Performance of Radiological Surveys

Nuclear Secured / Radiation Safety

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History and Approvals

History

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Approvals

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1. Purpose and Scope

1.1. Purpose

The purpose of this procedure is to specify the general survey requirements and methodology for performing radiological surveys. Any specific survey protocols such as detection sensitivity requirements, types of surveys to be performed, survey frequencies, survey design and Data Quality Objectives (DQOs) will be included in the site-specific plans or other project specific documentation.

1.2. Scope

This procedure applies to all health physics personnel and subcontractors at field project sites that perform radiological surveys under the Nuclear Secured (NS) radiation protection program (RPP). The specific types of surveys addressed within this procedure include:

- Exposure rate surveys,
- Total contamination surveys (direct measurement),
- Removable contamination surveys, and
- Surface scan surveys

Additional survey requirements such as sampling and analysis are not addressed within this procedure.

2. References

2.1. ISO Standard 7503-1, *Evaluation of Surface Contamination - Part 1 Beta Emitters (Maximum Beta Energy Greater than 0.15 MeV) and Alpha Emitters*

2.2. NUREG-1507, *Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions*

2.3. NUREG-1575, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*

2.4. NUREG-1575, Supplement 1, *Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual (MARSAME)*

2.5. NS-RS-PG-001, *Radiation Protection Program*

2.6. NS-RS-PR-102, *Project Records Management*

2.7. NS-RS-PR-400, *General Operations of Radiation Survey Instruments*

2.8. NS-RS-PR-401, *Instrument Calibration and Maintenance*

2.9. NS-RS-PR-402, *QA/QC of Portable Radiation Survey Instruments*

3. General

3.1. Definitions

3.1.1. *Beta Correction Factor (BCF)* – A factor used to correct the instruments beta response to the true exposure rate at the center of the ion chamber.

3.1.2. *Critical Level (L_C)* – Net instrument response in counts at which an instrument measurement can be considered “above background”.

3.1.3. *Detection Limit (L_D)* – Net instrument response in counts at which an instrument measurement has a fixed level of certainty.

3.1.4. *Direct Measurement* – A measurement of the surface activity using a contamination monitor or meter which determines the total surface contamination, fixed plus removable surface contamination.

3.1.5. *Fixed Surface Contamination* – Contamination adhering to a surface in such a way it is not transferable under normal working conditions.

3.1.6. *Geotropism* – Gravity’s effect on portable radiation survey instruments based on instrument orientation.

3.1.7. *Indirect Measurement* – A measurement of the removable activity on a surface by using a smear sample.

3.1.8. *Instrument Efficiency (ε_i)* - The ratio between the instruments reading and the surface emission rate of a source under given geometric conditions.

3.1.9. *Minimum Detectable Activity (MDA)* – An estimate of the smallest true value of the measurand that ensures a specific high probability of detection.

3.1.10. *Minimum Detectable Concentration (MDC)* - The Minimum Detectable Activity divided by the sample volume or mass.

3.1.11. *Radiological Survey Instrument* – A complete system designed to quantify one or more characteristics of ionizing radiation or radioactive material.

3.1.12. *Removable Surface Contamination* – Surface contamination that is removable or transferable under normal working conditions.

3.1.13. *Smear Test* – Taking a sample of removable activity by wiping the surface with a dry or wet smear and a subsequent evaluation of the amount of activity removed.

3.1.14. *Surface Efficiency (ε_s)* – The ratio between the number of particles emerging from the front face of a source, surface emission rate, and the number of particles released within the source or saturated layer per unit time.

3.1.15. *Surface Emission Rate* – The number of particles emerging from the front face of a source per unit time (2π).

3.2. Responsibilities

Depending on personnel qualifications and the size of the project, project personnel may be assigned multiple roles and/or responsibilities.

3.2.1. NS Radiation Safety Officer

The NS Radiation Safety Officer (RSO) maintains and oversees the implementation of the NS RPP. The RSO shall ensure that radiation safety, radioactive materials management, and radiological operations procedures and programs are kept up to date such that they comply with current regulations and incorporate current and relevant industry practices and regulatory guidance.

