

The MARSAME Methodology: Fundamentals, Benefits and Applications - 12135

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ABSTRACT

MARSAME is an acronym for the “Multi-Agency Radiation Survey and Assessment of Materials and Equipment.” Published in January 2009, MARSAME was a joint effort between the U.S. Department of Energy (DOE), the U.S. Department of Defense, the U.S. Department of Energy, and the U.S. Nuclear Regulatory Commission (NRC) to aid sites in the clearance of materials and equipment (M&E). The MARSAME manual *supplements* the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), published in 1997. As cited in the MARSAME, applicable M&E includes metals, concrete, tools, equipment, piping, conduit, and furniture. Also included are dispersible bulk materials such as trash, rubble, roofing materials, and sludge. Solids stored in containers, as well as liquids and gases, represent additional M&E. The MARSAME methodology covers multiple technical areas, including the initial assessment (IA), Measurement Quality Objectives (MQOs), survey approaches and considerations, survey plans, survey implementation, and Data Quality Assessment (DQA). These topics are generally captured under four phases of the data life cycle, which are Planning, Implementation, Assessment, and Decision-Making. Flexibility and a graded approach are inherent components of the MARSAME methodology pertaining to M&E property clearance programs. Because large quantities of M&E potentially affected by radioactivity are present in the United States, owners of the M&E need to identify acceptable disposition options. Thirteen disposition options, broadly defined under both release and interdiction scenarios, are described in MARSAME. Nine disposition options are listed for release; these options are categorized into two for reuse, two for recycle, four for disposal, and one that is essentially “status quo” (i.e., maintain current radiological controls). Four interdiction options are also cited. To date, applications of the MARSAME approach for M&E property clearance under reuse scenarios have been limited. However, this should change as familiarity increases. Known examples are provided from DOE-contractor and NRC-licensee facilities. If the methodology is appropriately planned and implemented, the benefits of the MARSAME approach include worker and public protection, reduction in the amount of disposed radioactive waste, reuse of materials (resulting in environmental and material sustainability advantages), and cost savings.

INTRODUCTION

NUREG-1575, Supplement 1, *Multi-Agency Radiation Survey and Assessment of Materials and Equipment* Manual (MARSAME), was originally published in January 2009 and was a joint effort of four federal agencies: the U.S. Environmental Protection Agency (EPA), the U.S. Nuclear Regulatory Commission (NRC), the U.S. Department of Defense (DoD), and the U.S. Department of Energy (DOE) [1]. MARSAME is a supplement to NUREG-1575, Revision 1, *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM), originally published in 1997 [2]. The MARSSIM is applicable to real property (e.g., buildings and land) whereas the scope of MARSAME is non-real property comprised of materials and equipment (M&E). The MARSAME methodology utilizes a graded approach and emphasizes flexibility in designing and implementing disposition surveys. It is a tool intended to not only aid sites in the clearance of M&E, but also to prevent inadvertent

releases of potentially radioactive contaminated personal property to the public. MARSAME has been specifically cited in the DOE Order 458.1, *Radiation Protection of the Public and the Environment* [3], as a methodology recognized by DOE as sufficient for radiological monitoring or surveying activities performed in support of property clearance.

To date, applications of the MARSAME approach for M&E property clearance scenarios have been limited. However, it is anticipated this will change as familiarity evolves in applying the MARSAME methodology. This is especially true for users already acquainted with the MARSSIM approach. If the methodology is appropriately planned and implemented, the benefits of the MARSAME approach include worker and public protection, reduction in the amount of disposed radioactive waste, reuse of materials (which has environmental and material sustainability advantages), and cost savings.

METHODOLOGY

MARSAME incorporates the four components of the data life cycle, namely, Planning, Implementation, Assessment, and Decision Making. A graphical representation of the data life cycle and MARSAME process are shown in Fig. 1. For those individuals unfamiliar with MARSAME, each component is discussed in turn.

Planning

Planning constitutes the initial phase of the data life cycle. A considerable amount of upfront effort is required in the planning phase to effectively develop and document a survey design. The Data Quality Objectives (DQO) process is a fundamental aspect of this phase. Once the M&E has been identified, categorized, segregated, and described, standard and item-specific disposition surveys may be developed and implemented appropriately. If sufficient information is collected in the initial assessment (IA) phase, the M&E can be adequately categorized as either impacted or non-impacted. Non-impacted M&E are exempt from further scrutiny whereas impacted M&E are subject to further assessments based on their classification. Adequate categorization of the M&E may result in considerable reduction in the number of person-hours and associated costs.

