Final Status Survey Plan

Kaiser Aluminum & Chemical Corporation
Thorium Remediation Project
Tulsa, Oklahoma

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Prepared By:

Penn E&R
Environmental & Remediation, Inc.

Penn Environmental & Remediation, Inc.
359 Northgate Drive, Suite 400
Warrendale, PA 15086

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EFFECTIVE DATE: MARCH 2004

Bill Vinzant

APPROVED BY: J.W. Vinzant, Project Manager

DATE: 3-31-04

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1.0 Introduction

Penn Environmental & Remediation, Inc. has been retained by Kaiser Aluminum & Chemical Corporation (Kaiser) to provide a radiological Final Status Survey Plan (FSSP) in support of the final decommissioning of their Kaiser Aluminum Specialty Products facility (Tulsa facility) located at 7311 East 41st Street in Tulsa, Oklahoma. Decommissioning of the Tulsa facility has been authorized by the Nuclear Regulatory Commission (NRC) pursuant to their approval of the decommissioning plan (DP) (Reference 1) and DP addendum (DPA) (Reference 2) for the Tulsa facility. The purpose of the DP and the DPA is to decommission the Tulsa facility safely and meet the NRC requirements for unrestricted use: residual radioactivity distinguishable from background will not result in a total effective dose equivalent (TEDE) to an average member of a critical group (resident farmer) that exceeds 25 millirem per year (mrem/yr). Additionally, implementation of the DP and the DPA will reduce residual radioactivity to levels that are as low as reasonable achievable (ALARA).

This FSSP implements the Final Status Survey (FSS) technical approach authorized by the NRC in Chapter 14.0 of the DP and DPA, namely the protocols and guidance provided in NUREG-1575, Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) (Reference 3) to demonstrate compliance with the DP and DPA release criteria discussed above. This FSSP documents the approach, methods, and techniques for the radiological FSS to be used to achieve unrestricted release of the Tulsa facility.

The DP addresses the remediation of the affected portions of the 14-acre "Pond Parcel" at the Kaiser facility and the DPA addresses the approximate 3.5-acre former "Operational Area." These areas are introduced further in Sections 1.2 and 1.3. The DP Pond Parcel is divided into three parts--the unaffected former Freshwater Pond area to the west (approximately 4 acres), the affected Retention Pond/Reserve Pond area to the east (approximately 9 acres), and the area adjacent to the Flux Building and paved area (approximately 1 acre). The known affected area covers approximately 10 acres east of the former Freshwater Pond eastern embankment. The DPA former Operational Area is principally a triangular parcel of land north of 41st Street and south of the Union Pacific Railroad (UPRR) right-of-way in which plant processes and operations occurred. Presently, none of the original buildings in which magnesium-thorium alloy processing occurred exist on site. The Flux Building, located to the northeast of the triangular parcel, is part of the former Operational Area.

1.1 Historical Operations Perspective

The Standard Magnesium Corporation (SMC) built the Kaiser plant in Tulsa, Oklahoma in the early to mid-1950s to manufacture magnesium products. Kaiser purchased the facility in 1964. SMC received a source materials license (C-4012) from the Atomic Energy Commission in March 1958 to receive possession and title to magnesium-thorium alloy (a thorium metal) with up to 4 percent thorium content for processing. Historical operations at the facility included the smelting of scrap magnesium alloy for the production of anodes. Scrap magnesium-thorium alloy was smelted, along with other magnesium materials, to recover the magnesium. Thorium alloy material comprised a small fraction of the total magnesium refined on site. Licensed operations involving the recovery of magnesium-thorium alloy began in 1958 and continued through 1968. Magnesium refining operations continued at the facility until approximately 1985. Aluminum replaced magnesium in smelting and anode manufacture, and the plant continued operating until the 1997-1998 time frame.

The scrap magnesium alloy refining process consisted of placing the material into large melting pots, heating the material until molten, and then siphoning off the pure magnesium. Impurities from the mixture, including thorium, separated from the magnesium. This residue material was removed, allowed to cool, and crushed. The crushed material was returned to the heating pots for a second recovery process. Once refined, the metallic dross residue material was crushed and disposed on site.

The quantity of material SMC and later Kaiser were authorized to possess at one time was amended from time to time, but generally was limited to 30,000 pounds of magnesium-thorium alloy containing no more than 4 percent thorium. There appears to be no records indicating the actual quantity of material that was on site at any give time.

In regard to decommissioning activities, the site is divided into two areas: the Pond Parcel area where the dross residues were stored and the former Operational Area where the site structures were located.

1.2 Pond Parcel Description

Extensive site characterization activities have been conducted since 1994 within the 14-acre land area of the facility known as the Pond Parcel. These characterization activities have indicated the presence of residual radioactive material within a 10-acre portion of the Pond Parcel. The radioactive material identified within this portion of land is a thorium-bearing dross containing the isotopes thorium-232 (Th-232), thorium-230 (Th-230), and thorium-228 (Th-228). No elevated uranium has been detected. Th-228 and Th-232 have been determined to be in secular equilibrium. In addition, a ratio of Th-230-to-(Th-232+Th-228)/2 of 3.5 has been calculated based on characterization data.

The affected portion of the parcel contains the Retention Pond and former Reserve Pond area. The unaffected portion of the Pond Parcel contains a former Freshwater Pond area. The DP was prepared to address the decommissioning of the Pond Parcel land area. The Pond Parcel land area considered for remediation is bounded by the south fence line, the former Freshwater Pond embankment on the west, Fulton Creek ditch on the north, the east fence line, and the northern and western edges of the Flux Building and paved area. A central feature of this area is the Retention Pond and associated embankments. Thorium-bearing dross was present on land adjacent to current Kaiser property along the east and south fence lines and represented the margins of the material. Kaiser has remediated this land by excavation and storing affected soil within the Pond Parcel. Affected soil generated during remediation of the adjacent land is considered as part of the on-site decommissioning.

During the evaluation and screening of possible remediation alternatives, data from past characterization studies were used to develop isoconcentration maps to clarify spatial distribution of thorium levels in soils. Kriging, a geostatistical technique, was utilized to accomplish this purpose and to develop volume estimates.

The remediation alternative chosen for the Pond Parcel requires excavating soil and soil-like material within the impacted area of the Pond Parcel. Material with Th-232 activity concentrations greater than the derived cutoff concentration level (DCCL) of 31.1 pCi/g Th-232 above background will be segregated and disposed off site as either exempt or nonexempt material at a permitted facility. The derivation of the DCCL is detailed in Section 2.2. Material with activity concentrations below the DCCL, (BDCCL) will be placed in the Pond Parcel excavation as backfill. The average Th-232 content of the BDCCL material is approximately 7 pCi/g. A layer of clean soil obtained from an off-site source will be placed over the BDCCL backfill and graded in a manner to direct drainage away from the site, after which the site will be revegetated.

During remediation, the site will be excavated to depths up to 15 to 20 feet and to an average depth estimated at 12 feet across most of the Retention and Reserve ponds. Approximately 4,000,000 cubic feet

(ft^3) of clean off-site soil will be used to backfill excavations. The minimum thickness of the clean fill layer will be 9.84 feet. The site will be graded and vegetated to minimize soil erosion and promote positive drainage.

1.3 Former Operational Area Description

The DP identified the potential for radioactive material beneath several currently paved areas and building floor surfaces of the former Operational Area, based upon an interpretation of historical data and/or observations made during the Adjacent Land Remediation Project (ALRP). As a result, a limited Additional Site Characterization Activities (ASCA) effort was conducted in the former Operational Area during mid-2001. The objective of the ASCA was to determine if thorium-bearing dross/radioactive material was present beneath these areas of concern. Soil data obtained during the ASCA indicated the presence of residual radioactive material beneath several concrete-paved surfaces at relatively shallow depths. The presence of this material beneath the surfaces is most likely the result of historical grading activities.

A Historical Site Assessment (HSA) was performed during late 2001 for the Operational Area of the former Kaiser Aluminum Specialty Products facility. The HSA was conducted as the first step toward decommissioning the former Operational Area at the facility. The objective of the HSA was to compile as much historical information as possible for the facility and, using the MARSSIM guidelines, categorize the land areas and structures of the former Operational Area of the facility as either impacted or nonimpacted. Presently, none of the original buildings in which magnesium-thorium alloy processing occurred exist on site. With the exception of the Flux Building, there are no buildings in the former Operational Area of the facility classified as impacted in the HSA. The Flux Building was initially classified as an impacted structure due to past and current uses of the building to house and process soil core and surface samples. Land areas initially classified as impacted included the land areas beneath the Maintenance Building, the Crusher Building, the Crusher Addition Building, the North Extrusion Building, the Warehouse Building, and the former Smelter Building, as well as concrete paved areas completed post-1958.

The results of the HSA (Appendix A of the DPA) were used to design radiological survey efforts for the structures and land areas of the former Operational Area. The recommended radiological extended scoping (nonimpacted structures) and characterization (impacted land areas) survey efforts were described in a work plan prepared by Earth Sciences Consultants, Inc. (Reference 4). The primary objectives of the extended scoping survey of the six structures were to verify their initial classification of "nonimpacted" during the HSA. The primary objectives of the characterization survey of the "impacted" land areas were to determine the nature and extent of residual radioactive materials within the former Operational Area and collect sufficient data to support evaluation of remedial alternatives and technologies for the impacted land areas of the former Operational Area. The radiological survey efforts were completed during the months of January and February 2002. Results of the radiological surveys are presented in Chapter 4.0 of the DPA.

Based on the results of the survey effort, select land areas of the former Operational Area were identified for remediation. These areas include the following and are illustrated in Figure 1-1.

- A portion of the land area beneath the former Warehouse Building (Characterization Survey Unit 7)
- A portion of the land area beneath the former Crusher Building (Characterization Survey Unit 9)
- The land area beneath a "built-up" dock area located immediately west of the former Crusher Building (Characterization Survey Unit 5)
- The land area beneath a built-up dock area located immediately west of the former Maintenance Building (Characterization Survey Unit 3)
- A portion of the land area beneath a paved concrete surface situated northwest of the former Maintenance Building, northeast of the former North Extrusion Building, and south of the Union Pacific Railroad right-of-way (Characterization Survey Unit 2)
- A portion of the land area along a concrete retaining wall situated at the southeastern corner of the former Maintenance Building (Survey Unit 5)
- A portion of the land area beneath a paved concrete surface situated to the north of the former Warehouse Building (Characterization Survey Unit 5)
- A portion of the land area beneath a paved concrete surface situated north of 41st Street and the former Crusher Building, south of the UPRR right-of-way, and west of the areas remediated during the ALRP (Survey Unit 8)

