Chapter 12
Radiological Assessment

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12.1 Introduction

The purpose of this chapter is to provide guidance on conducting and documenting radiological surveys and sampling episodes for demonstrating compliance with N.J.A.C. 7:28-12, *Remediation Standards for Radioactive Materials*.

The New Jersey Department of Environmental Protection (NJDEP) Contaminated Site Remediation and Redevelopment (CSRR) maintains a library of guidance manuals on its website at https://www.nj.gov/dep/srp/guidance/. It is recommended that the reader access the website and review the guidance documents pertinent to the respective task. Additional guidance may also be found at web sites of the USEPA and the Occupational Safety and Health Administration (OSHA). Examples of some of the relevant guidance manuals and webpages pertaining to this chapter are:

Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM): https://www.epa.gov/radiation/multi-agency-radiation-survey-and-site-investigation-manual-marssim.

NJDEP-Radiation Protection Element N.J.A.C. 7:28: https://www.state.nj.us/dep/rpp/njacdown.html

Occupational Safety and Health Administration (OSHA): https://www.osha.gov/shpguidelines/index.html;

Soil SI/RI/RA Technical Guidance: https://www.nj.gov/dep/srp/guidance/#si_ri_ra_soils;

Ground Water SI/RI/RA Technical Guidance: https://www.nj.gov/dep/srp/guidance/#pa_si_ri_gw;

Ecological Evaluation Technical Guidance: https://www.nj.gov/dep/srp/guidance/#eco_eval;

Vapor Intrusion Technical Guidance: https://www.nj.gov/dep/srp/guidance/#vi;

Fill material Guidance: https://www.nj.gov/dep/srp/guidance/#fill_srp

Preliminary Assessment Technical Guidance: https://www.nj.gov/dep/srp/guidance/#pa_guide

12.2 Categories of Radioactive Materials

Most radiological cases encountered by site remediation professionals involve discovery of soil contamination with Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM), therefore it is the focus of this guidance. TENORM is defined at N.J.A.C. 7:28-1.4 as any naturally occurring radioactive materials whose radionuclide concentrations or potential for human exposure have been increased by any human activities. This radioactive material is regulated under N.J.A.C. 7:28-4, but the absence of a TENORM license should not be used in lieu of investigating potential for TENORM being present.

Byproduct, Source, and Special Nuclear Materials (defined in the FSPM Glossary at https://www.nj.gov/dep/srp/guidance/fspm/manual_edition/2022/fspm_glossary.pdf) are other categories of radioactive materials which have been nationally regulated more closely under specific radioactive materials licensing and inspections which include decommissioning requirements. Therefore, these account for fewer facilities having residual radioactive materials to manage under technical requirements for site remediation. The guidance in FSPM 12 and MARSSIM are applicable to any radioactive material contamination/investigation.

The following industries have the potential to produce, transfer, distribute, sell, lease, receive, acquire, own, transport, store, dispose, possess, or use TENORM or other anthropogenic radioactive material contamination: historical use of radioactive materials (current or former radioactive materials licensee); large groundwater users such as water treatment facilities and paper/pulp facilities; paint and pigment manufacturing; metal foundry facilities; fertilizer plants; optical glass facilities; ceramics manufacturing; aircraft manufactures; munitions and armament manufactures; scrap metal recycling; zirconium manufacturing/use; oil and gas production, refining, and storage; electricity generation; cement and concrete product manufacture; radiopharmaceutical manufacturing; and geothermal energy production. For additional information please see the *Fill Material Guidance for SRP Sites* or the *Preliminary Assessment Technical Guidance*.

12.3 Applicability

On September 30, 2009, the U.S. Nuclear Regulatory Commission and New Jersey signed an Agreement authorizing the State to license and regulate byproduct, source, and certain special nuclear radioactive materials, therefore the scope and applicability of N.J.A.C. 7:28-12 was expanded beyond TENORM to include:

1. Remediation of radioactive contamination of real property by any technologically enhanced naturally occurring radioactive materials, source, by-product, certain special nuclear material, and diffuse naturally-occurring or accelerator-produced radioactive material; and
2. Any other remediation of radioactive contamination including, without limitation, any remediation pursuant to: the Spill Compensation and Control Act, N.J.S.A. 58:10-23.11 et seq.; the Water Pollution Control Act, N.J.S.A. 58:10A-1 et seq.; the Industrial Site Recovery Act, N.J.S.A. 13:1K-6 et seq.; the Solid Waste Management Act, N.J.S.A. 13:1E-1 et seq.; the Comprehensive Regulated Medical Waste Management Act, N.J.S.A. 13:1E-48.1 et seq.; the Major Hazardous Waste Facilities Siting Act, N.J.S.A. 13:1E-49 et seq.; the Sanitary Landfill Facility Closure and Contingency Fund Act, N.J.S.A. 13:1E-100 et seq.; the Regional Low Level Radioactive Waste Disposal Facility Siting Act, N.J.S.A. 13:1E-177 et seq.; any law or regulation by which the State may compel a person or licensee to perform remediation activities; or N.J.A.C. 7:26C.

An important observation is that the regulation is applicable to all real property (land areas and buildings with any contaminated materials and equipment, including impacts that may have migrated beyond the boundary of former site operations). Specific categories of radioactive material listed in item 1 are defined in the FSPM Glossary at https://www.nj.gov/dep/srp/guidance/fspm/manual_edition/2022/fspm_glossary.pdf.

12.4 Oversight

N.J.A.C. 7:26C-2.3, *Administrative Requirements for The Remediation of Contaminated Sites,* states at 2.3 (a)(3)(i)(4) the person who is responsible for conducting the remediation at a site pursuant to N.J.A.C. 7:26C-1.4(a) requires NJDEP approval if the site is suspected or known to be contaminated with anthropogenic radionuclide contamination of any media. Therefore, the responsible party shall still employ a licensed site remediation professional, but must request approval of workplans and reports relating to radiological assessment prior to field activities. Documentation should be submitted to the Bureau of Environmental Radiation's Radiological & Environmental Assessment Section (BER-REAS) for review and approval. The investigator must provide copies of proposed investigation and sampling workplans to BER-REAS to obtain comment and feedback in advance of conducting the investigations. It should be noted that NJDEP online portal does not currently allow the submission of stand-alone site investigation or remedial investigation workplans. As such, it is recommended to submit the site investigation or remedial investigation workplans via email to the assigned BER-REAS case manager for review and approval. Upon completion of the site investigation or remedial investigation, the site investigation or remedial investigation workplan must then be included with the corresponding site investigation or remedial investigation report developed in accordance with the reporting requirements per N.J.A.C. 7:26E and submitted through the NJDEP online portal (https://www.nj.gov/dep/online/) for official submission to CSRR. While there is the ability to submit the remedial action workplan through the NJDEP online portal, it is highly advisable to submit the remedial action workplan to the BER-REAS case manager in advance for review and comment prior to submission through the online portal. Correspondence should reference the site location, Program Interest (PI) number, case number, incident number or other applicable identifiers.

The person responsible for remediating a radiologically contaminated site must obtain the latest version of the MARSSIM (available at https://www.epa.gov/radiation/multi-agency-radiation-survey-and-site-investigation-manual-marssim) for reference. Integrating an individual/consultant with training and experience in MARSSIM and radiological assessment is encouraged. Please note that some of the requirements in this chapter are different than the guidance presented in the MARSSIM. This chapter instructs the reader when to use the MARSSIM.

