MKM Engineers, Inc.

FINAL STATUS SURVEY PLAN

# Final Status Survey Plan for Curtis Bay Former J and K Line Building Areas

## DRAFT-FINAL

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# 1.0 Introduction

This Plan has been prepared to guide the final status radiological survey of a portion of the Defense National Stockpile Center located at the Curtis Bay Depot in Glen Burnie, MD, a suburb of Baltimore. The survey covers the ground area where warehouses identified as the J and K Line warehouses were located. The former J and K line buildings occupied a land area of approximately 50 acres just to the east of the intersection of the entrance road to the Curtis Bay Depot and Kulig Road, the main east-west interior artery of the Depot. The building footprints each occupy about 3,000 $ft^2$ in area and are separated by about 300 ft in the former J and K Lines. Eight of the eleven former buildings are identified as impacted areas to be included in the scope of the final status survey. The final status survey design follows the methodology of the MARSSIM guidance document utilizing the US EPA's Data Quality Objectives (DQO) process [ref 1]. The survey is described in detail in the following sections addressing:

- Facility description and utilization
- Identification of radionuclides of concern
- Acceptable residual activity levels (DCGLs)
- Establishment of Survey Units and classification based on contamination potential
- Survey instrumentation and procedures
- DQO's for survey design
- Determination of number and location of samples
- Survey Quality Control
- Evaluation of results
- Final Status Survey Report

# 2.0 Background Information – Facility History

Prior to 1977, the J and K Line warehouse buildings were used to store thorium nitrate, described as reactor and mantle grade material (47% $ThO_2$ concentration) [ref 2]. During warehouse operation, the thorium nitrate was stored in fiberboard drums in the eight J and K Line Buildings located south of Kulig Rd, the main east-west artery traversing the Curtis Bay Depot. Many of the drums degraded in time and thorium nitrate leaked onto the flooring. In some cases, it also leaked through the flooring and into the soil below. After removal of the stored thorium nitrate, a cleanup and decontamination effort was conducted in 1997-98. As part of this effort, DNSC removed portions of the floors and excavated soil from beneath the structures. In 1978, the US Nuclear Regulatory Commission (NRC) performed an inspection and approved release of the buildings for unrestricted use [ref 2].

The buildings were demolished in July 2002. Radiological surveys were performed in parallel with demolition to confirm the radiological status of the building floors prior to disposal. After building removal, a radiological characterization survey of the soil at each building footprint was conducted to determine levels and distribution of any contaminated soil that may remain. These survey activities were conducted in accordance with a survey plan prepared by MKM Engineers and approved by the Army Operations Support Command

(OSC), the contracting organization for this project [ref 3]. Results of this survey, identified as the Phase I Survey, found that elevated gamma readings existed under five of the eight buildings. Soil sampling results showed that elevated thorium existed under three of the buildings. Because the gamma readings were more comprehensive (hundreds of gamma readings versus five soil samples, per building footprint), the Phase I Survey concluded that five of the eight footprints (nearly all the K-line) were potentially contaminated.

# 3.0 Survey Preparations

## 3.1 Radionuclides of Concern

As seen from the Phase I survey soil sample results [reference 4], and based on the historical use of the J and K line warehouses for storage of thorium nitrate, the principal radionuclides of concern are the natural thorium series members, Th-232 + daughters. It is also seen that Cs-137 was detected in several of the samples at concentrations several times higher than nominal soil concentrations from global fallout (weapons testing and Chernobyl). As there is no history of use or storage of materials containing Cs-137 at the J and K Line warehouses, it could be that the Cs-137 levels seen in the Phase I samples is due to global fallout. This possibility is supported by a literature review from which the following conclusions are drawn:

- Cs-137 distribution in soils is typically quite variable on a local scale. Individual sample concentrations in US soils within localized areas can vary within orders of magnitude and peak concentrations can be expected to be more than 10 times greater than predicted by fallout deposition studies. Levels in Northeastern US soil as high as 5.0 pCi/g were observed in the mid-1990's [ref. 5].
- Soil activity concentrations in the vicinity of buildings are found to show localized areas of elevated concentration in drainage areas such as roof drip-lines and drain spout discharge areas [ref. 6]. The situation at Curtis Bay was very conducive to this phenomenon, i. e., buildings with many years exposure to precipitation with roof runoff discharged to the soil adjacent to and underneath the buildings.

Nevertheless, Cs-137 will be evaluated as a contaminant of concern.

## 3.2 Acceptable Residual Activity Levels (DCGLs)

The proposed release criteria (DCGLs) are 1.1 pCi/g Th-232 (and daughters – assumed to be in secular equilibrium), and 11.0 pCi/g Cs-137. These are obtained from published NRC screening values [ref. 7]. Even though, it is likely that the Cs-137 observed in Phase I soil samples is probably not of Curtis Bay origin, it will be accounted for in determining satisfaction of DCGLs. If levels of Cs-137 are observed that are above nominal site "background" levels, compliance will be determined by applying the "sum of fractions" rule, using both Th-232 and Cs-137. For survey design purposes, the parameters for Th-232 distribution will be used to determine the number of samples required, since the Th-232 DCGL is controlling. In determining compliance with site release criteria, each impacted portion of the site (individual survey unit) is examined. The three compliance tests outlined in MARSSIM [ref 1] summarized in Section 5.0, Table 4 will be applied to the results from each survey unit.