MARSAME describes several technical attributes required to effectively implement the methodology. This skill set includes: A MARSSIM background, knowledge of health physics, an understanding of statistics, practical radiation protection experience, a radiation instrumentation background, and experience in the conduct of radiation surveys. A planning team (Team), with the requisite skill set, is recommended. The Team has the lead responsibility for the successful design and implementation of MARSAME disposition surveys. The “Team” concept is emphasized throughout this discussion.

The DQO process is a multi-step sequence described in, and often cited from, EPA QA/G-4, *Guidance on Systematic Planning Using the Data Quality Objectives Process* [4]. The steps range from “defining the problem” (Step 1) to “selecting an appropriate plan for obtaining data” (Step 7). The DQO process requires formal and systematic planning based on a graded approach to design surveys. The process is intended to be iterative. Thus, as additional disposition survey information becomes available, it is incorporated into the process and a determination made whether adjustments to the decision making, survey

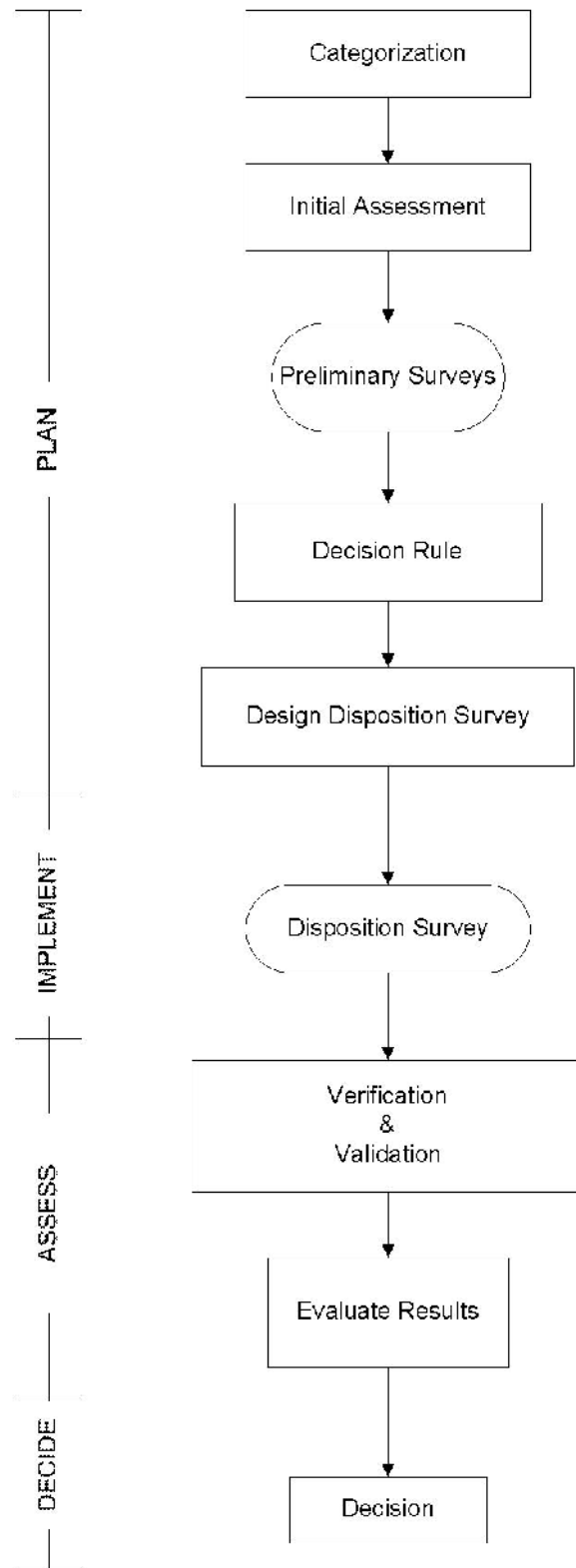


Fig. 1. Overview of the data life cycle and MARSAME process (Source: MARSAME Roadmap Figure 1).

design(s), and/or its implementation are required. M&E disposition surveys may exhibit a wide-range of complexity. Therefore, the Team is responsible for determining the level of planning detail (based on the DQO process) required for successful implementation.