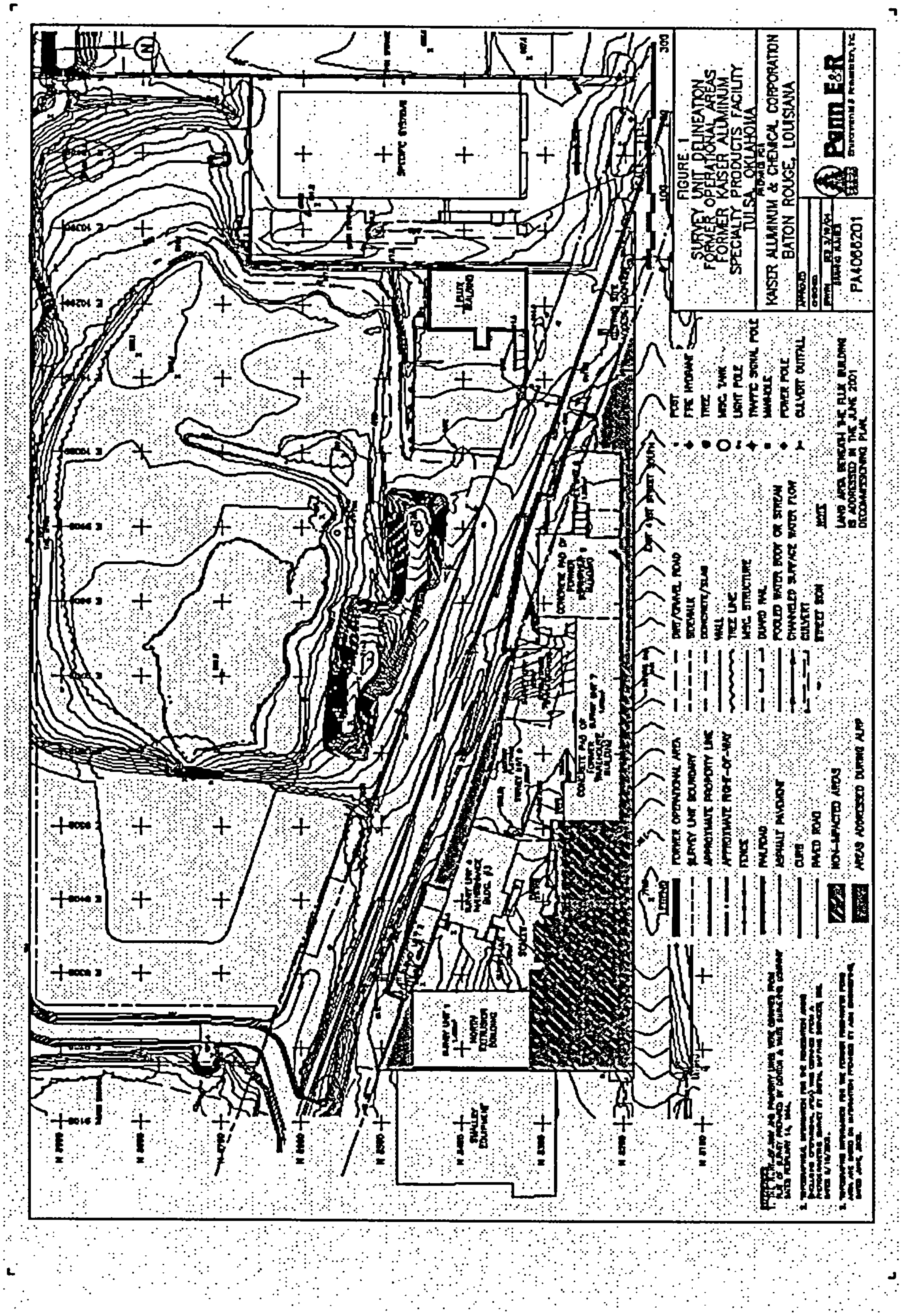
FIGURE 1
SURVEY UNIT DELINEATION
FORMER OPERATIONAL AREAS
FORMER KAISER ALUMINUM
SPECIALTY PRODUCTS FACILITY
TULSA, OKLAHOMA
KAISER ALUMINUM & CHEMICAL CORPORATION
BATON ROUGE, LOUISIANA
PA4066201
Penn E&R
FORMER OPERATIONAL AREA
SURVEY UNIT BOUNDARY
APPROXIMATE PROPERTY LINE
APPROXIMATE RIGHT-OF-WAY
FENCE
RAILROAD
ASPHALT PAVEMENT
CURB
PAVED ROAD
NON-IMPACTED AREAS
AREAS ADDRESSED DURING ALRP
DIRT/GRAVEL ROAD
SIDEWALK
CONCRETE/SLAB
WALL
TREE LINE
MISC. STRUCTURE
GUARD RAIL
POOLED WATER BODY OR STREAM
CHANNELED SURFACE WATER FLOW
CULVERT
STREET SIGN
POST
FIRE HYDRANT
TREE
MISC. TANK
LIGHT POLE
TRAFFIC SIGNAL POLE
MANHOLE
POWER POLE
CULVERT OUTFALL
LAND AREA BENEATH THE FLUX BUILDING IS ADDRESSED IN THE JUNE 2001 DECOMMISSIONING PLAN.
NORTH EXTRUSION BUILDING
CONCRETE PAD OF FORMER WAREHOUSE BUILDING
FLUX BUILDING
100
200
300

Figure 1-1

The planned remediation for the former Operational Area requires excavating material with a net Th-232 activity concentration greater than the Derived Concentration Guideline Level ($DCGL_w$) of 3.0 pCi/g. The excavated material will be transported to the Pond Parcel where material with Th-232 activity concentrations greater than 31.1 pCi/g Th-232 above background will be segregated on site and disposed off site as either exempt or nonexempt material at a permitted facility. Material with activity concentrations below 31.1 pCi/g Th-232 above background Th-232, BDCCL, will be placed in the Pond Parcel excavation as backfill. Once the former Operational Area is remediated to acceptable levels, it will be cleared through a MARSSIM-directed FSS. Most likely, this will be conducted in stages where certain survey units will be cleared and backfilled as excavation occurs in other areas.

Approximately 60,000 ft^3 of clean off-site soil will be used to backfill the excavations in the former Operational Area. The site will be graded and vegetated to minimize soil erosion and promote positive drainage.

1.4 FSSP Overview

This FSSP has been developed to address a wide range of decommissioning activities in accordance with the guidance of MARSSIM. The plan's technical approach is based on performing an FSS for open land (soil) areas and structural surface areas (including the embedded spillway) that are classified as impacted. The goal of this survey plan is to present a combination of measurements and analytical sampling/analyses based on the current guidance of MARSSIM that will achieve unrestricted release of the Tulsa facility.

In addition, gamma dose rate surveys will be performed in areas adjacent to the former Retention (dross) Pond identified in the ALRP FSSR, to confirm that elevated gamma levels measured during the ALRP were due to radioactive material in the pond.

The remainder of this document provides dose-based acceptance criteria (Chapter 2.0), survey unit classifications (Chapter 3.0), MARSSIM survey design parameters (Chapter 4.0), survey instrumentation and measurement techniques (Chapter 5.0), quality assurance/quality control (QA/QC) (Chapter 6.0), and interpretation of survey results (Chapter 7.0).

2.0 Release Criteria

The site will be released in accordance with decommissioning criteria of Subpart E, Radiological Criteria for License Termination of 10 Code of Federal Regulations (CFR) Part 20, Standards of Protection Against Radiation. Specifically, Subpart E, 10 CFR 20.1402, Radiological Criteria for Unrestricted Use (Reference 5), allows release of a site for unrestricted use if the residual radioactivity distinguishable from background results in a TEDE to an average member of the critical group that does not exceed 25 mrem/yr for 1,000 years and the residual radioactivity has been reduced to levels that are ALARA.

Dose-based criteria have been established for the Kaiser site for three distinct surveys: (1) surveys of the open land areas of the site including the former Operational Area, the processing/segregation area, and the bottom of the Pond Parcel excavation; (2) surveys of the Pond Parcel excavation BDCCL backfill material; and (3) surveys of structure surfaces.

2.1 Open Land Areas Acceptance Criteria

The concentration of residual radioactivity (per radionuclide) distinguishable from background that, if distributed uniformly throughout a survey unit, results in a TEDE of 25 mrem in 1 year to an average member of the critical group is the single radionuclide $DCGL_W$. Single radionuclide $DCGL_W$ values for the radionuclides of concern at the Kaiser site have been calculated using the guidance provided in NUREG-1549, Decision Methods for Dose Assessment to Comply With Radiological Criteria for License Termination (Reference 6) for open land areas of the site. In order to use Th-232 activity concentration as a surrogate for the presence of multiple radionuclides, the Unity Rule was applied, and the relative activities of all site radionuclides relative to Th-232 were use to adjust $DCGL_W$ values as shown in Table 2-1.

Table 2-1 - $DCGL_W$ Values

Radionuclide	Single Radionuclide $DCGL_W$ (pCi/g)	Ratio to Th-232 Assuming Equilibration	Average Concentration with Th-232 Radionuclide $DCGL_W$ (pCi/g)	Adjusted $DCGL_W$ to Meet Unity Rule (pCi/g)
Pb-210	1.751	0.043	0.15	0.12
Ra-226	5.9	0.082	0.28	0.24
Ra-228	4.3	1	3.4	3
Th-228	3.4	1	3.4	3
Th-230	102	3.5	12	10
Th-232	3.4	1	3.4	3

The result is a Th-232 surrogate value of 3 pCi/g that represents the full complement of site radionuclides; i.e., if the concentration of Th-232 is below 3 pCi/g, the resulting TEDE is less than 25 mrem in any 1 year for 1,000 years. This value is applicable acceptance criteria for the open land areas of the site including the former Operational Area, the processing/stockpile area, and the bottom of the Pond Parcel excavation.

Table 2-2 presents area factors (based upon MARSSIM guidance) to be used for elevated measurement comparisons (EMC) and to determine sampling requirements in situations where the scan instrument's minimum detectable concentration (MDC) is greater than the $DCGL_W$. The $DCGL_{EMC}$ values applicable to the open land areas of the site area are calculated by multiplying the $DCGL_W$ by the area factors presented in Table 2-2. $DCGL_{EMC}$ values are presented in Table 2-3.

$$DCGL_{EMC} = \text{Area Factor} * DCGL_W$$

Table 2-2 - Area Factors

	Area Factors								
Radio-nuclide	1 m^2 (11 ft^2)	3 m^2 (32 ft^2)	10 m^2 (108 ft^2)	30 m^2 (323 ft^2)	100 m^2 (1,076 ft^2)	300 m^2 (3,229 ft^2)	1,000 m^2 (10,764 ft^2)	3,000 m^2 (32,292 ft^2)	10,000 m^2 (107,639 ft^2)
Th-232	12.5	6.2	3.2	2.3	1.8	1.5	1.1	1.0	1.0

Table 2-3 - $DCGL_{EMC}$ Values for Open Land Areas

	$DCGL_{EMC}$ (pCi/g)								
Radio-nuclide	1 m^2 (11 ft^2)	3 m^2 (32 ft^2)	10 m^2 (108 ft^2)	30 m^2 (323 ft^2)	100 m^2 (1,076 ft^2)	300 m^2 (3,229 ft^2)	1,000 m^2 (10,764 ft^2)	3,000 m^2 (32,292 ft^2)	10,000 m^2 (107,639 ft^2)
Th-232	37.5	18.6	9.6	6.9	5.4	4.5	3.3	3.0	3.0

2.2 Pond Parcel Backfill Material Acceptance Criteria

In developing the remedial action plan for the Pond Parcel area, a derived cutoff concentration level (DCCL) of 31.1 pCi/g Th-232 above background has been determined. This value represents the dividing line concentration between material which must be exported to an off-site disposal facility and material which can remain on site under an unrestricted release scenario. Based upon kriging analyses (Appendix A of the DP), on average, material above the DCCL is exempt. Moreover, the kriging volume estimates together with the dose assessment presented in Chapter 5.0 of the DP demonstrate that unrestricted release dose levels can be achieved when BDCCL material is returned to the excavation. The average concentration of the BDCCL material remaining on site is termed the Average Derived Concentration Level (ADCL). Based upon dose evaluations, the ADCL, rounded to 7 pCi/g Th-232, results in a postremediation TEDE well below 1 mrem/yr.

The result is a Th-232 surrogate segregation value of 31.1 pCi/g Th-232 above background that represents the full complement of site radionuclides; i.e., segregated material at a concentration of below 31.1 pCi/g Th-232 above background results in a TEDE less than 25 mrem in any 1 year for 1,000 years. This value is applicable acceptance criteria for the Pond Parcel backfill material.

The three important Th-232 surrogate concentration criteria and their significance are summarized below in Table 2-4.

Table 2-4 - Th-232 Soil Concentration

Parameter	Value (pCi/g Th-232)	Application
$DCGL_W$	3.0	Release criterion for open land areas (former Operational Area, soil stockpile/processing area and Pond Parcel excavation bottom)
DCCL	31.1	Release criteria for Pond Parcel backfill material (segregation threshold for off-site disposal of material)
ADCL	7	Estimated average concentration of material left on site as backfill

Table 2-2 presents area factors (based upon MARSSIM guidance) to be used for EMCs and to determine sampling requirements in situations where the scan instrument's MDC is greater than the DCCL. For the BDCCL material used as Pond Parcel backfill, the ADCL value was multiplied by the area factors presented in Table 2-2 and the results are presented in Table 2-5.

$$ADCL_{EMC} = \text{Area Factor} * ADCL$$

However, since the material used as backfill is material below 31.1 pCi/g Th-232 above background, the EMC is only applicable to concentrations exceeding 31.1 pCi/g Th-232 above background. The ADCL value of 7 pCi/g of Th-232 was conservatively used to establish elevated measurement criteria for the backfill material greater than 31.1 pCi/g Th-232 above background, to maintain the average concentration of the backfill material ALARA.