In addition to satisfaction of tests for comparison of survey unit sample means (medians) to DCGLs (see discussion of $DCGL_W$ and the Wilcoxon Rank Sum test in Section, 6.3 below), consideration is given to treatment of small areas of elevated activity. An evaluation was conducted to determine an appropriate value for $DCGL_{EMC}$, the guideline value applied to small areas of elevated activity. For this survey, the largest "un-sampled area" in a Class I survey unit is about 22 $m^2$. An Area Factor value of 2.7 for Th-232 corresponding to 22 $m^2$ is obtained from MARSSIM Table 5.6 (by interpolation). The $DCGL_{EMC}$ is then found to equal ~ 3.0 pCi/g Th-232 ($DCGL_{EMC}$ = Area Factor x DCGL, or 2.7 x 1.1 pCi/g). The $DCGL_{EMC}$ determines the scan sensitivity needed to ensure that potential areas of elevated activity (that could lie between sampled areas) will be detected. The $DCGL_{EMC}$ compares well to the scanning MDC estimated in MARSSIM Table 6.7 (3.0 pCi/g vs. 1.8 pCi/g). Since the Area Factor is determined from actual sampling plans for the site, *a posteriori*, no additional samples are required to provide assurance that small areas of elevated activity are properly assessed.

## 3.3 Identification and Classification of Survey Units

As indicated above in the introduction, the eight J and K Line Building footprints located to the south of Kulig Road, and their immediate vicinity, comprise the scope of the final status survey. A survey unit has been established to cover each of the eight building footprints and, as appropriate, additional survey units are established to cover the ground area surrounding those survey units. Figure 1 shows a schematic view of the J and K Line area of the Depot. It identifies the eight impacted building footprints and the area selected as the "reference" area.

Based on results of the Phase I characterization survey, the six impacted K Line building footprints are classified as Class 1 survey units. The Building 511K footprint is established as the reference area for background determinations and statistical comparison tests of final status survey (FSS) results. The two J Line footprints are classified as Class 2, because Phase I survey results show surface gamma and soil sample results at or very near background levels [ref. 4], and thus are not expected to yield FSS measurements in excess of the $DCGL_w$. Additional Class 2 survey units are established to cover "buffer" areas surrounding the six-Class 1 J Line survey units. Figure 2 shows a conceptual layout of the survey units and their classification.

## 3.4 Instrumentation and Procedures

Surface scans of Class 1 areas will be performed with 100% coverage and approximately 50% average coverage in Class 2 areas. The scans will be performed using 2 x 2 in. sodium iodide detectors coupled to Ludlum scaler-rate meters, e.g., Model 2350-1.