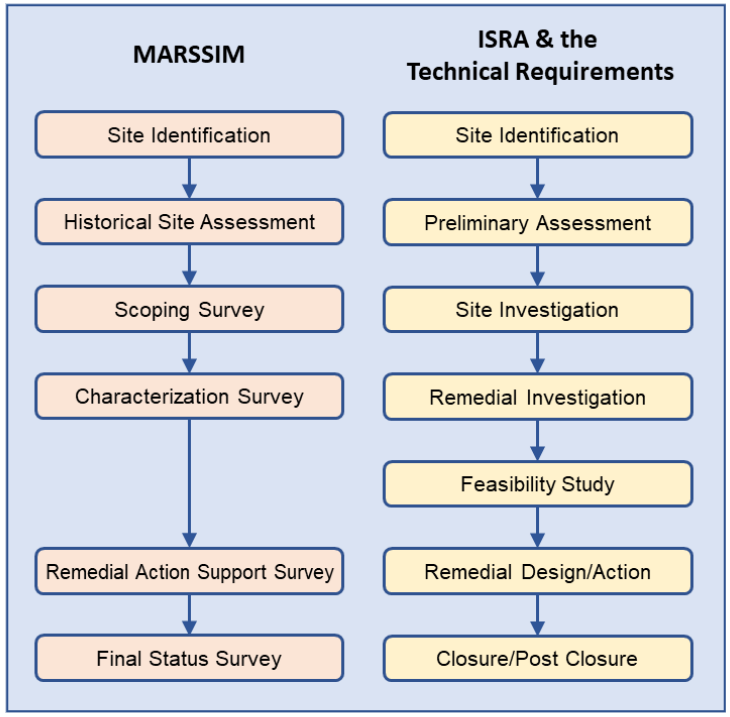

Figure 12.1 Comparison of MARSSIM and the Technical Requirements

Figure 12.1 shows the relationship between MARSSIM milestones/activities and the NJDEP *Technical Requirements for Site Remediation* (N.J.A.C. 7:26E).

Any questions regarding this chapter should be directed to the NJDEP, Bureau of Environmental Radiation (BER) at (609) 984-5400 or through the Bureau of Environmental Radiation's Radiological and Environmental Assessment Section's web site at https://www.state.nj.us/dep/rpp/reas/reas_main.htm. A list of references can be found at the end of this chapter. For definitions and acronyms, consult the following:

- MARSSIM Glossary (statistical terms are defined in the MARSSIM glossary)
- Definitions at N.J.A.C. 7:28-12.3
- Site Remediation Program Acronym Glossary: https://www.nj.gov/dep/srp/community/basics/glossary.htm
- FSPM Glossary: https://www.nj.gov/dep/srp/guidance/fspm/manual_edition/2022/fspm_glossary.pdf

12.5 The Planning Stage (Data Life Cycle)

The process of planning, implementing, assessing, and evaluating survey results is known as the Data Life Cycle. Survey designs should be developed and documented using the Data Quality Objectives (DQO) Process outlined in the MARSSIM (Appendix D, *The Planning Phase of the Data Life Cycle*, and Section 2.3.1, *Planning Effective Surveys – Planning Phase*). The expected output of planning surveys using the DQO process is a Quality Assurance Project Plan (QAPP) which should integrate all the technical and quality aspects of the Data Life Cycle. It should define in detail how specific quality assurance and quality control (QA/QC) activities will be implemented during the various surveys.

Specific sampling, survey, and laboratory requirements as they relate to QA/QC are found in N.J.A.C. 7:28-12.5, N.J.A.C. 7:26E-2, and Chapter 2 of this manual.

Note: The relationship between the MARSSIM process, the CERCLA process and RCRA process is discussed in Appendix F of the MARSSIM.

12.6 Site Identification/Historical Site Assessment

The purpose of the Historical Site Assessment (HSA) is to collect existing information on the site and its surroundings. A site as defined by MARSSIM is considered any installation, facility, or discrete, physically separate parcel of land that is being considered for survey and investigation. It is also useful in developing the site conceptual model.

The objectives of the HSA are to identify potential or known sources of contamination, determine if the site, or any portion of it, poses a threat to human health and the environment, and differentiate between impacted and non-impacted areas. It should also provide input for scoping and characterization surveys, assess the likelihood of contaminant migration, if migration off site is possible, and identify additional potential radiation sites related to the site being investigated (such as neighboring properties).

NJDEP Preliminary Assessment Technical Guidance (https://www.nj.gov/dep/srp/guidance/#pa_guide) discusses radioactive materials at sections 2.10 and A.1.9. The following are some industries having the potential to produce TENORM or other anthropogenic radioactive material contamination: historical use of radioactive materials (current or former radioactive materials licensee); mineral/ore processing, paper and pulp facilities; ceramics manufacturing; paint and pigment manufacturing; metal foundry facilities; optical glass facilities; fertilizer plants; aircraft manufactures; munitions and armament manufactures; scrap metal recycling; zirconium manufacturing; oil and gas production, refining, and storage; electricity generation; cement and concrete product manufacture; radiopharmaceutical manufacturing; and geothermal energy production. The checklist at MARSSIM page 3-5, *Table 3.1 Questions Useful for the Preliminary HSA Investigation*, should be used to collect existing information on the site. Further guidance on conducting a Historical Site Assessment is provided in MARSSIM Chapter 3 and Appendix A, *Example of MARSSIM Applied to a Final Status Survey*, including documentation of the *Historical Site Assessment Report*.

12.7 The Scoping Survey

The purpose of the scoping survey is to provide site-specific information based on limited measurements. The objectives of the survey may include performing a preliminary risk assessment and providing data to complete the site prioritization scoring process (CERCLA and RCRA sites only), supporting classification of all or part of the site as a Class 3[1] area (area classification is discussed further in Section 12.7.3 *Classify the Area by Contamination Potential*), evaluating the suitability of the survey plan for use in characterization, providing input into the design of the characterization survey, obtaining an estimate of the variability in the residual radioactivity of the site, and identifying non-impacted areas that may be appropriate for reference areas. These surveys typically consist of judgement measurements based on the results of the Historical Site Assessment. Sufficient data should be collected to facilitate the area classification process. Figure 4.1, *Sequence of Preliminary Activities Leading to Survey Design*, in the MARSSIM illustrates the preliminary steps necessary for planning a scoping survey.

12.7.1 Identify Contaminants

For sites with multiple radionuclide contaminants, one of the objectives of the scoping survey could be to

[1] An impacted area with little or no potential for delivering a dose above the release criterion, and little or no potential for small areas of elevated activity.

establish the ratios between each nuclide. For some sites, a review of the operating history would be helpful in establishing a ratio, and a limited number of samples could be collected to verify the suspected ratio. For other sites, a ratio might be better established as part of the characterization survey. Parts of the site might have different ratios, or there may not be a consistent ratio.

Determining a consistent ratio may be difficult. Before establishing the derived concentration guidance levels[2] (DCGLs) based on a ratio, consultation with the BER is required. MARSSIM Appendix I, Section I.11 provides some guidance to determine whether the radionuclides are correlated or not. A correlation coefficient of greater than 0.8 is ideal, but the department will consider other values on a case-by-case basis.

