in the sampling design. Consequently, fewer probabilistic samples are necessary when more judgmental samples are taken and/or when locations with judgmental samples are more likely to contain detectable contamination. Fewer probabilistic samples are also necessary as the *a priori* probability that a judgmental sample will detect contamination decreases. FNRs have not yet been implemented into the CJR sampling approach of the VSP software, so they were not considered for these calculations. For this reason, the X%/Y% clearance statement that can be made using the CJR approach in VSP is defined as "X% confidence that at least Y% of the area does not contain *detectable* contamination."

Figure 4.3 summarizes the number of probabilistic samples required to sample an area consisting of two typical rooms in the INL PBF-632 building using the CJR sampling approach. This figure assumes a 95% confidence level and the likelihood that a judgmental sample location is three times (3×) more likely to contain detectable contamination than a probabilistic sample location. The number of judgmental samples, the percentage of the two rooms that does not contain detectable contamination, and the *a priori* probability that a judgmental sample will detect contamination (10% or 30%) were allowed to vary. Figure 4.3 shows that given 12 negative judgmental samples (i.e., ones that do not detect contamination), 143 negative probabilistic samples would be necessary to have 95% confidence that at least 99% of the area in the two rooms does not contain detectable contamination. This result is obtained when the *a priori* probability that a judgmental sample will detect contamination is 10%.

(a) It would require 100% sampling of an area and a zero false-negative rate to state with 100% confidence that 100% of the area is not contaminated. With less than 100% sampling and possibly a false-negative rate higher than zero, an X%/Y% clearance statement must necessarily have X < 100 and Y < 100.

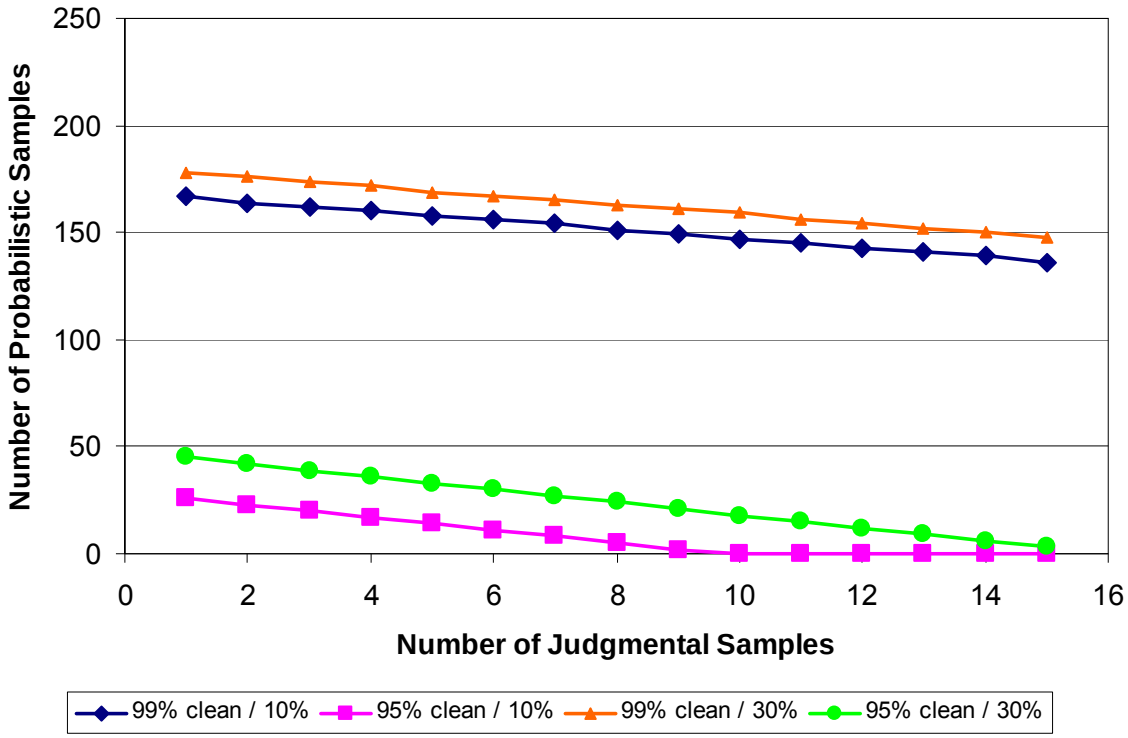

Figure 4.3. Number of Negative Probabilistic Samples Required to be 95% Confident that 95% or 99% of Two Rooms in the INL PBF-632 Building Do Not Contain Detectable Contamination Given Various Numbers of Negative Judgmental Samples. Colored lines represent the percentage of the two rooms (considered together) not containing detectable contamination and the *a priori* probability that a judgmental sample will detect contamination.

Figure 4.4 summarizes the number of probabilistic samples necessary to make a 99%/97% clearance statement about a single floor in the INL PBF-632 building when using the CJR sampling approach. Three parameters were allowed to vary: 1) the number of judgmental samples, 2) the *a priori* probability that a judgmental sample will detect contamination (10% or 30%), and 3) the likelihood that a judgmental sample location contains detectable contamination as compared to a probabilistic sample location (1× = judgmental location just as likely as probabilistic or 3× = judgmental location is three times as likely as probabilistic location, etc.). Figure 4.4 shows that with 20 negative judgmental samples, 124 negative probabilistic samples would be required to have 99% confidence that 97% of the floor does not contain detectable contamination. This result is obtained when (i) there is a 30% *a priori* probability that a judgmental sample will detect contamination and (ii) a judgmental sample location is just as likely (1×) to contain detectable contamination as a probabilistic sample location.

Figure 4.3 and Figure 4.4 show the numbers of judgmental and probabilistic samples needed with the CJR approach to clear either 95% or 99% of the area in two rooms (Figure 4.3) or a whole floor (Figure 4.4) with 95% confidence. Results for the cases of 10% and 30% *a priori* probability that a judgmental sample will detect contamination are shown. Caution is needed in interpreting and using these figures. As discussed previously in this section, the number of judgmental samples should correspond only to locations that have a higher risk of contamination. *It would be a misuse of the CJR*

approach to arbitrarily pick a larger number of judgmental samples in order to reduce the number of probabilistic samples.

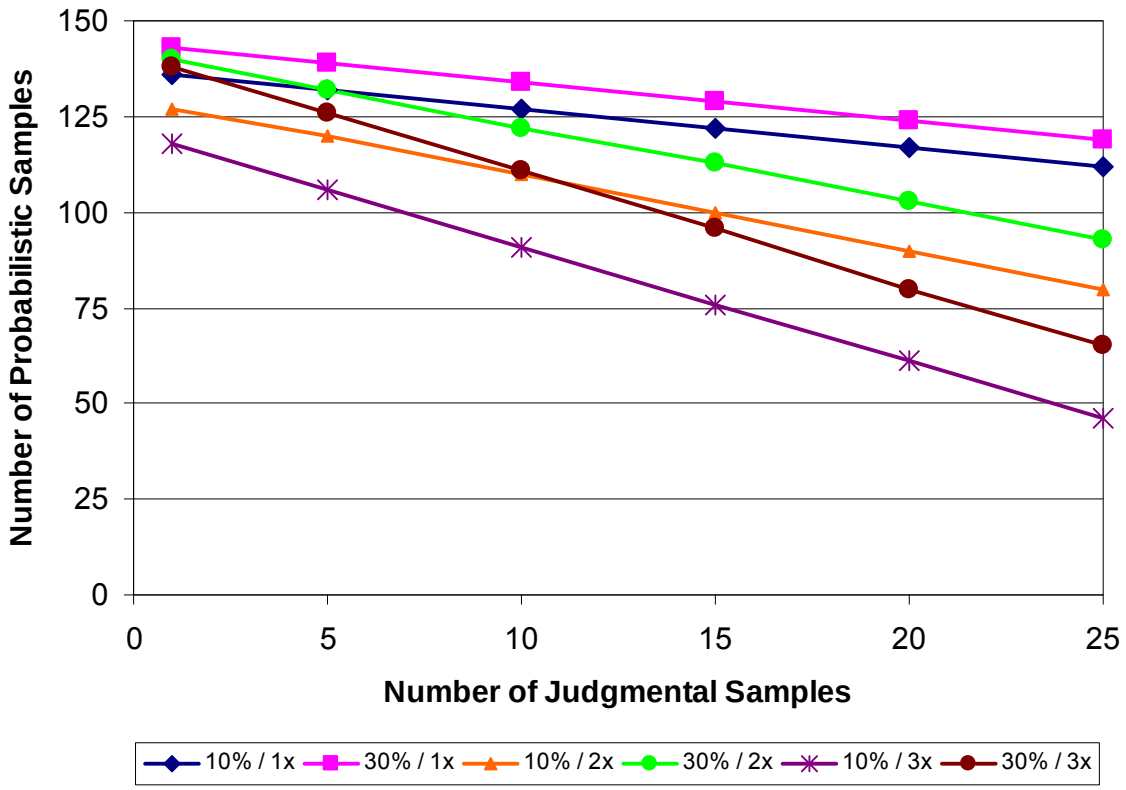

Figure 4.4. Number of Negative Probabilistic Samples Required to be 99% Confident that at Least 97% of a Typical Floor in the INL PBF-632 Building Does Not Contain Detectable Contamination Given Various Numbers of Negative Judgmental Samples. Colored lines represent the *a priori* probability that a judgmental sample will detect contamination and the likelihood of a judgmental sample location containing detectable contamination relative to a probabilistic sample location. Note that the "10%/1×" and "30%/3×" lines are nearly identical.

Figure 4.5 summarizes the number of negative probabilistic samples required to make an X%/Y% clearance statement about two typical rooms (considered together) in the INL PBF-632 building using only probabilistic samples. The percent confidence (X%) and the minimum percent of the room not containing detectable contamination (Y%) were allowed to vary. If 42 probabilistic samples all came back negative (the same number in the previous example for Figure 4.2), then there would 95% confidence that at least 93% (approximately) of the room does not contain detectable contamination. Thus, the 12 judgmental samples in the example associated with Figure 4.3, combined with the 42 probabilistic samples, increased the percentage of the room that can be declared not to contain detectable contamination from 93% to 99%. Although not illustrated in this report, it is also possible to calculate the reduction in percentage confidence (X%) associated with Y = 99% by only using probabilistic samples instead of the Bayesian combination of judgmental and probabilistic samples used in the CJR approach.

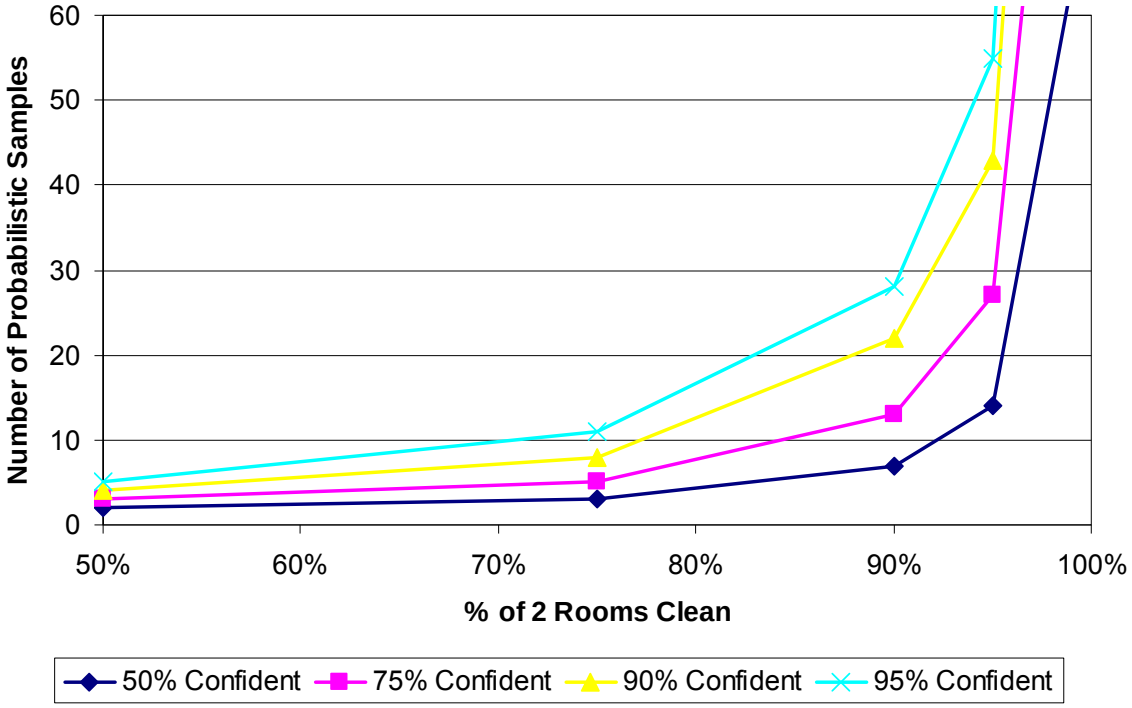

Figure 4.5. Number of Probabilistic Samples Required to Determine if a Given Percentage of Two Typical Rooms in the INL PBF-632 Building Does Not Contain Detectable Contamination (x-axis) with a Given Level of Confidence (color lines)

Figure 4.6 summarizes the number of probabilistic samples required to make an X%/Y% clearance statement about a single floor in the INL PBF-632 building using the only probabilistic samples. The percent confidence (X%) and the percent of the room that does not contain detectable contamination (Y%) were allowed to vary. This plot shows that if 119 probabilistic samples were taken and found to be negative (the same number as in the example above for Figure 4.4), then there would be 95% confidence that at least 96% of the floor does not contain detectable contamination. Although not illustrated, it is also possible to calculate the X% confidence associated with Y = 99% for a given number of probabilistic samples compared to also having a given number of judgmental samples in the CJR sampling approach.

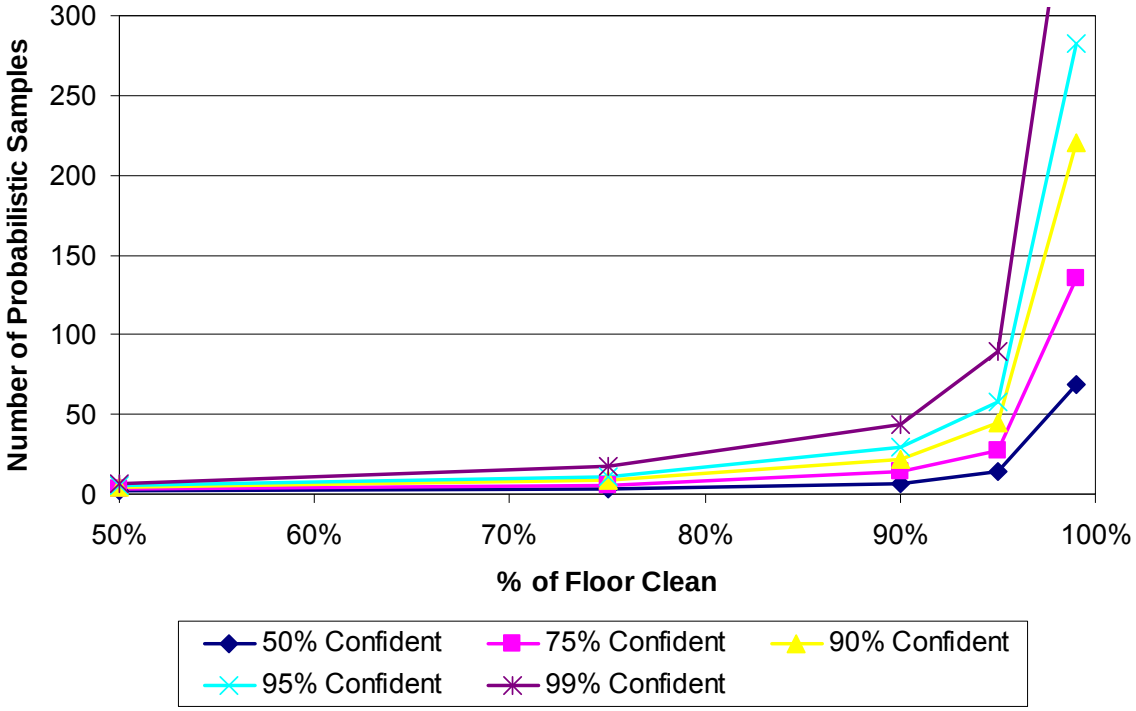

Figure 4.6. Number of Probabilistic Samples Required to Determine if a Given Percentage of a Typical Floor in the INL PBF-632 Building Does Not Contain Detectable Contamination (x-axis) with a Given Level of Confidence (color lines)

Figure 4.3 through Figure 4.6 were used to determine numbers of judgmental and probabilistic samples for determining clearance of a floor or a set of two rooms in the INL-2 Sample Collection Operational Test. Table 4.2 lists statistical statements for the Bayesian sampling approach given these numbers of judgmental and probabilistic samples and assuming that two of the three other variables are held constant. In each set of statistical statements, 95% or 99% confidence and a sample area of 1 ft^2 were used. In the first column of statistical statements, the likelihood that a judgmental sample location contains detectable contamination relative to a probabilistic sample location was set to 3×, and the *a priori* probability that a judgmental sample will detect contamination was set to 30%, so that the percent of the room not containing detectable contamination could be calculated. In the second column of statistical statements, the likelihood that a judgmental sample location contains detectable contamination relative to a probabilistic sample location was set to be equivalent (1×), and the *a priori* probability that a judgmental sample will detect contamination was set to 30%, so that the percent of the rooms/floor not containing detectable contamination could be calculated. The third column did not use the CJR sampling approach, but instead relied on a compliance sampling methodology that uses probabilistic sampling only (Bowen and Bennett 1988). It did not rely on assumptions about the *a priori* probability that a judgmental sample will detect contamination nor the relationship between the likelihood of detectable contamination existing in the judgmental and probabilistic sample locations. The statistical statement of the third column lists the percent of the rooms/floor that does not contain detectable contamination, given the number of negative probabilistic samples and desired 95% or 99% confidence.

Table 4.2. Statistical Statements Given the Number of Probabilistic and Judgmental Samples for Clearance of a Decontaminated or Non-Contaminated Area in the INL PBF-632 Building

# of Judgmental Samples	# of Probabilistic Samples	Statistical Statement 1[(a),(c)]	Statistical Statement 2[(b),(c)]	Statistical Statement 3[(d)]
Per Two Rooms				
8	26	95%/95.2%/3×/30% 90%/96.3%/3x/30%	95%/92.6%/1×/30% 90%/94.3%/1x/30%	95%/89.4% 90%/91.7%
Per Floor				
20	121	95%/98.6%/3x/10%	95%/98.1%/1x/10%	95%/97.6%[(e)]

(a) Statistical Statement 1 is listed as the percent confidence/percent of an area that does not contain a detectable contaminated/multiplier that indicates a judgmental sample location is 3× more likely to contain detectable contamination than a probabilistic sample location/*a priori* probability that a judgmental sample will detect contamination.

(b) Statistical Statement 2 is listed as the percent confidence/percent of an area that does not contain detectable contamination/multiplier that indicates a judgmental sample location is 1× more (equally) likely to contain detectable contamination than a probabilistic sample location/*a priori* probability that a judgmental sample will detect contamination.

(c) When decontamination has occurred (per floor), then the *a priori* probability was set to 10%. When decontamination had not occurred (per two rooms), then the *a priori* probability was set to 30%.

(d) Statistical Statement 3 is listed as the percent confidence/percent of an area that does not contain detectable contamination using only probabilistic sampling.

(e) The "percent cleared" value of 97.6% is not much different than the corresponding values in Statistical Statements 1 and 2 for CJR sampling. This is because of the 95% confidence required, the 10% chance that a judgmental sample is contaminated, and the number of judgmental samples being smaller relative to the number of probabilistic samples (than in the "two rooms" case).

There are other assumptions that are not allowed to vary when sampling for clearance because of limitations in the VSP software (Matzke et al. 2007). With the exception of CJR sampling designs, VSP does not (at this time) allow for different areas of the sampling grid to have different *a priori* probabilities that a judgmental sample will detect contamination. VSP also does not yet account for the FNR in a grid sampling approach.

5.0 Experimental and Sampling Design

The experimental and sampling design for the INL-2 Sample Collection Operational Test is described in this section. The rationales concerning characterization and clearance sampling are explained in Sections 5.1 and 5.2, respectively. Test Event 1 (the ORI) and Test Event 2 are described in Section 5.3, while Test Events 3, 4, and 5 are described in Sections 5.4 to 5.6, respectively. The sampling design for the numbers of samples to be collected is presented for each test event in Sections 5.3 to 5.6. The total numbers of samples for the characterization and clearance phases are summarized in Section 5.7. Additional details about the experimental and sampling design are discussed in Section 5.8.

5.1 Guidance for Characterization and Clearance Sampling Designs

Section 5.1.1 presents the guidelines provided by the VSPWG on the maximum number of samples that could be taken during the characterization and clearance phases of the five test events in the INL-2 study. Section 5.1.2 briefly summarizes the VSPWG guidance on composite sampling.

5.1.1 Guidelines on the Maximum Numbers of Samples for Characterization and Clearance

Generally, the VSPWG was interested in collecting close to the maximum number of samples feasible for the characterization and clearance phases of Test Events 1 to 5. Maximizing (within operational limitations) the numbers of samples would provide for sampling most (if not all) rooms and also possibly provide for over-sampling. Over-sampling (more sampling than required by defensible bases for selecting the number of judgmental and probabilistic samples) provides for the ability to better characterize building contamination patterns. Over-sampling also allows performing after-the-fact assessments of how sampling plans using fewer samples would have performed.

The VSPWG provided the following guidelines to help determine the numbers of samples to be collected during the characterization and clearance phases

- There will be four sampling teams working simultaneously during each of the characterization and clearance phases.
- The characterization sampling must be completed within a 6-hour period, including a break after 3 hours. The clearance sampling must be completed within a 4-hour period, including a break after 2 hours. These time limits include time to get into and out of protective gear.
- For the characterization phase, three RMC samples will be taken in each room that will be sampled. For the clearance phase, no RMC samples will be taken.
- It takes an average of 6 minutes per sample per sampling team. RMC samples will take less time, vacuum samples more time.
- It is recommended that a single sampling team should work in an individual room without being interrupted by taking a break.

Based on this guidance, the VSPWG specified the following maximum numbers of samples.

- Maximum 60 total rooms sampled over the characterization phases of the five test events.
- Maximum 70 total rooms sampled over the clearance phases of the five test events.
- Maximum 260 characterization samples for each of the characterization and clearance phases of each of the five test events.
- During the characterization phase, a maximum of 37 samples per room, with the following maximums for each sample type: Vacuum (15), Wipe (14), Swab (5), and RMC (3).
- Maximum of 19 samples per room, with the following maximums for each sample type: Vacuum (10), Wipe (6), Swab (3), and RMC (0).

Initial planning included five RMCs per sampled room for each of the characterization and clearance phases. However, Mike Walter (JPEO-CBD) and Dino Mattorano (EPA) subsequently decided on three RMCs per room for characterization sampling and no RMCs for clearance sampling. They concluded that three RMCs per room would be sufficient to characterize the extent of contamination during the characterization phase. Further, they concluded that sufficient information is available from the sampling matrices (vacuum, wipe, swab) to assess the efficacy of fumigation, thus making the clearance RMCs unnecessary. For example, suppose all RMCs were negative for the clearance phase of a test event, but several positive surface samples were found from the other matrices. Contamination would still be suspected either through handling or through residual contamination in the building left from the initial dispersal. The negative RMCs would have no impact on the assessments from that particular clearance phase. Hence, it was decided to eliminate placing RMCs for collection during the clearance phases of the test events.

Because of limitations on the numbers of samples and analyses that can be performed for the INL-2 study, it was decided that certain rooms in the INL PBF-632 building would not be sampled. These included men's and women's restrooms plus mechanical rooms on both the first and second floors, as well as two storage rooms on the second floor.

5.1.2 Limited Investigation of Composite Sampling

Finally, the VSPWG wanted to investigate using a composite-sampling method to collect judgment samples in at least one room per characterization phase for each of the test events. In the INL-1 study, the area sampled by each sampling method (wipe, swab, vacuum) was the same for all samples collected by each method, regardless of the samples being judgmental or probabilistic samples. Hence, multiple judgmental samples of a fixed area were required to sample a larger area, if desired. However, in practice, judgmental samples are often collected in a composite fashion (e.g., by wiping several areas with the same wipe). It was decided to investigate this way of collecting judgmental samples for limited portions of the INL-2 study.

As discussed subsequently, we decided to perform composite judgmental sampling in two rooms per test event. This provides for evaluating composite judgmental sampling in rooms having expected lower and higher contaminant concentrations. In all other rooms, the sample area will be the same size whether the sample is probabilistic or judgmental. Thus, in all other rooms, multiple judgmental samples will be necessary to sample a larger area if so desired. There should be enough planned numbers of judgmental samples to allow for multiple samples when needed.

5.2 Rationales for Characterization and Clearance Sampling

Sections 5.2.1 and 5.2.2 discuss the rationales for how the numbers of samples were determined for characterization and clearance sampling, respectively.

5.2.1 Characterization Sampling Rationale

For sampling with the goal of characterization, the resulting numbers of samples are based on three quantities: 1) percent confidence, 2) size of the contaminated area (assumed to be circular and quantified by the diameter, in feet) one wishes to be able to detect with high confidence, and 3) the FNR. For INL-2 sampling designs, the percent confidence was consistently set at 95%. Specifying values for any two of 1) contamination size, 2) FNR, and 3) number of samples permits calculating the third quantity. In each sampling case, two statistical statements were made. The first statement involved specifying the size (diameter) of a circular contaminated area with FNR = 10% and then calculating the required number of samples. For overt tests, the second statement involved choosing a consistent contaminated area size (10-ft diameter) and calculating the FNR for the number of samples calculated corresponding to the first statistical statement. For covert tests, the second statement involved choosing a consistent FNR (FNR = 30%) and calculating the contaminated area size for the number of samples calculated corresponding to the first statistical statement.

Each of these statistical statements allows the opportunity to see what advantage is gained when increasing the numbers of samples. The advantages include the ability to detect a smaller contaminated area and/or being able to detect contamination when the FNR is higher. Because it is not known at this time 1) how much of each room in the INL PBF-632 building will be contaminated after BG contaminant dissemination and 2) how the FNR will vary with contamination level, it is informative to consider what statistical statements is provided by each number of samples.