3.2.2. Project Manager

The Project Manager (PM) is responsible for ensuring that the proper program procedures and programs are implemented on the project site as required by customer agreements and contracts. The PM is responsible for ensuring that these programs and procedures are properly incorporated into project specific plans and procedures. The PM is responsible for ensuring that the NS RPP and client programs and procedures, as applicable, are available for use by project personnel.

3.2.3. Project Health Physicist

The Project Health Physicist (PHP) is responsible for assisting the RSO in providing health physics support to the PM and Radiation Protection Supervisor (RPS). This includes technical support to ensure procedural and regulatory compliance and to ensure that the project-specific Data Quality Objectives (DQOs) are met.

3.2.4. Radiation Protection Supervisor

The Radiation Protection Supervisor (RPS) is responsible for implementing the NS RPP at the project location. The RPS manages and oversees the project personnel in regards to radiation and respiratory protection and reports directly to both the PM and the RSO.

3.2.5. Health Physics Personnel

Health Physics personnel are responsible for performing and documenting radiological surveys in accordance with this procedure.

3.3. Precautions and Limitations

3.3.1. Ensure the proper instrumentation is used that can detect the radionuclides of concern with adequate detection sensitivities.

3.3.2. An evaluation of the environmental conditions should be performed by the PHP and/or RPS as significant changes in temperature or changes in elevation may affect the performance of field instruments depending on the calibration settings. General rules of thumb may be used to adjust the instruments high voltage to correct for changes in temperature and/or elevation based on the manufacturer's recommendations or the calibration facility. The PHP and/or RPS may also determine that a plateau test may be required to re-establish the high voltage based on the specific field conditions.

3.3.3. Be aware that the response of some instruments is affected by the way the instrument is held known as "geotropism". If geotropism is a factor, take note and notify the RPS.

3.3.4. When performing surveys in which there are multiple radionuclides of concern, use the most limiting efficiencies unless an average efficiency is calculated by the PHP. Average efficiency is based on the radionuclides of concern and their relative abundance.

3.3.5. When establishing the MDC for a survey protocol, the MDC should be less than 50% of the limit as practical; however, this may be difficult especially for scan surveys.

3.3.6. Use precauation when interpreting survey results using large area detectors (i.e., > 126 cm2) as small areas of activity may be missed because of area averaging. Large area detectors are more sensitive when detecting low levels of uniform contamination but my miss small areas of elevated activity.

3.3.7. Ensure that the survey instruments are properly calibrated for the radionuclides of concern (i.e., type of radiation and emission energies), so the proper instrument efficiencies are defined and used.

3.3.8. Be aware of sources of radiation in the area and fluctuating background which may impact the accuracy of survey results.

3.3.9. Properly protect instrumentation and detectors from becoming contaminated.

4. Pre-Requisites / Requirements

4.1. Establish the survey protocols and the release or survey criteria to which surveys will be performed. This will typically be defined in the project specific work plans and documents.

4.2. Operate instruments in accordance with NS-RS-PR-400, *General Operations of Radiation Survey Instruments*.

4.3. Ensure the instrumentation has been properly calibrated and inventoried in accordance with NS-RS-PR-401, *Instrument Calibration and Maintenance*.

4.4. Ensure the proper quality assurance and quality control parameters and testing criteria have been established for the survey instrumentation prior to instrument use in accordance with NS-RS-PR-402, *QA/QC of Portable Radiation Survey Instruments*.

4.5. Ensure the survey instrumentation has been response tested or source checked prior to instrument use.

5. Procedure

5.1. General Guidance

5.1.1. Ensure the proper instrumentation is selected to perform the surveys. Consideration shall be given to the following:

- Required detection sensitivities,
- Types of emissions and energies,
- Types of surfaces and surface geometry, and
- Data Quality Objectives and goals of the survey.

5.1.2. Design, plan and perform surveys in accordance with the project work plans such as a Characterization Plan or Final Status Survey Plan.