Table 2-5 - $ADCL_{EMC}$ Values for Pond Parcel Areas

	$ADCL_{EMC}$ (pCi/g)								
Radio-nuclide	1 m^2 (11 ft^2)	3 m^2 (32 ft^2)	10 m^2 (108 ft^2)	30 m^2 (323 ft^2)	100 m^2 (1,076 ft^2)	300 m^2 (3,229 ft^2)	1,000 m^2 (10,764 ft^2)	3,000 m^2 (32,292 ft^2)	10,000 m^2 (107,639 ft^2)
Th-232	87.5	43.4	22.4	16.1	12.6	10.5	7.7	7.0	7.0

2.3 Structures Acceptance Criteria

For structure surfaces, the radionuclide-specific average total contamination acceptance criteria were derived using the DandD code with all default parameters. Values calculated using DandD are referred to as screening values by the NRC. The NRC allows use of these screening values in lieu of site-specific DCGL values that must be submitted to the NRC for approval. (Refer to Federal Register [FR] Volume 63, No. 222, Page 64132-64134, November 18, 1998, Reference 7). The NRC screening values assume that removable contamination is not more than 10 percent of the total contamination screening value.

The acceptance criteria for structures shown in Table 2-6 are the average total surface contamination and the average removable surface contamination levels that correspond to the dose-based radiological criteria of 10 CFR 20 Subpart E. The limits are radionuclide specific and the sum of fractions (Unity Rule) must be applied to show compliance with the acceptance criteria.

Table 2-6 – Structures Radionuclide-Specific Release Criteria (dpm/100cm^2)

Radionuclide	Structures Total Contamination (dpm/100 cm^2)	Structures Removable Contamination (dpm/100 cm^2)
Th-228	41.1	4.11
Th-230	36.9	3.69
Th-232	7.31	0.731

From the radionuclide-specific values and the activity ratios of the radionuclides established for the site, a Gross Activity DCGL (GA-DCGL) was calculated using Formula No. 4-4 provided in MARSSIM. The calculated GA-DCGL value is 21.5 disintegrations per minute per 100 square cubic meters (dpm/100 cm^2) for average total surface contamination and 2.15 dpm/100 cm^2 for removable contamination. Refer to the calculation brief contained in Appendix D to the DPA for a derivation of these GA-DCGL values. The calculation brief also presents area factors (based upon default DandD code) to be used for EMC and to determine sampling requirements in situations where the scan instruments' MDC is greater than the GA-DCGL.

Table 2-7 - Structural Surfaces Area Factors

Elevated Area	100 cm^2	0.1 m^2	0.5 m^2	1 m^2	2 m^2	5 m^2	10 m^2
Area Factor	1,000	100	20	10	5	2	1

Table 2-8 - $DCGL_{EMC}$ Values for Structural Surfaces (dpm/100cm^2)

Elevated Area	100 cm^2	0.1 m^2	0.5 m^2	1 m^2	2 m^2	5 m^2	10 m^2
$DCGL_{EMC}$	21,500	2,150	430	215	107.5	43	21.5

3.0 Survey Area Classification

3.1 Initial Survey Area Classification

All Tulsa facility areas have undergone a characterization study and/or an HSA that is used as the basis for the initial determination of the area classification established in this section. The assessment included a combination of the following:

- A review of Kaiser records including licenses, drawings, operations procedures, and other relevant site records.
- Interviews with employees who were familiar with operations at the site.
- Building exteriors were evaluated based on a review of building entrances/exits, ventilation exhausts, and the presence of drains.

The characterization and HSA were performed to determine the current radiological status of site structures and open land areas. Each area was characterized as impacted or nonimpacted based on the following MARSSIM definitions:

- **Nonimpacted** areas have no reasonable potential for residual contamination and require no further evidence to demonstrate compliance with release criterion.
- **Impacted** areas have a potential for radioactive contamination (based on historical data) or contain known radioactive contamination (based on past or current survey data). For areas of known radioactive contamination, areas adjacent to these locations may also be characterized as impacted based on the potential for inadvertent spread of contamination.

3.1.1 Characterization Survey Results Summary

The former Freshwater Pond area is nonimpacted. Results of characterization surveys indicate that the remainder of the Pond Parcel east of the former Freshwater Pond area is impacted. The land areas have been classified in accordance with MARSSIM based on the existing characterization survey data. In addition, part of the adjacent land was impacted and was remediated in 2000-2001. The adjacent land area was surveyed under NUREG/CR-5849 (Reference 8) and the unrestricted release approved by the NRC in 2002.

3.1.2 Survey Area Classification Scheme

The survey area classification scheme for planning FSSs of land areas and structures is outlined in Table 3-1. Each impacted area and structure will be sampled in accordance with MARSSIM sampling density requirements and the area classification shown in Table 3-1.

Table 3-1
Survey Area Classification Scheme

Class	Definition	Survey Unit Size
Land Areas		
1	Areas known or expected to have radionuclide concentrations above the $DCGL_W$	Up to 2,000 m^2
2	Areas known or expected to have radionuclide concentrations above normal background concentrations but that are not expected to be above the $DCGL_W$	2,000 to 10,000 m^2
3	Areas that are not expected to have radionuclide concentrations detectable above normal background concentrations	No limit
Structure Surfaces		
1	Areas known or expected to have radionuclide concentrations above the $DCGL_W$	Up to 100 m^2 of floor area
2	Areas known or expected to have radionuclide concentrations above normal background concentrations but that are not expected to be above the $DCGL_W$	100 to 1,000 m^2
3	Areas that are not expected to have radionuclide concentrations detectable above normal background concentrations	No limit

3.1.3 Initial Survey Area Classifications

The initial (i.e., FSS planning basis) classification of the Tulsa facility is listed in Table 3-2 based on completion of Tulsa facility characterization discussed above. The majority of the land area is impacted and classified as Class 1. The only nonimpacted area is the Freshwater Pond parcel based on site history and the adjacent land based on FSS results. While the former Freshwater Pond area currently is not impacted, this area may be used as a material processing area. Therefore, all areas in the Pond Parcel, with the exception of the clean backfill cover and any of the Freshwater Pond not used for material processing, have been designated as impacted (Class 1) for purposes of classification and FSS.

The only identified subsurface structural surface is the spillway, impacted as Class 1. The spillway is a large concrete pad located beneath the impacted pond parcel. The spillway will again be covered with soil and soil like material after remediation is complete. As such, the spillway does not deliver dose as a structure (assumed occupancy of structure) but rather like the soil areas of the site. Because of this and the potential inaccessibility of the spillway structural surface, the final status survey protocol of the spillway may be a combination of soil and structural survey and sample techniques. All additional subsurface structures discovered during excavation in Class 1 open land areas will be classified as Class 1.

For Class 1 and 2 areas, the actual number of survey units that will be delineated depends on the total area size and the survey unit size constraint for the respective survey unit class.

Table 3-2
FSS Initial Survey Area Classifications

Area	Description	Classification
Processing Area (Fresh Water Pond)	Part of the area currently occupied by a Freshwater Pond which will be used for processing/stockpiling excavated materials (≈ 1-9 survey units).	1
Former Retention Pond Area Bottom and Sidewalls	Area formerly occupied by the dross Retention Pond and Reserve Pond, postexcavation of dross (≈21 survey units).	1
Former Retention Pond Area	Area formerly occupied by the dross Retention Pond and Reserve Pond, backfilled with below-criteria material in 2-foot survey lifts (≈21 survey units per lift).	1
Former Operational Area	The triangular parcel of land north of 41st Street and south of the UPRR right-of-way in which plant processes and operations occurred.	1
Spillway/Other Permanent Structures	Structures (such as the spillway) located where thoriated material is known to exist. The total area of these structures cannot be determined until uncovered by excavation.	1

3.1.4 Selection of Survey Units

Each impacted area listed in Table 3-2 will be divided into a number of survey units based on the classification scheme outlined in Table 3-1. Selection of the survey units will be based on areas having similar operational history or similar potential for residual radioactivity to the extent practical. Survey units also will have relatively compact shapes unless an unusual shape is appropriate for the site operational history or site conditions.

3.2 Reassignment of Survey Area Classifications

All areas will not have the same potential for residual contamination and, accordingly, will not need the same level of survey coverage to achieve the established release criteria. The initial area classifications are based on a combination of characterization data and historical information. Additional information obtained during the remediation process may lead to the determination that the initial classifications established in Table 3-2 should be revised to be consistent with the definitions given in Table 3-1. Each survey area classification change will be recorded as an FSSP variation and documented in the FSS report.

3.2.1 Classification Upgrades

Any area classification may be upgraded to a more restrictive final survey protocol (e.g., from Class 2 to Class 1) by the Data Manager or designee based on the receipt of additional survey or measurement information that justifies the need for the higher classification. Classification upgrades are not anticipated at the Tulsa facility since all initial area classifications (Table 3-2) are at the most restrictive Class 1 level.

3.2.2 Classification Downgrades

Any area classification may be downgraded to a less restrictive final survey protocol (e.g., from Class 1 to Class 2) by the Data Manager or designee based on the receipt of additional survey or measurement information that justifies the need for the lower classification. Downgrades are contingent on receipt of documented approvals from the NRC prior to completion of the downgraded final survey.

4.0 Survey Design

4.1 Final Status Surveys

FSSs will be performed to demonstrate that average residual radioactivity levels within each survey unit meet the applicable acceptance criteria identified in Chapter 2.0. The principal features of the FSS land area protocol to be applied at the Tulsa facility are discussed below and include the following:

- Hypothesis Testing
- Acceptable Decision Error Rates
- Wilcoxon Rank Sum (WRS) Testing
- Surrogate Radionuclide Selection
- Establishing Radiological Background
- Locating Discrete Soil Samples
- Scanning

4.1.1 Hypothesis Testing

To provide statistically robust decisions regarding survey unit acceptability with respect to achieving the unrestricted use acceptance criteria approved for the Tulsa facility, the paired hypothesis testing approach is used. The paired hypotheses are the null, H_O, and alternative H_A statements. The null hypothesis H_O poses that the measured average residual contamination in a survey unit *exceeds* the remedial objective (e.g., the $DCGL_W$ activity concentration). The complementary alternative hypothesis H_A presumes that the measured average residual contamination in a survey unit is *at or below* the remedial objective. The outcome of hypothesis testing is used to ascribe a statistically based level of confidence or probability (using the decision error rates and hypothesis testing matrix shown in Section 4.1.2) to the decision made regarding the "true" as-left condition of a survey unit.

4.1.2 Decision Error Rates

Survey unit radiological measurement data will be used to objectively determine the success or failure of the remediation work; i.e., whether the "true" as-left radiological condition is at or below ("success"), or above ("failure"), the applicable remedial objective. This FSS determination framework for the Tulsa facility is depicted in the matrix below.

Hypothesis Testing Matrix for Survey Unit FSS Measurement Decisions

		Survey Unit Decision	
	Hypothesis	*"Success"* (Reject H_O)	*"Failure"* (Accept H_O)
"True" Condition of the Survey Unit	**H_A** Meets remedial objective (e.g., at or below $DCGL_W$ value)	No decision error (probability = 1 - α)	Incorrectly fail to release survey unit (Type II error with probability = β)
	H_O Exceeds remedial objective (e.g., exceeds $DCGL_W$ value)	Incorrectly release survey unit (Type I error with probability = α)	No decision error (probability = 1 - β)

"Success" means that the null hypothesis H_O can be rejected and, therefore, the alternative hypothesis H_A is to be accepted at a decision error confidence interval of (1 - α). The rejection of H_O also means that there is a very small likelihood (equal to the interval α) that the "success" decision is incorrect. Similarly, "failure" means that H_O is accepted (and H_A rejected) at a decision error confidence interval of (1 - β), with again a small likelihood (equal to β) that the failure decision is incorrect.