# Figure 1

**Identification of Survey Units For Final Status Survey of Former J and K Line Building Areas (Not to Scale)**

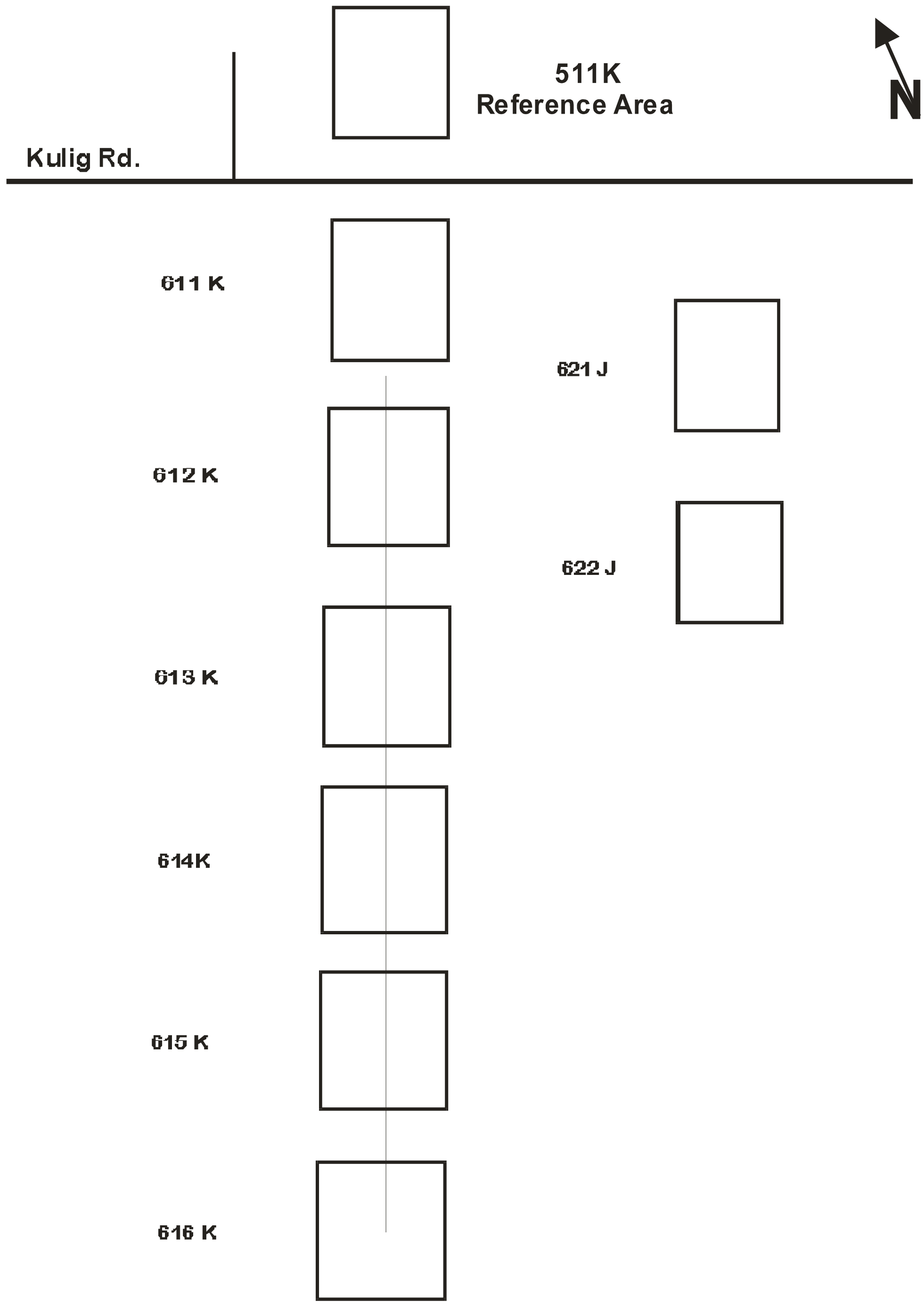
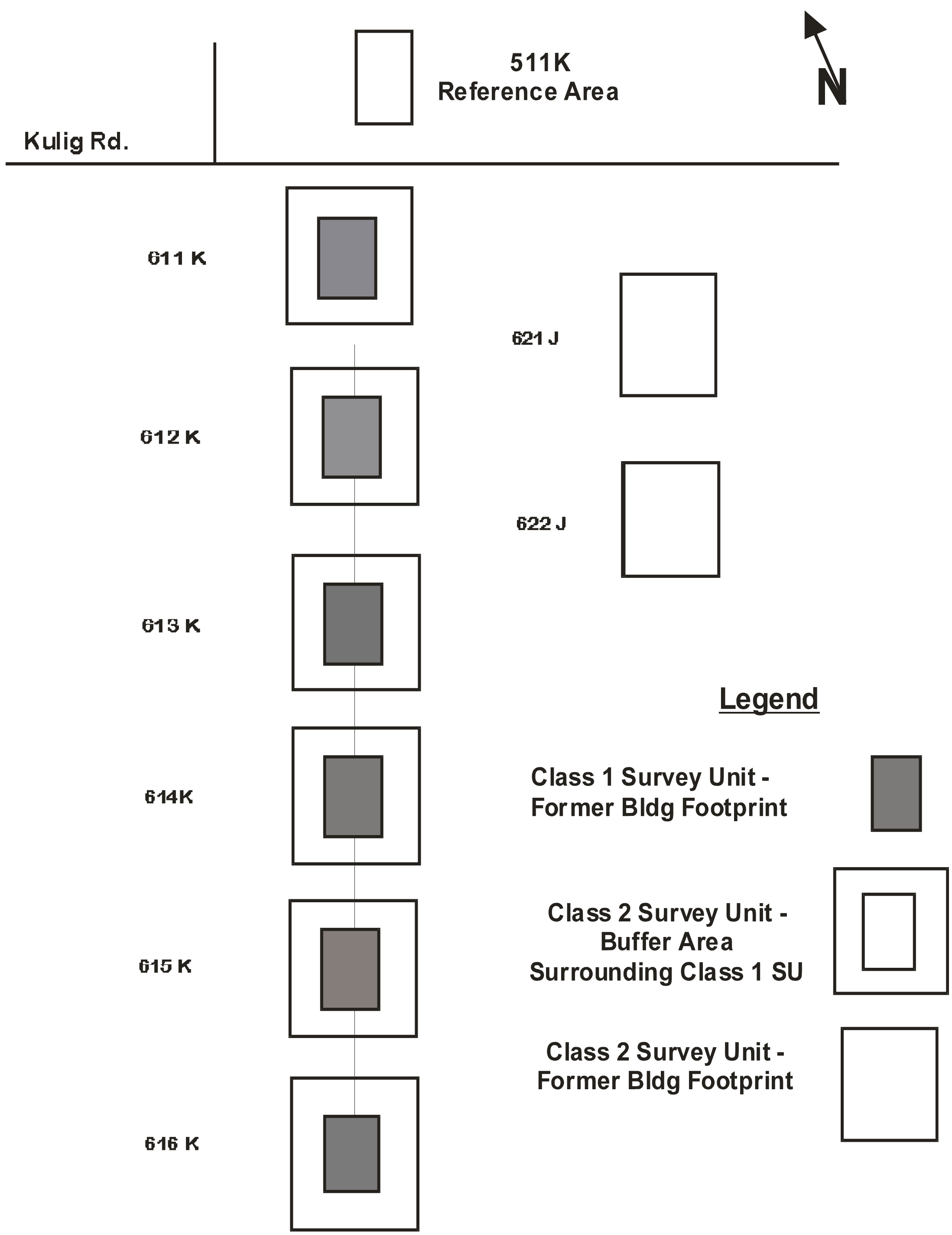