The numbers of samples to be taken after contamination in the INL-2 study are presented in Sections 5.3 to 5.6 and are summarized in Section 5.7. The numbers of characterization samples given in Sections 5.3 to 5.6 allow making 95% confidence statements about detecting contamination in circular areas ranging from 6 ft to 10 ft in diameter for a room or one complete floor of the INL PBF-632 building and have FNRs ranging from 10% to over 50%.

5.2.2 Clearance Sampling Rationale

For sampling with the goal of clearance, the resulting numbers of samples are based on four quantities: 1) percent confidence, 2) percent of a room or floor of the INL PBF-632 building that does not contain detectable contamination, 3) *a priori* probability that a judgmental will detect contamination, and 4) likelihood that a judgmental sample location contains detectable contamination relative to a probabilistic sample location. For this experimental and sampling design, the percent confidence was consistently set at 95% for two typical rooms and 99% for the whole floor, and the *a priori* probability that a judgmental sample will detect contamination was set to 30%. Specifying values for any two of 1) percent of area containing detectable contamination, 2) likelihood that a judgmental sample location contains detectable contamination relative to a probabilistic sample location, or 3) number of samples (judgmental and probabilistic) permits calculating the third quantity. In each sampling case, two statistical statements were made. Each statement lists the percentage of the room or floor not containing detectable contamination, given that a judgmental sample location was either 1× or 3× more likely to contain detectable contamination as a probabilistic sample location.

The numbers of clearance samples given in the following sections allow making clearance statements of the form "X% confidence that at least Y% of an area does not contain detectable contamination" with X = 95% or 99% and Y = 96% or 97%. The tables also show that increasing the likelihood that a judgmental sample location contains detectable contamination from 1× to 3× relative to a probabilistic sample location will increase Y by 1%. To appreciate these increases, it may be more appropriate to consider them in terms of the percentage of the area containing detectable contamination (i.e., 100% − Y%). If the percentage not containing detectable contamination increases from 96% to 97%, then this is actually a 25% decrease in the percentage containing detectable contamination (from 4% to 3%). The change is more dramatic when expressed in terms of the percentage of an area or floor that may contain detectable contamination.

The numbers of samples to be taken after decontamination are presented in Sections 5.3 to 5.6 and are summarized in Section 5.7. Because the decontamination process is expected to be the same after each test event and achieve thorough decontamination, the same numbers of post-decontamination samples are recommended for each test event.

5.3 Test Events 1 and 2

Test Events 1 and 2 involve covert releases on the first floor of the INL PBF-632 building, with unspecified locations for the release of the contaminant. The sampling designs for Test Events 1 and 2 are identical. Test Event 1 is the ORI, and it is not known ahead of time whether the results from that test event will be able to be included in the data analysis. Hence, the sampling design for Test Event 2 is the same as for Test Event 1.

The purpose of the ORI (Test Event 1) is to provide an opportunity for any issues that might arise (e.g., concerning the dissemination, contamination gradient, sampling, and decontamination) to be addressed before the remaining test events. Following the ORI, adjustments should be made to the process so that the subsequent test events will result in desirable contamination gradients, as described in Section 2.2. If the data from the ORI are deemed useful, they may be included in the data analyses.

If it is discovered in Test Event 1 that the amount of contaminant released is too high or too low to yield a desirable gradient (e.g., from moderate/low down to no/undetectable contamination), then the amount of contaminant released in Test Event 2 should be changed accordingly. *If a moderate-to-no/undetectable range of contamination is achieved in Test Event 1, it is recommended that a lower amount of contaminant be released in Test Event 2 to achieve a low-to-no/undetectable contaminant range.* This should provide more rooms with very-low concentrations of contaminant, which are needed to assess the performance of the sampling approaches, sampling methods, and analytical methods when the false negative rate is higher.

Table 5.1 summarizes the numbers of samples of each type (QC, RMC, judgmental, and probabilistic) to be taken after contamination and after decontamination during Test Events 1 and 2. Figure 5.1 and Figure 5.2 give visual displays of the sample locations after contamination and after decontamination, respectively, using the sampling design for Test Events 1 and 2. Figure 5.2 also includes Test Event 4, which is discussed subsequently in Section 5.5. It is assumed that the locations and order (see the last paragraph of Section 3.1) of all samples to be collected in a given room will be entered into a test matrix (see Appendix B) that will provide specific directions for the sampling teams.

Table 5.1. Numbers of Samples for INL-2 Test Events 1 and 2 on the First Floor of the INL PBF-632 Building. These events involve covert releases.

Area to be Sampled	QC Samples	Reference Material Coupons	Judgmental Samples	Probabilistic Samples	Total Samples[a]	Statistical Statement[b]
After Contamination (Characterization Phase)						
First floor[c]	44[d]	36[e]	36[f]	108	224	95%/7 ft/9% FNR 95%/9 ft/25% FNR[g]
After Decontamination (Clearance Phase)						
First floor[h]	44[d]	0	20	121	185	95%/98.6%/3× 95%/98.1%/1×[i]
Total Samples	88	36	56	229	409	N/A

(a) "Total Samples" is the sum of QC, RMC, judgmental, and probabilistic samples.

(b) These statistical statements are listed for characterization as percent confidence/diameter of circular contaminated area in feet/FNR. For clearance, they are listed as percent confidence/percent of room that does not contain detectable contamination/multiplier. The multiplier indicates a judgmental sample location is either 1× or 3× more likely to contain detectable contamination relative to a probabilistic sample location.

(c) Floor is being sampled with a characterization goal.

(d) There are three field blank samples (vacuum sock, wipe, and swab) for each of the 12 rooms to be sampled. In addition, there are two vacuum QC samples (nozzle and switch) for each of the four sampling teams/vacuums per entry. Hence, for each of the characterization and clearance phases, there is a total of 44 QC samples.

(e) Three RMCs will be collected in each of the 12 first-floor rooms to be sampled during the characterization phase.

(f) Three judgmental samples are to be collected in a composite fashion in each of two rooms during the characterization phase. It is suggested that the three composite judgment samples be collected in each of Offices 102 and 109 for consistency with Test Event 4, although the location of release is unknown for Test Event 1.

(g) The 108 probabilistic samples over the first floor provide 95% confidence for either detecting a single circular contaminated area of diameter 7 ft with an FNR of 9% or detecting a single circular contaminated area of diameter 9 ft with an FNR of 25%.

(h) Floor is being sampled with a clearance goal.

(i) CJR-based clearance statement: 95% confidence that 98.6% of the floor does not contain detectable contamination with a judgmental sample location being 3× more likely to contain detectable contamination relative to a probabilistic sample location, or 95% confidence that 98.1% of the floor does not contain detectable contamination with a judgmental sample location 1× more (equally) likely to contain detectable contamination as a probabilistic sample location. All clearance numbers of samples assume that the *a priori* probability that a judgmental sample will detect contamination is 10%.

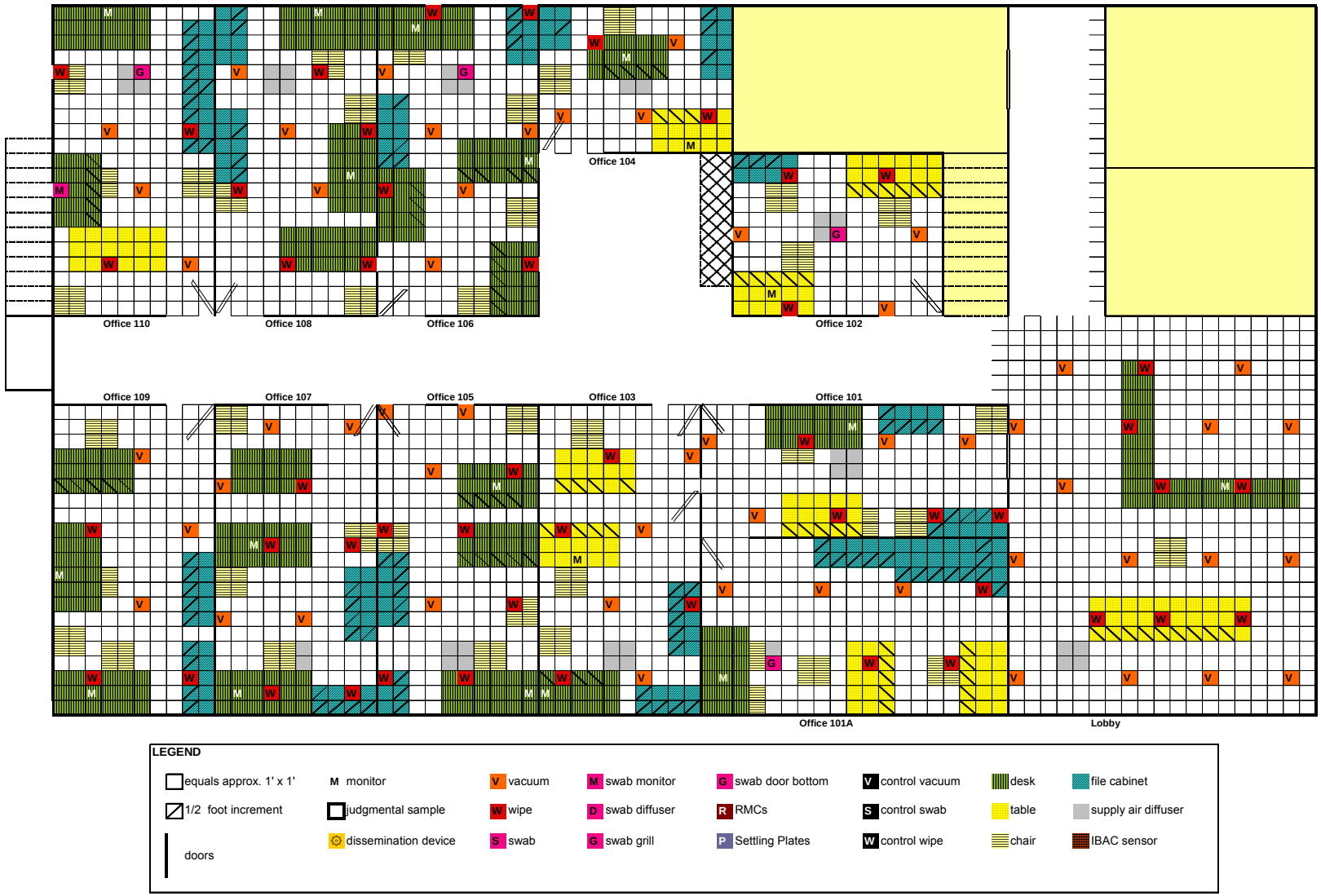

Figure 5.1. Map of Probabilistic Sample Locations and Types for Characterization Sampling of the First Floor of the INL Building During INL-2 Test Events 1 and 2

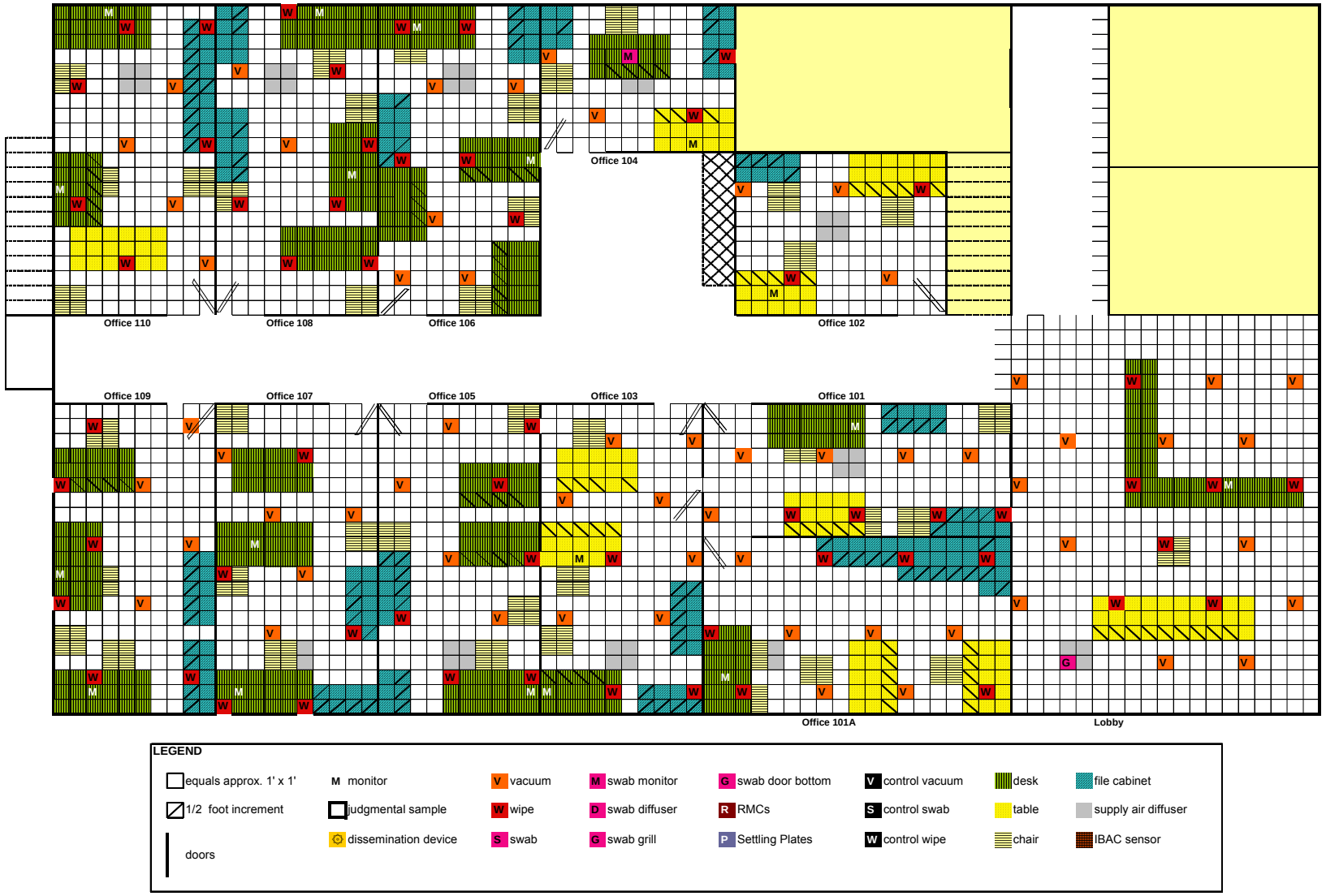

Figure 5.2. Map of Probabilistic Sample Locations and Types for Clearance Sampling of the First Floor of the INL Building During INL-2 Test Events 1, 2, and 4

The characterization phase of sampling in Test Events 1 and 2 includes 44 QC samples, 36 RMC samples, 36 judgmental samples, and 108 probabilistic samples. Two examples of the statistical statements about detecting contamination that are supported by the 108 probabilistic samples are shown in the last column of Table 5.1. The 36 judgmental samples is an average of three per the 12 rooms on the first floor. In two rooms, three judgmental samples should be collected in a composite fashion (as opposed to the fixed-area fashion of collecting other judgmental samples). For each of Test Events 1 and 2, it is recommended that three composite judgment samples be collected in each of Offices 102 and 109 for consistency with Test Event 4, although the location of release is unknown for Test Events 1 and 2.

The clearance phase of sampling in Test Events 1 and 2 includes 44 QC samples, 0 RMC samples, 20 judgmental samples, and 121 probabilistic samples. Note that the numbers of judgmental and probabilistic samples per floor after decontamination are the same for all five test events. Two examples of X%/Y% clearance statements supported by these numbers of judgmental and probabilistic samples are shown in the last column of Table 5.1.

5.4 Test Event 3

Test Event 3 involves a covert release on the second floor of the INL PBF-632 building, with an unspecified location for release of the contaminant. The sampling design for Test Event 3 is very close to that for Test Events 1 and 2, with the small difference a result of using the second floor of the building.

Table 5.2 summarizes the numbers of samples of each type (QC, RMC, judgmental, and probabilistic) to be taken after contamination and after decontamination during Test Event 3. Figure 5.3 and Figure 5.4 give visual displays of the locations of probabilistic samples after contamination and after decontamination, respectively, using the sampling design for Test Event 3. Figure 5.4 also includes Test Event 5, which is discussed subsequently in Section 5.6. The locations of QC, RMC, and judgmental samples will be determined subsequently by relevant experts and hence are not shown in Figure 5.3 and Figure 5.4. It is assumed that the locations and order (see the last paragraph of Section 3.1) of all samples to be collected in a given room will be entered into a test matrix (see Appendix B) that will provide specific directions for the sampling teams.

The characterization phase of sampling in Test Event 3 includes 53 QC samples, 45 RMC samples, 45 judgmental samples, and 105 probabilistic samples. Two examples of the statistical statements about detecting contamination that are supported by the 105 probabilistic samples are shown in the last column of Table 5.2. The 45 judgmental samples is an average of three per each of the 15 rooms on the second floor. In two rooms, three judgmental samples should be collected in a composite fashion (as opposed to the fixed-area fashion of collecting other judgmental samples). For Test Event 3, it is recommended that three composite judgment samples be collected in each of Offices 201 and 213 for consistency with Test Event 5, although the location of release is unknown for Test Event 3.

The clearance phase of sampling in Test Event 3 includes 53 QC samples, 0 RMC samples, 20 judgmental samples, and 121 probabilistic samples. Note that the numbers of judgmental and probabilistic samples per floor after decontamination are the same for all five test events. Two examples of X%/Y% clearance statements supported by these numbers of judgmental and probabilistic samples are shown in the last column of Table 5.2.

Table 5.2. Numbers of Samples for INL-2 Test Event 3 on the Second Floor of the INL PBF-632 Building. This event involves a covert release.

Area to be Sampled	QC Samples	Reference Material Coupons	Judgmental Samples	Probabilistic Samples	Total Samples[a]	Statistical Statement [b]
After Contamination (Characterization Phase)						
Second floor[c]	53[d]	45[e]	45[f]	105	248	95%/7 ft/9% FNR 95%/9 ft/25% FNR[g]
After Decontamination (Clearance Phase)						
Second floor[h]	53[d]	0	20	121	194	95%/98.6%/3× 95%/98.1%/1×[i]
Total Samples	106	45	65	226	442	N/A

(a) "Total Samples" is the sum of QC, RMC, judgmental, and probabilistic samples.

(b) These statistical statements are listed for characterization as percent confidence/diameter of circular contaminated area in feet/FNR. For clearance, they are listed as percent confidence/percent of room that does not contain detectable contamination/multiplier. The multiplier indicates a judgmental sample location is either 1× or 3× more likely to contain detectable contamination relative to a probabilistic sample location.

(c) The floor is being sampled with a characterization goal.

(d) There are three field blank samples (vacuum sock, wipe, and swab) for each of the 15 rooms (see Section 4.0) to be sampled. In addition, there are two vacuum QC samples (nozzle and switch) for each of the four sampling teams/vacuums per entry. Hence, for each of the characterization and clearance phases, there is a total of 53 QC samples.

(e) Three RMCs will be collected in each of the 15 second-floor rooms to be sampled during the characterization phase.

(f) Three judgmental samples are to be collected in a composite fashion in each of two rooms during the character-ization phase. It is suggested that the three composite judgment samples be collected in each of Offices 201 and 213 for consistency with Test Event 5, although the location of release is unknown for Test Event 3.

(g) The 105 probabilistic samples over the second floor provide 95% confidence for either detecting a single circular contaminated area of diameter 7 ft with an FNR of 9% or detecting a single circular contaminated area of diameter 9 ft with an FNR of 25%.

(h) The floor is being sampled with a clearance goal.

(i) CJR-based clearance statement: 95% confidence that 98.6% of the floor does not contain detectable contamination with a judgmental sample location being 3× more likely to contain detectable contamination relative to a probabilistic sample location, or 95% confidence that 98.1% of the floor does not contain detectable contamination with a judgmental sample location 1× more (equally) likely to contain detectable contamination as a probabilistic sample location. All clearance numbers of samples assume that the *a priori* probability that a judgmental sample will detect contamination is 10% after decontamination

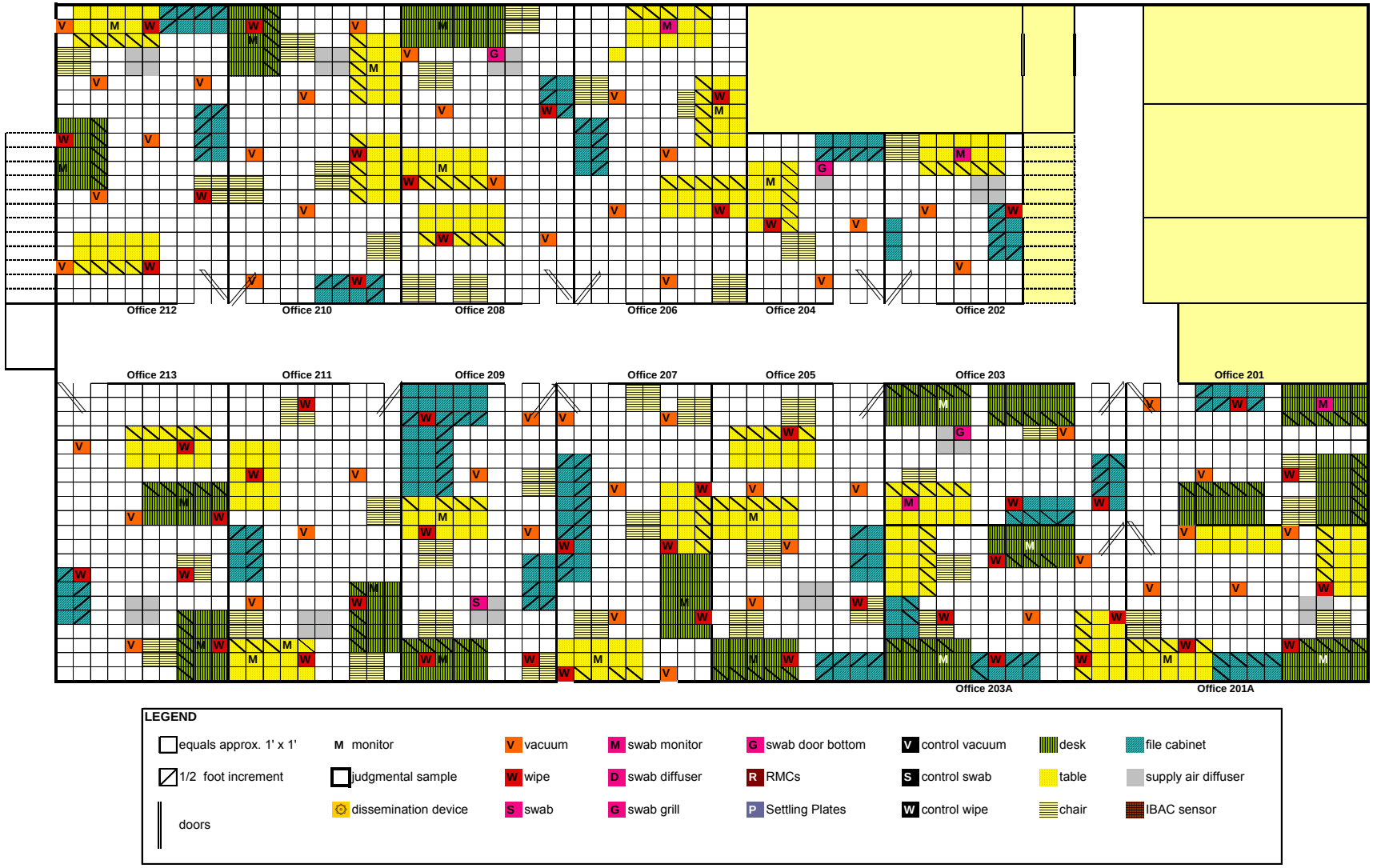

Figure 5.3. Map of Probabilistic Sample Locations and Types for Characterization Sampling of the Second Floor of the INL Building During INL-2 Test Event 3

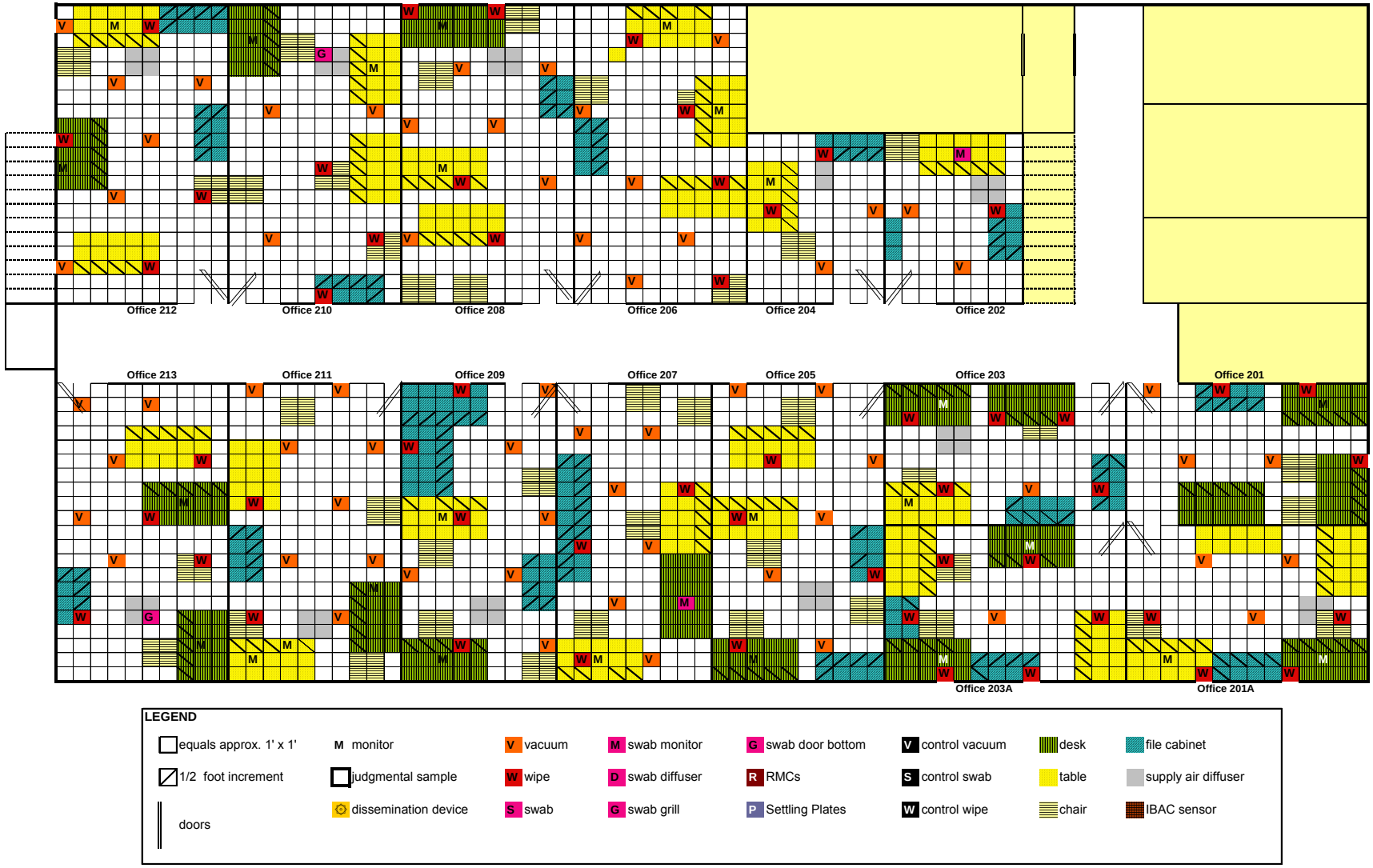

Figure 5.4. Map of Probabilistic Sample Locations and Types for Clearance Sampling of the Second Floor of the INL Building During INL-2 Test Events 3 and 5

5.5 Test Event 4

Test Event 4 involves an overt release on the first floor of the INL PBF-632 building, with Office 101A specified as the location for release of the contaminant. Office 101A was selected as the release location based on the results of pre-test tracer releases and measurements in the INL building. Specifically, the conditions of releases #5 and #7 from that work show that Offices 105 to 108 will be very lowly contaminated or uncontaminated.