The error control data quality objective (DQO) confidence intervals selected for the Tulsa facility are α = 0.05 for Type I errors and β = 0.05 for Type II errors. The Type I error control DQO was selected because decisions regarding the success of remediation efforts directly affect the sustained protection of human health and environmental resources. The same DQO is used to cap conservative Type II decision errors because it is also important to limit unwarranted remediation.

As explained in the next subsection, hypothesis testing will be implemented using the WRS Test using these DQO confidence intervals.

4.1.3 WRS Testing

All survey units will be evaluated to determine whether the average residual radioactivity concentration in the survey unit as a whole is below the applicable acceptance criterion concentration, i.e., the $DCGL_W$ or DCCL. The FSS will use both systematic grid sampling to determine this average radionuclide concentration in a survey unit in conjunction with scans to identify elevated areas of residual radioactivity. At least the minimum number of samples (N/2) will be taken in each survey unit. Since the radionuclides of remediation interest at the Tulsa facility also occur naturally in background, survey unit FSS data will be compared to data from a reference area under what is known as a "two-sample test," the WRS Test. Application of the WRS Test is described below.

When using the WRS Test, the minimum number of samples (N/2) is the number of samples required in the survey unit and in the reference background area. Hence "N" is the total number of samples required to complete the WRS Test. Paramount to determining the minimum number of samples is the determination of the relative shift, delta over sigma (Δ/σ). Delta is equal to the DCGL minus the lower-bound gray region (LBGR) value. The LBGR value is arbitrarily set at one-half the DCGL value to start the determination. Sigma is an estimate of the variability in a set of sample analysis results from a survey unit.

The estimate of sigma used is based on the standard deviations in Th-232 activity measured in survey units during the FSS sampling of the adjacent land remediation final survey (0.42). Sigma may be increased if the spatial variability of contaminants within a given survey unit is expected to be greater than 0.42. Since the Th-232 activity concentration of 3.0 pCi/g will be used as the surrogate DGCLw, Δ is equal to 3.0 - 1.5, or 1.5. Delta divided by the sigma of 0.42 results in a relative shift of 3.57 which is rounded to 3.5 for the purpose of determining the required number of samples. The number of samples will be calculated using the following formula or looked up in Table 5.3 of MARSSIM:

$$N/2 = \frac{(Z_{1-\alpha} + Z_{1-\beta})^2}{3(P_r - 0.5)^2}$$

where:

$Z_{1-\alpha}$ = percentile represented by selected value of α, Table 5.2 of MARSSIM,
$Z_{1-\beta}$ = percentile represented by selected value of β, Table 5.2 of MARSSIM, and
P_r = value obtained from Table 5.1 of MARSSIM.

Based on a relative shift of 3.5, the number of samples that are required to meet the Tulsa facility DQO is:

Tulsa Facility Minimum FSS Land Area Sample Collection Density

Survey Unit Area (m^2)	Land Area Classification	DQO Type I Error (α) Control	DQO Type II Error (β) Control	Sample Locations (N/2)
2,000	1	0.05	0.05	9
2,000 to 10,000	2	0.05	0.05	9
10,000 and above	3	0.05	0.05	9

The number of samples in the above table includes a factor to increase the number of required samples by 20 percent, as recommended by MARSSIM, to allow for lost or unusable data. The number of required samples may be further increased to increase the power level of the statistical tests. Additional sampling locations may also be necessary if characterization data and remedial action surveys and sampling indicate that there is greater than expected spatial variability (σ) of sample results within specific survey units. For example, if σ is 1 with a $DCGL_W$ of 3.0 and LBGR of 0.5, then Δ is 2.5 and the number of sample locations (N/2) is increased to 11. Likewise, if σ is 4 with a DCCL of 31.1 and LBGR of 21.1, then Δ is 10 and the number of sample locations (N/2) is increased to 11.

4.1.4 Establishing Radiological Background

Knowledge of the radiological background conditions in a suitable reference area is needed for the MARSSIM FSS because the radionuclides contained in the residual radioactivity at the Tulsa facility also appear naturally. Appendix F of the DP contains the reference area, surface soil, and background data consisting of 2 different reference areas located approximately 1 mile apart. The soil type in these reference areas was similar to the soil type at the Tulsa facility. The results of 30 different sampling locations in each reference area presented in the *Adjacent Land Characterization* (Kaiser Aluminum Specialty Products, Appendix A, Estimate of Volume of Off-Site Contaminated Soil, Adjacent Land Characterization Report, ADA, March 1999). Because there was no significant data variability between the 2 reference areas sampled, multiple reference areas are not required for the Tulsa facility.

The average background value for Th-232 activity concentration in soil established for the Tulsa facility is 1.1 pCi/g. The average is calculated from 380 6-inch soil sample analysis results presented in Table 4-1. The samples were taken at taken at two locations: on site in a nonimpacted area and approximately 1 mile off site. Thirty core samples of up to 48 inches were taken and analyzed from each site. The results will be used to select N/2 reference background values when performing the WRS Test.

Table 4-1
Soil Background

Location[1]	Length[2]	Depth							
		0" - 6"	6" - 12"	12" - 18"	18" - 24"	24" - 30"	30" - 36"	36" - 42"	
1	46"	0.98	0.92	1.47	1.35	1.49	1.24	1.09	
2	36"	0.80	1.34	1.24	1.16	1.01	0.67		
3	40"	0.35	0.66	0.57	0.81	0.77	0.76		
4	37"	0.61	1.06	1.07	1.08	1.50	1.16		
5	43"	0.90	0.94	0.81	0.90	1.11	0.98	0.79	
6	39"	0.95	0.84	1.29	1.36	1.46	0.99		
7	40"	0.70	1.18	1.26	1.30	1.33	1.50		
8	41"	1.24	1.33	1.07	1.25	1.63	1.41		
9	38"	0.86	0.82	0.93	1.03	1.27	1.02		
10	37"	0.57	0.47	0.94	0.49	1.18	0.38		
11	41"	0.97	1.07	1.26	1.47	1.32	2.04		
12	39"	0.96	1.21	1.48	1.32	1.63	1.42		
13	42"	1.31	1.09	1.43	1.16	1.27	1.42	0.96	
14	46"	1.13	0.87	0.75	0.89	1.16	1.26	0.96	
15	36"	1.11	1.27	0.99	1.48	1.42	0.56		
16	34"	0.53	0.97	1.25	0.91	1.49			
17	38"	0.91	0.80	1.22	1.52	1.31	1.16		
18	38"	0.60	1.04	0.86	0.92	0.81			
19	40"	0.36	0.57	0.70	0.66	0.60	0.84		
20	41"	1.38	1.25	1.42	1.41	2.06	1.13		
21	39"	1.25	1.25	0.97	1.03	1.30	1.21		
22	40"	1.07	1.43	1.36	1.51	1.63	1.47		
23	46"	1.08	1.22	1.03	1.43	1.54	1.31	1.45	
24	33"	0.85	0.79	1.28	1.35	1.41			
25	46"	0.56	1.18	0.86	1.05	1.18	0.93	0.94	
26	42"	1.47	0.88	1.23	1.02	1.62	1.03	0.74	
27	42"	1.24	0.98	1.06	1.56	1.37	1.38	0.74	
28	44"	1.18	1.46	1.37	0.79	2.32	0.87	1.08	
29	39"	0.90	0.87	0.98	0.90	0.97	1.12		
30	41"	1.25	1.37	1.50	1.22	1.46	1.50		
31	42"	1.33	0.97	1.52	1.62	1.49	1.72	0.47	
32	46"	1.36	1.37	1.27	1.29	1.43	1.32	1.18	
33	46"	0.92	0.67	0.85	0.94	0.84	1.25	0.97	
34	46"	1.12	1.17	1.06	1.45	1.37	1.21	1.31	
35	42"	1.07	0.89	1.04	1.13	1.25	1.22	0.74	
36	38"	0.41	0.57	0.96	0.64	0.70	0.55		
37	46"	0.86	1.09	0.91	1.28	1.12	0.95	0.99	
38	39"	1.02	1.39	1.22	1.32	1.25	0.89		
39	46"	0.70	1.37	1.46	1.01	1.03	0.82	1.02	
40	46"	1.13	1.01	1.20	0.86	1.17	1.11	1.26	
41	41"	0.92	0.91	1.20	1.19	1.39	1.36		
42	33"	0.90	1.04	1.00	1.19	0.87			
43	46"	0.96	1.12	1.09	1.02	1.18	1.21	1.21	
44	34"	1.29	1.45	1.88	1.59	1.20			
45	46"	1.23	0.95	0.54	0.73	0.64	1.04	0.79	
46	36"	0.58	0.98	1.32	0.99	1.13	0.46		
47	39"	0.63	1.00	1.45	2.25	1.02	1.10		
48	40"	1.10	1.01	1.30	1.62	1.37	1.61		
49	28"	0.99	1.27	1.19	1.22				
50	26"	0.97	1.26	1.20	1.31				
51	46"	1.72	1.16	1.16	1.38	1.19	1.26	0.84	
52	46"	1.63	1.50	1.07	1.25	1.31	1.14	1.06	
53	46"	1.29	1.28	0.86	1.20	1.29	1.61	1.32	
54	46"	1.24	0.82	0.78	0.57	0.93	0.86	0.95	
55	46"	1.31	1.29	1.12	1.18	0.89	0.84	0.99	
56	46"	1.17	0.65	0.92	1.14	0.96	0.90	0.96	
57	46"	0.96	1.10	0.64	0.70	1.26	0.87	0.99	
58	46"	1.04	1.20	0.71	0.60	0.79	0.82	0.77	
59	46"	0.96	1.32	1.24	1.29	0.85	1.16	1.02	
60	46"	1.00	1.08	0.96	1.08	1.38	1.07	1.20	Total
Count		60	60	60	60	58	53	29	380
Average		1.00	1.07	1.11	1.16	1.24	1.12	0.99	1.10
Minimum		0.35	0.47	0.54	0.49	0.60	0.38	0.47	0.35
Maximum		1.72	1.50	1.88	2.25	2.32	2.04	1.45	2.32
Median		0.99	1.08	1.11	1.19	1.27	1.13	0.99	1.11
Standard Deviation		0.29	0.24	0.26	0.32	0.32	0.32	0.21	0.30

Notes:
All measurements are for Th-232 (pCi/g).
(1)Numbers 1 through 30 taken on site in an nonimpacted area. Numbers 31 through 60 taken 1 mile off site.
(2)Length is the actual length of the recovered core from a 4-foot increment.

4.1.5 Surrogate Radionuclide Selection

Not all of the radionuclides present at the Tulsa facility can be identified by real-time gamma surveys or by gamma spectroscopy of soil samples--the most efficient and cost-effective measurements. In addition, each of the radionuclides present contributes in varying degrees to the total dose estimated for the Tulsa facility unrestricted use scenario.

Characterization activities have verified that the primary radionuclides of concern at the Tulsa facility are isotopes of thorium. Th-232 and Th-228 are part of the natural thorium decay chain and their relative activities have been verified to be approximately equal, evidence that a secular equilibrium relationship exists between the two nuclides as would be expected for undisturbed natural thorium. Another isotope of thorium, Th-230, has also been identified as a primary radionuclide of concern. Th-230 is a member of the natural uranium decay chain, the parent radionuclides (e.g., Th-234 or Pa-234m) have not been identified to account for the presence of Th-230. This is attributed to the fact that thorium in the magnesium/thorium alloy that was used as feedstock at the Kaiser facility was separated from uranium during purification. In the estimated 55 years since thorium (Th-230) was separated from the uranium decay chain, a small amount of Ra-226 (the next member of the decay chain after Th-230) has in fact grown in. Unfortunately, insufficient time has elapsed since the thorium was separated to regain secular equilibrium between Th-230 and Ra-226 (about 16,000 years would have to elapse for this to occur), so Ra-226 cannot be used to reliably imply the activity concentration of its difficult-to-measure parent Th-230.