12.7.2 Establish the Derived Concentration Guideline Levels (DCGLs)

Compliance with the dose standard at N.J.A.C. 7:28-12.8 is the goal of a remedial action. DCGLs are derived, radionuclide-specific activity concentration within a survey unit corresponding to the release criterion (regulatory limit expressed in dose or risk). The DCGL is derived from the activity/dose relationship through various exposure pathway scenarios and is established in N.J.A.C. 7:28-12. Default DCGLs for TENORM soil contamination are established in N.J.A.C. 7:28-12, *Soil Remediation Standards for Radioactive Materials* for unrestricted, limited restricted, and restricted use. The DCGLs listed in N.J.A.C. 7:28-12.9, "Minimum remediation standards for TENORM and source material contamination," are for use when only one radionuclide is present in the radioactive contamination on the site. If more than one nuclide is present, the sum of the fraction calculation must be performed as outlined in N.J.A.C. 7:28-12.9(b).

If an alternative standard is proposed, the requirements in N.J.A.C. 7:28-12.11, "Petition for alternative remediation standards for radioactive contamination," must be met. DCGLs for any radioactive material may be developed by the person responsible for remediating the site by following the methodologies in *Development of Generic Standards for Remediation of Radioactively Contaminated Soils in New Jersey, A Pathways Analysis Approach*. The Radioactive Soil Remediation Standards spreadsheet, or RaSoRS, was developed to derive the published standards and is available for use considering site specific DCGLs for NORM. Both documents may be obtained by calling (609) 984-5400 or from the Bureau of Environmental Radiation's Radiological and Environmental Assessment Sections web site at https://www.state.nj.us/dep/rpp/reas/reas_main.htm.

When developing alternative standards for restricted use scenarios, one must ensure that resulting annual incremental doses do not exceed:

- 15 mrem for all release scenarios, per N.J.A.C 7:28-12.8. This is referred to as the "Unrestricted" or "Controls-In-Place" release criterion.
- 100 mrem for scenarios where institutional and/or engineering control fail, per N.J.A.C 7:28-12.11(e). This is referred to as the "All Controls Fail" release criterion.

MARSSIM Section 4.3.3, *Use of DCGLs for Sites with Multiple Radionuclides*, discusses multiple radionuclides and how to apply the sum of the fractions rule. For sites with multiple radionuclide contaminants, it may be possible to measure just one of the contaminants and still demonstrate compliance for all the contaminants present using surrogate measurements. A discussion of the use of surrogates is found in MARSSIM Section 4.3.2, *DCGLs and the Use of Surrogate Measurements*.

The proper use of surrogate measurements considers the contribution to dose from multiple radionuclides by establishing a modified DCGL, and in this case, the sum of the fraction calculation is not necessary. The surrogate method depends on establishing consistent ratios and this may be difficult for two or more

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[2] Derived from the activity / dose relationship through various exposure pathway scenarios; established in N.J.A.C. 7:28-12.

radionuclides. Consultation with the BER is recommended when multiple radionuclides are involved.

12.7.3 Classify the Area by Contamination Potential

The NJDEP supports the MARSSIM classification methods as discussed in MARSSIM Section 4.4, *Classify Areas by Contamination Potential*. The area classification process looks at areas as either *non-impacted* or *impacted*, and further classifies *impacted* areas into Class 1, 2, or 3 based on the potential for residual radioactive contamination, with Class 1 having the greatest likelihood of being affected. The significance of survey unit classification is that this process determines the final status survey design and the procedures used to develop this design.

The scoping survey and historical site assessment can be used to determine initial classifications, but classification may change throughout the site investigation process. In order to classify an area, a comparison with the DCGL is made. All impacted areas are initially classified as Class 1 so that if a survey unit is classified incorrectly, the potential for making decision errors does not increase. MARSSIM defines Class 1 areas as areas that have, or had prior to remediation, a potential for radioactive contamination or known contamination above the DCGL, while Class 2 and 3 areas are not expected to exceed the DCGL.

The site should be broken down into smaller survey units if appropriate and each survey unit should have only one classification. MARSSIM Sections 2.5.2, *Classification*, and 4.6, *Identify Survey Units*, have further information on identifying survey units. The suggested size of the survey units for each classification are suggested maximum sizes and may be modified based on site-specific information. If an area greater than these suggested sizes is proposed, consultation with the BER is suggested before continuing with the site investigation process.

12.7.4 Determine Background

For radionuclides that are also present in background, MARSSIM Section 4.5, *Select Background Reference Areas*, provides information on selecting a background reference area. The scoping survey should be used to verify that the selected background reference area is non-impacted. Determination of the number of samples to collect in the background reference area is discussed under Section 12.8.2 *Determine Background*. MARSSIM Section 8.2, *Data Quality Assessment*, also provides methods of assessing surveys (including background reference areas).

12.7.5 Perform the Survey

Information on how to conduct surveys is discussed in MARSSIM Section 4.7, *Select Instruments and Survey Techniques*. The flow diagram (Fig. 4.2, *Flow Diagram for Selection of Field Survey Instrumentation for Direct Measurements and Analysis of Samples*) for selection of field instruments for direct measurements and analysis of samples should be used before proceeding with the survey. Criteria for selecting sample collection and measurement methods are discussed in MARSSIM Section 4.7.3, *Criteria for Selection of Sample Collection and Direct Measurement Methods*.

Selection of PPE should be described in a site-specific health and safety plan. Unique problems are associated with radioactive material, and it is beyond the scope of this manual to discuss them properly. A qualified health physicist should be consulted if radioactive materials are present. For additional information regarding soil sampling, please refer to FSPM Chapter 6, *Sample Collection*. For field scanning soil with a NaI detector, the MDC_{scan} values given in MARSSIM Table 6.7, *NaI(Tl) Scintillation Detector Scan MDCs for Common Radiological Contaminants*, provide an acceptable estimate of MDC_{scan}. The minimum detectable concentration is the activity level that a specific instrument and technique can be expected to detect 95% of the time. The MDC_{scan} is simply the minimum detectable concentration of the scanning survey given certain survey parameters. The instruments selected must be capable of detecting the nuclides of interest at the levels of interest.

MARSSIM section 4.8, *Site Preparation*, discusses how to prepare the site for the survey and how to lay out the reference coordinate system. MARSSIM Appendix A also has some useful information on the grid system and examples of scanning patterns. It may be useful to lay out the grid at this point for use later in the site investigation process.

FSPM Chapter 6 outlines the methodology for sampling surface soil, subsurface soil, ground water, streams, sediments, etc. These procedures shall be used. Water samples shall be analyzed for gross alpha and gross beta and isotopic gamma activity. If the gross alpha exceeds 5 pCi/L, additional tests shall be performed to identify and quantify specific radionuclides such as radium isotopes. If gross beta exceeds 50 pCi/L, the contributing radionuclides shall be identified and quantified. See N.J.A.C. 7:28-12.5, *Sampling, surveying, and laboratory requirements*, for information pertaining to laboratory requirements.

Quality Control, as it relates to survey activities, is discussed in FSPM Chapter 2 and MARSSIM Section 4.9, *Quality Control*.