Table 5.3 summarizes the numbers of samples of each type (QC, RMC, judgmental, and probabilistic) to be taken after contamination and after decontamination during Test Event 4. Table 5.3 shows the numbers of samples by room (after contamination) and floor (after decontamination). Figure 5.5 and Figure 5.2 give visual displays of the locations of probabilistic samples after contamination and after decontamination, respectively, using the sampling design for Test Event 4. The locations of QC, RMC, and judgmental samples will be determined subsequently by relevant experts and hence are not shown in Figure 5.5 and Figure 5.2. It is assumed that the locations and order (see the last paragraph of Section 3.1) of all samples to be collected in a given room will be entered into a test matrix (see Appendix B) that will provide specific directions for the sampling teams.

Additional discussion about the numbers of samples in Table 5.3 for Test Event 4 is given in the following bullets.

- Only 10 of the 12 offices on the first floor were selected for sampling after contamination because of limitations discussed in Section 5.1.1. The offices to be sampled include: 101, 102, 103, 104, 105, 106, 107, 108, 109, and 110. All 12 rooms (including the Lobby and Office 101A) will be sampled after decontamination.
- Eight vacuum QC samples (2 for each of the four sampling teams) will be collected after contamination and after decontamination. Three QC samples will be collected in each room sampled after contamination and after decontamination.
- Offices 101 and 102 close to the contaminant release point (Office 101A) were each assigned 7 probabilistic samples. Fewer probabilistic samples were assigned because it was assumed that contamination will be more easily detected in those offices. The 7 probabilistic samples provide 95% confidence of detecting a contaminated area 1) 8 feet in diameter with 10% FNR or 2) 10 feet in diameter with 29% FNR. Office 101 was assigned 4 single-increment judgmental samples while Office 102 was assigned 3 composite judgmental samples.
- Offices 103, 104, 109, and 110 were assigned 12 probabilistic samples because they are farther away from the contaminant release location (Office 101A). The 12 probabilistic samples provide 95% confidence of detecting a contaminated area 1) 6-feet in diameter with 10% FNR, or 2) 10 feet in diameter with 49% FNR. Offices 103, 104, and 110 were assigned 5 single-increment judgmental samples, while Office 109 was assigned 3 composite judgmental samples.

Table 5.3. Numbers of Samples for INL-2 Test Event 4 on the First Floor of the INL PBF-632 Building. This event involves an overt release from Office 101A.

Area to be Sampled	QC Samples	Reference Material Coupons	Judgmental Samples	Probabilistic Samples	Total Samples[a]	Statistical Statement[b]
After Contamination (Characterization Phase)						
Team Vacuum QC Samples	8	NA[c]	NA	NA	8	N/A
Office 101[d]	3	3	4	7	17	95%/8 ft/10% FNR 95%/10 ft/29% FNR[e]
Office 102[d]	3	3	3[f]	7	16	95%/8 ft/10% FNR 95%/10 ft/29% FNR
Office 103[d]	3	3	5	12	23	95%/6 ft/10% FNR 95%/10 ft/49% FNR
Office 104[d]	3	3	5	12	23	95%/6 ft/10% FNR 95%/10 ft/49% FNR
Office 109[d]	3	3	3[f]	12	21	95%/6 ft/10% FNR 95%/10 ft/49% FNR
Office 110[d]	3	3	5	12	23	95%/6 ft/10% FNR 95%/10 ft/49% FNR
Office 105 & 107[g]	6	6	8	26	46	90%/96.3%/3x 90%/94.3%/1x
Offices 106 & 108[g]	6	6	8	26	46	90%/96.3%/3x 90%/94.3%/1x
# Contamination Samples	38	30[h]	41	114	223	N/A
After Decontamination (Clearance Phase)						
Team Vacuum QC Samples	8	NA	NA	NA	8	N/A
First floor[i]	36[j]	0	20	121	177	95%/98.6%/3× 95%/98.1%/1×[k]
Total Samples	82	30	61	235	408	N/A

(a) "Total Samples" is the sum of QC, RMC, judgmental, and probabilistic samples.

(b) These statistical statements are listed for characterization as percent confidence/diameter of circular contaminated area in feet/FNR. For clearance, they are listed as percent confidence/percent of room that does not contain detectable contamination/multiplier. The multiplier indicates a judgmental sample location is either 1× or 3× more likely to contain detectable contamination relative to a probabilistic sample location.

(c) NA = not applicable.

(d) Room is being sampled with a characterization goal.

(e) Characterization statement: 95% confidence of detecting a single circular contaminated area of diameter 8 ft with an FNR of 10% or detecting a single circular contaminated area of diameter 10 ft with an FNR of 29%.

(f) These judgmental samples are to be collected in a composite fashion.

(g) The area (two adjacent rooms) is being sampled with a clearance goal, assuming a 30% *a priori* probability that a judgmental sample will detect contamination.

(h) Three RMCs will be collected for each of the 10 first-floor rooms to be sampled during the characterization phase.

(i) The floor is being sampled with a clearance goal.

(j) There are three field blank samples (vacuum sock, wipe, and swab) for each of the 12 rooms to be sampled for clearance.

(k) CJR-based clearance statement: 95% confidence that either 98.6% of the floor does not contain detectable contamination with a judgmental sample location being 3× more likely to contain detectable contamination relative to a probabilistic sample location, or 95% confidence that 98.1% of the floor does not contain detectable contamination with a judgmental sample location 1× more (equally) likely to contain detectable contamination as a probabilistic sample location. All clearance numbers of samples assume the *a priori* probability that a judgmental sample will detect contamination is 10% after decontamination.

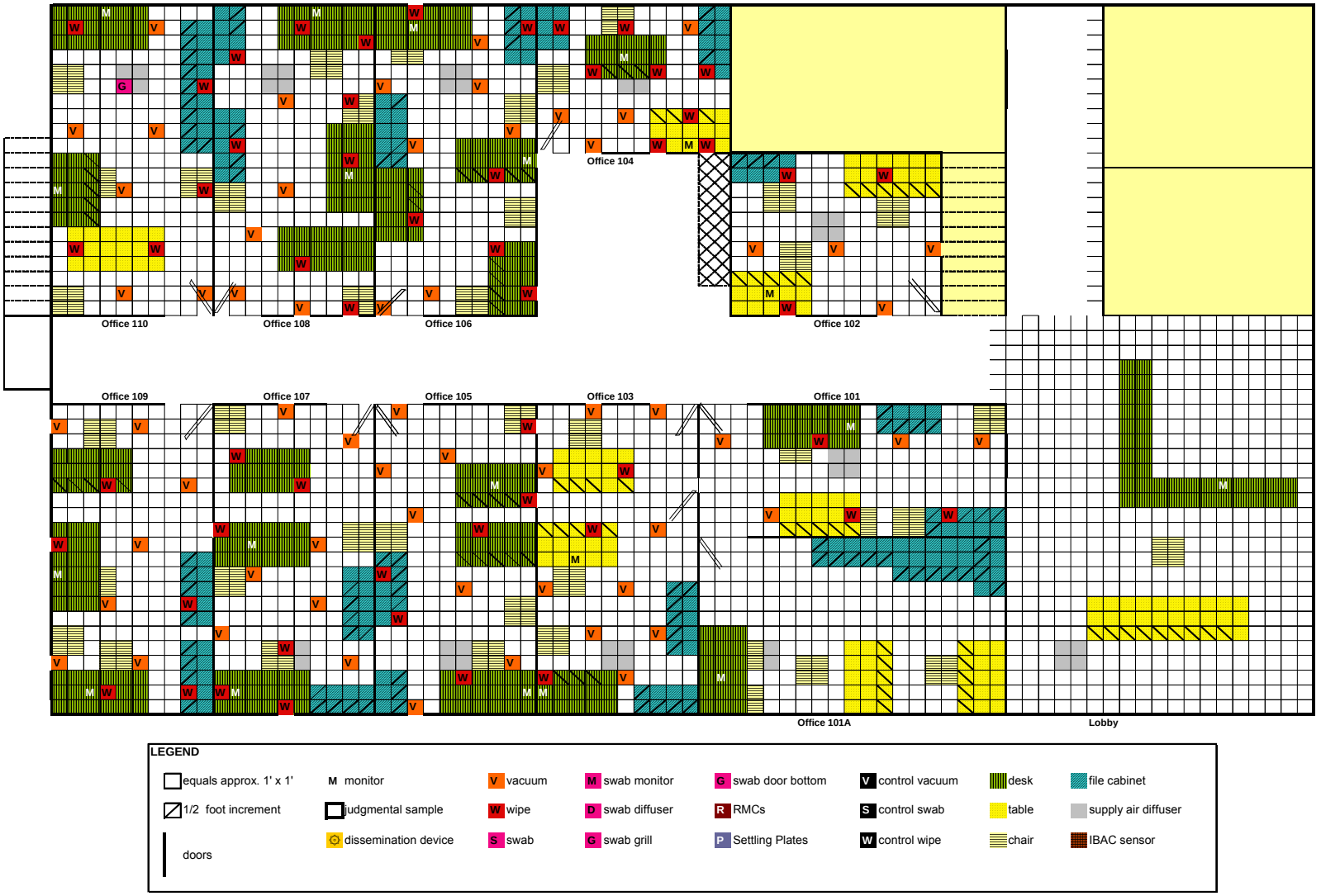

Figure 5.5. Map of Probabilistic Sample Locations and Types for Characterization Sampling of the First Floor of the INL Building During INL-2 Test Event 4

- Preliminary tracer studies indicated that releasing the contaminant from Office 101A may result in very low or no or contamination in Offices 105, 106, 107, and 108. Hence, pairs of offices (105/107 and 106/108) were selected for clearance sampling using the CJR sampling approach. Eight judgmental samples (single increment) and 26 probabilistic samples were selected. Provided all of the samples are negative (i.e., no detectable contamination), these numbers of samples provide 90% confidence that at least 96.3% of the area in a pair of offices does not contain detectable contamination. This is if a judgmental sample location is 3× more likely to contain detectable contamination than a probabilistic sample location. Instead, if a judgmental sample is 1× more (equally) likely to contain detectable contamination, a 90%/94.3% clearance statement can be made.
- Per the discussion in Section 5.1.1, three RMC samples were assigned to be taken in each of the 10 offices sampled during the characterization phase, and 2) no RMC samples were assigned to be taken during the clearance phase.

In the "after contamination" sampling design of Table 5.4, Offices 105 and 107 as well as 106 and 108 were paired to provide two opportunities for the CJR sampling approach to clear a portion of the floor during the characterization sampling phase. It was not clear from the preliminary tracer study results, but apparently no office doors were closed during the tracer studies. *It is recommended that the doors of Offices 105 and 107 be closed and sealed, and vents into those rooms be covered/sealed, to increase the chances of having no (or undetectable) contamination in those rooms.* The doors and vents of Offices 106 and 108 can remain open, provided that is how they were during the tracer studies.

Offices 102 and 109 were specified for performing composite judgmental sampling. Based on pre-test tracer studies performed in the INL building, Office 102 is expected to have a moderate contaminant concentration, while Office 109 is expected to have a lower concentration. Rooms nearby to these with similar contaminant concentrations (e.g., possibly Offices 104 and 110) where single-increment judgmental sampling will be performed can serve to compare the performance of single-increment and composite judgmental sampling.

The clearance phase of sampling in Test Event 4 includes 8 team-vacuum QC samples, 36 QC samples, 0 RMC samples, 20 judgmental samples, and 121 probabilistic samples. Note that the numbers of judgmental and probabilistic samples per floor after decontamination are the same for all five test events. Two examples of X%/Y% clearance statements supported by these numbers of judgmental and probabilistic samples are shown in the last column of Table 5.3.

5.6 Test Event 5

Test Event 5 involves an overt release on the second floor of the INL PBF-632 building, with Office 201A specified as the location for release of the contaminant. Office 201A was selected as the release location based on the results of pre-test tracer releases and measurements in the INL building. Specifically, the conditions of releases #9, #10, and #11 from that work involved closing the doors of Offices 205, 206, and 207 with the release from Office 201A. The results from the tracer study show that Offices 205 to 207 will be very lowly contaminated, if not uncontaminated.

Table 5.4 summarizes the numbers of samples of each type (QC, RMC, judgmental, and probabilistic) to be taken after contamination and after decontamination during Test Event 5. Table 5.4 shows the numbers of samples by room (after contamination) and floor (after decontamination). Figure 5.6 and Figure 5.4 give visual displays of the locations of probabilistic samples after contamination and after decontamination, respectively, using the sampling design for Test Event 5. The locations of QC, RMC, and judgmental samples will be determined subsequently by relevant experts, and hence are not shown in Figure 5.6 and Figure 5.4. It is assumed that the locations and order (see the last paragraph of Section 3.1) of all samples to be collected in a given room will be entered into a test matrix (see Appendix B) that will provide specific directions for the sampling teams.

Additional discussion about the numbers of samples in Table 5.4 for Test Event 5 is given in the following bullets.

- Only 10 of the 15 offices on the second floor were selected for sampling after contamination because of limitations discussed in Section 5.1.1. The offices to be sampled include 201, 202, 205, 206, 207, 208, 209, 210, 212, and 213. All 15 offices (including 201A, 203, 203A, 204, and 211) will be sampled after decontamination.
- Eight vacuum QC samples (2 for each of the four sampling teams) will be collected after contamination and after decontamination. In each room sampled after contamination and after decontamination, 3 QC samples will be collected.
- Offices 201 and 202, which are close to the contaminant release point (Office 201A), were each assigned 7 probabilistic samples. Fewer probabilistic samples were assigned because it was assumed that contamination will be more easily detected in those offices. The 7 probabilistic samples provide 95% confidence of detecting a contaminated area 1) 8 feet in diameter with 10% FNR, or 2) 10 feet in diameter with 29% FNR. Office 202 was assigned 4 single-increment judgmental samples, while Office 201 was assigned 3 composite judgmental samples.
- Offices 209, 210, 212, and 213 were assigned 12 probabilistic samples because they are farther away from the contaminant release location (Office 201A). The 12 probabilistic samples provide 95% confidence of detecting a contaminated area 1) 6 feet in diameter with 10% FNR, or 2) 10 feet in diameter with 49% FNR. Offices 209, 210, and 213 were assigned 5 single-increment judgmental samples, while Office 213 was assigned 3 composite judgmental samples.
- Preliminary tracer studies indicated that releasing the contaminant from Office 201A may result in very low or no or contamination in Offices 205, 206, 207, and 208. Hence, pairs of offices (205/207 and 206/208) were selected for clearance sampling using the CJR approach. Eight judgmental samples (single increment) and 26 probabilistic samples were selected. Provided all of the samples are negative (i.e., no detectable contamination), these numbers of samples provide 90% confidence that 96.3% of the area in a pair of offices does not contain detectable contamination. This is if a judgmental sample location is 3× more likely to contain detectable contamination than a probabilistic sample location. If, instead, a judgmental sample is 1× more (equally) likely to contain detectable contamination, a 90%/94.3% clearance statement can be made.
- Per the discussion in Section 5.1.1, three RMC samples were assigned to be taken in each of the 10 offices sampled during the characterization phase and no RMC samples were assigned to be taken during the clearance phase.

Table 5.4. Numbers of Samples for INL-2 Test Event 5 on the Second Floor of the INL PBF-632 Building. This event involves an overt release from Office 201A.

Area to be Sampled	QC Samples	Reference Material Coupons	Judgmental Samples	Probabilistic Samples	Total Samples[a]	Statistical Statement[b]
After Contamination (Characterization Phase)						
Team Vacuum QC Samples	8	NA[c]	NA	NA	8	N/A
Office 201[d]	3	3	3[e]	7	16	95%/8 ft/10% FNR 95%/10 ft/29% FNR[f]
Office 202[d]	3	3	4	7	17	95%/8 ft/10% FNR 95%/10 ft/29% FNR
Office 209[d]	3	3	5	12	23	95%/6 ft/10% FNR 95%/10 ft/49% FNR
Office 210[d]	3	3	5	12	23	95%/6 ft/10% FNR 95%/10 ft/49% FNR
Office 212[d]	3	3	5	12	23	95%/6 ft/10% FNR 95%/10 ft/49% FNR
Office 213[d]	3	3	3[e]	12	21	95%/6 ft/10% FNR 95%/10 ft/49% FNR
Office 205 & 207[g]	6	6	8	26	46	90%/96.3%/3x 90%/94.3%/1x
Offices 206 & 208[g]	6	6	8	26	46	90%/96.3%/3x 90%/94.3%/1x
# Contamination Samples	38	30[h]	41	114	223	N/A
After Decontamination (Clearance Phase)						
Team Vacuum QC Samples	8	NA	NA	NA	8	N/A
Second floor[i]	45[j]	0	20	121	186	95%/98.6%/3× 95%/98.1%/1×[k]
Total Samples	91	30	61	235	417	N/A

(a) "Total Samples" is the sum of QC, RMC, judgmental, and probabilistic samples.
(b) These statistical statements are listed for characterization as percent confidence/diameter of circular contaminated area in feet/FNR. For clearance, they are listed as percent confidence/percent of room that does not contain detectable contamination/multiplier. The multiplier indicates a judgmental sample location is either 1× or 3× more likely to contain detectable contamination relative to a probabilistic sample location.
(c) NA = not applicable.
(d) The room is being sampled with a characterization goal.
(e) These judgmental samples are to be collected in a composite fashion.
(f) Characterization statement: 95% confidence of detecting a single circular contaminated area of diameter 8 ft with an FNR of 10% or detecting a single circular contaminated area of diameter 10 ft with an FNR of 29%.
(g) The area (two adjacent rooms) is being sampled with a clearance goal, assuming a 30% *a priori* probability that a judgmental sample will detect contamination.
(h) Three RMCs will be collected for each of the 10 second-floor rooms to be sampled during the characterization phase.
(i) The floor is being sampled with a clearance goal.
(j) There are three field blank samples (vacuum sock, wipe, and swab) for each of the 15 rooms to be sampled for clearance.
(k) CJR-based clearance statement: 95% confidence that either 98.6% of the floor does not contain detectable contamination with a judgmental sample location being 3× more likely to contain detectable contamination relative to a probabilistic sample location, or 95% confidence that 98.1% of the floor does not contain detectable contamination with a judgmental sample location 1× more (equally) likely to contain detectable contamination as a probabilistic sample location. All clearance numbers of samples assume the *a priori* probability that a judgmental sample will detect contamination is 10% after decontamination.

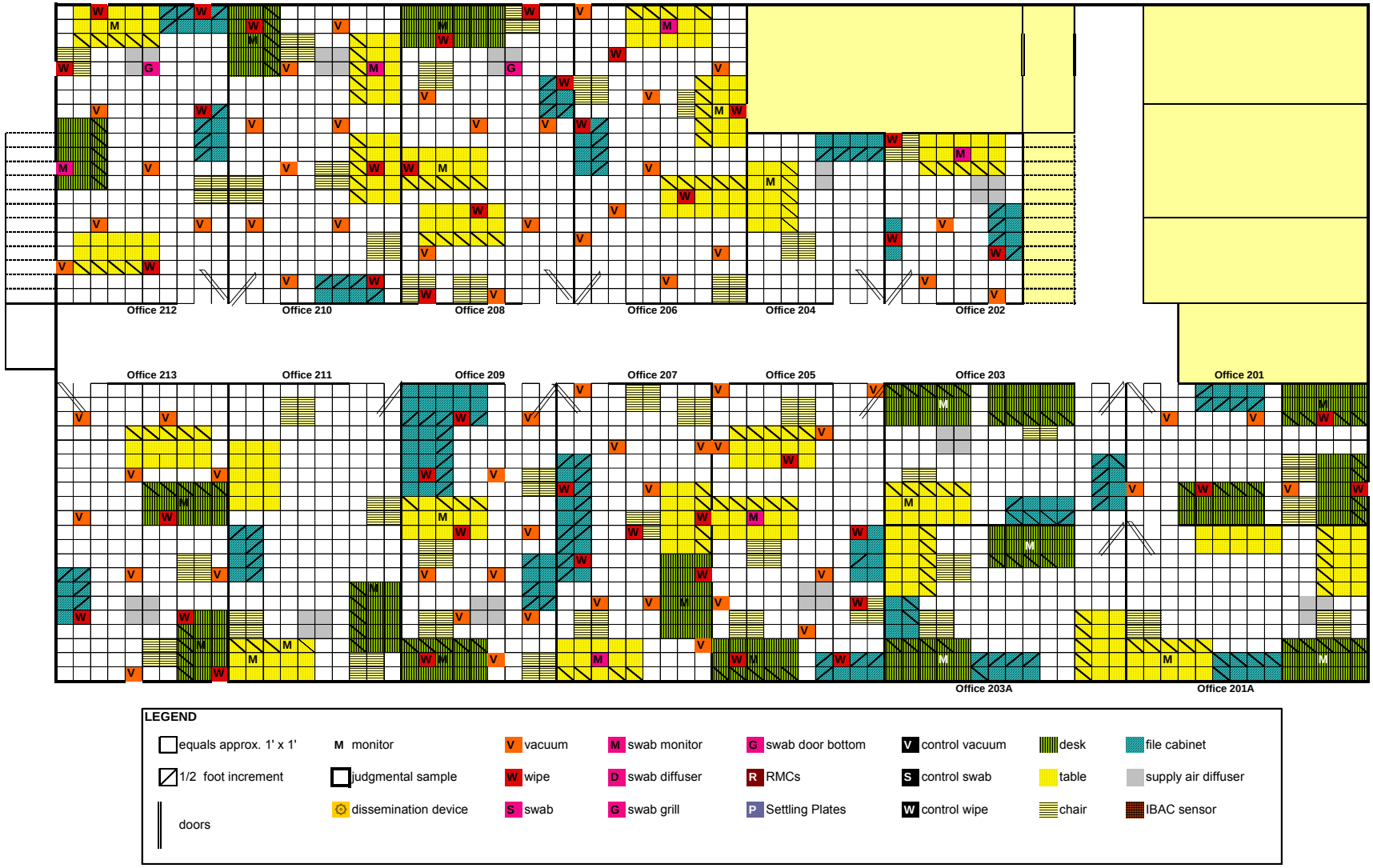

Figure 5.6. Map of Probabilistic Sample Locations and Types for Characterization Sampling of the Second Floor of the INL Building During INL-2 Test Event 5

In the "after contamination" sampling design of Table 5.4, Offices 205 and 207 as well as 206 and 208 were paired to provide two opportunities for the CJR sampling approach to clear a portion of the floor during the characterization sampling phase. *It is recommended that the door of Office 208 be closed and sealed in addition to the doors of Offices 205 to 207. Further, it is recommended that the vents into Offices 205 to 208 be covered and sealed. These measures should increase the chances of having no (or undetectable) contamination in at least one of the two pairs of rooms.* If some contaminant still makes its way into one or more of these four rooms despite closing and sealing their doors and vents, the results would still be very useful for evaluating the performance of sampling approaches, sampling methods, and analytical methods in rooms with very low contaminant concentrations.

Offices 201 and 213 were specified for performing composite judgmental sampling. Based on pre-test tracer studies performed in the INL building, Office 201 is expected to have a high contaminant concentration, while Office 213 is expected to have a lower concentration. Rooms nearby to these with similar contaminant concentrations (e.g., possibly Offices 202 and 212) where single-increment judgmental sampling will be performed can serve to compare the performance of single-increment and composite judgmental sampling.

The clearance phase of sampling in Test Event 5 includes 8 team-vacuum QC samples, 45 QC samples, 0 RMC samples, 20 judgmental samples, and 121 probabilistic samples. Note that the numbers of judgmental and probabilistic samples per floor after decontamination are the same for all five test events. Two examples of X%/Y% clearance statements supported by these numbers of judgmental and probabilistic samples are shown in the last column of Table 5.4.

5.7 Total Number of Samples

Table 5.5 summarizes the total numbers of samples across all five test events (the ORI and the subsequent four test events). There are a total of 2085 samples, with 1142 samples after contamination (54.8% of the total) and 943 samples after decontamination (45.2% of the total). Of the 2085 total number of samples, 455 (21.8%) are QC samples. There are 177 RMC samples planned after contamination, which is 15.5% of the total number of samples after contamination.