Since the gamma emissions from Th-232 daughter nuclide Ac-228 are readily detected with good efficiency, and its activity relationship with Th-230 has been reliably established (see FSSP Section 3.1.1), Th-232 has been selected as the surrogate radionuclide for the Tulsa facility. To determine Th-230 activity concentrations, the surrogate (Th-230:Th-232) activity concentration ratio of 3.5 will be used.

4.1.6 Locating Discrete Samples

4.1.6.1 Soil – Routine Method

The results of discrete soil sampling will be used to verify that the average soil concentration is less than the appropriate remediation criteria (i.e., $DCGL_W$ or DCCL activity concentration values). Regardless of the survey unit classification (Class 1, Class 2, or Class 3), a predetermined minimum number of samples will be collected in each survey unit as shown in Section 4.1.3. A random-start triangular pattern, or grid (generally the most efficient means of identifying small areas of elevated activity), will be used in Class 1 and Class 2 survey units to locate the soil samples. The triangular grid has approximately a 90 percent chance of detecting a circular hot spot of radius equal to one-half the grid spacing. For Class 3 survey units, the samples will be located randomly or at the discretion of the Data Manager.

The distance between each sampling grid node, *L*, will be determined by the following equation:

$$L = \sqrt{\frac{A}{0.866N}}$$

In the above equation, *A* is the survey unit area to be covered by the grid pattern and *N* (equal to N/2 for WRS testing) is the number of samples required for that survey unit. The random start point (X and Y coordinates) will be selected using a readily available random number generator such as the "RAND()" function in the Microsoft computer application *Excel*© (or the *Visual Sample Plan* computer application, Reference 9), or the methodology outlined in Section 5.5.2.5 of MARSSIM. Sample points will be identified in the field by flags or other means using a global positioning system (or equivalent locating tool) to spot each grid node.

Tulsa Facility Example FSS Land Area Sample Collection Density

Area A (m^2)	No. of Samples ($N/2$)	Distance between Grid Nodes L (m)	Size of "Hot Spot" (m^2)
100	9	3.6	10
500	9	8.0	50
1,000	9	11.3	101
2,000	9	16.0	202
4,000	9	22.7	403
5,000	9	25.3	504
10,000	9	35.8	1008

The distance between grid nodes (L) equal to 16.0 meters corresponding to a survey area of 2000 meters squared represents the maximum sample spacing for a Class 1 survey unit. If a Class 1 survey unit exceeds 2000 meters squared but is less than 4000 meters squared (an area easily divided into two Class 1 survey units) for example in a 2000 meter squared unit that has sidewalls adjacent to the surface area that raises the total area to 2600 meters squared, the equation:

$$L = \sqrt{\frac{A}{0.866N}}$$

can be solved for N using the new area (A) of 2600 meters squared and the maximum value of L equal to 16.0 meters, to yield 12 samples.

4.1.6.2 Soil – Scan MDC Greater Than Acceptance Criteria

The routine method described above presumes that the actual scan MDC is less than or equal to the required scan MDC (discussed in the following section), i.e., there is sufficient scan sensitivity available to detect small areas of elevated activity. An elevated scan MDC could be experienced due to an increased background signal attributable to meteorological conditions increasing the airborne concentration of natural radioactivity or confounding radiation sources in an adjacent area. For the infrequent situations where the actual scan MDC exceeds the required scan MDC (acceptance criteria for the survey unit), the alternate method for calculating the required number of samples *N* may be used. This alternate method is described in Section 5.5.2.4 of MARSSIM and involves the calculation of an area factor corresponding to the actual scan MDC as follows:

$$AreaFactor = \frac{ScanMDC(actual)}{DCGL_W}$$

(Depending on the survey unit, *DCCL* may be substituted for $DCGL_W$ in the above equation.) The size of an area of elevated radioactivity corresponding to this area factor is interpolated from Table 2-2 and divided into the survey unit area to determine the alternate number of sample locations N_{EA}. If N_{EA} exceeds the value assigned to *N* in Section 4.1.3, an alternate spacing L_{EA} for the systematic sampling grid is calculated using the equation:

$$L_{EA} = \sqrt{\frac{A}{0.866 N_{EA}}}$$

Otherwise, the equation in Section 4.1.6.1 will be used to specify a routine spacing *L*.

When the recalculated number of samples (N_{EA}) required exceeds the original number of samples (N/2), the samples may be screened on site in a low background area by counting each sample with a standard 2-inch by 2-inch sodium iodide detector for a predetermined count time, e.g., 2 minutes. The N/2 samples with the highest screening result may be sent for analytical analysis to show compliance. For example, if N_{EA} is equal to 12 and N/2 was equal to 9, the 9 samples with the highest gross gamma screening value may conservatively be sent for analytical analysis and completion of the Wilcoxon Rank Sum test.

4.1.6.3 Structure Surfaces

The results of discrete sample point measurements of structure surfaces will be used to verify that the total and removable activity concentrations are less than the GA-DCGL value. Regardless of the survey unit classification (Class 1, Class 2, or Class 3), a predetermined minimum number of sample points will be measured in each survey unit using the same method detailed for soil areas. A random-start triangular grid pattern will be used for equal-distant coverage of Class 1 and 2 areas. Class 3 areas may use the random-start triangular grid for equal-distant coverage or may bias sample locations based on potential for contamination.

The number of structural samples in the table below includes a factor increase of the number of required samples by 20 percent, as recommended by MARSSIM, to allow for lost or otherwise unusable data. The number of required samples may be increased further to raise the power of the statistical tests used to evaluate the sample data. Additional sampling locations may also be necessary if characterization data and sampling activities suggest that there is greater-than-expected spatial variability (σ) in the results within specific survey units. Sigma (σ) is expected to be 7 dpm/100 cm2 for total gross alpha contamination measurements; with a GA-DCGL of 21.5 dpm/100 cm2 and a LBGR of 10.75 ($\Delta = 10.75$), the relative shift is 1.5. Based on a relative shift of 1.5, the number of samples required to meet the Tulsa facility DQO are as follows:

Tulsa Facility Minimum FSS Structure Sample Point Density

Survey Unit Area (m^2)	Structure Classification	DQO: Type I Error (α) Control	DQO: Type II Error (β) Control	Sample Points (N/2)
100	1	0.05	0.05	18
100 – 1,000	2	0.05	0.05	18
Unlimited	3	0.05	0.05	18

The distance between sample grid nodes (L) and the increased number of samples based on scan MDC (N_{EA}) are calculated using the same equations presented for soil samples.

4.1.7 Obtaining Discrete Samples

4.1.7.1 Soil – Open Land Area and Pond Area Excavation Bottom/Sidewall Surface Samples

Surface soil sampling will be conducted to evaluate the average remaining activity concentration of a survey unit. Consistent with MARSSIM FSS method design, surface soil samples will be collected as a composite of the first 15-cm (6-inch) depth of soil removed from the surface. This shallow surface sample depth was conservatively chosen to correspond to the soil mixing or plow depth (root) zone featured in the RESRAD model for the plant uptake and erosion compartments. The entrance diameter of the sample hole needed to obtain the required sample mass for laboratory analysis and archival purposes is approximately 1 foot. The resulting soil sample will be mixed to the extent practical prior to splitting into the required number of analysis containers.

No sample preparation steps will be performed during the field processing of surface soil samples other than the removal of nonsoil material (grass, sticks, rocks, etc.) and decanting free water if present. If there is reason to believe that nonsoil objects are affected by radionuclides of remediation concern, they will be retained for possible further evaluation as a separate sample.

4.1.7.2 Soil – Pond Parcel BDCCL Soil

Some areas of the Tulsa facility will be backfilled at depths greater than 15 cm (6 inches) with BDCCL soil. For this situation where residual radioactivity remains at depth in the subsurface, a core sampling protocol will be used. The number of core samples obtained will be that required by the WRS Test, i.e., nine per Class 1 survey unit. Each core sample will be obtained through the approximate 3-meter (m) layer of placed BDCCL soil. Initially, the entire soil core will be scanned for uniformity using a 2x2 NaI detector in a low background area sufficient to achieve a typical scan MDC of less than 31.1 pCi/g Th-232 above background. The retrieved soil core will then be segmented into the following three fractions that are to be separated, mixed, and placed in analysis containers:

- Core Fraction 1 – 0 to 1 m (0 is referenced to core bottom)
- Core Fraction 2 – 1 m to 2 m
- Core Fraction 3 – 2 m to 3 m

All core fractions will be analyzed by gamma spectroscopy for Th-232 activity concentration with an MDC at a fraction of the DCCL (less than 25 percent).

Core Fractions 1, 2, and 3 are typical soil thicknesses that may be adjusted during the FSS to better represent conditions assumed in dose assessments performed for the Tulsa facility. For example, Core Fractions 1, 2, and 3 may be homogenized into a single fraction for laboratory analysis to better represent the contaminated zone thickness used in the RESRAD development of applicable criteria.

4.1.7.3 Structure Surfaces

Smears for removable contamination are obtained by wiping an area of approximately 100 cm^2, using a dry filter paper while applying moderate pressure. For gross alpha or beta analyses, a 47-millimeter-diameter filter is used. The smear counter MDC will be calculated in accordance with the static MDC equation in Chapter 5.0 with results between 25 and 75 percent of the applicable acceptance criteria.

4.1.8 Scanning

Gamma scanning surveys are to be performed to identify isolated areas of elevated radioactivity that may not be revealed by discrete soil sampling (i.e., confirm that radiological conditions in each survey unit are reasonably uniform) and record the direct radiological profile of each survey unit. (At the Retention Pond area, for example, each 2-foot-thick lift that is placed in an excavation will be completely scanned to ensure that there are no elevated areas.) Surveyor technique, i.e., the pace and pattern of surveyor and detector motion as well as the surveyor's professional judgment, will control the fraction of the survey unit soil surface that is effectively viewed or "covered" by the field instrumentation. The surveyor scanning technique to be employed at the Tulsa facility will limit the detector face-to-soil surface clearance to approximately 2 inches, with a half-meter per second serpentine detector motion. To permit the surveyor to focus on maintaining these detector clearance and motion constraints, the surveyor will rely on the audible response signal from the survey instrument.

The fraction of each survey unit's land area to be covered by gamma scans will be based upon the survey unit classification as shown below.

Land Area Scan Coverage Requirements

Survey Unit Classification	Scan Coverage
Class 1	100 percent
Class 2	10 to 100 percent Systematic and Judgmental
Class 3	Judgmental

The scanning coverage for Class 1 areas will always be total, i.e., 100 percent. The scanning coverage for Class 2 areas (should any Class 1 areas be downgraded to Class 2 at the Tulsa facility) will be adjusted based on the level of confidence supplied by existing data. Whenever partial scanning of a survey unit is required, the Data Manager will determine the degree of scan coverage and which areas are to be scanned based on the information available at the time of survey. For example, if the potential for contamination in a section of the survey unit is higher than the rest (e.g., the section that borders a Class 1 survey unit), this section may receive 100 percent coverage, while the remaining section may receive less (e.g., 50 percent) systematic coverage. If the survey unit has an equally unlikely potential for contamination (e.g., isolated with no previous history of contamination), a systematic 25 percent coverage protocol may be most appropriate and, therefore, chosen. Generally, a larger proportion of a Class 2 survey unit will be scanned if the residual radioactivity is close to the $DCGL_w$ or DCCL.

Class 3 areas have the lowest potential for nonuniform radiological conditions. For this reason, professional judgment-based scanning surveys are recommended for areas within each Class 3 survey unit (should any downgrades to the Class 3 level occur at the Tulsa facility) having the highest relative potential for contamination. This approach provides qualitative levels of confidence that discrete soil sampling will not miss areas of elevated activity or that the area classification is correct.