12.7.6 Document the Scoping Survey Results

Documentation should include identification of the survey areas, classifications of each (and justification), proposed use of surrogates and the established ratios of nuclides, if applicable, the site-specific DCGLs and supporting documentation for these items. Guidance on reporting requirements can also be found in N.J.A.C. 7:26E, Technical Requirements for Site Remediation.

12.8 The Characterization Survey

The characterization survey may be used to satisfy several specific objectives, including those outlined in N.J.A.C. 7:26E-4.1. It is important to identify *specific* characterization objectives before planning to collect and analyze samples or make measurements in the field. Some examples of specific questions that might be asked in order to formulate the objectives are:

- How deep is the contamination in the survey unit (area of concern)?
- What is the concentration of ^{226}Ra in the pile of soil near the fence line?

In order to answer these and other questions, measurements will have to be taken for comparison with the established DCGLs.

Examples of some other objectives include:

- evaluation of remedial alternatives (e.g., unrestricted use, limited restricted use, or alternative standards),
- collect additional data to be used: as input to the final status survey design, to reevaluate the initial classification of survey units, to select instrumentation based on the necessary MDCs, to establish the acceptable Type I and Type II errors, and to fulfill the requirements for a Remedial Investigation/Feasibility Study (CERCLA sites only), and
- evaluation of remediation technologies. The characterization objectives themselves determine the kinds of measurements, and in turn, the analyses and sensitivities needed for comparison with the DCGLs.

12.8.1 Determination of Lateral and Vertical Extent of Contamination

As discussed in Section 12.7.5 *Perform the Survey*, above, the NJDEP soil sampling procedures shall be used for the characterization survey. Valuable information may be obtained with field instrumentation through the implementation of downhole gamma scanning/logging, scanning core samples, and through test pit/trench investigations to identify the presence of subsurface deposits of gamma-emitting radionuclides.

When gamma logging a borehole, a sensitive gamma detector such as a NaI gamma scintillation probe is lowered into the borehole/casing to record count rates at 0.5-1-foot increments. The sensitivity and specificity of this technique may be improved by placing the detector inside a shielded collimator assembly and utilizing fixed count times. A geologic description of the subsurface shall also be made. Soil sampling at depth should also be performed, based on the results of the gamma logging. It may be necessary to take only one sample if the readings are consistent, or more if there is greater variability in the gamma readings along the core or when compared to other core scans.

When gamma logging a soil core, a removed core of soil is stationed in a background area and scanned with a sensitive gamma detector such as a NaI gamma scintillation probe. A count rate is determined at 0.5-foot increments. The sensitivity and specificity of this technique may be improved by considering the following:

- Core scan data can be of limited use if the following is not considered in planning/implementation.
    - A consistent, low background scanning location should be utilized for scanning cores. Lead or other shielding is recommended to lower the instrument background.
    - Cores or other potential sources should not be stored close enough to affect the detector background.
    - A very limited geometry is represented in the field of view of the detector and detecting low levels may be very challenging in the field.
    - A Microshield or other model of the core to detector geometry might be utilized to determine an MDC for bore hole and core scanning.
    - Fixed count times will produce better data quality than only recording count rates.
- Core samples may be homogenized or composite sampled over a soil thickness that is consistent with assumptions made in the dose assessment (the Vertical Extent modeled/assumed), however should not typically exceed 1 m intervals. Homogenizing greater depth intervals run an increased risk of sample dilution, especially where scanning MDC is insufficient or not determined.

While field data collection is valuable, samples shall also be analyzed in a NJDEP-certified laboratory in accordance with N.J.A.C. 7:28-12.5. Table 12.1 lists some common methods for radiological analysis of typical contaminants. A comprehensive list of certified laboratories, parameters, matrices, and analytical methods may be found using NJDEP's DataMiner tool available at https://njems.nj.gov/DataMiner/. Select Report Category "Certified Laboratories" and run the report titled "Radiological Lab Certifications."

Table 12.1 Common Methods for Radiological Analysis		
Nuclide	**Soil/Solid Matrix Method**	**Water/Liquid Matrix Method**
Radium-226	DOE RA-04 (1990); HASL-300 Ra-04 (1997); SM 7500-Ra B (most recent addition)	EPA 901.1 (1980); DOE 4.5.2.3 (1990); HASL-300 GA-01 R (1997); EPA 903.1 (2021); SM-7500-Ra B (most recent addition)
Radium-228	SW-846 9320 (2014)	EPA 904.0 (2022); EPA Ra-05 (19867); SM 7500-Ra D (most recent addition)
Uranium	EPA 908.0 (1980); DOE U-02 (1990)	EPA 908.0, EPA 908.1 (1980), DOE U-02 (1990)
Thorium	DOE 4.5.5 (1990); HASL-300 4.5.5 (1990)	DOE 4.5.5 (1990); HASL-300 4.5.5 (1990)

It may be possible to limit the cost of analysis by correlating the gamma readings to concentration values. This may be acceptable provided enough data is collected to demonstrate a correlation. A correlation coefficient shall be calculated to support the assumed correlation. A minimum of 30 samples, representing the range of values shall be used to establish the correlation. Based on such an evaluation some reduction in the number of certified laboratory analyses might be proposed, but laboratory analyses may not be eliminated altogether.

It may also be advantageous to measure for a surrogate nuclide in the same decay series as the target nuclide. For instance, Pb-214 or Bi-214 may be used as a surrogate for Ra-226 or U-238. However, a condition of using this method is that following sample preparation, samples must be sealed and held for a minimum of 21 days prior to analysis, to allow for ingrowth of the surrogate radioactive progeny quantified by an analysis.

The number of samples to be taken depends on the objectives of the survey. If the characterization data is intended to be used for the final status survey, then the number of samples must be determined as outlined in Section 12.7, *The Final Status Survey*. Otherwise, a sufficient amount of samples shall be collected to determine the vertical and lateral extent and to identify areas that require remediation (by comparing to the DCGLs). Vertical and lateral extents shall be considered established when results of soil samples and gamma scans of boreholes/cores indicate background levels, generally represented by the threshold defined as uncontaminated surface soil (USS), which is a concentration two standard deviations above the background average.

12.8.2 Determine Background

For radionuclides that are also present in background MARSSIM Section 4.5, *Select Background Reference Areas*, provides information on selecting a background reference area. In general, a site background reference area should be a non-impacted area[3] with similar physical, chemical, geological, radiological, and biological characteristics as the survey unit being evaluated. The characterization survey can be used to further define the background reference area by determining radionuclide concentrations in environmental media.

12.8.3 Classify the Area by Contamination Potential

Review the initial area classifications made during the Scoping Survey and determine if any of them have changed or if any need to be added.

12.8.4 Document the Characterization Survey Results

Documentation of the characterization survey should provide a complete record of the radiological status of the site. All sampling and analysis data (including QA/QC data) should be included, along with justifications for changes made to area classifications (if any). There should be enough information in this report to support approaches or alternatives to site cleanup.

12.9 The Remedial Action Support Survey

The remedial action support survey is conducted in order to support remediation activities by monitoring the effectiveness of the decontamination efforts. This survey should be limited to activities such as direct measurements and scanning surveys. One of the goals of the remedial action support survey is to help determine when a site is ready for a final status survey.

Measurement methods should be chosen which can detect the radiation of interest at concentrations between 10% and 50% of the $DCGL_W$.

MARSSIM section 5.4, *Remedial Action Support Surveys* provides specific guidance on this type of survey.