Table 5.5. Summary of the Numbers of Samples Needed for All INL-2 Test Events in the PBF-632 Building

	After Contamination (Characterization Phase)					After Decontamination (Clearance Phase)				
Test Event	**QC Samples**	**Reference Material Coupons**	**Judgmental Samples**	**Probabilistic Samples**	**Total Samples[a]**	**QC Samples**	**Reference Material Coupons**	**Judgmental Samples**	**Probabilistic Samples**	**Total Samples[a]**
Event 1[b]	44	36	36	108	224	44	0	20	121	185
Event 2	44	36	36	108	224	44	0	20	121	185
Event 3	53	45	45	105	248	53	0	20	121	194
Event 4	38	30	41	114	223	44	0	20	121	185
Event 5	38	30	41	114	223	53	0	20	121	194
Total	217	177	199	549	**1142**	238	0	100	605	**943**

(a) "Total samples" is the sum of QA samples, reference material (stainless steel) coupons, judgmental samples, and probabilistic samples.
(b) Event 1 is the Operational Readiness Inspection (ORI).

5.8 Experimental and Sampling Design Details

The details of each sample in each test should be stored in a test matrix to clearly specify the nature and location of each sample. It is not possible to complete all of the entries in such a table at this time. Some of this information cannot be filled out until the QC, RMC, and judgmental sample locations are determined, and sampling teams are assigned. However, locations of probabilistic samples are known at this time and are listed in Tables D.1 to D.6 of Appendix D.

A draft layout of a test matrix table can be found in Appendix B. This table represents the samples that would be taken in Office 101 during Test Event 4. Information about each sample could be stored within this table or a similar table or software package. The results from the culture analysis of each sample could also be stored in this table, making it a good source for the data needed to perform the eventual statistical analyses of the data.

6.0 Experimental and Sampling Design Limitations

The scope of the INL-2 Sample Collection Operational Test was limited because of the time and expense required to contaminate, sample, decontaminate, and re-sample a building in an operational environment. Concerns were expressed by the team planning the INL-2 Sample Collection Operational Test that it should not attempt to do too much. This section discusses several ways in which the INL-2 study was limited.

6.1 Concentration Gradient

One of the key aspects of the INL-2 Sample Collection Operational Test is the concentration gradient of the contaminant over a floor of the INL PBF-632 building. There is a possibility of three possible outcomes for a given gradient, two of which are undesirable. The ideal outcome is to obtain gradients with contaminant concentrations ranging from moderate to low contamination down to no contamination over a floor of the INL PBF-632 building. The two undesirable outcomes are that the contamination is evenly spread throughout the floor and is easily detectable in each room, or the contamination is confined to only the area of dissemination, and the other rooms are not contaminated. Because the experiment is dependent on obtaining good gradients, it will be important to review at least some of the results (perhaps the RMC samples) from the ORI (Test Event 1) before the second test event is started so adjustments can be made if necessary. Also, it is envisioned that the tracer studies conducted in the INL building before the testing will help define the characteristics necessary for desirable gradients.

6.2 Aerosol Release

While the experimental and sampling design for the INL-2 Sample Collection Operational Test was designed to study the performance of probabilistic and judgmental sampling, it is important to remember that only aerosol disseminations are being studied. Therefore, all conclusions made concerning the sampling approaches should state these limitations. For example, one of the main goals of the INL-2 study is to compare the capability of judgmental samples and probabilistic samples to detect contamination. It might be expected that judgmental samples should perform well in detecting an aerosol contaminant dispersed throughout a building via HVAC vents and return air pathways. An early draft of the experimental design contained one test event with localized “hot spot” contamination of smaller areas of varying size in different rooms, potentially in locations that would not naturally be chosen by judgmental samples. Such a contamination scenario would have been more likely to show the advantages of larger numbers of probabilistic samples (compared to typically smaller numbers of judgmental samples) in detecting smaller areas of contamination in less-likely locations. However, this contamination scenario was not included in a test event of the final experimental design because of issues about how to contaminate smaller areas with viable contaminant spores.

6.3 Probabilistic Sampling of Horizontal Surfaces

All probabilistic sampling for the experimental and sampling design of the INL-2 Sample Collection Operational Test has been designed to sample only horizontal surfaces. In developing the sampling plans, a decision was made if a sample location has more than one possible horizontal surface. Generally, it was decided to sample the highest vertical point of the sampling area without sampling anything on the ceiling. For example, if the vertical extension of a sample location has the floor, a desktop, and a ceiling

vent, it will be decided to sample the desktop. Future versions of the VSP software (Matzke et al. 2007) will include the capability to add furniture to the probabilistic sampling area so future experiments could be designed to take advantage of this feature. The VSP software already has the capability to sample from floors, walls, and ceiling of a room or building by "laying out" the room/building and then selecting "horizontal" samples from the "laid out" room/building. However, that capability requires larger numbers of samples to cover the increased surface area, and it was judged sufficient for the INL exercise to sample only horizontal surfaces on which aerosol-disseminated contaminant could settle.

6.4 Limited Knowledge of Information Required to Calculate Numbers of Samples

Many assumptions are necessary to calculate the numbers of samples required to make statistical confidence statements for detection and clearance. These assumptions include the size of the contaminated area, the FNR, how much more likely a judgmental sample location is to contain detectable contamination relative to a probabilistic sample location, and the *a priori* probability that a judgmental sample will detect contamination. A limitation of the experimental and sampling design for the INL-2 Sample Collection Operational Test is that previous research has not fully defined specific values for each of these assumptions. Reasonable ranges for each assumption were created using expertise from subject matter experts. Multiple statistical statements were made with each number of samples considered. These statistical statements look across the expected range of values for each assumption. These investigations were performed to minimize the limitation of not knowing the actual values of quantities involved in the assumptions.

6.5 Comparing Sample-Collection Methods

In general, the sample-collection methods to be used in the INL-2 Sample Collection Operational Test (swab, wipe, vacuum) are each used in unique sampling situations such that there is little opportunity to compare results from one sampling method to results from another. In early planning of the experimental and sampling design, the statistical comparison of results obtained from side-by-side wipe and vacuum samples of non-porous surfaces was considered. This testing would have also included side-by-side sampling with the same sampling methods as a way of quantifying the variation in contamination and uncertainty in sampling and analytical processes. However, it was ultimately decided that this sort of investigation was not feasible because of the limitations on the numbers of samples that could be collected and analyzed within the available time for testing at the INL PBF-632 building.

6.6 Comparing Judgmental and Probabilistic Samples to RMC Samples

The experimental and sampling design was not constructed to enable direct comparison of results from judgmental and probabilistic samples to those from RMC samples. The settling pattern of the BG contaminant on surfaces in a given room of the INL PBF-632 building is expected to vary considerably within a room and from room to room. Hence, results from RMC samples cannot be directly compared to results from judgmental and probabilistic samples because of the likelihood that locations where RMC samples are collected will be contaminated to different extents than the locations where judgmental and probabilistic samples are collected. However, it is possible to use RMC samples to give a general indication of the extent to which a given room was contaminated and to assess the relative levels of

contamination from room to room. Thus, the RMC samples will be useful in assessing how well desirable gradients across each floor of the INL PBF-632 building (see Section 2.2) were achieved.

6.7 Numbers of Test Events and Numbers of Samples

Because of the period of time available for testing at the INL PBF-632 building, as well as the time and funding available for sample collection and analysis, the number of test events and the total number of samples per test event were limited. These limitations ultimately impact the ability to perform statistical analyses of the test data. However, the limitations on numbers of samples were accommodated by 1) sampling only some rooms during the characterization phase of sampling and 2) assigning fewer samples to be collected from rooms closer to the contaminant release locations (for overt Test Events 4 and 5).

6.8 Limitations in VSP Software

Although the VSP software (Matzke et al. 2007) has had additional capabilities added in new versions over its 10-year history, it still has some limitations that impacted the calculation of numbers of samples associated with the experimental and sampling design for the INL-2 Sample Collection Operational Test. The VSP limitations include:

- VSP creates probabilistic sampling plans that are based on the assumption that the probability of contamination is the same for each sample location. Only in CJR sampling designs does VSP provide for different probabilities of detectable contamination for judgmental versus probabilistic samples.
- VSP can only account for the surface area covered by a single sample (i.e., the physical area that is swabbed, wiped, or vacuumed) when a 0% FNR is assumed. In that case, only one magnitude of surface area is allowed. If a positive FNR is specified, then VSP currently assumes "point samples." Not accounting for differences in surface area sampled is an unrealistic assumption when different sampling methods (such as swab, wipe, and vacuum) are used. Assuming point samples in the FNR > 0 case leads to larger numbers of samples than would otherwise be needed.
- The CJR sampling approach implemented in VSP for clearing uncontaminated or decontaminated areas currently only addresses the case where FNR = 0. If the FNR is actually greater than zero, then the numbers of samples calculated for the FNR = 0 case provide less protection than indicated by X and/or Y in a X%/Y% clearance statement. Not accounting for FNR > 0 also results in clearance statements of the form "X% confidence that at least Y% of the area does not contain detectable contamination," rather than the more desirable clearance statement "X% confidence that at least Y% of an area is uncontaminated."

6.9 Conclusions Regarding Study Limitations

The limitations identified and described in the preceding sections are not so severe that they compromise the ability to meet the objectives of the INL-2 Sample Collection Operational Test. Rather, they should be considered in the data analyses of the INL-2 study and any future studies.

7.0 Summary and Recommendations for Any Future Studies

Section 7.1 summarizes the work performed to generate the experimental and sampling design presented in this report for the INL-2 Sample Collection Operational Test. Section 7.2 makes recommendations for any future studies that may be conducted.

7.1 Summary

This report documents the experimental and sampling design developed for the INL-2 Sample Collection Operational Test.

The VSPWG developed five objectives for the INL-2 study. These objectives are listed in Section 1.2. The primary objectives that influenced developing the experimental and sampling design presented in this report are summarized below.

- Evaluate judgmental and probabilistic sampling for characterization as well as probabilistic and hybrid (judgment and probabilistic) sampling approaches for clearance.
- Conduct these evaluations for gradient contamination (from low or moderate down to absent or not detectable) for different initial concentrations of the contaminant.
- Explore judgment composite sampling approaches to reduce sample numbers.
- Collect baseline data to serve as an indication of the actual levels of simulant contamination in the tests.

The CJR sampling approach is a hybrid approach that combines judgmental and probabilistic (random) samples to make clearance statements of the form "X% confidence that at least Y% of a room (or floor of the building) does not contain detectable contamination." These are referred to as X%/Y% clearance statements.

The INL-2 experimental design described in this report includes five test events, the first of which is an ORI. The test events 1) vary the floor of the building on which the contaminant will be released, 2) provide for varying or adjusting the concentration of contaminant released to obtain desired concentration gradients across a floor of the building, and 3) investigate overt as well as covert release of contaminants (i.e., the responders either know or do not know the release point of the contaminant). Desirable contaminant gradients would have contaminant concentrations ranging from moderate to low and down to zero (i.e., not contaminated). Such gradients are desirable because they would provide a range of contamination levels to challenge the sampling, sample extraction, and analytical methods.

Test Event 1 is an Operational Readiness Inspection to confirm that the whole testing process is ready for testing and to make adjustments if needed. Test Events 1, 2, and 3 are covert scenarios in which the locations of contaminant release are not known to the people who selected the specific locations of judgmental and probabilistic samples or to the sampling teams. Test Events 4 and 5 are overt scenarios in which the locations of contaminant release are known to these participants.

For each of the five test events, the specified floor of the INL PBF-632 building will be contaminated with BG. The BG contaminant will be disseminated from a point-release device located in the room for each test event specified in the experimental design. Then QC, RMC, judgmental, and probabilistic samples will be collected according to the pre-specified sampling plan for each event. Judgmental samples will be selected based on professional judgment and prior information. Probabilistic samples were selected with a random aspect and in sufficient numbers to provide desired confidence for detecting contamination or clearing uncontaminated (or decontaminated) areas. Following sample collection for a given test event, the INL PBF-632 building will be decontaminated using Cl_2O gas.

For possibly contaminated areas (which may be individual rooms or a whole floor of the INL PBF-632 building), the numbers of probabilistic samples were chosen to provide 95% confidence of detecting contaminated areas of specified sizes. The numbers of judgmental samples were chosen based on guidance from experts in judgmental sampling. For rooms that may be uncontaminated following a contamination event or for whole floors after decontamination, the numbers of judgmental and probabilistic samples were chosen using the CJR sampling approach that combines judgmental and probabilistic samples. The numbers of judgmental and probabilistic samples were chosen to make clearance statements of the form "X% confidence that at least Y% of the floor does not contain detectable contamination". To clear a pair of rooms, X = 95% and Y = 92% or 95% depending on the values of parameters assumed for the CJR approach. To clear a floor of the building, X = 99% and Y = 96% or 97% depending on the parameters assumed for the CJR approach. The experimental and sampling design also provides for making X%/Y% clearance statements using only probabilistic samples, where 95%/89% was obtained for clearing two rooms and 99%/ 96% was obtained for clearing a floor of the building.

For each test event, the numbers of characterization and clearance samples were selected within limits based on operational considerations while still maintaining high confidence for detection and clearance aspects. The sampling design for all five test events specifies a total of 2085 samples, with 1142 after contamination (characterization and clearance) and 943 after decontamination (clearance). These numbers include QC, RMC, judgmental, and probabilistic samples. The experimental and sampling design specified in this report provides a good statistical foundation for achieving the objectives of the INL-2 Sample Collection Operational Test, despite some limitations of the experimental and sampling design.

The limitations of the experimental and sampling design for the INL-2 Sample Collection Test are briefly summarized below (see Section 6 for more detailed discussions).

- Concentration Gradient: All five test events relied on releasing the contaminant as an aerosol from a room at one end of either the first or the second floor of the INL PBF-632 building. Desirable gradients would have the contaminant concentration varying from moderate to low all the way down to uncontaminated. If desirable gradients are not achieved, it would limit the ability to achieve some of the objectives.
- Aerosol Release: Considering only aerosol releases meets the objectives of this particular study, but limits the ability to make conclusions about other types of contaminant releases. In particular, it limits the ability to compare probabilistic and judgmental samples when contamination occurs in "hot spots" (i.e., smaller areas of contamination surrounded by uncontaminated, or very lowly contaminated, areas).

- Probabilistic Sampling of Horizontal Surfaces: The numbers of probabilistic samples for the INL-2 sampling design were chosen assuming that only horizontal surfaces would be sampled. This reduced the number of samples required to detect contamination or clear an area, which was required to meet limitations on the time and personnel available for sampling. Sampling only horizontal surfaces is a limitation of the study to the extent that non-horizontal surfaces could be contaminated with a different chance than horizontal surfaces. This possibility was deemed unlikely for the aerosol dissemination method to be used.

- Limited Knowledge of Information Required to Calculate Numbers of Samples: Several input parameters are necessary to calculate the numbers of probabilistic samples needed to detect contamination or to clear an uncontaminated (or decontaminated) area. These include the size of the contaminated areas to be detected, the FNR, how much more likely it is that a judgmental sample location contains detectable contamination compared to a probabilistic sample location (required in the CJR sampling approach), and the *a priori* probability that a judgmental sample will detect contamination. Note that the FNR includes all "inefficiencies" and uncertainties associated with sample collection, sample recovery, sample transportation/aging, and analytical methods. Because good estimates of these input parameters were not available, it was necessary to perform calculations over a range of parameter values judged to be reasonable.

- Comparing Sample Collection Methods: The experimental and sampling design does not provide for statistically comparing sample collection methods (swab, wipe, vacuum). It was considered possible to compare wipe and vacuum methods for non-porous surfaces, but doing so was considered a lower priority given the number of additional samples that would have been required. Collecting some side-by-side samples using the same sampling method was also considered as a way to quantify the combined uncertainties in "nearby sampling," sample extraction, and analytical. This was also considered a lower priority given the additional number of samples that would have been required.

- Comparing Judgmental and Probabilistic Samples to RMC Samples: The experimental and sampling design was not constructed to enable direct comparison of results from judgmental and probabilistic samples to those from RMC samples. Results from RMC samples cannot be directly compared to results from judgmental and probabilistic samples because it is likely that RMC sample locations will be contaminated to different extents than judgmental and probabilistic sample locations. However, it is possible to use RMC samples to obtain a general indication of the extent to which a given room was contaminated and to assess the relative levels of contamination from room to room.

- Numbers of Test Events and Numbers of Samples: Because of the period of time available for testing at the INL PBF-632 building as well as the time and funding available for sample collection and analysis, the number of test events and the total number of samples per test event were limited in the INL-2 study. These limitations ultimately impact the ability to perform statistical analyses of the test data. However, the limitations on numbers of samples were accommodated by 1) sampling only some rooms during the characterization phase of sampling and 2) assigning fewer samples to be collected from rooms closer to the contaminant release locations (for overt Test Events 4 and 5).

- Limitations in VSP Software: The VSP software (Matzke et al. 2007) was well suited for use in calculating numbers of samples for characterization and clearance in the INL-2 Sample Collection Operational Test. However, VSP has some limitations, as follows.

1) The VSP creates probabilistic sampling designs that are based on the assumption that the probability of contamination is the same for each sample location. The CJR sampling designs in VSP do allow for different probabilities of contamination for judgmental versus probabilistic samples.

2) The VSP does not provide for different sampling methods covering different surface areas, such as occurs with swab, wipe, and vacuum samples.

3) When the FNR is greater than zero, the VSP assumes point samples (with negligible surface area), which yields larger numbers of samples than would otherwise be required.

4) The CJR sampling approach implemented in VSP for clearing uncontaminated or decontaminated areas currently only addresses the case where FNR = 0. If the FNR is actually greater than zero, then the numbers of samples calculated provide less protection (i.e., X and/or Y values) in a X%/Y% clearance statement. This also results in clearance statements of the form "X% confidence that at least Y% of the area does not contain detectable contamination," rather than the more desirable statement "X% confidence that at least Y% of an area is uncontaminated."

It is important to note that these limitations are not so severe that they compromise the ability to meet the objectives of this study. Hence, the experimental design and numbers of QC, RMC, judgmental, and probabilistic samples specified in this report provide a good statistical foundation for achieving the objectives of the INL-2 Sample Collection Operational Test.

7.2 Recommendations for any Future Studies

The following specific recommendations are made for any future testing that may be conducted at the INL PBF-632 building or other real-world facilities.

- Other Contamination Scenarios: Other contamination scenarios that may be possible in a real-world environment should be investigated in any future work. For example, "hot-spot" scenarios in which contaminated areas are surrounded by uncontaminated areas should be tested using a range of sizes for contaminated areas. This is a fundamentally different type of contamination scenario than the aerosol release scenario considered in this report. Hot-spot contamination is harder to detect and would more readily show the advantages of probabilistic sampling over judgmental sampling, especially if the hot spots of contamination are located (e.g., placed by a terrorist or disgruntled employee) in places that are not typically sampled by judgmental sampling.

- Contributors to FNR: To address congressional and GAO concerns (see Section 1.1) about making defensible conclusions based on negative results, it is extremely important to have good estimates of FNRs. The FNR is likely to be different for each sample collection, recovery, transportation/aging, and analytical method combination. The FNR will also depend on the level of contamination—the FNR increases as the level of contamination decreases.

- Information to Calculate Numbers of Samples: For any future studies, better estimates are needed for input parameters used in calculating the numbers of samples necessary to satisfy detection and clearance requirements. In addition to the FNR discussed in the previous bullet, other parameters include the size of contaminated areas to be detected, how much more likely a judgmental sample location is to be contaminated than a probabilistic sample location, and the *a priori* probability

that a judgmental sample will detect contamination. The last two items are required in the CJR sampling approach that combines judgmental and probabilistic sampling.

In general, it is also recommended that statisticians be involved in planning, experimental and sampling design, and data analyses of future validation work such as is described in the Interagency Strategic Plan.[(a)] Statistical involvement is critical to planning experimental studies and analyzing the data that result from them. In this way resources are used efficiently, testing and analytical uncertainties are accounted for, and that conclusions can be made with the desired statistical confidence. Statistical planning combined with proper statistical analysis of data leads to defensible conclusions that satisfy the research objectives.

(a) *Interagency Strategic Plan for Validation of Environmental Sampling Methods Used in Detection and Cleanup of B. Anthracis Contamination in Facilities*, June 29, 2007.

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Appendix A: Numbers of Probabilistic Samples

Figures A.1 through A.12 display the numbers of probabilistic samples calculated for confidence levels ranging from 50% to 95%, circular contaminated areas ranging from 1 foot to 10 feet in diameter, and false-negative rates ranging from 0% to 50%. Only combinations of these factors that result in 100 or less samples for a typical room in the INL PBF-632 building or 500 or less samples for a single floor are displayed. Odd-numbered figures display numbers of samples for a typical room, while even-numbered figures display numbers of samples for a single floor.

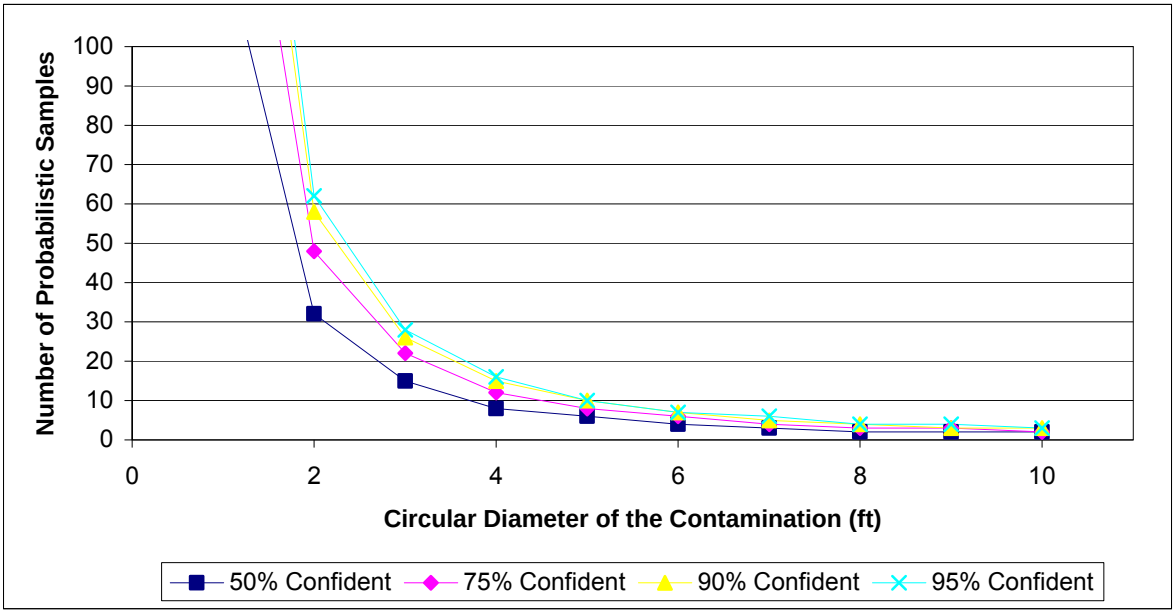

Figure A.1. Number of Probabilistic Samples Required to Detect with 0% False Negative Rate a Circular Contaminated Area of a Given Diameter with a Given Confidence (represented by the colored lines) within a Typical Room of the INL PBF-632 Building

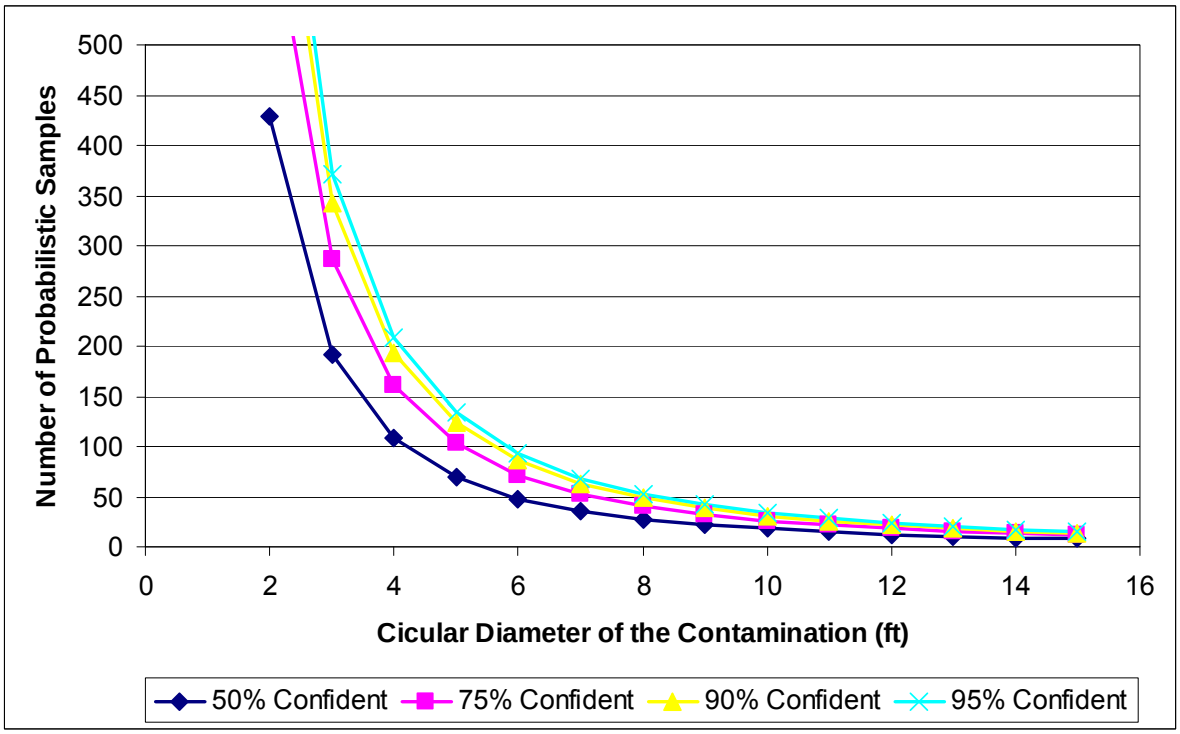

Figure A.2. Number of Probabilistic Samples Required to Detect with 0% False Negative Rate a Circular Contaminated Area of a Given Diameter with a Given Confidence (represented by the colored lines) within a Single Floor of the INL PBF-632 Building