5.1.3. Establish a routine survey schedule and survey frequencies (daily, weekly, monthly, quarterly) as necessary depending on the job scope. These may include:

- Control Points
- Radiological Work Areas (Contamination Area, Radioactive Materials storage, Radiation and High Radiation Areas, etc)
- Uncontrolled Areas and buffer zones
- Personnel Break Areas,
- Site perimeters

5.2. Survey Efficiencies

For instruments used to measure the levels of radioactive contamination (fixed and/or loose), the survey efficiency consists of two components, the instrument efficiency and the surface efficiency as discussed in ISO Standard 7503-1, *Evaluation of Surface Contamination - Part 1 Beta Emitters (Maximum Beta Energy Greater than 0.15 MeV) and Alpha Emitters* and the applicable regulatory guidance such NUREG-1575, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*.

Instrument efficiency (ε_i)

5.2.1. The instrument efficiency shall be established with a NIST traceable calibration source that is representative of the types of emissions and energies of the radionuclides of concern.

5.2.2. The instrument efficiency shall be established during the efficiency calibration. This will either be determined at the calibration facility and documented on the calibration paperwork, or it can be performed on site in accordance with NS-RS-PR-401, *Instrument Calibration and Maintenance*

5.2.3. If the instrument efficiency from the calibration paperwork is used, determine whether the efficiency was determined based on the source activity (i.e., 4π emission) or the surface emission rate.

5.2.4. If the instrument efficiency as reported is based on the 4π source activity, adjust the efficiency to reflect the surface emission rate. This can be estimated as follows based on the type of emission and energy, source backing material and the amount of backscatter.

$$\varepsilon_i = \frac{2 \cdot \varepsilon_{4\pi}}{(1 + BS)}$$

Where: $\varepsilon_{4\pi}$ = 4π Instrument Efficiency (%)
BS = Backscatter (%)

Table 1 - Source Backscatter[1]

Emission	Source Backing	Backscatter [1] (BS)
Alpha	NA	5 %
Beta > 0.15MeV	Aluminum / Metal	30 %
	Low-Z	20 %

[1] ISO Standard 7503-1, *Evaluation of Surface Contamination - Part 1 Beta Emitters (Maximum Beta Energy Greater than 0.15 MeV) and Alpha Emitters*

5.2.5. If the instrument efficiency is determined on site, use the surface emission rate as specified on the source certificate. If the source certificate only reports the source activity, estimate the surface emission rate as follows:

$$q_{2\pi} = \frac{A}{2} \cdot (1 + BS)$$

Where: $q_{2\pi}$ = Surface emission rate (α or β/min.)
A = Source Activity (dpm)

5.2.6. Use the average net detector response, $\bar{x}$, from the series of source counts performed during the instruments Chi-Square test in accordance with NS-RS-PR-402, *QA/QC of Portable Radiation Survey Instruments* and the surface emission rate of the source to determine the instruments efficiency as follows:

$$\varepsilon_i = \frac{\bar{x}}{q_{2\pi}}$$

5.2.7. Document the instrument efficiency with the instrument's calibration paperwork and Chi-Square test forms as applicable in accordance with NS-RS-PR-401, and NS-RS-PR-402, *QA/QC of Portable Radiation Survey Instruments*.

Surface efficiency (ε_S)

5.2.8. The surface efficiency is largely dependent on the type and energy of the emission and may be established in accordance with the guidance in ISO Standard 7503-1, *Evaluation of Surface Contamination - Part 1 Beta Emitters (Maximum Beta Energy Greater than 0.15 MeV) and Alpha Emitters* as summarized in Table 2.

Table 2 - Surface Efficiencies[2]

Emission	Surface Eff.[1] (ε_S)
Alpha	25%
Beta: 0.4 MeV > $E_{\beta\text{-max}}$ > 0.15 MeV	25%
Beta: $E_{\beta\text{-max}}$ > 0.4 MeV	50%

[2] ISO Standard 7503-1, *Evaluation of Surface Contamination - Part 1 Beta Emitters (Maximum Beta Energy Greater than 0.15 MeV) and Alpha Emitters*

5.2.9. Additional factors may impact the surface emission rate including the type of surface material, dust loading, surface condition and contour and the thickness of the saturation layer. The surface efficiency may also be evaluated and determined experimentally or based on the data as provided in NUREG-1507, *Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions*.