Personnel safety should be stressed throughout the project. The Team should identify and discuss potential safety hazards by conducting a Job Safety Analysis (JSA) or equivalent means. The Team is responsible for ensuring that health and safety considerations are appropriately addressed for all personnel involved in the project. The policy of stopping unsafe work should apply to all activities, and work should not be resumed until the safety issue is satisfactorily resolved.

The IA is the first significant step in the M&E investigation process. The Team is responsible for ensuring the objectives of the IA are accomplished. Components of the IA are described below.

Categorization is a new term used in MARSAME (i.e., it is absent from MARSSIM) that requires a determination as to whether or not the M&E is “impacted” (meaning that based on known information, the potential exists for radionuclide concentrations or radioactivity above background). As part of the IA, if a reasonable potential exists for the M&E to be impacted, MARSAME requires that the M&E be further “classified” into three classes (Class 1, 2, or 3). Alternatively, if the M&E is “non-impacted” no further efforts are required. The categorization decision is reached based on the results of visual inspections, historical records reviews, process knowledge, and sentinel measurements.

A visual inspection is useful to identify and document physical characteristics (attributes) of the M&E. MARSAME describes different approaches for accomplishing this step, including site visits, video, and photographs. Visual inspections and records of the results of this effort are fundamental to the process.

Review of historical records is often required to assist with a categorization decision. MARSAME describes several sources of information including site reviews, the facility radioactive materials license, permits, operating records, and inspection reports, among others. Interviews of current and former employees are also often advantageous, especially at facilities that have operated for several decades. The Team should consider conducting video interviews (with permission granted by the interviewee). Interviews should be tape-recorded, and notes taken for follow-up transcription and to ensure factual accuracy.

Process knowledge is a form of historical information and an important factor in determining whether the M&E is impacted or non-impacted. It is project-specific and ranges from simple to complex situations. The Team obtains all necessary information from cognizant personnel with a working knowledge of the facility containing M&E.

The word “sentinel” is a new term in MARSAME (i.e., it is absent from MARSSIM) that equates to the conduct of “biased” or “judgmental” measurements at key locations. These measurements, usually associated with difficult-to-measure areas, are another means to support a disposition action such as categorization. Depending on the situation, these measurements may not be required. The Team evaluates whether or not information from sentinel measurements is needed to support the characterization.

Preliminary surveys in MARSAME correspond to “scoping” and “characterization” surveys in MARSSIM. When needed, preliminary surveys are designed to address data gaps, such as the lack of sufficient information needed to design a disposition survey. The Team evaluates data gaps and the need to perform preliminary surveys.

If an existing Standard Operating Procedure (SOP) exists, it should be utilized in lieu of designing a disposition survey. However, when necessary, the Team should use the DQO process to guide the development and subsequent conduct of a preliminary disposition survey.

The Team describes the M&E in terms of both *physical* and *radiological* characteristics because it directly impacts the design of the disposition survey. Each of these, in turn, is further associated with four attributes.

The physical attributes of the M&E include physical dimensions, complexity, accessibility, and inherent value. The dimensions include size and geometric considerations. The complexity relates to the number and type of components comprising the M&E, including segregation considerations and grouping of similar M&E. Accessibility refers to the ability to access surfaces and individual components (essentially the M&E are either accessible or difficult-to-measure). The inherent value of the M&E should also be considered due to related costs of replacement and disposal, as well as recycle or reuse options.

Radiological attributes consist of the radionuclides of concern, their associated radioactivity and concentrations, the distribution of radioactivity, and the location of radioactivity. The first attribute requires a listing of radionuclides anticipated for a project-specific disposition. The second attribute refers to expected radionuclide activities or concentrations and possible relationships among radionuclides (e.g., inferring a Sr-90 activity or concentration from a known Cs-137 activity or concentration relationship). Review of available historical records and process knowledge are important components. The need to conduct sentinel measurements to address informational gaps should also be evaluated. Consideration of “distribution” relates to whether the radioactivity is uniformly distributed, clustered, or unknown. Location pertains to whether the radioactivity is superficial or volumetrically distributed. For superficial radioactivity, additional delineation of “fixed” versus “removable” levels (or a combination of both) is a key consideration. The Team should locate the areas of residual radioactivity via process knowledge information prior to conducting field measurements.

Selecting a disposition option is one of the Team’s key considerations when implementing the MARSAME methodology. MARSAME provides multiple disposition options for impacted M&E. In release scenarios, disposition options include reuse (two options), recycling (two options), and four disposal alternative actions. Maintaining currently instituted radiological controls is a ninth option. Four disposition options exist for interdiction applications.