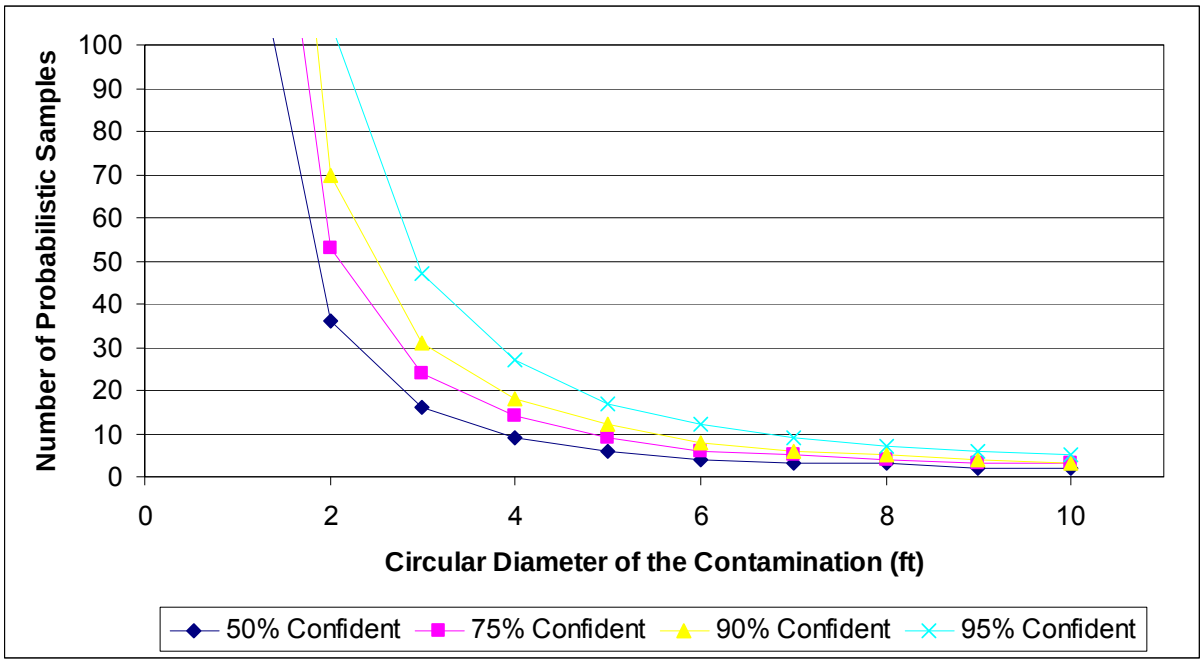

Figure A.3. Number of Probabilistic Samples Required to Detect with 10% False Negative Rate a Circular Contaminated Area of a Given Diameter with a Given Confidence (represented by the colored lines) within a Typical Room of the INL PBF-632 Building

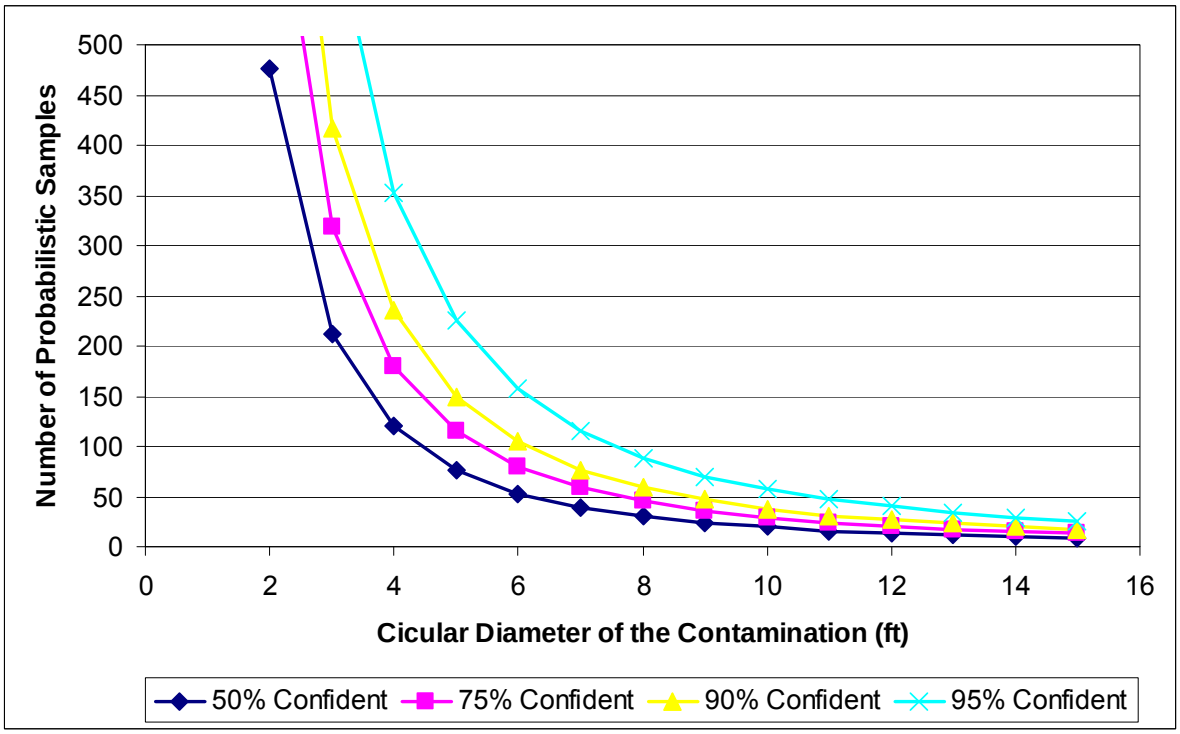

Figure A.4. Number of Probabilistic Samples Required to Detect with 10% False Negative Rate a Circular Contaminated Area of a Given Diameter with a Given Confidence (represented by the colored lines) within a Single Floor of the INL PBF-632 Building

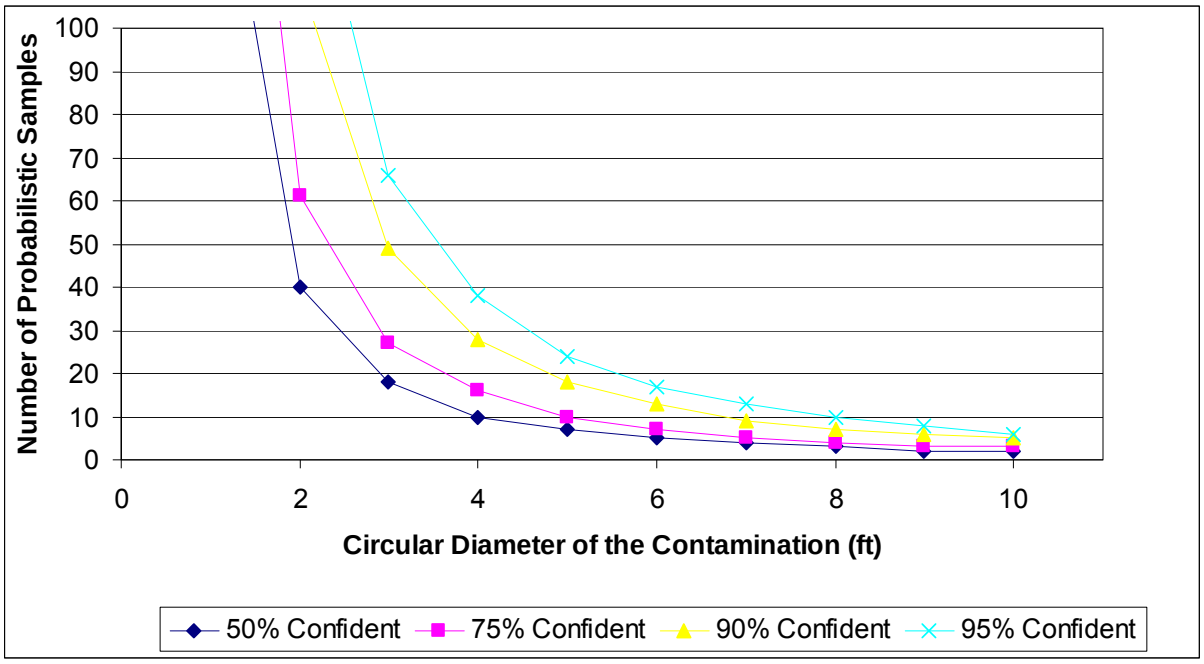

Figure A.5. Number of Probabilistic Samples Required to Detect with 20% False Negative Rate a Circular Contaminated Area of a Given Diameter with a Given Confidence (represented by the colored lines) within a Typical Room of the INL PBF-632 Building

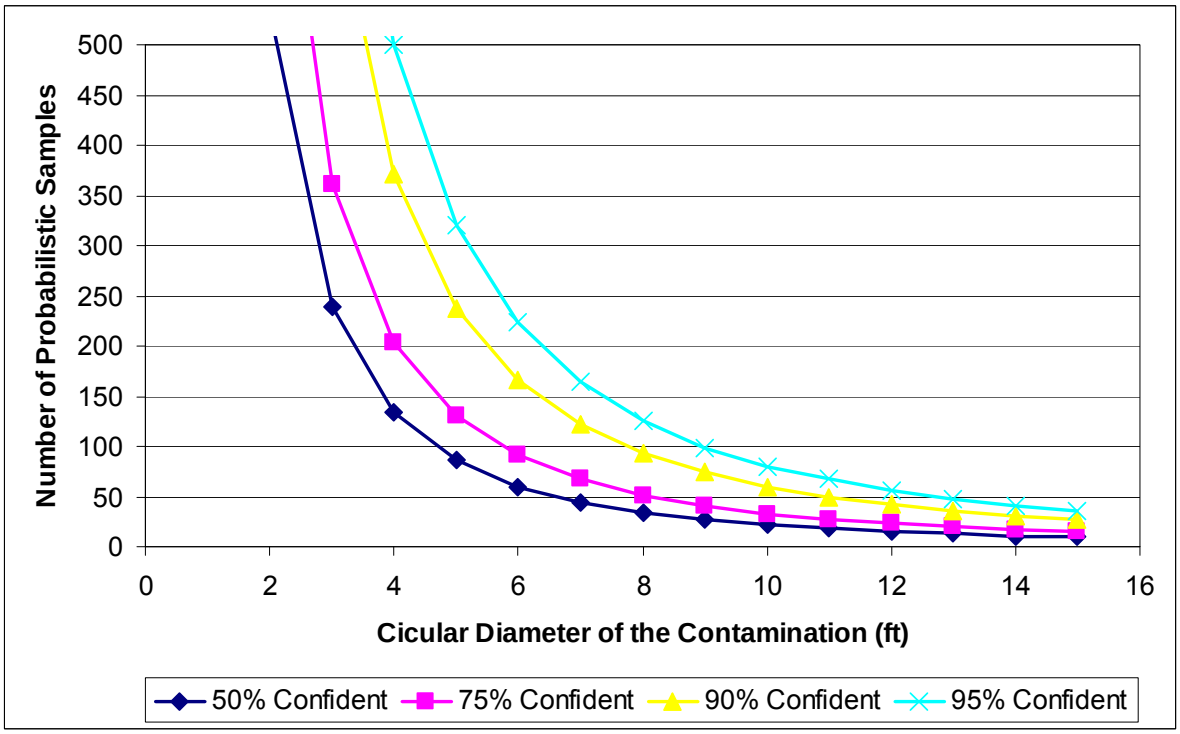

Figure A.6. Number of Probabilistic Samples Required to Detect with 20% False Negative Rate a Circular Contaminated Area of a Given Diameter with a Given Confidence (represented by the colored lines) within a Single Floor of the INL PBF-632 Building

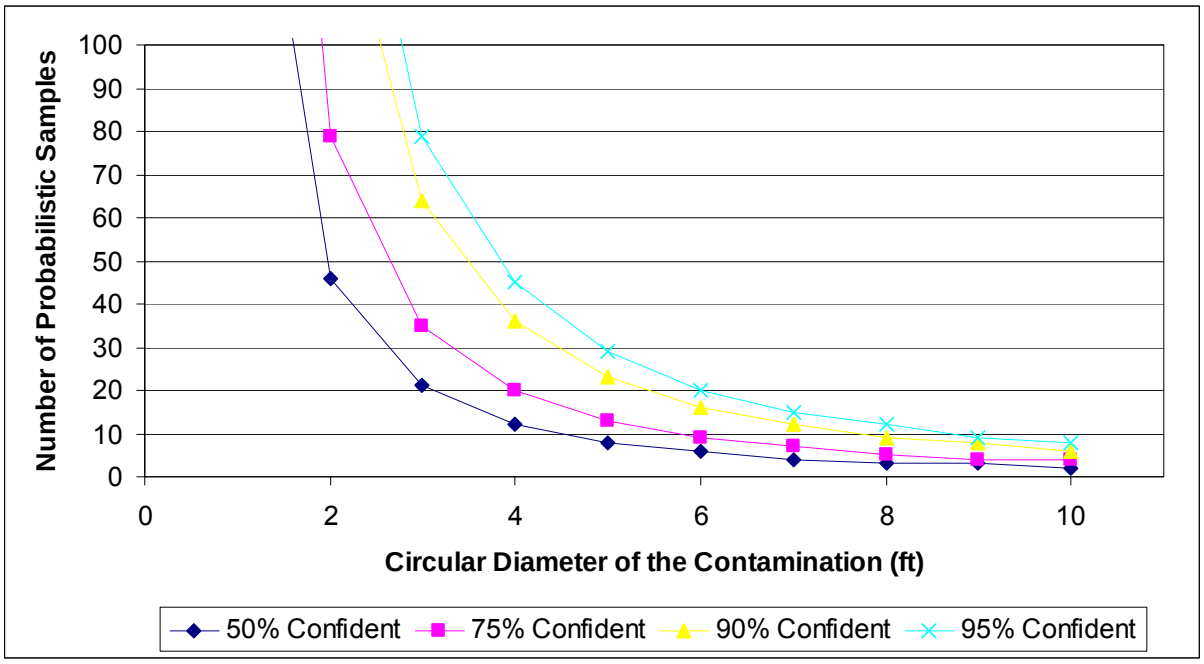

Figure A.7. Number of Probabilistic Samples Required to Detect with 30% False Negative Rate a Circular Contaminated Area of a Given Diameter with a Given Confidence (represented by the colored lines) within a Typical Room of the INL PBF-632 Building

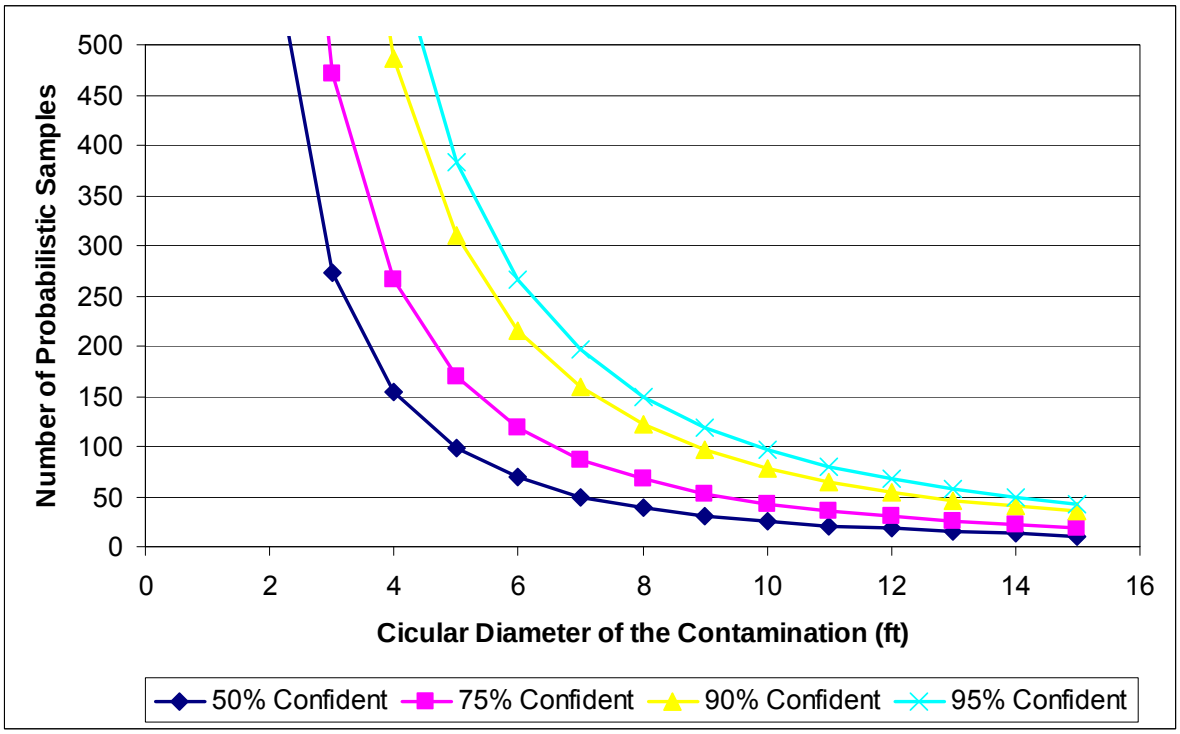

Figure A.8. Number of Probabilistic Samples Required to Detect with 30% False Negative Rate a Circular Contaminated Area of a Given Diameter with a Given Confidence (represented by the colored lines) within a Single Floor of the INL PBF-632 Building

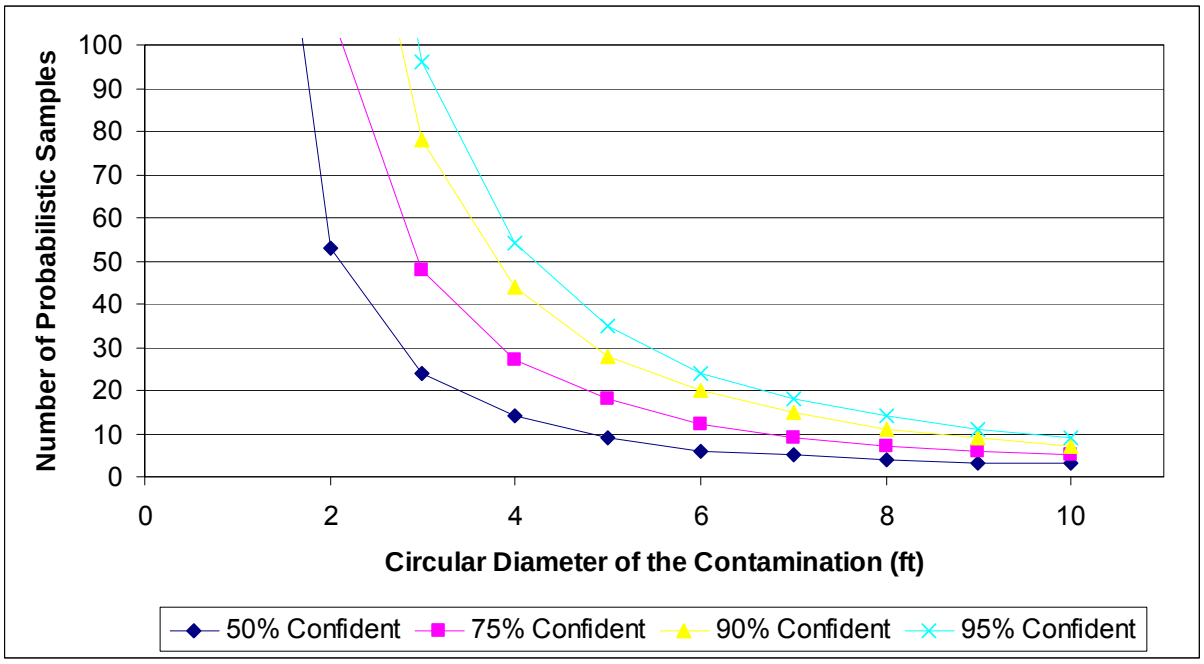

Figure A.9. Number of Probabilistic Samples Required to Detect with 40% False Negative Rate a Circular Contaminated Area of a Given Diameter with a Given Confidence (represented by the colored lines) within a Typical Room of the INL PBF-632 Building

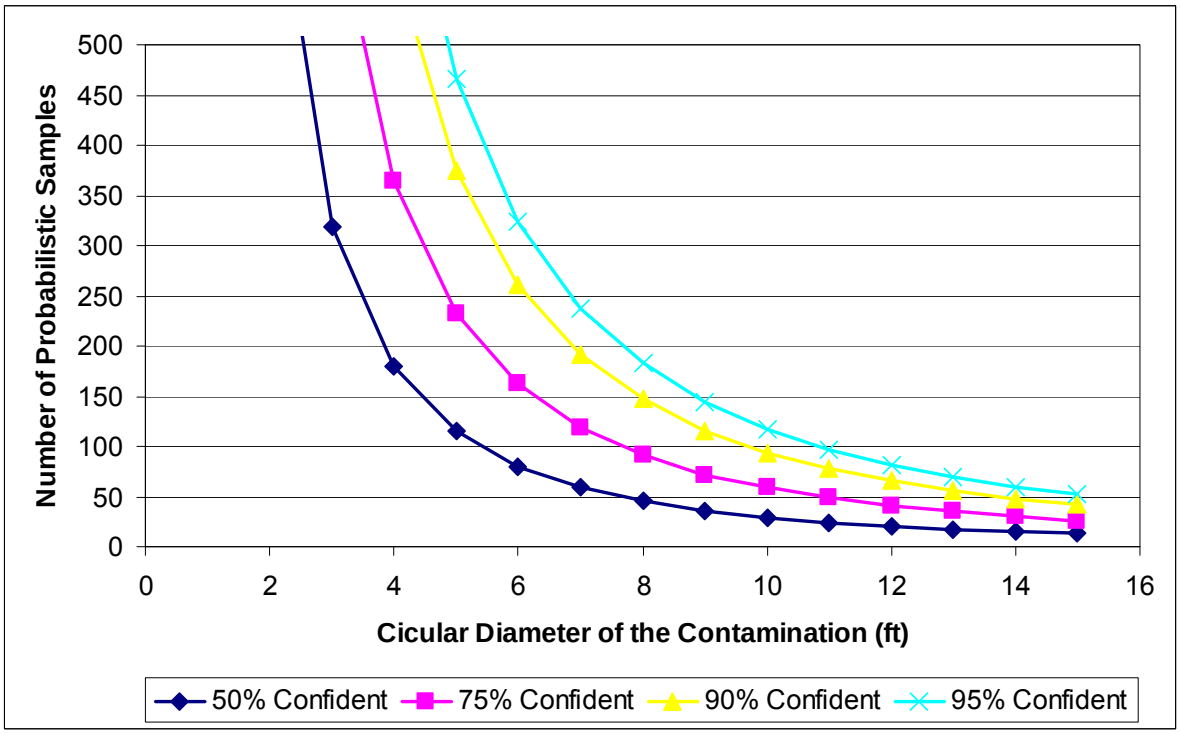

Figure A.10. Number of Probabilistic Samples Required to Detect with 40% False Negative Rate a Circular Contaminated Area of a Given Diameter with a Given Confidence (represented by the colored lines) within a Single Floor of the INL PBF-632 Building

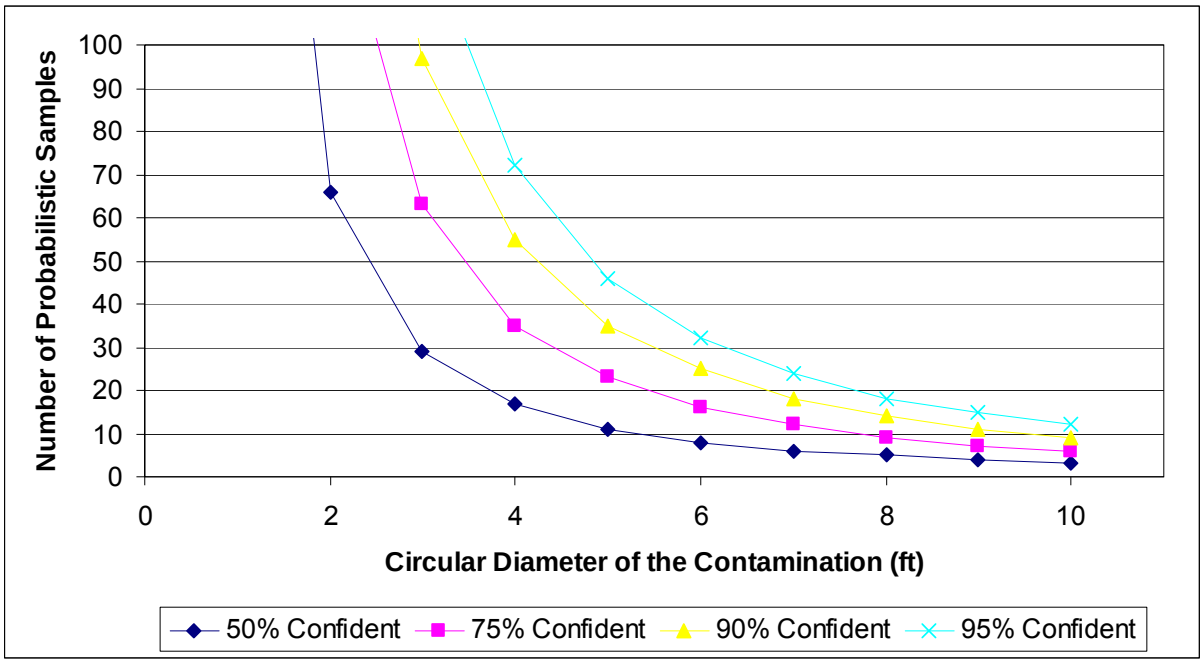

Figure A.11. Number of Probabilistic Samples Required to Detect with 50% False Negative Rate a Circular Contaminated Area of a Given Diameter with a Given Confidence (represented by the colored lines) within a Typical Room of the INL PBF-632 Building

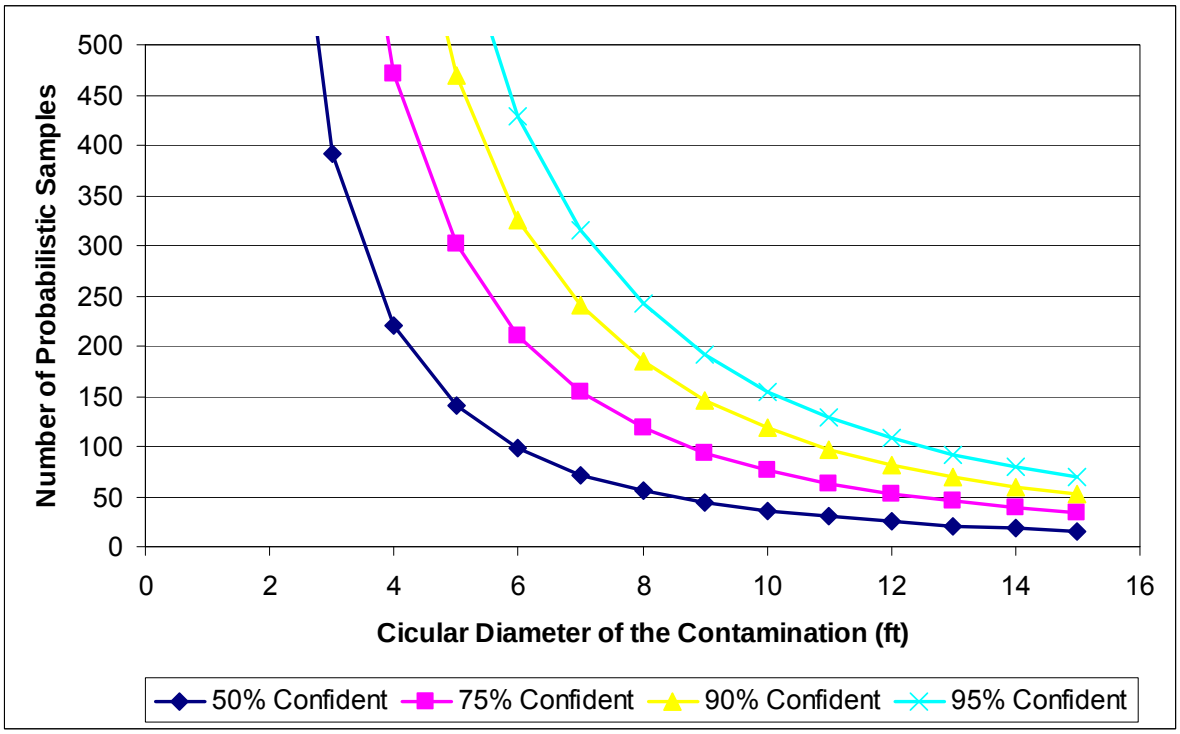

Figure A.12. Number of Probabilistic Samples Required to Detect with 50% False Negative Rate a Circular Contaminated Area of a Given Diameter with a Given Confidence (represented by the colored lines) within a Single Floor of the INL PBF-632 Building

Appendix B: Details to be Included in the Eventual Complete Test Matrix

Table B.1 illustrates the details to be contained in a test matrix prepared for each test event in the sampling design for contamination and decontamination testing during the INL-2 study in the PBF-632 building at the Idaho National Laboratory (INL). Details on probabilistic samples in Office 101 during Test Event 4 are used for illustration purposes.