**Figure 2**

Curtis Bay Depot - Classification of Survey Units
(Not to Scale)



Following remediation, final status survey samples of soil will be collected and analyzed by a qualified laboratory. The release of the facility will be based on the results of the soil sampling and analysis. The number of soil samples to be taken from each of the survey units and background area is detailed below. The soil samples will be taken in a systematic manner on a grid spacing of approximately 2.5 meters in class 1 areas and 10 meters in Class 2 areas. In accordance with MARSSIM methodology, a randomly selected starting point for the grid pattern in each survey unit will be used to provide an unbiased method for determining measurement locations. Surface (0-15 cm) samples will be collected from each sampling location.

The samples will be sent to the Severn-Trent Laboratory in St. Louis, MO for analysis by gamma spectroscopy on an HPGe gamma spectroscopy system. The analytical laboratory requires approximately 500 g. of soil for the analysis. Approximately 750 g. of soil will be collected from each location. Samples are prepared by removing vegetation, rocks, and foreign objects exceeding ¼ inch in diameter. The samples, once prepared, are placed into an appropriate container. Sampling equipment and tools will be cleaned and monitored after each sampling; in accordance with MKM procedures to ensure no cross contamination occurs during the sampling process. If contamination is found above the minimum detectable count rate of the survey instrument, the equipment will be decontaminated. Sampling methods, chain of custody, and analysis requirements are detailed in MKM SOP's.

Background nuclide concentrations in soil will also be measured. Background locations at former Building 511K will be selected. This is the footprint of a similar former warehouse that was not used for radioactive material storage. Sufficient samples will be collected; to allow statistical comparisons with affected building footprints as determined by the survey design procedure presented in Section 4.2 below.

# 4.0 Survey Design

## 4.1 Data Quality Objectives

The objective of this final status radiological survey is to obtain data of sufficient quantity and quality to demonstrate that the excavated areas meet the criteria for unrestricted release. That is, contamination levels are below the approved DCGLs. As described above, laboratory analysis of soil samples will be used to meet this objective.

A summary of the Data Quality Objectives (DQO) process is given in Table 1. The results of this process include:

- definition of hypothesis for testing achievement of DCGLs
- decision-error tolerance limits
- parameters to implement the MARSSIM methodology for estimation of number of samples (LBGR, relative shift, etc)
- estimates of variability of soil Th-232 concentrations in the reference area and in the impacted areas
- minimum detectable activities (MDAs) for soil sample analytical method

These are discussed in the following sections. Regarding the last bullet, the laboratory has determined, *a priori*, that it can achieve a Minimum Detectable Activity (MDA) of less than or equal to 0.1 pCi/gram. This level of activity represents less than 25% of the specified DCGL of 1.1 pCi/gm.

**Table 1. Data Quality Objectives**

| DQO Step | DQO |
|---|---|
| State the Problem | Radioactive material storage may have resulted in the release of radioactive materials to soils under the building floors. |
| Identify the Decision | Does the residual radioactivity in the survey unit exceed the release criteria? |
| Identify Inputs to Decision | Confirmation that radionuclides were used.<br>Types of radionuclides that were used or present at facility.<br>Physical characteristics of survey areas.<br>Physical and chemical form of radioactive material (is it dispersible?).<br>Area classification (1, 2, or 3).<br>Surface release criterion (DCGL).<br>Residual radioactivity levels in suspect areas and background survey unit.<br>Quantitative data from survey units. |
| Define the Boundaries of the Study | Footprints of former storage buildings (warehouses) and areas immediately surrounding the footprints. |
| Develop a Decision Rule | Determine if results of analytical measurements exceed the release criteria (DCGL). |
| Specify Limits on Decision | The DCGL is set for each radionuclide. For thorium-232 it is 1.1 pCi/gram; for cesium-137 it is 11 pCi/gram. |
| Optimize Design | Described in the following sections. |
| | |

## 4.2 Number of Samples

An important factor in performing this survey is the number of soil samples to be collected. The number of samples required is determined in accordance with Project DQOs as described above. The number of samples for each area (survey unit) is calculated using equation 5-2 in MARSSIM [ref. 1]. This is:

$\mathbf{N = (Z_{1-\alpha} + Z_{1-\beta})^2 / 3(Pr - 0.5)^2}$, where:

$\mathbf{Z_{1-\alpha}}$ = Type I decision error probability

$\mathbf{Z_{1-\beta}}$ **=** Type II decision error probability

$\mathbf{P_r}$ = non-parametric probability parameter that expresses the true probability that a sample result exceeds the hypothetical population median probability (hypothetical probability of exceeding the median is 0.5)

**3 =** value associated with the Wilcoxon rank sum test

The parameter values identified in the discussion of DQO's were used to determine the number of samples for the individual class 1 and class 2 survey units (SU). The number of samples for each survey unit are presented in Table 2 below. As explained in the Table 2 notes, the principal assumptions are:

- The number of samples for each Class 1 SU, and the reference area, is calculated using MARSSIM Equation 5-2 with $\alpha = 0.05$ and $\beta = 0.05$.
- The number of samples for each Class 2 SU is calculated using MARSSIM Equation 5-2 with $\alpha = 0.05$ and $\beta = 0.10$.
- The lower bound of Gray Area (LBGA) is assumed to be one-half DCGL (DCGL = 1.1 pCi/g Th-232+ progeny).
- The No. of samples for each survey area is the greater of the No. calculated for the reference area or the individual SU in question.