Following a categorization decision that impacted M&E exist, the Team classifies the impacted M&E into three classes: Class 1, 2, or 3, in a manner equivalent to the MARSSIM methodology. Classification is used to determine the appropriate level of survey effort based on estimates of radioactivity levels. When historical or process knowledge is either limited or non-existent, the Team defaults to a Class 1 survey effort in lieu of project or task-specific

available information; the greatest level of survey effort will be required in these instances. In other words, Class 1 areas require the greatest level of survey effort, Class 3 the least.

MARSAME devotes significant emphasis to the selection of action levels (ALs), encompassing both surface and volumetric contamination. Several sources for these levels exist, based on dose or risk, a regulatory threshold, as low as reasonably achievable (ALARA) considerations, Waste Acceptance Criteria (WAC), and other factors. Under Scenario “A,” as originally described in MARSSIM (and now in MARSAME), the AL is equivalent to the Upper Bound of the Gray Region (UBGR) and the discrimination limit (DL) is equivalent to the Lower Bound of the Gray Region (LBGR). In Scenario “B,” the order is reversed and the AL and DL are the LBGR and UGBR, respectively.

At DOE facilities, Order 5400.5, *Radiation Protection of the Public and the Environment*—effectively superseded by DOE Order 458.1 in February, 2011—is still used to provide average, maximum and removable surface contamination levels (dpm/100 cm²) for several different groups of radionuclides [5]. This transitional situation will remain pending the issuance of updated values for the new Order 458.1. The NRC cites specific ALs in, for example, Regulatory Guide 1.86 [6]. For volumetric considerations, ANSI/HPS N13.12-1999 (R2010) provides screening levels (pCi/g) [7]. These citations constitute pre-approved (generic) AL limits. In addition, derived limits may be required through the use of exposure pathway models (e.g., the RESRAD family of codes.) The Team determines the appropriate selection of ALs. Consideration should also be given to the fact that ALs may change based on the iterative nature of the DQO process.

The selection of ALs may be simple or complex, depending on whether single or multiple radionuclides are involved. MARSAME provides illustrative examples (repeated from MARSSIM) to discuss gross activity level determinations, the impact of naturally occurring radioactive decay series, and measured versus inferred radionuclide contributions. MARSAME recommends that the most restrictive ALs be chosen based on human health environmental considerations.

The Team next identifies the parameters of interest. The parameter of interest applies to a population parameter (e.g., a mean or median) that impacts decisions about the target population. Possible measurement results that could be used to support a disposition decision concerning the M&E are collected and investigated.

MARSAME provides an example where the parameter of interest may be specified as part of an AL: DOE Order 5400.5, Figure IV-1. In this case, the following occurs:

Action Level:	Surface contamination limits in dpm/100 cm ²
Parameter of Interest:	Average and maximum surface contamination values in dpm/100 cm ²
Target Populations:	1 m ² (average) and 100 cm ² (maximum and removable limits)

The Team identifies the possible alternative actions needed for disposition of M&E (including a “no action” alternative). MARSAME lists examples of disposition options and their appropriate alternative actions.

A survey unit is the specific lot, amount, or piece of M&E on which measurements are made to support a disposition decision. MARSAME recommends the clear delineation of survey unit boundaries, primarily based on the assumptions used to develop the ALs. MARSAME notes that survey unit boundary modifications may be needed based on practical data collection constraints. The Team defines and modifies the survey unit boundaries.

The Team develops the decision rules associated with the M&E. A decision rule is a fundamental precursor to disposition survey design. In MARSAME, two different types of decision rules are defined: “theoretical” and “operational.” A theoretical decision rule assumes that ideal data is available and no uncertainty exists in the decision making process. An operational rule, incorporated into the final disposition survey design, relies on an estimate of the target population parameter of interest (rather than a true value).

Both rules are written in the form of an “if...then...” statement and incorporate an AL, a parameter of interest, and an alternative action. An example from MARSAME of a theoretical decision rule is: “Hypothetically, if the mean concentration of ^{226}Ra in 20,000 kg (8.3 m^3 , one truckload) of concrete rubble is less than the clearance action level of 0.34 Bq/g for volumetric radioactivity, then the concrete rubble can be cleared, otherwise radiological control of the concrete will continue.” More than one theoretical or operational decision rule may be required. This may occur when more than one AL is selected or multiple disposition options are involved. This will be the case at facilities where a variety of radionuclides are encountered.