Table B.1. Illustration of Details to be Contained in an Eventual Complete Test Matrix for a Given Room in the INL PBF-632 Building. Entries for Office 101 during Test Event 4 are shown for illustrative purposes only, and do not represent the actual sampling order.

Order of Sample Collection[a]	Sample ID[b]	Event ID (1 to 5)	Sampling Floor (1,2)	Sampling Room (Office #)	Contam/ Decon (C,D)	Sampling Approach (Q,R,J, JC,P)[c]	Surface to Sample	Sample Collection Method (Wipe, Swab, Vacuum)	Sampler (Team) (1 to 4)	Sample x-Coordinate within Room	Sample y-Coordinate within Room
1	4C001	4	1	101	C	J	(d)	(d)	1	(d)	(d)
2	4C002	4	1	101	C	P	(d)	vacuum	1	682.4718	410.4892
3	4C003	4	1	101	C	R	(d)	(d)	1	(d)	(d)
4	4C004	4	1	101	C	Q	(d)	(d)	1	(d)	(d)
5	4C005	4	1	101	C	P	(d)	wipe	1	749.1072	410.4892
6	4C006	4	1	101	C	J	(d)	(d)	1	(d)	(d)
7	4C007	4	1	101	C	P	(d)	wipe	1	815.7427	410.4892
8	4C008	4	1	101	C	R	(d)	(d)	1	(d)	(d)
9	4C009	4	1	101	C	J	(d)	(d)	1	(d)	(d)
10	4C010	4	1	101	C	P	(d)	vacuum	1	649.1541	463.8049
11	4C011	4	1	101	C	Q	(d)	(d)	1	(d)	(d)
12	4C012	4	1	101	C	P	(d)	wipe	1	715.7895	463.8049
13	4C013	4	1	101	C	J	(d)	(d)	1	(d)	(d)
14	4C014	4	1	101	C	P	(d)	vacuum	1	782.4249	463.8049
15	4C015	4	1	101	C	R	(d)	(d)	1	(d)	(d)
16	4C016	4	1	101	C	Q	(d)	(d)	1	(d)	(d)
17	4C016	4	1	101	C	P	(d)	vacuum	1	849.0604	463.8049

(a) The test matrix should list the samples in the order to be collected by the sampling team so that quality control, reference material coupon, judgmental, and probabilistic samples are collected in an intermingled order that minimizes as much as possible excess movement through a room (see the last paragraph of Section 3.1).

(b) In the proposed Sample ID number, the first character is a number (1, 2, 3, 4, or 5) representing the test event. The third character is a letter (C or D) denoting whether the sample is from the contamination or decontamination phase of the test event. The final three characters are numbers denoting the sample number within a test event.

(c) Q = quality assurance, R = reference material coupon, J = judgmental, JC = judgmental composite, and P = probabilistic. This column should not be included in the version of the test matrix used by a sampling team to sample a given room since the team is not to know whether samples are judgmental samples or probabilistic samples. If appropriate, QA and RMC samples can be identified in the test matrix.

(d) Not determined as part of the work in this report.

Appendix C: Breakdowns of Numbers and Types of Samples for Characterization and Clearance in INL-2 Test Events

Tables C.1 to C.4 provide the breakdowns of the numbers of quality control, judgmental, and probabilistic samples collected using each sampling method for the characterization phases of Test Events 1 to 5. Choosing the locations of judgmental samples was not part of the PNNL work, so only the total numbers of judgmental samples are shown in Tables C.1 to C.4. Tables C.5 and C.6 provide similar information for the clearance phases of Test Events 1 to 5.

Table C.1. Breakdown of Numbers and Types of Samples for Characterization of the First Floor of the INL PBF-632 Building in Covert Test Events 1 & 2

		QC Samples			Judgmental Samples			Probabilistic Samples			Number of Samples Left in Kit[a]			Total Sample Types[b], [c]			
Area to be Sampled	RMC[d]	Vacuum	Wipe	Swab	Vacuum	Wipe	Swab	Vacuum	Wipe	Swab	Vacuum	Wipe	Swab	Vacuum (15 limit)	Wipe (14 limit)	Swab (5 limit)	RMC (5 limit)[d]
Vacuums	-	-	-	8	-	-	-	-	-	-	-	-	-	0	0	8	0
Lobby	3	1	1	1				14	7	0	(0)[e]	(6)	(4)				3
101A	3	1	1	1				3	3	1	(11)	(10)	(3)				3
101	3	1	1	1				4	4	0	(10)	(9)	(4)				3
102	3	1	1	1				3	3	1	(11)	(10)	(3)				3
103	3	1	1	1				4	4	0	(10)	(9)	(4)				3
104	3	1	1	1				3	2	0	(11)	(11)	(4)				3
105	3	1	1	1				4	6	0	(10)	(7)	(4)				3
106	3	1	1	1				5	4	1	(9)	(9)	(3)				3
107	3	1	1	1				5	5	0	(9)	(8)	(4)				3
108	3	1	1	1				3	5	0	(11)	(8)	(3)				3
109	3	1	1	1				3	3	0	(11)	(10)	(4)				3
110	3	1	1	1				3	3	2	(11)	(10)	(2)				3
Totals	36	12	12	20		36[f]		54	49	5							36

(a) These columns indicate how many of each sample type are available in each room/kit after probabilistic and QC samples are taken. This information will be used by Dino Mattorano (EPA) in placing the judgmental samples.
(b) The totals of the sample types are to be completed by Dino Mattorano (EPA) after he has selected the judgmental sample locations.
(c) The limit given for each sample type is per room.
(d) The kits prepared for sampling rooms allowed for up to five RMCs to be collected per room during the characterization phase of sampling for each test event. However, it was ultimately decided to place and collect only three RMCs per room, as discussed in Section 5.1.
(e) These numbers are in parentheses to indicate that they are to help in placing judgmental samples and are not part of the total samples.
(f) The total allotted number of judgmental samples is 36. The distribution of these across the rooms and types of samples will be completed by Dino Mattorano.

Table C.2. Breakdown of Numbers and Types of Samples for Characterization of the Second Floor of the INL PBF-632 Building in Covert Test Event 3

		QC Samples			Judgmental Samples			Probabilistic Samples			Number of Samples Left in Kit[a]			Total Sample Types[b], [c]			
Area to be Sampled	**RMC[d]**	**Vacuum**	**Wipe**	**Swab**	**Vacuum**	**Wipe**	**Swab**	**Vacuum**	**Wipe**	**Swab**	**Vacuum**	**Wipe**	**Swab**	**Vacuum (15 limit)**	**Wipe (14 limit)**	**Swab (5 limit)**	**RMC (5 limit)[d]**
Vacuums	-	-	-	8	-	-	-	-	-	-	-	-	-	0	0	8	0
201	3	1	1	1				2	2	1	(12)[e]	(11)	(3)				3
201A	3	1	1	1				4	3	0	(10)	(10)	(4)				3
203	3	1	1	1				1	2	2	(13)	(11)	(2)				3
203A	3	1	1	1				2	5	0	(12)	(8)	(4)				3
202	3	1	1	1				2	1	1	(12)	(12)	(3)				3
204	3	1	1	1				2	1	1	(12)	(12)	(3)				3
205	3	1	1	1				4	3	0	(10)	(10)	(4)				3
206	3	1	1	1				4	2	1	(10)	(11)	(3)				3
207	3	1	1	1				5	5	0	(9)	(8)	(4)				3
208	3	1	1	1				4	3	1	(10)	(10)	(3)				3
209	3	1	1	1				3	4	1	(11)	(9)	(3)				3
210	3	1	1	1				5	3	0	(9)	(10)	(4)				3
211	3	1	1	1				3	4	0	(11)	(9)	(4)				3
212	3	1	1	1				6	4	0	(8)	(9)	(4)				3
213	3	1	1	1				3	5	0	(11)	(8)	(4)				3
Totals	45	15	15	23		45[f]		50	47	8							45

(a) These columns indicate how many of each sample type are available in each room/kit after probabilistic and QC samples are taken. This information will be used by Dino Mattorano (EPA) in placing the judgmental samples.
(b) The totals of the sample types are to be completed by Dino Mattorano (EPA) after he has selected the judgmental sample locations.
(c) The limit given for each sample type is per room.
(d) The kits prepared for sampling rooms allowed for up to five RMCs to be collected per room during the characterization phase of sampling for each test event. However, it was ultimately decided to place and collect only three RMCs per room, as discussed in Section 5.1.
(e) These numbers are in parentheses to indicate that they are to help in placing judgmental samples and are not part of the total samples.
(f) The total allotted number of judgmental samples is 45. The distribution of these across the rooms and types of samples will be completed by Dino Mattorano.

Table C.3. Breakdown of Numbers and Types of Samples for Characterization of the First Floor of the INL PBF-632 Building in Overt Test Event 4

		QC Samples			Judgmental Samples			Probabilistic Samples			Number of Samples Left in Kit[a]			Total Sample Types[b], [c]			
Area to be Sampled	**RMC[d]**	**Vacuum**	**Wipe**	**Swab**	**Vacuum**	**Wipe**	**Swab**	**Vacuum**	**Wipe**	**Swab**	**Vacuum**	**Wipe**	**Swab**	**Vacuum (15 limit)**	**Wipe (14 limit)**	**Swab (5 limit)**	**RMC (5 limit)[d]**
Vacuums	-	-	-	8	-	-	-	-	-	-	-	-	-	0	0	8	0
101	3	1	1	1		4		4	3	0	(10)[e]	(10)	(4)				3
102	3	1	1	1		3		4	3	0	(10)	(10)	(4)				3
103	3	1	1	1		5		9	3	0	(5)	(10)	(4)				3
104	3	1	1	1		5		4	8	0	(10)	(5)	(4)				3
105	3	1	1	1		8[f]		7	6	0	(7)	(7)	(4)				3
107	3	1	1	1		(f)		7	6	0	(7)	(7)	(4)				3
106	3	1	1	1		8[g]		7	6	0	(7)	(7)	(4)				3
108	3	1	1	1		(g)		5	8	0	(9)	(5)	(4)				3
109	3	1	1	1		3		7	5	0	(7)	(8)	(4)				3
110	3	1	1	1		5		6	5	1	(8)	(8)	(3)				3
Totals	30	10	10	18		41[h]		60	53	1							30

(a) These columns indicate how many of each sample type are available in each room/kit after probabilistic and QC samples are taken. This information will be used by Dino Mattorano (EPA) in placing the judgmental samples.
(b) The totals of the sample types are to be completed by Dino Mattorano (EPA) after he has selected the judgmental sample locations.
(c) The limit given for each sample type is per room.
(d) The kits prepared for sampling rooms allowed for up to five RMCs to be collected per room during the characterization phase of sampling for each test event. However, it was ultimately decided to place and collect only three RMCs per room, as discussed in Section 5.1.
(e) These numbers are in parentheses to indicate that they are to help in placing judgmental samples and are not part of the total samples.
(f) These eight judgmental samples are to be allocated between rooms 105 and 107.
(g) These eight judgmental samples are to be allocated between rooms 106 and 108.
(h) The total allotted number of judgmental samples is 41, with the allotted numbers per room shown in the "Wipe" column. The distribution of these numbers of judgmental samples per room over the three types of samples will be completed by Dino Mattorano.

Table C.4. Breakdown of Numbers and Types of Samples for Characterization of the Second Floor of the INL PBF-632 Building in Overt Test Event 5

		QC Samples			Judgmental Samples			Probabilistic Samples			Number of Samples Left in Kit[a]			Total Sample Types[b], [c]			
Area to be Sampled	**RMC[d]**	**Vacuum**	**Wipe**	**Swab**	**Vacuum**	**Wipe**	**Swab**	**Vacuum**	**Wipe**	**Swab**	**Vacuum**	**Wipe**	**Swab**	**Vacuum (15 limit)**	**Wipe (14 limit)**	**Swab (5 limit)**	**RMC (5 limit)[d]**
Vacuums	-	-	-	8	-	-	-	-	-	-	-	-	-	0	0	8	0
201	3	1	1	1		3		4	3	0	(10)[e]	(10)	(4)				3
202	3	1	1	1		4		3	3	1	(11)	(10)	(4)				3
205	3	1	1	1		8[f]		7	5	1	(7)	(8)	(3)				3
207	3	1	1	1		(f)		7	5	1	(7)	(8)	(3)				3
206	3	1	1	1		8[g]		8	4	1	(6)	(9)	(3)				3
208	3	1	1	1		(g)		6	6	1	(8)	(7)	(3)				3
209	3	1	1	1		5		8	4	0	(6)	(9)	(4)				3
210	3	1	1	1		5		8	3	1	(6)	(10)	(3)				3
212	3	1	1	1		5		5	5	2	(9)	(8)	(2)				3
213	3	1	1	1		3		8	4	0	(6)	(9)	(4)				3
Totals	30	10	10	18		41[h]		64	42	8							30

(a) These columns indicate how many of each sample type are available in each room/kit after probabilistic and QC samples are taken. This information will be used by Dino Mattorano (EPA) in placing the judgmental samples.
(b) The totals of the sample types are to be completed by Dino Mattorano (EPA) after he has selected the judgmental sample locations.
(c) The limit given for each sample type is per room.
(d) The kits prepared for sampling rooms allowed for up to five RMCs to be collected per room during the characterization phase of sampling for each test event. However, it was ultimately decided to place and collect only three RMCs per room, as discussed in Section 5.1.
(e) These numbers are in parentheses to indicate that they are to help in placing judgmental samples and are not part of the total samples.
(f) These eight judgmental samples are to be allocated between rooms 205 and 207.
(g) These eight judgmental samples are to be allocated between rooms 206 and 208.
(h) The total allotted number of judgmental samples is 41, with the allotted numbers per room shown in the "Wipe" column. The distribution of these numbers of judgmental samples per room over the three types of samples will be completed by Dino Mattorano.

Table C.5. Breakdown of Numbers and Types of Samples for Clearance of the First Floor of the INL PBF-632 Building in Test Events 1, 2, and 4

		QC Samples			Judgmental Samples			Probabilistic Samples			Number of Samples Left in Kit[a]			Total Sample Types[b], [c]			
Area to be Sampled	**RMC[d]**	**Vacuum**	**Wipe**	**Swab**	**Vacuum**	**Wipe**	**Swab**	**Vacuum**	**Wipe**	**Swab**	**Vacuum**	**Wipe**	**Swab**	**Vacuum (10 limit)**	**Wipe (6 limit)**	**Swab (3 limit)**	**RMC (5 limit)[d]**
Vacuums	-	-	-	8	-	-	-	-	-	-	-	-	-	0	0	8	0
Lobby	0	1	1	1				13	7	1	(-4)[e],[f]	(-2)[f]	(1)				0
101A	0	1	1	1				6	6	0	(3)	(-1)[f]	(2)				0
101	0	1	1	1				5	4	0	(4)	(1)	(2)				0
102	0	1	1	1				3	2	0	(6)	(3)	(2)				0
103	0	1	1	1				7	3	0	(2)	(2)	(2)				0
104	0	1	1	1				2	2	1	(7)	(3)	(1)				0
105	0	1	1	1				4	6	0	(5)	(-1)[f]	(2)				0
106	0	1	1	1				5	5	0	(4)	(0)	(2)				0
107	0	1	1	1				5	5	0	(4)	(0)	(2)				0
108	0	1	1	1				2	7	0	(7)	(-2)[f]	(2)				0
109	0	1	1	1				4	6	0	(5)	(-1)[f]	(2)				0
110	0	1	1	1				4	6	0	(5)	(-1)[f]	(2)				0
Totals	0	12	12	20		20[g]		60	59	2							0

(a) These columns indicate how many of each sample type are available in each room/kit after probabilistic and QC samples are taken. This information will be used by Dino Mattorano (EPA) in placing the judgmental samples.
(b) The totals of the sample types are to be completed by Dino Mattorano (EPA) after he has selected the judgmental sample locations.
(c) The limit given for each sample type is per room.
(d) The kits prepared for sampling rooms allowed for up to five RMCs to be collected per room during the clearance phase of sampling for each test event. However, it was ultimately decided not to place RMCs and collect them after decontamination, as discussed in Section 5.1.
(e) These numbers are in parentheses to indicate that they are to help in placing judgmental samples and are not part of the total samples.
(f) A negative number of samples left in the kit indicates that more samples need to be allocated into the kits for these rooms.
(g) The total allotted number of judgmental samples is 20. The distribution of these across the rooms and types of samples will be completed by Dino Mattorano, as appropriate for the clearance objective with a hybrid sampling approach.

Table C.6. Breakdown of Numbers and Types of Samples for Clearance of the Second Floor of the INL PBF-632 Building in Test Events 3 and 5

		QC Samples			Judgmental Samples			Probabilistic Samples			Number of Samples Left in Kit[a]			Total Sample Types[b], [c]			
Area to be Sampled	**RMC[d]**	**Vacuum**	**Wipe**	**Swab**	**Vacuum**	**Wipe**	**Swab**	**Vacuum**	**Wipe**	**Swab**	**Vacuum**	**Wipe**	**Swab**	**Vacuum (10 limit)**	**Wipe (6 limit)**	**Swab (3 limit)**	**RMC (5 limit)[d]**
Vacuums	-	-	-	8	-	-	-	-	-	-	-	-	-	0	0	8	0
201	0	1	1	1				3	3	0	(6)[e]	(2)	(2)				0
201A	0	1	1	1				3	4	0	(6)	(1)	(2)				0
203	0	1	1	1				1	5	0	(8)	(0)	(2)				0
203A	0	1	1	1				1	6	0	(8)	(-1)[f]	(2)				0
202	0	1	1	1				2	1	1	(7)	(4)	(1)				0
204	0	1	1	1				2	2	0	(7)	(3)	(2)				0
205	0	1	1	1				6	4	0	(3)	(1)	(2)				0
206	0	1	1	1				6	4	0	(3)	(1)	(2)				0
207	0	1	1	1				6	3	1	(3)	(2)	(1)				0
208	0	1	1	1				6	4	0	(3)	(1)	(2)				0
209	0	1	1	1				6	4	0	(3)	(1)	(2)				0
210	0	1	1	1				3	3	1	(6)	(2)	(1)				0
211	0	1	1	1				8	2	0	(1)	(3)	(2)				0
212	0	1	1	1				6	4	0	(3)	(1)	(2)				0
213	0	1	1	1				5	4	1	(4)	(1)	(1)				0
Totals	0	15	15	23		20[g]		64	53	4							0

(a) These columns indicate how many of each sample type are available in each room/kit after probabilistic and QC samples are taken. This information will be used by Dino Mattorano (EPA) in placing the judgmental samples.
(b) The totals of the sample types are to be completed by Dino Mattorano (EPA) after he has selected the judgmental sample locations.
(c) The limit given for each sample type is per room.
(d) The kits prepared for sampling rooms allowed for up to five RMCs to be collected per room during the clearance phase of sampling for each test event. However, it was ultimately decided not to place RMCs and collect them after decontamination, as discussed in Section 5.1.
(e) These numbers are in parentheses to indicate that they are to help in placing judgmental samples and are not part of the total samples.
(f) A negative number of samples left in the kit indicates that more samples need to be allocated into the kits for these rooms.
(g) The total allotted number of judgmental samples is 20. The distribution of these across the rooms and types of samples will be completed by Dino Mattorano, as appropriate for the clearance objective with a hybrid sampling approach.

Appendix D: Coordinates and Sample Types for Probabilistic Sample Locations

Tables D.1 to D.6 contain the coordinates of probabilistic sample locations output by the Visual Sampling Plan (VSP) software, as well as the sample types. Note that the samples types are not part of the VSP output and were added separately. The VSP coordinates may need to be translated to the INL PBF-632 building coordinates for use in the BROOM software. Tables D.1 to D.6 contain the locations and types of probabilistic samples for

- Events 1 and 2, Floor 1 characterization
- Event 3, Floor 2 characterization
- Event 4, Floor 1 characterization
- Event 5, Floor 2 characterization
- Events 1, 2, and 4, Floor 1 clearance
- Events 3 and 5, Floor 2 clearance,

respectively.

Note that Tables D.1 to D.6 each contain a column "Label" that is blank and a column "Value" containing zeros. These are columns provided for in the output of the VSP software but that were not used for the INL-2 study. However, for completeness, those columns are included in Tables D.1 to D.6.

The "Type", "Row", and "Col" columns in Tables D.1 to D.6 provide information about the types and row/column locations of samples. When "Type" = "Hot Spot Cell", the sample is a grid point (on a triangular grid for INL-2) selected with an objective of detecting contamination of a given size. When "Type" = "Grid Cell", the sample typically is grid point selected for a clearance objective. However, this led to an uneven coverage of the half-size Office 202, so an adaptive fill algorithm to better space samples was used.