4.1.9 FSS Protocol

4.1.9.1 Final Survey for Open Land (Soil) Areas

When remediation activities in a survey unit are completed, the following survey tasks will be performed:

- The exposed soil surface will be surveyed by gamma scan to confirm acceptable radiological conditions and identify any elevated areas.
- After any elevated areas have been evaluated and/or remediated and resurveyed, the sample grid and locations will be identified in the field.
- Surface soil samples will be taken and submitted to the laboratory for gamma spectroscopy analysis.
- Survey and sample data will be reviewed as described in Chapter 7.0.

4.1.9.2 Final Survey for Excavation Areas

When remediation activities in a survey unit that required the excavation of a substantial volume of overburden soil are completed, the following survey tasks will be performed for each two foot lift of acceptable BDCCL material returned to the excavation:

- The excavation floor and walls to be covered by the BDCCL lift will be surveyed by gamma scan to confirm acceptable radiological conditions and identify any elevated areas.

- After any elevated areas have been evaluated and/or remediated and resurveyed, the sample grid and locations will be identified in the field.

- Surface soil samples will be taken and submitted to the laboratory for gamma spectroscopy analysis.

- A maximum 2-foot layer of BDCCL containing less than 31.1 pCi/g Th-232 above background will be placed on the excavation floor.

- The BDCCL floor surface and (if necessary) remaining exposed walls will be surveyed by gamma scan.

Once the excavation is filled with the desired amount of below-criteria material:

- the sample grid and locations will be identified in the field,
- the core sampling and analysis event will proceed as described in Section 4.1.7.2, and
- sample data will be reviewed as described in Chapter 7.0.

No surveys of areas backfilled with off-site material are required.

4.1.9.3 Final Survey for the Spillway

The spillway is a large concrete pad located beneath the impacted pond parcel. The spillway will again be covered with soil and soil like material after remediation is complete. As such, the spillway does not deliver dose as a structure (assumed occupancy of structure) but rather like the soil areas of the site. Because of this and the potential inaccessibility of the spillway structural surface, the final status survey protocol of the spillway may be a combination of soil and structural survey and sample techniques. The combination of survey and sampling techniques may include a gamma scan of the surface to identify elevated areas followed by systematic smear samples for removable contamination. If sufficient data of the proper quality cannot be obtained, the spillway may be removed from the excavation and surveyed.

4.1.9.4 Final Survey for Structures

When remediation activities in a survey unit are completed, the following survey tasks will be performed:

- The exposed structural surface will be surveyed by alpha scan to confirm acceptable radiological conditions and identify any elevated areas.

- After any elevated areas have been evaluated and/or remediated and resurveyed, the systematic sample points will be located.

- Static counts for total alpha contamination will be performed at each sample point

- Smear samples will be taken at each sample point and analyzed for removable alpha contamination.

- Survey and static count data will be reviewed as described in Chapter 7.0.

5.0 Survey Instrumentation and Measurement Techniques

This chapter presents a description of radiological field instrumentation and laboratory measurements that will be used during implementation of the Tulsa facility FSSP.

5.1 Land Areas Survey Instrumentation

The gamma-emitting progeny of the surrogate radionuclide Th-232 emit high-energy photons and are easily detected using survey instruments equipped with NaI scintillation crystal detectors. Scanning for gross gamma activity will be used during FSS activities. The following field and process control instruments (or other instruments providing equivalent detection sensitivity) will be used to survey soil to achieve the FSS objectives:

Meter Manufacturer and Model	Detector Manufacturer and Model	Detector Type	Use
Ludlum 2221	Ludlum 44-10 2″ × 2″ NaI scintillator	Sodium Iodide (shielded & unshielded)	FSS Scans or Static Measurements for Gamma-Emitting Radionuclides
Shonka Research Associates (SRA)[a]	SRA[a]	Sodium Iodide Array (shielded)	FSS Scans for Processing Soil by Segregation

a. Potential equipment vendor.

5.1.1 Detection Sensitivity Requirements

Field instrument use will be evaluated and controlled to verify that MDCs of less than 75 percent of the appropriate limit ($DCGL_W$ or DCCL) for direct measurements and/or scanning measurements are routinely achieved. Process equipment use will be evaluated and controlled to verify that MDCs of less than 75 percent of the DCCL are routinely achieved. Section 4.1.6.2 provides survey guidance for MDCs greater than the appropriate acceptance criteria. Implementation of these MDC requirements is discussed in the subsections that follow.

5.1.2 Field Instrument Scanning

The MARSSIM framework for determining the MDC for field instrument scanning activities is based on the premise that there are two stages of scanning. That is, surveyors do not make decisions on the basis of a single indication; rather, upon noting an increased number of counts, they pause briefly and then decide whether to move on or take further measurements. Thus, scanning consists of two components: continuous monitoring and stationary sampling. Accordingly, field instrument surveyor scan MDCs, $MDCR_S$, are calculated to control the occurrence of Type I (false negative) and Type II (false positive) errors using the following MARSSIM equation:

$$MDCR_S = \frac{MDCR}{\sqrt{p\varepsilon}}$$

where $MDCR$ is the minimum detectable count rate (cpm), p is the surveyor efficiency (estimated in MARSSIM to be between 0.5 and 0.75; the value of 0.5 results in a more conservative $MDCR_S$ calculation and, therefore, will be used), and ε is the instrument efficiency (cpm per µR/hr; Table 6.4 of NUREG-1507, Reference 10). In addition:

$$MDCR = s_i\left(\frac{60}{i}\right)$$

$$s_i = d'\sqrt{b_i}$$

where s_i (counts) is the minimal number of net source counts required for a specified level of performance for the counting interval i (seconds); d' is the index of sensitivity; and b_i is the number of background counts in the interval. Index of sensitivity d' values are listed in MARSSIM Table 6.5 based on the proportions for required true positive and tolerable false positive occurrence rates. The index of sensitivity value selected for initial use at the Tulsa facility is 1.38, corresponding to a true positive proportion of 0.95 and a false positive proportion of 0.60. While this index of sensitivity value will result in at least 95 percent "correct" scanning detections as required by the Tulsa facility DQO for Type I error control, up to 60 percent "incorrect" (false positive) scanning detections may occur. Should this become an intolerable compromise, a larger index of sensitivity value corresponding to the 0.95 true positive proportion may instead be used provided the required scan MDC is achieved.

Typical calculated Th-232 scan MDCs for a survey instrument equipped with 2x2 NaI detector using this MARSSIM two-stage scanning framework are summarized in the table below for increasing background count rates.

Typical Soil Scan Sensitivities for Th-232 Detection Using a 2 × 2 NaI Detector[a]

Bkg	i	P	ε	d'	s_i	$MDCR$	$MDCR_S$	CF[b]	Scan MDC[c]	
cpm	sec	-	cpm per µR/hr	-	counts	ncpm	ncpm		µR/hr	pCi/g
5,000	1	0.5	830	1.38	13	756	1069	0.99	1.29	1.3
10,000					18	1069	1512		1.82	1.8

a. Th-232 in equilibrium with progeny uniformly distributed in a source thickness of 6 inches.

b. Conversion factor (pCi/g per µR/hr) taken from NUREG-1507, modeled using *MicroShield*. CF = Scan MDC (pCi/g) / Scan MDC (µR/hr)

c. *Scan MDC* (µR/hr) = $MDCR_S/\varepsilon$ and *Scan MDC* (pCi/g) = $(MDCR_S/\varepsilon)CF$

5.2 Structure Survey Instrumentation

For surface contamination scanning and static measurements, the radionuclides of concern and/or their progeny emit alpha and/or beta particles that are easily detected using survey instruments equipped with gas proportional detectors and scalers. Scanning for gross alpha or gross beta activity will be used as part of status surveys of structural surface survey units to ensure elevated areas of activity are not missed. In addition, static counts of structural surfaces at predetermined sample points are used to assess total contamination of structural surfaces. Measurements of alpha activity will be used to show compliance with the structural surface total and removable contamination acceptance criteria in units of (dpm/100 cm^2). Whenever possible, measurements of beta/gamma total and removable contamination will also be recorded as a QC tool. The following instruments (or other instruments providing equivalent detection sensitivity) will be used to survey structural surfaces to achieve the FSS objectives:

Meter Manufacturer and Model	Detector Manufacturer and Model	Detector Type	Use
Ludlum 2224	Ludlum 43-89 Dual Phosphor Alpha/Beta Detector	Zinc Sulfide (ZnS) Scintillator	FSS scans and static counts for alpha- and beta-emitting radionuclides
Ludlum 2221	Ludlum 43-68 Gas Proportional	Gas Proportional	FSS scans and static counts for alpha- and beta-emitting radionuclides

5.2.1 Detection Sensitivity Requirements

Structure survey instrument use will be evaluated and controlled to verify that MDCs of less than the $DCGL_w$ for direct measurements and/or scanning measurements are routinely achieved. Field instrument scan MDCs are calculated to control the occurrence of Type I (false negative) and Type II (false positive) as discussed in the subsections that follow.

5.2.1.1 Alpha Scan

There are two equations based on the MARSSIM two-stage scan methodology used to determine the alpha scanning MDC depending on the background level. For a typical alpha background level of less than 3 cpm, the probability of detecting a single count while passing over the contaminated area is:

$$P(n \geq 1) = 1 - e^{\frac{-GEd}{60v}}$$

where:

$P(n \geq 1)$ = probability of observing a single count,
G = activity (dpm),
E = 4π detector efficiency (cpd),
d = width of detector in direction of scan (cm), and
v = scan speed (cm/s).

Increase the value of G until the corresponding probability equals the desired confidence level, e.g., 95 percent. For a background level of 3 cpm to about 10 cpm, the probability of detecting two or more counts while passing over the contaminated area is:

$$P(n \geq 2) = 1 - \left(1 + \frac{(GE+B)d}{60v}\right)\left(e^{-\frac{(GE+B)d}{60v}}\right)$$

where:

$P(n \geq 2)$	=	probability of observing two or more counts,
G	=	activity (dpm),
E	=	4π detector efficiency (cpd),
B	=	background count rate (cpm),
d	=	width of detector in direction of scan (cm), and
v	=	scan speed (cm/s).

Increase the value of G until the corresponding probability equals the desired confidence level, e.g., 95 percent.

Beta Scan

Based on the MARSSIM two-stage scan methodology, the beta scanning MDC at a 95 percent confidence level is calculated using the following equation which is a combination of MARSSIM Equations 6-8, 6-9, and 6-10:

$$MDC_{scan} = \frac{d'\sqrt{b_i}\left(\frac{60}{i}\right)}{\sqrt{p} \cdot E_{tot} \cdot \frac{A}{100\,cm^2}}$$

where:

MDC_{scan}	=	MDC level in dpm/100 cm^2,
d'	=	desired performance variable (nominally 1.38),
b_i	=	background counts during the residence interval,
i	=	residence interval in seconds,
ρ	=	surveyor efficiency (0.5 – 0.75, 0.5 is conservative),
A	=	detector probe physical (active) area in cm^2, and
E_{tot}	=	total detector efficiency for radionuclide emission of
	=	$E_i \times E_s$,

where:

E_i = 2π instrument efficiency in counts per disintegration (cpd) and

E_s = source (or surface contamination) efficiency.

Note: Es values can be determined or the default values provided in NUREG-1507 can be used as follows: 0.25 for all alpha energies and beta maximum energies between 0.15 and 0.4 MeV, 0.5 for all beta maximum energies greater than 0.4 MeV. Note that instrument efficiency will be provided in the calibration records for each instrument.

5.2.1.2 Alpha or Beta Static Counts

Minimum counting times for static counts of total and removable contamination will be chosen to provide an MDC that is a fraction (25 to 75 percent) of the survey unit-specific acceptance criteria. However, since the GA-DCGL value for total contamination of 21.5 dpm/100cm^2 is relatively low, high background may preclude achieving 75% of this value in count times less than 30 minutes. If this is the case, MDC values greater than 75% of 21.5 but less than 21 dpm/100cm^2 may be used. MARSSIM equations have been modified to convert to units of dpm/100 cm^2. Count times are determined using the following equation. Static counting MDCs at a 95 percent confidence level are calculated using the following equation which is an expansion of NUREG-1507, Equation 6-7 (Strom & Stansbury, 1992):

$$MDC_{static} = \frac{3 + 3.29\sqrt{B_r \cdot t_s \cdot (1 + \frac{t_s}{t_b})}}{t_s \cdot E_{tot} \cdot \frac{A}{100}}$$

where:

MDC_{static} = minimum detectable concentration level in dpm/100 cm^2,
B_R = background count rate in counts per minute,
t_B = background count time in minutes,
t_S = sample count time in minutes,
A = detector probe physical (active) area in cm^2, and
E_{tot} = total detector efficiency for radionuclide emission of
= $E_i \times E_s$,
where:
E_i = 2π instrument efficiency in counts per disintegration (cpd) and
E_s = source (or surface contamination) efficiency.