5.2.10. The PHP or RSO and the RPS shall ensure that both the instrument and surface efficiencies used for the survey represent the measured field conditions.

5.3. Establishing Background

There are two components to background that must be considered when performing surveys. These include the ambient background as measured by shielding the face of the detector and natural activity in materials such as granite, concrete, tile, etc.

Ambient Background:

5.3.1. Shield the detector face and perform ambient area background measurement within the survey area as directed by the RPS or PHP. The RPS or PHP shall establish the background count time depending on the required detection sensitivities (typically 5 to 10 minutes).

Material Background:

5.3.2. Perform background surveys to assess any natural activity within building materials for either material specific background subtraction or statistical comparison as directed by the PHP.

5.3.3. Select a background area representative of the areas to be surveyed, which is known to be unaffected and not contaminated.

5.3.4. Perform ambient area background measurements within the background area in accordance with Step 5.3.1.

5.3.5. Perform a series of direct measurements on a variety of construction materials as directed by the PHP. Typically, a minimum of 10 to 20 measurements is required for each type of material where natural activity is of concern.

5.3.6. The PHP or designee shall statistically assess the data and determine any levels of natural activity within the construction materials for either subtraction from the survey results or for statistical comparison.

5.3.7. Document all background surveys in accordance with Section 5.9.

5.4. Exposure Rates

5.4.1. Perform exposure or dose rates surveys as required including contact and general area exposure rates as applicable.

5.4.2. Contact surveys are typically performed within 1-inch of a particular surface.

5.4.3. General Area surveys are typically performed in areas that may normally be occupied but no closer than 30-cm or 1-foot from any surface.

5.4.4. For ion chambers, understand where the effective center is located for the instrument so the instrument may be properly located and positioned during surveys.

5.4.5. Hold the instrument at the location of interest and allow the meter to stabilize.

5.4.6. Obtain open and closed window readings as applicable if beta exposure rates are of concern.

5.4.7. Record the reading(s) on the survey form in accordance with Section 5.9 and identify the specific measurement location(s) using the appropriate units and geometries (i.e., contact vs. general area and open window vs. closed window readings).

5.4.8. As applicable, determine and record any beta exposure rates, ER_β, as follows for ion chamber instruments:

$$ER_\beta = (OW - CW) \cdot BCF$$

Where:	*OW*	=	Open window reading (mr/hr)
	CW	=	Closed window reading (mr/hr)
	BCF	=	Beta correction factor (mrad/hr per mr/hr)

5.5. Total Direct Contamination

5.5.1. The RPS or PHP shall determine the appropriate background and measurement count times in order to meet the applicable DQOs and detection sensitivities for scalar/integrating counters.

5.5.2. Perform area (i.e., ambient) background measurements as necessary in accordance with Section 5.3.

- Cover or shield the detector face and obtain an area background measurement prior to and at the end of the survey for each survey area or unit.
- Perform periodic ambient background counts as necessary during the survey if background is noticed to fluctuate from area to area.
- For widely fluctuating background, location specific backgrounds may be required (i.e., an ambient background reading for each measurement location).

5.5.3. Calculate and document the detection sensitivities or MDCs for the survey in accordance with Section 5.8.

5.5.4. Place the unshielded detector probe on or near the surface to be measured. For surfaces where removable surface contamination is expected, hold the detector as close as possible to the surface without touching the surface, in order to minimize the potential of contaminating the detector.

- For scalar counters, collect a static count for the appropriate count time.
- For rate meters, allow the instrument to stabilize for approximately 5 to 10 seconds and note the average reading.

5.5.5. Record the background measurements and gross measurement reading(s) in counts or counts per minute (cpm) on the appropriate survey form in accordance with Section 5.9 and identify the specific measurement location(s) and units.

- For scalar counters, record the gross counts and the applicable count time.
- For rate meters, record the gross count rate in cpm.