The conduct of a disposition survey relies, in part, on the selection of a *measurement method*. A measurement method consists of two components: instrument selection and measurement technique. Examples of the former include Geiger-Mueller (G-M) detectors, sodium iodide (NaI) gamma scintillation detectors and gamma ray spectrometers. Measurement techniques include scanning, *in situ* measurements, and sample collection. The Team determines the instrumentation and measurement technique appropriate for the specific task. MARSAME identifies several factors influencing the selection of a measurement method. These include the physical and radiological attributes of the M&E, ALs, background levels, and other factors.

MARSAME utilizes a new term, “Measurement Quality Objectives” (MQO), a subset of DQOs, to “identify characteristics of a measurement method required to meet the objectives of a survey.” The Team should evaluate the six MQOs discussed in the methodology—consisting of measurement method uncertainty, detection capability, quantification capability, range, specificity, and ruggedness—and determine their applicability. This list is not exhaustive. MARSAME recommends the planning team develop additional or other MQOs on a project-specific basis as needed. Three of the six MARSAME-cited MQOs are “statistically-based”: measurement method uncertainty, detection capability, and quantification capability. Range, specificity, and ruggedness are more “application-based” MQOs.

The complexity of the M&E, nuclides of concern, and survey methodology will directly influence the selection of the measurement method adequate to meet the MQOs on a project-specific basis. MARSAME discusses in detail the selection of measurement methods for potential applications (as well as their advantages and disadvantages).

Prior to use of any instrument, a general inspection of the operational condition of the instrument should be performed. MARSAME discusses measurement and instrument performance indicators. Proper calibration of survey instrumentation is essential to ensure adequate measurement of the radioactive emissions and energies of interest. Upon completion of calibration, acceptable operational source responses for all instruments are established. For example, a maximum range of $\pm 3\sigma$ of the mean value is often used as an operational indicator for acceptable instrument response. The surveyor should perform operational source response verifications at least twice daily; for example, at the beginning and end of each work shift.

Background measurements are performed on areas with little or no radioactivity (excluding the radionuclides of concern). When practicable, background measurements are performed utilizing materials of similar construction as those to be surveyed. When background measurements on similar construction materials are not feasible, ambient background may be used as a substitute. Background measurements should be performed daily, at the beginning and end of each work shift.

Development of a usable (workable) survey design requires the consideration of many factors. The design builds on the information gathered during the IA and inputs to the decision. The development of an *operational* decision rule is fundamentally important to the basis for the survey design. As the disposition survey design is based on the DQO process—which is an iterative process—the Team modifies the survey design as needed.

Because MARSAME emphasizes statistical decision-making, the Team evaluates the selection of a null hypothesis, chooses a discrimination limit, and defines the decision errors (Type I and II). The null hypothesis is dependent on the choice of either Scenario “A” (the contamination in the M&E survey unit exceeds the AL) or Scenario “B” (the contamination in the M&E survey unit is indistinguishable from background).

The discrimination limit (DL) is a value that can be “reliably distinguished” from the AL. This assumption requires conducting field measurements or sample analysis. In Scenario A, the DL is found graphically below the AL. The reverse is true for Scenario B. The difference between the two values is referred to as the “shift,” symbolized by Δ . When the standard deviation associated with the arithmetic mean of the DL is introduced, the term is renamed the “relative shift” (Δ/σ). The Team must determine some measure of the relative shift as it impacts the level of survey effort, including the number of samples to be collected. MARSAME illustrates the relationship between the DL, AL, and small versus large relative shifts.

Type I (“ α ”) and Type II (“ β ”) decision errors refer respectively to “rejecting the null hypothesis when it is true” and “failing to reject the null hypothesis when it is false.” Decision errors are required because uncertainty is an inherent component of radiological surveys. The Team establishes the maximum allowable Type I and Type II decision error rates corresponding to a radionuclide concentration or level equal to or above the AL (Type I) or

equal to the DL (Type II). These errors have practical impacts as incorrect decisions regarding the level of radioactivity relative to being below or above the AL can result in increased risks in health, ecology, economic interests, and social impacts.

Other survey design factors include the M&E classification decisions (Class 1, 2 or 3) and the selection of measurement technique (e.g., scan-only, *in situ*, or MARSSIM-type surveys) associated with the classification decision.