Table D.1. Coordinates and Sample Types for Probabilistic Sample Locations of Characterization Samples on Floor 1 of INL PBF-632 for INL-2 Test Events 1 and 2

Area	X Center	Y Center	Label	Value	Type	Row	Col	Sample Type
Lobby	875.0559	262.9762		0	Hot Spot Cell	1	0	vacuum
	940.4949	262.9762		0	Hot Spot Cell	1	1	vacuum
	1005.9339	262.9762		0	Hot Spot Cell	1	2	vacuum
	1071.3729	262.9762		0	Hot Spot Cell	1	3	vacuum
	907.7754	315.2557		0	Hot Spot Cell	2	1	wipe
	973.2144	315.2557		0	Hot Spot Cell	2	2	wipe
	1038.6534	315.2557		0	Hot Spot Cell	2	3	wipe
	875.0559	367.5353		0	Hot Spot Cell	3	0	vacuum
	940.4949	367.5353		0	Hot Spot Cell	3	1	vacuum
	1005.9339	367.5353		0	Hot Spot Cell	3	2	vacuum
	1071.3729	367.5353		0	Hot Spot Cell	3	3	vacuum
	907.7754	419.8148		0	Hot Spot Cell	4	1	vacuum
	973.2144	419.8148		0	Hot Spot Cell	4	2	wipe
	1038.6534	419.8148		0	Hot Spot Cell	4	3	wipe
	875.0559	472.0944		0	Hot Spot Cell	5	0	vacuum
	940.4949	472.0944		0	Hot Spot Cell	5	1	wipe
	1005.9339	472.0944		0	Hot Spot Cell	5	2	vacuum
	1071.3729	472.0944		0	Hot Spot Cell	5	3	vacuum
	907.7754	524.3739		0	Hot Spot Cell	6	1	vacuum
	973.2144	524.3739		0	Hot Spot Cell	6	2	wipe
	1038.6534	524.3739		0	Hot Spot Cell	6	3	vacuum
Office 101	669.2894	391.2868		0	Hot Spot Cell	1	1	vacuum
	734.7285	391.2868		0	Hot Spot Cell	1	2	wipe
	800.1675	391.2868		0	Hot Spot Cell	1	3	wipe
	865.6065	391.2868		0	Hot Spot Cell	1	4	wipe
	636.5699	443.5663		0	Hot Spot Cell	2	1	vacuum
	702.0090	443.5663		0	Hot Spot Cell	2	2	wipe
	767.4480	443.5663		0	Hot Spot Cell	2	3	vacuum
	832.8870	443.5663		0	Hot Spot Cell	2	4	vacuum
Office 101A	677.9060	282.1718		0	Hot Spot Cell	2	1	swab grill
	743.3450	282.1718		0	Hot Spot Cell	2	2	wipe
	808.7840	282.1718		0	Hot Spot Cell	2	3	wipe
	645.1865	334.4513		0	Hot Spot Cell	3	0	vacuum
	710.6255	334.4513		0	Hot Spot Cell	3	1	vacuum
	776.0645	334.4513		0	Hot Spot Cell	3	2	vacuum
	841.5035	334.4513		0	Hot Spot Cell	3	3	wipe
Office 102	695.8001	573.6097		0	Hot Spot Cell	1	1	wipe
	754.4243	573.6097		0	Hot Spot Cell	1	2	vacuum
	666.4880	619.9875		0	Hot Spot Cell	2	1	vacuum
	725.1122	619.9875		0	Hot Spot Cell	2	2	swab grill
	783.7364	619.9875		0	Hot Spot Cell	2	3	vacuum
	695.8001	666.3652		0	Hot Spot Cell	3	1	wipe
	754.4243	666.3652		0	Hot Spot Cell	3	2	wipe

Table D.1. Coordinates and Sample Types for Probabilistic Sample Locations of Characterization Samples on Floor 1 of INL PBF-632 for INL-2 Test Events 1 and 2 (contd)

Area	X Center	Y Center	Label	Value	Type	Row	Col	Sample Type
Office 103	526.581	285.1029		0	Hot Spot Cell	2	1	wipe
	592.0201	285.1029		0	Hot Spot Cell	2	2	vacuum
	559.3005	337.3825		0	Hot Spot Cell	3	1	vacuum
	624.7396	337.3825		0	Hot Spot Cell	3	2	wipe
	526.581	389.6620		0	Hot Spot Cell	4	1	wipe
	592.0201	389.6620		0	Hot Spot Cell	4	2	vacuum
	559.3005	441.9416		0	Hot Spot Cell	5	1	wipe
	624.7396	441.9416		0	Hot Spot Cell	5	2	vacuum
Office 104	510.8124	732.2643		0	Hot Spot Cell	2	1	vacuum
	576.2514	732.2643		0	Hot Spot Cell	2	2	vacuum
	641.6905	732.2643		0	Hot Spot Cell	2	3	wipe
	543.5319	784.5438		0	Hot Spot Cell	3	1	wipe
	608.971	784.5438		0	Hot Spot Cell	3	2	vacuum
Office 105	393.1366	275.3355		0	Hot Spot Cell	1	0	wipe
	458.5756	275.3355		0	Hot Spot Cell	1	1	wipe
	425.8561	327.6151		0	Hot Spot Cell	2	1	vacuum
	491.2951	327.6151		0	Hot Spot Cell	2	2	wipe
	393.1366	379.8946		0	Hot Spot Cell	3	0	wipe
	458.5756	379.8946		0	Hot Spot Cell	3	1	wipe
	425.8561	432.1742		0	Hot Spot Cell	4	1	vacuum
	491.2951	432.1742		0	Hot Spot Cell	4	2	wipe
	393.1366	484.4537		0	Hot Spot Cell	5	0	vacuum
	458.5756	484.4537		0	Hot Spot Cell	5	1	vacuum
Office 106	431.0181	610.3778		0	Hot Spot Cell	2	1	vacuum
	496.4571	610.3778		0	Hot Spot Cell	2	2	wipe
	398.2986	662.6573		0	Hot Spot Cell	3	0	wipe
	463.7376	662.6573		0	Hot Spot Cell	3	1	vacuum
	431.0181	714.9369		0	Hot Spot Cell	4	1	vacuum
	496.4571	714.9369		0	Hot Spot Cell	4	2	vacuum
	398.2986	767.2164		0	Hot Spot Cell	5	0	vacuum
	463.7376	767.2164		0	Hot Spot Cell	5	1	swab grill
	431.0181	819.4960		0	Hot Spot Cell	6	1	wipe
	496.4571	819.4960		0	Hot Spot Cell	6	2	wipe
Office 107	311.3559	264.1128		0	Hot Spot Cell	1	1	wipe
	376.7949	264.1128		0	Hot Spot Cell	1	2	wipe
	278.6364	316.3924		0	Hot Spot Cell	2	1	vacuum
	344.0754	316.3924		0	Hot Spot Cell	2	2	vacuum
	311.3559	368.6719		0	Hot Spot Cell	3	1	wipe
	376.7949	368.6719		0	Hot Spot Cell	3	2	wipe
	278.6364	420.9515		0	Hot Spot Cell	4	1	vacuum
	344.0754	420.9515		0	Hot Spot Cell	4	2	wipe
	311.3559	473.2310		0	Hot Spot Cell	5	1	vacuum
	376.7949	473.2310		0	Hot Spot Cell	5	2	vacuum
	311.3559	264.1128		0	Hot Spot Cell	1	1	wipe

Table D.1. Coordinates and Sample Types for Probabilistic Sample Locations of Characterization Samples on Floor 1 of INL PBF-632 for INL-2 Test Events 1 and 2 (contd)

Area	X Center	Y Center	Label	Value	Type	Row	Col	Sample Type
Office 108	314.9008	610.7505		0	Hot Spot Cell	2	1	wipe
	380.3398	610.7505		0	Hot Spot Cell	2	2	wipe
	282.1813	663.0301		0	Hot Spot Cell	3	0	vacuum
	347.6203	663.0301		0	Hot Spot Cell	3	1	vacuum
	314.9008	715.3096		0	Hot Spot Cell	4	1	vacuum
	380.3398	715.3096		0	Hot Spot Cell	4	2	wipe
	282.1813	767.5892		0	Hot Spot Cell	5	0	vacuum
	347.6203	767.5892		0	Hot Spot Cell	5	1	wipe
Office 109	180.3254	282.9416		0	Hot Spot Cell	2	1	wipe
	245.7645	282.9416		0	Hot Spot Cell	2	2	wipe
	213.0449	335.2211		0	Hot Spot Cell	3	1	vacuum
	180.3254	387.5007		0	Hot Spot Cell	4	1	wipe
	245.7645	387.5007		0	Hot Spot Cell	4	2	vacuum
	213.0449	439.7802		0	Hot Spot Cell	5	1	vacuum
Office 110	187.4826	613.5805		0	Hot Spot Cell	2	1	wipe
	252.9217	613.5805		0	Hot Spot Cell	2	2	vacuum
	154.7631	665.8600		0	Hot Spot Cell	3	0	swab monitor
	220.2022	665.8600		0	Hot Spot Cell	3	1	vacuum
	187.4826	718.1396		0	Hot Spot Cell	4	1	vacuum
	252.9217	718.1396		0	Hot Spot Cell	4	2	wipe
	154.7631	770.4192		0	Hot Spot Cell	5	0	wipe
	220.2022	770.4192		0	Hot Spot Cell	5	1	swab grill

Table D.2. Coordinates and Sample Types for Probabilistic Sample Locations of Characterization Samples on Floor 2 of INL PBF-632 for INL-2 Test Event 3

Area	X Center	Y Center	Label	Value	Type	Row	Col	Sample Type
Office 201	1062.134	419.9414		0	Hot Spot Cell	1	1	vacuum
	1129.108	419.9414		0	Hot Spot Cell	1	2	wipe
	1028.647	473.5503		0	Hot Spot Cell	2	1	vacuum
	1095.621	473.5503		0	Hot Spot Cell	2	2	wipe
	1162.595	473.5503		0	Hot Spot Cell	2	3	swab monitor
Office 201A	1057.281	273.8041		0	Hot Spot Cell	1	1	wipe
	1123.904	273.8041		0	Hot Spot Cell	1	2	wipe
	1023.969	327.1091		0	Hot Spot Cell	2	1	vacuum
	1090.592	327.1091		0	Hot Spot Cell	2	2	vacuum
	1157.216	327.1091		0	Hot Spot Cell	2	3	wipe
	1057.281	380.4140		0	Hot Spot Cell	3	1	vacuum
	1123.904	380.4140		0	Hot Spot Cell	3	2	vacuum
Office 202	876.5383	593.7855		0	Hot Spot Cell	1	1	vacuum
	844.7463	644.4586		0	Hot Spot Cell	2	1	vacuum
	908.3303	644.4586		0	Hot Spot Cell	2	2	wipe
	876.5383	695.1316		0	Hot Spot Cell	3	1	swab monitor
Office 203	847.4285	409.3645		0	Hot Spot Cell	1	0	swab monitor
	914.0515	409.3645		0	Hot Spot Cell	1	1	wipe
	980.6745	409.3645		0	Hot Spot Cell	1	2	wipe
	880.7400	462.6694		0	Hot Spot Cell	2	1	swab grill
	947.3630	462.6694		0	Hot Spot Cell	2	2	vacuum
Office 203A	899.4484	247.1297		0	Hot Spot Cell	1	1	wipe
	966.0715	247.1297		0	Hot Spot Cell	1	2	wipe
	866.1369	300.4347		0	Hot Spot Cell	2	1	wipe
	932.7599	300.4347		0	Hot Spot Cell	2	2	vacuum
	999.3830	300.4347		0	Hot Spot Cell	2	3	wipe
	899.4484	353.7396		0	Hot Spot Cell	3	1	wipe
	966.0715	353.7396		0	Hot Spot Cell	3	2	vacuum
Office 204	774.6132	578.8964		0	Hot Spot Cell	1	1	vacuum
	741.3016	632.2014		0	Hot Spot Cell	2	1	wipe
	807.9247	632.2014		0	Hot Spot Cell	2	2	vacuum
	774.6132	685.5063		0	Hot Spot Cell	3	1	swab grill
Office 205	776.8733	245.0875		0	Hot Spot Cell	1	1	wipe
	743.5618	298.3924		0	Hot Spot Cell	2	1	vacuum
	810.1848	298.3924		0	Hot Spot Cell	2	2	wipe
	776.8733	351.6974		0	Hot Spot Cell	3	1	vacuum
	743.5618	405.0023		0	Hot Spot Cell	4	1	vacuum
	810.1848	405.0023		0	Hot Spot Cell	4	2	vacuum
	776.8733	458.3073		0	Hot Spot Cell	5	1	wipe

Table D.2. Coordinates and Sample Types for Probabilistic Sample Locations of Characterization Samples on Floor 2 of INL PBF-632 for INL-2 Test Event 3 (contd)

Area	X Center	Y Center	Label	Value	Type	Row	Col	Sample Type
Office 206	660.3499	586.4829		0	Hot Spot Cell	1	1	vacuum
	627.0384	639.7879		0	Hot Spot Cell	2	1	vacuum
	693.6614	639.7879		0	Hot Spot Cell	2	2	wipe
	660.3499	693.0928		0	Hot Spot Cell	3	1	vacuum
	627.0384	746.3978		0	Hot Spot Cell	4	1	vacuum
	693.6614	746.3978		0	Hot Spot Cell	4	2	wipe
	660.3499	799.7027		0	Hot Spot Cell	5	1	swab monitor
Office 207	606.9418	240.0361		0	Hot Spot Cell	1	0	wipe
	673.5648	240.0361		0	Hot Spot Cell	1	1	vacuum
	640.2533	293.3410		0	Hot Spot Cell	2	1	vacuum
	706.8763	293.3410		0	Hot Spot Cell	2	2	wipe
	606.9418	346.6460		0	Hot Spot Cell	3	0	wipe
	673.5648	346.6460		0	Hot Spot Cell	3	1	wipe
	640.2533	399.9509		0	Hot Spot Cell	4	1	vacuum
	706.8763	399.9509		0	Hot Spot Cell	4	2	wipe
	606.9418	453.2559		0	Hot Spot Cell	5	0	vacuum
	673.5648	453.2559		0	Hot Spot Cell	5	1	vacuum
Office 208	523.3028	607.3784		0	Hot Spot Cell	2	1	wipe
	589.9258	607.3784		0	Hot Spot Cell	2	2	vacuum
	489.9913	660.6834		0	Hot Spot Cell	3	0	wipe
	556.6143	660.6834		0	Hot Spot Cell	3	1	vacuum
	523.3028	713.9883		0	Hot Spot Cell	4	1	vacuum
	589.9258	713.9883		0	Hot Spot Cell	4	2	wipe
	489.9913	767.2933		0	Hot Spot Cell	5	0	vacuum
	556.6143	767.2933		0	Hot Spot Cell	5	1	swab grill
Office 209	505.7497	245.6547		0	Hot Spot Cell	1	0	wipe
	572.3727	245.6547		0	Hot Spot Cell	1	1	wipe
	539.0612	298.9597		0	Hot Spot Cell	2	1	swab grill
	505.7497	352.2646		0	Hot Spot Cell	3	0	wipe
	572.3727	352.2646		0	Hot Spot Cell	3	1	vacuum
	539.0612	405.5695		0	Hot Spot Cell	4	1	vacuum
	505.7497	458.8745		0	Hot Spot Cell	5	0	wipe
	572.3727	458.8745		0	Hot Spot Cell	5	1	vacuum
Office 210	383.8727	584.9502		0	Hot Spot Cell	1	0	vacuum
	450.4957	584.9502		0	Hot Spot Cell	1	1	wipe
	417.1842	638.2552		0	Hot Spot Cell	2	1	vacuum
	383.8727	691.5601		0	Hot Spot Cell	3	0	vacuum
	450.4957	691.5601		0	Hot Spot Cell	3	1	wipe
	417.1842	744.8651		0	Hot Spot Cell	4	1	vacuum
	383.8727	798.1700		0	Hot Spot Cell	5	0	wipe
	450.4957	798.1700		0	Hot Spot Cell	5	1	vacuum

Table D.2. Coordinates and Sample Types for Probabilistic Sample Locations of Characterization Samples on Floor 2 of INL PBF-632 for INL-2 Test Event 3 (contd)

Area	X Center	Y Center	Label	Value	Type	Row	Col	Sample Type
Office 211	420.0035	249.8492		0	Hot Spot Cell	1	1	wipe
	386.6920	303.1541		0	Hot Spot Cell	2	1	vacuum
	453.3151	303.1541		0	Hot Spot Cell	2	2	wipe
	420.0035	356.4591		0	Hot Spot Cell	3	1	vacuum
	386.6920	409.7640		0	Hot Spot Cell	4	1	wipe
	453.3151	409.7640		0	Hot Spot Cell	4	2	vacuum
	420.0035	463.0690		0	Hot Spot Cell	5	1	wipe
Office 212	250.7538	583.4267		0	Hot Spot Cell	1	0	vacuum
	317.3768	583.4267		0	Hot Spot Cell	1	1	wipe
	284.0653	636.7317		0	Hot Spot Cell	2	1	vacuum
	350.6883	636.7317		0	Hot Spot Cell	2	2	wipe
	250.7538	690.0366		0	Hot Spot Cell	3	0	wipe
	317.3768	690.0366		0	Hot Spot Cell	3	1	vacuum
	284.0653	743.3415		0	Hot Spot Cell	4	1	vacuum
	350.6883	743.3415		0	Hot Spot Cell	4	2	vacuum
	250.7538	796.6465		0	Hot Spot Cell	5	0	vacuum
	317.3768	796.6465		0	Hot Spot Cell	5	1	wipe
Office 213	289.8700	275.3860		0	Hot Spot Cell	1	1	vacuum
	356.4930	275.3860		0	Hot Spot Cell	1	2	wipe
	256.5585	328.6909		0	Hot Spot Cell	2	1	wipe
	323.1815	328.6909		0	Hot Spot Cell	2	2	wipe
	289.8700	381.9958		0	Hot Spot Cell	3	1	vacuum
	356.4930	381.9958		0	Hot Spot Cell	3	2	wipe
	256.5585	435.3008		0	Hot Spot Cell	4	1	vacuum
	323.1815	435.3008		0	Hot Spot Cell	4	2	wipe

Table D.3. Coordinates and Sample Types for Probabilistic Sample Locations of Characterization Samples on Floor 1 of INL PBF-632 for INL-2 Test Event 4

Area	X Center	Y Center	Label	Value	Type	Row	Col	Sample Type
Office 101	682.4718	410.4892		0	Hot Spot Cell	1	1	vacuum
	749.1072	410.4892		0	Hot Spot Cell	1	2	wipe
	815.7427	410.4892		0	Hot Spot Cell	1	3	wipe
	649.1541	463.8049		0	Hot Spot Cell	2	1	vacuum
	715.7895	463.8049		0	Hot Spot Cell	2	2	wipe
	782.4249	463.8049		0	Hot Spot Cell	2	3	vacuum
	849.0604	463.8049		0	Hot Spot Cell	2	4	vacuum
Office 102	711.4785	577.3680		0	Hot Spot Cell	1	1	wipe
	774.5852	577.3680		0	Hot Spot Cell	1	2	vacuum
	679.9251	627.6277		0	Hot Spot Cell	2	1	vacuum
	743.0319	627.6277		0	Hot Spot Cell	2	2	vacuum
	806.1386	627.6277		0	Hot Spot Cell	2	3	vacuum
	711.4785	677.8875		0	Hot Spot Cell	3	1	wipe
	774.5852	677.8875		0	Hot Spot Cell	3	2	wipe
Office 103	516.8157	266.5276		0	Hot Spot Cell	1	0	wipe
	572.2008	266.5276		0	Hot Spot Cell	1	1	vacuum
	544.5083	310.1002		0	Hot Spot Cell	2	1	vacuum
	599.8933	310.1002		0	Hot Spot Cell	2	2	vacuum
	516.8157	353.6727		0	Hot Spot Cell	3	0	vacuum
	572.2008	353.6727		0	Hot Spot Cell	3	1	vacuum
	544.5083	397.2453		0	Hot Spot Cell	4	1	wipe
	599.8933	397.2453		0	Hot Spot Cell	4	2	vacuum
	516.8157	440.8179		0	Hot Spot Cell	5	0	vacuum
	572.2008	440.8179		0	Hot Spot Cell	5	1	wipe
	544.5083	484.3905		0	Hot Spot Cell	6	1	vacuum
Office 104	543.9542	699.7594		0	Hot Spot Cell	1	1	vacuum
	588.1645	699.7594		0	Hot Spot Cell	1	2	wipe
	632.3747	699.7594		0	Hot Spot Cell	1	3	wipe
	521.8491	733.6542		0	Hot Spot Cell	2	1	vacuum
	566.0594	733.6542		0	Hot Spot Cell	2	2	vacuum
	610.2696	733.6542		0	Hot Spot Cell	2	3	wipe
	543.9542	767.5491		0	Hot Spot Cell	3	1	wipe
	588.1645	767.5491		0	Hot Spot Cell	3	2	wipe
	632.3747	767.5491		0	Hot Spot Cell	3	3	wipe
	521.8491	801.4440		0	Hot Spot Cell	4	1	wipe
	566.0594	801.4440		0	Hot Spot Cell	4	2	wipe
	610.2696	801.4440		0	Hot Spot Cell	4	3	vacuum

Table D.3. Coordinates and Sample Types for Probabilistic Sample Locations of Characterization Samples on Floor 1 of INL PBF-632 for INL-2 Test Event 4 (contd)

Area	X Center	Y Center	Label	Value	Type	Row	Col	Sample Type
Office 105	419.25	245.5		0	Grid Cell	1	3	vacuum
	455.25	269.5		0	Grid Cell	3	6	wipe
	491.25	293.5		0	Grid Cell	5	9	vacuum
	407.25	305.5		0	Grid Cell	6	2	wipe
	455.25	329.5		0	Grid Cell	8	6	vacuum
	395.25	341.5		0	Grid Cell	9	1	wipe
	467.25	377.5		0	Grid Cell	12	7	wipe
	419.25	389.5		0	Grid Cell	13	3	vacuum
	503.25	413.5		0	Grid Cell	15	10	wipe
	395.25	437.5		0	Grid Cell	17	1	vacuum
	443.25	449.5		0	Grid Cell	18	5	vacuum
	503.25	473.5		0	Grid Cell	20	10	wipe
	407.25	485.5		0	Grid Cell	21	2	vacuum
Office 106	395	576		0	Grid Cell	1	1	vacuum
	431	588		0	Grid Cell	2	4	vacuum
	503	588		0	Grid Cell	2	10	wipe
	467	624		0	Grid Cell	5	7	wipe
	419	648		0	Grid Cell	7	3	wipe
	467	684		0	Grid Cell	10	7	wipe
	419	708		0	Grid Cell	12	3	vacuum
	491	720		0	Grid Cell	13	9	vacuum
	395	756		0	Grid Cell	16	1	vacuum
	455	756		0	Grid Cell	16	6	vacuum
	455	792		0	Grid Cell	19	6	vacuum
	503	804		0	Grid Cell	20	10	wipe
	419	816		0	Grid Cell	21	3	wipe
Office 107	325	245.5		0	Grid Cell	1	5	wipe
	277	257.5		0	Grid Cell	2	1	wipe
	361	281.5		0	Grid Cell	4	8	vacuum
	325	293.5		0	Grid Cell	5	5	wipe
	277	305.5		0	Grid Cell	6	1	vacuum
	349	329.5		0	Grid Cell	8	7	vacuum
	301	353.5		0	Grid Cell	10	3	vacuum
	349	377.5		0	Grid Cell	12	7	vacuum
	277	389.5		0	Grid Cell	13	1	wipe
	337	425.5		0	Grid Cell	16	6	wipe
	289	449.5		0	Grid Cell	18	2	wipe
	373	461.5		0	Grid Cell	19	9	vacuum
	325	485.5		0	Grid Cell	21	5	vacuum

Table D.3. Coordinates and Sample Types for Probabilistic Sample Locations of Characterization Samples on Floor 1 of INL PBF-632 for INL-2 Test Event 4 (contd)

Area	X Center	Y Center	Label	Value	Type	Row	Col	Sample Type
Office 108	336.25	576		0	Grid Cell	1	6	vacuum
	372.25	576		0	Grid Cell	1	9	wipe
	288.25	588		0	Grid Cell	2	2	vacuum
	336.25	624		0	Grid Cell	5	6	wipe
	300.25	636		0	Grid Cell	6	3	vacuum
	324.25	672		0	Grid Cell	9	5	vacuum
	372.25	696		0	Grid Cell	11	9	wipe
	288.25	708		0	Grid Cell	12	2	wipe
	324.25	744		0	Grid Cell	15	5	vacuum
	372.25	744		0	Grid Cell	15	9	wipe
	288.25	780		0	Grid Cell	18	2	wipe
	384.25	792		0	Grid Cell	19	10	wipe
	336.25	804		0	Grid Cell	20	6	wipe
Office 109	188.6864	249.6813		0	Hot Spot Cell	1	1	wipe
	244.1247	249.6813		0	Hot Spot Cell	1	2	wipe
	160.9673	293.3000		0	Hot Spot Cell	2	1	vacuum
	216.4056	293.3000		0	Hot Spot Cell	2	2	vacuum
	188.6864	336.9186		0	Hot Spot Cell	3	1	vacuum
	244.1247	336.9186		0	Hot Spot Cell	3	2	wipe
	160.9673	380.5373		0	Hot Spot Cell	4	1	wipe
	216.4056	380.5373		0	Hot Spot Cell	4	2	vacuum
	188.6864	424.1560		0	Hot Spot Cell	5	1	wipe
	244.1247	424.1560		0	Hot Spot Cell	5	2	vacuum
	160.9673	467.7747		0	Hot Spot Cell	6	1	vacuum
	216.4056	467.7747		0	Hot Spot Cell	6	2	vacuum
Office 110	202.8835	581.4392		0	Hot Spot Cell	1	1	vacuum
	258.1514	581.4392		0	Hot Spot Cell	1	2	vacuum
	175.2496	624.9103		0	Hot Spot Cell	2	1	wipe
	230.5175	624.9103		0	Hot Spot Cell	2	2	wipe
	202.8835	668.3813		0	Hot Spot Cell	3	1	vacuum
	258.1514	668.3813		0	Hot Spot Cell	3	2	wipe
	175.2496	711.8524		0	Hot Spot Cell	4	1	vacuum
	230.5175	711.8524		0	Hot Spot Cell	4	2	vacuum
	202.8835	755.3235		0	Hot Spot Cell	5	1	swab grill
	258.1514	755.3235		0	Hot Spot Cell	5	2	wipe
	175.2496	798.7945		0	Hot Spot Cell	6	1	wipe
	230.5175	798.7945		0	Hot Spot Cell	6	2	vacuum

Table D.4. Coordinates and Sample Types for Probabilistic Sample Locations of Characterization Samples on Floor 2 of INL PBF-632 for INL-2 Test Event 5

Area	X Center	Y Center	Label	Value	Type	Row	Col	Sample Type
Office 201	1012.379	413.7051		0	Hot Spot Cell	1	0	vacuum
	1070.587	413.7051		0	Hot Spot Cell	1	1	wipe
	1128.796	413.7051		0	Hot Spot Cell	1	2	vacuum
	1187.004	413.7051		0	Hot Spot Cell	1	3	wipe
	1041.483	459.7225		0	Hot Spot Cell	2	1	vacuum
	1099.691	459.7225		0	Hot Spot Cell	2	2	vacuum
	1157.900	459.7225		0	Hot Spot Cell	2	3	wipe
Office 202	898	572		0	Grid Cell	1	7	vacuum
	850	584		0	Grid Cell	2	3	vacuum
	898	620		0	Grid Cell	5	7	wipe
	826	632		0	Grid Cell	6	1	wipe
	862	644		0	Grid Cell	7	4	vacuum
	874	692		0	Grid Cell	11	5	swab monitor
	826	704		0	Grid Cell	12	1	wipe
Office 205	730.5	253.5		0	Grid Cell	2	2	wipe
	802.5	265.5		0	Grid Cell	3	8	wipe
	766.5	301.5		0	Grid Cell	6	5	vacuum
	718.5	325.5		0	Grid Cell	8	1	vacuum
	814.5	325.5		0	Grid Cell	8	9	wipe
	778.5	349.5		0	Grid Cell	10	6	vacuum
	802.5	385.5		0	Grid Cell	13	8	wipe
	742.5	397.5		0	Grid Cell	14	3	swab monitor
	766.5	433.5		0	Grid Cell	17	5	wipe
	718.5	445.5		0	Grid Cell	18	1	vacuum
	790.5	457.5		0	Grid Cell	19	7	vacuum
	718.5	481.5		0	Grid Cell	21	1	vacuum
	826.5	481.5		0	Grid Cell	21	10	vacuum
Office 206	661	584		0	Grid Cell	2	5	vacuum
	709	608		0	Grid Cell	4	9	vacuum
	613	620		0	Grid Cell	5	1	vacuum
	637	644		0	Grid Cell	7	3	vacuum
	685	656		0	Grid Cell	8	7	wipe
	661	680		0	Grid Cell	10	5	vacuum
	613	704		0	Grid Cell	12	1	wipe
	721	716		0	Grid Cell	13	10	wipe
	661	728		0	Grid Cell	14	5	vacuum
	709	752		0	Grid Cell	16	9	vacuum
	637	764		0	Grid Cell	17	3	wipe
	673	800		0	Grid Cell	20	6	swab monitor
	613	812		0	Grid Cell	21	1	vacuum