5.5.6. If data logging instruments are used to automatically record measurements, the data should be downloaded periodically to a computer to prevent the loss of any data.

5.5.7. Convert the field measurements (cpm) to activity (dpm per 100 cm^2) using the following equation:

$$Gross\ Activity = \frac{(R_S - R_B)}{\varepsilon_i \cdot \varepsilon_s \cdot \left({}^{A_{det}}\!/_{100cm^2} \right)}$$

Where:			
	R_S	=	Gross sample measurement (cpm)
	R_B	=	Ambient Background count rate (cpm)
	ε_i	=	Instrument Efficiency (%)
	ε_s	=	Surface Efficiency (%)
	A_{det}	=	Detector Active Area (cm^2)

5.5.8. Determine the net activity by subtracting material specific background, if applicable, and as determined necessary by the PHP. For relatively high release criteria (where material background is a small percentage of the release criteria), it may not be necessary to subtract material specific background due to natural activity:

$$Net\ Activity = Gross\ Activity - B_{Mat}$$

Where: B_{Mat} = Material Background (dpm/100cm^2)

5.6. Removable Contamination

5.6.1. The RPS or PHP shall determine the appropriate background and measurement count times in order to meet the applicable DQOs and detection sensitivities for scalar/integrating counters.

5.6.2. Calculate and document the detection sensitivities or MDCs for the survey in accordance with Section 5.8.

5.6.3. Obtain a smear at each measurement location as follows:

5.6.3.1. Pass a Whatman filter paper smear, cloth smear with adhesive backing, or equivalent over a representative portion of the surface in an “S” or “Z” pattern using moderate pressure. For a 2-cm diameter filter paper, the length of the smear or swipe should be about 50 cm or 16 inches for an area of approximately 100 cm^2.

5.6.3.2. Do not damage the smear by wiping the area with too much pressure.

5.6.3.3. Avoid excessive “loading” of the smear surface with dirt and avoid wet surface areas.

5.6.3.4. Protect the smear from cross contamination or loss of activity by using a “smear book” composed of wax paper sheets, placing smears in coin envelopes, or other similar method.

5.6.3.5. When taking multiple smears, each smear shall be numbered or identified with the location of the smear for documentation.

5.6.3.6. For tritium measurements, paper smears should be dampened with DI water prior to obtaining the smear and placed directly into the liquid scintillation vial with a small amount of DI water to keep the tritium in solution. Synthetic (foam) smears that dissolve in the cocktail solution may be used. Load each vial with the appropriate amount and type of scintillation cocktail and DI water as directed by the PHP.

5.6.4. Record the smear location(s) on the appropriate survey form.

5.6.5. Smears should be counted on a stationary scalar or automated smear counter such as the Ludlum Model 2929, 3030 or 3030E, Eberline Models BC-4 and SAC-4, Protean counter or Tennelec counter.

5.6.6. Smears collected for low energy beta emitters such as tritium shall be counted on a liquid scintillation counter, which is not addressed in this procedure.

5.6.7. Pre-screen the smears using a portable survey instrument prior to loading smears into a stationary or automated smear counter to avoid potential contamination of the counter.

5.6.7.1. If a smear exceeds 1,000 cpm using a portable survey instrument, do not count the smear on the stationary or automated counter unless approved by the RPS or PHP and the appropriate precautions are taken to minimize any potential of contaminating the instrument.

5.6.7.2. Estimate the activity of the smear using the portable field instruments following Step 5.6.11.

5.6.8. Place the smear in a counting tray or planchet.

5.6.9. Dry the smears, if needed.

5.6.10. Count the smear for the predetermined count time and record the gross counts on the appropriate survey form.

5.6.11. Convert the gross cpm readings to units of dpm per 100 cm^2 using the following equation:

$$Activity = \frac{(R_S - R_B)}{\varepsilon_{4\pi}}$$

5.6.12. For heavily loaded smears, consult the PHP for direction on alternate analysis or correction factors to account for self-adsorption within the sample.