The specific project will also influence the survey approach. Scan-only surveys are categorized by several advantages, including flexibility in the choice of hand-held or conveyorized systems, the least financial impact on designing and implementing the survey, the large number of measurements possible using short count times, ease of incorporation into SOPs, and the ability to institute a “clean as you go” practice for Class 1 surveys. The primary drawback is increased measurement uncertainty.

When the Team assumes a Class 1 survey will be performed, 100% of the impacted M&E will be scanned. However, if additional information is available on a project-specific basis, MARSAME provides formulas (for the implementation of a more limited Class 2 scan survey) to determine the “scan only” percentage. The percentage of scan coverage is directly influenced by the relative shift and will range between 10% and 100%. Class 3 scan-only surveys are handled in the same manner as Class 2 surveys, with the possibility that less than 10% scan coverage will be sufficient due to the low probability that the M&E will exceed the AL.

In contrast to scanning, an *in situ* approach utilizes static measurements and is performed when scanning is determined to be unacceptable for the survey design. These measurements require the use of “fixed geometry” (and typically more bulky) instrumentation such as high-purity germanium detectors. MARSAME categorizes portable, hand-held instruments (e.g., G-M, NaI, ZnS [zinc sulfide], and gas proportional detectors) as *in situ* devices. In general, longer count times and a more limited number of measurements, relative to scan surveys, are characteristics of these measurements.

The Team evaluates, on a project-specific basis, the need to adopt an *in situ* measurement approach. When used, the classification of the M&E will determine the survey effort, as discussed and implemented for scan-only surveys (100% for Class 1; 10% to 100% for Class 2; and less than 10%, as warranted, for Class 3).

A MARSSIM-based survey design is the last of the three principal designs for the measurement of impacted M&E. In contrast to an *in situ* approach where 100% of the item is measured, MARSSIM-based surveys employ statistically-based static measurements in conjunction with scanning. MARSAME makes it clear that this type of survey design might be more complex and more resource intensive. In addition, it is intended for “large, complicated M&E” with a “high inherent value” and implemented only after the rejection of scan-only and *in situ* surveys.

Class 1, 2, and 3 MARSSIM-based survey designs may be implemented. While the values may change, all three classes necessitate the determination of the required number of measurements in each survey unit, incorporating the shift (Δ), variability in radionuclide concentrations or levels of radioactivity, and the Type I/II decision errors. As with scan-only

surveys, scan coverage varies from 100% (Class 1) to less than 10% for Class 3 areas. Unlike MARSSIM, where the size of the survey unit varies with classification, this is not the case for a MARSSIM-based M&E survey—all three classes retain the same survey unit size.

Development of the survey design is also impacted by whether routine surveys are anticipated. If so, MARSAME permits the use of existing SOPs that satisfy the established MQOs. If this is not the case, a specific survey design will be required for so-called “single event surveys.”

Figure 2 presents a flow diagram for the disposition survey design.

Implementation

Implementation is the second phase of the data life cycle. In order to encourage flexibility and innovation in implementing the survey design, MARSAME does not provide specific implementation techniques. Therefore, the Team discusses and determines the appropriate approach(es) to implement the survey, tailored to the specific disposition option.

In addition to flexibility, the basic steps discussed in MARSAME to perform the disposition survey(s) include choosing a measurement method that will satisfy the MQOs, performing the number and type of measurements specified in the survey design, evaluating selected ALs in support of disposition decisions in the field, and collecting and analyzing Quality Control (QC) data.

Implementation of the established disposition survey should incorporate many of the issues described in the MARSAME methodology. These include:

- Health and safety considerations
- Handling the M&E
- Segregating the M&E
- Establishing the MQOs
- Selecting measurement methods
- Data reporting

Health and safety considerations should be emphasized prior to and during each project-specific work effort. M&E can create multiple physical and chemical hazards. A JSA should be conducted in support of an associated health and safety plan. In addition, radiation work permits and other documentation should be developed as needed.

Handling the M&E may require preparing a grid, providing access for performing measurements, and transporting the M&E to an alternative location.