Note: Es values can be determined or the default values provided in NUREG-1507 can be used as follows: 0.25 for all alpha energies and beta maximum energies between 0.15 and 0.4 MeV, 0.5 for all beta maximum energies greater than 0.4 MeV.

Table 5-1 below contains example static alpha MDC calculation results for structural surfaces.

Table 5-1 Structural Surface Alpha Static MDC

Background Gross Alpha Count Rate (cpm)	Background Count Time (min)	Static Measurement Count Time (min)	Total Detector Efficiency	Detector Probe Area (cm^2)	Static MDC (dpm/100 cm^2)	Percent of Gross Alpha DCGL
0.1	10	5	0.055	126	17	79
0.2	10	5	0.055	126	20	94
0.3	10	5	0.055	126	16	74
0.4	10	5	0.055	126	19	83

5.2.2 Static Sample Point Measurements

Static sample point measurements are taken at each sample point location to determine the total contamination. Static measurements for gross alpha are performed by placing the detector on the surface to be measured. Care should be taken if removable contamination is suspected. Notes about the surface condition (e.g., smooth or porous) should be taken. Static sample point measurements will be taken on building surfaces in impacted areas utilizing instrumentation capable of detecting the GA-DCGL and the best geometry based on the surface at the survey location. Additionally, locations of elevated activity identified and marked during the scan survey will require direct survey measurements.

Direct surveys will be performed using hand-held 125 cm^2 scintillation detectors, 126 cm^2 gas proportional detectors, or 15 cm^2 detectors for small geometry surveys. Total surface activity measurements are taken at each identified sample point. Scaled count times will be determined based on the MDC_{static} of the applicable survey instrument.

5.3 Laboratory Analysis

FSS laboratory analytical services will be provided by Outreach of Broken Arrow, Oklahoma. In the event that Outreach is not available, another qualified analytical laboratory will be used.

FSS soil samples will be analyzed by gamma spectroscopy. The samples will be counted as received, i.e., they will not be dried and/or ground. The MDC value required for each gamma spectroscopy analysis is 25 percent of the release criteria for Th-232. Characterization survey results confirm that Th-232 is in secular equilibrium with its short-lived progeny Ac-228 and Th-228. Th-232 activity will be identified based on the Ac-228 activity (primary gamma energy of 911.1 keV). The Th-228 activity will be calculated by multiplying the Th-232 activity by 1. The Th-230 activity will be calculated by multiplying the Th-232 activity by 3.5.

To exclude the bias introduced when grouping analytical results containing "less than" values, the laboratory will be instructed to report observed counting data when reporting results that are below the critical level L_C (and thus "not detected") established for each analysis.

Smear samples of removable contamination may be analyzed on site. A fraction of the smear samples will also be submitted to a qualified laboratory for analysis of gross alpha activity in dpm per sample. All analytical results reported will include the activity, the 95 percent confidence level error (2-sigma error), and the MDC all in the same units for each smear sample analyzed.

6.0 QA Program

The objective of the Tulsa facility FSS QA program (QAP) is to identify and implement sampling and analytical methodologies that limit the introduction of error into analytical data. This chapter establishes the program necessary to ensure that FSS activities produce results that are of the type and quality needed and expected for their intended use. The QAP includes QC functions that cover all aspects of data collection, including both field radiation instrument surveys, and soil and smear sampling for laboratory analysis, through the preparation of the documentation of the results. The evaluation of the results is covered in Chapter 7.0.

6.1 FSSP Performance Assessment

Periodic audits and surveillances of FSSP implementation will be conducted in accordance with project QAP requirements. To the extent permitted by FSSP requirements, the formal audits will be performance-based and focus on the technical efficacy of the results produced. Corrective actions resulting from audits shall be promptly implemented. Surveillances (work practice observations) will be informal routine occurrences at the Tulsa facility. The surveillance objective is twofold: (1) verify FSSP requirements are being anticipated and implemented correctly, and (2) identify improvements in work practices improving project efficiency. Supervisory project personnel will be responsible for the effectiveness of the surveillance portion of FSSP performance assessment.

6.2 Instrumentation

For all counting systems and instruments used as part of analytical analyses, at a minimum, the following QC principles will be applied.

6.2.1 Procedures

Counting systems and instruments will be used in accordance with approved procedures.

6.2.2 Source and Instrument Checks

Each day that a counting system and instrument are used, the system's response will be checked using an appropriate source before use. Additional response checks may be necessary depending on the counting system used. In addition:

- For field instrumentation, source check acceptance criteria (e.g., ±2 σ for direct [integrated] measurements and ±20 percent for rate measurements) will be established prior to beginning the project.
- All source check results will be documented.
- Failed source checks will be repeated. Consecutive failure will result in additional testing of the counting system, in accordance with the applicable procedure, and ultimately removing the counting system from service.
- Survey data acquired prior to an instrument failing a source check will be reviewed and documented by the Data Manager to determine the validity of the data.
- All instrument failures in the field will be followed by a documented investigation by the Data Manager of suspect data.
- For field instruments of increased complexity (e.g., single-channel analyzer or soil segregation system), additional checks such as energy calibration and efficiency checks may be performed and documented.

6.2.3 Background Determination

When FSS activities are conducted, the ambient background will be determined and documented at least once daily per instrument, depending on the instrument used and the variability in the background.

6.2.4 Calibration

All counting systems and instruments will be calibrated with a National Institute of Standards and Technology- (NIST) traceable source at intervals not exceeding 12 months for laboratory counting systems and at intervals not exceeding 6 or 12 months, as recommended by the manufacturer for portable field survey instruments. The source used will be appropriate for the type and the energy of the radiation to be detected. All calibrations will be documented and include the source data.

6.3 Sample Collection

6.3.1 Procedure

Soil samples will be collected in accordance with written procedures. Sampling tools will be cleaned and monitored, as appropriate, after each use. Samples will be collected in clean/unused sealable containers. Smear samples will be collected and stored in clean containers in accordance with written procedures.

6.3.2 Sample Identification

Sample containers will be permanently labeled/marked in the field at the time of collection by the individual collecting the sample. At a minimum, the following information will be recorded on the sample container: sample date/time, sample identification number, sample location, and initials of person collecting the sample. The Data Manager will assure proper coding of appropriate information on the sample container (e.g., sample type, location, and sample depth) by an established sample identification scheme.

The outside of sample containers with quantities of radioactive material in excess of the applicable 10 CFR 30, Appendix B labeling limits or which, because of their form or amount, may be a potential laboratory contamination or measurement concern, will be identified with a "radioactive material" caution label. Samples being shipped from the Tulsa site will be packaged and labeled in compliance with applicable Department of Transportation hazardous materials regulations (HMR) (HMRs; 49 CFR 173) and recipient laboratory specifications.

6.3.3 Sample Control

An approved chain of custody (CoC) procedure will be implemented ensuring complete sample integrity control from the time the sample is obtained through final disposition (disposed or maintained in the sample archive). The CoC procedure will feature both administrative sample custody transfer and physical controls.

6.4 Analytical Laboratory Services

Radiological analytical services provided by each laboratory will be provided in accordance with an internal QAP implemented by documented policies and procedures. The Data Manager shall confirm that the management objectives of the QAP, policies, and procedures are to produce data that are scientifically valid, defensible, and of known and documented quality. The Data Manager shall be cognizant of the nature and extent of each laboratory's QAP and establish a notification protocol with the laboratory should the laboratory QC officer identify QAP deviations adversely affecting results for the Tulsa facility.

6.4.1 Laboratory Analysis Specifications

For each laboratory analysis requested, the following minimum specifications will be provided to the laboratory on the appropriate CoC record:

- Required analyses and/or analytical methodology.
- The required MDC value for each radionuclide.
- Nonstandard results presentation requirements.
- Sample disposition (disposed or archived).
- Turnaround time required.

6.4.2 Laboratory Measurements Verification

The accuracy and precision of measurement results provided by the analytical laboratory will be routinely checked using performance evaluation (PE) samples for measurement. The dual PE sample measurement categories, internal and external, to be implemented are discussed below.

6.4.2.1 Internal PE

All measuring and test equipment affecting the accuracy and precision of measurements will be calibrated and/or verified initially and on a continuing basis using NIST-traceable source materials and standard reference materials. The internal PE (IPE) samples may include laboratory controls, duplicates, matrix spikes, and method blanks. Where possible, the matrix matched IPE samples should be analyzed singly alongside each group of samples to ensure the sample preparation and/or measurement processes will be "in control."

6.4.2.2 External PE

External PE (EPE) samples will be sent to the analytical laboratory at a frequency no less than 5 percent of the total FSS sample load for the respective measurement protocol. The EPE sample load will be a distribution of the following sample categories:

- Blanks - Soil from the background reference areas established for the Tulsa facility.
- Spikes - Soil containing a known quantity of Th-232 if available
- Duplicates - Soil analyzed a second time.

All EPE samples will be submitted "blind" to the laboratory with the CoC and sample identification convention used for FSS samples being followed. The Data Manager will maintain the 5 percent EPE sample load. For field blanks and field spikes, the performance of the laboratory measurement system will be considered in control when the range of the EPE sample activity concentration result (defined by the reported ±2σ counting uncertainty interval) bounds all or part of the known result and its ±2σ counting uncertainty interval. In the event that an EPE sample measurement results in no activity being identified above the critical level for the analysis, the acceptance criterion becomes the value of the required MDC. For duplicates, evaluation of the precision results will be performed using the relative percent difference (RPD) method. The RPD method utilizes three steps: calculation of the RPD, calculation of the statistical counting error in the mean result, and acceptance testing. The RPD is equal to the positive difference of the duplicate measurements for each radionuclide identified multiplied by 100 and divided by the average of the duplicate measurements:

$$RPD_i = \left(\frac{|x_1 - x_2|}{\bar{x}_i}\right) \times 100$$

where:

x_1 = initial measurement result for radionuclide *i*,
x_2 = duplicate measurement result for radionuclide *i*, and
$\bar{x}_i$ = mean of the initial and duplicate measurement results for radionuclide *i*.

The statistical counting error in the mean result for radionuclide *i*, expressed as a percentage of the mean, is determined as follows:

$$2s_{\bar{x}_i} = \left(\frac{\sqrt{(2s_{x_1})^2 + (2s_{x_2})^2}}{2\bar{x}_i}\right) \times 100$$

where:

$2s_{x_1}$ = initial measurement 2-sigma statistical counting error for radionuclide *i*,
$2s_{x_2}$ = duplicate measurement 2-sigma statistical counting error for radionuclide *i*, and
$\bar{x}_i$ = mean of the initial and duplicate measurement results for radionuclide *i*.

Acceptance testing of the initial and duplicate results for each radionuclide i identified in the analysis pair is accomplished using the following inequality:

$$RPD_i \le \left(2s_{\bar{x}_i} + 20\%\right)$$

6.5 Surrogate-Implied Radionuclide Relationship Verification

Th-232 has been selected as the surrogate radionuclide for the Tulsa facility (as discussed in Section 4.1.5) for the determination of implied Th-230 activity concentrations. This determination will be conducted using the previously established implied:surrogate (Th-230:Th-232) activity concentration ratio of 3.5. While it is fully expected that this implied:surrogate nuclide relationship will remain valid for all FSS activities, a QC practice will be adopted to confirm this expectation. This QC practice will select a suitable number of FSS and/or 10 CFR 61 waste profile soil samples (at least five samples) for more precise quantification of Th-232, Th-230, and Th-228 content by alpha spectrometry at a specified MDC of 0.5 pCi/g.