5.7. Surface Scanning

5.7.1. Gamma scans are normally performed by slowly walking, while moving the detector above the surface using an “S” shaped serpentine motion. The survey or work plan should specify walking speed and the appropriate coverage (% of area to be surveyed) depending on the DQOs. The detector distance from the surface should also be specified in the survey or work plan, and typically range from 4 inches to 1 foot for soil surveys.

5.7.2. Calculate and document the scan MDC(s) for the survey in accordance with Section 5.8 depending on the type of scan survey performed.

5.7.3. For alpha and beta surface scans, move the detector probe over the surface, generally within light contact to 1 cm of the surface being scanned. The distance can be greater for higher energy beta and gamma emitters.

5.7.4. For certain instruments, instrument alarm rates may be established in accordance with the instruments user manuals to aid in the detection of elevated activity. Consult the RPS or PHP for alarm settings.

5.7.5. Scan at the predetermined rate by the RPS or PHP as specified in the project specific work plans or procedures, depending on the detection sensitivities required. The scanning rate may be calculated by using the equation for the scan sensitivity and back calculating the scan rate depending on the type of instrument(s) used, instrument efficiencies and the acceptable decision errors.

5.7.6. Document the maximum and average observed count rates (in gross cpm) on the appropriate survey form in accordance with the project work plans and procedures unless the scan data is electronically logged.

5.7.7. If an elevated area is identified during surface scans, re-survey the area to allow the instrument to fully respond, obtain direct measurements as applicable, and identify and mark the area as appropriate.

5.7.8. As required by the project and the PHP, convert the recorded scan results from cpm to dpm/100 cm^2 following the applicable equation(s) in Section 5.5.

5.8. Detection Sensitivity

The detection sensitivity of a measurement refers to the quantity of activity that can be measured or detected with a certain level of confidence and is a function of the instrument parameters and survey techniques. The detection sensitivities as follows are determined using the guidance provided in NUREG-1507, *Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions*, Section 6.7 of NUREG-1575, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)* and Section 7.5 of NUREG-1575, Supplement 1, *Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual (MARSAME)*.

Direct or Static Measurements:

5.8.1. The critical level, L_C, in net counts at which the field instrument response is considered above background may be determined as follows:

$$L_C = z_{1-\alpha} \sqrt{N_B \cdot \frac{t_S}{t_B} \left(1 + \frac{t_S}{t_B}\right)}$$

Where:

Where:	$z_{1-\alpha}$	=	Type I error or false positive
	N_B	=	Background counts
	t_B	=	Background count time (min)
	t_S	=	Sample count time (min)

5.8.2. The detection level, L_D, in net counts at which the field instrument response of a measurement with a determined confidence level as follows assuming the same error rate for both type I and type II errors:

$$L_D = z^2{}_{1-\beta} + 2 \cdot L_C$$

Where: $z_{1-\beta}$ = Type II error or false negative

5.8.3. The MDC for direct surface contamination in dpm/100 cm² is determined as follows:

$$MDC_{Direct} = \frac{L_D}{\varepsilon_i \cdot \varepsilon_s \cdot t_S \cdot \left({}^{A_{Det}}/_{100\ cm^2}\right)}$$

Where: A_{Det} = Detector areas in square centimeters

5.8.4. Using the standard false positive and false negative error rates of 5% (i.e., z statistic of 1.645), the MDC equation reduces to the following:

$$MDC_{Direct} = \frac{\frac{2.71}{t_S} + 3.29 \cdot \sqrt{\left(\frac{R_B}{t_S} + \frac{R_B}{t_B}\right)}}{\varepsilon_i \cdot \varepsilon_s \cdot \left({}^{A_{Det}}/_{100\ cm^2}\right)}$$

5.8.5. For low background count rates (i.e., < 100 cpm and alpha counting), the constant 2.71 should be 3, based on the Poisson count distribution.

5.8.6. For different error rates (i.e., type I and type II errors are not equal), consult the equations as provided in NUREG-1507, *Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions*, NUREG-1575, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*, or NUREG-1575, Supplement 1, *Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual (MARSAME)*.