The calculations of sample numbers for Class 1 units are shown in detail in Appendix 1 and the calculations for Class 2 units are in Appendix 2.

It is intended to use a number of soil sample results from the Phase I characterization survey as part of the final status survey. The results used are from grids that will not be remediated or disturbed during the upcoming soil remediation activity. The net number of samples in each survey unit is given in Table 3.

**Table 2.**
**Curtis Bay Final Status Survey Design Summary – Number of Soil Samples**

| Survey Unit | Class One Units No. of Samples | Class Two Units No. of Samples |
|---|---|---|
| 511K (ref. Area) | 11 | -- |
| 611K | 11 | 9 |
| 612K | 11 | 9 |
| 613K | 11 | 9 |
| 614K | 11 | 9 |
| 615K | 11 | 9 |
| 616K | 17 | 9 |
| 621J | -- | 12 |
| 622J | -- | 10 |
| Totals | 83 | 76 |

Table 2 Notes:

1. Number of samples for each Class 1 SU, and the reference area, is calculated using MARSSIM Equation 5-2 with $\alpha = 0.05$ and $\beta = 0.05$.
2. Number of samples for each Class 2 SU is calculated using MARSSIM Equation 5-2 with $\alpha = 0.05$ and $\beta = 0.10$.
3. Lower bound of Gray Area (LBGA) is assumed to be one-half DCGL (DCGL = 1.1 pCi/g Th-232+ progeny)
4. The No. of samples for each survey area is the greater of the No. calculated for the reference area or the individual SU in question.

**Table 3.**
**Net Number of Samples To Be Collected in Final Status Survey**

| Survey Unit | Class One Units No. of Samples | Class Two Units No. of Samples | No. of Valid Phase I Samples | Class One Units Net No. of Samples – | Class Two Units Net No. of Samples – |
|---|---|---|---|---|---|
| 511K (ref. area) | 11 | -- | 5 | 6 | |
| 611K | 11 | 9 | 5 | 6 | 9 |
| 612K | 11 | 9 | 4 | 7 | 9 |
| 613K | 11 | 9 | 3 | 8 | 9 |
| 614K | 11 | 9 | 3 | 8 | 9 |
| 615K | 11 | 9 | 5 | 6 | 9 |
| 616K | 17 | 9 | 3 | 14 | 9 |
| 621J | -- | 12 | 5 | -- | 7 |
| 622J | -- | 10 | 5 | -- | 5 |
| Totals | 83 | 76 | 38 | 55 | 66 |

Table 3 Note:
1.Phase I soil samples from grids not remediated will be used as FSS samples.

### 4.3 Reference Grid System and Selection of Sample Locations

Sample locations in each survey unit have been established using the Visual Sample Plan (VSP)©, software package.[1] The VSP module for implementation of MARSSIM non-parametric sampling designs was used. Sample locations were established by systematic sampling on a triangular grid with random starting location. The VSP output for each survey unit includes a graphic (to scale) and a table showing the coordinates of each sample location. Sample locations are provided in each survey unit for the number of samples specified in Table 3 above (in survey units with valid Phase I sample results, the Phase I sample locations are substituted for the nearest VSP selected locations). The coordinates for the sample locations in each survey unit are expressed in terms of a local coordinate system

[1] Visual Sample Plan is a software program for statistical design of environmental sampling plans developed by Battelle Memorial Institute at Pacific Northwest Laboratories. The current version is 2.0. (see the VSP web site at " www.dqo.pnl.gov/vsp/").

established for the survey unit with origin at the NW corner of the building. The building NW corners are also located on the Maryland State Plane coordinate system to provide a location reference to the Curtis Bay site. The sample plans for each survey unit are being prepared for use in the field, and will be included in the final status survey report.

# 5.0 Survey Quality Control

## 5.1 Survey QC

The MKM Project Manager will ensure that survey technicians are complying with the Final Status Survey Plan during their operations in the field. Any deviations will be resolved immediately to ensure compliance. Issues that cannot be resolved will be brought to the attention of the MKM Program Manager. Any QC audits will be recorded.

## 5.2 Instrumentation QC

Instrumentation used for the surveys will be subject to standard quality assurance (QA) tests. Background, battery checks, efficiency determinations, and two daily source checks were performed for all instruments. The instruments will be checked once at the beginning of the workday and once at the end of the day. Calibration certificates, minimum detectable activity (MDA) calculations, and chi-square determination will be included in the final status report.