Table D.4. Coordinates and Sample Types for Probabilistic Sample Locations of Characterization Samples on Floor 2 of INL PBF-632 for INL-2 Test Event 5 (contd)

Area	X Center	Y Center	Label	Value	Type	Row	Col	Sample Type
Office 207	629.25	265.5		0	Grid Cell	3	3	swab monitor
	701.25	265.5		0	Grid Cell	3	9	vacuum
	629.25	313.5		0	Grid Cell	7	3	vacuum
	665.25	313.5		0	Grid Cell	7	6	vacuum
	701.25	337.5		0	Grid Cell	9	9	wipe
	617.25	349.5		0	Grid Cell	10	2	wipe
	653.25	373.5		0	Grid Cell	12	5	wipe
	701.25	385.5		0	Grid Cell	13	9	wipe
	605.25	409.5		0	Grid Cell	15	1	wipe
	665.25	409.5		0	Grid Cell	15	6	vacuum
	641.25	445.5		0	Grid Cell	18	4	vacuum
	701.25	445.5		0	Grid Cell	18	9	vacuum
	617.25	481.5		0	Grid Cell	21	2	vacuum
Office 208	505	572		0	Grid Cell	1	2	wipe
	553	572		0	Grid Cell	1	6	vacuum
	505	608		0	Grid Cell	4	2	vacuum
	565	632		0	Grid Cell	6	7	vacuum
	541	656		0	Grid Cell	8	5	wipe
	493	680		0	Grid Cell	10	1	wipe
	541	704		0	Grid Cell	12	5	vacuum
	589	704		0	Grid Cell	12	9	vacuum
	505	728		0	Grid Cell	14	2	vacuum
	601	740		0	Grid Cell	15	10	wipe
	565	752		0	Grid Cell	16	7	swab grill
	517	788		0	Grid Cell	19	3	wipe
	577	812		0	Grid Cell	21	8	wipe
Office 209	497.3562	251.4881		0	Hot Spot Cell	1	0	wipe
	551.4910	251.4881		0	Hot Spot Cell	1	1	vacuum
	524.4236	293.9779		0	Hot Spot Cell	2	1	vacuum
	578.5584	293.9779		0	Hot Spot Cell	2	2	vacuum
	497.3562	336.4677		0	Hot Spot Cell	3	0	vacuum
	551.4910	336.4677		0	Hot Spot Cell	3	1	vacuum
	524.4236	378.9575		0	Hot Spot Cell	4	1	wipe
	578.5584	378.9575		0	Hot Spot Cell	4	2	vacuum
	497.3562	421.4473		0	Hot Spot Cell	5	0	wipe
	551.4910	421.4473		0	Hot Spot Cell	5	1	vacuum
	524.4236	463.9372		0	Hot Spot Cell	6	1	wipe
	578.5584	463.9372		0	Hot Spot Cell	6	2	vacuum

Table D.4. Coordinates and Sample Types for Probabilistic Sample Locations of Characterization Samples on Floor 2 of INL PBF-632 for INL-2 Test Event 5 (contd)

Area	X Center	Y Center	Label	Value	Type	Row	Col	Sample Type
Office 210	415.8897	577.0364		0	Hot Spot Cell	1	1	vacuum
	471.2986	577.0364		0	Hot Spot Cell	1	2	wipe
	388.1853	620.6296		0	Hot Spot Cell	2	1	vacuum
	443.5942	620.6296		0	Hot Spot Cell	2	2	vacuum
	415.8897	664.2227		0	Hot Spot Cell	3	1	vacuum
	471.2986	664.2227		0	Hot Spot Cell	3	2	wipe
	388.1853	707.8159		0	Hot Spot Cell	4	1	vacuum
	443.5942	707.8159		0	Hot Spot Cell	4	2	vacuum
	415.8897	751.4091		0	Hot Spot Cell	5	1	vacuum
	471.2986	751.4091		0	Hot Spot Cell	5	2	swab monitor
	388.1853	795.0023		0	Hot Spot Cell	6	1	wipe
	443.5942	795.0023		0	Hot Spot Cell	6	2	vacuum
Office 212	255.9664	592.0109		0	Hot Spot Cell	1	0	vacuum
	311.9433	592.0109		0	Hot Spot Cell	1	1	wipe
	283.9548	636.0961		0	Hot Spot Cell	2	1	vacuum
	339.9318	636.0961		0	Hot Spot Cell	2	2	vacuum
	255.9664	680.1812		0	Hot Spot Cell	3	0	swab monitor
	311.9433	680.1812		0	Hot Spot Cell	3	1	vacuum
	283.9548	724.2664		0	Hot Spot Cell	4	1	vacuum
	339.9318	724.2664		0	Hot Spot Cell	4	2	wipe
	255.9664	768.3515		0	Hot Spot Cell	5	0	wipe
	311.9433	768.3515		0	Hot Spot Cell	5	1	swab grill
	283.9548	812.4366		0	Hot Spot Cell	6	1	wipe
	339.9318	812.4366		0	Hot Spot Cell	6	2	wipe
Office 213	299.5618	241.8135		0	Hot Spot Cell	1	1	vacuum
	354.8550	241.8135		0	Hot Spot Cell	1	2	wipe
	271.9151	285.3065		0	Hot Spot Cell	2	1	wipe
	327.2084	285.3065		0	Hot Spot Cell	2	2	wipe
	299.5618	328.7996		0	Hot Spot Cell	3	1	vacuum
	354.8550	328.7996		0	Hot Spot Cell	3	2	vacuum
	271.9151	372.2927		0	Hot Spot Cell	4	1	vacuum
	327.2084	372.2927		0	Hot Spot Cell	4	2	wipe
	299.5618	415.7858		0	Hot Spot Cell	5	1	vacuum
	354.8550	415.7858		0	Hot Spot Cell	5	2	vacuum
	271.9151	459.2789		0	Hot Spot Cell	6	1	vacuum
	327.2084	459.2789		0	Hot Spot Cell	6	2	vacuum

Table D.5. Coordinates and Sample Types for Probabilistic Sample Locations of Clearance Samples on Floor 1 of INL PBF-632 for INL-2 Test Events 1, 2, and 4

Area	X Center	Y Center	Label	Value	Type	Row	Col	Sample Type
Lobby	905.1964	271.7238		0	Hot Spot Cell	1	1	swab grill
	967.1662	271.7238		0	Hot Spot Cell	1	2	vacuum
	1029.136	271.7238		0	Hot Spot Cell	1	3	vacuum
	874.2115	320.9989		0	Hot Spot Cell	2	1	vacuum
	936.1813	320.9989		0	Hot Spot Cell	2	2	wipe
	998.151	320.9989		0	Hot Spot Cell	2	3	wipe
	1060.121	320.9989		0	Hot Spot Cell	2	4	vacuum
	905.1964	370.2740		0	Hot Spot Cell	3	1	vacuum
	967.1662	370.2740		0	Hot Spot Cell	3	2	wipe
	1029.136	370.2740		0	Hot Spot Cell	3	3	vacuum
	874.2115	419.5491		0	Hot Spot Cell	4	1	vacuum
	936.1813	419.5491		0	Hot Spot Cell	4	2	wipe
	998.151	419.5491		0	Hot Spot Cell	4	3	wipe
	1060.121	419.5491		0	Hot Spot Cell	4	4	wipe
	905.1964	468.8241		0	Hot Spot Cell	5	1	vacuum
	967.1662	468.8241		0	Hot Spot Cell	5	2	vacuum
	1029.136	468.8241		0	Hot Spot Cell	5	3	vacuum
	874.2115	518.0992		0	Hot Spot Cell	6	1	vacuum
	936.1813	518.0992		0	Hot Spot Cell	6	2	wipe
	998.1510	518.0992		0	Hot Spot Cell	6	3	vacuum
	1060.121	518.0992		0	Hot Spot Cell	6	4	vacuum
Office 101	630.8571	402.3126		0	Hot Spot Cell	1	0	vacuum
	689.2283	402.3126		0	Hot Spot Cell	1	1	wipe
	747.5994	402.3126		0	Hot Spot Cell	1	2	wipe
	805.9706	402.3126		0	Hot Spot Cell	1	3	wipe
	864.3418	402.3126		0	Hot Spot Cell	1	4	wipe
	660.0427	448.4712		0	Hot Spot Cell	2	1	vacuum
	718.4138	448.4712		0	Hot Spot Cell	2	2	vacuum
	776.7850	448.4712		0	Hot Spot Cell	2	3	vacuum
	835.1562	448.4712		0	Hot Spot Cell	2	4	vacuum
Office 101A	663.0169	257.8554		0	Hot Spot Cell	1	1	wipe
	724.9866	257.8554		0	Hot Spot Cell	1	2	vacuum
	786.9564	257.8554		0	Hot Spot Cell	1	3	vacuum
	848.9261	257.8554		0	Hot Spot Cell	1	4	wipe
	632.0320	307.1305		0	Hot Spot Cell	2	1	wipe
	694.0018	307.1305		0	Hot Spot Cell	2	2	vacuum
	755.9715	307.1305		0	Hot Spot Cell	2	3	vacuum
	817.9413	307.1305		0	Hot Spot Cell	2	4	vacuum
	663.0169	356.4056		0	Hot Spot Cell	3	1	vacuum
	724.9866	356.4056		0	Hot Spot Cell	3	2	wipe
	786.9564	356.4056		0	Hot Spot Cell	3	3	wipe
	848.9261	356.4056		0	Hot Spot Cell	3	4	wipe

Table D.5. Coordinates and Sample Types for Probabilistic Sample Locations of Clearance Samples on Floor 1 of INL PBF-632 for INL-2 Test Events 1, 2, and 4 (contd)

Area	X Center	Y Center	Label	Value	Type	Row	Col	Sample Type
Office 102	690.5869	611.1912		0	Hot Spot Cell	2	1	wipe
	753.6963	611.1912		0	Hot Spot Cell	2	2	vacuum
	659.0323	661.4532		0	Hot Spot Cell	3	0	vacuum
	722.1416	661.4532		0	Hot Spot Cell	3	1	vacuum
	785.2509	661.4532		0	Hot Spot Cell	3	2	wipe
Office 103	556.5035	264.0828		0	Hot Spot Cell	1	1	wipe
	618.4732	264.0828		0	Hot Spot Cell	1	2	wipe
	525.5186	313.3579		0	Hot Spot Cell	2	1	vacuum
	587.4883	313.3579		0	Hot Spot Cell	2	2	vacuum
	556.5035	362.6330		0	Hot Spot Cell	3	1	wipe
	618.4732	362.6330		0	Hot Spot Cell	3	2	vacuum
	525.5186	411.9081		0	Hot Spot Cell	4	1	vacuum
	587.4883	411.9081		0	Hot Spot Cell	4	2	vacuum
	556.5035	461.1831		0	Hot Spot Cell	5	1	vacuum
	618.4732	461.1831		0	Hot Spot Cell	5	2	vacuum
Office 104	550.0930	727.4776		0	Hot Spot Cell	1	1	vacuum
	617.1208	727.4776		0	Hot Spot Cell	1	2	wipe
	516.5792	781.1331		0	Hot Spot Cell	2	1	vacuum
	583.6069	781.1331		0	Hot Spot Cell	2	2	swab monitor
	650.6346	781.1331		0	Hot Spot Cell	2	3	wipe
Office 105	436.5812	275.3192		0	Hot Spot Cell	1	1	wipe
	498.5509	275.3192		0	Hot Spot Cell	1	2	wipe
	405.5963	324.5943		0	Hot Spot Cell	2	1	wipe
	467.5661	324.5943		0	Hot Spot Cell	2	2	vacuum
	436.5812	373.8693		0	Hot Spot Cell	3	1	vacuum
	498.5509	373.8693		0	Hot Spot Cell	3	2	wipe
	405.5963	423.1444		0	Hot Spot Cell	4	1	vacuum
	467.5661	423.1444		0	Hot Spot Cell	4	2	wipe
	436.5812	472.4195		0	Hot Spot Cell	5	1	vacuum
	498.5509	472.4195		0	Hot Spot Cell	5	2	wipe
Office 106	401.4339	609.7976		0	Hot Spot Cell	2	1	vacuum
	463.4037	609.7976		0	Hot Spot Cell	2	2	vacuum
	432.4188	659.0726		0	Hot Spot Cell	3	1	vacuum
	494.3885	659.0726		0	Hot Spot Cell	3	2	wipe
	401.4339	708.3477		0	Hot Spot Cell	4	1	wipe
	463.4037	708.3477		0	Hot Spot Cell	4	2	wipe
	432.4188	757.6228		0	Hot Spot Cell	5	1	vacuum
	494.3885	757.6228		0	Hot Spot Cell	5	2	vacuum
	401.4339	806.8979		0	Hot Spot Cell	6	1	wipe
	463.4037	806.8979		0	Hot Spot Cell	6	2	wipe

Table D.5. Coordinates and Sample Types for Probabilistic Sample Locations of Clearance Samples on Floor 1 of INL PBF-632 for INL-2 Test Events 1, 2, and 4 (contd)

Area	X Center	Y Center	Label	Value	Type	Row	Col	Sample Type
Office 107	274.4811	246.6699		0	Hot Spot Cell	1	0	wipe
	336.4508	246.6699		0	Hot Spot Cell	1	1	wipe
	305.4660	295.9450		0	Hot Spot Cell	2	1	vacuum
	367.4357	295.9450		0	Hot Spot Cell	2	2	wipe
	274.4811	345.2201		0	Hot Spot Cell	3	0	wipe
	336.4508	345.2201		0	Hot Spot Cell	3	1	vacuum
	305.4660	394.4951		0	Hot Spot Cell	4	1	vacuum
	367.4357	394.4951		0	Hot Spot Cell	4	2	vacuum
	274.4811	443.7702		0	Hot Spot Cell	5	0	vacuum
	336.4508	443.7702		0	Hot Spot Cell	5	1	wipe
Office 108	319.6228	617.8642		0	Hot Spot Cell	2	1	wipe
	381.5926	617.8642		0	Hot Spot Cell	2	2	wipe
	288.6379	667.1393		0	Hot Spot Cell	3	0	wipe
	350.6077	667.1393		0	Hot Spot Cell	3	1	wipe
	319.6228	716.4144		0	Hot Spot Cell	4	1	vacuum
	381.5926	716.4144		0	Hot Spot Cell	4	2	wipe
	288.6379	765.6895		0	Hot Spot Cell	5	0	vacuum
	350.6077	765.6895		0	Hot Spot Cell	5	1	wipe
	319.6228	814.9645		0	Hot Spot Cell	6	1	wipe
Office 109	185.6624	272.0587		0	Hot Spot Cell	1	1	wipe
	247.6321	272.0587		0	Hot Spot Cell	1	2	wipe
	154.6775	321.3338		0	Hot Spot Cell	2	1	wipe
	216.6473	321.3338		0	Hot Spot Cell	2	2	vacuum
	185.6624	370.6089		0	Hot Spot Cell	3	1	wipe
	247.6321	370.6089		0	Hot Spot Cell	3	2	vacuum
	154.6775	419.8840		0	Hot Spot Cell	4	1	wipe
	216.6473	419.8840		0	Hot Spot Cell	4	2	vacuum
	185.6624	469.1590		0	Hot Spot Cell	5	1	wipe
	247.6321	469.1590		0	Hot Spot Cell	5	2	vacuum
Office 110	203.4891	597.2734		0	Hot Spot Cell	1	1	wipe
	265.4588	597.2734		0	Hot Spot Cell	1	2	vacuum
	172.5042	646.5484		0	Hot Spot Cell	2	1	wipe
	234.4740	646.5484		0	Hot Spot Cell	2	2	vacuum
	203.4891	695.8235		0	Hot Spot Cell	3	1	vacuum
	265.4588	695.8235		0	Hot Spot Cell	3	2	wipe
	172.5042	745.0986		0	Hot Spot Cell	4	1	wipe
	234.4740	745.0986		0	Hot Spot Cell	4	2	vacuum
	203.4891	794.3737		0	Hot Spot Cell	5	1	wipe
	265.4588	794.3737		0	Hot Spot Cell	5	2	wipe

Table D.6. Coordinates and Sample Types for Probabilistic Sample Locations of Clearance Samples on Floor 2 of INL PBF-632 for INL-2 Test Events 3 and 5

Area	X Center	Y Center	Label	Value	Type	Row	Col	Sample Type
Office 201	1058.329	431.3752		0	Hot Spot Cell	2	1	vacuum
	1120.572	431.3752		0	Hot Spot Cell	2	2	vacuum
	1182.815	431.3752		0	Hot Spot Cell	2	3	wipe
	1027.208	480.8868		0	Hot Spot Cell	3	0	vacuum
	1089.451	480.8868		0	Hot Spot Cell	3	1	wipe
	1151.693	480.8868		0	Hot Spot Cell	3	2	wipe
Office 201A	1071.766	240.5494		0	Hot Spot Cell	1	1	wipe
	1134.009	240.5494		0	Hot Spot Cell	1	2	wipe
	1040.644	290.0610		0	Hot Spot Cell	2	1	wipe
	1102.887	290.0610		0	Hot Spot Cell	2	2	vacuum
	1165.130	290.0610		0	Hot Spot Cell	2	3	wipe
	1071.766	339.5725		0	Hot Spot Cell	3	1	vacuum
	1134.009	339.5725		0	Hot Spot Cell	3	2	vacuum
Office 202	860.7741	602.5726		0	Hot Spot Cell	1	1	vacuum
	829.6527	652.0842		0	Hot Spot Cell	2	1	vacuum
	891.8955	652.0842		0	Hot Spot Cell	2	2	wipe
	860.7741	701.5957		0	Hot Spot Cell	3	1	swab monitor
Office 203	881.7774	412.9497		0	Hot Spot Cell	1	1	wipe
	944.0202	412.9497		0	Hot Spot Cell	1	2	vacuum
	1006.263	412.9497		0	Hot Spot Cell	1	3	wipe
	850.6560	462.4613		0	Hot Spot Cell	2	1	wipe
	912.8988	462.4613		0	Hot Spot Cell	2	2	wipe
	975.1416	462.4613		0	Hot Spot Cell	2	3	wipe
Office 203A	886.6639	244.2941		0	Hot Spot Cell	1	1	wipe
	948.9068	244.2941		0	Hot Spot Cell	1	2	wipe
	855.5425	293.8056		0	Hot Spot Cell	2	1	wipe
	917.7854	293.8056		0	Hot Spot Cell	2	2	vacuum
	980.0282	293.8056		0	Hot Spot Cell	2	3	wipe
	886.6639	343.3172		0	Hot Spot Cell	3	1	wipe
	948.9068	343.3172		0	Hot Spot Cell	3	2	wipe
Office 204	782.9838	596.3914		0	Hot Spot Cell	1	1	vacuum
	751.8624	645.9029		0	Hot Spot Cell	2	1	wipe
	814.1052	645.9029		0	Hot Spot Cell	2	2	vacuum
	782.9838	695.4145		0	Hot Spot Cell	3	1	wipe

Table D.6. Coordinates and Sample Types for Probabilistic Sample Locations of Clearance Samples on Floor 2 of INL PBF-632 for INL-2 Test Events 3 and 5 (contd)

Area	X Center	Y Center	Label	Value	Type	Row	Col	Sample Type
Office 205	726.7541	282.8966		0	Hot Spot Cell	2	1	wipe
	788.9969	282.8966		0	Hot Spot Cell	2	2	vacuum
	757.8755	332.4081		0	Hot Spot Cell	3	1	vacuum
	820.1183	332.4081		0	Hot Spot Cell	3	2	wipe
	726.7541	381.9197		0	Hot Spot Cell	4	1	wipe
	788.9969	381.9197		0	Hot Spot Cell	4	2	vacuum
	757.8755	431.4312		0	Hot Spot Cell	5	1	wipe
	820.1183	431.4312		0	Hot Spot Cell	5	2	vacuum
	726.7541	480.9428		0	Hot Spot Cell	6	1	vacuum
	788.9969	480.9428		0	Hot Spot Cell	6	2	vacuum
Office 206	640.2574	579.6158		0	Hot Spot Cell	1	1	vacuum
	702.5002	579.6158		0	Hot Spot Cell	1	2	wipe
	609.1360	629.1273		0	Hot Spot Cell	2	1	vacuum
	671.3788	629.1273		0	Hot Spot Cell	2	2	vacuum
	640.2574	678.6389		0	Hot Spot Cell	3	1	vacuum
	702.5002	678.6389		0	Hot Spot Cell	3	2	wipe
	609.1360	728.1504		0	Hot Spot Cell	4	1	vacuum
	671.3788	728.1504		0	Hot Spot Cell	4	2	wipe
	640.2574	777.6620		0	Hot Spot Cell	5	1	wipe
	702.5002	777.6620		0	Hot Spot Cell	5	2	vacuum
Office 207	613.6646	247.4172		0	Hot Spot Cell	1	0	wipe
	675.9074	247.4172		0	Hot Spot Cell	1	1	vacuum
	644.7860	296.9287		0	Hot Spot Cell	2	1	vacuum
	707.0288	296.9287		0	Hot Spot Cell	2	2	swab monitor
	613.6646	346.4403		0	Hot Spot Cell	3	0	wipe
	675.9074	346.4403		0	Hot Spot Cell	3	1	vacuum
	644.7860	395.9518		0	Hot Spot Cell	4	1	vacuum
	707.0288	395.9518		0	Hot Spot Cell	4	2	wipe
	613.6646	445.4634		0	Hot Spot Cell	5	0	vacuum
	675.9074	445.4634		0	Hot Spot Cell	5	1	vacuum
Office 208	489.0392	610.5625		0	Hot Spot Cell	2	1	vacuum
	551.2820	610.5625		0	Hot Spot Cell	2	2	wipe
	520.1606	660.0740		0	Hot Spot Cell	3	1	wipe
	582.4035	660.0740		0	Hot Spot Cell	3	2	vacuum
	489.0392	709.5856		0	Hot Spot Cell	4	1	vacuum
	551.2820	709.5856		0	Hot Spot Cell	4	2	vacuum
	520.1606	759.0971		0	Hot Spot Cell	5	1	vacuum
	582.4035	759.0971		0	Hot Spot Cell	5	2	vacuum
	489.0392	808.6087		0	Hot Spot Cell	6	1	wipe
	551.2820	808.6087		0	Hot Spot Cell	6	2	wipe

Table D.6. Coordinates and Sample Types for Probabilistic Sample Locations of Clearance Samples on Floor 2 of INL PBF-632 for INL-2 Test Events 3 and 5 (contd)

Area	X Center	Y Center	Label	Value	Type	Row	Col	Sample Type
Office 209	525.3797	278.4087		0	Hot Spot Cell	2	1	wipe
	587.6225	278.4087		0	Hot Spot Cell	2	2	vacuum
	494.2583	327.9202		0	Hot Spot Cell	3	0	vacuum
	556.5011	327.9202		0	Hot Spot Cell	3	1	vacuum
	525.3797	377.4318		0	Hot Spot Cell	4	1	wipe
	587.6225	377.4318		0	Hot Spot Cell	4	2	vacuum
	494.2583	426.9433		0	Hot Spot Cell	5	0	wipe
	556.5011	426.9433		0	Hot Spot Cell	5	1	vacuum
	525.3797	476.4549		0	Hot Spot Cell	6	1	wipe
	587.6225	476.4549		0	Hot Spot Cell	6	2	vacuum
Office 210	427.2668	575.6266		0	Hot Spot Cell	1	1	wipe
	396.1454	625.1381		0	Hot Spot Cell	2	1	vacuum
	458.3882	625.1381		0	Hot Spot Cell	2	2	wipe
	427.2668	674.6497		0	Hot Spot Cell	3	1	wipe
	396.1454	724.1612		0	Hot Spot Cell	4	1	vacuum
	458.3882	724.1612		0	Hot Spot Cell	4	2	vacuum
	427.2668	773.6728		0	Hot Spot Cell	5	1	swab grill
Office 211	382.5532	282.0610		0	Hot Spot Cell	2	1	wipe
	444.7960	282.0610		0	Hot Spot Cell	2	2	vacuum
	413.6746	331.5725		0	Hot Spot Cell	3	1	vacuum
	475.9174	331.5725		0	Hot Spot Cell	3	2	vacuum
	382.5532	381.0841		0	Hot Spot Cell	4	1	wipe
	444.7960	381.0841		0	Hot Spot Cell	4	2	vacuum
	413.6746	430.5956		0	Hot Spot Cell	5	1	vacuum
	475.9174	430.5956		0	Hot Spot Cell	5	2	vacuum
	382.5532	480.1072		0	Hot Spot Cell	6	1	vacuum
	444.7960	480.1072		0	Hot Spot Cell	6	2	vacuum
Office 212	253.1032	596.0517		0	Hot Spot Cell	1	0	vacuum
	315.3461	596.0517		0	Hot Spot Cell	1	1	wipe
	284.2246	645.5632		0	Hot Spot Cell	2	1	vacuum
	346.4675	645.5632		0	Hot Spot Cell	2	2	wipe
	253.1032	695.0748		0	Hot Spot Cell	3	0	wipe
	315.3461	695.0748		0	Hot Spot Cell	3	1	vacuum
	284.2246	744.5863		0	Hot Spot Cell	4	1	vacuum
	346.4675	744.5863		0	Hot Spot Cell	4	2	vacuum
	253.1032	794.0979		0	Hot Spot Cell	5	0	vacuum
	315.3461	794.0979		0	Hot Spot Cell	5	1	wipe

Table D.6. Coordinates and Sample Types for Probabilistic Sample Locations of Clearance Samples on Floor 2 of INL PBF-632 for INL-2 Test Events 3 and 5 (contd)

Area	X Center	Y Center	Label	Value	Type	Row	Col	Sample Type
Office 213	259.5028	272.4577		0	Hot Spot Cell	2	1	wipe
	321.7456	272.4577		0	Hot Spot Cell	2	2	swab grill
	290.6242	321.9692		0	Hot Spot Cell	3	1	vacuum
	352.8670	321.9692		0	Hot Spot Cell	3	2	wipe
	259.5028	371.4808		0	Hot Spot Cell	4	1	vacuum
	321.7456	371.4808		0	Hot Spot Cell	4	2	wipe
	290.6242	420.9923		0	Hot Spot Cell	5	1	vacuum
	352.8670	420.9923		0	Hot Spot Cell	5	2	wipe
	259.5028	470.5039		0	Hot Spot Cell	6	1	vacuum
	321.7456	470.5039		0	Hot Spot Cell	6	2	vacuum

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