<u>Smears:</u>

5.8.7. For removable activity measurements (i.e., smears), the MDC is calculated using the same equation(s) above; however, since smears are typically collected over an approximate area of 100 cm², the area term is removed as follows:

$$MDC_{Smear} = \frac{\frac{2.71}{t_S} + (3.29) \cdot \sqrt{\frac{R_B}{t_S} + \frac{R_B}{t_B}}}{\varepsilon_i \cdot \varepsilon_s}$$

5.8.8. For low background count rates (i.e., < 100 cpm and alpha counting), the constant 2.71 should be 3, based on the Poisson count distribution.

Surface Scans - Beta

5.8.9. Calculate the observation interval (*i*) or the time that any one point remains under the detector or within the field of view in seconds during the surface scans as follows:

$$i = \frac{W_{Det}}{Rate}$$

Where: W_{Det} = Detector width or the field of view (inches)
$Rate$ = Scan speed or rate (inches/sec)

5.8.10. Determine the anticipated or expected background counts, b_i, within the observation interval as follows:

$$b_i = R_B \cdot \frac{i}{60(sec/min)}$$

Where: R_B = Background count rate (cpm)

5.8.11. Determine the minimum detectable source counts, s_i, within the observation period using the following equation as provided in NUREG-1575, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*.

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

Where: *d'* = Index of sensitivity (detectability value) as selected from Table 6.5 of NUREG-1575, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*

5.8.12. Calculate the Minimum Detectable Count Rate (MDCR) in cpm within the observation interval using the follow equation.

$$MDCR = s_i \cdot \frac{60}{i}$$

5.8.13. The beta scan MDC can then be calculated by using the following equation as provided in NUREG-1575, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*, in terms of dpm/100 cm^2.

$$MDC_{Scan-\beta} = \frac{MDCR}{\sqrt{p} \cdot \varepsilon_i \cdot \varepsilon_s \cdot \left({}^{A_{Det}}/_{100cm^2}\right)}$$

Where: *p* = Surveyor efficiency, typically considered to be 50%

Surface Scans – Gamma (Open Land)

5.8.14. Consult the PHP or RSO for determining the scan sensitivities for open land surveys for soil. The equations used above for determining beta scan sensitivities may be used; however, because of the complexity as a result of the larger fields of view and depth of detection in soil, dose modeling and the detectors energy response will be required.

5.8.15. NUREG-1507, *Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions* provides guidance for determining the scan sensitivity for open land areas.

5.8.16. The use of data logging and positional instruments, (e.g., GPS), may increase the surveyor efficiency and reduce the MDA or the MDC by enabling scan data to be reviewed in more detail.

5.8.17. The MDA or MDC may be validated and confirmed through biased sampling following a review of the scan results.

Surface Scans - Alpha

Scanning for alpha emitters is significantly different from scanning for either beta or gamma emitters because the release limits are generally low and because the alpha background rate is very low or close to zero. Registering one count is often enough cause for the surveyor to stop and investigate. As a result, the scan MDC for alpha scanning can be calculated by determining the probability of detecting an area of contamination at a given contamination level and scan rate, which can be represented in one of two ways as follows:

5.8.18. Determine the probability of detecting a single count while passing over a contaminated area of a given activity as follows:

$$P(n \geq 1) = 1 - e^{\frac{-1 \cdot G \cdot \varepsilon_i \cdot \varepsilon_s \cdot W_{det}}{60 \cdot Rate}}$$

Where: G = activity (dpm)

5.8.19. If the probability is greater than 70%, then the scan speed is generally considered acceptable.

5.8.20. If the probability is less than 70%, notify the PHP. The scanning methodology either needs to be re-evaluated or it may be determined that this is the best than can be achieved.