The ratemeter will be subject to rigorous quality control tests. These tests include background determination, MDA calculation, source checks, and chi-square determination. The daily source check is compared to the one established after calibration, to ensure measurements are within ± 20% of the established average. Instrument calibrations will be less than one year old.

## 5.3 Contract Laboratory QC

The fundamental objective for the accuracy, precision, sensitivity, completeness, and comparability of the laboratory analyses, is to meet the quality-control acceptance criteria specified for that analytical method and for that matrix. MKM's contract with analytical laboratories shall specify the required precision, accuracy, sensitivity, and completeness.

### 5.3.1 Accuracy of Analytical Measurements

The analytical results from control samples and matrix spikes/matrix spike duplicates shall be assessed to ascertain the accuracy of a radio-analytical method or analysis. The percent recovery of matrix spikes and the percent difference of lab duplicates are used to generate accuracy-control charts.

Range analysis also may be used to evaluate the accuracy of radiological data. Statistical range analysis is used to calculate the expected mean range and control limits for a replicate or duplicate result, and assess whether the result is "in control;" a range analysis value that lies within three standard deviations of the mean is considered in control. Those greater than this are considered to be "out of control."

Results that are out of control may be re-analyzed as required by the method, or they may be flagged or qualified for use during data validation.

### 5.3.2 Precision of Analytical Measurements

To assess the precision of an analytical method, instrument measurement, or laboratory analysis, a routine program of duplicate or replicate analysis shall be followed. The results are used to calculate the relative percent difference (RPD) or Relative Error Ratio (RER) for duplicates, matrix-spike duplicates, or replicates. These values then may be used to generate precision control charts for radiation measurements. The RPD or RER may be used to assess the precision of repeat field measurements, field duplicates, matrix-spike duplicates, or laboratory replicate measurements for radiochemical analyses. The RER statistical test is used when the duplicate concentrations are less than three times the minimum detectable concentrations.

Range analysis may be used to evaluate the precision or reproducibility of radiological data derived from methods for which the performance data are not available. Statistical range analysis is used to calculate the expected mean range and control limits for a replicate or duplicate result, and to assess whether the result is "in control." A range analysis result that lies within three standard deviations of the mean is considered in control; those greater are considered to be "out of control." The latter may be re-analyzed as required by the method, or may be flagged or qualified for use during data validation.

### 5.3.3 Sensitivity of Analytical Measurements

Minimum detectable concentrations (MDCs) are the objective measures of an instrument's sensitivity for radiochemical analyses. Instrument sensitivity during a specific analysis or measurement is monitored by the analyses of method blanks, environmental background measurements, calibration check samples, and laboratory control samples.

Minimum detectable concentration is also used to specify the sensitivity for total surface and removable surface contamination measured with portable radiation detection instruments. Instrument detection limits for portable instrumentation are a function of the ambient background level at the point of measurement. For Th-232 analysis, the laboratory has determined, *a priori*, that it can achieve a Minimum Detectable Activity (MDA) of less than or equal to 0.1 pCi/gram. This level of activity represents less than 10% of the specified DCGL of 1.1 pCi/gm.

The gamma spectroscopy counting system is calibrated for the nuclides of concern using a NIST-traceable standard in the appropriate sample geometry. System performance is QA/QC verified daily using a NIST-traceable standard. Daily source and background checks are documented.

#### 5.3.4 Completeness of Data

The completeness of data can be defined by the percentage of total useable points from the set of total data-points collected, analyzed, and available. Data points may not be useable if sample holding-times were exceeded, quality-control criteria were not met and resulted in the data being qualified as rejected "R" or estimated with a negative bias "J (-)", or if the samples cannot be re-analyzed correctly. Also, data may not be useable if sample bottles were damaged or lost during shipment to the laboratory.

Completeness is expected to be at least 90 percent for this survey. If there are insufficient data points to meet data quality objectives, the valid data obtained shall be used and additional sampling and analysis will be considered to meet the survey objectives.

## 6.0 Evaluation of Survey Results

### 6.1 Soil Sample Results

The laboratory utilizes the gamma emissions from the daughter product Ac-228 (assumed to be in secular equilibrium) to determine Th-232 concentration. Gamma activities will be also be determined for, Pb-212, Bi-212, Tl-208, Pb-214, and Bi-214—other gamma emitting members of the thorium decay series. The results will be examined to confirm secular equilibrium. Any other peaks found, such as Cs-137, will also be reported. The activity of Th-232, Analytical error ($2\sigma$) and MDA for each analysis result will also be reported.

### 6.2 Comparison to DCGLs

Analytical results of soil sampling will be compared to DCGL values, after subtraction of background levels using the MARSSIM approach for evaluation when a reference area is used. The evaluation steps include:

- Compare the largest site measurement to the smallest background measurement.
- Compare the average site measurement to the average background measurement.
- Use the Wilcoxon rank sum test to determine if the site data (less background) exceed the DCGL.

This process is summarized in tabular form in Table 4.