Segregating the M&E is important because it impacts the estimation of measurement uncertainty, the handling of M&E, and disposition options. Segregation is influenced by the physical and radiological attributes of the M&E. M&E can be separated into “similar” and “non-similar” items by factors such as weight; the M&E requiring preparation (e.g.,

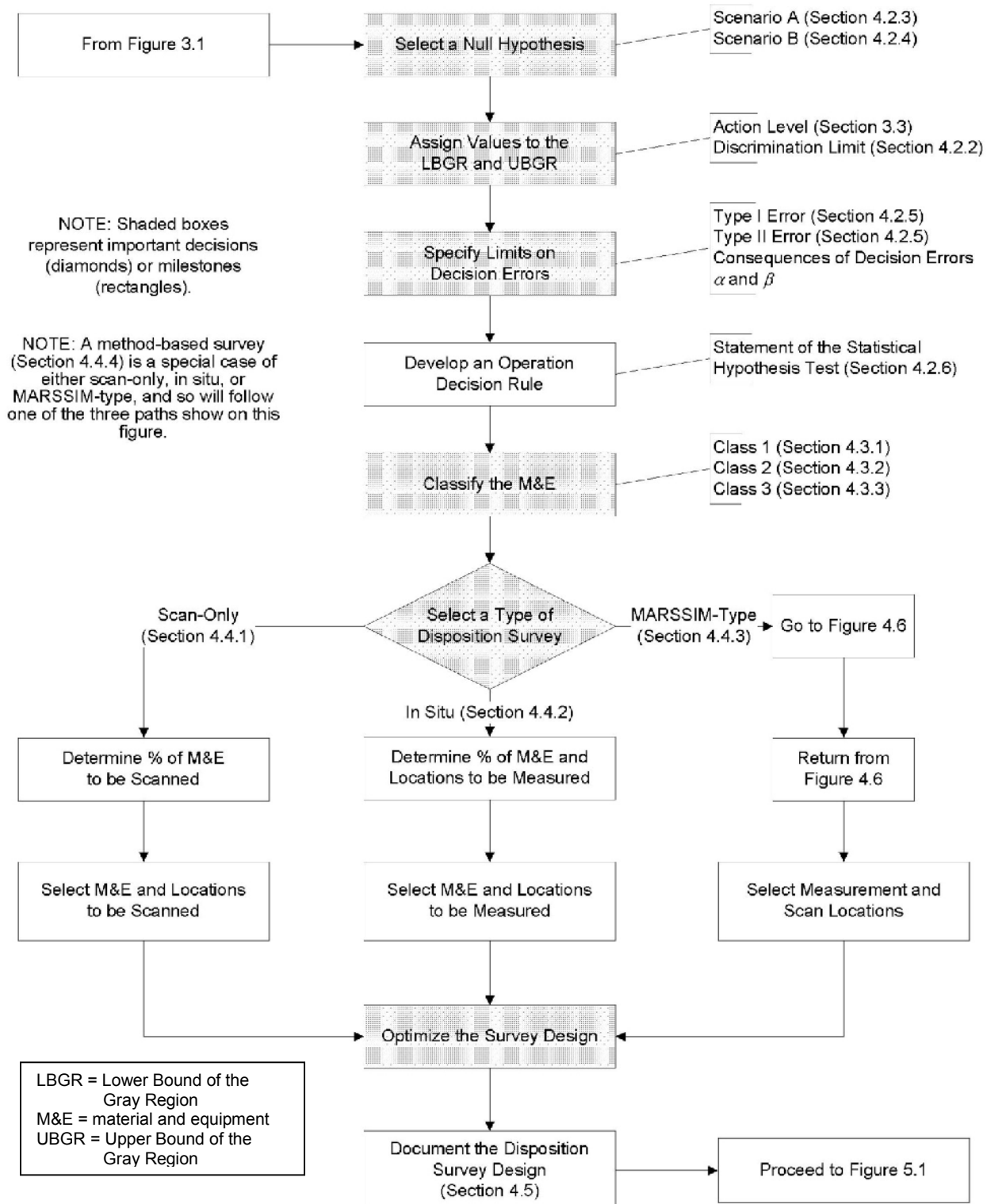


Fig. 2. Flow diagram for a disposition survey design (Source: MARSAME, Figure 4.5)

disassembly) prior to the conduct of a survey; whether or not the M&E can be surveyed “as is”; and the disposition options being considered (e.g., reuse or recycle versus disposal).

MQOs impacting the implementation phase of the project (from a more statistically-based standpoint) include measurement uncertainty (perhaps the most important MQO), measurement detectability, and measurement quantifiability. The terms “detectability” and “quantifiability” primarily refer to the terms “minimum detectable concentration” and “minimum quantifiable concentration.” The Team should evaluate these statistical issues as it relates to the instrumentation selected for building disposition surveys. The Team should select measurement methods appropriate for the M&E to be dispositioned in accordance with the project-specific survey objectives.