Provided sufficient analytical sensitivity is achieved, these verification measurement results will be included in a statistical determination of the observed implied:surrogate activity concentration ratio. Should it be concluded that the difference between the previously established and observed ratios results in their statistical separation, an evaluation of the impact that the observed ratio has on FSS activities will be performed.

6.6 As-Collected Sample Analysis

The laboratory processes FSS samples for gamma spectrometry on an "as-collected" basis, systematically biasing the measurement relative to dry analysis results due to each sample's moisture content. This protocol is in accordance with the DP, DPA, and MARSSIM Section 7.7.1 that states:

> "There is no special sample preparation required for counting samples using a germanium detector or sodium iodide detector beyond placing the sample in a known geometry for which the detector has been calibrated. The samples can be measured as they arrive at the laboratory, or the sample can be dried, ground to a uniform particle size, and mixed to provide a more homogenous sample if required by the SOPs."

The moisture content of soil samples will be estimated and included as part of analytical results.

7.0 Data Assessment

Data will be reviewed by the Data Manager to ensure that the requirements are implemented as prescribed and that the results of the data collection activities support the objectives of the survey, or permit a determination that these objectives should be modified. The Data Manager will determine if the data are of the right type, quality, and quantity to demonstrate compliance with the FSSP objective. The review will check that the appropriate number of samples were taken in the correct locations and that they were analyzed with measurement systems with appropriate sensitivity. After the data are analyzed, an estimate of data variability (sample standard deviation, σ) and the actual number of valid measurements will be used to determine that the sampling design provides adequate power to determine that the objectives of the survey design are met.

7.1 Preliminary Data Review

The Data Manager will review field and laboratory data records as they are provided; prepare data graphs as necessary to permit proper interpretation; and calculate statistical quantities to analyze the structure of the data and identify patterns, relationships, or potential anomalies. The preliminary data examination includes the following:

- Evaluation of data completeness.
- Verification of instrument calibration.
- Verification of sample identification and traceability back to sampling location.
- Measurement of precision using duplicates, replicates, or split samples.
- Measurement of bias using reference materials or spikes examination or blanks for contamination.
- Assessment of adherence to method specifications and QC limits.
- Evaluation of method performance in the sample matrix.
- Applicability and validation of analytical procedures for site-specific measurements.
- Assessment of external QC measurement results and QA assessments including the results of analytical laboratory QA/QC reports related to the analysis of FSS samples.

7.1.1 Data Evaluation and Conversion

For comparison of survey data to $DCGL_{WS}$ or DCCLs, the survey data from field and laboratory measurements will be converted to $DCGL_W$ or DCCL units. The Data Manager will ensure data measurements retain traceability to NIST and conversion factors are appropriate for the radiation quantity. The preliminary data reports will be reviewed to ensure adequate measurement sensitivity is being achieved and to resolve any detector sensitivity problems. Analytical reports will be reviewed for proper MDC values. The analytical results will be reported whether the result is above or below the reported MDC value so that the MDC value is not used in the data assessment. Preliminary scan data will also be reviewed against the percent coverage requirement of the survey unit.

An evaluation will be made to determine that the data are consistent with the underlying assumptions made for survey plan statistical procedures. The basic statistical quantities that will be calculated for the survey unit are the following:

- Mean
- Standard deviation
- Median
- Minimum
- Maximum

The value of the sample standard deviation will be used to determine if a sufficient number of samples were collected to achieve the desired power of the statistical test. A verification that the sample sizes determined for the tests are sufficient to achieve the DQOs set for the Type I (α) and Type II (β) error rates will be completed. Additionally, verification of the power of the tests ($1-\beta$) to detect adequate remediation may be performed. If an insufficient number of samples were taken, a resurvey will be performed. A resurvey will be performed only if the sample size must be increased by more than 20 percent, since MARSIMM Tables 5.3 and 5.5 include a correction factor of 20 percent to allow for loss or unusable data.

Certain departures from the survey plan assumptions may be determined to be acceptable when given the actual data and other information. More sophisticated tools for determining the extent of the validity of the survey data may be used (e.g., U.S. Environmental Protection Agency [USEPA] QA/G-9, Reference 11) by the Data Manager. These evaluations will be documented.

If it is not possible to show that the DQOs were met with reasonable assurance, a resurvey may be performed.

The parameter of interest to demonstrate achievement of the FSSP objective is the mean concentration in the survey unit. The two-sample statistical test (WRS Test) will be used. The two-sample WRS Test will evaluate whether the mean of the data is above or below the $DCGL_W$ or DCCL.

Summary of Statistical Tests

Survey Result	Conclusion
Difference between maximum survey unit measurement and minimum reference area measurements is less than $DCGL_W$/DCCL	Survey unit meets release criterion
Difference of survey unit average and reference area average is greater than $DCGL_W$/DCCL	Survey unit does not meet release criterion
Difference between any survey unit measurement and any reference area measurement greater than $DCGL_W$/DCCL or the difference of survey unit average and reference area average is less than $DCGL_W$/ DCCL	Conduct WRS Test and elevated measurement comparison

The null hypothesis is assumed to be true unless the WRS Test indicates that it should be rejected in favor of the alternative. The result of the hypothesis test determines whether or not the survey unit as a whole is deemed to meet the release criterion. The WRS Test will be applied as outlined in the following steps.

1. Adjusted reference area measurements will be obtained by adding the $DCGL_W$ or DCCL to each reference area measurement.
2. The m adjusted reference area sample measurements and the n sample measurements from the survey unit will be pooled and ranked in order of increasing size from 1 to N, where N = m + n.
3. If measurements are tied in rank, each of the tied values will be assigned the same average rank of that group of tied measurements.
4. The ranks from the reference area will be summed as W_r.
5. The value of W_r will be compared with the critical value given in MARSSIM Table I.4 for the appropriate values of m and n at the required Type I error decision rate ($\alpha = 0.05$). If W_r is greater than the critical value, the null hypothesis that the survey unit exceeds the release criterion was rejected.

Both the measurements at discrete locations and the scans will be used to identify elevated areas within a survey unit. Analytical results of soil samples will be used to complete the elevated measurement comparison. If residual radioactivity is found in a localized area of elevated activity--in addition to the residual radioactivity distributed relatively uniformly across the survey unit--the Unity Rule discussed above will be used to ensure that the release criterion has been met as follows:

$$\frac{\delta}{DCGL} + \sum_{x+1}^{n} \frac{(\delta_{EMC} - \delta)}{DCGL_{EMC}} \leq 1$$

where:

δ = is the average concentration of Th-232 over the entire survey unit,
δ_{EMC} = the average concentration of Th-232 over the elevated area x within the survey unit,
DCGL = the $DCGL_w$ or DCCL for Th-232,
$DCGL_{EMC}$ = (area factor for elevated area x) X (DCGL or ADCL),
x = refers to one of the elevated areas within the survey unit, and
n = the total number of elevated areas within the survey unit.

If there is more than one elevated area, a separate term will be included for each area. The result of the EMC will be used as a trigger for further investigation. The investigation may involve taking further measurements to determine that the area and level of the elevated residual radioactivity are such that the resulting dose or risk meets the release criterion. The investigation will provide adequate assurance, using the DQO process, that there are no other undiscovered areas of elevated residual radioactivity in the survey unit that might otherwise result in a dose or risk exceeding the release criterion. In some cases, this may lead to reclassifying a survey unit--unless the results of the investigation indicate that reclassification is not necessary.

7.1.2 Investigation Levels

The Data Manager will apply radionuclide-specific investigation levels when reviewing preliminary FSS data to determine if additional investigations may be necessary. These investigation levels (listed below) will also serve as a QC check to determine when a measurement process appears out of control.

Postremediation Survey Investigation Levels

Survey Unit Classification	Flag Direct Measurement or Sample Result When:	Flag Scanning Measurement Result When:
Class 1	>$DCGL_{EMC}$ / DCCLor > $DCGL_W$ / DCCL and the mean of the survey unit is greater than 0.75 of the $DCGL_W$ / DCCL	>$DCGL_{EMC}$ or >DCCL
Class 2	> $DCGL_W$	> $DCGL_W$ or >MDC
Class 3	> 0.5 of the $DCGL_W$ + background	> $DCGL_W$ or >MDC

A measurement that exceeds the investigation level may indicate that the survey unit has been improperly classified or it may indicate a failing instrument. When an investigation level is exceeded, the first step will be to confirm that the initial measurement/sample actually exceeds the particular investigation level. This may involve taking further measurements to determine that the area and level of the elevated residual radioactivity are such that the resulting dose or risk meets the release criterion. Depending on the results of the investigation actions, the survey unit may (1) be reclassified, (2) be remediated further, and/or (3) be resurveyed. If the FSS data suggest that the survey unit is misclassified, the original DQOs will be redeveloped for the correct classification. The sampling design and data collection documentation will be reviewed for consistency with the DQOs.

7.2 FSS Report

An FSS report (FSSR) will be prepared documenting the final radiological conditions of the Tulsa facility to include, at a minimum, the following:

- An overview of the results of FSS.
- A discussion or tabulation of any changes (variations) that were made in FSS implementation from what was described in the FSSP.

- A description of the method by which the number of samples was determined for each survey unit.
- A summary of the values used to determine the number of samples and justification for these values.
- A summary of QAP implementation results.

The survey results for each survey unit including the following:

- The number of samples taken for the survey unit.
- A map or drawing of the survey unit showing the reference system and random-start systematic sample locations.
- The measured sample concentrations.
- The statistical evaluation of measured concentrations.
- Judgmental and miscellaneous sample data sets reported separately from those samples collected for performing the statistical evaluation.
- A discussion of anomalous data including any areas of elevated direct radiation detected during scanning that exceeded the investigation level or measurement locations in excess of the $DCGL_W$ or DCCL.
- A statement that a given survey unit satisfied the $DCGL_W$ or DCCL and the elevated measurement comparison, if any sample points exceeded the $DCGL_W$ or DCCL.
- A description of any changes in initial survey unit assumptions relative to the extent of residual radioactivity.
- A discussion of a survey unit reclassification including applicable data.

Additionally, Kaiser may elect to prepare a separate dose reassessment report (DRR) using information presented in the FSSR. The objective of the DRR is to depict the as-left Tulsa facility in terms of its dose delivery potential with respect to present and future hypothetical site occupants. The unique feature of the DRR is the incorporation of actual survey unit characteristics and radiological data in a remodeling effort. Consequently, the DRR will document an estimate of the potential dose posed by as-left conditions at the Tulsa facility with greater precision (and possibly greater accuracy) than was possible when preparing the FSSP.

References

(1) Kaiser Aluminum & Chemical Corporation Decommissioning Plan for Tulsa Oklahoma Facility, June 2001, Revised 2003.

(2) Kaiser Aluminum & Chemical Corporation Decommissioning Plan Addendum for Tulsa Oklahoma Facility, May 2002, Revised May 2003.

(3) USEPA 402-R-97-016, December 1997, Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), NUREG-1575.

(4) Earth Sciences Consultants, Inc., December 2001, Work Plan, Characterization Survey of the Operational Area, Former Kaiser Aluminum Specialty Products Facility, Tulsa, Oklahoma

(5) Title 10 CFR Part 20, Subpart E, Radiological Criteria for License Termination.

(6) NUREG-1549, Decision Methods for Dose Assessments to Comply With Radiological Criteria for License Termination

(7) 63 FR 64132, November 18, 1998, Supplemental Information on the Implementation of the Final Rule on Radiological Criteria for License Termination.

(8) NUREG/CR-5849, June 1992, Manual for Conducting Radiological Surveys in Support of License Termination.

(9) Pacific Northwest National Laboratory, Visual Sample Plan, DQO Web Site, http://etd.pnl.gov:2080/DQO/.

(10) NRC, 1997, Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions, NUREG/CR-1507, Final, NRC, Washington, DC.

(11) USEPA, 1998, Guidance for Data Quality Assessment, EPA QA/G-9, Quality Assurance Division, Washington, DC.