**Table 4.**
**Evaluation of Sample Results When a Reference Area is Used**

| Survey Result | Conclusion |
|---|---|
| Difference between the largest survey measurement and the smallest background measurement is less than the DCGL. | Site meets release criterion. |

| | |
|---|---|
| Difference between the average survey measurement and the average background measurement is greater than the DCGL. | Site does not meet release criterion. |
| Difference between the average survey measurement and the average background measurement is less than the DCGL, but the difference between any site measurement and any background measurement exceeds the DCGL. | Site meets release criterion if Wilcoxon rank sum test is negative. |

### 6.3 Statistical Considerations

In accordance with the MARSSIM [ref. 1] distribution-free or non-parametric statistics will be used to demonstrate compliance with numerical goals for soil activity concentration measurements. The Wilcoxon rank sum test will be used to compare the measurements from each bay to measurements from the background area.

Using the MARSSIM methodology, the Null hypothesis is stated as "the residual activity in the survey unit exceeds the release criteria" [ref. 1]. Thus, in order to pass the survey unit (that is, release the area), a higher standard must be met (more protective), by rejecting the null hypothesis. Under this hypothesis, the probability of making a Type 1 error is denoted by alpha ($\alpha$), and a Type II error is denoted by beta (ß). Alpha is set at 0.05, and beta is set a 0.05, which may be interpreted as a regulator's tolerance (of 5 percent) for an incorrect decision to release the site (using the prescribed statistical test) at the numerical goal. As the site concentration proportionately exceeds the numerical goal, the regulator's error probability will decrease.

The Wilcoxon rank sum test will be performed as described in MARSSIM [ref.1], using $\alpha$ = ß = 0.05. Each Survey Unit meeting the third condition in Table 1 will be tested using this test. The test will determine if the survey area's median thorium concentration exceeds the background plus the DCGL.

## 7.0 Final Status Survey Report

Upon completion of the final status radiological survey, a Final Status Survey Report will be compiled to include an executive summary, survey results, an evaluation of the survey results, photo-documentation (digital) of site activities, and other necessary documentation.

## 8.0 References

1. US Environmental Protection Agency, et, al. "Multi-Agency Radiation Survey and Site Investigation Manual" (MARSSIM). NUREG-1575/ EPA402-R-97-016, Final December 1977..

2. US Army Operations Support Command, "Scope of Work – Radiological Decommissioning Curtis Bay Depot, Curtis Bay, MD", HQ OSC Project DLA 00-004-RAD, March 19, 2002.

3. MKM Engineers, Inc. "Radiological Survey Plan for J and K Lines, Curtis Bay Army Depot Baltimore, Maryland", June 2002, Rev 2.

4. MKM Engineers, Inc, "Radiological Survey in Support of Decommissioning of J- and K-line Buildings at Curtis Bay Depot, September, 2002.

5. G. P. Bernhardt, et. al, "Cs-137 in Wood Ash within the State of Maine", Health Physics, June 1992; 62 (6 Suppl.)

6. A. Wallo III, et. al, "Investigations of Natural Variations of Cs-137 Concentrations in Residential Soils", Health Physics, June 1994; 66 (6 Suppl).

7. US Nuclear Regulatory Commission, "Consolidated NMSS Decommissioning Guidance", NUREG-1757 Volume 1, Appendix B.

## Attachments:

1. **Curtis Bay FSS Design - Calculated Number of Soil Samples for Class 1 Areas**

2. **Curtis Bay FSS Design - Calculated Number of Soil Samples for Class 2 Areas**