12.10 The Final Status Survey

The final status survey is performed in order to demonstrate that the residual radioactivity in each survey unit meets the predetermined criteria for release, whether it be for unrestricted, limited restricted, restricted, or alternate use. A final status survey is necessary to release any area with radioactive materials impacts, not just those requiring a remedial action. For the final status survey, the fundamental components being examined are the survey units.

Compliance is demonstrated using statistical tests (either the Wilcoxon Rank Sum (WRS) test when the contaminant is present in the background, or the Sign Test, if the contaminant is not present in the background. The statistical tests evaluate the average concentration in each survey unit with the elevated measurement comparison for evaluating small areas of elevated activity. MARSSIM section 8.2.3, *Select the Tests*, discusses the choice of statistical tests). It is the primary goal of the final status survey to demonstrate that all radiological parameters satisfy the established guideline values and conditions. Data obtained at other points in the survey and site investigation process can provide useful information.

It may be possible that the DCGLs selected for a given site are close to background. This may be the case where multiple nuclides are present, the background is variable, and the site is to be released for unrestricted

[3] any area with no potential for contamination or residual radioactivity in excess of natural background levels. When contaminants are present in background, concentrations meeting the USS definition may be considered as a screening level for bounding radiological impacts

use. In this case, following the MARSSIM recommended statistical test methods may be difficult. In these situations, it is recommended that the Scenario B guidance in MARSSIM Appendix D and NUREG 1505, *A Non-Parametric Statistical Methodology for the Design and Analysis of Final Status Decommissioning Surveys*. In Scenario B, instead of having to prove that the survey unit meets the release criterion, the survey must prove that the survey unit is indistinguishable from background.

12.10.1 Revisit the Area Classifications

It is important at this stage in the process to be certain that all areas are classified correctly, as this information will be used to determine compliance. The criteria used for designating areas as Class 1, 2, or 3 shall be described in the final status survey, and compliance with the classification criteria shall be demonstrated in the final status survey. More information on survey investigations and reclassifications can be found in Section 5.5.3, *Developing an Integrated Survey Strategy*, of the MARSSIM.

12.10.2 Determine the Relative Shift

To be certain that the conclusions drawn from the samples are correct, a minimum number of samples are needed to obtain statistical confidence. To determine the number of samples, you must first determine the relative shift (Δ/σ_s). The relative shift is the ratio involving the concentration to be measured relative to the variability in that concentration and can be thought of as an expression of the resolution of the measurements.

$$\Delta/\sigma_s = (DCGL_W - LBGR) / \sigma_s$$

where:

$DCGL_W$ = derived concentration guideline level

LBGR = concentration at the lower bound of the gray region; the Type II (β) error is set at the LBGR. The LBGR is always below the $DCGL_w$

σ_s = an estimate of the standard deviation of the concentration of residual radioactivity in the survey unit

The value for σ_s is determined either from existing measurements or by limited sampling. It could also be estimated if remediation will be performed. When multiple radionuclides are present, the following equation for determining the overall standard deviation for use in relative shift calculations:

$$\sigma(T) = \sqrt{\left(\frac{\sigma(C_1)}{DCGL_1}\right)^2 + \left(\frac{\sigma(C_2)}{DCGL_2}\right)^2 + \cdots + \left(\frac{\sigma(C_i)}{DCGL_i}\right)^2 + \cdots + \left(\frac{\sigma(C_n)}{DCGL_n}\right)^2}$$

Where:

$\sigma(T)$ is the standard deviation or estimated uncertainty of the sum of ratios

$\sigma(C_i)$ is the standard deviation or estimate of uncertainty in the concentration in the survey unit of the ith radionuclide for i=1,…n.

$DCGL_i$ is the DCGL of the ith radionuclide for i=1,…n.

If, during the survey process, a background reference area is used and the standard deviation in the reference area (σ_r) is greater than σ_s in the survey unit, the larger value should be used to design the survey.

The NJDEP concurs with the MARSSIM recommendation to initially set the LBGR at 0.5 $DCGL_W$ when insufficient data exists on an area, however this assumption should be re-evaluated following further data collection. Underestimating the LBGR can result in reduced statistical power, leading to Type II errors. Alternatively, the LBGR could be set at the expected concentration in the survey unit following remediation, or at the time of the final status survey. Since small values of Δ/σ_s result in large numbers of samples, it may be desirable to make the Δ/σ greater than 1. There are two ways to increase Δ/σ. The first is to increase the width of the gray region by making LBGR small. Only Type II decision errors occur in the gray region. The disadvantage of making the gray region larger is that the probability of incorrectly failing to release a survey unit will increase. The second way to increase Δ/σ is to make σ smaller. One way to make σ smaller is to have survey units that are relatively homogeneous for measured radioactivity. That is why selecting the boundaries of the survey unit is an important consideration. Another way to make σ small is by using more precise measurement methods. The more precise methods might be more expensive, but this may be compensated for by the decrease in the number of required measurements.

Generally, the design goal should be to achieve Δ/σ values between one and three. Overly optimistic estimates for σ should be avoided. The consequence of taking fewer samples than are needed, given the actual measurement variations, will be unnecessary remediations (increased Type II decision errors).

Section 5.5.2.2, *Contaminant Present in Background-Determining Numbers of Data Points for Statistical Tests*, and Appendix D, *The Planning Phase of the Data Life Cycle*, in the MARSSIM provide greater detail.

12.10.3 Determination of Acceptable Type I and Type II Decision Errors

A decision error is the probability of making an error in the decision on a survey unit by passing a survey unit that should fail (alpha or Type I) or by failing a survey unit that should pass (beta or Type II). The acceptable Type I (alpha) decision error rate is 0.05 or less. Any Type II (beta) decision error rate is acceptable to the NJDEP. However, the higher the Type II rate, the greater the probability that the site will not pass the statistical test, even though the survey unit should pass.

Section 5.5.2.1, *Application of Decommissioning Criteria*, and Appendix D.6, *Specify Limits on Decision Errors*, of the MARSSIM provide greater detail on this process.

12.10.4 Determine the Number of Samples Needed

The minimum number of samples needed, N, can be determined from the equation for N found in Equation 5.1 in the MARSSIM. N is the total number of data points for each survey unit/reference area combination. For contaminants that are also present in background, the N data points are divided between the survey unit and the reference area. So, N/2 measurements are performed in each survey unit, and N/2 measurements are performed in each reference area. Fewer samples will increase the probability of an acceptable survey unit failing to demonstrate compliance. Alternately, once the values for Δ/σ and the error types (α and β) have been established, the values for N/2 or N can be found in Tables 5.3, *Values of N/2 for Given Values of the Relative Shift, Δ/σ, when the Contaminant is Present in Background*, and 5.5, *Values of N for Given Values of the Relative Shift, Δ/σ, α, and β when the Contaminant is Not Present in Background*, of the MARSSIM.

Section 5.5.2.2, *Contaminant Present in Background-Determining Numbers of Data Points for Statistical Tests*, in the MARSSIM outlines the process. If the radionuclides of interest are not present in the background, or they are a small percentage of the $DCGL_w$, then a determination will need to be made for the number of samples needed to perform a Sign Test, instead of the WRS Test. This information can be found in the same sections of the MARSSIM.