5.8.21. The scan MDC may also be determined by solving for the activity level assuming that the scan MDC is defined as the amount of activity, G, that can be detected at a given Poisson probability by rearranging the probability equation as follows:

$$MDC_{Scan-\alpha} = \frac{-1 \cdot ln\big(1 - P(n \geq 1)\big) \cdot Rate \cdot 60}{\varepsilon_i \cdot \varepsilon_s \cdot W_{det}}$$

5.9. Survey Documentation

5.9.1. Assign each survey a unique survey number or ID based on a numbering system as designated by the RPS or PHP.

5.9.2. Enter the survey number on the survey log, Attachment 7.1 or equivalent.

5.9.3. Document the survey results on the survey form, Attachments 7.2 through 7.4, or equivalent as applicable.

5.9.4. The survey documentation should include the following as a minimum and as applicable:

- The location of measurements and/or samples (i.e., survey map)
- The date and time of the survey
- Gross and/or net instrument readings
- Activity calculation results
- Name of the surveyor
- Sample analysis results and dates
- Instrument data (type, serial number, calibration date and due date)
- Detection sensitivities
- Name of person reviewing the survey results

5.9.5. The survey documentation should be of sufficient detail to allow for the recreation of the survey as applicable.

5.9.6. As required in work plans and procedures or as directed by the PHP, subtract natural activity background based on the types of materials surveyed.

5.9.7. It should be noted, that some net activity results may be less than the MDA. Always retain the actual calculated results, including negative results, as these are required for proper statistical analysis of the data.

5.9.8. Each survey shall receive an independent review to ensure the survey is complete and properly documented. This review shall be documented by signature and date.

5.9.9. Any measurement results determined to be suspect shall be reviewed by the PHP and investigated as needed.

6. Records

6.1. Survey Log

6.2. Survey Documentation

6.3. Instrument QA/QC Records

6.4. Instrument Calibrations

7. Appendices and Forms

7.1. Survey Log (Example)

7.2. Survey Cover (Example)

7.3. Direct/Removable Activity Sheet (Example)

7.4. Exposure Rates Sheet (Example)

Attachment 7.1 **Survey Log**

Survey ID	Description	Type [a]	HPT	Date

a Survey types may include characterization, scoping, FSS, routine, MARSSIM/MARSAME, information, etc.

Attachment 7.2 **Survey Cover (Example)**

Survey Cover

Survey ID: ____________

Page ____ of ____

Survey Type: ____________
Description: ____________
Performed by: ____________
Date: ____________

☐ Direct Survey
☐ Smear Survey
☐ Exposure Rate Survey

Instrumentation

	Model	Serial Number	Calibration Due Date	Mode Scalar / Rate	Det. Area (cm2)	Inst Eff. (ε_i) (%)	Surface Eff. (ε_s) (%)
Alpha (Direct/Removable)							
D							
R					NA		
Beta (Direct/Removable)							
D							
R					NA		
Gamma						BCF mrad per mR/hr	Cal. Const. cts per mR/hr
D					NA		N/A

Diagram

Key

Contamination

- LAW
- Smear
- Direct

Dose Rates (OW/CW)

* - Contact

\# - Gen. Area

Air Sampling

A/S - Location

Reviewed by: ____________________ Date: __________

Attachment 7.3 **Direct/Removable Activity Sheet (Example)**

Direct/ Removable Activity (α/β)

Survey ID: ___________

Page ____ of ____

Parameter	Units	Alpha		Beta	
		Direct	Removable	Direct	Removable
Sample CT	min				
Bkgd CT	min				
Resp. Time	min				
Background	cpm				
MDC	dpm/100 cm^2				
Flag / Limit	dpm/100 cm^2				

GA Background (gross cts)	
Alpha	Beta

Location	Alpha				Beta				
	Direct		Removable		Direct			Removable	
	Gross cts	dpm/100 cm^2	Gross cts	dpm/100 cm^2	Gross cts	Bkgd (cpm)	dpm/100 cm^2	Gross cts	dpm/100 cm^2
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									

Reviewed by: ______________________ Date: _________

Attachment 7.4 **Exposure Rates Sheet (Example)**

Exposure Rates (β-γ)

Survey ID: ____________

Page ____ of ____

Location	Ion Chamber			NaI(Tl)		
	OW	CW	Beta	Rate Mode	Scalar Mode	
	mR/hr	mR/hr	mRad/hr	mR/hr	cpm	mR/hr
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
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34						
35						

Reviewed By: ______________________ Date: __________