## Contract No.: DAAA09-02-G-0017-0001
## Final Status Survey Plan
## Curtis Bay Former J and K Line Building Areas

### Appendix 1
### Calculated No of Soil Samples for Class I Areas
### (Fixed LBGA with a = 0.05 and b = 0.05)

| Survey Unit | Sample ID | Th-232 (pCi/g) | Unit Avg | Unit Std Dev | Relative Shift Δ/σ | $P_r$ | N | N + 20% | (N + 20%) / 2 | No of Samples Required |
|---|---|---|---|---|---|---|---|---|---|---|
| **511K** | 511K-001 | 1.55 | | | | | | | | |
| **(ref. area)** | 511K-002 | 1.28 | | | | | | | | |
| | 511K-003 | 1.12 | | | | | | | | |
| | 511K-004 | 0.92 | | | | | | | | |
| | 511K-005 | 1.29 | | | | | | | | |
| | | | 1.23 | 0.23 | 2.363 | 0.944167 | 18.29 | 21.95 | 10.97 | 11 |
| **611K** | 611K-001 | 1.32 | | | | | | | | |
| | 611K-002 | 1.32 | | | | | | | | |
| | 611K-003 | 1.37 | | | | | | | | |
| | 611K-004 | 1.12 | | | | | | | | |
| | 611K-005 | 0.87 | | | | | | | | |
| | | | 1.20 | 0.21 | 2.645 | 0.961428 | 16.95 | 20.33 | 10.17 | 11 |
| **612K** | 612K-001 | 1.57 | | | | | | | | |
| | 612K-001D | 1.39 | | | | | | | | |
| | 612K-003 | 1.25 | | | | | | | | |
| | 612K-004 | 1.23 | | | | | | | | |
| | 613K-005 | 1.5 | | | | | | | | |
| | | | 1.39 | 0.15 | 3.673 | 0.993329 | 14.83 | 17.79 | 8.90 | 11 |
| **613K** | 613K-001 | 1.26 | | | | | | | | |
| | 613K-002 | 1.57 | | | | | | | | |
| | 613K-004 | 1.36 | | | | | | | | |
| | | | 1.40 | 0.16 | 3.476 | 0.983039 | 15.46 | 18.56 | 9.28 | 11 |
| **614K** | 614K-001 | 1.06 | | | | | | | | |
| | 614K-002 | 1.14 | | | | | | | | |
| | 614K-003 | 0.77 | | | | | | | | |
| | | | 0.99 | 0.19 | 2.825 | 0.974067 | 16.05 | 19.27 | 9.63 | 11 |
| **615K** | 615K-001 | 1 | | | | | | | | |
| | 615K-002 | 1.01 | | | | | | | | |
| | 615K-003 | 0.69 | | | | | | | | |
| | 615K-004 | 0.77 | | | | | | | | |
| | 615K-005 | 1.08 | | | | | | | | |
| | | | 0.91 | 0.17 | 3.244 | 0.983039 | 15.46 | 18.56 | 9.28 | 11 |
| **616K** | 616K-002 | 0.24 | | | | | | | | |
| | 616K-004 | 0.94 | | | | | | | | |
| | 616K-005 | 0.71 | | | | | | | | |
| | | | 0.63 | 0.36 | 1.542 | 0.855541 | 28.54 | 34.25 | 17.13 | 17 |
| **Combined Areas** | | | 1.11 | 0.32 | 1.715 | 0.885299 | 24.30 | 29.16 | 14.58 | |
| | | | | | | | | | **Total** | **83** |

**Notes:**
1. Number of samples is calculated using MARSSIM Equation 5-2, with $\alpha = 0.05$ and $\beta = 0.05$.
2. Lower Bound of Gray Area is assumed to be one-half of the DCGL.
3. 511K is used as the reference area for this calculation.
4. The value of $P_r$ is obtained from MARSSIM Table 5.1
5. Each survey unit is evaluated in combination with 511K, so the number of samples required is the larger of the 511k result and the unit in question.
6. Sample results used in calculating the required number of FSS Samples include only those Phase I results less than the DCGL plus background, i. e., < 2.33 pCi/g Th-232. Grids above this value will be remediated.

**Contract No.: DAAA09-02-G-0017-0001**
**Final Status Survey Plan**
**Curtis Bay Former J and K Line Building Areas**

**Appendix 2**
**Calculated No of Soil Samples for Class 2 Areas**
**(Fixed LBGA with a = 0.05 and b = 0.10)**

| Survey Unit | Sample ID | Th-232 (pCi/g) | Unit Avg | Unit Std Dev | Relative Shift $\Delta/\sigma$ | $P_r$ | N | N + 20% | (N + 20%) / 2 | No of Samples Required |
|---|---|---|---|---|---|---|---|---|---|---|
| **511K (ref. area)** | 511K-001 | 1.55 | | | | | | | | |
| | 511K-002 | 1.28 | | | | | | | | |
| | 511K-003 | 1.12 | | | | | | | | |
| | 511K-004 | 0.92 | | | | | | | | |
| | 511K-005 | 1.29 | | | | | | | | |
| | | | 1.23 | 0.23 | 2.363 | 0.944167 | 14.48 | 17.37 | 8.69 | 9 |
| **621J** | 621J-001 | 0.88 | | | | | | | | |
| | 621J-001DI | 1.15 | | | | | | | | |
| | 621J-002 | 1.67 | | | | | | | | |
| | 621J-003 | 1.51 | | | | | | | | |
| | 621J-004 | 1.46 | | | | | | | | |
| | 621J-005 | 0.91 | | | | | | | | |
| | | | 1.26 | 0.33 | 1.659 | 0.871014 | 20.75 | 24.90 | 12.45 | 12 |
| **622J** | 622J-001 | 0.8 | | | | | | | | |
| | 622J-002 | 1.09 | | | | | | | | |
| | 622J-003 | 1.3 | | | | | | | | |
| | 622J-004 | 1.49 | | | | | | | | |
| | 622J-005 | 1.17 | | | | | | | | |
| | | | 1.17 | 0.26 | 2.147 | 0.921319 | 16.09 | 19.31 | 9.65 | 10 |
| **Combined Areas** | | | 1.22 | 0.26 | 2.076 | 0.921319 | 16.09 | 19.31 | 9.65 | 10 |
| | | | | | | | | | **Total** | **31** |

**Notes:**
1. Number of samples is calculated using MARSSIM Equation 5-2, with $\alpha$ = 0.05 and $\beta$ = 0.10.
2. Lower Bound of Gray Area is assumed to be one-half of the DCGL.
3. 511K is used as the reference area for this calculation.
4. Class 2 areas associated with K Line Class 1 areas use reference area relative shift value (2.363).
5. The value of $P_r$ is obtained from MARSSIM Table 5.1
6. Each survey unit is evaluated in combination with 511K, so the number of samples required is the larger of the 511k result and the unit in question.