As an example, suppose you had the following scenario:

Background: A site has 14 survey units and one (1) reference area. ^{238}U is the radionuclide of concern, and measurements will be of nuclide concentration.

$$DCGL_W\ ^{238}U = 10\ pCi/g$$

σ_s = 3.2 pCi/g

Bkg. in reference area = 1.2 pCi/g

σ_r = 0.6 pCi/g

LBGR is selected to be 5 pCi/g

Δ/σ is then = (10-5)/3.2= 1.56

If α is 0.05 and β is 0.10, looking at Table 5.3, *Values of N/2 for Given Values of the Relative Shift,* Δ/σ, *when the Contaminant is Present in Background*, in the MARSSIM gives a value of N/2 of 13 (meaning 13 samples from the reference area and 13 from the survey unit).

These data points are then positioned throughout the survey unit by first randomly selecting a start point and establishing a systematic pattern. **The systematic sampling grid must be triangular for Class 1 areas.** The number of calculated survey locations, N/2 (for when the contaminant is present in background; N if the Sign test is used), is used to determine the grid spacing, L, of the systematic sampling pattern (see MARSSIM Section 5.5.2.5 *Determining Survey Locations*). The grid area that is bounded by these survey locations is given by A_{GRID}=0.866 x L^2 for a triangular grid. For a rectangular grid, $A_{GRID} = L^2$.

12.10.5 Additional Samples for Elevated Measurement Comparison in Class 1 Areas

Class 1 survey units may have small areas where concentrations exceed the $DCGL_W$. The area between systematic sample points is the size of the area that could be missed through the established sampling pattern. In order to avoid missing an elevated area of this size, an *a priori* $DCGL_{EMC}$ must be determined using the equation below:

$$DCGL_{EMC} = (\text{Area Factor}) \text{ X } (DCGL_W)$$

Area factors were calculated using RESRAD[4] (version 6.2.1) and are presented in Table 12.2. These area factors were determined by running RESRAD for each nuclide and varying the lot size and the length parallel to the aquifer. The area factors were then computed by taking the ratio of the dose per unit concentration generated by RESRAD for the default values (10,000 m^2) to that generated for the other areas listed. For sites with multiple radionuclides, the most conservative area factor (the smallest) can be used. Additionally, when site specific release criteria are proposed, it is necessary to determine site specific area factors utilizing MARSSIM methodology available at: https://www.epa.gov/radiation/multi-agency-radiation-survey-and-site-investigation-manual-marssim.

[4] The RaSoRS spreadsheet cannot be used when the size of the elevated area is smaller than the size of the house (1000 ft^2). However, since the area factors used in RaSoRS were obtained directly from RESRAD, the numbers in Table F.1 are acceptable for determining a $DCGL_{EMC}$.

Table 12.2 Outdoor Area Dose Factors									
	Grid Area								
Nuclide	**1 m²**	**3 m²**	**10 m²**	**30 m²**	**100 m²**	**300 m²**	**1000 m²**	**3000 m²**	**10,000 m²**
Ra-226, Po-210	26.5	11.9	5.6	3.9	2.8	2	1	1	1
Th-232, Th-228, Ra-228	15	6.9	3.3	2.4	1.8	1.5	1.1	1	1
U-238, Th-230, U-234	48.8	22.1	10.1	6.2	3.4	2.1	1.1	1	1

Next, the minimum detectable concentration (MDC) of the scan procedure, needed to detect an area of elevated activity at the limit determined by the area factor, must meet the following condition:

$$\text{Scan MDC}_{\text{required}} < \text{DCGL}_{\text{EMC}}$$

The actual MDCs of scanning techniques are then determined for the available instrumentation (see Section 6.7 *Detection Sensitivity* of the MARSSIM). If the actual scan MDC of the selected instrument is less than the required scan MDC, no additional sampling points are necessary for assessment of small areas of elevated activity. In other words, the scanning technique exhibits adequate sensitivity to detect the small areas of elevated activity that are missed by systematic sampling.

If the actual scan MDC is greater than the required scan MDC, then it is necessary to calculate the area factor that corresponds to the actual scan MDC using the following equation:

$$\text{Area Factor} = \frac{\text{scan MDC(actual)}}{\text{DCGL}_{\text{W}}}$$

Next, find the grid area corresponding to that Area Factor from Table 12.2. Then calculate the number of sample points needed to produce that grid area as follows:

$$n_{EA} = \frac{\text{(Survey Unit Area)}}{\text{(Grid Area)}}$$

The calculated number of survey locations, n_{EA}, is used to determine a revised spacing, L, of the systematic pattern (refer to Section 5.5.2.5 *Determining Survey Locations* of the MARSSIM). Specifically, the spacing, L, of the pattern (when driven by areas of elevated activity) is given by:

$$L = \sqrt{\frac{A}{0.866 n_{EA}}}$$

for a triangular grid or:

$$L = \sqrt{\frac{Asu}{n_{EA}}}$$

for a rectangular grid.

where A_{SU} is the area of the survey unit. Grid spacing shall be rounded down to the nearest distance that can be conveniently measured in the field. If n_{EA} is calculated to be smaller than N (the number of data points calculated in Section 12.7.4 of this chapter), then N should be used to determine L.

Continuing with the example above, suppose you had the following:

Survey Unit area = 380m^2
$DCGL_W$ = 10 pCi/g of ^{238}U
Number of samples = 13

To determine the area that might be missed, first calculate L, the length of the grid:

$$L = \sqrt{\frac{380m^2}{(0.866)(13)}}$$

L = 5.8m

Then determine the area of the grid:

A = .866 x L^2
A = 29 m^2

Look in Table 12.2. The area factor that corresponds to a 29m^2 for ^{238}U is 6.2. Now determine the $DCGL_{EMC}$:

$DCGL_{EMC}$ = (Area Factor)($DCGL_W$)
$DCGL_{EMC}$ = 6.2 x 10 pCi/g = 62 pCi/g
Actual MDC_{scan} = 80 pCi/g

Since the Actual MDC is greater than the $DCGL_{EMC}$, the grid spaces must be made smaller by increasing the number of samples.

To determine the new number of samples needed (n_{EA}), the area factor corresponding to the MDC must be determined:

Area Factor = MDC_{scan}/$DCGL_w$
Area Factor = 80/10 = 8

Next, go to Table 12.2 and find the size of the new grid block area. In this case, for ^{238}U, an area factor of 8 corresponds to an area of about 20 m^2.

Now, calculate the number of sample points needed to produce that grid area:

n_{EA}= 380m^2/20m^2 = 19
So, the length of the grid spacing is:

$$L = \sqrt{\frac{380m^2}{0.866(19)}}$$

L = 4.8 m

Figure 12.2 depicts in blue the unsampled area between systematic sample locations, which is used to determine the *a priori* $DCGL_{EMC}$ discussed above for comparison to MDC_{scan}. However, during final status survey it is possible that sampling detects a hot spot exceeding the $DCGL_W$. The elevated area could be as large at that bounded by neighboring compliant sample locations, which is depicted as a red hexagon in Figure 12.2. Bias sampling and scan data may be useful for justifying a smaller lateral area. The area factor representative of this final area would be used to determine the *a posteriori* $DCGL_{EMC}$ specific to that hot spot. If the Elevated Measurement results are compliant with the $DCGL_{EMC}$, this indicates this hot spot alone is compliant.