M&E disposition surveys aim to produce technically and legally defensible documentation. MARSAME offers several recommendations for reporting the results of these surveys.

Data Assessment¹

Data assessment is the third phase of the data life cycle. All prior planning and implementation activities associated with the disposition survey culminate in the generation of data. The data results should first be verified and validated. The data is then evaluated to determine whether it is of the right type, quality, and quantity to support its intended use. This is accomplished through a formal data quality assessment (DQA). The Team should evaluate data generated during MARSAME disposition surveys using existing internal procedures and the following MARSAME DQA recommendations as a basis for data review:

- Step 1: Review the DQOs and survey design
- Step 2: Conduct a preliminary data review
- Step 3: Select the statistical test
- Step 4: Verify the assumptions of the statistical test
- Step 5: Draw conclusions from the data

The results can be compared directly to the UBGR for individual measurement results or to an Upper Confidence Level for the mean of a sampled population. The selected disposition survey scenario, either Scenario A or B, should be considered in the context of results comparisons.

The Team considers the use of the Sign test (contaminant not present in background), the Wilcoxon Rank Sum test (contaminant present in background), or other applicable statistical tests to determine whether the null hypothesis is accepted or rejected.

Decision-Making²

Decision-making is the final phase of the data life cycle. Once all the data has been reviewed, a decision is required as to whether to accept or reject the selected null

¹ May occur during the implementation phase under certain circumstances.

² May occur during the implementation phase under certain circumstances.

hypothesis. The operational decision rule, established for the specific work effort, should be used to reach a decision. If, for example, the default null hypothesis for the disposition of M&E is based on Scenario B, “Indistinguishable from Background” (as is often encountered at, for example, NRC-licensed reactor sites), and the M&E are then determined to exceed an AL of “0” or above background, the null hypothesis is rejected.

RESULTS AND DISCUSSION

Large quantities of diverse M&E, potentially affected by radioactivity, are present in the United States, requiring owners of the M&E to identify acceptable disposition options. Thirteen disposition options applicable to impacted M&E, and broadly defined under both release and interdiction scenarios, are described in MARSAME. These include nine disposition options under release scenarios: two for reuse, two for recycle, four for disposal, and one option that is essentially “status quo” (maintain current radiological controls). Four interdiction options are also available.

To date, applications of the MARSAME approach for M&E property clearance under reuse scenarios have been limited to a few isolated cases. However, this should change as familiarity increases. Example applications have been identified within the DOE (involving the survey and disposition of railroad rails), an NRC-licensee considering the disposition of transformers as part of an ongoing reactor decontamination and decommissioning, and a similar activity (though with different M&E) at an operational nuclear power plant.

The DOE M&E activity utilized an *in situ* rail monitoring system to survey over 100 miles of track with possible surface contamination (Fig. 3). The MARSAME approach included a reuse scenario (consistent with its intended purpose) and a disposal option. The survey culminated with reporting the following benefits: protection of workers and the public; a reduction of 80,000 cubic feet of waste disposed, resulting in a projected savings of \$500,000; reuse of materials that sustained valuable materials; a significant cost reduction (88%) by surveying the rails with a moving monitoring system rather than a 100% hand survey; and lower impact to the environment.

In the NRC-licensee application, a survey package was developed based on the MARSAME methodology to evaluate several large transformers at the facility. The survey package included an IA; categorization into impacted and non-impacted surfaces; classification of impacted surfaces as Class 3; a description of physical and radiological attributes; the implementation of preliminary surveys; selection of a preferred disposition option; a detailed survey design, including discussion and selection of measurement quality objectives, survey implementation, results, and a DQA to determine an appropriate disposition decision.

In regard to the operational nuclear power plant, the plant has been actively developing survey packages for a wide variety of M&E in its pursuit of a MARSAME-based disposition strategy.



Fig. 3. Mobile rail monitoring system at DOE facility

CONCLUSION

The MARSAME methodology is largely an evolution of the MARSSIM approach, applied to non-real property. These field-based methodologies, developed over the past 15 years, incorporate a more statistically-based approach to the decontamination and decommissioning of buildings and land, and the disposition of materials and equipment, respectively. While not without its flaws, the MARSAME methodology was designed to promote consistency in the disposition of M&E. If the MARSAME methodology is appropriately planned and implemented, several benefits related to waste management can result, including worker and public protection, reduction in the amount of disposed radioactive waste, reuse of materials (which has environmental and material sustainability advantages), and identified cost savings.

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