For multiple radionuclides, an MDC and an Area Factor of the mix may be needed. Chapters 9 and 13 of *Decommissioning Health Physics: A Handbook for MARSSIM Users*, (Abelquist, 2014) provides examples of how to determine these values.

Figure 5.3 (*Flow Diagram for Identifying Data Needs for Assessment of Potential Areas of Elevated Activity in Class 1 Survey Units*) in the MARSSIM provides a concise overview of the procedure used to identify data needs for the assessment of small areas of elevated activity.

If the EMC test passes, then the following condition must also be met, then the elevated measurement comparison is acceptable:

$(\delta/ DCGL_W) + \{(\text{avg. conc. in elevated area} - \delta)/(\text{area factor for elevated area x } DCGL_W)\} < 1$ where δ = the average residual radioactivity concentration for all sample points in the survey unit.

If there is more than one elevated area, a separate term should be included for each one.

As an example, suppose you had the following data:

$DCGL_W$ ^{226}Ra = 3 pCi/g
The area factor for the elevated 1 m^2 area is 26.5.
a posteriori $DCGL_{EMC}$ = 79.5 pCi/g

The elevated area has an average concentration of 60 pCi/g.
The results (pCi/g) of the other sampling points are:

1.0, 2.0, 1.5, 0.5, 2.2, 2.9, 1.0, 0.3, 2.0, and 1.0.
δ = 6.76 pCi/g above background

Since

6.76/3 + (60-6.76)/(26.5x3) is not < 1, therefore, the elevated area must be remediated.

The elevated measurement comparison method is described further in MARSSIM Section 8.5.1, *Elevated Measurement Comparison*, and Section 5.5.2.4, *Determining Data Points for Small Areas of Elevated Activity*, of the MARSSIM.

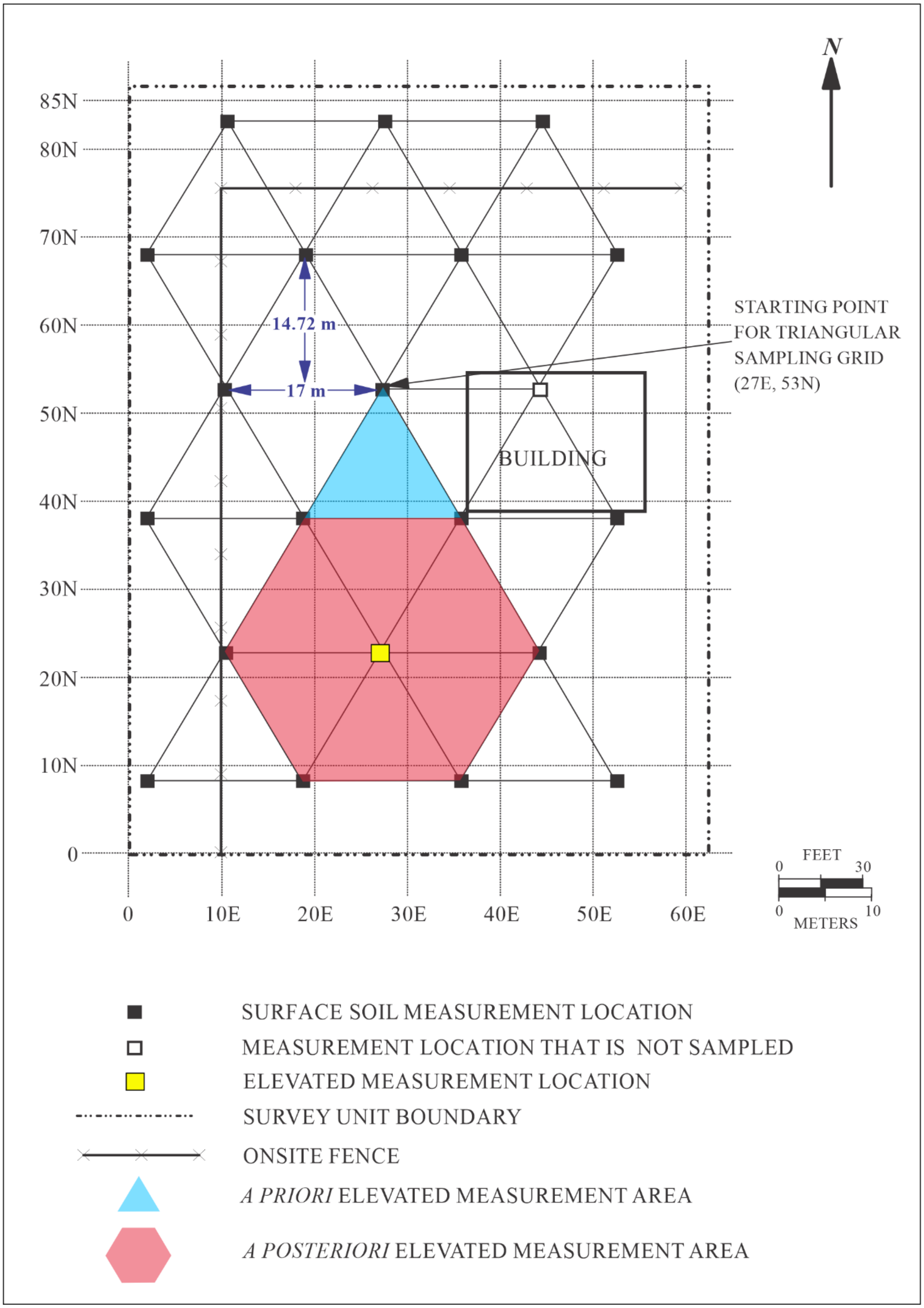

Figure 12.2 Example of a Random-Start Triangular Grid Measurement Pattern
(Adapted from MARSSIM, Revision1, August 2000)

12.10.6 Determining Sample Locations

A reference coordinate system must first be established for the impacted areas. A single reference coordinate system may be used for a site, or different systems may be used for each survey unit or groups of survey units. Section 4.8.5, *Reference Coordinate System*, of the MARSSIM describes how to establish such a system.

Class 1 sampling locations are established in a triangular pattern. A rectangular or triangular pattern may be used for Class 2 areas. Measurements and samples in Class 3 survey units and reference areas should be taken at random locations. Biased sample locations should also be selected where scanning data or other information indicate the potential for contamination. More information on establishing survey locations can be found in Section 5.5.2.5, *Determining Survey Locations*, of the MARSSIM.

12.10.7 Investigation Levels and Scanning Coverage Fractions

Investigation levels are radionuclide-specific levels of radioactivity used to indicate when additional investigations may be necessary. Investigation levels also serve as a quality control check to determine when a measurement process begins to get out of control. For example, a measurement that exceeds the investigation level may indicate that the survey unit has been improperly classified or it may indicate a failing instrument.

The investigation levels in Table 12.3 should be implemented. When an investigation level is exceeded, the first step is to confirm that the initial measurement/sample actually exceeds the particular investigation level. This may involve taking further measurements and/or biased samples to determine that the area and level of the elevated residual radioactivity are such that the resulting dose meets the release criterion. Depending on the results of the investigation actions, the survey unit may require reclassification, remediation, and/or resurvey. If after further investigation it is determined that the area does exceed the investigation level, then it should be remediated. Further information on investigation levels is found in Section 5.5.2.6 *Determining Investigation Levels* of the MARSSIM.

Table 12.3 Final Status Survey Investigation Levels

Survey Unit Classification	Flag Direct Measurement of Sample Result When:	Flag Scanning Measurement Result When:
Class 1	> $DCGL_W$ and a statistical parameter-based value	> *a priori* $DCGL_{EMC}$
Class 2	> $DCGL_W$	> $DCGL_W$ or MDC_{SCAN}
Class 3	> fraction of $DCGL_W$	> $DCGL_W$ or MDC_{SCAN}

Scanning is performed to locate small areas of elevated concentrations of residual radioactivity. Table 5.9 *Recommended Survey Coverage for Structures and Land Areas*, in the MARSSIM illustrates the acceptable scanning coverage based on Area Classification. NUREG 1507, Revision 1, "*Minimum Detectable Concentrations with Typical Radiation Survey for Instruments for Various Contaminants and Field Conditions*" may be consulted in addition to MARSSIM.

12.10.8 Special Survey Considerations Subsurface Residual Radioactivity

The MARSSIM final status survey method was designed specifically for residual radioactivity in the top 15 cm of soil. If previous surveys, historical documentation, or other observations suggest potential for subsurface residual radioactivity, this must be considered. The characterization survey should determine both the depth and lateral extent of residual radioactivity. If RaSoRS was used to develop the $DCGL_W$, it was based on the assumption that this activity may be excavated in the future and that mixing of the residual radioactivity will occur in the process (note that since N.J.A.C. 7:28-12 bases the DCGLs on the vertical extent of contamination, subsurface residual radioactivity may be permitted to be left in place).

When the appropriate DCGLs are established, the final status survey is performed by taking core samples to the depth of the residual radioactivity. The number of cores to be taken is the number N required for the WRS or sign test, as appropriate. Since the final status survey is performed before any cover is placed over the area, the elevated measurement comparison test should be performed to detect any areas of elevated activity (on the surface). The grid spacing shall be adjusted if necessary. Triangular grids are required for Class 1 areas due to their better efficiency in locating areas of elevated concentration.

The NJDEP is awaiting the MARSSIM guidance on subsurface contamination. Until that time, subsurface contamination will be treated on a case-by-case basis. The U.S. Nuclear Regulatory Commission (NRC) held public workshops on the technical basis for guidance on conducting and evaluating surveys of residual radioactivity in the subsurface soils of licensee sites. The NRC began to address this problem in NUREG/CR-7021, "A Subsurface Decision Model for Supporting Environmental Compliance," issued January 2012 and is working with stakeholders and a consultant on the preparation of technical basis document currently titled "Guidance on Surveys for Subsurface Radiological Contaminants" (draft March 2022). Some guidance has also been included in Section G.3 of NUREG 1757 Volume 2, Revision 2, "Consolidated Decommissioning Guidance: Characterization, Survey, and Determination of Radiological Criteria" (July 2022)

12.10.9 Determining Compliance

The measurement data should first be reviewed to determine if the areas were properly classified. Refer to Section 8.2.2, *Conduct a Preliminary Data Review*, of the MARSSIM for an acceptable method. If it is shown during the final status survey that an area was misclassified with a less restrictive classification, the area should receive the correct classification and the final status survey for that area should be repeated.

If there are several areas that appear to be misclassified, it may be necessary to repeat the characterization, reclassify the areas, and re-survey them for the new classification.

The next step is to determine if the measurement results show that the survey unit(s) meets the release criteria. Chapter 8, *Interpretation of Survey Results*, of the MARSSIM provides an in-depth discussion of the interpretation of survey results, particularly for the final status survey.

Table 8.2, *Summary of Statistical Tests*, in the MARSSIM summarizes acceptable ways to interpret the sample measurements. A description of the WRS test is found in Section 8.4, *Contaminant Present in Background*, of the MARSSIM, the Sign Test is found in Section 8.3, *Contaminant Not Present in Background*, and the elevated measurement comparison is described in Section 8.5 *Evaluating the Results: The Decision*. Note that only unbiased randomly distributed or systematic samples are included in these statistical tests. Biased sample locations are measured separately against the applicable DCGL.

If a survey unit fails, the measurement results should be evaluated to determine why. A survey unit fails when the null hypothesis is not rejected. When the null hypothesis is not rejected, it may be because it is in fact true, or it may be because the test did not have sufficient power to detect that it is not true. A retrospective power curve can be generated to determine if the test had sufficient power. If the retrospective power analysis shows that the test did not have sufficient power, then more samples may be all that is necessary rather than remediation. Of course, some failures may be because the residual radioactivity does not meet the remediation standards and further remediation will have to be performed.

Passing the statistical test is not the only criteria for determining compliance with the remediation standards. The following example illustrates this point. A Class 1 Survey unit passes the statistical tests and contains some areas that were flagged for investigation during scanning. Further investigation, sampling and analysis indicates one area is truly elevated. This area has a concentration that exceeds the

$DCGL_{EMC}$. This area is then remediated. Remediation control sampling shows that the residual radioactivity was removed, and no other areas were contaminated with removed material. In this case one may simply document the original final status survey, the fact that remediation was performed, the results of the remedial action support survey, and the additional remediation data. In some cases, additional final status survey data may not be needed to demonstrate compliance with the release criterion.

MARSSIM Section 8.2.2, *Conduct a Preliminary Data Review*, 8.5.3, *If the Survey Unit Fails*, and Appendix D, *The Planning Phase of the Data Life Cycle*, of the MARSSIM provide acceptable methods for reviewing measurement results.

Once the survey is complete, any backfilling of excavated areas shall be performed in accordance with the NJDEP's Fill Material Guidance for SRP Sites, available at https://www.nj.gov/dep/srp/guidance/#fill_srp. All backfill and any required cover materials must be sampled to show compliance with the N.J.A.C. 7:28-12 definition of Uncontaminated Surface Soil. This ensures that additional radiation dose is not contributed by the remedial action restoration materials. Surveys for release of equipment and materials shall be performed in accordance with MARSSIM.

12.10.10 Mixing After Demonstrating Compliance with the Pre-mixing DCGLs

N.J.A.C. 7:28-12.9(b) allows soils at the DCGLs listed in Tables 4A through 5B to remain at the specified thickness (vertical extent) together with the specified thickness of uncontaminated surface soil (USS). After it is demonstrated that the site meets the DCGLs in these tables, there is a requirement to mix the residual layer with the uncontaminated surface soil so that a uniform concentration is achieved throughout the soil column. This might be done to limit the need for excavation and avoid the requirement for a deed restriction to maintain the cover. A uniform concentration is determined by using the same number of sample points as determined above. At each sample point, a borehole shall be advanced to the depth of the disturbed soil. Surface soil samples shall be taken and analyzed at a certified laboratory. Gamma scanning may be used to verify that the concentration at depth does not vary by more than 30%.

12.10.11 Documenting the Final Status Survey

Documentation for the final status survey should be complete and provide a clear record of the radiological status of the survey unit(s) relative to the established DCGLs. Sufficient data and information should be provided so that an independent evaluation of the survey results can be performed.

While much of the information in the final status survey will be available in other reports generated during the site survey and investigation process, where practical, this report should be a stand-alone document. Further guidance on documentation may be found in Appendix N, *Data Validation Using Data Descriptors*, of the MARSSIM.

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